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World Energy Projection System

Model Documentation

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Preface

The World Energy Projection System (WEPS) was developed by the Office of Integrated Analysis and Forecasting within the Energy Information Administration (EIA), the independent statistical and analytical agency of the U.S. Department of Energy. WEPS is an integrated set of personal computer-based spreadsheets containing data compilations, assumption specifications, descriptive analysis procedures, and projection models. The WEPS accounting framework incorporates projections from independently documented models and assumptions about the future energy intensity of economic activity (ratios of total energy consumption divided by gross domestic product [GDP]), and about the rate of incremental energy requirements met by natural gas, coal, and renewable energy sources (hydroelectricity, geothermal, solar, wind, biomass, and other renewable resources). Projections produced by WEPS are published in the annual report, *International Energy Outlook.*

This reports documents the structure and procedures incorporated in the 1998 version of the WEPS model. It has been written to provide an overview of the structure of the system and technical details about the operation of each component of the model for persons who wish to know how WEPS projections are produced by EIA. This report was written to comply with requirements of EIA Standard, 96-01-03 for Model Documentation, effective August 9, 1996.

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1. Introduction

Background

The World Energy Projection System (WEPS) is an accounting framework that incorporates projections from independently documented models and assumptions about the future energy intensity of economic activity (ratios of total energy consumption divided by gross domestic product [GDP]) and about the rate of incremental energy requirements met by natural gas, coal, and hydroelectricity and other renewable sources to produce projections of world energy consumption published annually by the Energy Information Administration (EIA) in the *International Energy Outlook* (*IEO*). Two independently documented models, the International Energy Module (IEM)—a module of the National Energy Modeling System (NEMS)—and the International Nuclear Model, PC Version (PC-INM) provide projections of oil and nuclear power consumption, respectively, which are incorporated into the WEPS model and published in the *IEO*. IEM also provides the *IEO*'s regional projections of oil production and oil productive capacity.

Nuclear capacity projections and world coal trade flows are also produced by independently documented models and appear in the *IEO*, although they are not, per se, linked to WEPS. Nuclear capacity projections are developed using two methods: projections for the reference case and low economic growth case projections are developed based upon analysts' knowledge of the nuclear programs in different countries; the high economic growth case is generated by the World Integrated Nuclear Evaluation System (WINES)—a demand-driven model. The NEMS Coal Export Submodule (CES) is used to derive flows in international coal trade.

WEPS is an integrated set of personal-computer-based spreadsheets containing data compilations, assumption specifications, descriptive analysis procedures, and projection models. WEPS provides projections disaggregated by 7 individual countries and 9 regions. WEPS projects total energy consumption by energy source, net electricity consumption, and carbon emissions. For both historical data and projections, WEPS provides analytical computations of percentages of energy consumption attributed to each primary energy source, total energy consumption per dollar of GDP, per capita energy consumption, and an energy/GDP index.

WEPS is maintained by the Energy Information Administration, Office of Integrated Analysis and Forecasting, Energy Demand and Integration Division. This report documents the 1998 version of WEPS.

Purpose

WEPS was developed by the Energy Information Administration to provide a consistent, integrated, economical, and flexible accounting framework for analyzing and projecting trends in

world energy markets. WEPS provides historical data and projections of energy consumption across the range of primary energy sources; coverage of major countries and regions worldwide; and projections in common time framework: 2000, 2005, 2010, 2015, and 2020. Tables are produced in a format required for the annual publication of the *International Energy Outlook*.

This documentation report provides a general overview of the WEPS system, describes the underlying database, provides technical descriptions of the component ,models, diagrams the system and subsystem flows, describes the equations, and provides definitions and sources of all variables used in the system. The documentation is provided to enable users of EIA projections generated by WEPS to understand the underlying procedures used and to replicate the model projections.

Report Organization

This report is divided into three chapters. Chapter 1 is the Introduction. Chapter 2 provides an overview of WEPS in terms of structure, subsystems, flow, and scope. Chapter 3 provides detailed technical descriptions for each of the subsystem models. Also contained in this report are four appendices: system abstract, variable definition listings, location of variables, and location of equations.

