PNNL-24563

Pacific Northwest NATIONAL LABORATORY

Proudly Operated by Battelle Since 1965

ImSET 4.0: Impact of Sector Energy Technologies Model Description and User's Guide

July 2015

OV Livingston
MJ Scott
SR Bender
RW Schultz

U.S. DEPARTMENT OF ENERGY

Prepared for the U.S. Department of Energy
under Contract DE-AC05-76RL01830

PACIFIC NORTHWEST NATIONAL LABORATORY
operated by
BATTELLE
for the
UNITED STATES DEPARTMENT OF ENERGY
under Contract DE-AC05-76RL01830

Printed in the United States of America

**Available to DOE and DOE contractors from the
Office of Scientific and Technical Information,
P.O. Box 62, Oak Ridge, TN 37831-0062;
ph: (865) 576-8401
fax: (865) 576-5728
email: reports@adonis.osti.gov**

**Available to the public from the National Technical Information Service
5301 Shawnee Rd., Alexandria, VA 22312
ph: (800) 553-NTIS (6847)
email: orders@ntis.gov <http://www.ntis.gov/about/form.aspx>
Online ordering: http://www.ntis.gov**

This document was printed on recycled paper.
(8/2010)

PNNL-24563

ImSET 4.0: Impact of Sector Energy Technologies Model Description and User's Guide

OV Livingston
MJ Scott
SR Bender
RW Schultz

July 2015

Prepared for
the U.S. Department of Energy
under Contract DE-AC05-76RL01830

Pacific Northwest National Laboratory
Richland, Washington 99352

Executive Summary

As part of measuring the impact of government programs in improving energy efficiency within the nation's infrastructure, the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE) is interested in assessing the economic impacts of these programs, specifically as they relate to national employment and wage income. As a consequence, EERE funded Pacific Northwest National Laboratory (PNNL) to develop a simple-to-use method for in-house estimation of economic impacts of individual programs.

This 4.0 version of the Impact of Sector Energy Technologies (ImSET) model represents the newest generation of the ImSET model (previous version ImSET 3.1.1). ImSET was developed in 2005 to estimate the macroeconomic impacts of energy-efficient technology in buildings. In essence, ImSET is a special-purpose version of the National Benchmark Input-Output (I-O) model that has been modified specifically to estimate the national employment and income effects of the deployment of energy-saving technologies developed by the EERE. This version of ImSET uses the U.S. Bureau of Economic Analysis 2007 national input-output table, which is the latest benchmark I-O table available.

While ImSET does not include the ability to model certain dynamic features of markets for labor and other factors of production considered in more complex models, for most purposes such features are not critical for analysis of energy-efficiency technologies. The simplified (I-O) approach embedded in ImSET is credible as long as the assumption holds that relative prices in the economy would not be substantially affected by energy-efficiency investments or resulting energy savings. In most cases, the expected scale of these investments is small enough relative to the rest of the economy that neither labor markets nor production cost relationships should seriously affect national prices as the investments are made. The exact timing of impacts on gross product, employment, and earnings from energy-efficiency investments is not well-enough understood such that much special insight can be gained from the additional dynamic sophistication of a macroeconomic simulation model. Thus, we believe that this version of ImSET is a cost-effective method for estimating the economic impacts of the development and deployment of energy-efficient technologies.

Acronyms and Abbreviations

BEA	Bureau of Economic Analysis
BEAR	Berkeley Energy and Resources
CGE	computable general equilibrium
DEEPER	Dynamic Energy Efficiency Policy Evaluation Routine
DOE	U.S. Department of Energy
EERE	DOE’s Office of Energy Efficiency and Renewable Energy
GDP	gross domestic product
IMPLAN	Impact Analysis for Planning (I/O model)
ImSET	Impact of Sector Energy Technologies
I-O	input-output
kW	kilowatts
mills/kWh	mills per kilowatt-hour
NAICS	North American Industry Classification System
NZEH	near zero-energy house
O&M	operations and maintenance
PCE	personal consumption expenditure
PNNL	Pacific Northwest National Laboratory
PIRG	public interest research group
R&D	research and development
SAM	social accounting matrix

Contents

Figures

Tables

1.0 Introduction

As part of measuring the impact of government programs in improving energy efficiency within the nation's infrastructure, the U.S. Department of Energy's (DOE's) Office of Energy Efficiency and Renewable Energy (EERE) is interested in assessing the economic impacts of these programs. Therefore, in the middle 1990s EERE funded Pacific Northwest National Laboratory (PNNL) to develop a simple-to-use method to estimate the economic impacts of individual programs. After surveying three fundamental methods available to estimate employment and wage income impacts for selected energy-efficiency improvements in the U.S. economy (multipliers, input-output [I-O] models, and macroeconomic simulation models), the I-O approach was selected as the best overall approach (for an overview of each of these approaches, see the original documentation by Scott et al. [1998, 2002]). The current version 4.0 of the Impact of Sector Energy Technologies (ImSET) model also has features that assess impacts of technologies designed to reduce energy use in industrial processes, transportation, and electric power generation.

Version 4.0 of ImSET uses essentially the same methodology as the previous version (see Scott et al. [2009]), but has redefined several sectors of the economy to match the Bureau of Economic Analysis (BEA) 2007 benchmark I-O table. The major updates to ImSET are as follows:

- The I-O structure is based on the BEA benchmark I-O accounts of the U.S. economy for 2007, specially aggregated for this project to 187 sectors.
- The model now automatically generates the gross output by sector used to drive estimates of the demand for capital stock and investment (in monetary terms, and selectively, in physical terms).

The model is a static I-O model, but it allows ample flexibility regarding the types of energy-efficiency effects that can be accommodated. For example, ImSET accounts for the detailed effects of certain inter-industry purchases. Some energy-efficiency investments will not only reduce the quantities of energy required but also the requirements for labor and other goods and services. In the language of economics, ImSET accounts for investment-specific increases in productivity and value added,[1] and the *changes* to the I-O structure brought about by increased energy efficiency. The improvement in productivity is a desired effect at the core of many investment decisions. Savings in the energy, labor, materials, and services from improved productivity are the source of subsequent rounds of investment and economic growth.

ImSET can be used to estimate the impact of changes in overall efficiency and productivity in the economic sectors that make energy-efficiency investments. As an example, ImSET could apply to an investment by a paper mill in more energy-efficient equipment, the investment by an electric utility in a more efficient plant, or improvements in transportation infrastructure. ImSET also can keep track of the potential increases in value added that result from the improvement in efficiency and can—with appropriate assumptions—calculate the macroeconomic effects associated with spending this increased income.

The chief drawbacks of ImSET, or any conventional I-O model, are that 1) it does not provide information about the *timing* of impacts (e.g., such models do not predict how long an investment in efficiency will take to work its way through the economy); and 2) because no prices or explicit behavioral

[1] Value added is the difference between the value of the output of a sector and the costs of the purchased goods and services that go into the sector. It is mainly composed of labor and proprietor income, retained earnings of corporations, rents, and taxes.

adjustment mechanisms are typically found in I-O models, no internal market features are present, such as increasing prices for factors of production that automatically limit the size of impacts. In an I-O model, it is assumed that inputs needed for production in each sector are available, without limits, in constant proportions, at constant unit cost. Therefore, when analyzed in an I-O framework, even very large-scale investments that increase the scale of an industry several times over would not encounter either labor or material shortages and associated price increases. In the real world, price increases or input shortages would dampen the economic response.

While the authors of this report acknowledge the drawbacks to this (I-O model) approach, the scale of most energy-efficiency improvements relative to the overall economy is generally small enough to make the drawbacks inconsequential. To analyze larger-scale efficiency improvements or investments, a macroeconomic simulation model would be more appropriate because it would account for changes in relative prices that could be expected from very large investment cases.

The rest of this user's guide is organized as follows. Section 2.0 describes the general structure of the ImSET model and provides an overview of the calculations using simple hypothetical examples. Section 3.0 elaborates on how to set up scenarios for model use and provides examples of model input, output, and interpretation, using two example energy-efficiency programs. Section 4.0 compares the ImSET model impact estimates in the literature with those of other similar economic impact models, providing quantative results where possible. Section 5.0 provides the user with step-by step instructions for operating the ImSET model, illustrated with sample pictures of the computer screens from the user interface that the user will encounter while conducting an analysis. Section 6.0 contains a brief conclusion. Section 7.0 contains literature references. Appendix A contains data on the Section 3.0 energy-efficiency programs. Appendix B contains a listing of ImSET economic sectors, together with their equivalent 2007 North American Industry Classification System (NAICS) codes and BEA 2007 benchmark I-O sectors. Appendix C is an annotated copy of the ImSET model's code.

2.0 Approach

The macroeconomic impacts of EERE programs can be analyzed using the following four-step process, as shown in Figure 2.1. The first three steps are conducted as part of an established analytical process to estimate the benefits of energy efficiency, as typically is done in the EERE's Appliance and Equipment Standards Program (http://energy.gov/eere/buildings/appliance-and-equipment-standards-program).

The fourth step (calculating the economic impacts) has been automated in ImSET. The goal of the model-building process was to create an analytical tool that required only knowledge of efficient technologies' costs, savings, and market penetration to estimate the macroeconomic impacts of technology adoption. The ImSET national I-O model is a 187- by 187-sector version of the detailed U.S. benchmark I-O table for 2007 (available with documentation at the BEA website http://www.bea.gov/industry/io_annual.htm). The 187 sectors are those deemed most important for analyzing the economic impacts of EERE technologies; this structure is sufficiently comprehensive to cover all energy-efficient technologies produced within EERE. A full list of ImSET 4.0 sectors and corresponding North American Industry Classification System (NAICS) 2007 codes is included in Appendix B.

2.1 Details of the Approach

The four individual steps are described below.

Step 1. Identify program economic characteristics.

To analyze energy-efficiency programs, a set of assumptions must be developed concerning the effects in the marketplace when, in the future, more efficient technologies are developed or adopted as a result of current program activities. Relevant program information includes the size of the incremental investment in the technology over time compared with the conventional technology it replaces, corresponding extra energy savings by fuel type in physical and monetary terms (may include additional use of some fuels when one type of fuel replaces another), and non-energy operations savings (if any) in comparison with current (conventional) technology.[1] Sufficient information of this type currently exists for many programs. Two hypothetical technologies are used as examples in this report; they were chosen to demonstrate different types of programs, as well as some related macroeconomic issues. They are not intended to represent actual DOE programs.

- *Residential Technology*. The purpose of this hypothetical program is to develop a specific residential heating and cooling technology that can meet certain requirements of a near-zero-energy house (NZEH).
- *Commercial Efficiency Program.* This multi-technology "whole building" energy-efficiency program defines the minimum efficiency requirements for several types of commercial equipment.

[1] Some EERE programs also save water, and there is increased interest in calculating the economic consequences of these savings. ImSET 4.0 allows the user to analyze the impacts of water savings. However, the PNNL development team notes that in the 2007 national 389-sector I-O table, water utilities (which are estimated to be highly capital-intensive) are grouped with solid waste management (a much more labor-intensive industry). The two sectors cannot be separated at this time at the detailed 389-industry level; therefore, calculated water savings impacts on employment may be misleading.

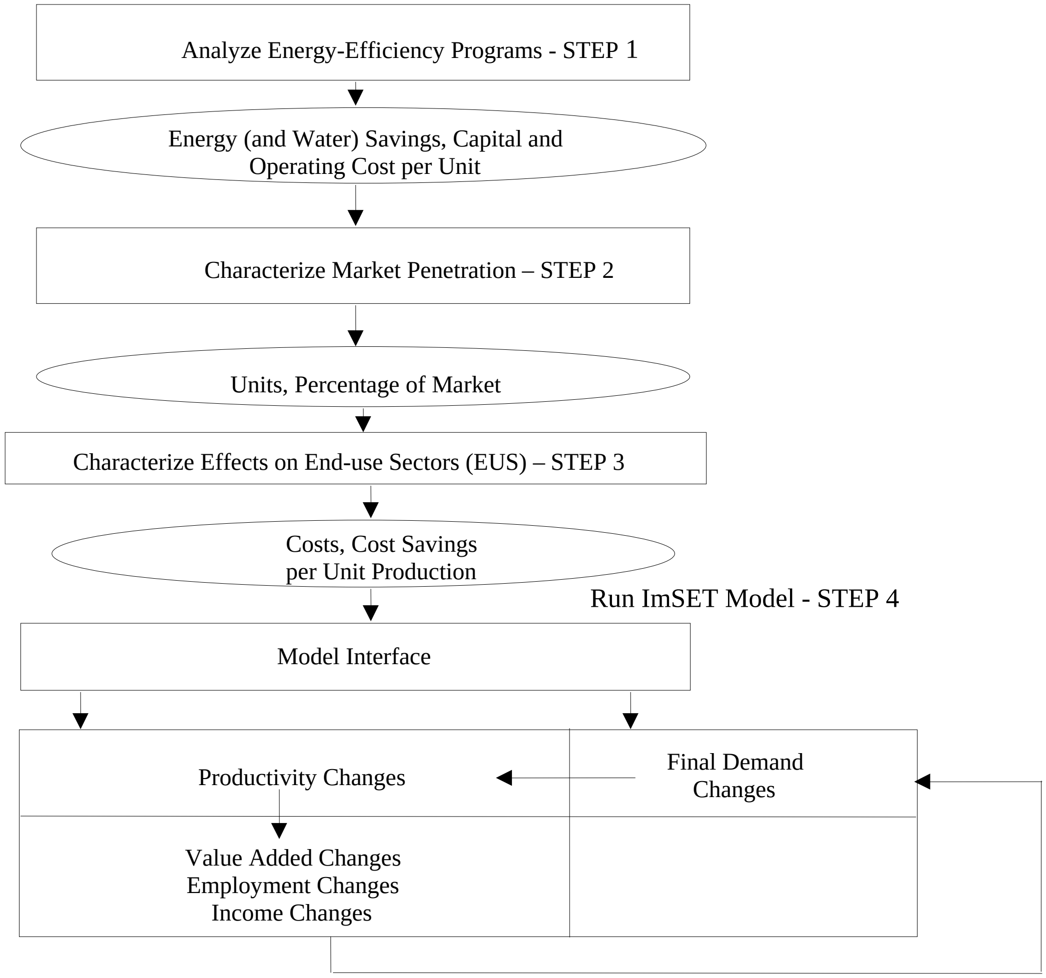


Figure 2.1. Process for Analyzing Economic Impact of Energy-efficiency Programs

These examples demonstrate the impact of programs aimed at both residential and commercial technology development.

Step 2. Characterize the market penetration of the new technologies.

Existing research on the size and characteristics of the market (s) being addressed by the EERE technologies or programs is used to estimate the market penetration of the new technologies or programs (for examples, see Elliott et al. [2004, 2008]). Analyst judgment is combined with available market information to construct the penetration functions used to model technology or project impacts.

Step 3. Characterize the effects of the EERE programs on end-use sectors (residential and commercial buildings, industrial, transportation and power production sectors).

The effects of the program on the end-use sectors, using the technology or results of the program, are characterized in Step 3. This step combines analysis from Steps 1 and 2. The model interface is used to match buildings and equipment investments in end-use sectors (e.g., classes of commercial buildings) to the economic sectors that construct, operate, or occupy these buildings. This process is necessary because although the EERE programs are organized around the principal energy-consuming sectors of the economy and their end uses, I-O models use economic sectors organized according to NAICS codes.

Step 4. Calculate economic impacts.

Using the data developed in Steps 1 through 3, the ImSET model then calculates the estimated impacts of energy-efficiency programs on output, employment, and earnings in the following three sub-steps.

Step 4a. Calculate initial investment impacts.

First, the model estimates the gross output, income, and employment effects of initial spending on energy-efficiency investments. (These impacts include the initial spending on the plant and equipment by businesses and households that adopt energy-efficient equipment and practices. The impact of spending by the efficiency programs on services provided by government, universities, and other contractors typically is not computed.) In an I-O model, this impact is estimated by changing expenditure levels in the government, household consumption, and business investment columns of final demand and in the productivity changes box of Figure 2.1. The left-hand side of Figure 2.2 illustrates the necessary calculations and related user interfaces with the model in more detail.

In Figure 2.2, there are two primary pathways by which a given efficiency scenario may affect the economy. These are the year-by-year investments required to improve the stock of energy-using buildings and equipment, and the year-by year energy and non-energy savings resulting from the improved stock. The investment pathway is divided into three sub-pathways: procurement, installation, and saved investment. The investment pathway covers the impacts on the economy from changing the stock of buildings and equipment. Using the ImSET model's user interface, the user supplies the model with estimates of the year-by-year incremental expenditures for buildings and equipment required to achieve energy savings, and estimates of the proportions of the investment going to equipment purchases (by supplying industry—the procurement subpathway) and construction (the installation sub-pathway). Both the incremental procurement costs and incremental construction costs positively affect spending in the economy. However, because the invested funds have to come from somewhere (the negative sign shows this as an offsetting effect on the economy), the user interface also assists the user in making assumptions about the source of project financing. In the energy savings sub-pathway, energy savings estimated on the right side of Figure 2.2 may allow electric and gas utilities to save or defer investments in infrastructure (a negative impact on spending), and release the saved investment funds to the general economy for other purposes (a positive effect). The model's interface helps the user to make assumptions about the size and other characteristics of these savings.

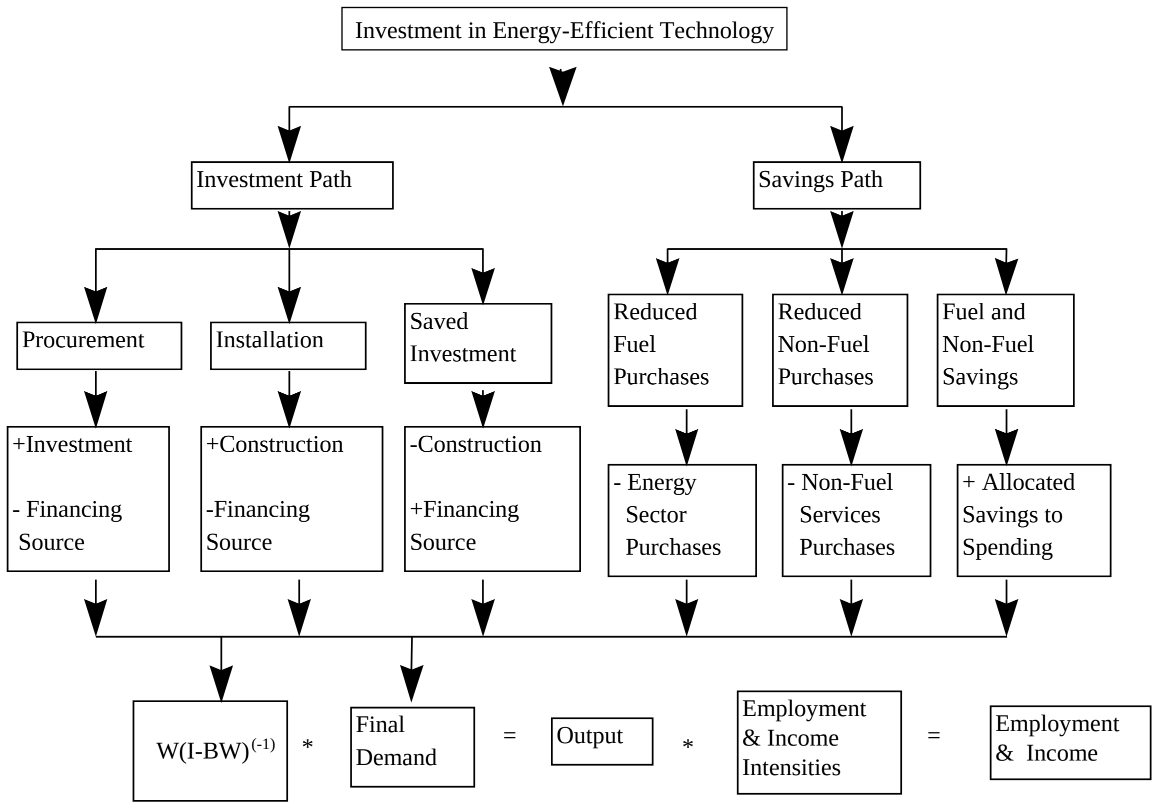


Figure 2.2. Detailed Calculations of the ImSET Model

The savings path also is divided into three sub-pathways: reduced fuel purchases, reduced non-fuel purchases, and fuel and non-fuel savings. To use the interface, the user first calculates the year-by-year physical and monetary savings in fuel oil, natural gas, and electricity as a result of the stock of improved energy-using buildings and equipment in place. (Note that the economic impact of these savings depends on the size of the year-by-year improved stock in place, whereas the impact of investment depends only on the costs related to changing the stock.) The monetary fuel savings are automatically subtracted from the sales of oil and natural gas companies and electric utilities (shown with a negative sign in the figure), which reduces the scale of the economy, and non-fuel savings in water and maintenance are allocated to purchases from the water-supplying and building and equipment service sectors, which also reduces the scale of the economy. In the case of commercial and industrial energy savings, the model also makes corresponding small adjustments to the coefficients within the model that determine how much the economy expands or contracts per unit of expenditure to reflect the fact that less energy is needed to support a given level of economic activity. However, these savings can be released to expand purchases elsewhere in the economy (for example on new clothes or new commercial services), which has a positive impact on overall spending and is the major economic effect of the savings on the economy. The user interface can be used to tell the model where in the economy these released funds are assumed to be going.

The model takes the information from the user interface to adjust its own coefficients and to create a year-by year pattern of changes in spending in the economy, by commodity (final demand). The model itself is a large matrix multiplication that contains the mapping of commodities to industries (W), the requirements of each industry from every other industry for a one dollar change in final demand (B), an identity matrix (I), and the necessary matrix multiplication, including the matrix inversion of I-BW (see Horowitz and Planting [2009] for details). For each year analyzed, this produces a vector of the final impact on economic output by industry measured in dollars. This vector is multiplied by the corresponding vectors of employment and wage income per dollar of output to generate year-by-year estimates of the effects on total employment and total income.

The residential and commercial buildings investments are estimated, based on Step 2, and then allocated to business sectors through bridging calculations. This calculation is done directly in the business sector for commercial businesses, industrial processes, transportation, and power production.

The size and algebraic sign of the national employment impacts of the initial investment process can depend on project financing. Investment typically must be financed by diverting resources from elsewhere in the economy. Therefore, the net employment impact of these energy-saving investments depends not only on the labor intensity of the investment process itself, but also on the relative labor intensities of the sectors from which the necessary investment resources are diverted. For example, as will be shown in Section 3.1, the positive impact of the initial capital investment is dampened considerably and may be reversed after the opportunity cost of the investment funds is taken into account.

Step 4 b. Calculate the impact of energy savings on value added and residential savings.

ImSET calculates economic savings (see Figure 2.2) associated with changes in the use of energy, labor, and materials resulting from the application of the improved technologies and practices. In the case of residential buildings and private transportation applications, this is relatively straightforward because residential and private transportation savings are assumed to be recycled into final demand.[2] For commercial buildings, commercial transportation, industry, and power production applications, the process is more complicated because the inter-industry relationships between specific sectors are affected, not just final demand. For example, if a commercial building saves electricity, the business sectors operating and occupying these buildings would have lower purchases from the electric utility industry per dollar of output; thus, the coefficients in the utility industry row of the I-O structure of the economy must be reduced. Results from Step 3 are inserted into the ImSET model in the inter-industry portion of the I-O table (shown as "Productivity Changes" in the bottom portion of Figure 2.1); then, the model is run with the recomputed table. Because the energy and maintenance intensity of the commercial sector changes at each annual time step, the coefficients of the I-O structure are automatically recalculated at each annual time step.

The financial impacts of energy and non-energy savings in the commercial building, commercial transportation, industry, and power production sectors (for example, savings in building maintenance) are computed by the model. These savings are regarded as an increase in value added that is available to be saved or invested by the sector collecting the income.

The energy and non-energy savings do not affect employment in the national economy until they are reinvested or spent. For purposes of the analysis conducted for this report, the increments to value added (savings) are assumed to be allocated to final demand as with all other value added in each sector. That is, the additional income of these sectors is assumed to be spent on final demand. These increments to value added increase the gross domestic product (GDP), so the increments are accumulated and are used to modify the vector of final demands (in equal proportions) so that the sum of value added and GDP are

[2] Final demand is an I-O modeling term that refers to purchases of goods and services, excluding those purchases of inputs for intermediate production. BEA sometimes now refers to this concept as "final use." Value added refers to the difference between an industry's output and the cost of its intermediate inputs. It is equal to compensation of employees, taxes on production and imports less subsidies, and gross operating surplus. For these and other I-O concepts see Horowitz and Planting (2009).

again in balance. Thus, an energy saving that occurs for industry, transportation, or commercial activity is assumed to contribute to the value added and thus increase the overall GDP, however slightly.[3]

Step 4c. Calculate the economic impact of value added and residential savings.

ImSET accumulates the energy and non-energy savings in the residential buildings and personal transportation sector and the value-added changes associated with energy and non-energy savings within the commercial buildings, industrial, power production, or commercial transportation sectors. The model then calculates spending impacts associated with these savings by proportionately increasing final demand across relevant economic sectors as noted, while at the same time reducing final demand in the sectors that supplied the saved resources. This step accounts for the spending associated with the monetary savings and improvements in technological efficiency and for the associated shift from energy to non-energy spending. It also accounts for changes in the patterns of economic activity within the economy because of technological changes caused by the EERE programs (e.g., in retail trade, less electricity is used per dollar of output because of more efficient lighting).[4] This calculation is shown in the last row of Figure 2.2 (the first box represents the recalculation of the direct and indirect requirements matrix as these technological changes occur).

ImSET collects the estimates of the initial investments, energy and non-energy savings, and economic activity associated with spending of the savings (increases in final demand in personal consumption, business investment, and government spending), and provides overall estimates of the change in national output for each NAICS sector using the adjusted I-O matrix. Finally, the model applies estimates of employment and wage income per dollar of economic output for each sector and calculates impacts on national employment and earnings. When finished, the results of ImSET model runs can be saved for later use.

2.2 Components of Impacts: A Once Only Investment

Energy conservation technology affects the activity level of the U.S. economy through three primary mechanisms. First, if the incremental capital costs of the new technology per installed unit are different (either more or less) than those of the conventional technology it replaces, changes in final demand will occur in the sectors involved in manufacturing, distribution, and installation for both technologies, changing the level of overall economic activity.[5] Second, depending on how the efficiency investment is

[3] In terms of the U.S. National Income and Product Accounts, the additional income can be thought of as increases in corporate profits and proprietors' income. The assumption here is that some of this income will be spent on investment (e.g., via retained earnings by corporations) and some on consumption goods (funded by corporate dividends to households and a portion of proprietors' income). (Some increase in government spending is also assumed as tax revenue increases.) This formulation is based upon an I-O structure with fixed output prices. An alternative formulation would be for the economic sectors to pass along the cost savings in energy as lower output prices. The alternative formulation would increase the complexity of the model substantially (requiring an explicit sub-model for prices) and would require further assumptions about what constitutes a final equilibrium of the economy after the efficiency investment is made.

[4] ImSET does not account for all long-run impacts of technological change. The change in energy-using capital in the commercial sector, for example, could alter the productivity and marginal value of factors of production other than energy (including labor and capital) and could induce a rearrangement of capital and labor that ultimately results in an increase in output and in final demand. The authors of this report show part of this effect—that of the initial spending associated with the savings—but not the effect of increased capital stock that would be created by the investment portion of the spending. Most economic models, including many dynamic simulation models, do not completely reflect the effect of capital accumulation and growth in capacity on final output and employment.

[5] Frequently, a premium is present in the cost of the purchase and installation of a new technology, over and above the cost of an alternative conventional system. For this chapter, we have assumed that the premium attached to the

financed, it may "crowd out" other potential domestic business investments and consumer spending, which somewhat reduces overall economic activity. Third, energy and some non-energy expenditures are reduced; however, this reduction lowers final demand in the electric and gas utility sectors, as well as the trade and services sectors that provide maintenance, parts, and services. It increases net disposable income of households and businesses and increases general consumer and business spending in all sectors (including some increases in expenditures for electric and gas utility services and retail trade and services).

Figure 2.3 illustrates how these mechanisms work in the ImSET model by showing the effect of a hypothetical once-only investment in residential energy conservation technology. Five cases are presented. For all five cases, it is assumed consumers spend a premium of $100 million beyond what they otherwise would have spent to obtain more efficient residential appliances in the year 2015 and will each year thereafter save $15 million in electricity costs, $30 million in natural gas costs, and $5 million in building maintenance expenditures, for an annual savings of $50 million. This $50 million dollar annual savings yields a simple payback period of 2 years. The net employment impacts are presented in Figure 2.3 and Table 2.1.

