Chapter 3

STUDY METHODOLOGY[1]

3.1 OVERVIEW OF METHODOLOGY

The methodology developed for this study is driven largely by the objective of assessing national policies to address the multiple energy and environmental challenges faced by the United States. This objective requires that the methodology be:

- flexible to examine policies that affect not only financial decisions, but also policies directed at information dissemination, behavior, and regulation,
- scenario-based to allow examination of a range of uncertainties,
- dynamic with an extended time period to capture impacts over the longer term,
- consistent across sectors to ensure balance and fairness,
- integrated across sectors to capture inter-sectoral dependencies, and
- broad in assessing not only direct energy impacts, but also macro-economic impacts and costs.

The methodology developed here largely meets these requirements by employing a combination of tools and analytical approaches. A scenario-based approach is used to examine sets of public policies that are consistent with varying levels of public commitment to solving the nation’s energy-related challenges. The scenarios allow us to examine the substantial synergisms between policies that are not evident when policies are viewed one at a time.

While scenarios assist in capturing a range of policy responses to climate change and other energy issues, there remains a very large number of uncertainties with respect to the outcome for each scenario. Within the limits of our resources, we partially address these uncertainties through sensitivity analyses. While we do present a number of sensitivities, we are forced to present our principal results as point estimates for each scenario. Consequently, individual elements of the results should not be construed as precise estimates, but rather as representative of a range of possible outcomes.

The two principal methodological enhancements that distinguish this study from the Five-Lab Study (Interlaboratory Working Group, 1997) are the analysis of policy impacts and the use of the CEF-NEMS model to integrate across market sectors. Policies included in the scenarios were selected based on the need to overcome specific market failures or barriers to attaining national energy and environmental objectives. As mentioned in Chapter 1, policies range from tax incentives to voluntary agreements to domestic carbon trading. The evaluation of such diverse policies required a variety of analytical tools and a range of expertise. The central integrating energy model, the CEF-NEMS model, was used to pull these diverse analyses together to evaluate each scenario’s overall policy set. Technology and end-use-specific models were built and used to analyze some policies and sectors and their results integrated back into CEF-NEMS. Other portions of the analysis were completed outside of the CEF-NEMS model. These include:

- the assessment of policies to promote combined heat and power systems (see Appendix E-5);

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[1] Authors: Walter Short, National Renewable Energy Laboratory (NREL) and Marilyn A. Brown, Oak Ridge National Laboratory (ORNL).

- the estimation of administrative costs of public policies and programs (see Appendix E-1); and
- the analysis of macro-economic impacts.

Many methodological improvements and technology updates to the individual sector analyses were also made. For buildings, we updated the existing cost and performance data for new and existing technologies and gathered additional information about the nature of miscellaneous energy uses. For industry, a new data gathering effort is used to enhance the analysis of three key industrial subsectors (cement, steel, and forest products). Considerable attention is also given to assessing the market potential of combined heat and power and energy-efficient motors and drives. For transportation, more attention is devoted to the economics of advanced technologies for light-duty vehicles and heavy trucks. In the electricity sector, improvements are made to the analytical treatment of renewable energy resources, plant retirements, and life extension of nuclear power. Finally, by using CEF-NEMS we are able to take advantage of the fossil fuel supply models of the NEMS which provide a price response to demand levels that was absent in the Five-Lab Study.

3.2 SCENARIOS

The purpose of scenario analysis, as explained by Peter Schwartz in his now classic book, *The Art of the Long View*, is to explore several possible futures in a systematic way (Schwartz 1996). Scenarios are tools “for ordering one’s perceptions about alternative future environments.” They help analysts think through both the opportunities and the consequences of a given future. The end result is not an accurate picture of tomorrow, but better decisions about the future.

3.2.1 Policy Implementation Pathways of the Scenarios

The CEF scenarios are defined by policies that are consistent with increasing levels of public commitment to solving the nation’s energy-related challenges. The definition of these scenarios and the policy implementation pathways that they include were the subject of two workshops held in December 1998. One focused on energy efficiency and the other on renewable energy policies. Workshop participants included representatives of energy and environmental nongovernmental organizations (NGOs), gas and electric utilities and their associations, industry, State Energy Offices, the Association of State Energy Research and Technology Transfer Institutions, DOE and other federal agencies, and the study’s National Laboratory team. These workshops led to the following scenario definitions.

Business-As-Usual Scenario (BAU). The BAU Scenario is the baseline forecast against which the other two scenarios are compared. The BAU Scenario is developed from the Reference Case published in the Energy Information Administration’s *Annual Energy Outlook 1999* (AEO99)[2]. We start from the AEO99 Reference Case because it is widely available, frequently referenced, and a well-documented projection. We view the AEO99 Reference case as only a starting point for our analysis, not necessarily the most likely outcome even in a BAU world.

The BAU results vary only slightly from those of the AEO99 Reference Case. The differences are due primarily to changes in inputs for nuclear power relicensing and a few industrial process input parameters. The input variations are documented in detail in Appendix A. These slight input variations decrease U.S. primary energy consumption in the BAU 2010 and 2020 Scenarios by 0.5 quads relative to the EIA’s Reference Case. Carbon emissions in the BAU Scenario are almost 1% less in 2010 and are 2% less in 2020 than the AEO99 Reference Case. Additional details on these changes can be found in Chapter 1 and in the sector results in the chapters that follow. In general, the BAU case assumes that no further

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[2] The AEO99 was the most recent available *Annual Energy Outlook* at the time the analysis was conducted.

legislative action is taken, but that scheduled administrative actions – such as the issuance of scheduled standards – will take place. Further, it assumes that the federal government's funding of energy R&D continues at approximately its current level. This ongoing investment, in combination with other private- and public-sector actions (some spurred by Federal collaboration), results in a steady pace of moderate technological progress.

The other two scenarios examined in this study reflect greater levels of enhanced national commitment to increasing the nation's energy productivity, reducing oil dependence, improving air quality, and addressing the threat of global warming. These alternative scenarios are labeled "Moderate" and "Advanced."

Moderate Scenario. The Moderate scenario is defined by a set of policies that the authors felt to be consistent with a national commitment to address these energy and environmental goals, if costs can be kept low. Thus, a modest shift in political will and public opinion is assumed. This shift enables the implementation of supporting policies and programs that would be difficult to implement in today's political environment. The shift also results in a greater willingness for individuals and businesses to purchase more energy-efficient and low-carbon technologies, a change that would reduce the costs and increase the effectiveness of complementary policy actions.

The policy implementation pathways that are employed in the Moderate scenario to increase investments in energy-efficient and low-carbon technologies fit the following criteria:

- are not highly controversial today
- generally have no increased net direct cost to the customer
- would not impose significant direct costs on any single region or sizable group
- correct one or more market imperfections
- involve a maximum increase of 50% in mature federal deployment program budgets
- involve a maximum increase of 50% in federal R&D budgets over the study period
- would not involve new fiscal policies that tax energy, either directly or indirectly.