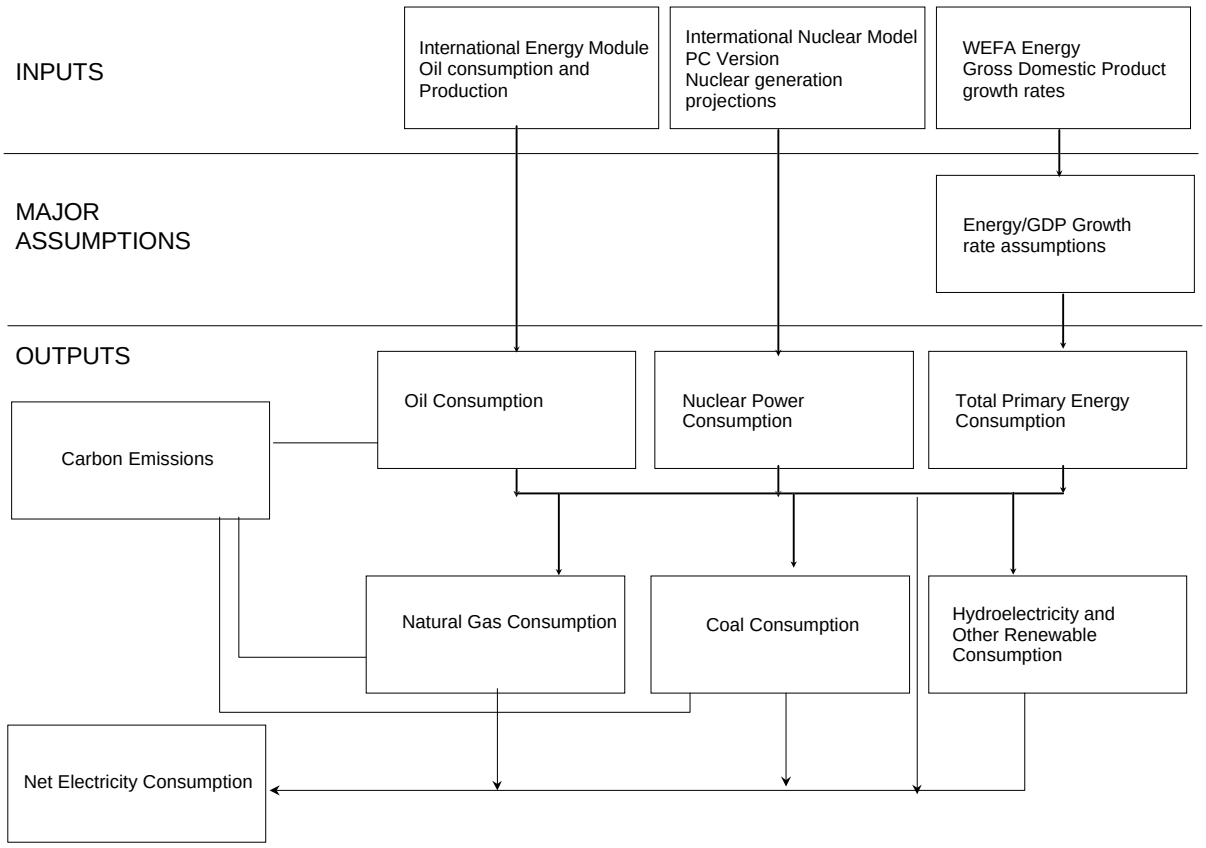
2. System Overview

The projections of world energy consumption published annually by the EIA in the *International Energy Outlook* (*IEO*) are derived from the World Energy Projection System (WEPS). WEPS is an integrated set of personal-computer-based spreadsheets containing data compilations, assumption specifications, descriptive analysis procedures, and projection models. The WEPS accounting framework incorporates projections from independently documented models and assumptions about the future energy intensity of economic activity (ratios of total energy consumption divided by gross domestic product [GDP]) and about the rate of incremental energy requirements met by natural gas, coal, and renewable energy sources (hydroelectricity, geothermal, wind, solar, biomass, and other renewable sources). The structure of the WEPS model is depicted in Figure 1.

WEPS provides projections of total world primary energy consumption, as well as projections of energy consumption by primary energy type (oil, natural gas, coal, nuclear, and hydroelectricity and other renewable resources), and projections of net electricity consumption. Carbon emissions resulting from fossil fuel use are derived from the energy consumption projections. All projections are computed in 5-year intervals through the year 2020. For both historical series and projection series, WEPS provides analytical computations of energy intensity and energy elasticity (the percent change in energy consumption per percent change in GDP).