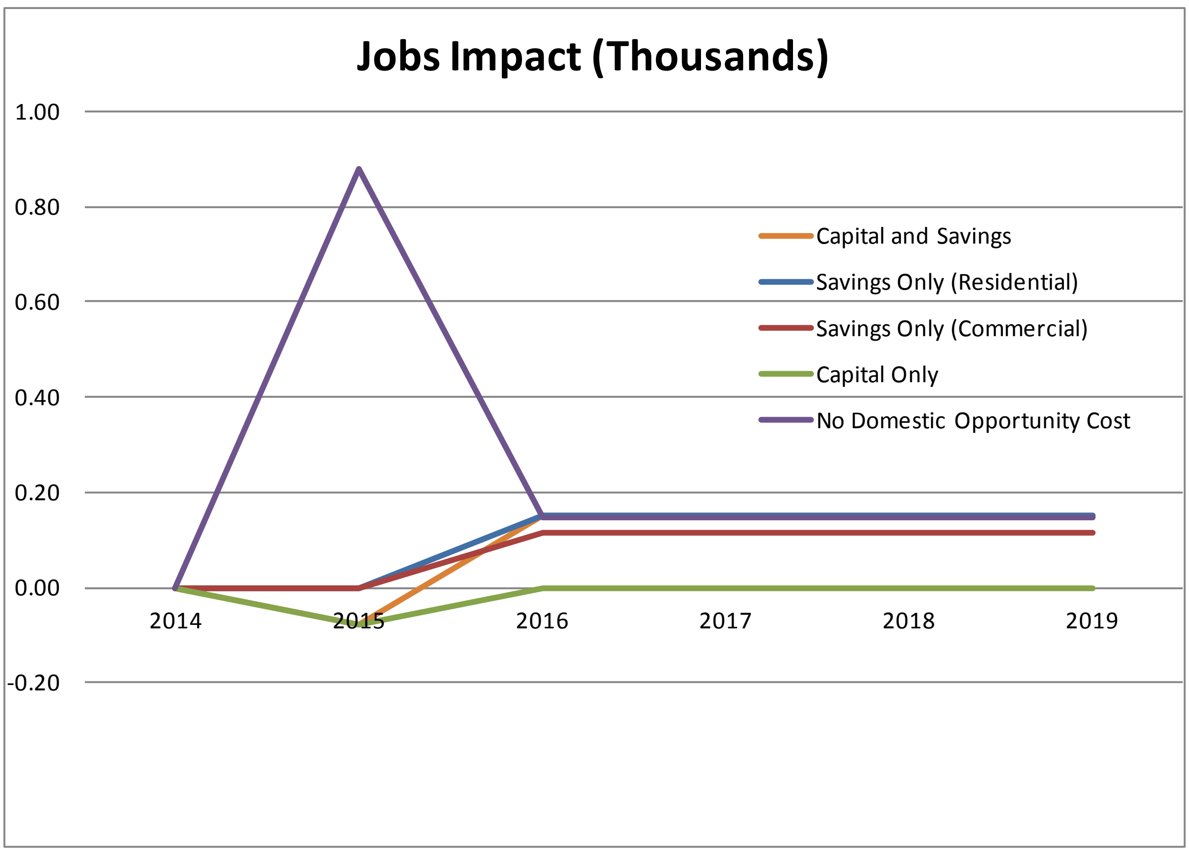


Figure 2.3. Impact on National Employment of a Hypothetical Once-Only Investment

---

new technology is caused entirely by the differential cost of manufacturing the equipment. Distributor markups and dealer costs are assumed to be unaffected. The share of the premium from incremental installation costs, if any, may be assigned to the construction sector or some other sector performing the installation, as appropriate.

Table 2.1. Employment Impact of Hypothetical Once-Only Investment (Thousands)

Case#	Run Title	End-Use Sector	2014	2015	2016	2017	2018	2019
1	Capital and Savings	Residential	-	-0.08	0.15	0.15	0.15	.15
2	Savings Only	Residential	-	0.00	0.15	0.15	0.15	.15
3	Savings Only	Commercial	-	0.00	0.12	0.12	0.12	.09
4	Capital Only	Residential	-	-0.08	0.00	0.00	0.00	-
5	No Domestic Opportunity Cost	Residential	-	0.88	0.15	0.15	0.15	.15

Case 1 in Figure 2.3 shows the employment effects of both the $100 million investment and the $50 million savings in residential buildings. The negative employment impacts (80 jobs) of the $100 million upfront investment are seen in 2015, where the employment impacts (150 jobs) of the $50 million in annual savings are seen in 2016 and following years. Cases 2 and 3 show only the effect of the $50 million in savings. In Case 2, the savings are experienced by consumers occupying the residential buildings, and the savings are assumed to be *recycled* in the economy as consumer final demand, spent on the usual mix of consumer goods and services. Case 3 shows that the impacts would change if these energy savings had instead been realized in the commercial buildings, where the savings are initially experienced as reductions in intermediate energy expenditures of commercial businesses (ImSET sectors 140 and 150−185; see Appendix B). These reductions in business costs are assumed to be shared by the firms' workers as compensation, by the companies as profits, and by government as additional taxes. These monies are then assumed to be *recycled* in the economy as spending by workers, spending by companies, and spending by government, with each group's usual respective mixes of goods and services. In Case 2 (impacts shown in Figure 2.3 and listed in Table 2.1), the energy and maintenance savings in the residential sector of $50 million have a net impact on the U.S. economy of about 150 jobs. The impact in Case 3 is somewhat smaller (120 jobs) because the energy savings occur in the commercial sector, and the employment intensity of the spending mix of businesses, their workers, and government associated with commercial savings is slightly lower than the employment intensity of the spending mix of consumers.

Figure 2.3 (and Table 2.1) includes a fourth and fifth case to show the employment impacts of the hypothetical $100 million investment premium. Case 4 shows the impact of the investment premium (no savings, only capital cost entered) under the assumption that national savings is not affected, so that (as is normally the case) investments made in any particular sector are financed by someone, somewhere else in the economy, not obtaining a loan or having to reduce spending. The investment is assigned to the air-conditioning, refrigeration, and forced-air heating sector (ImSET sector 66 in Appendix B), which is assumed to make the more efficient appliances. In this case, although additional investment in the technology itself generates employment, the short-run *net* employment impact is quite small and negative (-80 jobs) because the investment has an opportunity cost—the goods and services (and as a result, the jobs) that it would have produced elsewhere in the U.S. economy if expenditures had not been on more efficient appliances. By coincidence, this displaced activity is almost exactly as labor-intensive as the specific manufacturing sector (ImSET sector 66) that makes the more efficient appliances, so jobs gained in sector 66 and its supplying industries are offset by job losses elsewhere.[6]

[6] Strictly speaking, the labor intensity that counts is the employment, direct *and indirect*, that is created by each dollar of spending. Thus, it is theoretically possible for a capital-intensive industry to buy lots of labor-intensive inputs from other industries and the total effect to be labor intensive as a result. See Section 3.2 for further discussion.

Typically, energy-efficiency programs are thought by casual observers to be relatively labor-intensive, but this is not always the case. Heating and air-conditioning manufacturing, for example, has a direct and indirect labor intensity that is very similar to the overall economy, while some other sectors producing advanced energy technologies are much less labor-intensive. The air-conditioning, refrigeration, and forced-air heating sector has an employment multiplier of about 9.1 jobs per million dollars of sales, while the average employment multiplier for the economy as a whole is about 10.5. By contrast, the employment multiplier for household refrigerators and freezers (ImSET sector 94), which would manufacture advanced residential refrigerators, is only 7.5 jobs per million dollars of sales.

The strength and direction of the net investment effect on employment depends on the size of the investment premium and its combined domestic direct and indirect labor intensity, relative to that of other domestic spending (the opportunity cost of the investment). For the employment impact of the investment to be positive, the sectors supplying the new technology must on average create more domestic jobs per dollar of spending than other domestic spending. An extreme form of this positive investment effect would occur if the investment were financed internationally (i.e., no domestic opportunity cost is included). This is shown in Case 5, which shows a short-run jobs impact of 880 jobs, with an employment impact as a result of the energy savings unchanged from Case 2. Case 5 also corresponds, at the national level, to the assumption made in many regional analyses of energy conservation impacts, where the investment funds are assumed to come from *somewhere else* and have no opportunity cost in the region.

3.0 ImSET 4.0 Model Results for Sample EERE Programs

This section provides the results obtained by using the ImSET model to calculate the employment and income consequences of two building programs as they are introduced into the U.S. residential and commercial sectors. The two programs were chosen because they represent the diversity of EERE energy-efficiency programs, are likely to affect the economy in different ways, and illustrate a number of issues concerning the economic impact of energy-efficient end-use technologies.

3.1 Comparison of Capital and Operating Cost Scenarios for Sample Technologies

The impact of energy-efficient technologies on the national economy depends on the market penetration of these technologies and their associated investments and operating costs. This section describes the nature of two hypothetical programs and summarizes their costs and savings. Appendix A shows the detailed values of these savings and expenditures for the specific scenarios of market penetration. Figure 3.1 shows the premium in capital costs (measured in 2014 dollars) for the market penetration scenarios associated with two programs in fiscal year 2015: research and development (R&D) on a residential space-heating technology and building energy codes and energy-efficiency standards on commercial equipment. These choices illustrate two basic types of EERE programs: a focused R&D program (focused on a residential sector technology) and a broader efficiency standards program encompassing both buildings and equipment (focused on the commercial sector). The effects of the programs are loosely based on effects forecasted for some former EERE programs and should not be considered descriptive of any current program.

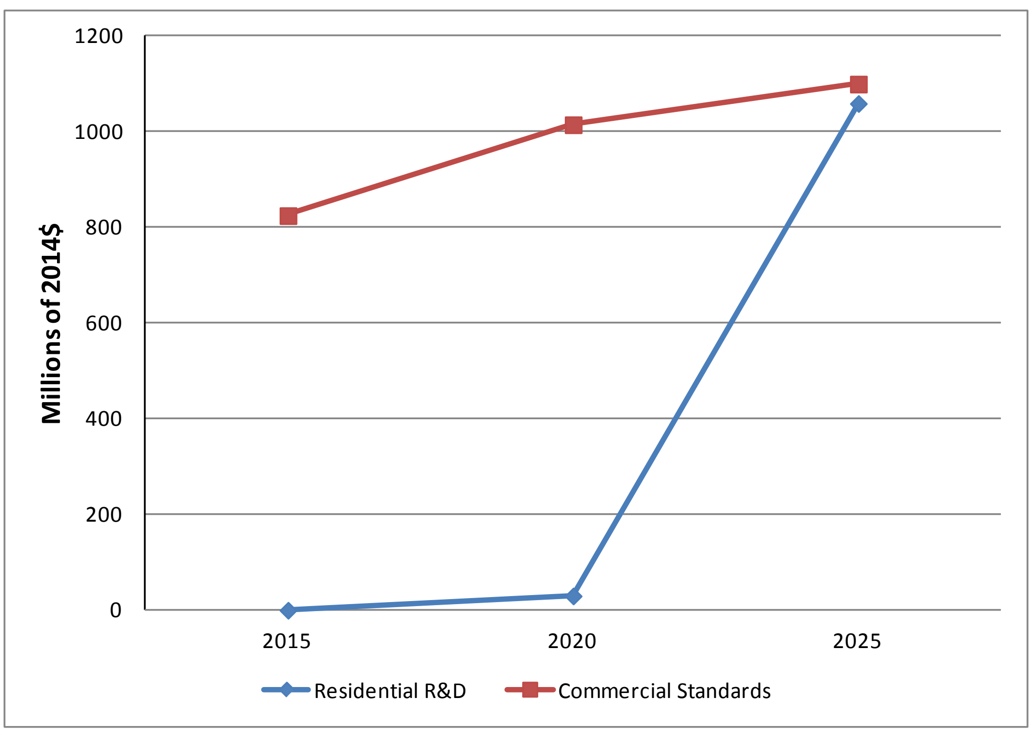


Figure 3.1. Incremental Capital Costs by Year for Market Penetration Scenarios of Residential R&D and Commercial Efficiency Standards Programs

Table 3.1. Incremental Capital Costs by Year for Residential R&D and Commercial Efficiency Program (Millions of 2014$)

	Run Title	End-Use Sector	2015	2020	2025
1	Residential R&D	Residential	0.00	30	1059
2	Commercial Efficiency Standards	Commercial	825	1015	1100

Figure 3.2 and Table 3.2show the associated energy and non-energy savings (reduction in operating costs) compared with conventional technologies. All cost premiums and savings are measured in 2014 dollars relative to baseline conditions. These figures represent total increases or decreases in cash outlays in the year shown and not the annualized savings or costs.[1] Cash outlays vary not only because of the characteristics of the technologies themselves, but also because the market penetration of each technology is expected to change over time as a result of program success.

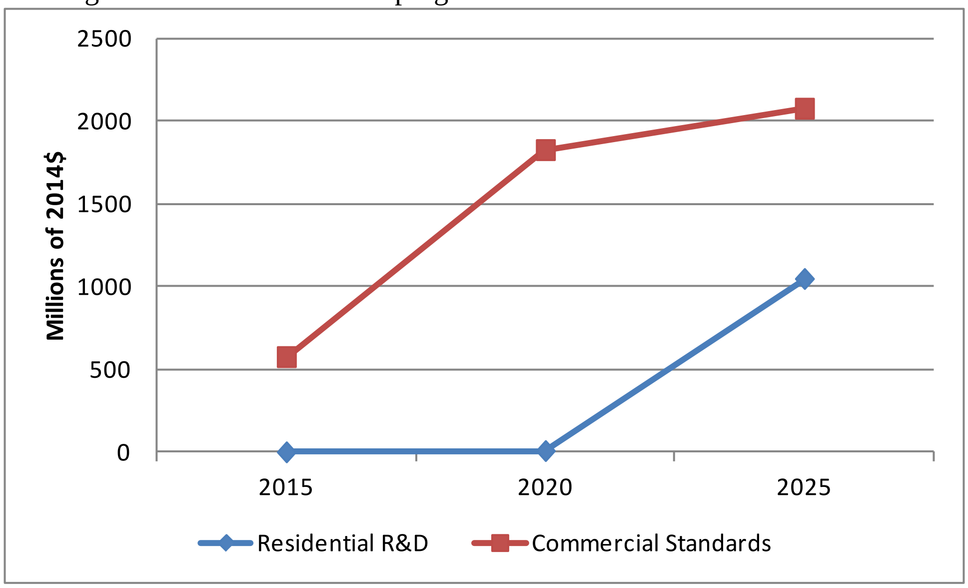


Figure 3.2. Value of Energy Savings by Year Relative to Baseline for Market Penetration Scenarios

Table 3.2. Value of Energy Savings by Year Relative to Baseline for Residential R&D and Commercial Efficiency Standards (Millions of 2014$)

	Run Title	End-Use Sector	2015	2020	2025
1	Residential R&D	Residential	-	7.6	1,046.7
2	Commercial Energy Efficiency	Commercial	575	1825.0	2075.0

[1] The authors show these figures in this manner because economic impacts, such as employment, will occur when the money is actually being spent, not when the economic entities incur the financial costs associated with the spending. Thus, for purposes of this analysis, if an investment is made in the year 2015, the jobs created are the same whether the money to pay the workers is accumulated cash or borrowed funds. The impact of the opportunity cost is more of a question because financing theoretically could change the time distribution of the impact on the cost side. Shown is the impact as if it all occurred in the same year as the investment in energy efficiency.

Both programs show significant energy cost savings in Figure 3.2—over $1 billion annually for the hypothetical residential R&D program by 2025, and over $2 billion annually for the hypothetical commercial energy-efficiency program. These cost savings depend on 1) the cumulative number of units installed compared with the same market developed with more conventional technology, 2) the relative amount of energy used or saved, and 3) any additional non-energy costs or savings. In addition, besides being more efficient, the residential program introduces a technology that substitutes electricity for gas or fuel oil.

The values used as inputs to ImSET sometimes have been derived from program assessments that are treated in isolation from each other. That is, each of the programs assumes that it has no impact on any other program. Ignoring interactions overstates the total benefits when the effects of all deployed technologies are aggregated. In the examples shown in this report, the input data were assumed to have accounted for potential program interactions.

3.2 Residential Technology R&D Impacts

Figure 3.3 and Table 3.3**.** show the employment impacts associated with variations of the residential R&D market penetration scenario. An essential feature in all scenarios is the ever-increasing investment in the residential technology throughout the forecast period out to 2025, with a high and still-growing level of new investments ($1.1 billion) in the last year. The net result is that for any time period, the economy is experiencing a mix of consequences from energy cost savings offset by additional new energy-efficiency investments, with the prospect that increased investment consequences could dominate and thereby depress employment. For example, by 2025 energy cost savings in residential natural gas and oil purchases from the replacement of conventional technologies (almost $1.4 billion per year) exceed the increased cost of the additional electricity needed to operate the electric technology that replaces them ($349 million), for a net savings of consumer energy cost of $1.0 billion.

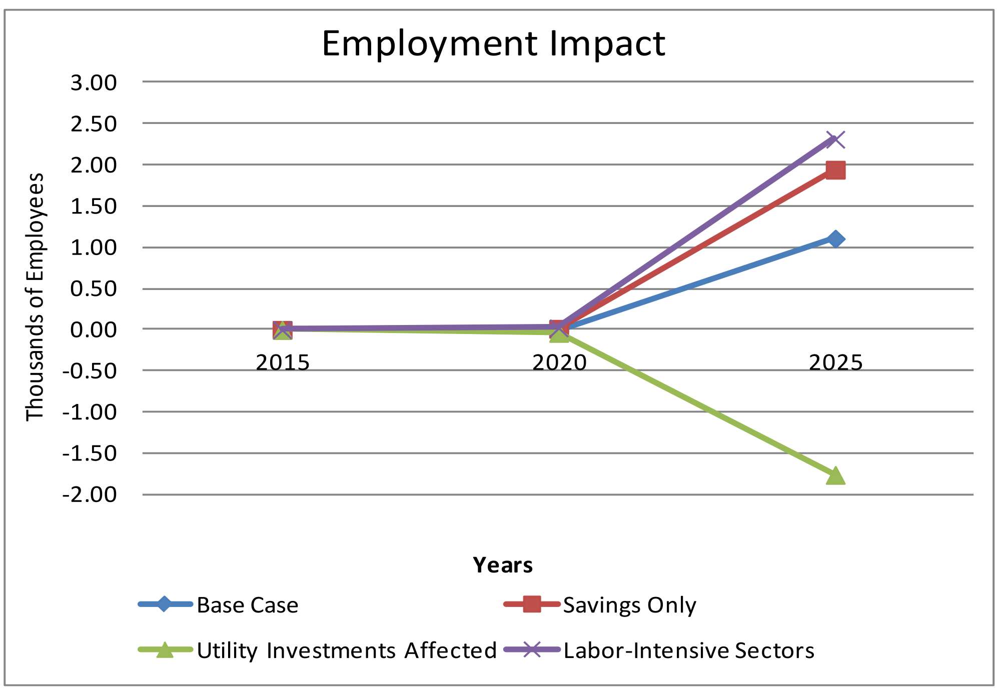


Figure 3.3. Employment Impacts of Investment in Residential Technology

Table 3.3. Employment Impacts of Investment in Residential Technology (Thousands of Employees)

Case No.	Run Title	End-Use Sector	2015	2020	2025
1	Base Case	Residential	0.000	-0.01	1.11
2	Savings Only	Residential	0.000	.01	1.95
3	Utility Investments Affected	Residential	0.00	-.04	-1.76
4	Labor-Intensive Sectors	Residential	0.00	.02	2.32

The Base Case in Figure 3.3 includes both the negative net impact on jobs from the investment in residential technology and the positive new employment effect of the energy savings. Because the investment cost in 2025 ($1.1 billion) is larger than the net value of energy savings ($1.0 billion), but has a relatively weak (negative) impact on job creation, the impact of the investment on jobs subtracts from the positive impact of energy savings but the impact remains positive. Thus, the Base Case lies below the Savings-Only Case in Figure 3.3.

The Savings-Only Case demonstrates that the net employment effect of the $1 billion savings on employment is relatively strong (about 1,950 jobs) in 2025. This is because the negative impacts of lower energy sales in the energy industry and its supplying industries in 2025 are about -8,720 jobs, and the positive impacts of consumers' spending of the saved funds are about +10,670 jobs.

At the same time, a substantial investment is required to produce these net energy cost savings. This means that in any particular time period, the economy is experiencing a mix of consequences from energy savings and the required new energy-efficiency investments. The investment in residential technology alone produces a net negative impact on jobs because spending is transferred from the more labor-intensive general economy to a less labor-intensive sector of the economy, as discussed for a simpler case in Section 2.2.

Next, we consider the effect of energy conservation on investment in capital by electric utilities and gas utilities. If energy consumption decreases, it may be possible for utilities to defer investments they otherwise would make in plant and equipment. To analyze this question, the 2013 Annual Energy Outlook overnight capital cost comparisons were used to determine that the increase of annual electricity demand increases electric utility investment by about $1436 per kW of capacity. Likewise, reduction of annual natural gas demand would reduce gas utility investment by about $0.30 per cubic foot per day of capacity based on information released by the Energy Information Administration (EIA) regarding addition to capacity on the U.S. natural gas pipeline network.[2] Reduced investment by gas utilities releases investment demand from gas utility construction to the economy as a whole, which is slightly more labor-intensive; but this effect is more than offset in this case by an increase in electricity investment demand, and labor intensity is similar to that for gas utility construction. The net utility investment increase in the economy by 2025 is about $1.26 billion, diverted from the more labor-intensive general economy, which causes a net decrease of 2,870 jobs (the overall net employment impact is about -1,760 in this case as compared with the base case of +1,110). Thus, the additional utility

[2] For this report, we estimated electric power plant construction savings at about $1436/kW of delivered electric energy, based on data in EIA (2013). The equivalent value for natural gas is about $0.30 per cubic foot per day capacity, based on EIA (2008).

investment causes net job losses. Avoided utility investment on its own, to the extent it occurs, would have had a positive impact on employment.[3]

So far, this analysis has assumed that the cost premium for this residential technology derives entirely from its manufacture. The Labor-Intensive Sectors Case in Figure 3.3is a sensitivity case that shows that if the more labor-intensive appliance distribution sectors of the economy were also affected by the initial investment (not just appliance manufacturing), the net employment effects of the investment premium would be higher, and the overall net employment effects could be above those of the Base Case.[4]

However, there is no reason to assume that wholesale and retail trade percentage markups would be levied on top of the incremental higher manufacturing costs. It is more likely that distribution, marketing, and installation costs would be about the same for the residential technology and the competitor unit.

Figure 3.4 is the wage income equivalent of Figure 3.3. As shown in Figure 3.4, and in the accompanying Table 3.4, in the Base Case the initial investment in itself reduces national wage income. This can be seen from the fact that the Savings-Only Case shows a more positive impact on wage income than the Base Case. This difference occurs mostly because the initial investment occurs in a high-wage but slightly capital-intensive sector. As was noted in the discussion of Figure 3.3, energy savings and fuel switching, if they are large enough, also could reduce utility investment in new plants and equipment (which is mostly construction activity). As in Figure 3.3 the Utility Investments Affected Case in Figure 3.4 features net increased spending on utility construction activity (because the increase in electricity investment more than offsets the reduction in gas investment), which diverts dollars into utility construction from the more labor-intensive general economy, and in turn reduces employment. However, the relatively higher wages in industries affected by utility construction offset the relative loss of jobs, producing a slightly positive impact on national wage income in Figure 3.4.[5] Thus, the net impact on national wage income in the Utility Impact Affected Case is a very slight increase relative to the Base Case even though the commensurate effect on employment is negative.

---

[3] This analysis assumes that saved utility investment funds would be recycled in the economy in proportion to the all spending in final demand. If saved utility investment funds were used to make foreign investments instead of recirculated to other domestic spending, for example, the negative impact would be significant—roughly 7,550 jobs lost per billion dollars shipped out of the economy.

[4] The differential employment impact of the residential technology investment arises because the appliance manufacturing sector and its suppliers are slightly less capital intensive as a group than the economy as a whole. Thus, diverting investment funds from the rest of the economy to appliance manufacturing tends to increase employment slightly. If the investment cost premiums were spread among more labor-intensive sectors—such as wholesale and retail trade—the average employment intensity of the residential technology investment would be significantly above the national average. For the sensitivity case in Figure 3.3, it was assumed that manufacturing took 46% of the investment premium; wholesale and retail trade, 19% and 18% respectively; and residential new and remodeling construction, 12% and 5%, respectively. These proportions assume that the investment premium is spread among installers and trade markups in addition to the manufacturing sector.

[5] In the case analyzed, the net effect is small and could be of either sign depending on exactly which sectors are affected. When relatively capital-intensive sectors spend the released investment funds, the effect is negative for both employment and income; when labor-intensive sectors spend the money, the net effect is positive for both. The illustrated case involves a mix of sectors.

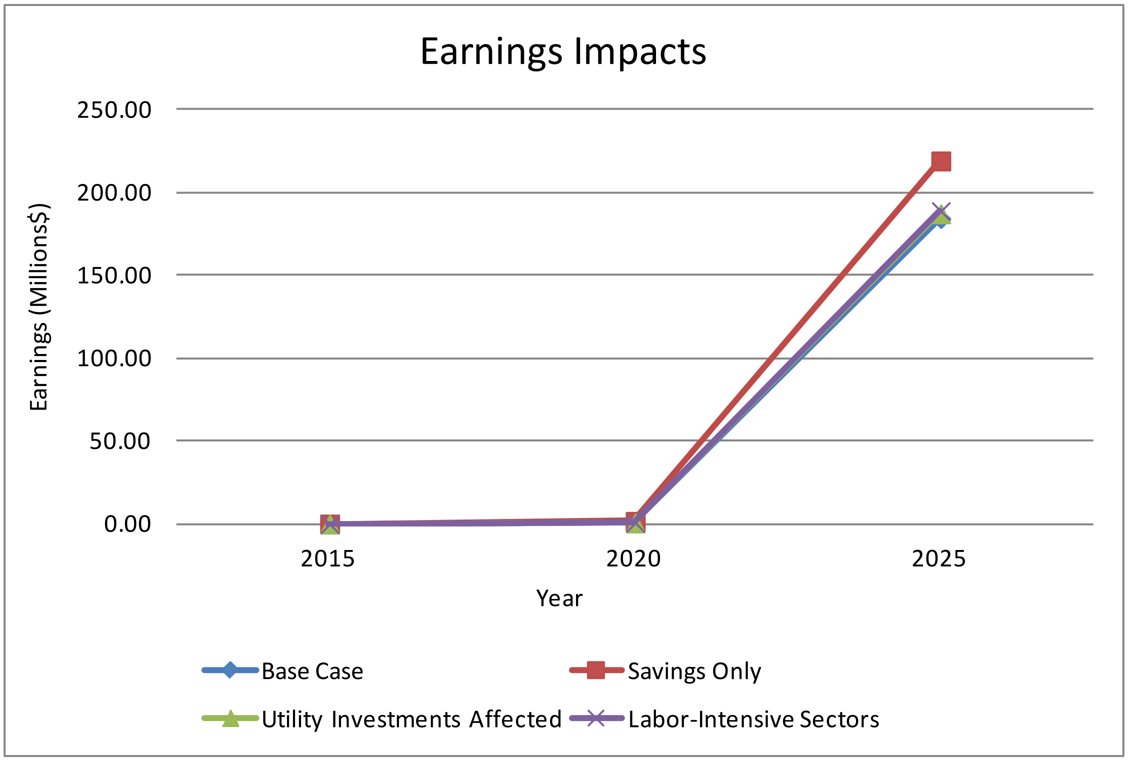


Figure 3.4. Sensitivity of Impacts on National Wage Income to Residential Technology Investments

Table 3.4. Sensitivity of Impacts on National Wage Income to Residential Technology Investments (Million 2014$)

Case No.	Run Title	End-Use Sector	2015	2020	2025
1	Base Case	Residential	0.00	0.64	184.48
2	Savings Only	Residential	0.00	1.62	219.27
3	Utility Investments Affected	Residential	0.00	0.67	187.34
4	Labor-Intensive Sectors	Residential	0.00	0.77	188.99

Finally, the Labor-Intensive Sectors Case in Figure 3.4 shows that if the investment in this residential technology were distributed across more labor-intensive industries rather than just appliance manufacturing, there would be only a slightly larger net increase in national wage income than in the Base Case. This happens because in contrast with the Base Case this alternative investment pattern involves significantly greater spending of investment dollars in labor-intensive but relatively low-wage retail and wholesale distribution (as well as in high-wage construction and capital-intensive manufacturing), increasing employment but not total wage income.[6] However, it is likely that the base case is more realistic because a majority of the investment cost premium, at least in most cases, would occur as a result of the additional cost of manufacturing, not because of retail and wholesale margins.

[6] In this case, the investment premium was distributed 46% to air conditioning, forced air, and heating; 19% to wholesale trade; 18% to retail trade; and 12% to residential new construction and 5% to residential remodeling construction sectors,respectively, for installation.