The Moderate scenario is defined by combinations of policies such as information outreach efforts, enhanced R&D, government procurement programs, voluntary industry agreements, technical assistance, stricter codes and standards, feebates, rebates, and tax credits. The specific policies examined in both the Moderate and Advanced scenarios are listed in each of the sector chapters (4 through 7), and are illustrated in Tables 1.1 through 1.4.

Advanced Scenario. The Advanced scenario is defined by a set of policies that the authors felt to be consistent with a nationwide sense of urgency at meeting significant goals relative to energy productivity, oil supply vulnerability, air quality, and greenhouse gas mitigation. Thus, a substantial change in public opinion and political will is assumed. This change enables the implementation of supporting policies and programs that the authors felt would not be politically feasible in the Moderate scenario.

Policies in the Advanced scenario fit the following criteria:

- include all the Moderate scenario policies or more stringent versions of same
- may be highly controversial today
- may have net direct costs up to approximately $50/tonne

- may impose significant costs on one or more regions or sizeable groups
- correct one or more market imperfections
- involve a maximum increase of 100% in mature federal deployment program budgets
- involve a maximum increase of 100% in federal R&D budgets over the study period
- include a domestic carbon trading system

One key policy assumed in the Advanced scenario is the establishment of a system for the trading of carbon permits within the United States. This domestic trading system is applied to all fuels and all sectors of the economy; it is assumed to be announced in the year 2002 and fully implemented by the year 2005.

Carbon permits can be distributed in a number of different ways. They may be auctioned by the Federal government with the resulting revenues used or distributed back to taxpayers, or they may be allocated to existing carbon emitters. In the Advanced scenario, we assume the allowances are auctioned annually by the Federal government. Energy prices are based on marginal costs and therefore include the full carbon permit value, regardless of the allocation process[3]. However, the impact on the economy can vary significantly among different permit allocation schemes. Such macroeconomic impacts are discussed in more detail in Chapter 1, Section 3.5.2, and Appendix E-4 (qualitative analysis).

The level of the cap on domestic carbon emissions is not tied to any assumption regarding the ability of the United States to purchase allowances on the international markets, nor in the capability of the United States to reduce other greenhouse gases. The level of the cap was selected to keep the value of a carbon-trading permit to a level of about $50/tonne of carbon in the year 2010. This value was thought by the study participants and reviewers to represent a level consistent with the Advanced scenario's assumption of a "nationwide sense of urgency." Should the price of permits under an international permit trading system be lower than $50/ton of carbon, then one would expect to see lower carbon permit prices in the United States as well, and fewer domestic carbon emission reductions than shown in this Advanced scenario. Conversely, higher international carbon allowance trading prices may yield more domestic reductions.

The policy pathways that define the Advanced scenario also include significant tax incentive programs, more stringent non-fiscal policies such as stricter fuel-economy or carbon-emission standards, accelerated R&D, and enhanced voluntary programs with outreach and incentive features that exceed those in the Moderate scenario.

3.2.2 Macroeconomic Inputs

All of the scenarios described in this report use the AEO99 forecasts of national economic output as measured by gross domestic product (GDP), which is projected to increase by 2.1% per year through 2020. Similarly, the buildings sector uses the AEO99 forecast of annual growth in residential buildings (1.1%) and commercial floorspace (0.8%). The industrial sector uses the AEO99 assumption of a 2.0% annual growth rate for manufacturing production; and the transportation sector uses the AEO99 forecast of a 1.6% annual increase in vehicle miles traveled and a 3.8% annual increase in air travel (EIA, 1998a).

All of the scenarios use the AEO99 world oil price forecast wherein world oil prices are assumed to rise from $18.55 per barrel in 1997 to $22.73 per barrel (in 1997$) in 2020. The Business-As-Usual scenario

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[3] Distribution schemes can be devised that would impact the energy results. For example, an output-based distribution in which all current generators are allocated permits based on their generation level, not their emission levels, would provide an economic advantage to nuclear, renewables, and other technologies that emit little or no carbon dioxide.

utilizes AEO99 assumptions for coal and natural gas as well. Coal and natural gas prices vary with the policy-based scenarios because they are determined endogenously within CEF-NEMS as a function of domestic supply and demand. The pricing models for these fossil fuels are taken directly from the AEO99 version of NEMS without alteration.

3.2.3 Time Frames

To capture the longer-term impacts of policies, we have extended the period of analysis from 2010 in the 5-Lab study to 2020 in this study. This extended period also allows the benefits of many technologies just now being introduced to the market to be more fully evaluated. While the CEF-NEMS model develops results on one-year time intervals, they are reported here for the principal years of interest: 1990, 1997, 2010 and 2020. The year 1990 is included because it is a reference point for the Kyoto accords on greenhouse gas emissions. The year 1997 is included as the last year of historical data in the AEO99 (although the latest 1998 data have become available during the course of our analysis and are discussed in several chapters).

Results for additional intermediate years are reported in the appendices. Finally, Chapter 8 provides a look beyond 2020.

3.2.4 Carbon Measurement

Throughout the report, the potential climate benefits of energy-efficient and low-carbon technologies are quantified in terms of reductions in millions of metric tons of carbon (MtC) emitted. Carbon dioxide is measured in carbon units, defined as the weight of the carbon content of carbon dioxide. Carbon dioxide units at full molecular weight (typically, MtC) can be converted into carbon units by dividing by 44/12, or 3.67. This approach has been adopted for two reasons. First, carbon dioxide is most commonly measured in carbon units in the scientific community, in part because it is argued that not all carbon from combustion is, in fact, emitted in the form of carbon dioxide. Second, carbon units are more convenient for comparisons with data on fuel consumption and carbon sequestration (EIA, 1998b). Note that, in the U.S., a "ton" (sometimes referred to as a "short ton") equals 2000 pounds; a metric ton, or "tonne," equals 1000 kilograms (approximately 2204 pounds).

Carbon dioxide emissions reductions are estimated by using factors to convert the energy impacts into million tonnes of carbon (MtC). The conversion factors come from EIA’s *Emissions of Greenhouse Gases in the United States* (1998, Table B1, p. 106) and are shown in Table 3.1.