Projections of world oil consumption are provided to WEPS from EIA's International Energy Module, which is a submodule of the National Energy Modeling System (NEMS). Projections of world nuclear consumption are derived from nuclear power electricity generation projections from EIA's International Nuclear Model (INM), PC Version (PC-INM). All U.S. projections are input from EIA's *Annual Energy Outlook* (*AEO*). Nuclear capacity projections—which do not directly feed into the WEPS system, but which are published in the *International Energy Outlook*—are developed using two methods: the reference case projections are based on analysts' knowledge of the nuclear programs in different countries; the high growth case is generated by the demand-driven model, World Integrated Nuclear Evaluation System (WINES). Finally, the NEMS Coal Export Submodule (CES) is used to derive flows in international coal trade and is used as a way to gauge regional projections of coal consumption.

Figure 1. World Energy Projection System Process Flow Diagram



Regional Coverage

WEPS projections are provided for regions and selected countries. Projections are made for seven individual countries, four of which—United States, Canada, Mexico, and Japan—are part of the designation "industrialized countries." Individual country projections are also made for China, India, and Brazil, all of which are considered "developing countries." Beyond these individual countries, the rest of the world is divided into regions. Industrialized regions include North America (Canada, Mexico, and the United States), Western Europe, and Pacific (Japan and Australasia [Australia, New Zealand, and the U.S. Territories]).

Developing regions include developing Asia (China, India, and other Asia), Middle East, Africa, and Central and South America (Brazil and other Latin America). The transitional economies consisting of the countries in Eastern Europe (EE) and the former Soviet Union (FSU) are considered as a separate country grouping, neither industrialized nor developing.

The WEPS model provides total energy consumption and energy consumption by primary energy source for each of these regions. Oil production and oil productive capacities are derived via the International Energy Module and the "DESTINY" International Energy Forecast Software.[1] Oil productive capacity is published for the Organization of Petroleum Exporting Country's (OPEC) Persian Gulf (Iran, Iraq, Kuwait, Qatar, Saudi Arabia, and the United Arab Emirates); other OPEC (Algeria, Gabon, Indonesia, Libya, Nigeria, and Venezuela); non-OPEC industrialized (United States, Canada, Mexico, Australia, North Sea, and Other); Eurasia (China, FSU, and EE); and other Non-OPEC (Central & South America, Middle East, Africa, and Asia). Oil production is derived for the aggregate Persian Gulf OPEC and other OPEC, United States, Canada, Mexico, Western Europe, other industrialized, China, FSU, EE, non-OPEC Central and South America, non-OPEC Pacific Rim, and other non-OPEC.

Regional designations for the WEPS model are somewhat fluid, given the continual changing emphasis on energy demand in different parts of the world, as well as the inevitable political and economic shifts. For instance, WEPS could no longer maintain the designation, Organization for Economic Cooperation and Development (OECD). This is largely because of the difficulties in obtaining historical and economic energy consumption data for the OECD members added in 1995 and 1996[2]. Further, the ramifications of the economic collapse of the EE/FSU made it difficult to consider the transitional economies of this region together with those of the emerging economies, particularly Asia. WEPS, therefore, changed from a OECD and non-OECD breakdown to the industrial, developing, EE/FSU grouping used in the 1997 report. The WEPS user should expect the regional designations to change further in the years to come.

As of 1998, the WEPS model regional designations are as follows:

Industrialized Countries: Australia, Austria, Belgium, Canada, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Japan, Luxembourg, Mexico, the Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, the United Kingdom, and the United States.

Eastern Europe: Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Czech Republic, Hungary, Macedonia, Poland, Romania, Serbia and Montenegro, Slovakia, and Slovenia.

Former Soviet Union: The Baltic States of Estonia, Latvia, and Lithuania, as well as Armenia, Azerbaijan, Belarus, Georgia, Kazakhstan, Kyrgyzstan, Moldova, Russia, Tajikistan, Turkmenistan, Ukraine, and Uzbekistan.

Developing Asia: China, India, and other developing Asia. Other developing Asia includes

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[1]Petroconsultants, 1997, Dallas, Texas.

[2]In particular, there are no historical data that distinguish energy consumption for the Czech Republic (which was formed when Czechoslovakia split into the Czech Republic and Slovakia in 1994) from that for Slovakia. As a result, economic growth rates are not currently available for the Czech Republic alone.