3.3 Commercial Efficiency Standards Impacts

Commercial building energy codes and equipment efficiency standards set minimum requirements for the efficiencies of commercial buildings and equipment. Adherence to the new standards is expected to require an incremental investment to commercial customers. This is an important distinction from residential technology measures. This difference is important because the ultimate pathway for expenditures that develops as a result of the energy and non-energy operational savings in the commercial sector is not obvious. Potentially, energy savings would increase the profitability of firms with new equipment that complies with more stringent energy standards. Alternatively, the additional value added per dollar of output could be shared with the work force (in the form of higher wages resulting from higher productivity) and with the government (in the form of additional tax collections). With respect to business profits, it is not clear how much would be spent or invested, or how much would be saved.

However, even if a particular business had no immediate investment plans for the funds provided by energy savings, the economy as a whole would have abundant investment and consumption options available and the capital markets could readily absorb any savings. Therefore, it is assumed that energy savings by commercial businesses are proportionately allocated to labor earnings, business profits, and taxes (in the shares they compose of value added for each industry), and then are immediately recycled in the economy as consumer spending, business investments, and government spending, respectively. The impact on national employment is shown for the savings alone in the Savings-Only Case in Figure 3.5 and Table 3.5. The Base Case in the figure additionally accounts for the (slightly negative) impacts of the investments required to achieve these savings.[7] The Utility Investments Affected Case in Figure 3.5 illustrates that if the energy savings allow for the deferral of significant capital-intensive electric and gas utility infrastructure investments (and allowance is made for the recycling of this money into the economy), there is a positive impact on overall employment for the same reasons as in Figure 3.3. In Figure 3.5, however, electric utility investment is reduced rather than increased, so the net impact on employment is strongly positive. If some portion of the cost savings were not re-spent inside the U.S. economy (e.g., if in the extreme case that all business energy cost savings were invested in telecommunications in Asia), that portion of the energy savings would have no positive effect on the domestic economy. This is illustrated in Figure 3.5 as the No Commercial Recycle Case.

[7] Capital spending estimates were $825 million in 2015, $1.0 billion in 2020, and $1.1 billion in 2025. The distribution of capital spending among sectors was assumed to be as follows: commercial building construction, 7.5%; new residential construction, 10%; commercial remodeling construction, 7.5%; residential remodeling construction, 5%; glass and glass products manufacturing, 20%; air-conditioning, refrigeration, and forced-air heating manufacturing, 22.5%; air-purification equipment manufacturing, 7.5%; electronic components manufacturing, 10%; electric lamp bulb and parts manufacturing, 5%; and electric lighting fixtures manufacturing, 5%. The labor intensity of the displaced activity is slightly greater than that of the activity supported by the investment, so there is a small negative impact on employment from the investment required to deploy the building codes and equipment standards.

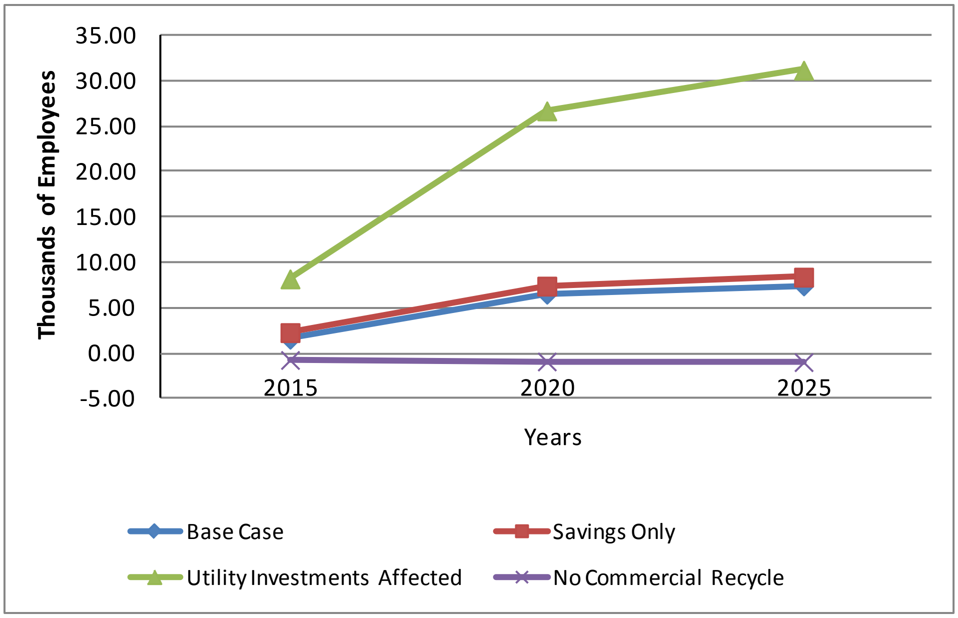


Figure 3.5. Impact on National Employment of Commercial Efficiency Standards

Table 3.5. Impact on National Employment of Commercial Efficiency Standards (Thousands of Employees)

Case No.	Run Title	End-Use Sector	2015	2020	2025
1	Base Case	Commercial	1.57	6.52	7.44
2	Savings Only	Commercial	2.29	7.41	8.40
3	Utility Investments Affected	Commercial	8.21	26.72	31.20
4	No Commercial Recycle	Commercial	-0.72	-0.89	-0.97

Figure 3.6 and accompanying Table 3.6 show national wage income impacts of the same cases discussed in Figure 3.5. The impact on national wage income is significant and positive, except for the No Commercial Recycle Case, where commercial sector energy savings do not enter the domestic economy. The sole impact in that case is the small net positive impact of the slightly higher wages of the industries involved in the initial energy efficiency investment. The Base Case produces slightly more income than the Savings-Only Case because, although employment is slightly lower, the initial efficiency investment is in industries that have slightly higher wages than the general economy. In the Utility Investments Affected case, activity is diverted from a set of relatively high-wage capital-intensive industries engaged in utility investment to relatively more labor-intensive, lower-wage industries in the general economy. Although employment is higher than in the Base Case, total wage earnings are lower.

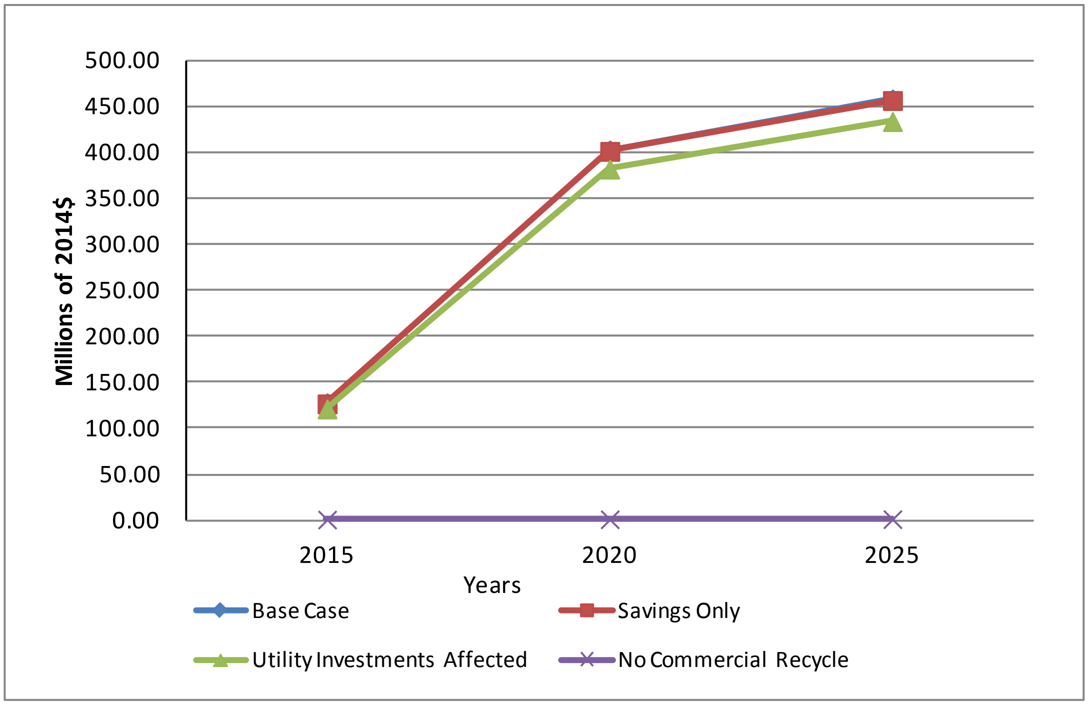


Figure 3.6. Impact of Commercial Equipment Efficiency Standards Energy Savings on National Wage Income

Table 3.6. Impact of Building Energy Codes Energy Savings on National Wage Income (Million 2014$)

Case No.	Run Title	End-Use Sector	2015	2020	2025
1	Base Case	Commercial	128.09	402.71	458.08
2	Savings Only	Commercial	126.86	401.18	456.41
3	Utility Investments Affected	Commercial	121.35	381.92	433.54
4	No Commercial Recycle	Commercial	1.22	1.50	1.62

Figure 3.7 and accompanying Table 3.7 show the net impact of commercial efficiency standards investments on employment levels when different financing scenarios are considered. The impacts of the financing cases on jobs are all positive. The impacts in the Free Financing Case are the largest, because the economy enjoys the positive impacts of the investment program to deploy the building energy codes without having to reduce other domestic spending to pay for it. Because the investment program for commercial efficiency standards includes purchases in a variety of sectors with varying degrees of labor intensity, the spending pattern of the commercial efficiency standards investment has about the same labor intensity as the rest of the economy. Thus, two of the remaining cases (Consumption Affected and Investment Affected) have impacts very similar to each other, and similar to the Base Case, all of which are dominated by the impacts of the energy savings rather than the investments required to produce them. The impact is a little lower for the State and Local Government Affected case. Because the State and Local Government sector is more labor-intensive than the general economy, the investments in energy efficiency tend to cost more jobs than if the general economy were affected.

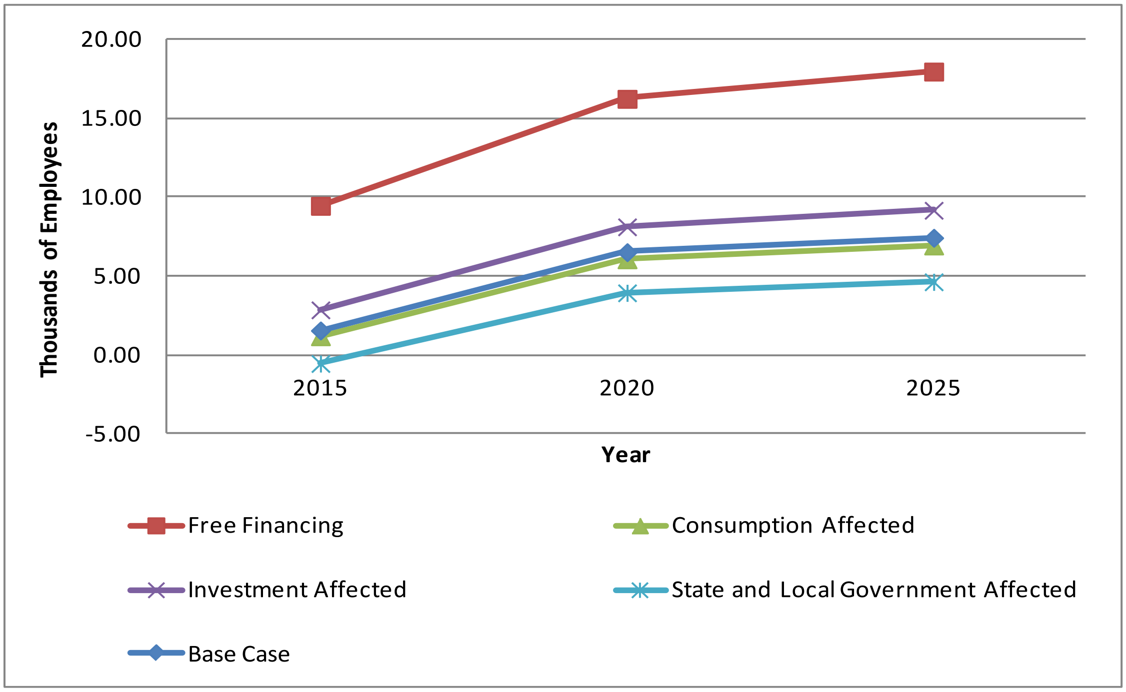


Figure 3.7. Effect of Commercial Efficiency Standards Financing on Employment Levels

Table 3.7. Effect of Commercial Efficiency Standards Financing on Employment Levels (Thousands of Employees)

Case No.	Run Title	End-Use Sector	2015	2020	2025
1	Base Case	Commercial	1.57	6.52	7.44
2	Free Financing	Commercial	9.46	16.24	17.96
3	Consumption Affected	Commercial	1.20	6.07	6.95
4	Investment Affected	Commercial	2.87	8.13	9.18
5	State and Local Government Affected	Commercial	-0.53	3.95	4.65

Figure 3.8 and the accompanying Table 3.8 show the net impact of commercial efficiency standards financing on the wage income in the economy. The national wage income is the highest in the Free Financing Case, because of the positive impacts of the energy cost savings (common to all of the cases in the figure) and because there is assumed to be no domestic financing cost of the investment required to deploy the commercial efficiency standards in the Free Financing Case. The State and Local Government Affected Case is the lowest because that sector is very labor-intensive and has relatively high wages, which means that efficiency investment dollars taken from that sector have a large negative impact on overall national earning.

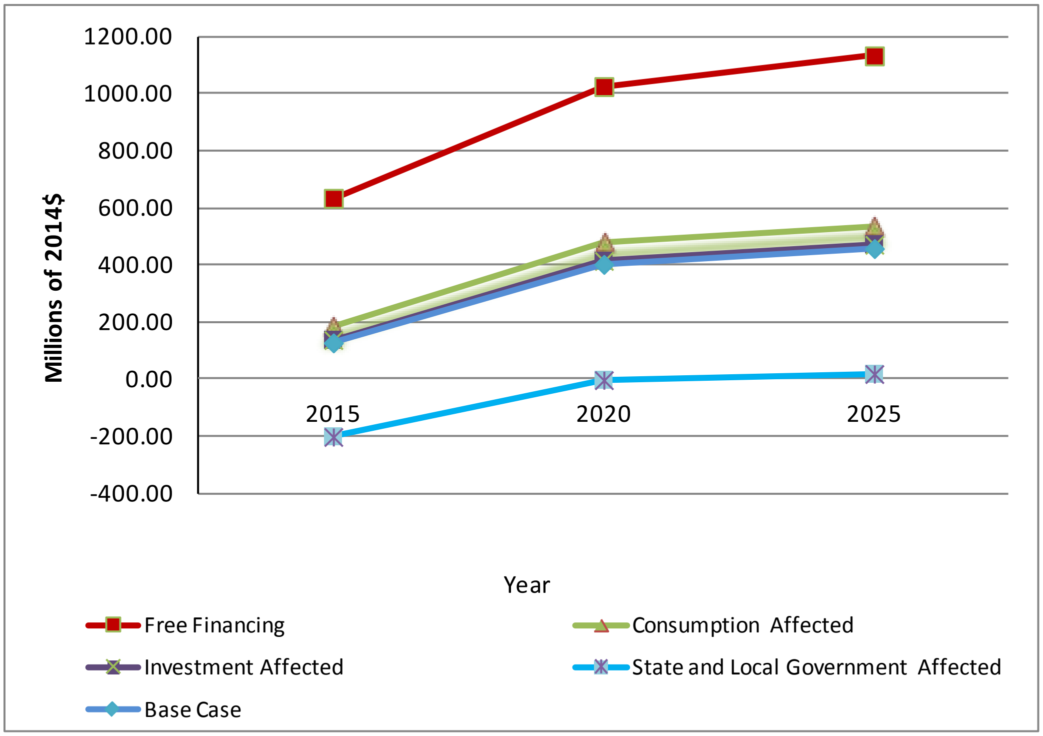


Figure 3.8. Effect of Commercial Efficiency Standards Financing on National Wage Income

Table 3.8. Effect of Commercial Efficiency Standards Financing on National Wage Income (Million 20014$)

Case No.	Run Title	End-Use Sector	2009	2015	2025
1	Base Case	Commercial	128.09	402.71	458.08
2	Free Financing	Commercial	633.97	1025.07	1132.55
3	Consumption Affected	Commercial	189.37	478.13	539.81
4	Investment Affected	Commercial	138.02	414.92	471.30
5	State and Local Government Affected	Commercial	-201.25	-2.48	18.95

4.0 Comparison with Other Studies: An Update

A number of studies have been completed in recent years examining the impact of energy-efficiency programs on employment and national income. Where possible, we attempted to reproduce and compare the results of those studies using Version 4.0 of ImSET. This exercise is similar to ones conducted for previous versions of the ImSET model (see, for example, Scott et al. [2009] and Roop et al. [2005]). Our conclusions generally remain the same. Where we have been able to conduct direct comparisons to other models using the same inputs, ImSET's results are quite similar to those of the other models we reviewed. Where results differ from the other work, the differences are in large measure due to differences in sector aggregation as well as to differences in a few critical assumptions among the authors of the various papers. The most recent detailed comparison is available in Section 2 of the analysis by Anderson et al. (2014).

4.1 Comparisons of the ImSET Approach to Other Studies

As a framework for differentiating between different approaches to estimating impacts on macroeconomic variables such as employment or income, Berck and Hoffmann (2002) provide a taxonomy of five approaches. In order of increasing complexity, the approaches are as follows:

1. Supply and demand analysis of the affected industry
2. Partial equilibrium analysis of multiple markets
3. Fixed-price general equilibrium simulations
4. Nonlinear computable general equilibrium (CGE) simulations models
5. Econometric estimation of the adjustment process.

Included in the third approach are both I-O and social accounting matrix (SAM) models, into which ImSET 4.0 falls. Berck and Hoffmann (2002) note on their page 135 that I-O, SAM, and CGE represent a continuum of approaches, with I-O and SAM models providing an upper bound to the employment impacts because factor substitution (e.g., between labor and capital) does not occur.[1] In a classical CGE model, which operates with a fully employed labor force, factor substitution would be complete, and there would be no net employment impacts in the economy, although there might be income impacts as a result of the migration of labor from one industry to another. Berck and Hoffmann (2002) apply the I-O/SAM approach to estimating the employment impacts of a decline in redwood timber sales from Del Norte and Humboldt counties in northern California. (See Xie [2000] for an application of SAM to environmental policy in China.) In pointing out the limitations of the third approach (fixed-price general equilibrium), Berck and Hoffmann (2002) note that

> ". . . with policies that do not affect relative prices, linear models are more likely to provide good approximations of actual changes than in situations where the policy impact is large enough to affect relative prices." (p. 145)

Earlier, the case was made that the technology changes examined in ImSET 4.0 are usually so small relative to the size of the economy and the economic sectors affected, that relative prices are unlikely to

[1] Factor substitution does not occur in I-O models because each economic sector is assumed to always use the same ratio of capital, land, labor, and other inputs in fixed proportions regardless of the scale of the sector. These resources are also assumed to exist in whatever amounts are needed at constant relative prices, so there is no reason to substitute one relatively scarce and expensive input for another.

be affected. Therefore, the I-O approach will provide reasonably good estimates of the impacts of the penetration of DOE technologies into the economy.

Kaiser and Pulsipher (2003) and Kaiser et al. (2004) used a similar approach to estimate the impact of establishing a Louisiana Public Benefit Fund (proposed, but not enacted), which would levy a 1 mill/kWh ($0.001/kWh) surcharge on all electricity sales; these funds would then be leveraged with other public and private funds to provide low-income energy bill assistance, low-income weatherization assistance programs, and residential and commercial energy conservation programs.[2] Kaiser and Pulsipher (2003) and Kaiser et al. (2004) used the Impact Analysis for Planning (IMPLAN) model's I-O table for Louisiana provided by the company MIG, Inc., to estimate the economic impacts of the Public Benefit Fund. Their expected outcome would provide over 32,000 residential homes with insulation, nearly 19,000 commercial buildings improved with energy savings of $26.6 million, and a benefit/cost ratio of 1.7. Their expectation is there would be almost 1700 jobs created, additional tax revenues to the state of $8.3 million, and a net economic benefit of $345.9 million.

This approach is similar to ImSET 4.0 but does not modify the use matrix in the I-O framework to show the impact of adopted technologies on expenditures by commercial and industrial firms (see Section 2.1). Our interpretation of the Kaiser et al. (2004) results suggest that a distribution of benefits and costs (30th, 50th, and 80th percentiles) were estimated using multipliers from the IMPLAN model to determine output, value added, and through these output changes, employment changes in the Louisiana economy. Specific discussion of the financing of the investments is absent in Kaiser et al., suggesting that financing of investments is treated as if the costs and benefits are on an annualized life-cycle cost basis or on a net present value basis.

Nayak (2005) (a description of the model was provided by Economic Research Associates [2005]) examined the economic and consumer benefits of clean energy policies. The I-O model used in Nayak's study is very similar in approach to that used in the Geller et al. (1992) study. The national model has 15 sectors and it analyzes the impact of reduced expenditures on energy over a period of 10 years. The payback period for any energy-efficiency project is assumed to be 4 years; the financing of the project would be at 80 percent of the cost, at 8 percent interest; and ad hoc adjustments for increased productivity and energy prices are factored into the analysis.[3] Over the 10-year time period, labor productivity changes would occur and would reduce jobs per unit of output in all but the energy savings sector. In one example, changes in energy prices during the forecast period were assumed to have no effect on the cost of initial building improvements or the energy sector's lost revenues (these are fixed outside of the model), but the increasing real energy prices would increase the impact of physical energy savings on final demand in the economy by 8 percent. Meanwhile, the impact of reduced utility revenues on final demand would reduce final demand by 6 percent. Interest rate changes would increase final demand by 2 percent in the buildings improvement sector and would increase the revenue impacts, but would have no impact on energy savings or utility revenues. A number of state models were derived from the national

[2] The Kaiser et al. (2005) paper uses an approach that measures the impact of the (enacted) Louisiana Energy Fund, a public/private cooperative effort partially funded by tax-exempt state bonds to fund energy and water conservation projects.

[3] Exactly how this is done is not explained. It is clear from the example in the Nayak report that these effects are multiplicative: the table on p. 4 shows what effect labor productivity, price effects, and interest rate changes have on final demand, but the derivation of the prices and interest rate changes is not explained. With a 4-year payback, the 10-year energy savings would be $2.5 million. Presumably, the productivity impacts are derived from Bureau of Labor Statistics estimates, as explained in the first paragraph on p. 6 of the Nayak report.

model and were designed to allow for specific effects, as requested by the U.S. Public Interest Research Groups (PIRG) Education Fund.[4]

The Nayak study was designed to examine the impact of two major policy changes to a federal government energy strategy proposal that they call the 2004 Federal Energy Package: 1) shifting $35 billion in government expenditures from subsidizing fossil and nuclear industries under the 2004 Federal Energy Package to instead spending the $35 billion on renewable energy and energy efficiency; and 2) enacting a 20 percent national renewable energy portfolio standard (the 20% Renewable Energy Standard), which would require that the United States generate 20 percent of its electricity from clean energy by 2020. Nayak (2005) shows impacts on jobs and GDP for three scenarios: 1) the 2004 Energy Package; 2) the 20 Percent Renewable Energy Standard; and 3) the Clean Energy Package, which is a combination of both the 20 Percent Renewable Standard and the $35 billion shift in government expenditures. The net impact going from the first to the third scenario in 2020 is an increase of about 130,000 jobs, $5.1 billion in wages (2001$), and an increase of nearly $4.5 billion in GDP.

While direct comparisons between ImSET 4.0 and the model used by the U.S. PIRG Educational Fund are not possible, it is possible to roughly compare employment impact multipliers, as seen in Table 4.1. The term "roughly" is used because the authors of this report have taken a simple average of the set of industries represented by the sectors reported by Nayak (2005), rather than aggregating and properly weighting the impacts by output measures. While these averages are only indicative, it is fair to report that the ImSET 4.0 employment impact multipliers, based on the 2007 U.S. I-O table and Bureau of Labor Statistics' sectoral employment intensities, are generally smaller than those reported by Nayak (2005) or ImSET 3.1, which was based on the employment data corresponding to 2002 U.S. I-O Benchmark table. Nayak's employment intensities were based on the ImPLAN 2001 database (in turn based on the 1997 U.S. I-O table and 2001 prices and labor intensities). The values for ImSET 2.0 were very close to those in the Nayak report (2005), in which the sector definitions were very similar—e.g., coal mining, electricity utilities, construction, wholesale and retail trade, and finance (Roop et al. 2005). However, in comparing ImSET 2.0, 3.1, and 4.0, we have noticed that sectoral employment intensities per dollar of output dropped significantly (perhaps 20 percent) between the 1997 and 2002 U.S. I-O tables, as well as between 2002 and 2007 U.S. I-O tables. So the fact that ImSET 4.0 shows lower employment multipliers than we observe in Nayak (2005) or ImSET 3.1 is not surprising.

[4] Again, neither the number of state models nor the specific states are identified. It is not clear whether these are composite state models derived from the national model or specific state models constructed from IMPLAN data files.

Table 4.1. Employment Multipliers, Nayak, and Selected ImSET 4.0 Industries (Jobs per Million Dollars of Final Demand)

Sector	Employment Multipliers, Nayak (2005)	ImSET 3.1 Employment Multipliers	ImSET 4.0 Employment Multipliers
Agriculture	24.2	12.08	9.20
Oil and gas extraction	9.1	8.75	3.56
Coal mining	9.9	7.04	5.69
Other mining	11.1	7.15	5.83
Electric utilities	6.1	3.87	4.80
Natural gas distribution	7.1	10.06	7.60
Construction	18.3	10.98	9.77
Manufacturing	11.6	10.65	8.60
Wholesale trade	11.5	9.67	7.59
Transport and utilities	15.9	19.55	14.94
Retail trade	25.0	19.08	16.12
Services	15.4	13.09	10.71
Finance	11.1	7.27	6.87
Source: Nayak (2005)	Nayak (2005), p. 20	ImSET 3.1, selected industries	ImSET 4.0, selected industries

Laitner and McKinney (2008) examined 48 reports that document the economic impacts associated with energy-efficiency investments, mostly at the level of individual states. A summary of the results of these studies is shown in Table 4.2. In terms of study time horizons, the period of analysis averaged 12 years in the reviewed studies, with a low of 5 years and a high of 26 years. The average in terms of energy savings over a reference case in the 48 studies was 23 percent, with savings (generally savings in the energy bill rather than physical energy) ranging from 6 to 33 percent. All programs examined within the 48 studies reported benefits exceeding costs, with benefit-cost ratios ranging from 1.1 to 4.8. Further, each program generated positive net jobs. The net impact on GDP was positive in nearly all cases, with an average impact of 0.15 percent and a high of 0.6 percent. The increase in GDP among programs was attributed to the following: 1) the net benefits of energy efficiency exceeded the investment costs, and 2) there was a shift in business activity away from energy-producing sectors, which are less labor-intensive and tend to provide a smaller value-added contribution to the overall economy relative to other sectors. These conclusions support those drawn in this report based on analysis of ImSET model output.

Table 4.2. Summary of Selected Past Energy-Efficiency Studies

Key Indicator	Low	High	Average
Period of analysis (years)	5	26	12
Efficiency potential (savings over reference case)	6%	33%	23%
Benefit-cost ratio of policy scenario	1.10	4.80	1.95
Net jobs gained per trillion Btu of efficiency gains	9	95	49
Net impact on GDP (as percent change in reference case)	-0.1%	+0.6%	+0.15%

Source: Laitner and McKinney (2008).

Laitner and McKinney (2008) went further to use the comparable data from 24 of the studies to estimate national economic impacts associated with energy-efficiency investments. The authors found that the economic impact of efficiency programs was a function of the magnitude of the energy-efficiency savings and the economic efficiency of the programs, as measured by benefit-cost analysis.[5] Through careful examination of the data supporting the aforementioned 24 studies, a matrix correlating benefit-cost ratios and energy-efficiency gains to employment effects was constructed. The results of the analysis suggest that at the national level, investments resulting in energy-efficiency savings of 20 percent and a benefit-cost ratio of 2.0 would create 838,000 jobs in 2030. Investments resulting in energy-efficiency gains of 25 percent with benefit-cost ratios of 3.0 would result in an increase in employment of 1.5 million. However, no direct comparison with ImSET results can be conducted because the Laitner and McKinney (2008) study does not explicitly mention the level of investments required to achieve suggested energy savings.

Roland-Holst (2008) examines the economic impact of existing and proposed future energy-efficiency policies in California. In so doing, the goal of the analysis was to assess the economic impact of the state's drive toward reducing greenhouse gas emissions and associated impacts on global warming. These goals include those outlined in California Executive Order #S-3-05, which calls for a 30 percent reduction in greenhouse gas emissions by 2020 and an 80 percent reduction below 1990 levels by 2050.