Table 3.1 Factors for Converting Fossil Energy Savings into Carbon Emission Reductions

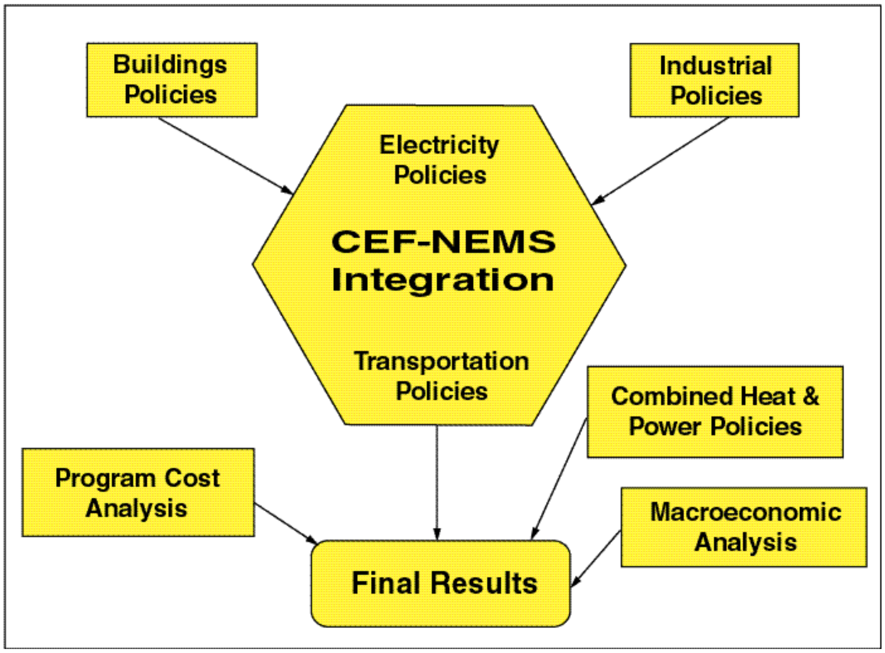
	Conversion Factors (MtC/TBtu)
Natural Gas	0.0145
Petroleum Fuels:	
Distillate Fuel	0.0200
LPG	0.0170
Petrochemical Feedstock	0.0194
Residual Fuel	0.0215
Other Petroleum	0.0168
Coal:	
Metallurgical Coal	0.0255
Steam Coal	0.0257

3.3 ANALYSIS METHODS

A variety of analytical tools were used in assessing the above scenarios and their policy impacts on the multiple energy and environmental challenges faced by the United States. As shown by Fig. 3.1, sector-specific analyses and models were used extensively in the buildings and industrial sectors. In particular, the buildings sector used a variety of spreadsheet analyses and models to estimate and integrate the simultaneous impact of policies ranging from R&D improvements to voluntary programs. The synergies between policies impacting the industrial sector were assessed at the subsector level using technology possibilities, international experience, and empirical observations of past energy intensity changes. These sectors' results are translated into inputs to the energy integrating CEF-NEMS model, which is described below. For the transportation and electric sectors, inputs to CEF-NEMS were developed by starting from the inputs to the AEO99 Reference case (EIA 1998a) and modifying them to represent the policies of our two policy scenarios.

In general the above approach reasonably captured the energy markets of the different scenarios. However, as shown in Fig. 3.1, there were three principal areas that could not be well integrated within CEF-NEMS. Clearly the cost of implementing Federal policies and programs is not addressed in an integrating energy market model like CEF-NEMS. Also as shown in Fig. 3.1, industrial combined heat and power (CHP) systems are not captured by CEF-NEMS. Finally, we have assessed macroeconomic impacts of our scenarios outside of CEF-NEMS relying heavily on economic arguments and past analyses found in the literature.

Fig. 3.1 Analysis Methodology



3.3.1 Sector Approaches

To capture the significant interactions among technologies and policies, the buildings and industrial sectors required detailed accounting and judgment, not available in CEF-NEMS. For both these sectors, the general process was to use spreadsheets to first estimate the economic potential of the technology using the cost of capital for the discount rate. This economic potential implicitly assumes all market barriers and transaction costs have been removed. For those technologies with significant economic potential under these extremely optimistic assumptions, the next step was to estimate market penetration by considering the contribution that individual policies can make in removing the actual market barriers. In other words, rather than the standard practice of rolling all the barrier implications into a single discount rate or "hurdle rate," barriers were considered individually along with the policies designed to address them. This second step also considered careful stock accounting, retirement rates, scheduled maintenance practices, etc. With these considerations, estimates were made of the rate of market penetration of specific technologies under the different CEF policy scenarios. In the buildings sector, penetration rates were developed in correspondence with individual policies, taking into account interactions amongst the policies. In the industrial sectors, policies were considered at a more aggregated level but for a more diverse set of end uses.

For example, for the three energy-intensive industrial subsectors – paper, steel, cement – detailed evaluations were conducted at the process level. To identify retrofit opportunities, over one hundred commercially available technologies were characterized with respect to economic potential. For those policies that directly impact economic potential, multiple estimates of potential were developed. For those policies that impact market barriers and the response of the market, the policies were considered in aggregate and estimates were made of market penetration changes due to the policies. Policy-driven changes in energy use in the remaining industrial subsectors (glass, aluminum, agriculture, mining, construction, food, chemicals, metals-based durables, and other manufacturing) were assessed at a more aggregate level considering both historic trends and efficiency potentials identified in recent U.S. and international literature. Combined heat and power opportunities and improvements to motor and drive systems across all industrial subsectors were examined with separate models to estimate economic potential.

The results of these off-line buildings and industrial sector analyses were reinserted into CEF-NEMS using the parameters available in CEF-NEMS that most closely approximate the impact of the policies. In the buildings sector, this was accomplished through the discount rate, buildings and appliance standards, costs and other parameters in CEF-NEMS' buildings modules. In the industrial sector, these included the discount rates, energy intensity, and stock turnover rates. For example, after estimating the impact of an expanded lighting program under the Energy Star Buildings using spreadsheet models based on recent Green Lights experience, the discount rates and lighting standards employed in the CEF-NEMS building sector end-use models were adjusted to yield the same results. While this is something of an art, there is a strong rationale for the adjustment of discount rates in that they are set in the EIA's NEMS model to reflect historical records of consumers' energy purchases (as opposed to being set to the cost of capital to consumers). A policy like Energy Star Buildings alters consumers' purchases by removing market barriers and providing information and is therefore most accurately captured by changes to the implicit discount rates found in NEMS. In fact, in the AEO99 Reference case, the EIA does include an adjustment to discount rates to reflect their interpretation of the existing Green Lights program (EIA 1999). Details on these analyses outside of NEMS can be found in the individual sector chapters of the report and the appendices.

The electricity and transportation sector used CEF-NEMS for all market penetration estimates. Changes to NEMS in the electric sector varied from simple production tax credits for renewables to reduced SO_2 ceilings to represent tighter particulate matter standards, to competitive pricing in all regions to capture deregulation of the sector. For the most part, CEF-NEMS includes distinct parameters capable of representing such policies. For example, the duration of a tax credit is set by an input on the year of expiration. Similarly, a simple parameter for each region dictates the fraction of the electricity generated in the region that is priced competitively in that region (at the margin, as opposed to an average regulated electricity price). In the transportation sector, changes to NEMS included, among other things, a tax credit for high efficiency vehicles represented by changes in the capital cost of the vehicle, accelerated RD&D-driven reductions in the cost of ethanol, higher average miles per gallon reflecting voluntary agreements with vehicle manufacturers regarding fuel economy, and pay-at-the-pump insurance policies effected in NEMS through fuel price increases.