Afghanistan, Bangladesh, Bhutan, Brunei, Cambodia (Kampuchea), Fiji, French Polynesia, Hong Kong, Indonesia, Kiribatia, Laos, Malaysia, Macau, Maldives, Mongolia, Myanmar (Burma), Nauru, Nepal, New Caledonia, Niue, North Korea, Pakistan, Papua New Guinea, Philippines, Samoa, Singapore, Solomon Islands, South Korea, Sri Lanka, Taiwan, Thailand, Tonga, Vanuatu, and Vietnam.

Middle East: Bahrain, Cyprus, Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia, Syria, the United Arab Emirates, and Yemen.

Africa: Algeria, Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Cape Verde, Central African Republic, Chad, Comoros, Congo (Brazzaville), Congo (Kinshasa— formerly Zaire), Djibouti, Egypt, Equatorial Guinea, Eritrea, Ethiopia, Gabon, Gambia, Ghana, Guinea, Guinea-Bissau, Ivory Coast, Kenya, Lesotho, Liberia, Libya, Madagascar, Malawi, Mali, Mauritania, Mauritius, Morocco, Mozambique, Namibia, Niger, Nigeria, Reunion, Rwanda, Sao Tome and Principe, Senegal, Seychelles, Sierra Leone, Somalia, South Africa, St. Helena, Sudan, Swaziland, Tanzania, Togo, Tunisia, Uganda, Western Sahara, Zambia, and Zimbabwe.

Central and South America: Brazil and other Central and South America. Other Central and South America includes: Antarctica, Antigua and Barbuda, Argentina, Aruba, Bahama Islands, Barbados, Belize, Bolivia, British Virgin Islands, Cayman Islands, Chile, Colombia, Costa Rica, Cuba, Dominica, Dominican Republic, Ecuador, El Salvador, Falkland Islands, French Guiana, Grenada, Guadeloupe, Guatemala, Guyana, Haiti, Honduras, Jamaica, Martinique, Montserrat, Netherlands Antilles, Nicaragua, Panama Republic, Paraguay, Peru, St. Kitts-Nevis, St. Lucia, St. Vincent/Grenadines, Suriname, Trinidad and Tobago, Uruguay, and Venezuela.

In addition, the *International Energy Outlook* includes frequent references to additional country groupings, which include:

G-7 Countries: Canada, France, Germany, Italy, Japan, the United Kingdom, and the United States.

Organization of Petroleum Exporting Countries (OPEC): Algeria, Gabon, Indonesia, Iran, Iraq, Kuwait, Libya, Nigeria, Qatar, Saudi Arabia, the United Arab Emirates, and Venezuela.

Pacific Rim Developing Countries: Hong Kong, Indonesia, Malaysia, Philippines, Singapore, South Korea, Taiwan, and Thailand.

Persian Gulf: Bahrain, Iran, Iraq, Kuwait, Qatar, Saudi Arabia, and the United Arab Emirates.

Organization for Economic Cooperation and Development (OECD): Australia, Austria, Belgium, Canada, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Luxembourg, Mexico, the Netherlands, New Zealand, Norway, Poland, South Korea, Spain, Sweden, Switzerland, Turkey, the United Kingdom, and the United

States.

Eurasia: China, former Soviet Union, and Eastern Europe.

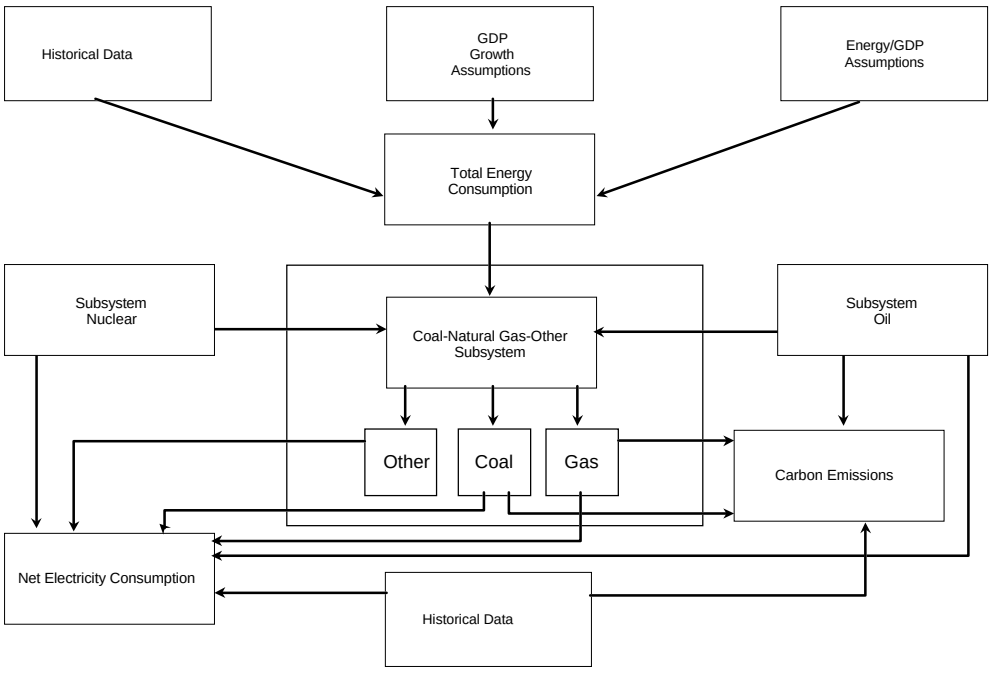
Annex I Countries: Australia, Austria, Belarus, Belgium, Bulgaria, Canada, Croatia, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Latvia, Lithuania, Luxembourg, the Netherlands, New Zealand, Norway, Poland, Portugal, Romania, Russia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, the Ukraine, the United Kingdom, and the United States.