Detailed I-O tables were constructed for the United States and California and were used to examine the historical impact of California's energy-efficiency policies inside a general computable equilibrium model of the California economy named the Berkeley Energy and Resources (BEAR) model. These I-O tables comprised value added, inter-industry flows, and final demand for 500 activity and commodity categories. The data covered the 1972 through 2006 time period, and were aggregated up to a 50-sector framework. The I-O model was then used to compare two cases: 1) a baseline where no efficiency gains were made, and 2) a scenario that considers the impact of the programs that allow California per-capita energy demand to fall 40 percent below the national average. The study found the energy-efficiency gains experienced between 1972 and 2006 had enabled California households to divert $56 billion from energy expenditures towards other goods and services. The economic effects of the reduced energy costs included the expansion of employment by 1.5 million full-time equivalent jobs and an increase in payroll by $45 million.

[5] Regardless of whether an investment is cost-effective or not, the results always show GDP and net job impacts because it is the size and distribution of expenditures that affect GDP and employment, not whether there are any net benefits at all. An extreme example of a project with no economic benefit that has positive GDP and employment impacts is a make-work project that hires two teams of workers: one team to bury rocks, and a second team to dig them up. Cost-effectiveness of the investment requires a separate calculation.

BEAR, used to examine historical energy-efficiency gains in California, has some similarities to ImSET inasmuch as it contains an I-O model that accounts for inter-industry flows, value added, final demand, and multiplier (indirect and induced) effects. However, it does not appear to take into account the effects of financing the technologies required to achieve the energy-efficiency gains. Nor does BEAR appear to account for the capital costs associated with investment in new technologies (Roland-Holst 2008). For comparison purposes, ImSET 3.1 previously was run to assess the impacts of savings in California in isolation, but with our assumptions, the net annual job growth in ImSET was only 8100 jobs, and the net income increase was approximately $240 million. These values now would be 7,780 and 311 million.[6] We cannot however directly compare our results with those of Roland-Holst (2008) because the ImSET model requires more detailed information than could be found in the documentation of the BEAR model results.

Sedano et al. (2005) examines the economic impact of energy-efficiency programs and renewable energy investments in New England. More specifically, the study used the IMPLAN I-O model to estimate the direct, indirect, and induced effects of three distinct programs: 1) energy-efficiency-oriented programs beginning in 2000 with planned funding levels extended through 2010; 2) renewable energy deployments since 2000; and, 3) the two previous scenarios with additional investments required to meet existing renewable portfolio standards requirements. Sedano et al. account for the tradeoffs between reduced electricity prices, enhanced business profitability, increased consumer purchasing power, and enhanced spending on efficiency-related goods and services relative to fuel and operating expenses for power plants. Their projected result of the energy-efficiency programs in New England includes a net increase in economic output of $2 billion, employment of almost 15,000 job-years (15,000 cumulative years of employment over the study period), and about $700 million in cumulative income over the 2000-2010 time period. Similar analysis using ImSET 3.1 showed a job increase of 28 thousand job-years and $1.8 billion in cumulative income over the 2000−2010 time period. ImSET 4.0 shows 32 thousand job-years and $2.1 billion in cumulative income.[7]

As noted previously, Sedano et al. (2005) use the IMPLAN model to estimate the economic impacts of energy scenarios. The model traces the flows of income, goods and services, and employment among various sectors of the economy. IMPLAN, as employed by Sedano et al. (2005), is very similar to ImSET in that it considered energy cost savings, increased costs associated with investments in technologies, and a shift away from business activity in the generation of power, all in a static manner. The Sedano et al. (2005) estimate was for a regional economy. Using the same assumptions, ImSET, which is a national model, should show (and does show) a larger impact because it incorporates economic impacts that ordinarily would be part of the "leakage out of regional economy such as New England's" (Sedano et al. 2005). However, it is not entirely clear from available documentation whether there is complete equivalency of assumptions.

Eldridge et al. (2008) examines the energy and economic impacts associated with a suite of policy proposals aimed at enhancing energy efficiency in Maryland. In modeling the macroeconomic effects of the energy-efficiency gains associated with the proposed energy policies, Eldridge et al. (2008) used the American Council for an Energy-Efficient Economy's Dynamic Energy Efficiency Policy Evaluation

---

[6] The Savings-Only Case was computed with $160 million of annual savings assigned to residential oil expenditures, $571 million to residential natural gas expenditures, and $869 million to residential electricity expenditures. Reduction of the investment in electric utilities and natural gas distribution as a result of natural gas and electricity savings was also considered.

[7] The ImSET analysis assumed free financing and included the transitory impacts of the efficiency investment. The input data set was developed based on Tables 2.12 and 2.13 in Sedano (2008). The energy-efficiency impact was adjusted to account for reduction of investment in utilities as a result of electricity savings.

Routine (DEEPER) model. Inputs used by the model include annual program spending, electricity savings resulting from energy-efficiency investments, and the capital and operating, including financing, costs associated with those investments. The DEEPER model is described as a quasi-dynamic input-output model with six key modules:

1. Global data (economic time series data, key model coefficients, and parameters needed to generate final model results)
2. Macroeconomic model (input-output relationships based on IMPLAN data)
3. Investment, expenditures, and energy savings
4. Price dynamics
5. Final demand
6. Results.

The macroeconomic modeling procedures used in DEEPER, which includes I-O matrices, are similar to those in ImSET. Further, like ImSET, DEEPER considers the impact of investment financing costs. Unlike ImSET, DEEPER also includes modules designed to explore the impact of reduced energy consumption on wholesale electricity prices.

Policies evaluated by Eldridge et al. (2004) include implementation of federal and state appliance standards, more stringent residential and commercial building codes, policies designed to encourage investment in combined heat and power systems, and expanded utility demand response programs. The impacts of these policies were estimated to result in 15 percent savings in energy consumption compared to the reference forecast, producing $861 million in consumer energy cost savings in 2015 and $2.6 billion by 2025. On average, households in Maryland are forecast to save $8 on their monthly electricity bill in 2015 with an additional $2 in savings resulting from the impact of declining demand on wholesale energy prices. These energy savings are forecast to result in positive net employment effects of 8,067 jobs in 2015 and 12,241 jobs in 2025. Wages are forecast to increase by a net $462 million in 2015 and $780 million in 2025.

Assuming a Savings Only case with savings split equally between residential and commercial sectors, the results of ImSET calculations for the same level of savings show a net job increase of 5930 jobs in year 2015 and 17,930 in 2025. The net earnings increase is $156 million in 2015 and $470 million in 2025. While the models are different and the documentation available in the Eldridge et al. (2008) report did not allow exact duplication of assumptions for ImSET, it appears that both models obtained impact results of roughly the same order of magnitude.

5.0 Operating the ImSET 4.0 Model

ImSET 4.0 runs on the Windows® operating system. It requires installation of the software using SETUP.EXE program provided. Prior to installing ImSET 4.0, all previous versions need to be uninstalled. This will ensure that all components of the model are installed properly. Once ImSET 4.0 is installed, the user starts the program using normal Windows interface methods. On startup, the ImSET 4.0 program displays the main “Run specifications” screen (see Figure 5.1). The user uses this screen to add records to represent specific program assumptions.

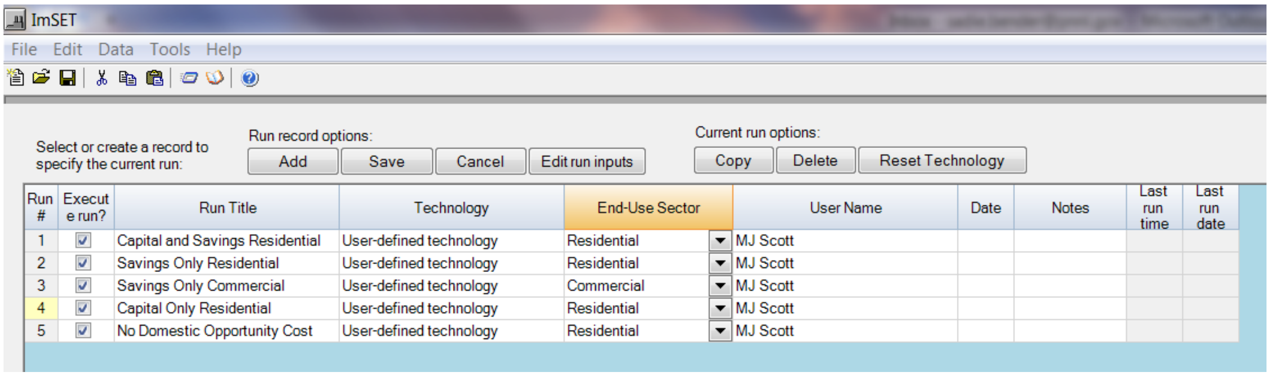


Figure 5.1. ImSET 4.0 “Run Selection” Screen

5.1 ImSET 4.0 Options

The “ImSET Run Selection” screen is used to specify unique program scenarios. Each input record signifies a unique program scenario. Users can add as many records as there are unique scenarios to be compared. However, only the records that have “Execute run” checkbox checked will be executed (see Figure 5.1). By specifying “run records,” the user creates a new “run database”, which is a Microsoft Access Database (.mdb) file. The user can create, save, or open scenario files using the menu options under the “File” menu (see Figure 5.2). The run database will hold all information and results specific to the scenarios established and specified. Thus, a user can make any number of run databases for specifying unique scenarios.

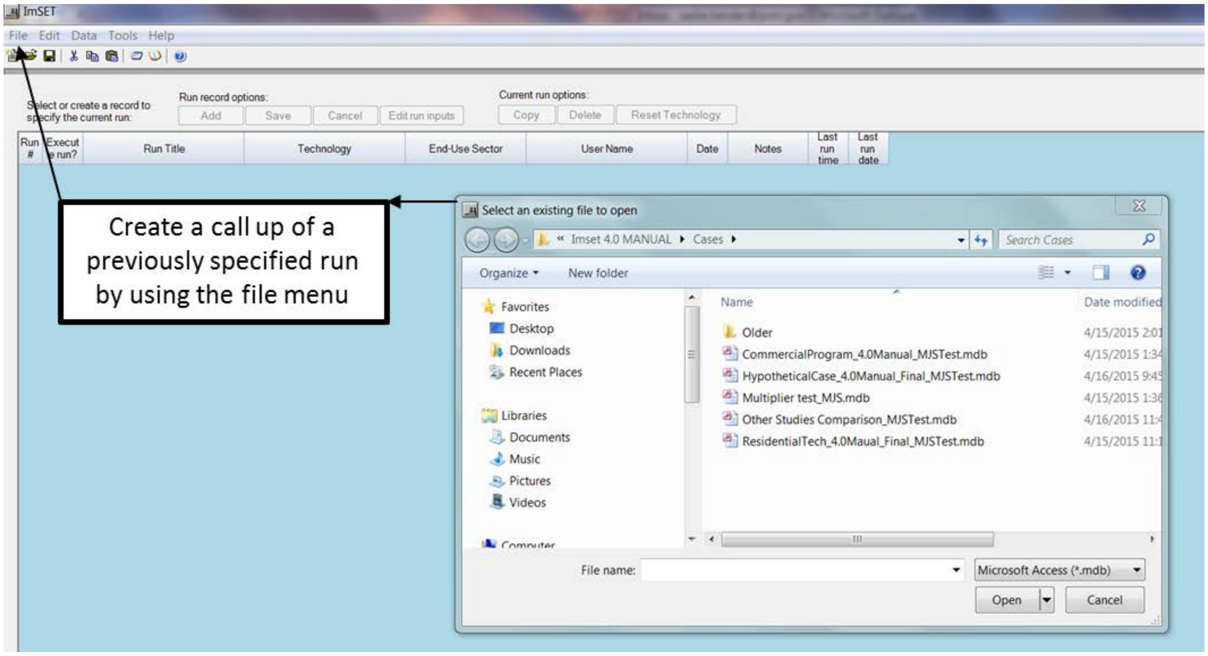


Figure 5.2. Run Selection Screen Showing File Menu

Screen functions are as follows:

- **Add** − Adds a run record to the run database.
- **Save** − Saves the run records currently listed on the screen to the currently open run database.
- **Cancel** – Cancels any unsaved changes to a run record and refreshes the display.
- **Edit run inputs** − Displays a screen of detailed “run inputs” that can be edited by the user.
- **Copy** − Copies the currently selected run record and adds a duplicate to the bottom of the current database (the currently selected record is indicated by yellow marker in the column farthest left and/or in status bar at the bottom of the screen). To select an existing run record, point the cursor at its title and left click, or use the keyboard up and down arrows.
- **Delete** – Removes the currently selected run record from the screen and the run database. A “Confirmation request” is displayed to verify the request. The “Confirmation request” can be “turned off” for future deletions by checking the appropriate check box in the “Confirmation request” screen.
- **Compute program impacts** – Computations of program/technology impacts are run on all run records that have the “Execute run” column checked. After computations are done, the results screen is displayed.

- **View program impacts** – Displays the results screen without running computations. Results are displayed for the last computed impacts.

- **Help** − Displays the help file.

- **Exit** – Exits the ImSET program.

"Run specification" columns (Figure 5.3) are described in the following:

- **Run #** – A unique identifier for a run record. This is a non-editable column and is determined programmatically.

- **Run title** – User provides description of the specified run record.

- **Technology** – The technology/program is assigned to the specified run record. When a run record is added, the technology list is displayed as a drop-down list containing all default technologies/ programs. Select the appropriate choice.

  Note: The user cannot change the technology choice after it is saved using the run record. However, after saving the record, the user can edit the technology description and edit its underlying data and/or copy the edited technology to another run record.

- **End-use sector** – Identifies the appropriate energy end-use sector for the run record. The selection determines what energy use sectors the user will have access to in the "Run inputs" screen. The energy end-use sectors in ImSET are the residential, commercial, industrial, and transportation sectors. Depending on the end-use sector selected, different subsets of ImSET's 187 economic sectors experience energy savings.[1]

- **User name** – User provides name for reference purposes only.

- **Date** – User provides date for reference purposes only.

- **Notes** − Place available to enter brief explanatory notes on the run record. Save the notes after entering by using the Save button under Run Record Options on the screen.

- **Last run time** – Indicates the time the record impacts were last evaluated.

- **Last run date** – Indicates the date the record impacts were last evaluated.

[1] ImSET economic sectors that are benefitted by commercial energy end-use savings are sectors 11,12, 13, 140 and 150−175 and government enterprises in sectors 177−185; sectors that benefit from industrial end-use also include agricultural, mining, and construction sectors and comprise sectors 1 through 139 (except for 12−14); and transportation end-use savings benefit sectors 141 through 149 and 179. Household enterprises (176), owner-occupied housing, and rest-of-world (186−187) cover the rest of the economic sectors. They are not affected by energy and water savings. Residential end-use savings are treated separately and automatically by ImSET and benefit almost all sectors through consumer spending.

If a run database has been newly created, it will appear without any run records. Click the Add button to add a new record and then fill in the cells. Run Title, Technology, and End-Use Sector must be specified. Select Save to save any new run records or changes to existing run records.

To access the underlying economic and technical data of the run record, select the Edit run inputs button and review/edit the data as needed.

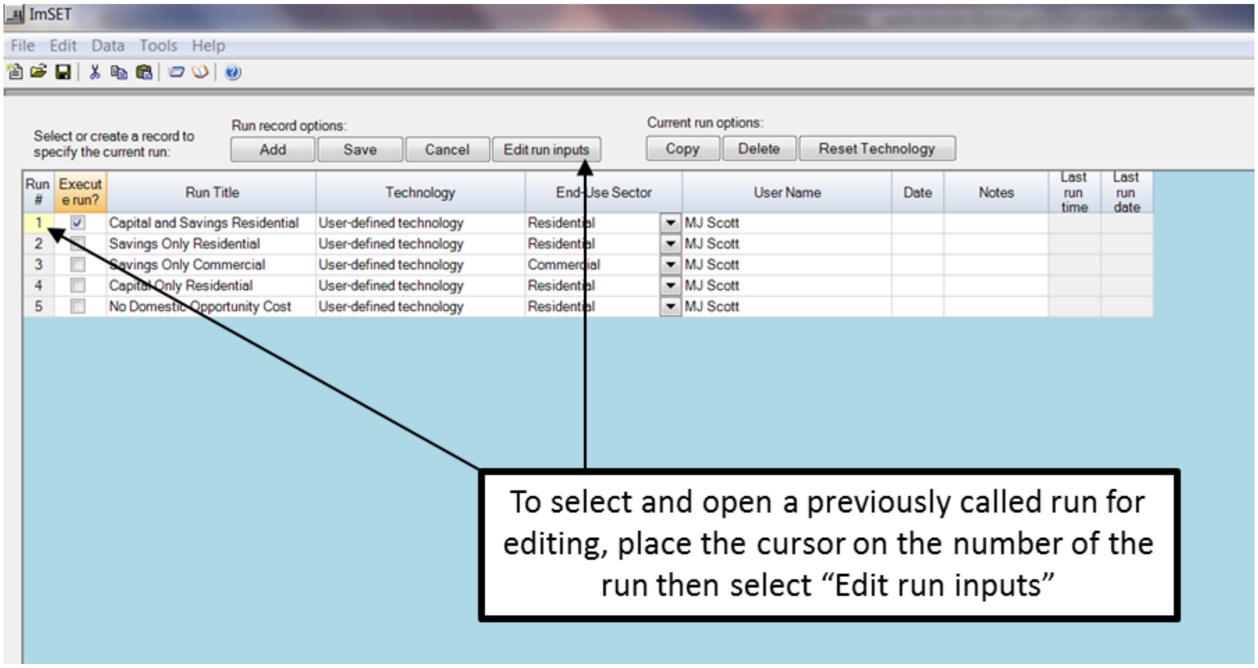
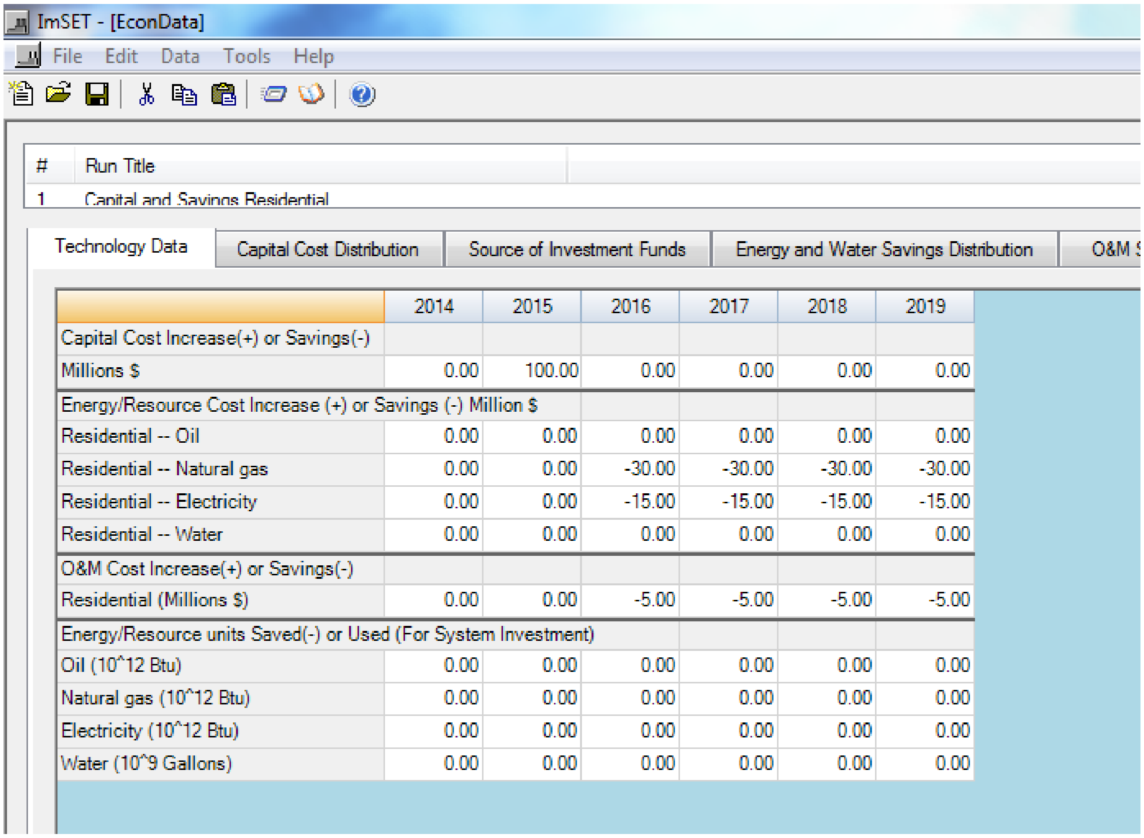


Figure 5.3. Selecting a Run for Editing

When all data have been specified, the user can select Compute program impacts to perform the actual calculations and display results. Note that only those run records that have "Execute run" checked will be included in the calculation process and displayed in the results screen. If there are no changes since the last calculations were run and the user simply wants to review the results, select the View program impacts button.

5.1.1 Tab 1: Technology Data

The Technology Data tab (see Figure 5.4) is used to enter and edit the model user's assumptions concerning incremental programmatic impacts on capital cost, installation cost, energy or resource cost, operations and maintenance (O&M) cost, and energy or resource savings for a single run record. The appropriate units for each variable are displayed in the row headings. Note that all data are specific to the run record described in the drop-down list at the top of the screen. Furthermore, the rows displayed in the screen are dependent on the "End-use sector" (residential, commercial, industrial, or transportation) that is selected for the run record. To view the technology data for a different run record, select a different run record at the top of the screen.



	2014	2015	2016	2017	2018	2019
Capital Cost Increase(+) or Savings(-)						
Millions $	0.00	100.00	0.00	0.00	0.00	0.00
Energy/Resource Cost Increase (+) or Savings (-) Million $						
Residential -- Oil	0.00	0.00	0.00	0.00	0.00	0.00
Residential -- Natural gas	0.00	0.00	-30.00	-30.00	-30.00	-30.00
Residential -- Electricity	0.00	0.00	-15.00	-15.00	-15.00	-15.00
Residential -- Water	0.00	0.00	0.00	0.00	0.00	0.00
O&M Cost Increase(+) or Savings(-)						
Residential (Millions $)	0.00	0.00	-5.00	-5.00	-5.00	-5.00
Energy/Resource units Saved(-) or Used (For System Investment)						
Oil (10^12 Btu)	0.00	0.00	0.00	0.00	0.00	0.00
Natural gas (10^12 Btu)	0.00	0.00	0.00	0.00	0.00	0.00
Electricity (10^12 Btu)	0.00	0.00	0.00	0.00	0.00	0.00
Water (10^9 Gallons)	0.00	0.00	0.00	0.00	0.00	0.00

Figure 5.4. Technology Data Tab

Values on the Technology Data tab can be cut and pasted into the tab or entered and edited by hand. However, this step requires an understanding of the total market impacts (e.g., energy savings, cost savings, investment costs) of the technology; which would usually be derived from another model or analytical framework. For example, in performing assessments for the Appliance and Equipment Standards' Program, PNNL has used results from national impact analysis models. For other situations, the BEAMS model (Elliott et al. 2004, 2008) was used to develop many of these estimates. Years covered by the scenario can also be changed.

Note that all costs or savings values are considered to be *differences* from the conventional competing technology. In the example shown in Figure 5.4, the adoption of the energy-efficiency technology results in $100 million in additional investments during the year 2015. As shown in Figure 5.4, this investment yields the following annual expenditure impacts: $15 million saved in residential electricity, $30 million in residential natural gas, $5 million in residential natural gas, and $5 million in residential non-energy operating costs, with no change in water expenditures and no change in oil expenditures. The energy and operating cost savings are differentials between some base case cost savings and those produced by the new technology. The costs are expressed in annual savings for the year shown even though those savings (entered as negative values) depend on cumulative investments. The capital costs are the cash investments in the year shown (entered as positive values). This accounting is required by the I-O model's structure with requires an annual cash flow.

Technology Data Tab Key Functions

Advanced technology options – Two buttons (**Add Technology to 'Default' list…** and

Delete Default Technology…) enable the user to add and/or delete a technology to or from the "Default" technology list. This feature allows the user to establish customized versions of a technology that can then be used repeatedly when adding new run records.

Add/remove years − Enables the user to add and/or remove years from the currently displayed run record

Note: Choices made on the Technology Data tab only affect the currently displayed run record. Before run records in a run data set can be processed by the model to calculate impacts, all run records in the run data set must have the same set of years.

Changing the Default Technology Options

Add Technology to 'Default' list… − Enables the user to add a technology to the "Default" technology list (see Figure 5.5). This feature allows the user to establish customized versions of a technology that can then be used repeatedly when adding new run records to a run data set. More specifically, the user may have a particular set of technology data and years that are not currently represented in the "Default" technology list. To create a new "Default" technology, simply select an existing run record (which can be an existing "Default" technology or a "User-defined technology"), edit it if desired, save any changes, and then select the Add Technology to 'Default list…' button on the Technology Data tab. The user will see a new "Add technology" screen appear (Figure 5.5), in which a unique technology name can be entered where requested, then select Save and Close. At this point, the user can return to the "Run Selection" screen.

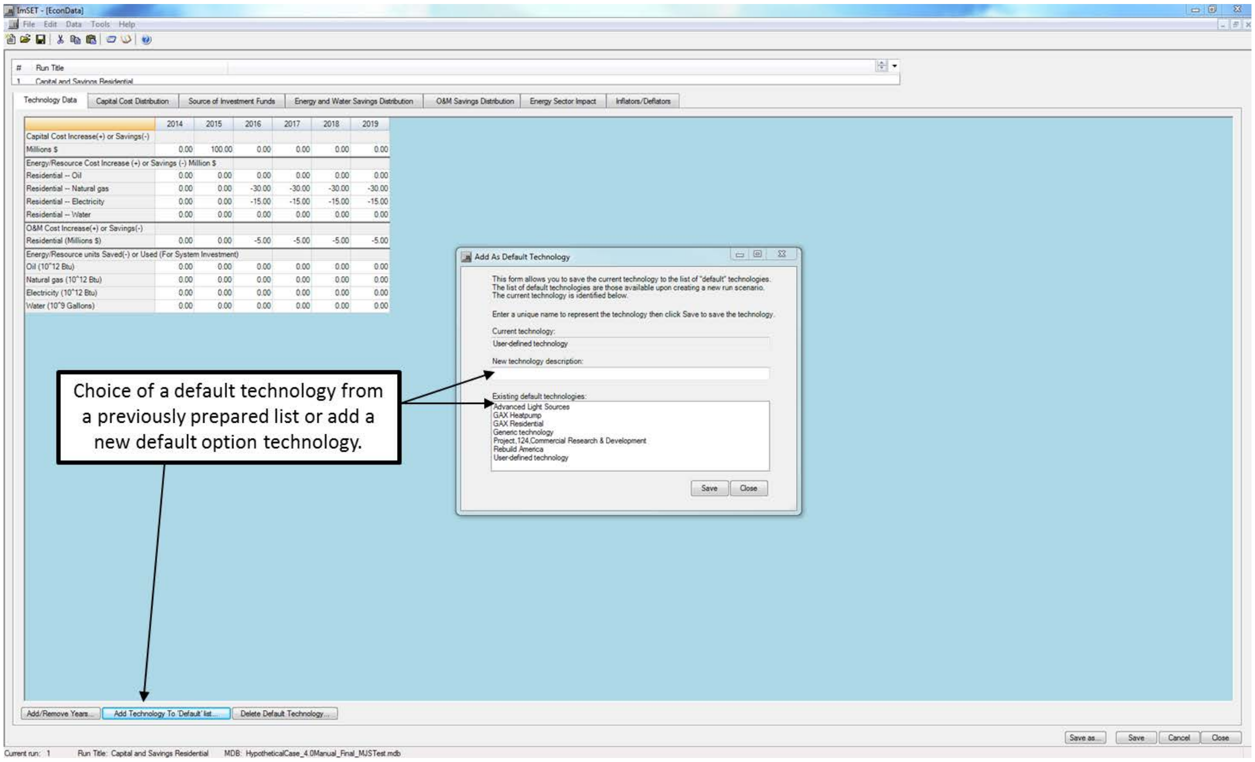


Figure 5.5. Adding to the Technology Options

If the user adds new run records, the newly created technology will appear in the drop-down list of “Default” technologies.

Delete Default Technology… – Enables the user to delete technologies from the “Default” technology list. **Note:** deletion of a technology only affects the “Default” technology list and in no way deletes records from the user database file.

5.1.2 Tab 2: Capital Cost Distribution

Enter the percentage values (enter “50 percent” as “50”) that represent the distribution of capital cost premiums for the applicable sectors. The total of all values ordinarily must equal 100.[2] In the example shown in Figure 5.6, the capital cost premium is allocated to a single sector to equal 100%. Completing this table requires some understanding of both the nature of the technology as well as the structure of the economy that will need to produce that technology. When finished entering values in the table, enter Save and Close. Each time a value is entered by hitting “enter,” the “Total %” cell will update, showing the sum of the values entered (if all values are zero, the cell will be 0). The current system default is zero for all values in the table. The Reset all to 0 button sets all of the values in the table to zero.