One particularly important policy for all sectors is the increase in R&D funding assumed for both the Moderate and Advanced scenarios. No reliable model exists that can take a policy that increases Federal R&D spending and translate it to future technology cost and performance improvements. A more realistic approach is to use expert judgment, peer-reviewed literature, and sensitivity analysis. The approach used in this study varied between sectors to reflect the differences in sectors. For example, in the electric sector we assumed the initial R&D funding increases would be focused on generating technologies that don't emit significant carbon, while the greater R&D funding of the Advanced scenario would include more improvements to fossil-fired generators. Actual values for future costs, heat rates, etc. were taken from published estimates of possible improvements, as well as from discussions with experts and reviewers and inserted into CEF-NEMS. On the other hand, in the industrial sector with its wide range of technologies, estimates of efficiency improvements were made in consultation with industry for over 100 specific processes in three major energy consuming industries (paper, cement and steel). Much broader assumptions were made for all the less-energy-intensive industries based on the general literature. More sector-specific detail can be found in the individual sector chapters and appendices.

3.3.2 CEF-NEMS

The integrating energy model employed for this study is the CEF-NEMS. The CEF-NEMS model is derived from the version of the National Energy Modeling System (NEMS) developed by the Energy Information Administration (EIA) for the analysis behind its 1999 Annual Energy Outlook (EIA, 1998a). This NEMS model has been developed over the last decade with significant peer review both directly and through the analyses it has been used to produce. The NEMS model is documented both in hardcopy (EIA, 1999 a, b, c) and on the worldwide web at:

http://www.eia.doe.gov/bookshelf/docs.html

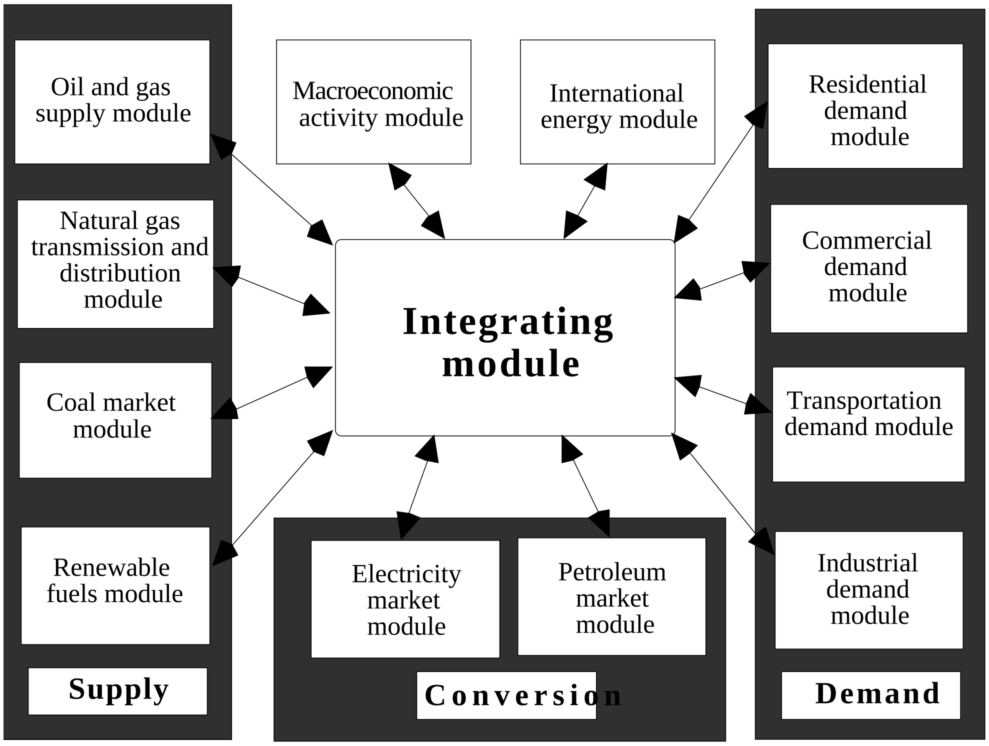
At the EIA’s request, we have appended the acronym CEF (Clean Energy Future) to the front of the name, CEF-NEMS, to call attention to the fact that we have modified many of the inputs to the model in assessing our scenarios. We have not modified the basic structure of the model. Thus much of the description that follows is taken directly from EIA’s description of NEMS (EIA, 1998a).

CEF-NEMS simulates the behavior of U.S. energy markets and their interactions with the U.S. economy. The model achieves a supply/demand balance in the end-use energy demand regions, defined as the nine Census divisions, by solving for the prices of each energy product that will balance the quantities producers are willing to supply with the quantities consumers wish to consume. The system reflects market economics, industry structure, and energy policies and regulations that influence market behavior.

CEF-NEMS represents domestic energy markets by explicitly representing the economic decision making involved in the production, conversion, and consumption of energy products. For example, the penetration of a new or advanced technology for electricity generation is projected only if the technology is deemed to be economic when considering the cost-minimizing mix of fuels.

As shown in Fig. 3.2, CEF-NEMS consists of one module that provides the mechanism to achieve a general market equilibrium among all the other modules; four supply modules (oil and gas, natural gas transmission and distribution, coal, and renewable fuels); two conversion modules (electricity and petroleum refineries); four end-use demand modules (residential commercial, transportation, and industrial); one module to simulate energy/economy interactions (macroeconomic activity); and one module to simulate world oil market (international energy activity). To assess the country’s ability to reduce carbon while still achieving the economic growth of the Reference scenario under the same world oil prices, the macroeconomic and international energy modules were prevented from modifying world oil prices, and economic growth projections in the policy scenarios. Since this analysis focuses on policies and technologies in the electric sector and the end-use sectors, we provide below a brief introduction to how those CEF-NEMS modules work.

Fig. 3.2 Schematic Representation of the CEF-NEMS



Source: Adapted from EIA, 1998b.

Residential Demand Module. The residential sector encompasses residential housing units classified as single-family, multifamily, and mobile homes. Energy consumed in residential buildings is the sum of energy required to provide specific energy services that use selected technologies according to energy efficiency levels of building structures. The Residential Sector Demand Module projects energy demand following a sequence of five steps. The first step is to forecast housing stock. The second step is to simulate the behavior of residential consumers based on the relative importance of life-cycle costs, capital cost, and operating costs of competing technologies. The third step is to forecast appliance stocks using a piecewise linear decay function to retire equipment based on minimum and maximum life expectancies. The fourth step is to forecast changes in shell integrity for existing and new buildings. The fifth step uses price elasticities to capture consumer responses to fuel price changes in estimating the energy consumed by the equipment chosen to meet the demand for energy services (EIA, 1998c).