Structure

WEPS is an accounting framework that incorporates a set of models and related assumptions (Figure 1). This section provides an overview of each of the major components of WEPS in terms of projected output, data sources, and projection methods. Detailed documentation of the equations and solution procedures used by individual components of WEPS are contained in Chapter 3.

Figure 2 depicts the general WEPS system interaction used to project world energy consumption. There are five major elements of this system: (1) project total energy consumption, (2) project

Figure 2. World Energy Consumption System Interaction



GDP = Gross Domestic Product

and (5) derive energy consumption by fuel type, (3) derive high and low economic growth scenarios, (4) project net electricity consumption and the fuels consumed for the purpose of electricity generation, world carbon emissions by fossil fuel (i.e., oil, natural gas, and coal).

Total Energy Consumption

Processing begins by computing a reference case total energy consumption projection for each country or region. All projections are computed in 5-year intervals through the year 2020. Total energy projections are products of an assumed GDP growth rate, an assumed energy consumption per GDP growth elasticity, and total energy consumption for the prior year.

In the first instance, the prior year consumption is based upon historical data. Subsequent calculations are based upon the projected prior year energy consumption amount. The model accommodates individualized GDP growth rate and elasticity assumptions for each year. GDP growth rates are based upon rates obtained from the WEFA Group's report, *World Economic Outlook: 20-Year Extension*. Energy consumption per GDP growth elasticity assumptions are developed by EIA analysts.

Energy Consumption by Primary Energy Type

Given total energy consumption, the next step—as depicted in Figure 2—is to calculate energy consumption by fuel type (oil, natural gas, coal, nuclear, and hydroelectricity and other renewable sources). This calculation uses three subsystems: oil subsystem, nuclear subsystem, and the coal-natural gas-other subsystem. The oil and nuclear subsystems utilize exogenous data and models to project oil and nuclear energy consumption. The coal-natural gas-other subsystem projects consumption of natural gas, coal, and hydroelectricity and other renewables.

Projections of oil consumption and production, which comprise the oil subsystem, are provided from the International Energy Module (IEM), part of the National Energy Modeling System (NEMS). IEM is a recursive model of world petroleum supply and demand by region derived from EIA's Oil Market Simulation Model (OMS-PC) with enhanced detail on U.S. market conditions from the NEMS Petroleum Market Module (PMM). The model determines Petroleum Administration for Defense (PAD) district-level import supply schedules by refined product type and crude oil grade consistent with estimated world oil price. IEM outputs include forecasted world oil price, OPEC and non-OPEC production, and OPEC oil production and capacity utilization, as well as worldwide regional oil consumption. IEM generates low world oil price and high world oil price scenarios for the oil production forecasts. WEPS generates high and low economic growth scenarios for the oil consumption forecasts, as described below.