[2] The user may want to account for investments that have a large import component. The authors recommend that the user record the portion of the investment that is domestic in the Technology Data tab, allocate that domestic portion to equal 100% (as shown in Figure 5.6), and then under the Source of Funds tab (discussed in Section 5.2.5), record the domestic opportunity cost of funds as more than 100% to account for both the domestic and imported portions of the investment; e.g., if 50% of a $100 million cost were domestic, the user would record $50 million, allocate 100% of that, and then ensure the source of funds summed to 200% (of the $50 million).

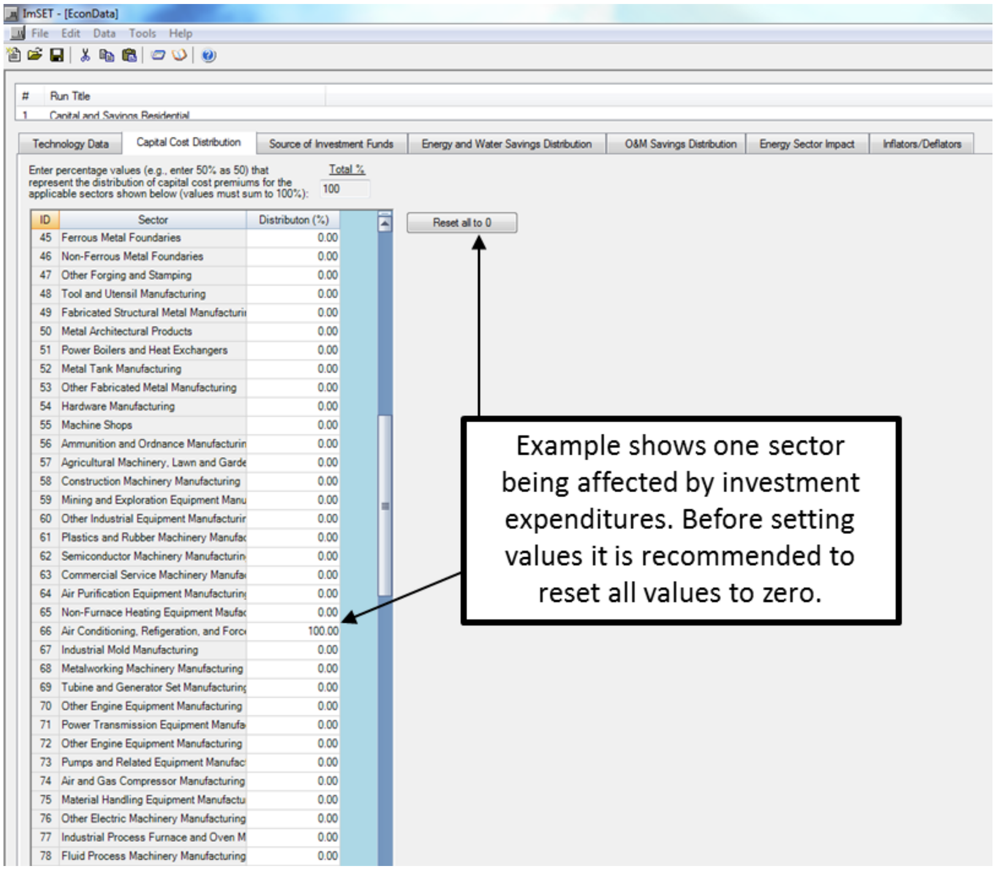


Figure 5.6. Allocation of Capital Cost

5.1.3 Tab 3: Source of Investment Funds

Investment funds spent on energy-efficient equipment have an opportunity cost; that is, they would have been spent somewhere else in the domestic economy or overseas if they had not been spent on energy-efficient equipment. This tab allows the user to specify the source of the funds used for investment. Enter the percentage values (e.g., enter "50 percent" as "50") that represent the share of the energy-efficient investment funding provided by each applicable source in the economy (personal consumption expenditures or PCEs, investment, etc). The most common assumption is that investment funds will come proportionately from all domestic spending.

There are occasions when the user may not want to consider the opportunity cost of some or all the funds used for investment. For example, if only the impacts on a local region were being considered and the funds came from the national financial markets, the local area might see the positive impact of the investment as well as any energy savings, but would not experience costs to the national economy. These costs would be felt elsewhere. Another reason might be if a substantial part of the displaced spending were somewhere else in the world and only the domestic impact was important.

The sum of the sector allocations does not need to equal 100 percent, but if it does not, the model will proportionately allocate the remaining percentage to sum to 100 percent[3] unless it is overwritten. The

[3] The model allocates spending reductions within the remainder (unallocated) percentage using the average proportions that consumption, investment, etc. compose in all final demand in the 2002 economy. To see how this works, note that the actual shares in the 2002 economy were 70.2%, for PCEs and 15.1% for investment. Thus, if

overwrite check box allows some or all of the opportunity cost of invested funds to not be counted against domestic final demand. If opportunity cost of the investment funds is irrelevant to the analysis, then all values can be set to 0. To do this, set all of the sectors to 0, check the check box, and then enter 0 in the "Share to allocate" box as well. However, note that even if all explicit shares in the Distribution % box are set to 0, each sector will have its spending reduced by the proportion it represents of all final demand *unless* the overwrite check box is checked.

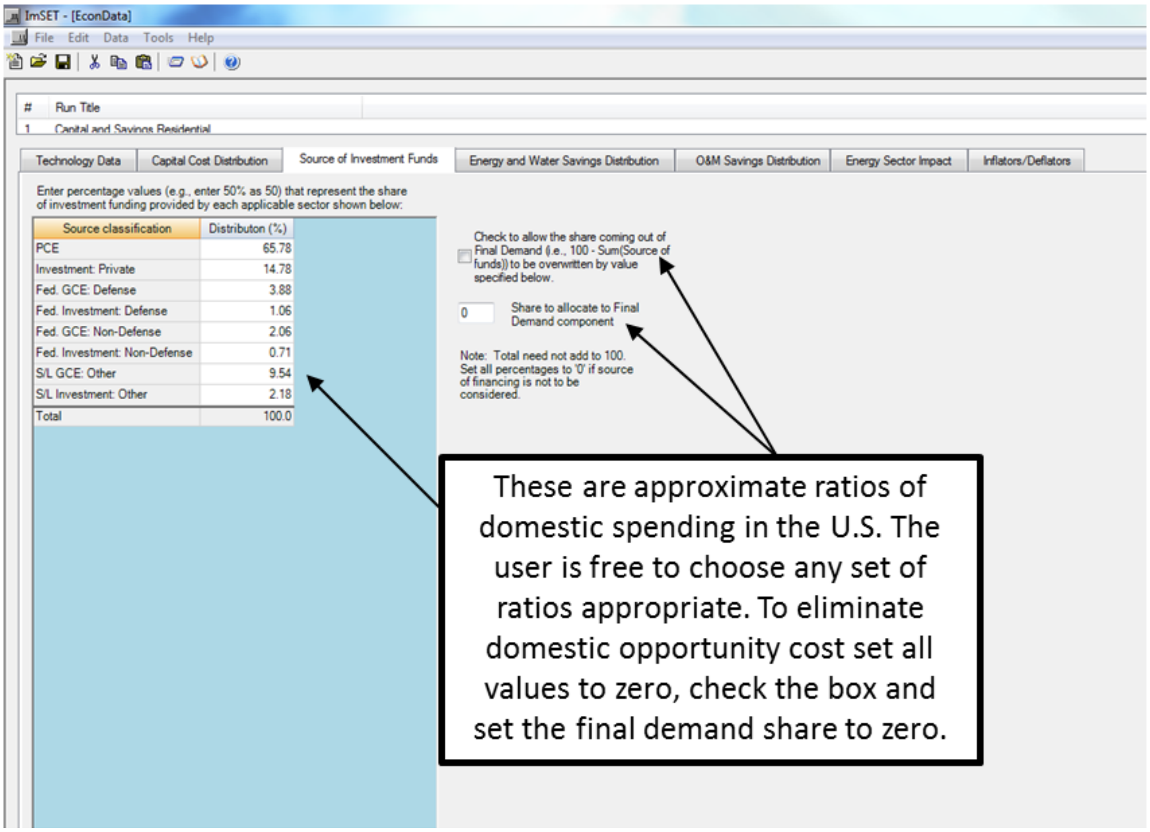


Figure 5.7. Opportunity Cost of Investment Funds

5.1.4 Tab 4: Energy and Water Savings Distribution

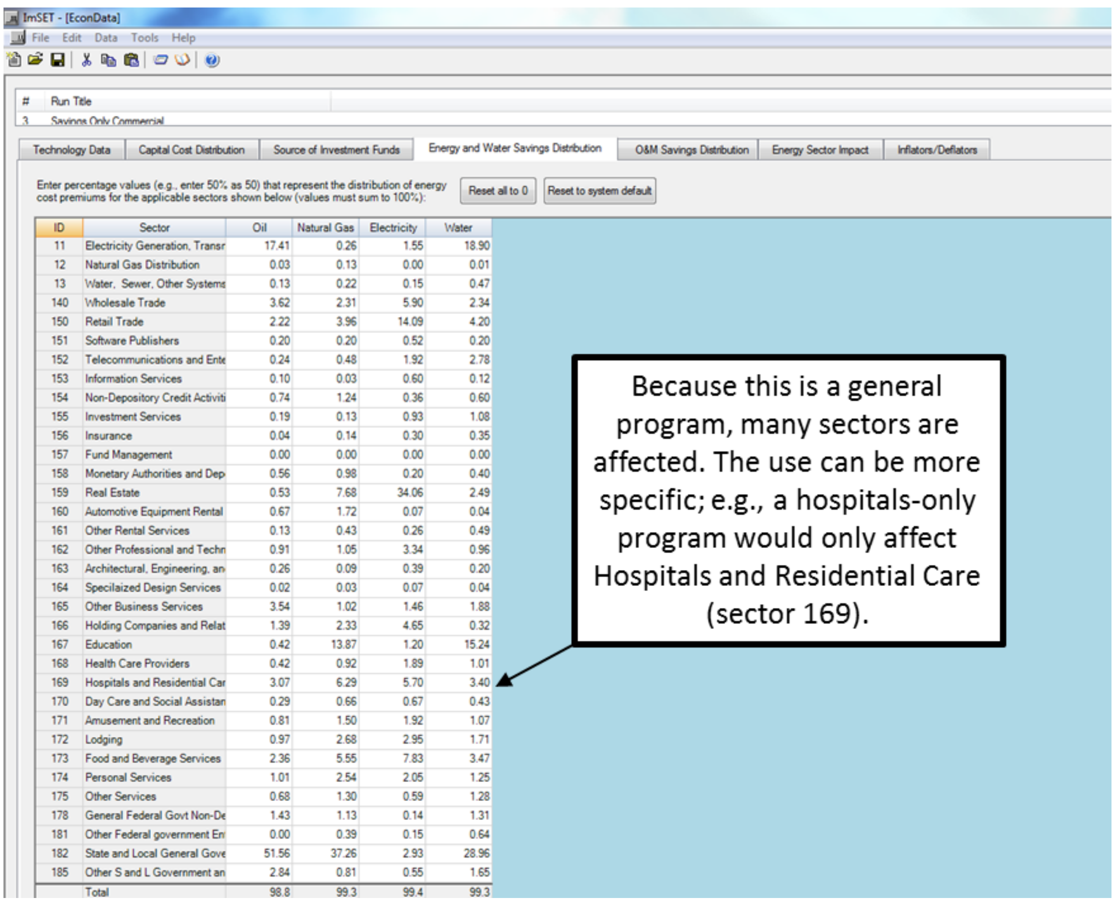
Enter the percentage values (enter "50 percent" as "50") that represent the distribution of energy and water cost savings for the applicable sectors (see Figure 5.8). The total of all values must equal 100. Note the sectors shown will depend on the end-use sector targeted by the technology or program. For example, commercial end-use energy cost savings can be felt in sectors 11−13, 140, 150−175, 178, 180−181, and 185; industrial end-use energy cost savings (including agriculture, mining, and construction) can be felt in sectors 1−139 (except for sectors 11−13), 177, and 186; and transportation energy cost savings can be felt in sectors 141−149, 179 (Postal Service), and 183 (state and local passenger transit). Each sector experiencing savings is assumed to experience these savings as value added in the sector (personal compensation, retained earnings, or indirect business taxes) and the savings are assumed to be spent in the same manner (personal consumption, investment, or government spending). Federal government defense services (sector 177) are assumed to be relatively large energy

---

the sum of the explicit values in the "Distribution %" column were 90%, the remaining 10% of the opportunity cost would be allocated proportionately as 7% (70.2% × 10%) to PCEs, 1.5% to investment (15.1% × 10%), etc.

users and are grouped with “industrial” users. Government enterprises and government services in sectors 178, 181, 182, and 185 are treated as “commercial” for purposes of energy savings distributions. The remaining handful of sectors include household enterprises (176) and accounting conventions (180,184, 186−187), which are not treated as beneficiaries of end-use energy savings. Residential end-use technology and program cost savings will affect all final demand; thus, no specific industry sectors will be directly affected. Residential energy savings are allocated to final demand. The spending of residential savings is allocated across industries in the same proportions as all other residential final demand.

Energy savings in commercial buildings by default are allocated to each commercial sector in proportion to fuel likely purchased for each sector; e.g., if sector 140 (wholesale trade) purchased 4.57 percent of baseline electricity purchased in commercial buildings, then sector 140 would likely have accumulated 4.57 percent of the savings as well. The user is free to change these proportions. On the other hand, if a particular program were focused only on electricity used by hospitals, it would make sense to make sector 169 (Hospitals and Residential Care) the sole beneficiary of the energy savings for that program and allocate 100% of electricity savings to that sector. The model also includes water cost savings; this is important for water-using equipment, such as laundry equipment.



ID	Sector	Oil	Natural Gas	Electricity	Water
11	Electricity Generation, Transr	17.41	0.26	1.55	18.90
12	Natural Gas Distribution	0.03	0.13	0.00	0.01
13	Water, Sewer, Other Systems	0.13	0.22	0.15	0.47
140	Wholesale Trade	3.62	2.31	5.90	2.34
150	Retail Trade	2.22	3.96	14.09	4.20
151	Software Publishers	0.20	0.20	0.52	0.20
152	Telecommunications and Ente	0.24	0.48	1.92	2.78
153	Information Services	0.10	0.03	0.60	0.12
154	Non-Depository Credit Activiti	0.74	1.24	0.36	0.60
155	Investment Services	0.19	0.13	0.93	1.08
156	Insurance	0.04	0.14	0.30	0.35
157	Fund Management	0.00	0.00	0.00	0.00
158	Monetary Authorities and Dep	0.56	0.98	0.20	0.40
159	Real Estate	0.53	7.68	34.06	2.49
160	Automotive Equipment Rental	0.67	1.72	0.07	0.04
161	Other Rental Services	0.13	0.43	0.26	0.49
162	Other Professional and Techn	0.91	1.05	3.34	0.96
163	Architectural, Engineering, an	0.26	0.09	0.39	0.20
164	Specilaized Design Services	0.02	0.03	0.07	0.04
165	Other Business Services	3.54	1.02	1.46	1.88
166	Holding Companies and Relat	1.39	2.33	4.65	0.32
167	Education	0.42	13.87	1.20	15.24
168	Health Care Providers	0.42	0.92	1.89	1.01
169	Hospitals and Residential Car	3.07	6.29	5.70	3.40
170	Day Care and Social Assistan	0.29	0.66	0.67	0.43
171	Amusement and Recreation	0.81	1.50	1.92	1.07
172	Lodging	0.97	2.68	2.95	1.71
173	Food and Beverage Services	2.36	5.55	7.83	3.47
174	Personal Services	1.01	2.54	2.05	1.25
175	Other Services	0.68	1.30	0.59	1.28
178	General Federal Govt Non-De	1.43	1.13	0.14	1.31
181	Other Federal government En	0.00	0.39	0.15	0.64
182	State and Local General Gove	51.56	37.26	2.93	28.96
185	Other S and L Government an	2.84	0.81	0.55	1.65
	Total	98.8	99.3	99.4	99.3

Figure 5.8. Energy/Water Cost Savings Distribution among Sectors

5.1.5 Tab 5: Operating and Maintenance Savings Distribution

Default allocations for each of the end-use sectors are currently shown in Figure 5.9, but these can be modified to suit the user. O&M activities, if they are purchased from one of the sectors shown, would probably all be spent on personal services. Distributions for the other end-use sectors were calculated by summing the purchases from these four sectors, then dividing each sector's sales by the total. The modest activities that transportation services sell to the commercial sector were deemed to be activities other than O&M, so this cell is specified as zero by default. Rather than construct a distribution of O&M expenditures for each of the end-use sectors, these changes were treated as applying to final demands.

Sensitivity tests were run with varying distributions of O&M expenditures among the sectors shown in Figure 5.9 to determine if this would make a substantial difference in the output of the model, and the changes were found to be modest, in the extreme—in the thousandths of a percentage point for reasonable estimates of O&M costs/savings.

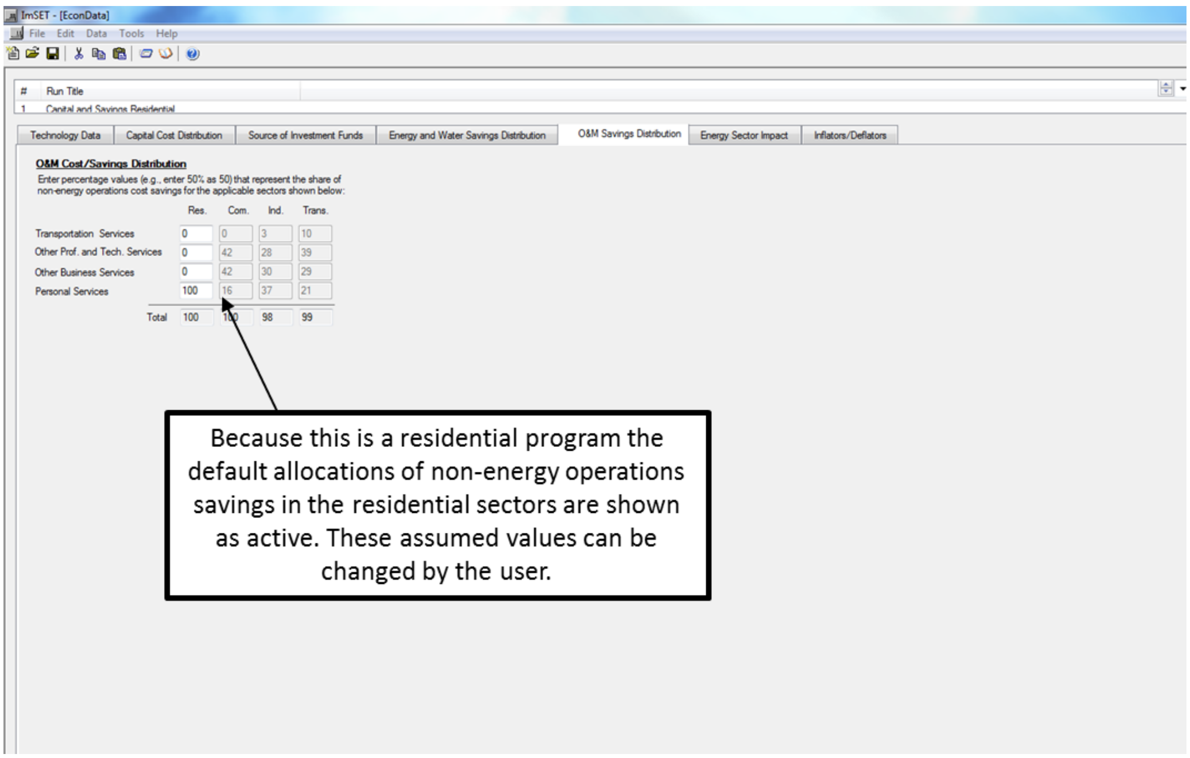


Figure 5.9. Operations and Maintenance Cost Savings for Residential and Commercial Sector

5.1.6 Tab 6: Energy Sector Impact

This screen allows the user to specify how the technology/program impacts will affect the investment in the energy sector, particularly the electricity and natural gas industries. Significant energy savings might allow electricity and natural gas production, transmission, and distribution companies to reduce the amount of investment they undertake, which frees up investment capital for the general economy (this is the mirror image of the "source of funds" allocation described for Tab 5). If reductions in electricity and gas investment occur because the technology/program is implemented, then enter "Yes" for the applicable question and enter any changes to load/capacity factors and costs as necessary.[4] If either "Yes" is selected, then enter where (percentage shares) investment dollars would be allocated to (what sectors would benefit) in the right-hand box. In the example in Figure 5.10, the freed-up funds are proportionately released to the economy as a whole, which spends them on consumption, investment, etc. Note that in this case, the sum of those shares is handled the same way as the opportunity cost of invested funds (see discussion of Tab 5). The "benefit" of investment savings need not remain in the region of interest.

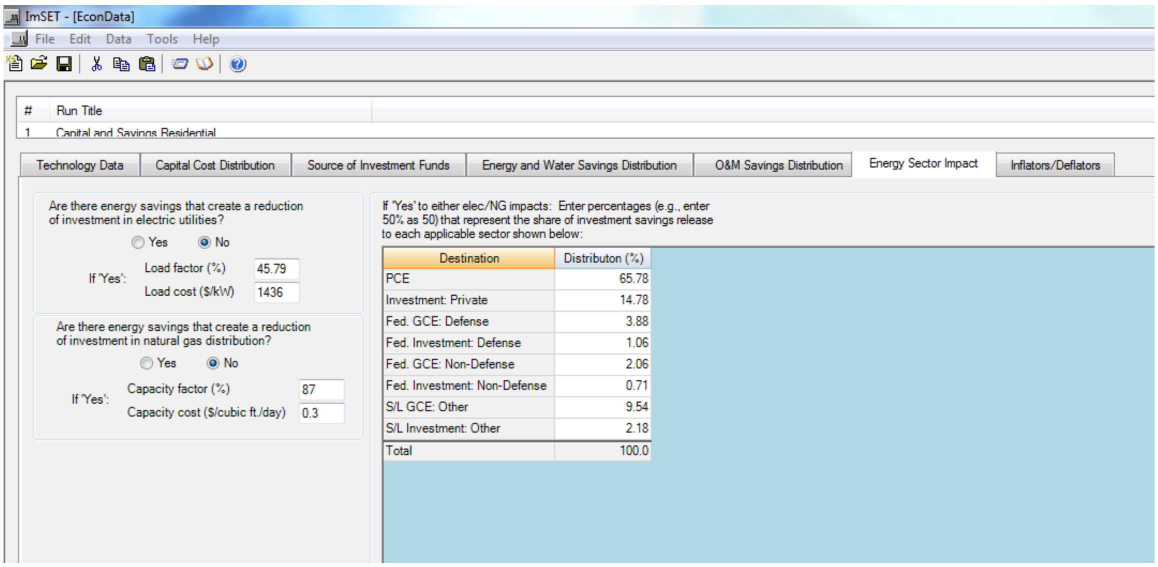


Figure 5.10. Impact of Energy Savings on Energy Sector Investments and Released Funds

5.1.7 Tab 7: Inflators and Deflators

The inflators/deflators page is designed to allow easy conversion of costs and savings to the appropriate year's dollars. The I-O table at the core of ImSET 4.0 is in 2007 dollars, so inputs to the model need to be converted to a 2007 basis. In the example shown in Figure 5.11, capital costs were expressed in 2014 dollars and savings originally available to the analysts were expressed in 2014 dollars, which needed to be converted to 2007 dollars. This is the purpose of the deflators. However, for reporting purposes, many users would like to see earnings numbers in some later year's constant dollars, not 2007 dollars. For example, in recent use of the model, some income results have been reported in 2014 dollars. This is the purpose of the inflators. To compute costs for a particular year, enter the appropriate inflators/deflators for calculation in the model (see Figure 5.11). Note that capital cost deflators are used to adjust capital cost, installation costs, and utility impact costs to the base I-O year (2007). Operations cost deflators are used to adjust energy costs and O&M costs to the base I-O year. Both of these are based on GDP deflators. The inflator input is based on the appropriate year's Consumer Price Index and is used to adjust base I-O results for earnings to the technology database year, or to some other year for reporting purposes. Note that in computing both the deflators and inflators, the 2007 value is always in the denominator. Thus the current capital cost number is *divided by* the deflator value to obtain capital inputs

---

[4] Electricity generation and natural gas transmission and distribution systems do not use their full capacity at all times. Capacity is fully used only at peak demand (and even then, a reserve margin will be maintained). Annual load factors are used to translate between British thermal units of energy consumed in the course of a year and the peak demand. A 45.79% load factor means that over the course of a year, the hourly average demand is about 45.79% of peak demand. It can be computed as annual consumption/(8760 hr $\times$ peak demand) $\times$ 100%.

in 2007 dollars, but the 2007 earnings impact value is *multiplied by* the CPI inflator to obtain earnings in some other year’s dollars (for example, 2014 dollars).

5.2 Computing Program Impacts

Selecting the “Compute program impacts” button will run the computations for determining the impacts of the “Run specifications.” Only those records marked with “Execute run” will be processed (see Figure 5.12). Before running computations, the program checks for a common set of years between all technologies/programs. It will also test for conditions where no years are represented.

With data integrity checks complete, the process loops through each “Run scenario” and, in turn, creates an associated file of data that will be read by the ImSET 4.0 model. The processing code in Appendix C is then called and when finished, the process retrieves the output file created by the model and parses and stores the results to the user database file. With that process complete, the ImSET 4.0 tool opens the results screen and presents the calculated impacts in spreadsheet form (see Figure 5.13 and Figure 5.14).

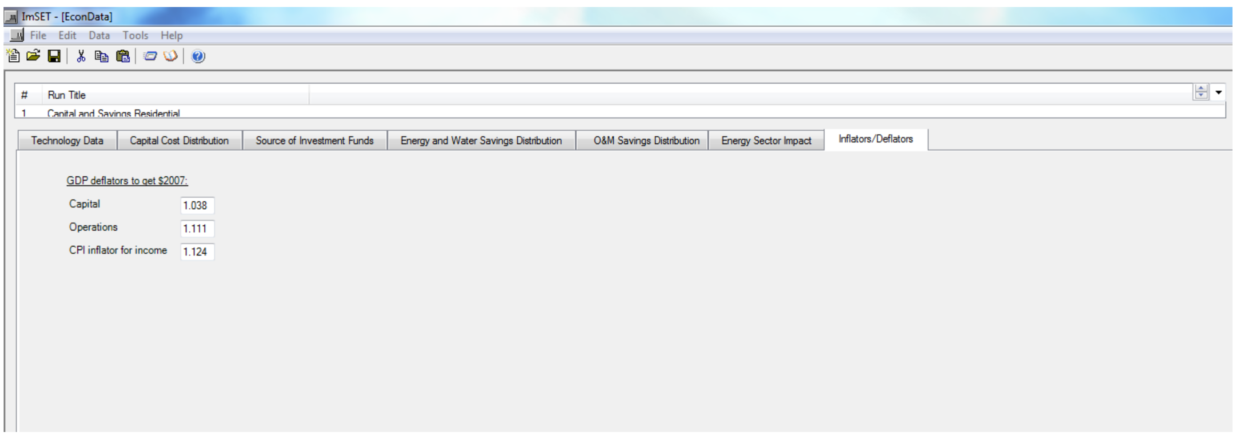


Figure 5.11. Assigning Inflators and Deflators

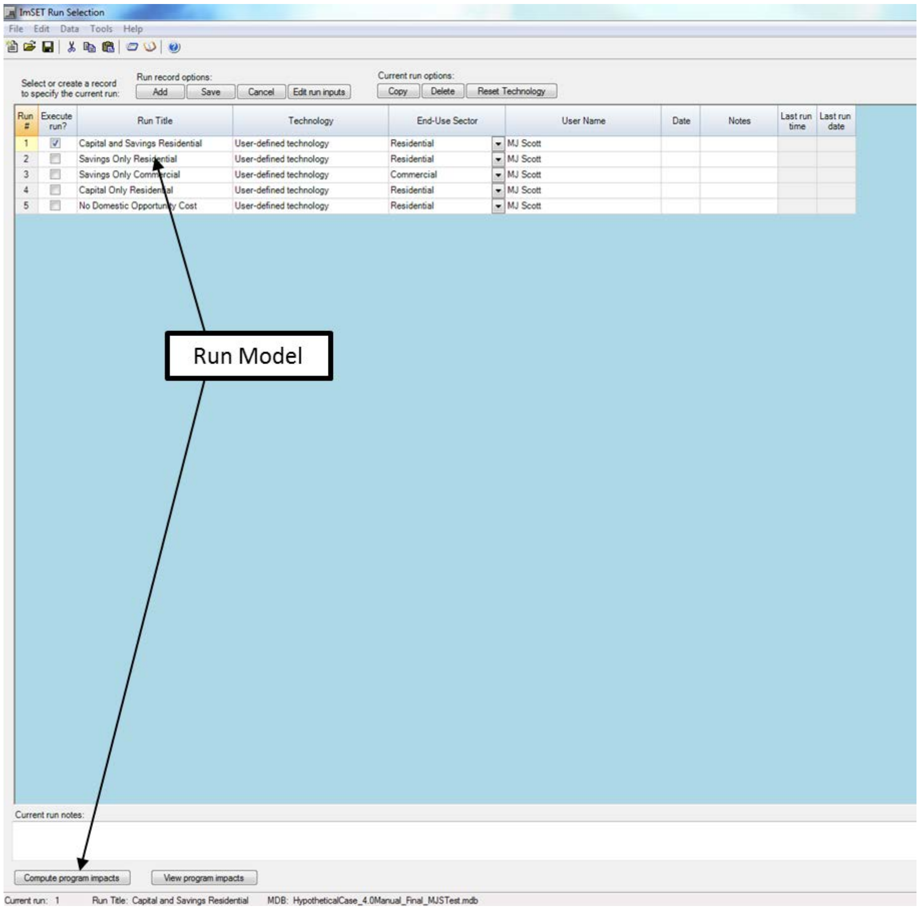


Figure 5.12. Running the ImSET Model

Note: In this print screen, the "Buildings Energy Codes" base case is being computed using the "Compute program inputs" button. The user can also view current stored results by clicking the "View program impacts" button.