***Commercial Demand Module*.** The Commercial Sector Demand Module uses economic and engineering relationships to model commercial sector energy demands at the nine Census division level for eleven distinct categories of commercial buildings. Commercial equipment selections are performed for the major fuels of electricity, natural gas, and distillate fuel, for the major services of space heating, space cooling, water heating, ventilation, cooking, refrigeration, and lighting. The market is modeled using a constrained life-cycle cost minimization algorithm that considers commercial sector consumer behavior and time preference premiums. Numerous specialized considerations are incorporated, including the effects of changing building shell efficiencies, the relationship between non-utility generation of electricity and the relative price of fuels, and consumption to provide district services (EIA, 1998d).

Industrial Demand Module. The Industrial Demand Module estimates energy consumption by energy source for 9 manufacturing and 6 non-manufacturing industries. The manufacturing industries are further subdivided into the energy-intensive manufacturing industries and non-energy-intensive manufacturing industries. The energy-intensive manufacturing industries are modeled through the use of a detailed process flow accounting procedure, whereas for the non-energy intensive manufacturing industries unit energy consumption is held constant in the absence of price changes. The model forecasts energy consumption at the four Census region levels and apportions the forecast to the Census division level based on SEDS data (EIA, 1999a).

Transportation Demand Module. The NEMS Transportation Model comprises a series of semi-independent models, which address different aspects of the transportation sector. The primary purpose of this model is to provide mid-term forecasts of transportation energy demand by fuel type including, but not limited to, motor gasoline, distillate, jet fuel, and alternative fuels not commonly associated with transportation. Forecasts are generated through the separate consideration of energy consumption within the various modes of transport, including: private and fleet light-duty vehicles; aircraft; marine, rail, and truck freight; and various modes with minor overall impacts, such as mass transit and recreational boating. This approach is useful in assessing the impacts of policy initiatives, legislative mandates which affect individual modes of travel, and technological developments.

The model also provides forecasts of selected intermediate values, which are generated in order to determine energy consumption. These elements include estimates of passenger travel demand by automobile, air, or mass transit; estimates of the efficiency with which that demand is met; projections of vehicle stocks and the penetration of new technologies; and estimates of the demand for freight transport which are linked to forecasts of industrial output. (EIA, 1999c).

Electric Market Module (EMM). The EMM represents the capacity planning, generation, transmission, and pricing of electricity in the 13 NERC regions, subject to: delivered prices for coal, petroleum products and natural gas, the cost of centralized generation facilities, the cost of capital, and electric load shapes and demand. The submodules consist of load and demand-side management, capacity planning, fuel dispatching, and finance and pricing.

The solution sequence through the submodules for each time period can be viewed as follows (EIA, 1999b):

1. The load and demand-side management submodule processes electricity demand to construct load curves.
2. Given the load curves and fuel and system costs, the electricity capacity planning submodule uses a linear program optimization to project the construction of new plants.
3. Given the load curves, fuel costs, and plants; the electricity fuel dispatch submodule dispatches the available generating units, both utility and non-utility.
4. The electricity finance and pricing submodule calculates total revenue requirements for each utility operation and computes average and marginal-cost based electricity prices.

3.4 ANALYSIS OF CROSS-CUTTING TECHNOLOGIES

There are several technologies that apply to multiple sectors. These include combined heat and power or cogeneration systems, bioenergy, and fuel cells. The use of CEF-NEMS as an integrating model, which considers all sectors simultaneously, simplifies the evaluation of these technologies. However special considerations in their treatment are discussed briefly below.

3.4.1 Bioenergy

There are two principal forms of bioenergy considered by CEF-NEMS. These are biomass power and ethanol from biomass. Biomass power is further disaggregated in CEF-NEMS to include cofiring of coal plants with biomass and biogasification power plants. There is considerable overlap between these different bioenergy forms in terms of the biomass resources they require as feedstock. CEF-NEMS keeps track of all the demands on the biomass resources from these different conversion processes within different sectors (electricity and transportation) and prices the biomass resources accordingly. No additional modifications are required to handle this intersectoral dependency. Biomass gasification is also considered as a source of combined heat and power in industry. This is treated as an off-line analysis (see below) and is not integrated into CEF-NEMS.

3.4.2 Combined Heat and Power

The buildings and industrial end use sectors are currently taking advantage of opportunities to produce electricity and heat on site. These combined heat and power plants are expected to multiply over the next decade as turbine and fuel cell technologies improve. CEF-NEMS has a simplistic representation of the potential for these cogeneration technologies in the industrial sector, as it allows cogeneration to be used only to meet a fixed portion of new steam demand (depending on fuel and electricity costs), additional to demand in the baseyear, as industrial boilers are not retired in the model. Thus for this analysis combined heat and power opportunities in the industrial sector have been assessed using Resource Dynamics Corporation's DISPERSE model[4] (see Appendix A-2).

DISPERSE estimates the achievable economic potential for CHP applications by comparing on-site generation economics with competing grid prices. The model not only determines whether on-site generation is more cost effective, but also which technology and size appears to be the most economic. By permitting retirement of existing boilers (CEF-NEMS does not allow industrial boiler retirements) where economically feasible, the model estimates cogeneration potential for both traditional (where all unit output is used on-site) and non-traditional (where sales of electricity to the grid is permitted) applications of CHP. For each scenario, Resource Dynamics Corporation used the DISPERSE model results for economic potential in estimating industrial CHP production of electricity and steam, as well as the fuel consumption associated with that production.

The DISPERSE results have not been fully integrated into the CEF-NEMS model due to difficulties associated with replicating the results at the industrial subsector and regional level in CEF-NEMS. Instead, an off-line analysis of CHP in industry was conducted in order to estimate the overall impact of expanded CHP capacity on primary energy consumption and carbon dioxide emissions. This analysis was partially integrated with the Moderate and Advanced scenarios in that it uses the resulting estimates of industrial demand for steam and it displaces grid electricity resources that are the marginal resources in each scenario.

The off-line analysis of increased CHP examines three factors to assess impacts on primary energy consumption and carbon dioxide emissions:

- The fuel displaced at electric utilities at the margin,
- The boiler fuel displaced in the industrial sector, and

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[4] Distributed Power Economic Rationale Selection (DISPERSE) model.

- The fuel used by the CHP units.