The International Nuclear Model (INM), PC version (INM-PC) is the nuclear subsystem of the WEPS model and provides reference case nuclear generation forecasts from which nuclear consumption is derived by region for WEPS. INM-PC is a deterministic model used to project domestic and international nuclear energy requirements. INM-PC projects aggregate spent fuel discharges, fuel cycle requirements, on-line and year-end capacities, and electricity generation for

domestic and foreign nuclear reactors on an annual basis, using a simple accounting technique. The model can be used to produce projections for any country in the world for any specified time period. Currently eight different country groups are projected through the year 2015. To produce the forecasts, EIA develops a set of operational assumptions for capacity factors, full power days, reactor size, and reload quantities. These assumptions are derived statistically from historical operating data and from utilities' projected fuel management schemes and are incorporated into fuel management plans. Estimates of nuclear fuel cycle trends are determined by surveying utilities, fuel vendors, and other industry experts. WEPS derives high and low economic growth scenarios for nuclear consumption, which are discussed below.

The coal-natural gas-other subsystem, calculates the amount of the change in total energy consumption not assumed by oil and nuclear energy consumption. In this subsystem, the model allocates any remaining change in total consumption from one period to the next to coal, natural gas, and hydroelectricity and other renewables based upon assumed shares for each country or region and each forecast year. The allocation shares are based on examination of historical data in WEPS and consideration of exogenous information. The coal shares are reviewed for consistency with assumption and projections from the Coal Export Submodule, a submodule of the NEMS model. Natural gas and hydroelectricity and other renewables shares are reviewed for consistency with projections from other forecasting associations (such as the International Energy Agency's *World Energy Outlook* reports and DRI/McGraw-Hill's *World Energy Service* outlooks). Total coal, natural gas, and renewable consumption equals previous year consumption of each fuel, plus the change in consumption allocated to each.

High and Low Economic Growth Cases

Long-term projections of energy consumption are subject to substantial uncertainties. Two key issues for energy consumption projections relate to (1) consequences of alternative paths of economic growth and (2) consequences of alternative paths of energy use relative to income growth. WEPS forecasts include a baseline set of assumptions for these variables to provide a reference case. To depict a range of uncertainty, two additional cases were developed, with higher and lower economic growth rates relative to those in the reference case.

There have been substantial differences in economic growth rates both within and between regions over time. For developing nations, in particular, unexpected outcomes have played a major role in national or regional development in the past and are likely to do so in the future. The more mature industrialized economies grow more slowly and show less variation than those of the developing nations and the EE/FSU, but their economic growth is also subject to uncertainty.

For the high and low economic growth cases, different assumptions are made about the range of possible economic growth rates for developing and industrialized nations, reflecting the greater uncertainty inherent in attempts to forecast economic growth in developing economies. The same pattern of change in energy intensity relative to change in GDP (discussed below) is assumed for the high and low growth cases as for the reference case. For industrialized countries, increments of +1.0 and -1.0 percentage points, respectively, are added to the reference case growth rates to

generate the high and low growth cases. For nonindustrialized countries and/or regions—apart from China and EE/FSU—increments of +1.5 and -1.5 percentage points are used to generate the high and low growth cases.

China and the EE/FSU countries are special cases with regard to prospects for future economic growth. China has experienced quite high economic growth in the past few years, and the EE/FSU region has suffered a severe economic downturn. For both regions, the opportunity for a substantial change in growth exists: China has the potential for a larger decline in growth rate given its currently high rate, and there are prospects for a substantial increase in the rate of growth for EE/FSU nations should their current political and institutional problems be moderated sufficiently for the recovery of a considerable industrial base. Reflecting these uncertainties, -3 percentage points are added to China's growth rate for the low economic growth case and +1.5 for the high case; and +3.0 percentage points are added to the EE/FSU growth rate for the high economic growth case and -1.5 for the low case.

Having determined the ranges of suitable economic growth in the high and low economic growth cases, the WEPS model is rerun with revised growth rates to determine a total energy consumption outlook in each case. Each fuel's share of total energy consumption is held constant from the reference case projections, and these shares are applied to the totals in the growth cases to obtain by-fuel projections under high and low economic growth.

Net Electricity Consumption and Energy Used to Generate Electricity

Net electricity consumption is computed by applying assumptions about the future share of energy consumption attributable to electric power. Similarly, to compute projections of energy consumed by electric utilities for electricity generation by fuel, the share of each fuel consumed in the electric utility sector is applied to projections of energy consumption of primary energy by source.

Once the reference and high and low economic growth cases for total energy consumption, as well as primary energy consumption by fuel have been generated, electricity consumption and fuels consumed for the purpose of electricity generation may be computed. The electricity share of total energy consumed, historical and projected, is determined for each of the three scenarios.