5.3 Viewing Program Impacts

If the user wishes to view the last computed impacts without rerunning the calculations, he/she should select the "View program impacts" button on the screen shown in Figure 5.12. The displayed data will depend on the "Impacts data type" choice that is available at the top of the macro outputs screen (Figure 5.13). Additional options in this screen include viewing detailed output-by-industry data and exporting all impact data types to an Excel® spreadsheet file. The name assigned to the Excel file will be the same as the user database file.

Results are presented in tabular form in individual "tab" frames. Use the "Impacts data type" drop-down list at the top of the screen to select the individual run results impact data for employment, wage income, and gross product, as well corresponding baseline values for these three variables) that are available. Data may be exported and stored in Excel spreadsheet format for additional manipulation. In the example shown in Figure 5.13, the hypothetical base case produces a potential increase of 3890 net jobs in the economy in 2015.

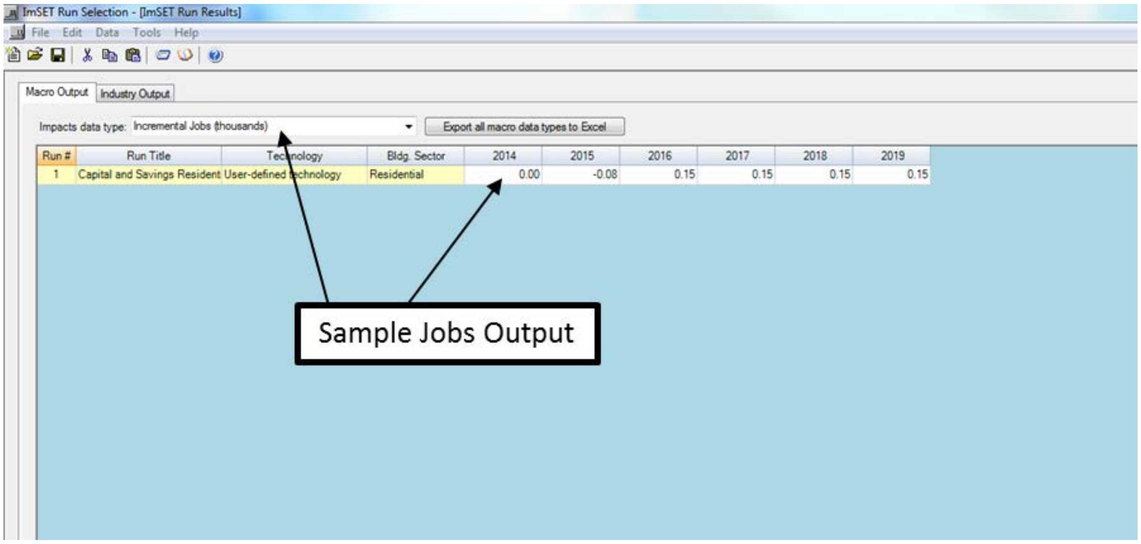
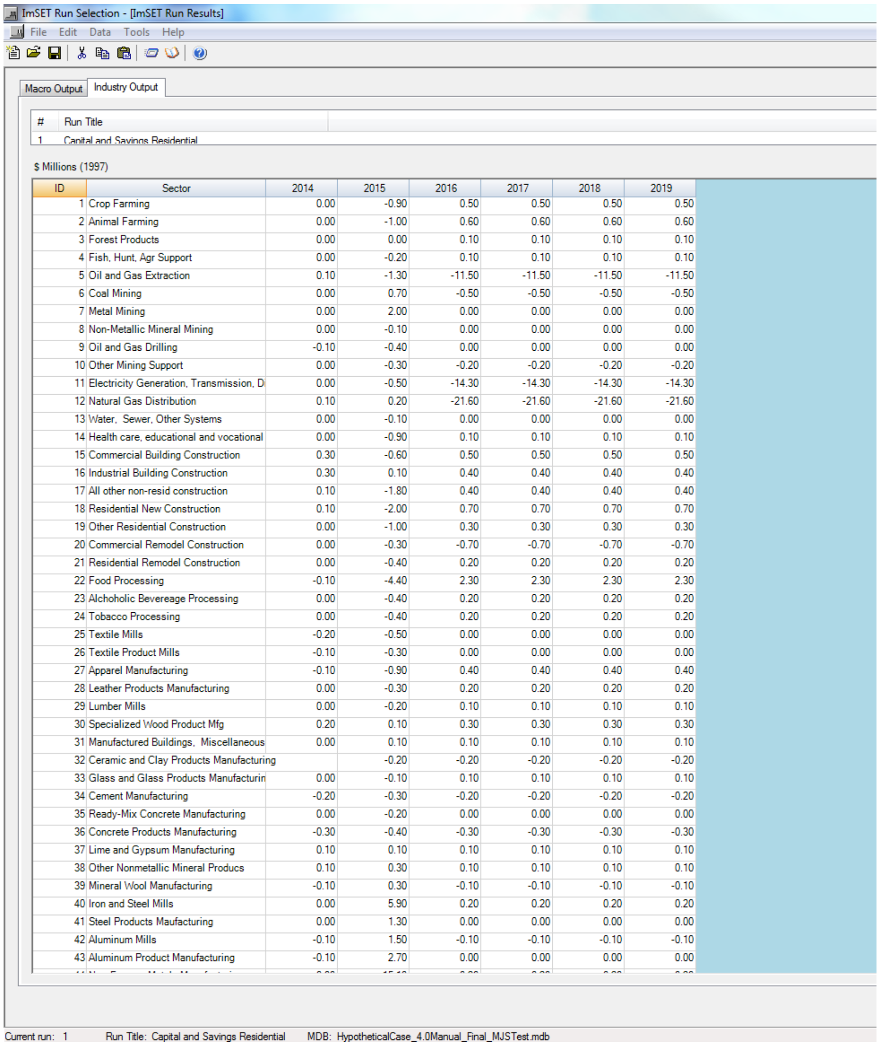


Figure 5.13. Macro Output Screen

It is often useful to have access to the impact results for individual sectors for an individual model run in order to estimate impacts such as capital flows and investment, environmental emissions, or other industry-specific outcomes.[5] ImSET provides results for period-by-period changes in gross output by sector for the most recent case run by the model. Data may be exported and stored in Excel spreadsheet format for additional manipulation. In the example shown in Figure 5.14, the hypothetical base case produces a variety of impacts on individual sectors, reducing gross product in sectors that sell energy services (e.g., Sector 11, Electric Generation and Transmission and Sector 12, Natural Gas Distribution) and industries that are closely related to energy services (Sector 5, Oil and Gas Extraction), but increasing output in several retail and service industries. The net impact on gross product in 2025 in Electric Generation and Transmission is a loss of $1279 million (2007$); however, a number of sectors such as Commercial Building Construction benefit from the Building Energy Codes. The net effect across all of the economy's economic sectors in this case is an increase of almost $254 million.

[5] For example, ImSET model output of this type has been used with a supplemental spreadsheet model to estimate the impact of energy efficiency programs on reducing the need for the economy to maintain energy-related investment. See Scott et al. (2008).



ID	Sector	2014	2015	2016	2017	2018	2019
1	Crop Farming	0.00	-0.90	0.50	0.50	0.50	0.50
2	Animal Farming	0.00	-1.00	0.60	0.60	0.60	0.60
3	Forest Products	0.00	0.00	0.10	0.10	0.10	0.10
4	Fish, Hunt, Agr Support	0.00	-0.20	0.10	0.10	0.10	0.10
5	Oil and Gas Extraction	0.10	-1.30	-11.50	-11.50	-11.50	-11.50
6	Coal Mining	0.00	0.70	-0.50	-0.50	-0.50	-0.50
7	Metal Mining	0.00	2.00	0.00	0.00	0.00	0.00
8	Non-Metallic Mineral Mining	0.00	-0.10	0.00	0.00	0.00	0.00
9	Oil and Gas Drilling	-0.10	-0.40	0.00	0.00	0.00	0.00
10	Other Mining Support	0.00	-0.30	-0.20	-0.20	-0.20	-0.20
11	Electricity Generation, Transmission, D	0.00	-0.50	-14.30	-14.30	-14.30	-14.30
12	Natural Gas Distribution	0.10	0.20	-21.60	-21.60	-21.60	-21.60
13	Water, Sewer, Other Systems	0.00	-0.10	0.00	0.00	0.00	0.00
14	Health care, educational and vocational	0.00	-0.90	0.10	0.10	0.10	0.10
15	Commercial Building Construction	0.30	-0.60	0.50	0.50	0.50	0.50
16	Industrial Building Construction	0.30	0.10	0.40	0.40	0.40	0.40
17	All other non-resid construction	0.10	-1.80	0.40	0.40	0.40	0.40
18	Residential New Construction	0.10	-2.00	0.70	0.70	0.70	0.70
19	Other Residential Construction	0.00	-1.00	0.30	0.30	0.30	0.30
20	Commercial Remodel Construction	0.00	-0.30	-0.70	-0.70	-0.70	-0.70
21	Residential Remodel Construction	0.00	-0.40	0.20	0.20	0.20	0.20
22	Food Processing	-0.10	-4.40	2.30	2.30	2.30	2.30
23	Alchoholic Bevereage Processing	0.00	-0.40	0.20	0.20	0.20	0.20
24	Tobacco Processing	0.00	-0.40	0.20	0.20	0.20	0.20
25	Textile Mills	-0.20	-0.50	0.00	0.00	0.00	0.00
26	Textile Product Mills	-0.10	-0.30	0.00	0.00	0.00	0.00
27	Apparel Manufacturing	-0.10	-0.90	0.40	0.40	0.40	0.40
28	Leather Products Manufacturing	0.00	-0.30	0.20	0.20	0.20	0.20
29	Lumber Mills	0.00	-0.20	0.10	0.10	0.10	0.10
30	Specialized Wood Product Mfg	0.20	0.10	0.30	0.30	0.30	0.30
31	Manufactured Buildings, Miscellaneous	0.00	0.10	0.10	0.10	0.10	0.10
32	Ceramic and Clay Products Manufacturing		-0.20	-0.20	-0.20	-0.20	-0.20
33	Glass and Glass Products Manufacturin	0.00	-0.10	0.10	0.10	0.10	0.10
34	Cement Manufacturing	-0.20	-0.30	-0.20	-0.20	-0.20	-0.20
35	Ready-Mix Concrete Manufacturing	0.00	-0.20	0.00	0.00	0.00	0.00
36	Concrete Products Manufacturing	-0.30	-0.40	-0.30	-0.30	-0.30	-0.30
37	Lime and Gypsum Manufacturing	0.10	0.10	0.10	0.10	0.10	0.10
38	Other Nonmetallic Mineral Producs	0.10	0.30	0.10	0.10	0.10	0.10
39	Mineral Wool Manufacturing	-0.10	0.30	-0.10	-0.10	-0.10	-0.10
40	Iron and Steel Mills	0.00	5.90	0.20	0.20	0.20	0.20
41	Steel Products Maufacturing	0.00	1.30	0.00	0.00	0.00	0.00
42	Aluminum Mills	-0.10	1.50	-0.10	-0.10	-0.10	-0.10
43	Aluminum Product Manufacturing	-0.10	2.70	0.00	0.00	0.00	0.00

Figure 5.14. Industry Output Screen (Gross Product Impact by Sector)

6.0 Summary and Conclusion

The ImSET input-output model, developed and tailored to assess the economic impacts of U.S. energy efficiency programs, has been in use since the middle 1990s. Version 4.0, documented in this user's guide, has been updated to match the most recent available comprehensive data on the interindustry structure of the U.S. economy, contained in the 2007 national benchmark input-output accounts. The model is simple to use because it is operated through a user interface that facilitates the building and launching, analysis, and reporting the results of energy-efficiency scenarios. This user guide helps the user employ the interface to account for critical economic assumptions that affect the size of impacts, providing documented default values for most of these critical assumptions. In addition, the model can conveniently run a single or multiple scenarios for multiple time periods with a single command and automatically collects and saves or exports the results to spreadsheets that can be used for further analysis. Because it is an input-output model, ImSET does not account for some of the economic effects of very large scale changes to the economy, such as supply-side changes in the prices of labor and other resources that are the strength of certain types of econometric and computable general equilibrium models. Offsetting that are the advantages of rich inter-industry detail and close attention that has gone into ImSET's accounting for the economic impacts of energy savings, deatailed requirements for investments to achieve those savings, and the opportunity-cost impacts on the economy of financing those investments. Compared with other types of economic impact models, ImSET is largely unique in these respects. The model is ideal for simple (and at the same time sophisticated) analysis of energy-efficiency technologies and programs as they affect the U.S. economy.

7.0 References

Anderson DM, DB Belzer, OV Livingston, and MJ Scott. 2014. *Assessing National Employment Impacts of Investment in Residential and Commercial Sector Energy Efficiency: Review and Example Analysis*. PNNL-23402, Pacific Northwest National Laboratory, Richland, Washington.

Berck P and S Hoffmann. 2002. "Assessing the Employment Impacts of Environmental and Natural Resource Policy." *Environmental and Resource Economics* 22:133−156.

Economic Research Associates. 2005. *Modeling the Economic Impacts of National and State Energy Policy Scenarios*. A Working Paper for the U.S. PIRG Education Fund, Alexandria, Virginia.

Eldridge M, N Elliott, W Prindle, K Ackerly, S Laitner, V McKinney, S Nadel, M Neubauer, A Silverstein, B Hedman, A Hampson, and K Darrow. 2008. *Energy Efficiency: The First Fuel for a Clean Energy Future*. American Council for an Energy-Efficient Economy, Washington, D.C.

Elliott DB, DM Anderson, DB Belzer, KA Cort, JA Dirks, and DJ Hostick. 2004. *Methodological Framework for Analysis of Buildings-Related Programs: GPRA Metrics Effort.* PNNL-14697, Pacific Northwest National Laboratory, Richland, Washington.

Elliott, DB, JA Dirks, and DJ Hostick. 2008. *Methodological Framework for Analysis of Buildings-Related Programs with BEAMS, 2008*. PNNL-17725, Pacific Northwest National Laboratory, Richland, Washington.

Energy Information Administration, Office of Oil and Gas (EIA). 2008. *Additions to Capacity on the U.S. Natural Gas Pipeline Network: 2007*. U.S. Department of Energy, Washington, D.C.

Energy Information Administration (EIA). 2013. *Annual Energy Outlook 2013*. DOE/EIA-0383(2013), U.S. Department of Energy, Washington, D.C.

Geller H, J DeCicco, and S Laitner. 1992. *Energy Efficiency and Job Creation: The Employment and Income Benefits from* Investing *in Energy Conserving Technologies*. American Council for an Energy-Efficient Economy, Washington, D.C.

Horowitz KJ and MA Planting. 2009. *Concepts and Methods of the Input-Output Accounts*. U.S Department of Commerce, Bureau of Economic Analysis, Washington D.C., September 2006. Updated April 2009. Accessed June 10, 2015 at http://www.bea.gov/industry/index.htm#benchmark_io.

Kaiser MJ and AG Pulsipher. 2003. "A Generalized Modeling Framework for Public Benefit Program Valuation." *Energy: The International Journal* 28(6):519−538.

Kaiser MJ, AG Pulsipher, and RH Baumann. 2004. "The Potential Economic and Environmental Impact of a Public Benefit Fund in Louisiana." *Energy Policy* 32(2):191−206.

Kaiser MJ, WO Olatubi, and AG Pulsipher. 2005. "Economic, Energy, and Environmental Impact of the Louisiana Energy Fund." *Energy Policy* 33(7):873−883.

Laitner J and V McKinney. 2008. *Positive Returns: State Energy Efficiency Analyses Can Inform U.S. Energy Policy Assessments.* Report E084, American Council for an Energy-Efficient Economy, Washington, D.C.

Nayak N. 2005. *Redirecting America's Energy: The Economic and Consumer Benefits of Clean Energy Policies.* U.S. PIRG Education Fund, Washington, D.C. Accessed March 4, 2009, at http://www.environmentamerica.org/home/reports/report-archives/new-energy-future/new-energy-future/redirecting-americas-energy-the-economic-and-consumer-benefits-of-clean-energy-policies.

Roland-Holst D. 2008. *Energy, Efficiency, Innovation, and Job Creation in California*. Prepared by the Center for Energy, Resources, and Economic Sustainability, Berkeley, California.

Roop JM, MJ Scott, and RW Schultz. 2005. *ImSET: Impact of Sector Energy Technologies*. PNNL-15273, Pacific Northwest National Laboratory, Richland, Washington.

Scott MJ, DJ Hostick, and DB Belzer. 1998. *ImBuild: Impact of Building Energy Efficiency Programs*. PNNL-11884, Pacific Northwest National Laboratory, Richland, Washington.

Scott MJ, JM Roop, and RW Schultz. 2002. *ImBuild II: Impact of Technologies on Energy Efficiency Programs*. PNNL-13926, Pacific Northwest National Laboratory, Richland, Washington.

Scott MJ, JM Roop, RW Schultz, DM Anderson, KA Cort. 2008. "The Impact of DOE Building Technology Energy Efficiency Programs on U.S. Employment, Income, and Investment." *Energy Economics* 30 (5):2283–2301.

Scott MJ, OV Livingston, PJ Balducci, JM Roop, and RW Schultz. 2009. *ImSET 3.1: Impact of Sector Energy Technologies*. PNNL-18412, Pacific Northwest National Laboratory, Richland, Washington.

Sedano R, C Murray, and W Steinhurst. 2005. *Electric Efficiency and Renewable Energy in New England: An Assessment of Existing Policies and Prospects for the Future*. The Regulatory Assistance Project, Montpelier, Vermont.

Xie J. 2000. "An Environmentally Extended Social Accounting Matrix: Conceptual Framework and Application to Environmental Policy Analysis in China." *Environmental and Resource Economics* 16:391–406.

Appendix A

Base Cases for Energy Efficiency Technologies

Appendix A

Base Cases for Energy Efficiency Technologies

Table A.1. Residential R&D Program, Base Case

	2015	2020	2025
Capital Cost Increase(+) or Savings(-)			
Millions $	0	29.88	1059.37
Energy/Resource Cost Increase (+) or Savings (-) Million $			
Residential – Oil	0	-0.35	-39.38
Residential − Natural gas	0	-10.36	-1356.72
Residential – Electricity	0	3.09	349.39
Residential – Water	0	0	0
O&M Cost Increase(+) or Savings(-)			
Residential (Millions $)	0	0	0
Commercial (Millions $)	0	0	0
Industrial (Millions $)	0	0	0
Transportation (Millions $)	0	0	0
Energy/Resource Units Saved(-) or Used (For System Investment)			
Oil (10^12 Btu)	0	-0.03	-2.9
Natural gas (10^12 Btu)	0	-1.01	-123.68
Electricity (10^12 Btu)	0	0.12	13.13
Water (10^9 Gallons)	0	0	0

Table A.2. Commercial Energy-Efficiency Standards, Base Case

	2015	2020	2025
Capital Cost Increase(+) or Savings(-)			
Millions $	825.0	1015.0	1100.0
Energy/Resource Cost Increase (+) or Savings (-) Million $			
Commercial – Oil	0	0	0
Commercial -- Natural gas	-50.0	-100.0	-125.0
Commercial – Electricity	-525.0	-1725.0	-1950.0
Commercial – Water	0	0	0
O&M Cost Increase(+) or Savings(-)			
Commercial (Millions $)	0	0	0
Energy/Resource Units Saved(-) or Used (For System Investment)			
Oil (10^12 Btu)	0	0	0
Natural gas (10^12 Btu)	-11.25	-50.0	-60.0
Electricity (10^12 Btu)	-28.0	-85.0	-100.0
Water (10^9 Gallons)	0	0	0

Appendix B

Sectoral Detail

Appendix B

Sectoral Detail

Table B.1. Cross Reference between ImSET 4 Sectors and 2007 U.S. Input-Output Table Sectors

NAICS Code	NAICS 2007 Description	ImSET 4.0 Sector	ImSET 4.0 Sector Description
1111A0	Oilseed farming	1	Crop Farming
1111B0	Grain farming	1	Crop Farming
111200	Vegetable and melon farming	1	Crop Farming
111300	Fruit and tree nut farming	1	Crop Farming
111400	Greenhouse, nursery, and floriculture production	1	Crop Farming
111900	Other crop farming	1	Crop Farming
1121A0	Beef cattle ranching and farming, including feedlots and dual-purpose ranching and farming	2	Animal Farming
112120	Dairy cattle and milk production	2	Animal Farming
112A00	Animal production, except cattle and poultry and eggs	2	Animal Farming
112300	Poultry and egg production	2	Animal Farming
113000	Forestry and logging	3	Forest Products
114000	Fishing, hunting and trapping	4	Fish, Hunt, Agr. Support
115000	Support activities for agriculture and forestry	4	Fish, Hunt, Agr. Support
211000	Oil and gas extraction	5	Oil and Gas Extraction
212100	Coal mining	6	Coal Mining
2122A0	Iron, gold, silver, and other metal ore mining	7	Metal Mining
212230	Copper, nickel, lead, and zinc mining	7	Metal Mining
212310	Stone mining and quarrying	8	Non-Metallic Mineral Mining
2123A0	Other nonmetallic mineral mining and quarrying	8	Non-Metallic Mineral Mining
213111	Drilling oil and gas wells	9	Oil and Gas Drilling
21311A	Other support activities for mining	10	Other Mining Support

221100	Electric power generation, transmission, and distribution	11	Electricity Generation, Transmission, Distribution
221200	Natural gas distribution	12	Natural Gas Distribution
221300	Water, sewage and other systems	13	Water, Sewer, Other Systems
233210	Health care structures	14	Health Care, Educational and Vocational Structures
233262	Educational and vocational structures	14	Health Care, Educational and Vocational Structures
2332A0	Commercial structures, including farm structures	15	Commercial Building Construction
233230	Manufacturing structures	16	Industrial Building Construction
233240	Power and communication structures	17	All Other Non-Resid. Construction
233293	Highways and streets	17	All Other Non-Resid. Construction
2332B0	Other nonresidential structures	17	All Other Non-Resid. Construction
233411	Single-family residential structures	18	Residential New Construction
233412	Multifamily residential structures	18	Residential New Construction
2334A0	Other residential structures	19	Other Residential Construction
230301	Nonresidential maintenance and repair	20	Commercial Remodel Construction
230302	Residential maintenance and repair	21	Residential Remodel Construction
311111	Dog and cat food manufacturing	22	Food Processing
311119	Other animal food manufacturing	22	Food Processing
311210	Flour milling and malt manufacturing	22	Food Processing
311221	Wet corn milling	22	Food Processing
31122A	Soybean and other oilseed processing	22	Food Processing
311225	Fats and oils refining and blending	22	Food Processing
311230	Breakfast cereal manufacturing	22	Food Processing
311300	Sugar and confectionery product manufacturing	22	Food Processing
311410	Frozen food manufacturing	22	Food Processing
311420	Fruit and vegetable canning, pickling, and drying	22	Food Processing
31151A	Fluid milk and butter manufacturing	22	Food Processing
311513	Cheese manufacturing	22	Food Processing
311514	Dry, condensed, and evaporated dairy product manufacturing	22	Food Processing
311520	Ice cream and frozen dessert manufacturing	22	Food Processing

31161A	Animal (except poultry) slaughtering, rendering, and processing	22	Food Processing
311615	Poultry processing	22	Food Processing
311700	Seafood product preparation and packaging	22	Food Processing
311810	Bread and bakery product manufacturing	22	Food Processing
3118A0	Cookie, cracker, pasta, and tortilla manufacturing	22	Food Processing
311910	Snack food manufacturing	22	Food Processing
311920	Coffee and tea manufacturing	22	Food Processing
311930	Flavoring syrup and concentrate manufacturing	22	Food Processing
311940	Seasoning and dressing manufacturing	22	Food Processing
311990	All other food manufacturing	22	Food Processing
312110	Soft drink and ice manufacturing	22	Food Processing
312120	Breweries	23	Alcoholic Beverage Processing
312130	Wineries	23	Alcoholic Beverage Processing
312140	Distilleries	23	Alcoholic Beverage Processing
312200	Tobacco product manufacturing	24	Tobacco Processing
313100	Fiber, yarn, and thread mills	25	Textile Mills
313200	Fabric mills	25	Textile Mills
313300	Textile and fabric finishing and fabric coating mills	25	Textile Mills
314110	Carpet and rug mills	26	Textile Product Mills
314120	Curtain and linen mills	26	Textile Product Mills
314900	Other textile product mills	26	Textile Product Mills
315000	Apparel manufacturing	27	Apparel Manufacturing
316000	Leather and allied product manufacturing	28	Leather Products Manufacturing
321100	Sawmills and wood preservation	29	Lumber Mills
321200	Veneer, plywood, and engineered wood product manufacturing	29	Lumber Mills
321910	Millwork	30	Specialized Wood Product Mfg
3219A0	All other wood product manufacturing	31	Manufactured Buildings, Miscellaneous Wood Products
327100	Clay product and refractory manufacturing	32	Ceramic and Clay Products Manufacturing

327200	Glass and glass product manufacturing	33	Glass and Glass Products Manufacturing
327310	Cement manufacturing	34	Cement Manufacturing
327320	Ready-mix concrete manufacturing	35	Ready-Mix Concrete Manufacturing
327330	Concrete pipe, brick, and block manufacturing	36	Concrete Products Manufacturing
327390	Other concrete product manufacturing	36	Concrete Products Manufacturing
327400	Lime and gypsum product manufacturing	37	Lime and Gypsum Manufacturing
327910	Abrasive product manufacturing	38	Other Nonmetallic Mineral Products
327991	Cut stone and stone product manufacturing	38	Other Nonmetallic Mineral Products
327992	Ground or treated mineral and earth manufacturing	38	Other Nonmetallic Mineral Products
327999	Miscellaneous nonmetallic mineral products	38	Other Nonmetallic Mineral Products
327993	Mineral wool manufacturing	39	Mineral Wool Manufacturing
331110	Iron and steel mills and ferroalloy manufacturing	40	Iron and Steel Mills
331200	Steel product manufacturing from purchased steel	41	Steel Products Manufacturing
33131A	Alumina refining and primary aluminum production	42	Aluminum Mills
331314	Secondary smelting and alloying of aluminum	42	Aluminum Mills
33131B	Aluminum product manufacturing from purchased aluminum	43	Aluminum Product Manufacturing
331411	Primary smelting and refining of copper	44	Non-Ferrous Metals Manufacturing
331419	Primary smelting and refining of nonferrous metal (except copper and aluminum)	44	Non-Ferrous Metals Manufacturing
331420	Copper rolling, drawing, extruding and alloying	44	Non-Ferrous Metals Manufacturing
331490	Nonferrous metal (except copper and aluminum) rolling, drawing, extruding and alloying	44	Non-Ferrous Metals Manufacturing
331510	Ferrous metal foundries	45	Ferrous Metal Foundries
331520	Nonferrous metal foundries	46	Non-Ferrous Metal Foundries
33211A	All other forging, stamping, and sintering	47	Other Forging and Stamping
332114	Custom roll forming	47	Other Forging and Stamping
33211B	Crown and closure manufacturing and metal stamping	47	Other Forging and Stamping
332200	Cutlery and hand tool manufacturing	48	Tool and Utensil Manufacturing
332310	Plate work and fabricated structural product manufacturing	49	Fabricated Structural Metal Manufacturing