3.4.3 Fuel Cells

Fuel cells are a technology that cut across sectors both because they can serve as a combined heat and power system as described above and because they can be used either to meet general electric loads or to propel a vehicle. Some of the improvements to stationary fuel cells can also be applied to mobile applications in vehicles, and vice versa. However these different applications of fuel cells require different performance characteristics. For example, a fuel cell as a stationary central power source might be built largely on site, as one stage in a ternary cycle operating at full load for 20 – 30 years with minimal maintenance requirements and substantial power conditioning equipment. On the other hand, a vehicular application would ultimately be mass produced by the millions to operate as a single stage at low (safer) temperatures on a highly cyclical schedule for less than the number of hours in a single year, but with regular maintenance. These differences in operating environments favor different fuel cell technologies in different applications with different costs and performance capabilities. Thus it is extremely difficult to compare the fuel cell costs and performance assumptions used in the electric, transportation, and other end use sectors. For this analysis, the type of fuel cell and its cost and performance were derived by consulting with experts on each individual application.

3.5 *ASSESSMENT OF BENEFITS AND COSTS*

Benefits and costs of the Moderate and Advanced scenarios are measured relative to the BAU Scenario. The different forms of benefits and costs are described below along with a brief statement as to how each has been assessed.

3.5.1 Benefits

Five types of benefits are quantified in this report.

Energy Bill Savings. The reductions in energy use that result from the policies evaluated are captured directly by the CEF-NEMS and sectoral modeling and analysis described above. The reductions in fossil fuel demands exerts a dampening influence on fossil fuel prices[5]. The combination of reduced demands and reduced prices significantly reduces the nation’s energy bill. Such energy bill savings are considered in our calculation of net direct savings below.

Local Air Pollution Benefits. For the electric sector these are estimated in CEF-NEMS. Emissions from the end-use sectors are not estimated by CEF-NEMS and therefore are not included in this report. However, shortly after publication of this report, the EPA is expected to release a study containing an independent analysis of all emissions associated with these scenarios.

Greenhouse Gas Emission Benefits. As stated earlier, the only greenhouse gas emissions analyzed are carbon emissions from fossil fuel use. However a qualitative assessment of the potential to reduce other greenhouse gases is provided in Appendix E-6.

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[5] In the Advanced scenario with its carbon trading system, the price of energy to the consumer will increase due to the carbon value paid by producers to the government for carbon allowances. Inasmuch as the government returns these allowance dollars to the private sector, they can be treated as a transfer payment that does not impact direct benefits or costs (but will most likely have indirect costs as discussed in the following section on “Macroeconomic Costs.”)

National Energy Security and Secure Oil Supplies. Alternative fuels and efficiency improvements, especially in the transportation sector, reduce the demand for oil. Through the integrating mechanism of the CEF-NEMS model we are able to calculate the total U.S. oil demand, domestic supply, and the residual imports required.

Macroeconomic Benefits. Inasmuch as there are large-scale market and organizational failures that prevent consumers and firms from obtaining energy services at least cost, the economy is not on its aggregate production-possibilities frontier. Thus at the aggregate level, a Pareto improvement is available in the economic efficiency of the economy. On the other hand, policies that change relative prices can create at least short-term reductions in measured GDP. See the section below on macroeconomic costs for a more complete discussion on the assessment of macroeconomic impacts.

3.5.2 Costs

There are three distinct forms of costs that we consider in evaluating the scenarios and their policies – incremental technology investment costs, policy implementation and administration costs, and macroeconomic costs.

Incremental Technology Investment Costs. Incremental technology costs refer to the additional technology investment required by consumers and businesses to purchase the more efficient equipment or energy service. Since we compute costs on an annual basis, our incremental technology investment cost in a particular year is the annualized cost of the total investment. Since CEF-NEMS does not explicitly track such investment costs in the end-use sectors, we approximate them by calculating an investment cost per unit energy conserved and multiplying this cost of conserved energy (CCE, in $/kWh or $/MBtu) by the annual energy savings in that year.

For example, policies promoting more efficient residential refrigerators are projected to save 6 billion kWh in 2020 in the Advanced case. The cost of conserved energy for those savings is $0.034/kWh (every kWh saved costs 3.4¢). In addition, the program implementation cost for capturing those savings is $0.006/kWh. The annualized technology cost associated with these savings would be 6 billion kWh times $0.034/kWh, or about $0.2 billion in 2020. Including program costs, total annualized cost for capturing these savings would be 6 billion kWh times ($0.034 + $0.006), or $0.24 billion in 2020 alone.

Calculating the CCE requires a real discount rate and an equipment lifetime. For both the Moderate and Advanced scenarios, we used sector-specific, real discount rates to calculate the CCEs. These discount rates are: 7% for buildings, 15% for industry, and 10% for transportation. For these discount rates, we use the real cost of capital in these sectors because we are trying to measure the actual costs to the investor. As such, these CCE discount rates are lower than the “hurdle rates” that can be implicitly derived from actual investor decisions in these sectors (Meier, 1983, and Train, 1985). Such hurdle rates typically include market barriers and consumer preferences[6]. With these discount rates, efficiency technology CCEs are on the order of 1-5 1997$/MBtu for fuels and 6-10 1997$/MBtu for site electricity depending on the sector and energy end-use. (These CCEs are also used to estimate the economic potential of a technology, but not the market penetration of the technology. Market penetration is projected by reducing the economic potential to account for market barriers, less the impact of the CEF policies on those barriers.)

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[6] Hurdle rates may also include transaction costs. Insofar as transaction costs are actual monetary costs, they could also be included in a CCE calculation.

Policy Implementation and Administrative Costs. Policy implementation costs include the costs of administering the public policies and programs that are modeled in each scenario and the incremental R&D costs. For the purposes of this project, ***administrative costs*** include the following:

- program planning, design, analysis, and evaluation;
- activities designed to reach customers, bring them into the program, and deliver services such as marketing, audits, application processing, and bid reviews;
- inspections and quality control;
- staff recruitment, placement, compensation, development, training, and transportation;
- data collection, reporting, record-keeping, and accounting; and
- overhead costs such as office space and equipment, vehicles, and legal fees.

Preliminary cost increments were developed by estimating the administrative costs and energy savings associated with a range of policies and programs that have been in operation over the past decade or two. Estimates have been compiled to date for 12 policies and programs (see Table 3.2 and Appendix E-1 for details on these individual estimates). These policies and programs span a broad spectrum of interventions including building codes and standards, technical assistance to manufacturers, information on gas mileages, utility-operated demand-side management programs, weatherization assistance, and grants to small businesses for R&D.

The administrative costs associated with these 12 policies and programs show considerable variability. The smallest administrative cost estimates are for DOE's Building Standards and Guidelines Program ($0.052 per MBtu saved), and the largest estimates are for Southern California Edison’s market transformation programs in the residential market ($2.486 per MBtu).

Because of the small sample size, it is not possible to explain the differences across programs. However, it is likely the administrative costs will be greater in the early years of a program and that they might be less for regulatory policies such as codes and standards than for programs that provide a great deal of technical assistance and information outreach.

The average administrative cost for these 12 policies and programs is $0.54 per Mbtu of primary energy saved. This cost was rounded to $0.6/Mbtu and is used as the cost of policy implementation and administration within this CEF study. For end-use sector fuel savings, it is added directly to the incremental technology costs. For electricity savings in the end-use sectors, it is first multiplied by 2.9 to account for the difference between primary energy and delivered electricity.

These estimates of administrative costs are quite consistent with the independent findings of Berry (1991 and 1989). Berry reviewed the expenses incurred by utilities to administer demand-side management programs in the 1980s. Her work appears to provide the only published overview of administrative costs relevant to energy efficiency programs. She estimated that administrative costs are approximately 20% of the incremental technology costs per MBtu of energy saved. Similar proportions result when the administrative cost estimate of $0.54 per MBtu of primary energy saved is used in the Clean Energy Future Study – both in 2010 and 2020, and for both the Moderate and Advanced scenarios.

Net Direct Savings. Net Direct Savings are computed as the energy bill savings minus the sum of the direct costs (annualized incremental technology investment cost plus the program implementation and administration costs). These calculations are explained in detail in Chapter 1.

Macroeconomic Costs: The issue of macroeconomic costs and benefits devolves to almost a philosophical debate as to whether or not there is an "energy efficiency gap" that can be at least partially closed through energy policies i.e., are there cost-effective opportunities to reduce current energy use that are not being pursued because of market failures that can be removed through policy. If one believes that such a gap exists and can be reduced by policy, then the economy is not at its aggregate production-possibilities frontier, and such policies can yield a net benefit to the economy, not a net cost.

It is also true that while an efficiency gap may exist, not all policies examined in this study are directed solely at closing that gap. In particular, the carbon trading policy included in our Advanced scenario through a $50/tonne value on carbon emissions, may close the efficiency gap somewhat, but also has impacts – both short and long term – that do not necessarily move the economy closer to the production possibilities frontier. While we have not modeled these impacts directly, we have reviewed the literature (see Appendix E-4) and found a range of estimates for the GDP impacts of a carbon charge.

We present a host of evidence in Chapter 2 and the end-use sector chapters of this report to buttress our claim that an efficiency gap does exist that can be closed at least in part through policy. However even if one does not accept this evidence, it can be argued that the annualized incremental investment cost driven by the policies of this study (other than the carbon trading system) are overwhelmed by the aggregate total investment in the U.S. economy ($1,364 billion in 1998). Thus even assuming the economy is currently on its production-possibilities frontier, any attempt to estimate the size of the macroeconomic costs associated with these policies must be able to capture changes in second order impacts due to changes in a relatively small portion of the U.S. investment portfolio. Short-term transition costs associated with these second-order effects are even more difficult to model, especially given that most models:

1. capture only energy consumption, not changes in energy services;
2. extrapolate from past trends, missing opportunities for markets and the Federal government to react differently in the future;
3. can not model the substitution of information for energy that many of these policies effect.

Given the above modeling problems, we have estimated macroeconomic costs for only the domestic carbon trading policy, and that is done based largely on the literature. We have also estimated the direct economic impacts of the carbon trading policies on energy consumers and producers. Faced with higher energy prices due to a carbon value, consumers demand less energy. The higher price and reduction in consumption produce a loss in consumer surplus. Similarly, producers sell less and receive (after the carbon value is paid to the government auction) less for their energy, i.e. there is a loss in producer surplus.

Table 3.2 A Review of Administrative Costs for Energy-Efficiency Programs

Policy/Program	Type of Policy/Program
Residential Appliance and Commercial Equipment Program	Regulatory policies—Codes and Standards
Building Standards and Guidelines Program	Regulatory policies—Codes and Standards
Demand-Side Management Programs of the Bonneville Power Administration: Residential	Financing and investment enabling
Demand-Side Management Programs of the Bonneville Power Administration: Commercial	Financing and investment enabling
Weatherization Assistance Program	Financing and investment enabling
Market Transformation Programs of the Southern California Edison: Residential	Financing and investment enabling
Energy Star Programs: buildings and industry	Voluntary, information and technical assistance
Market Transformation Programs of the Southern California Edison: Non-Residential	Financing and investment enabling
Industrial Assessment Centers	Voluntary, information and technical assistance
Demand-Side Management Programs of the Bonneville Power Administration: Industrial	Financing and investment enabling
Energy-Related Inventions Program	Public-private RD&D partnerships
Fuel Economy Guide	Voluntary, information and technical assistance

3.6 REMAINING ANALYSIS NEEDS

As with any study of this magnitude, there are many areas where the analysis could be improved. The sector chapters (chapters 4 – 7) provide recommendations for improved analysis for individual sectors. The discussion that follows focuses on analysis issues that impact all the sectors.

Probably the largest single issue is a more complete treatment and presentation of the uncertainties inherent in any future scenarios. Secondly, the evaluation of the impact of policies that are non-fiscal in nature such as information programs, labeling, and voluntary agreements needs extensive detailed primary data collection and analysis. Other major analysis needs that cut across the sectors of the economy include the need to refine our estimates of the macroeconomic impacts of policies, the need to address non-energy-related greenhouse gas emissions and GHG reduction opportunities, and the need for an expanded time frame with finer geographic disaggregation of the analysis.

3.6.1 Analysis of the Impact of Non-Fiscal Policies

Most of the non-fiscal policies we examined are designed to change a decision-maker’s response to the energy situation confronting him or her. Models like NEMS generally have a built in response function that simulates the decision-maker’s response under a business-as-usual scenario. Thus the common approach to simulating a policy that impacts the decision-maker’s response is to change the parameters of the model’s response function. For example, one might lower the consumer discount rate to reflect increased knowledge of the options available due to an information program. The difficulty in this approach lies in determining how much to change the response function parameters.

We have chosen a less arbitrary, more detailed way of performing the analysis. Instead of changing model parameters, we have surveyed analyses and estimates of the performance of the different types of programs in impacting the decisions of consumers, overcoming market barriers, and thus causing increased penetration of more efficiency systems and technologies. We have applied our judgment to these estimates, and have attempted to be conservative in ascribing results to specific programs[7]. While perhaps more insightful than the simple model parameter change approach, this approach is also uncertain. However, there are ways that the estimates could be improved.

One method is to improve the empirical foundation for linking policies and programs with impacts. Many energy program evaluations have been undertaken – see, for example, the proceedings of the biennial National Energy Program Evaluation Conferences (1999). However, these program evaluations often do not have sufficient rigor for forecasting future impacts. Thus, filling key program evaluation gaps with strong assessments would be very helpful. A second method is to use the collective judgment of a group of knowledgeable individuals, experts in the fields of energy policy and program evaluation. The goal would be to estimate program costs and effectiveness under the assumption of much-expanded programs. Such estimates should represent a range of possible outcomes, reflecting uncertainties inherent in forecasting and modeling These could be derived through workshops or a structured delphi approach.