332320	Ornamental and architectural metal products manufacturing	50	Metal Architectural Products
332410	Power boiler and heat exchanger manufacturing	51	Power Boilers and Heat Exchangers
332420	Metal tank (heavy gauge) manufacturing	52	Metal Tank Manufacturing
332430	Metal can, box, and other metal container (light gauge) manufacturing	53	Other Fabricated Metal Manufacturing
332600	Spring and wire product manufacturing	53	Other Fabricated Metal Manufacturing
332720	Turned product and screw, nut, and bolt manufacturing	53	Other Fabricated Metal Manufacturing
332800	Coating, engraving, heat treating and allied activities	53	Other Fabricated Metal Manufacturing
33291A	Valve and fittings other than plumbing	53	Other Fabricated Metal Manufacturing
332913	Plumbing fixture fitting and trim manufacturing	53	Other Fabricated Metal Manufacturing
332991	Ball and roller bearing manufacturing	53	Other Fabricated Metal Manufacturing
332996	Fabricated pipe and pipe fitting manufacturing	53	Other Fabricated Metal Manufacturing
33299B	Other fabricated metal manufacturing	53	Other Fabricated Metal Manufacturing
332500	Hardware manufacturing	54	Hardware Manufacturing
332710	Machine shops	55	Machine Shops
33299A	Ammunition, arms, ordnance, and accessories manufacturing	56	Ammunition and Ordnance Manufacturing
333111	Farm machinery and equipment manufacturing	57	Agricultural Machinery, Lawn and Garden Eqpt. Manufacturing
333112	Lawn and garden equipment manufacturing	57	Agricultural Machinery, Lawn and Garden Eqpt. Manufacturing
333120	Construction machinery manufacturing	58	Construction Machinery Manufacturing
333130	Mining and oil and gas field machinery manufacturing	59	Mining and Exploration Equipment Manufacturing
33329A	Other industrial machinery manufacturing	60	Other Industrial Equipment Manufacturing
333220	Plastics and rubber industry machinery manufacturing	61	Plastics and Rubber Machinery Manufacturing
333295	Semiconductor machinery manufacturing	62	Semiconductor Machinery Manufacturing
33331A	Vending, commercial laundry, and other commercial and service industry machinery manufacturing	63	Commercial Service Machinery Manufacturing
333313	Office machinery manufacturing	63	Commercial Service Machinery Manufacturing
333314	Optical instrument and lens manufacturing	63	Commercial Service Machinery Manufacturing
333315	Photographic and photocopying equipment manufacturing	63	Commercial Service Machinery Manufacturing
33341A	Air purification and ventilation equipment manufacturing	64	Air Purification Equipment Manufacturing

333414	Heating equipment (except warm air furnaces) manufacturing	65	Non-Furnace Heating Equipment Manufacturing
333415	Air conditioning, refrigeration, and warm air heating equipment manufacturing	66	Air Conditioning, Refrigeration, and Forced-Air Heating
333511	Industrial mold manufacturing	67	Industrial Mold Manufacturing
33351A	Metal cutting and forming machine tool manufacturing	68	Metalworking Machinery Manufacturing
333514	Special tool, die, jig, and fixture manufacturing	68	Metalworking Machinery Manufacturing
33351B	Cutting and machine tool accessory, rolling mill, and other metalworking machinery manufacturing	68	Metalworking Machinery Manufacturing
333611	Turbine and turbine generator set units manufacturing	69	Turbine and Generator Set Manufacturing
333612	Speed changer, industrial high-speed drive, and gear manufacturing	70	Speed Changer, Industrial High-Speed Drive, and Gear Manufacturing
333613	Mechanical power transmission equipment manufacturing	71	Power Transmission Equipment Manufacturing
333618	Other engine equipment manufacturing	72	Other Engine Equipment Manufacturing
33391A	Pump and pumping equipment manufacturing	73	Pumps and Related Equipment Manufacturing
333912	Air and gas compressor manufacturing	74	Air and Gas Compressor Manufacturing
333920	Material handling equipment manufacturing	75	Material Handling Equipment Manufacturing
333991	Power-driven hand tool manufacturing	76	Other Electric Machinery Manufacturing
33399A	Other general purpose machinery manufacturing	76	Other Electric Machinery Manufacturing
333993	Packaging machinery manufacturing	76	Other Electric Machinery Manufacturing
333994	Industrial process furnace and oven manufacturing	77	Industrial Process Furnace and Oven Manufacturing
33399B	Fluid power process machinery	78	Fluid Process Machinery Manufacturing
334111	Electronic computer manufacturing	79	Electronic Computer Manufacturing
334112	Computer storage device manufacturing	80	Computer Peripheral Products Manufacturing
33411A	Computer terminals and other computer peripheral equipment manufacturing	80	Computer Peripheral Products Manufacturing
334210	Telephone apparatus manufacturing	81	Communications Equipment Manufacturing
334220	Broadcast and wireless communications equipment	81	Communications Equipment Manufacturing
334290	Other communications equipment manufacturing	81	Communications Equipment Manufacturing
334300	Audio and video equipment manufacturing	82	Electronic Components Manufacturing
33441A	Other electronic component manufacturing	82	Electronic Components Manufacturing
334413	Semiconductor and related device manufacturing	82	Electronic Components Manufacturing

334418	Printed circuit assembly (electronic assembly) manufacturing	82	Electronic Components Manufacturing
334510	Electromedical and electrotherapeutic apparatus manufacturing	83	Instruments Manufacturing
334511	Search, detection, and navigation instruments manufacturing	83	Instruments Manufacturing
334512	Automatic environmental control manufacturing	84	Automatic Environmental Control Manufacturing
334513	Industrial process variable instruments manufacturing	85	Industrial Process Variable Instruments Manufacturing
334514	Totalizing fluid meter and counting device manufacturing	86	Fluid Meters and Counting Device Manufacturing
334515	Electricity and signal testing instruments manufacturing	87	Electricity and Signal Testing Instruments Manufacturing
334516	Analytical laboratory instrument manufacturing	88	Other Laboratory and Related Instruments Manufacturing
334517	Irradiation apparatus manufacturing	88	Other Laboratory and Related Instruments Manufacturing
33451A	Watch, clock, and other measuring and controlling device manufacturing	88	Other Laboratory and Related Instruments Manufacturing
334610	Manufacturing and reproducing magnetic and optical media	89	Electronic Media Processing
335110	Electric lamp bulb and part manufacturing	90	Electronic Lamp, Bulb, and Part Manufacturing
335120	Lighting fixture manufacturing	91	Lighting fixture Manufacturing
335210	Small electrical appliance manufacturing	92	Small Household Appliance Manufacturing
335221	Household cooking appliance manufacturing	93	Household Cooking Appliance Manufacturing
335222	Household refrigerator and home freezer manufacturing	94	Household Refrigerator and Freezer Manufacturing
335224	Household laundry equipment manufacturing	95	Household Laundry Equipment Manufacturing
335228	Other major household appliance manufacturing	96	Other Major Household Appliance Manufacturing
335311	Power, distribution, and specialty transformer manufacturing	97	Electric Power, Distribution and Specialty Transformer Manufacturing
335312	Motor and generator manufacturing	98	Motor and Generator Manufacturing
335313	Switchgear and switchboard apparatus manufacturing	99	Industrial Controls
335314	Relay and industrial control manufacturing	99	Industrial Controls
335911	Storage battery manufacturing	100	Storage Battery Manufacturing
335912	Primary battery manufacturing	101	Primary Battery Manufacturing
335920	Communication and energy wire and cable manufacturing	102	Communication and Energy Wire and Cable Manufacturing
335930	Wiring device manufacturing	103	Miscellaneous Electrical Equipment Manufacturing

335991	Carbon and graphite product manufacturing	103	Miscellaneous Electrical Equipment Manufacturing
335999	All other miscellaneous electrical equipment and component manufacturing	103	Miscellaneous Electrical Equipment Manufacturing
336111	Automobile manufacturing	104	Car and Light Truck Manufacturing
336112	Light truck and utility vehicle manufacturing	104	Car and Light Truck Manufacturing
336211	Motor vehicle body manufacturing	104	Car and Light Truck Manufacturing
336120	Heavy duty truck manufacturing	105	Heavy Duty Truck Manufacturing
336212	Truck trailer manufacturing	105	Heavy Duty Truck Manufacturing
336213	Motor home manufacturing	106	Recreation Vehicle Manufacturing
336214	Travel trailer and camper manufacturing	106	Recreation Vehicle Manufacturing
336310	Motor vehicle gasoline engine and engine parts manufacturing	107	Motor Vehicle Parts Manufacturing
336320	Motor vehicle electrical and electronic equipment manufacturing	107	Motor Vehicle Parts Manufacturing
3363A0	Motor vehicle steering, suspension component (except spring), and brake systems manufacturing	107	Motor Vehicle Parts Manufacturing
336350	Motor vehicle transmission and power train parts manufacturing	107	Motor Vehicle Parts Manufacturing
336360	Motor vehicle seating and interior trim manufacturing	107	Motor Vehicle Parts Manufacturing
336370	Motor vehicle metal stamping	107	Motor Vehicle Parts Manufacturing
336390	Other motor vehicle parts manufacturing	107	Motor Vehicle Parts Manufacturing
336411	Aircraft manufacturing	108	Aerospace Product Manufacturing
336412	Aircraft engine and engine parts manufacturing	108	Aerospace Product Manufacturing
336413	Other aircraft parts and auxiliary equipment manufacturing	108	Aerospace Product Manufacturing
336414	Guided missile and space vehicle manufacturing	108	Aerospace Product Manufacturing
33641A	Propulsion units and parts for space vehicles and guided missiles	108	Aerospace Product Manufacturing
336500	Railroad rolling stock manufacturing	109	Railroad Rolling Stock Manufacturing
336611	Ship building and repairing	110	Ship Building and Repairing
336612	Boat building	111	Boat and Cycle Manufacturing
336991	Motorcycle, bicycle, and parts manufacturing	111	Boat and Cycle Manufacturing

336992	Military armored vehicle, tank, and tank component manufacturing	112	Other Transportation Equipment Manufacturing
336999	All other transportation equipment manufacturing	112	Other Transportation Equipment Manufacturing
337110	Wood kitchen cabinet and countertop manufacturing	113	Household Furniture Manufacturing
337121	Upholstered household furniture manufacturing	113	Household Furniture Manufacturing
337122	Non-upholstered wood household furniture manufacturing	113	Household Furniture Manufacturing
33712A	Other household non-upholstered furniture	113	Household Furniture Manufacturing
337127	Institutional furniture manufacturing	114	Institutional Furniture Manufacturing
33721A	Office furniture and custom architectural woodwork and millwork manufacturing	115	Office Furniture and Custom Architectural Woodwork
337215	Showcase, partition, shelving, and locker manufacturing	116	Showcase, Partition, Shelving , and Locker Manufacturing
337900	Other furniture related product manufacturing	117	Miscellaneous Furniture Manufacturing
339112	Surgical and medical instrument manufacturing	118	Medical and Dental Equipment and Supplies Manufacturing
339113	Surgical appliance and supplies manufacturing	118	Medical and Dental Equipment and Supplies Manufacturing
339114	Dental equipment and supplies manufacturing	118	Medical and Dental Equipment and Supplies Manufacturing
339115	Ophthalmic goods manufacturing	118	Medical and Dental Equipment and Supplies Manufacturing
339116	Dental laboratories	118	Medical and Dental Equipment and Supplies Manufacturing
339910	Jewelry and silverware manufacturing	119	Miscellaneous Manufacturing
339920	Sporting and athletic goods manufacturing	119	Miscellaneous Manufacturing
339930	Doll, toy, and game manufacturing	119	Miscellaneous Manufacturing
339940	Office supplies (except paper) manufacturing	119	Miscellaneous Manufacturing
339950	Sign manufacturing	119	Miscellaneous Manufacturing
339990	All other miscellaneous manufacturing	119	Miscellaneous Manufacturing
322110	Pulp mills	120	Pulp Mills
322120	Paper mills	121	Paper Mills
322130	Paperboard mills	122	Paperboard Mills
322210	Paperboard container manufacturing	123	Paperboard Container Manufacturing
322220	Paper bag and coated and treated paper manufacturing	124	Converted Paper Product Manufacturing
322230	Stationery product manufacturing	124	Converted Paper Product Manufacturing
322291	Sanitary paper product manufacturing	124	Converted Paper Product Manufacturing

322299	All other converted paper product manufacturing	124	Converted Paper Product Manufacturing
323110	Printing	125	Commercial Printing
323120	Support activities for printing	125	Commercial Printing
324110	Petroleum refineries	126	Petroleum Refineries
324121	Asphalt paving mixture and block manufacturing	127	Asphalt Paving, Other Petroleum and Coal Product Manufacturing
324190	Other petroleum and coal products manufacturing	127	Asphalt Paving, Other Petroleum and Coal Product Manufacturing
324122	Asphalt shingle and coating materials manufacturing	128	Asphalt shingle and coating materials manufacturing
325110	Petrochemical manufacturing	129	Petrochemical Manufacturing
325120	Industrial gas manufacturing	130	Inorganic Chemical Manufacturing
325130	Synthetic dye and pigment manufacturing	130	Inorganic Chemical Manufacturing
325180	Other basic inorganic chemical manufacturing	130	Inorganic Chemical Manufacturing
325190	Other basic organic chemical manufacturing	131	Organic Chemical Manufacturing
325211	Plastics material and resin manufacturing	132	Plastics Material and Resin Manufacturing
3252A0	Synthetic rubber and artificial and synthetic fibers and filaments manufacturing	133	Synthetic Rubber and Artificial Fiber Manufacturing
325310	Fertilizer manufacturing	134	Fertilizer and Pesticide Manufacturing
325320	Pesticide and other agricultural chemical manufacturing	134	Fertilizer and Pesticide Manufacturing
325411	Medicinal and botanical manufacturing	135	Pharmaceutical and Medicine Manufacturing
325412	Pharmaceutical preparation manufacturing	135	Pharmaceutical and Medicine Manufacturing
325413	In-vitro diagnostic substance manufacturing	135	Pharmaceutical and Medicine Manufacturing
325414	Biological product (except diagnostic) manufacturing	135	Pharmaceutical and Medicine Manufacturing
325510	Paint and coating manufacturing	136	Paint and Coating Manufacturing
325520	Adhesive manufacturing	137	Miscellaneous Chemical Product Manufacturing
325610	Soap and cleaning compound manufacturing	137	Miscellaneous Chemical Product Manufacturing
325620	Toilet preparation manufacturing	137	Miscellaneous Chemical Product Manufacturing
325910	Printing ink manufacturing	137	Miscellaneous Chemical Product Manufacturing
3259A0	All other chemical product and preparation manufacturing	137	Miscellaneous Chemical Product Manufacturing
326110	Plastics packaging materials and unlaminated film and sheet manufacturing	138	Plastics and Related Products Manufacturing
326120	Plastics pipe, pipe fitting, and unlaminated profile shape manufacturing	138	Plastics and Related Products Manufacturing

326130	Laminated plastics plate, sheet (except packaging), and shape manufacturing	138	Plastics and Related Products Manufacturing
326140	Polystyrene foam product manufacturing	138	Plastics and Related Products Manufacturing
326150	Urethane and other foam product (except polystyrene) manufacturing	138	Plastics and Related Products Manufacturing
326160	Plastics bottle manufacturing	138	Plastics and Related Products Manufacturing
326190	Other plastics product manufacturing	138	Plastics and Related Products Manufacturing
326210	Tire manufacturing	139	Rubber Products Manufacturing
326220	Rubber and plastics hoses and belting manufacturing	139	Rubber Products Manufacturing
326290	Other rubber product manufacturing	139	Rubber Products Manufacturing
420000	Wholesale trade	140	Wholesale Trade
481000	Air transportation	141	Air Transportation
482000	Rail transportation	142	Rail Transportation
483000	Water transportation	143	Water Transportation
484000	Truck transportation	144	Truck Transportation
485000	Transit and ground passenger transportation	145	Transit and Ground Passenger Transportation
486000	Pipeline transportation	146	Pipeline Transportation
48A000	Scenic and sightseeing transportation and support activities for transportation	147	Sightseeing and Support Activities
492000	Couriers and messengers	148	Private Courier Services
493000	Warehousing and storage	149	Warehousing and Storage
441000	Motor vehicle and parts dealers	150	Retail Trade
445000	Food and beverage stores	150	Retail Trade
452000	General merchandise stores	150	Retail Trade
4A0000	Other retail	150	Retail Trade
511110	Newspaper publishers	151	Publishers
511120	Periodical Publishers	151	Publishers
511130	Book publishers	151	Publishers
5111A0	Directory, mailing list, and other publishers	151	Publishers
511200	Software publishers	151	Publishers
512100	Motion picture and video industries	152	Telecommunications and Entertainment

512200	Sound recording industries	152	Telecommunications and Entertainment
515100	Radio and television broadcasting	152	Telecommunications and Entertainment
515200	Cable and other subscription programming	152	Telecommunications and Entertainment
517110	Wired telecommunications carriers	152	Telecommunications and Entertainment
517210	Wireless telecommunications carriers (except satellite)	152	Telecommunications and Entertainment
517A00	Satellite, telecommunications resellers, and all other telecommunications	152	Telecommunications and Entertainment
518200	Data processing, hosting, and related services	153	Information Services
5191A0	News syndicates, libraries, archives and all other information services	153	Information Services
519130	Internet publishing and broadcasting and Web search portals	153	Information Services
522A00	Non-depository credit intermediation and related activities	154	Non-Depository Credit Activities
523A00	Securities and commodity contracts intermediation and brokerage	155	Investment Services
523900	Other financial investment activities	155	Investment Services
524100	Insurance carriers	156	Insurance
524200	Insurance agencies, brokerages, and related activities	156	Insurance
525000	Funds, trusts, and other financial vehicles	157	Fund Management
52A000	Monetary authorities and depository credit intermediation	158	Monetary Authorities and Depository Credit Activities
531000	Real estate	159	Real Estate
532100	Automotive equipment rental and leasing	160	Automotive Equipment Rental and Leasing
532A00	Consumer goods and general rental centers	161	Other Rental Services
532400	Commercial and industrial machinery and equipment rental and leasing	161	Other Rental Services
533000	Lessors of nonfinancial intangible assets	161	Other Rental Services
541100	Legal services	162	Other Professional and Technical Services
541511	Custom computer programming services	162	Other Professional and Technical Services
541512	Computer systems design services	162	Other Professional and Technical Services
54151A	Other computer related services, including facilities management	162	Other Professional and Technical Services

541200	Accounting, tax preparation, bookkeeping, and payroll services	162	Other Professional and Technical Services
541610	Management consulting services	162	Other Professional and Technical Services
5416A0	Environmental and other technical consulting services	162	Other Professional and Technical Services
541700	Scientific research and development services	162	Other Professional and Technical Services
541800	Advertising, public relations, and related services	162	Other Professional and Technical Services
5419A0	Marketing research and all other miscellaneous professional, scientific, and technical services	162	Other Professional and Technical Services
541920	Photographic services	162	Other Professional and Technical Services
541940	Veterinary services	162	Other Professional and Technical Services
541300	Architectural, engineering, and related services	163	Architectural, Engineering, and Related services
541400	Specialized design services	164	Specialized Design Services
561100	Office administrative services	165	Other Business Services
561200	Facilities support services	165	Other Business Services
561300	Employment services	165	Other Business Services
561400	Business support services	165	Other Business Services
561500	Travel arrangement and reservation services	165	Other Business Services
561600	Investigation and security services	165	Other Business Services
561700	Services to buildings and dwellings	165	Other Business Services
561900	Other support services	165	Other Business Services
562000	Waste management and remediation services	165	Other Business Services
811300	Commercial and industrial machinery and equipment repair and maintenance	165	Other Business Services
550000	Management of companies and enterprises	166	Holding Companies and Related
611100	Elementary and secondary schools	167	Education
611A00	Junior colleges, colleges, universities, and professional schools	167	Education
611B00	Other educational services	167	Education
621100	Offices of physicians	168	Health Care Providers
621200	Offices of dentists	168	Health Care Providers
621300	Offices of other health practitioners	168	Health Care Providers

621400	Outpatient care centers	168	Health Care Providers
621500	Medical and diagnostic laboratories	168	Health Care Providers
621600	Home health care services	168	Health Care Providers
621900	Other ambulatory health care services	168	Health Care Providers
622000	Hospitals	169	Hospitals and Residential Care
623A00	Nursing and community care facilities	169	Hospitals and Residential Care
623B00	Residential mental retardation, mental health, substance abuse and other facilities	169	Hospitals and Residential Care
624100	Individual and family services	170	Day Care and Social Assistance
624A00	Community food, housing, and other relief services, including rehabilitation services	170	Day Care and Social Assistance
624400	Child day care services	170	Day Care and Social Assistance
711100	Performing arts companies	171	Amusement and Recreation
711200	Spectator sports	171	Amusement and Recreation
711A00	Promoters of performing arts and sports and agents for public figures	171	Amusement and Recreation
711500	Independent artists, writers, and performers	171	Amusement and Recreation
712000	Museums, historical sites, zoos, and parks	171	Amusement and Recreation
713100	Amusement parks and arcades	171	Amusement and Recreation
713200	Gambling industries (except casino hotels)	171	Amusement and Recreation
713900	Other amusement and recreation industries	171	Amusement and Recreation
721000	Accommodation	172	Lodging
722110	Full-service restaurants	173	Food and Beverage Services
722211	Limited-service restaurants	173	Food and Beverage Services
722A00	All other food and drinking places	173	Food and Beverage Services
811100	Automotive repair and maintenance	174	Personal Services
811200	Electronic and precision equipment repair and maintenance	174	Personal Services
811400	Personal and household goods repair and maintenance	174	Personal Services
812100	Personal care services	174	Personal Services
812200	Death care services	174	Personal Services
812300	Dry-cleaning and laundry services	174	Personal Services

812900	Other personal services	174	Personal Services
813100	Religious organizations	175	Other Services
813A00	Grant making, giving, and social advocacy organizations	175	Other Services
813B00	Civic, social, professional, and similar organizations	175	Other Services
814000	Private households	176	Private Households
S00500	Federal general government (defense)	177	General Federal Govt Defense Services
S00600	Federal general government (nondefense)	178	General Federal Govt Non-Defense Services
491000	Postal service	179	Postal Services--Fed Govt Enterprises
S00101	Federal electric utilities	180	Federal Electric Utilities--Fed Govt Enterprises
S00102	Other federal government enterprises	181	Other Federal Government Enterprises--Fed Govt Enterprises
S00700	State and local general government	182	State and Local General Government
S00201	State and local government passenger transit	183	S and L Passenger Transit--SL Gov Enterprises
S00202	State and local government electric utilities	184	S and L Electric Utilities--SL Gov Enterprises
S00203	Other state and local government enterprises	185	Other S and L Government and Enterprises --SL Gov Enterprises
S00401	Scrap	186	Miscellaneous Goods
S00402	Used and secondhand goods	186	Miscellaneous Goods

Appendix C

The C++ Calculator

Appendix C

The C++ Calculator

This appendix describes the input file generated by the Visual Basic program ImSET 4.0, three C++ routines used to the calculations, and the output file that returns the calculations to ImSET 4.0.

C.1 The Input File

The C++ calculator is designed to process a data stream generated by the program ImSET 4.0. Such a file (named “qminput.txt”) is shown in the box below (line numbers have been added for readability):

(1) QMIO INPUT FILE. Data provided by ImSET 4.0
(2) Run number: 1
(3) Run title: Demo
(4) Technology: Sample Technology
(5) End-use sector: Residential
(6) User name:
(7) 50,50,0,0,0,0,0,0,0
(8) 70,5,4,3,3,2,1,1,9
(9) 10,6
(10) 1,2,3,4,5,10,15,20,25,30
(11) 12,188,32.899,65.799,98.698,0.000,0.000,0.000,0.000,0.000,0.000,0.000
(12) 13,188,0.000,0.000,0.000,0.000,0.000,0.000,0.000,0.000,0.000,0.000
(13) 22,189,1.866,2.799,3.731,4.664,0.000,0.000,0.000,0.000,0.000,0.000
(14) 12,22,-1.867,-1.867,-1.867,0.000,0.000,0.000,0.000,0.000,0.000,0.000
(15) 147,190,-0.014,-0.014,-0.014,0.000,0.000,0.000,0.000,0.000,0.000,0.000
(16) 162,190,-0.131,-0.131,-0.131,0.000,0.000,0.000,0.000,0.000,0.000,0.000
(17) 163,190,-0.140,-0.140,-0.140,0.000,0.000,0.000,0.000,0.000,0.000,0.000
(18) 174,190,-0.173,-0.173,-0.173,0.000,0.000,0.000,0.000,0.000,0.000,0.000

The first six lines describe the project. Line 7 represents nine weights for the various sources of funds. Line 8 represents nine weights for the various shares of investment funding provided for reduction of investment in electric and natural gas utilities. Line 9 provides the calculator how many years of data are included (i.e., 10) and the number of sector changes to read (6). Line 10 lists the abbreviated years to consider (i.e., 2, 3, etc.). The year numbers are added to 2000 so the results are reported as 2001, 2002, etc. Lines 11 and 12 report the capacity adjustments as a result of energy savings, one for electricity and one for gas utilities, both as applied to final demand. Following these capacity changes are six sets of changes to the sector data, one for each of the sectors 22, 12, 147, 162, 163, and 174. Cross referencing these sectors (see Appendix B) reveals that line 13 represents the capital changes for food processing (sector 22), and line 14 represents electricity generation and transmission (sector 12) and final demand (matrix row 190). The second index number, for capital expenditures 190, indicates that these changes are to be made to the final demand vector, specifically to investment. If residential equipment was considered rather than commercial equipment, there would be changes to other industry sectors. For fuel savings, the second index number is 188, indicating the savings occurs in the consumption vector.

C.2 C++ Calculator Program

The “C++” Calculator program is named IMSETEngine.exe. This program begins in the “main” function and in turn calls functions QM3 and DEMAND. The main program reads the data file described above and transfers the data to the calculating subroutine QM3, which returns the results to the main function and writes the data file that is then read by the Visual Basic (VB) program. The function QM3 first reads the core data from a comma separated value file that holds the 2007 Benchmark I-O data, then calculates the base period employment, earnings, and output. It then loops through each of the years to be processed, changing the “Use” matrix data or the final demand data, and then recalculates the employment, earnings, and output. When all years are processed, the function transfers the results back to the main function. In the course of this processing, QM3 calls the DEMAND subroutine to make adjustments to final demands and assure that the final demand vector is appropriately rescaled. In addition, five other routines multiply, add, and invert matrices, which are briefly described but not shown here.

ImSET Engine

The main body of the calculator program (ImSETEngine) is shown in the text boxes below. While comments in the code explain most of the operations, this explanation will be cued to the input file, shown above. After a number of parameter and variable definitions, the program opens two files, the input file above, and the file to which the results will be printed, QM-CHG.DAT. The program then skips over the six lines of documentation text that are not used by the calculator. The next read statements put the first set of 9 weights into the variable iwgt, and the second set of weights into the variable jwgt. Because the final demand vectors include both exports and imports, two additional weights (both 0) are added to be consistent with the structure of final demand. The next two read statements (in the continuation text box) assign the number of years processed to JYR and the number of changes to be made to N. The next two read statements read the capacity changes into the variable “y.” Each of the remaining input file line reads initialize two variables, inx and indx, that hold the set of industry or final demand indexes, along with all the associated I-O changes into X.

The program then has input the data stream and turns over processing to QM3. When the results are returned from QM3, they are contained in six variables: SUMJ, SUMH, and SUMQ contain the base period jobs, earnings, and total output. Vectors SJ, SH, and SQ contain the calculated model results, one for each year, of which there are JYR years. The program next prints the base period values to the output file, then calculates and prints out the difference between subsequent years calculated values and the base period values to this same file. The final output is the industry output sector-by-sector. A rounding adjustment factor is applied both this output and to the yearly differences output to account for rounding errors associated with the I-O binary input and C++ math rounding process.

At this point, all processing has been completed so control is transferred back to the VB user interface program.