In assessing the potential effectiveness of expanding existing programs, one needs to consider a variety of influencing factors, most of which evolve over time, confounding the process of developing scenarios and forecasts. These factors include diminishing returns and free riders that would tend to reduce effectiveness over time. They also include learning, free drivers and spillovers, and economies of scale and scope that would all tend to increase effectiveness. These factors need to be better characterized and understood.

There are also difficulties with evaluating the impact of several policies all of which impact the same decision maker. For many of the policies proposed, there is little empirical data on past policies of a similar nature and certainly a lack of data on packages of policies. Such data and analysis of it are needed to better evaluate many of the policies suggested here. At a minimum, a more detailed assessment could reduce any remaining possible overcounting of impacts where multiple programs affect the same consumers.

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[7] In the building sector, CEF-NEMS was run to calculate the behavioral parameters that yielded the results of the independent analyses of the programs. This was done for analytic convenience (i.e., to permit the model to be used for sensitivity studies in the different scenarios). It was, however, not the basis for the estimate of the impacts of policies.

3.6.2 Expanded Technology Representations

Due to time and resource limitations, a number of technologies have not been explicitly considered in this analysis. In the buildings sector, we have not had an opportunity to include all shell measures, fuel cells, district heating and cooling, integrated space and water heating, advanced cooking technologies, nor photovoltaics in commercial buildings. In the transportation sector, we have included only the more promising alternative fuel vehicles. In the electric sector, we have not yet included all distributed generation options, nor new small, gas-cooled nuclear reactors, nor coal-fired generator refurbishments for improved efficiency.

The inclusion of these technologies presents formidable modeling issues in many cases. Our efforts to treat combined heat and power presents a good example of an important research need. The strategy was to perform a highly disaggregate model of combined heat and power (CHP) separate from NEMS and then to incorporate these results into NEMS. Because the assumptions and calculational procedures in NEMS for CHP were so different from those used in the independent analysis, it was impossible to achieve this integration (of a disaggregate analysis with the more aggregate analysis of NEMS). A serious analysis of the differences in the approaches in the two models, combined with an independent analysis of parameters to best characterize CHP, could go a long way toward reducing uncertainty in the role of CHP in different scenarios including the BAU scenario.

Similar modeling efforts are needed for characterizing possible roles of distributed electricity systems. Such modeling is much earlier in development, and will require considerable data and analysis before meaningful linkages can be achieved between disaggregate analyses and the more aggregate analysis in NEMS.

Many of the issues relating to retirement of coal plants and replacement by natural gas at different coal/gas price differentials have been resolved by improvements in the NEMS electricity module. There will likely continue to be important issues in this area that need attention.

In addition to modeling issues, there continues to be a need for improved characterization of technologies on both the demand and supply side for inclusion in the models. While technology analysis is needed in all sectors, the industrial sector needs the most attention. This study is one of the few efforts to evaluate segments of the industrial sector from the “bottom” up (i.e., by assessing energy efficiency technologies for the most energy-intensive sectors. We are encouraged that such analysis does improve the understanding of opportunities for industrial energy analysis at the sectoral level. Nonetheless, this work is in early stages and needs considerably more effort.

3.6.3 Transition Costs and Macroeconomic Impacts of Policies

While we have made the qualitative argument that there are macroeconomic benefits associated with moving closer to the production possibility frontier by closing the “energy efficiency gap,” our quantification of those benefits is limited to the calculation of lower electricity and fuel bills. Similarly our treatment of policies not specifically directed at closing the energy gap is limited to the adoption of costs from the literature for the carbon trading system assumed in the Advanced scenario. Future efforts might include the refinement and use of macroeconomic models in conjunction with NEMS, or similar technology-rich models, to capture these impacts as well as to address equity issues, foreign trade implications, and regional employment implications. Foreign trade implications may require a general broadening of the analysis to an international framework.

3.6.4 Air Pollutants

While it has been our intent to direct this study towards a range of energy and environmental issues, we have not adequately addressed local air pollutant emissions. At this point, we have made estimates of only SO_x and NO_x emissions from the electric sector. Emission estimates for the end-use sectors require substantial technology detail not currently available in CEF-NEMS. It is our understanding that the EIA is modifying NEMS to estimate NO_x emissions in the transportation sector. Still other tools could be used in the future to develop better end-use sector estimates.

3.6.5 Non-Energy Emissions and GHG Reduction Opportunities

This study focuses on reductions in carbon dioxide emissions from the use of energy in the United States. However, 16% of the global warming potential of the gases emitted in 1997 by the United States can be attributed to greenhouse gases other than carbon dioxide. These include methane (9%), nitrous oxide (5%) and halocarbons and other gases (2%). While some of these non-carbon GHG emissions are also associated with energy use, most are emitted by agriculture and industrial processes (see Fig. 2.2). Analysis of these sectors and processes will require a different set of models and expertise. A review of the literature is provided in Appendix E-3.

Additional opportunities for reducing the impact of greenhouse gases include non-energy related carbon sequestration and management, aerosols and other light scattering mechanisms, and others. Reforestation and ocean fertilization to encourage planktonic growth are examples of non-energy-related carbon sequestration. Such opportunities are not included in this study. They need to be further researched and compared with the energy-related options discussed in this report. An assessment of carbon sequestration strategies can be found in a recent report sponsored by DOE's Offices of Science and Fossil Energy (1999).

3.6.6 Time Frame and Geographic Disaggregation

The climate change problem is a long-term problem. It will require continuing attention throughout this new century and beyond. The time frame of this study has been limited to 2020 to focus on near-term policy options to address not only climate change, but also other major energy and environmental issues. Unfortunately such a time frame does not capture the full potential of many of the opportunities identified in this report involving energy efficiency and advanced non-carbon-emitting technologies such as renewable energy. The promise of these technologies will be accentuated in a study that explores impacts beyond the 2020 time frame.

The performance and value of both clean energy and energy efficiency technologies can be highly dependent on the local climate, environment, and economic conditions. Recognition of these local variations is extremely important in assessing the potential of advanced technologies that need these niche market opportunities to develop further. Thus a valuable next step might be to conduct analyses at a finer geographic scale to produce national estimates that reflect such local variations.

3.6.7 Robustness of the Study's Conclusions

The various analysis needs and limitations described in this section do not invalidate the two key conclusions of this study:

- Smart public policies can contribute significantly to meeting the energy-related challenges facing the United States

- The direct economic benefits of these policies can outweigh their costs.

These conclusions are based on results which show overlapping opportunities between technologies competing with each to reduce carbon emissions at least cost. Certainly other opportunities will also arise beyond those which we have considered here. Consequently, the study's conclusions are unlikely to change materially even with improved modeling capability such as the ability to simulate non-fiscal policies, expanded technology representations, and greater geographic disaggregation. The expansive set of sensitivity runs, in conjunction with the substantial body of supporting literature, gives added confidence in the robustness of the conclusions reached by the study.

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