The "main" function of ImSETEngine.exe

```
// This program will read in data, make a few calculations, then
// transfer operation to QMIOS, which does the work:  Changes the
// Use matrix, then calculate output then multiply the outputs by
// the employment intensities, after adjusting final demands by iwgt.
// JYR is the number of years.  jwgt is used for capital distribution.
// The years for analysis are then read in as 1, 2, etc., then
// these are added to 2000 to construct the vector of years reported.
// There are twelve categories of final demand: C, I, X, M, FI,
// for both Defense and Nondefense (D, N), FC for both D&N, SLI
// for Education and Other (E & O) and SLC (E & O), but just
// ten are read in
//  -- no X or M (weights for these are set to zero.
// The thirteenth column is total final demand.
// If iwgt(11)=100 changes are just made to the total vector.
// This version allows up to 350 changes and 50 years of data.

int const MP( 999 );
int const NY( 100 );
int const NZ( 187 );
int const DF_ARRAY_SIZE( 11 );
FArray1D_int iyr( NY );
FArray2D_int inx( 2, 2 );
FArray2D_int indx( MP, 2 );
FArray1D_int iwgt( DF_ARRAY_SIZE - 2 );
FArray1D_int jwgt( DF_ARRAY_SIZE - 2 );
FArray2D_double X( MP, NY );
FArray1D_double SH( NY );
FArray1D_double SJ( NY );
FArray1D_double SQ( NY );
FArray1D_double wgt(DF_ARRAY_SIZE,, 0.0 );
FArray1D_double wgt2(DF_ARRAY_SIZE,, 0.0 );
FArray2D_double y( 2, NY );
FArray2D_double TA( NZ, NY );
FArray1D_double baselineIO( NZ );
FArray1D_double IORoundingAdjFactor( NZ );

std::cout << "  BEGIN EXECUTION" << std::endl;

// This section reads in the input file, for one technology
// First skip the first 6 lines, then read in two sets of 7 weights
// one for final demand (wgt), one for capacity savings (wgt2)
// These integer values are divided by 100 to change to floating point

std::ifstream QMinput_stream( "QMINPUT.TXT" );

QMinput_stream >> skip >> skip >> skip >> skip >> skip >> skip;
    /*Expected order of fund sources is as follows:
```

```
       PERSONAL_CONS_EXP = 1
       PRIVATE_INVEST = 2
       NAT_DEFENSE_CONS_EXP = 3
       NAT_DEFENSE_GROSS_INVEST = 4
       NONDEFENSE_CONS_EXP = 5
       NONDEFENSE_GROSS_INVEST = 6
       STATE_LOCAL_GOV_CONS_EXP_EDU = 7
       STATE_LOCAL_GOV_GROSS_INVEST_EDU = 8
       STATE_LOCAL_CONS_EXP_OTHER = 9
       STATE_LOCAL_GOV_GROSS_INVEST_OTHER = 10
       100 - Sum() = 11
     */
for ( int i = 1; i <= (DF_ARRAY_SIZE - 2); ++i ) iwgt(i) = csv_int(
QMinput_stream ); QMinput_stream >> skip;
for ( int i = 1; i <= (DF_ARRAY_SIZE - 2); ++i ) jwgt(i) = csv_int(
QMinput_stream ); QMinput_stream >> skip;

// NOTE!  11 weights are read in but 13 are passed to the calculator
//        The difference is, we construct zero weights for M, X.

for ( int j = 1; j <= (DF_ARRAY_SIZE - 2); ++j ) {
   int const k( j <= 2 ? j : j + 2 );
   wgt(k) = iwgt(j);
   wgt2(k) = jwgt(j);
   wgt2(k) /= 100;
   wgt(k) /= 100;
}

// Now read the # of years and number of changes to read in
int const JYR = csv_int( QMinput_stream );
int const N = csv_int( QMinput_stream );
QMinput_stream >> skip;

// Now read in the vector of years, to which we add 2000
for ( int j = 1; j <= JYR; ++j ) {
   iyr(j) = csv_int( QMinput_stream ) + 2000;
}
QMinput_stream >> skip;

// Now read in the dollar values of the capacity savings to be
// adjustd using wgt2

inx(1,1) = csv_int( QMinput_stream );
inx(1,2) = csv_int( QMinput_stream );
for ( int j = 1; j <= JYR; ++j ) y(1,j) = csv_double( QMinput_stream );
QMinput_stream >> skip;
inx(2,1) = csv_int( QMinput_stream );
inx(2,2) = csv_int( QMinput_stream );
for ( int j = 1; j <= JYR; ++j ) y(2,j) = csv_double( QMinput_stream );
QMinput_stream >> skip;

// Now read in all changes to the Use matrix or Final Demand vector
// If the column ID is 189, the change effects final demands.

{ // Scope
   int i( 0 );
   while ( ( QMinput_stream ) && ( ++i <= N ) ) {
```

```
      indx(i,1) = csv_int( QMinput_stream );
      indx(i,2) = csv_int( QMinput_stream );
      for ( int m = 1; m <= JYR; ++m ) X(i,m) =
         csv_double( QMinput_stream );
      QMinput_stream >> skip;
   }
   QMinput_stream.close();
}

// N is the number of changes read in total
// indx points to the row and column of either the USE matrix
// or the final demand column to change
// and X are the change values for the JYR years

// Now do the calculations
// This version of the calculator handles capacity savings
double SUMH, SUMJ, SUMQ;
QM3(X,N,indx,inx,SUMJ,SUMH,SUMQ,SJ,SH,SQ,TA,wgt,JYR,y,wgt2,baselineIO);

// Now write results

std::ofstream QMchg_stream( "QM-CHG.DAT" );

QMchg_stream << '\n'
 << "   Results for Experimental Data Set " << '\n'
 << "   Base Year Jobs (in Thousands) =" << F( 12, 1, SUMJ ) << '\n'
 << "   Base Year Earnings (in Millions) =" << F( 12, 1, SUMH ) << '\n'
 << "   Base Year Output (in Millions) =" << F( 12, 1, SUMQ ) << "\n\n"
 << "Year  New-Base Jobs New-Base Earnings  New-Base Output" << "\n\n";
for ( int j = 1; j <= JYR; ++j ) {
   double const DJ = SJ(j) - SUMJ + 0.038;
   double const DH = SH(j) - SUMH + 1.907;
   double const DQ = SQ(j) - SUMQ + 4.845;
      QMchg_stream << ' ' << I( 5, iyr(j) ) << F( 13, 3, DJ ) << F( 16, 3, DH
      ) << F( 16, 3, DQ ) << '\n';
}
QMchg_stream.close();

//Output the industry output. This will need to be the calculated levels"
minus the 2007 IO Levels as retrieved from file.
//Also, need to impose equivalent adjustment factors to the 4.845 above.
Those adjustment factors have been provided
//by Olga Livingston 4/17/2009. They will be read in from IOAdjFactor.
ReadIO1DArrayInput( "IOAdjFactor.csv", IORoundingAdjFactor, NZ );
std::ofstream Qout_stream( "QOUT.TXT" );
for ( int i = 1; i <= 187; ++i ) {
      Qout_stream << ' ';
      for ( int j = 1; j <= JYR; ++j ) {
            Qout_stream << F( 9, 1, ( TA(i,j)  - baselineIO(i) -
IORoundingAdjFactor(i) ) );
            if ( j == JYR )
                  Qout_stream << '\n';
            else
                  Qout_stream << ',';
            }
}
Qout_stream.close();
```

The Calculator – QM3

The lengthy code on the following pages is a list of the calculation function, QM3. The first set of comments explains how the naming convention changes from the main program within this routine. Parameters and variables are then defined and the 2007 Benchmark I-O data are opened and read in. The data from this file are arrays, W; the market share matrix, U; the use matrix, Q; the vector of industry outputs, DF; the final demand matrix; and EI, the matrix of employment and earnings intensity by industry. The dimensionality of each of these variables can be determined from the variable definitions at the beginning of the program.

Once the I-O data are returned, they are used to construct the base period employment, earnings, and output. Base period results are constructed by multiplying industry output, the first column of Q, by two sets of industry intensities. These intensities are found in the variable EI; the first column contains job intensities and the second earnings intensities. Multiplying each industry's output by these intensities yields jobs and earnings, which are cumulated over all industries. Total output is also cumulated and returned in the scalar variables SUJ, SUE, and SUQ.

A looping process through each year's data is then executed. The processing of each year begins by re-reading the I-O data, to assure that any changes will be made to the original data because the changes to these data will be different for each year. The next set of statements zero out the set of variables used to differentiate between changes to capital purchases, changes in fuel use, changes in water use, and changes in operations and maintenance (O&M) expenses. Then, vectors are defined that allow the program to identify which changes fall into each of these categories. These are the vectors FL, KL, WL, and OM, consisting of zeros and ones, where the units identify the change as falling into the specific categories, with F, K, W, and OM referencing fuel, capital water and O&M changes, respectively.

After these assignments, QM3 begins processing each year's data. After zeroing out two variables to hold the sum of final demand and the sum of changes to value added, identified by fuel type, the total capacity adjustment is calculated for this year. That is stored in the variable ADJK. Then, the changes to final demand and the use matrix are made, identifying the capital and O&M, fuel, and water final demand changes separately. The value-added changes to the use matrix are made to each of the appropriate columns, which are then cumulated into SVA. O&M changes are cumulated into OAM. While specific industries have their use of the fuels adjusted within the use matrix, the impact on the fuel-supplying industry is applied to the final demand vector.

After these changes are made and results for this year have been zeroed out, I-O data are processed to create a total requirements matrix.[1] This is done by creating a matrix, B, which is derived from the use matrix by dividing each element in the columns by that industry's output. This loop is also used to create the identity matrix ai. First, W is constructed by multiplying PH by D the market share matrix—this is derived from the make matrix. Then, W is multiplied by B. These matrix multiplications rely on calls to a matrix multiply function, MMULT, which multiplies a matrix of dimension (k x n) by a second (n x m) matrix and returns a (k x m) matrix. A similar routine, MMULT1, multiplies a (k x n) matrix by an (n x 1) vector to create a (k x 1) vector. This B*W matrix (called "a" in the program) is then subtracted from the identity matrix, ai, using the subroutine MADD (which adds or subtracts, depending on the value of j,

[1] See Horowitz and Planting 2009 in references list.

-1 in this case for subtraction). The result, which replaces the "Use" matrix, is then inverted using two subroutines from numerical recipes.[1]

QM3 Function:

```
// In this function, j1=n, l1=INDX, and X1 is X in ImSET.for
// This program will change the Use matrix, then calculate output
// then multiply the outputs by the employment intensities
// X1 contains j1 rows and up to 100 columns of changes to the
// Final Demand vectors and/or the Use Matrix.
// l1 is j1x2: first element is the row ID, second is the column ID

int const MP( 187 );
int const NP( 187 );
int const NZ( 999 );
int const NY( 100 );
int const DF_ARRAY_SIZE( 11 );

X1.dimension( NZ, NY );
l1.dimension( NZ, 2 );
INX.dimension( 2, 2 );
SJ.dimension( NY );
SH.dimension( NY );
SQ.dimension( NY );
TA.dimension( NP, NY );
wgt.dimension(DF_ARRAY_SIZE – 2);
Y1.dimension( 2, NY );
wgt2.dimension(DF_ARRAY_SIZE – 2 );

FArray1D_int indx( NP );
FArray1D_double FL( NZ );
FArray1D_double KL( NZ );
FArray1D_double WL( NZ );
FArray1D_double CF( NP );
FArray1D_double CW( NP );
FArray1D_double CK( NP );
FArray1D_double OM( NZ );
double TMP, OAM;
FArray2D_double a( NP, NP );
FArray2D_double b( NP, MP );
FArray2D_double ai( NP, NP );
FArray1D_double x( NP );
FArray1D_double y( NP );
double sva;
FArray1D_double CV( NP );
FArray1D_double P( NP );
double TFD, ADJK;
FArray2D_double t( MP, MP );
FArray2D_double W( NP, NP );
double z;
FArray2D_double U( NP, NP );
FArray2D_double Q( NP, 2 );
FArray2D_double D( NP, NP );
```

[1] Press WH, WT Vetterling, SA Teukolsky, and BP Flannery. 1986. *Numerical Recipes: The Art of Scientific Computing*. Cambridge University Press, New York. For matrix inversion, see p. 38.

```
FArray2D_double DF( NP, 13 );
FArray2D_double EI( NP, 3 );
FArray2D_double PH( NP, NP );
std::ifstream io97_stream( "IO-97", std::ios_base::binary );

// Read CVS files containing 2007 I-O files and EI=employment &
// earnings intensities; P is the scrap adjustment
ReadIO2DArrayInput( "W.csv", W, NP, NP );
ReadIO2DArrayInput( "U.csv", U, NP, NP );
ReadIO2DArrayInput( "GQ.csv", Q, NP, 2 );
ReadIO2DArrayInput( "DF.csv", DF, NP, 13 );
ReadIO2DArrayInput( "EI.csv", EI, NP, EICols );

// Zero out results to be returned
SuJ = 0.0;
SuH = 0.0;
SuQ = 0.0;

// Now calculate employment and hours with output, Q
TMP = 0.0;
for ( int l = 1; l <= MP; ++l ) {
   SuJ += Q(l,1)*EI(l,1);
   SuH += Q(l,1)*EI(l,2);
   SuQ += Q(l,1);
   for ( int k = 1; k <= DF_ARRAY_SIZE - 1; ++k ) {
      TMP += DF(l,k);
   }
}

// SU"J,H.Q" are all base case numbers (jobs, earning, and output)
// Identify Fuel and Water changes so each can be added to consumption
// Capital and O&M are added to investment
// Now process changes
// BIG LOOP:  EACH YEAR FROM 2001 TO whenever
for ( int m = 1; m <= JYR; ++m ) {
   ReadIO2DArrayInput( "W.csv", W, NP, NP );
   ReadIO2DArrayInput( "U.csv", U, NP, NP );
   ReadIO2DArrayInput( "GQ.csv", Q, NP, 2 );
   ReadIO2DArrayInput( "DF.csv", DF, NP, DF_ARRAY_SIZE);
   ReadIO2DArrayInput( "EI.csv", EI, NP, EICols );

   // Zero out vectors -- Final Demand changes from x1
   // TFD is the sum of all of final demand
   // sva is the sum of the value added changes
   for ( int i = 1; i <= MP; ++i ) {
      CV(i) = 0.0;
      CW(i) = 0.0;
      CK(i) = 0.0;
      CF(i) = 0.0;
   }
   TFD = 0.0;
   sva = 0.0;
   OAM = 0.0;

      // Zero out then identify fuel, water, services, and capital changes
   for ( int i = 1; i <= j1; ++i ) {
      int k = l1(i,1);
```

```
      int l = l1(i,2);
      FL(i) = 0.0;
      KL(i) = 0.0;
      WL(i) = 0.0;
      OM(i) = 0.0;
      if ( k == 126 || k == 11 || k == 12 && l == 188 )
            FL(i) = 1.0;
      if ( k == 13 && l == 188 ) WL(i) = 1.0;
      if ( l == 189 ) KL(i) = 1.0;
      if ( l == 190 ) OM(i) = 1.0;
   }

   // First construct ADJK, capacity adjustments for this period
   // Capacity savings are negative, so change sign
   ADJK = -1.0E0*(Y1(1,m)+Y1(2,m));

   // Make the changes to the use matrix first, J1=N.
   // Aggregate all final demand changes into CV
// Partition CV into Fuel, Capital (and O&M) and Water Changes (for
// future use). Value added total is also calculated as is total O&M.
   for ( int l = 1; l <= j1; ++l ) {
      int i = l1(l,1);
      int j = l1(l,2);
      if ( j >= 188 && j <= 190 ) CV(i) += X1(l,m);
      if ( j == 188 ) CF(i) += X1(l,m) * FL(l);
      if ( j == 189 ) CK(i) += X1(l,m) * KL(l);
      if ( j == 190 ) CK(i) += X1(l,m) * OM(l);
      if ( j == 188 ) CW(i) += X1(l,m) * WL(l);
      if ( j == 190 ) OAM += X1(l,m) * OM(l);
      if ( j < 188 ) U(i,j) += X1(l,m);
      if ( j < 188 ) sva -= X1(l,m);
   }

   // Zero out results to be returned
   SJ(m) = 0.0;
   SH(m) = 0.0;
   SQ(m) = 0.0;

   // Construct the PH, the scrap matrix Inverse(I-Phat)
   // and B, based on modified Use matrix, a vector with all ones,
   // and the identity matrix, ai
   TMP = 0.0;
   for ( int l = 1; l <= MP; ++l ) {
      for ( int k = 1; k <= MP; ++k ) {
         ai(l,k) = 0.0;
         if (Q(l,1) == 0.0) b(k,l) = 0.0;
         if (Q(l,1) != 0.0) b(k,l) = U(k,l)/Q(l,1);
      }
      ai(l,l) = 1.0;
   }

   // create a=B*W and subtract from ai
   mmult(b,MP,MP,W,NP,a);
   madd(ai,MP,MP,a,U,false);

   // Now invert I-BW
   // perform decomposition
   ludcmp(U,MP,MP,indx,z);
```

```
   // now invert by columns
   for ( int k = 1; k <= MP; ++k ) {
      lubksb(U,MP,MP,indx,ai(1,k));
   }

   // Check ai
   // construct t = W(I - BW)^-1
   mmult(W,MP,MP,ai,MP,t);

   // Now construct final demand vector x(l)
   DEMAND(x,CV,CF,CK,CW,DF,wgt,wgt2,ADJK,sva,OAM);

   // Check sum of final demand to determine value
   // Now construct output, y = t*x
   mmul1(t,MP,MP,x,y);

   TMP = 0.0;
   for ( int k = 1; k <= MP; ++k ) {
      TMP += y(k);
   }

   // Now construct employment, earnings and output for this year
   for ( int l = 1; l <= MP; ++l ) {
      SJ(m) += y(l)*EI(l,1);
      SH(m) += y(l)*EI(l,2);
      SQ(m) += y(l);
      TA(l,m) = y(l);
      if ( m == 3 && l == 10 )
         std::cout << G( 23, 15, TA(l,m) ) << std::endl;
   }

} // Complete BIG loop and close binary file

std::cout << "  END BIG LOOP" << std::endl;
//Write out the IO baseline to IO97.TXT.
//IO97.TXT is not to imply 1997 I/O data was used.
//It is simply a legacy file name usage.
      std::ofstream Qout_stream( "IO97.TXT" );
      for ( int i = 1; i <= NP; ++i ) {
            baselineIO(i) = Q(i,1);
            Qout_stream << F( 9, 1, baselineIO(i) );
            Qout_stream << '\n';
      }

Qout_stream.close();
// That's a wrap
```

The resulting inverse (replacing ai) is then multiplied by the modified market share matrix, W, to yield the total requirements matrix, labeled t. At this point, we are ready to create the final demand vector, so a call is made to the DEMAND function. This returns the final demand vector x, which is then multiplied by the total requirements matrix, t, to yield the output vector, y. Output then is multiplied by each column of the intensity matrix to yield this year's jobs and earnings. This period's output is then just the sum of all of the industry outputs. When each of the JYRs of data has been processed, the big loop is complete and the results are returned to the main function.

Changing Final Demands – DEMAND

The call to this subroutine transfers the changes to final demand read in by the main function, contained in the vectors CV, CF, CK, and CW, and the array of final demands, DF, read in from the binary file. In addition, the weights to distribute the financing charges and the weights to allocate the capacity changes are transferred in the wgt and WGT2, along with the value of the capacity changes, contained in ADJK. Finally, all the value-added variables, a total and a variable for each of the fuel changes, and the total value of O&M changes contained in OAM are transferred. The first set of statements below the initial comments zero out accumulator variables, aggregate the finance and capacity weights, and sum each of the components of final demand. The 11th column in this array is the total final demand vector, and the other columns correspond to consumption, investment, exports, imports, various federal government investment and consumption components, and various state and local investment and consumption components. The next block of calculations zero out the vector of final demands to be returned, cumulate the changes to final demand, and then partition these changes into capital and O&M purchases (which affect investment), and fuel and water purchases (which affect consumption).

The capital and O&M changes (all those changes in final demand except for changes in the fuel vectors) are added to the investment vector, just as the fuel savings are subtracted from the consumption vector. These investments need to be financed by "taxing" some component of final demand, after adjusting for O&M expenses, which are not "financed." The strategy with this version of the model is to first determine how the different components of final demand are to be taxed; then adjust components of final demand for the tax, carrying along all changes to the 10 vectors that constitute the components of final demand. In the event that all the "tax" applies to the aggregated component (the 11th column), then these weights for the various components are zero and no adjustment occurs to them. From a computational point of view, this simply means that the components are not modified when adjustments are made. Once the aggregation occurs, if a portion of the "tax" is to be applied to the aggregate component, then that is processed. A similar scheme is used if the "savings" achieved by a reduction in the building of energy capacity is distributed back to final demand or are simply applied to the aggregate final demand.

Accordingly, the first step is to adjust the consumption vector for the fuel savings and redistribute these savings back to other consumption. Similarly, adjustments to the investment vector are made according to the distribution of capital expenditures after adjusting for O&M changes, then each of the vectors of final demand are "taxed" by multiplying the weight associated with this component of GDP (which in our example, is line 7) by the total capital expense and rescaling each component of GDP to reflect the cost of financing the investment. (Note that if the investment costs are nil, then no scaling occurs, but the adjustment proceeds as if the weights were there.) Then if capacity adjustments are to be made, they are subtracted from the applicable sector activity row of the final demand vector. The scalars provided by the user to make these adjustments are used to expand (or contract) the vector of final demand so it is scaled appropriately. Note also that if the capital costs are not financed, then the total of final demand will expand by that capital expense just as if the capacity savings are not redistributed to other sectors, then these savings are "lost" and the total of final demand is reduced.

Capital costs and capacity adjustments might not be fully added back in, depending on the sum of the weights provided in wgt and WGT2.

Before final adjustments are made, the 10 components of final demand are aggregated to a single vector. Then the program branches to the concluding section that makes adjustments if there is a non-zero weight in component 11 of the two weighting vectors. The next step adjusts this aggregate vector for the changes either to the financing of capital expenditures or for the distribution of capacity savings changes. As with each component of final demand, we construct a scalar that integrates the financing proportion or the capacity adjustment used to scale the total final demand vector. The 11th weight in each case is used to construct a scalar, Z1, which is the total of final demand minus the 11th weight times the capital change divided by the total of final demand. In symbols, as in the code, z1=(ztot-WGT(DF_ARRAY_SIZE)*SCK)/ztot (note that this is one if WGT(DF_ARRAY_SIZE - 2) is zero). The remaining task is the adjustment for changes in value added if changes were made to the use matrix. (The continuation statement 45 shows the entry point from the section where final demand is treated as a single vector; recall that the same variable, SCV, was used to sum total final demand.) A scaling multiplier, z1, is constructed by adding the sum of value added, SVA, to SCV, then dividing by SCV. Z1 is then used to multiply each element of the final demand vector x, which is then returned to QM3.

DEMAND Function:

```
int const DF_ARRAY_SIZE( 11 );

FArray1Da_double x,
FArray1Da_double CV,
FArray1Da_double CF,
FArray1Da_double CK,
FArray1Da_double CW,
FArray2Da_double DF,
FArray1Da_double wgt,
FArray1Da_double wgt2,
double const ADJK,
double const SVA,
double const OAM
)
{
// This routine calculates changes to final demands and adjusts
// these to scale depending on the wgt vectors. This routine
// returns a vector x, used to calculate output and employment.
// CV contains all the changes to the use matrix and final demand;
// DF is the original set of final demands; ADJK is the change to
// capacity, and sva is the sum of changes to value added (in the
// use matrix). sw is the sum of weights for capital financing.

int const MP( 187 );

x.dimension( MP );
CV.dimension( MP );
CF.dimension( MP );
CK.dimension( MP );
CW.dimension( MP );
DF.dimension( MP, DF_ARRAY_SIZE );
wgt.dimension(DF_ARRAY_SIZE);
wgt2.dimension(DF_ARRAY_SIZE);

double Z1 = 0.0;
double sw = 0.0;
double sw1 = 0.0;
double s2w = 0.0;
double s2w1 = 0.0;
double scf = 0.0;
double sck = 0.0;
double SCV = 0.0;
double ztot = 0.0;
FArray1D_double SDF(DF_ARRAY_SIZE);
```

```
FArray2D_double Y( MP, DF_ARRAY_SIZE);
FArray1D_double x1( MP );
FArray1D_double z(DF_ARRAY_SIZE);
FArray1D_double sy(DF_ARRAY_SIZE);
FArray1D_double sy1(DF_ARRAY_SIZE);

for ( int j = 1; j <= DF_ARRAY_SIZE; ++j ) {
   sw += wgt(j);
   if ( j <= 13 ) sw1 = sw1+wgt(j);
   if ( j <= 13 ) s2w1 = s2w1+wgt2(j);
   s2w += wgt2(j);
   sy(j) = 0.0;
   sy1(j) = 0.0;
   z(j) = 1.0;
   SDF(j) = 0.0;
   for ( int i = 1; i <= MP; ++i ) {
      Y(i,j) = 0.0;
      SDF(j) += DF(i,j);
   }
}

// Zero out columns and aggregate all changes (fuel and water are combined)
for ( int i = 1; i <= MP; ++i ) {
   x1(i) = 0.0;
   x(i) = 0.0;
   sck += CK(i);
   scf += CF(i)+CW(i);
   SCV += CV(i);
}

// Create Y, which contains the original final demands plus the
// changes to final demand (assume fuel and water got to consumption)
// and capital purchases goto investment, then subtract financing
// for capital purchases. Thirteenth weight is not relevant now.
for ( int i = 1; i <= MP; ++i ) {
   Y(i,1) += CF(i)+CW(i);
   for ( int j = 1; j <= (DF_ARRAY_SIZE - 1); ++j ) {
      Y(i,j) += DF(i,j);
      sy(j) += Y(i,j);
   }
}

z(1) = (sy(1)-scf)/sy(1);
sy(1) = 0.0;

// Adjust consumption by the full amount of the fuel savings
// and calculate a new sum for investment adjustments
for ( int i = 1; i <= MP; ++i ) {
   Y(i,1) *= z(1);
   sy(1) += Y(i,1);
}

// Consumption adjustment complete; adjust for investment, if necessary
for ( int i = 1; i <= MP; ++i ) {
   Y(i,2) += CK(i);
}
```

```
// First correct for O&M changes (redistribute so total investment is
// equal to original total plus capital changes) { adjust investment.
z(2) = (sy(2)-OAM)/sy(2);
sy(2) = 0.0;
for ( int i = 1; i <= MP; ++i ) {
   Y(i,2) *= z(2);
   sy(2) += Y(i,2);
}
for ( int j = 1; j <= (DF_ARRAY_SIZE - 1); ++j ) {
   z(j) = (sy(j)-wgt(j)*(sck-OAM))/sy(j);
   sy(j) = 0.0;
}


// Now adjust each FD vector by z and get new totals --
// recall that the 13th column is the difference between SFD and
// the weighted sum of the first 12 columns.
for ( int i = 1; i <= MP; ++i ) {
   for ( int j = 1; j <= (DF_ARRAY_SIZE - 1); ++j ) {
      Y(i,j) *= z(j);
      sy1(j) += Y(i,j);
   }
}

// Now adjust for capacity changes, if needed
if ( ADJK == 0.0 ) goto L50;

Y(17,2) -= ADJK;
sy1(2) -= ADJK;
for ( int j = 1; j <= (DF_ARRAY_SIZE - 1); ++j ) {
   z(j) = (sy1(j)+(wgt2(j)*ADJK))/sy1(j);
   for ( int i = 1; i <= MP; ++i ) {
      Y(i,j) *= z(j);
   }
}

L50:

// Using the Y vectors as the adjusted GDP, make adjustments when
// the aggregate vector is identified as the appropriate one to adjust.
for ( int i = 1; i <= MP; ++i ) {
   for ( int j = 1; j <= (DF_ARRAY_SIZE - 1); ++j ) {
      x(i) += Y(i,j);
   }
   ztot += x(i);
}

// First address the financing issues.

Z1 = 1.0;
if ( wgt(DF_ARRAY_SIZE - 2) == 0.0 ) goto L17;
Z1 = (ztot-(sck*wgt(DF_ARRAY_SIZE - 2)))/ztot;

// Adjust GDP for financing portion that applies to total FD
// Then reallocate capital expenses
L17:
SCV = 0.0;
```

```
for ( int i = 1; i <= MP; ++i ) {
   x(i) *= Z1;
   SCV += x(i);
}

// Now adjust GDP for capacity savings that are distributed as is GDP
if ( wgt2(13) == 0.0 ) goto L45;
Z1 = (SCV+ADJK*wgt2(DF_ARRAY_SIZE - 2))/SCV;
// reallocate consumption savings and capital expenses
SCV = 0.0;
for ( int i = 1; i <= MP; ++i ) {
   x(i) *= Z1;
   SCV += x(i);
}

// x is the modified final demand vector
// SCV is now the sum of the new (or old) FD vector
// Now do value added correction
L45:
Z1 = (SCV+SVA)/SCV;
for ( int i = 1; i <= MP; ++i ) {
   x(i) *= Z1;
}
// That's a wrap
```

C.3 The Output File

The calculations from the ImSET Engine program generate a file called QM-CHG.DAT, which contains the results of the calculations, an example of which is shown in the text box below. This file is read back into the ImSET 4.0 user interface program to provide the data to other applications, such as spreadsheets. The numbers graphed are the same as the right-hand column of outputs shown in the text box.

Example of QM-CHG.DAT:

Results for Experimental Data Set
Base Year Jobs (in Thousands) = 129174.2
Base Year Earnings (in Millions) = 4678287.0
Base Year Output (in Millions) = 14862876.2

Year	New-Base Jobs	New-Base Earnings	New-Base Output
2001	-0.972	34.854	244.522
2002	-0.902	31.688	233.736
2003	-0.997	34.494	265.278
2004	-0.951	32.246	262.970
2005	-0.855	28.264	248.447
2010	-0.488	11.448	204.857
2015	1.191	-51.792	-188.537
2020	1.149	-50.710	-179.832
2025	1.200	-52.761	-194.602
2030	1.184	-52.536	-192.41

Pacific Northwest
NATIONAL LABORATORY

Proudly Operated by **Battelle** *Since 1965*

U.S. DEPARTMENT OF
ENERGY

902 Battelle Boulevard
P.O. Box 999
Richland, WA 99352
1-888-375-PNNL (7665)

www.pnnl.gov