The share of each of the fossil fuels (oil, natural gas, and coal) consumed at the electric utility sector is also computed. WEPS assumes that all nuclear power and hydroelectricity and other renewable resources are consumed at the electric utility.

World Carbon Emissions by Fossil Fuel

World carbon emissions are derived according to the projected consumption of each fossil fuel (oil, natural gas, and coal) over the forecast period. Carbon emissions coefficients (million metric tons of carbon per quadrillion British thermal unit [Btu]) are computed for each of the fossil fuels

(and—for oil—by country and region) and then multiplied to projections of oil, natural gas, and coal in the WEPS reference case, as well as the low and high economic growth cases. The final carbon emissions projections are smoothed according to historical estimates produced by the Office of Energy Markets and End Use (published in the *Annual Energy Review*, DOE/EIA-0384, beginning in 1997[3]) to obtain a consistent time series.

There is some variation in the methods used to derive carbon coefficients between the fuels. The carbon emissions coefficient for coal was derived using factors presented in the feature article, "Carbon Dioxide Emission Factors for Coal," by B. D. Hong and E. R. Slatick which appeared in the EIA report, *Quarterly Coal Report January-March 1994*, DOE/EIA-0121(94/1Q), page 4. These coefficients break out the emissions attributed to coal by type (i.e., anthracite—27.85 metric tons of carbon per billion Btu, bituminous—25.12, and lignite—26.35). The coefficients are applied to total world coal production statistics from EIA's *International Energy Annual*, DOE/EIA-0219. The resulting single carbon coefficient (25.61) is applied to coal consumption projections across all WEPS countries and regions.

Coefficients for natural gas and oil were derived from coefficients which appear in the EIA annual report *Emissions of Greenhouse Gases in the United States*, DOE/EIA-0573, (Appendix B, Table B1, page 98, in the 1995 edition of the report).

The oil coefficients are available from the *Emissions* report according to petroleum product and so these coefficients are applied to the latest available historical year's world apparent consumption refined petroleum products data from the EIA report, *International Energy Annual*, DOE/EIA-0219 (for instance, in the 1995 version of the report, Table 3.5, pages 55-57). Oil carbon coefficients are computed by taking a weighted average of the consumed petroleum products by country or region. The resulting coefficients appear in Table 1.

A single natural gas coefficient was derived as a weighted average of world historical dry natural gas production (14.47 million metric tons of carbon per quadrillion Btu) and flared gas data (14.92 million metric tons of carbon per quadrillion Btu) which appear in the EIA report, *International Energy Annual, DOE/EIA-0219*. This coefficient is applied across all countries and regions in WEPS to obtain the emissions resulting from natural gas consumption.

[3]That is, EIA, *Annual Energy Review 1996*, DOE/EIA-0384(96) (Washington, DC, July 1997).

Table 1. Region Carbon Coefficients for Oil Consumption, by Country/Region, 1995-2020
(Million Metric Tons of Carbon per Quadrillion Btu)

Country/Region	Coefficients
United States	19.557196
Canada	19.597134
Mexico	19.965900
Japan	19.934316
United Kingdom	19.779523
France	19.913947
Germany	20.035206
Italy	20.166449
Netherlands	20.236424
Other Western Europe	19.988198
Australasia	19.971632
Former Soviet Union	20.214735
Eastern Europe	20.290855
Developing Asia	20.146319
China	20.180417
India	19.974443
Middle East	20.110996
Africa	20.048848
Central and South America	19.844133
Brazil	19.873847

Source: Derived from Energy Information Administration, *Emissions of Greenhouse Gases in the United States 1995*, DOE/EIA-0573(95) (Washington, DC, October 1996) and EIA, *International Energy Annual 1995*, DOE/EIA-0219(95) (Washington, DC, December 1996).

Sources

The WEPS spreadsheet files are revised annually. Data and estimates are taken from a variety of sources. The most frequently used sources are:

1. Energy Information Administration, *Annual Energy Outlook*, DOE/EIA-0383.
2. Energy Information Administration, *International Energy Annual*, DOE/EIA-0219.
3. International Energy Agency, *Energy Statistics and Balances of Non-OECD Countries*.
4. International Energy Agency, *Energy Statistics of OECD Countries*.
5. International Energy Agency, *Energy Balances of OECD Countries*.
6. International Energy Agency, *Coal Information*.
7. International Energy Agency, *Electricity Information.*
8. WEFA Group, *World Economic Outlook: 20-Year Extension.*

9. WEFA Group, *World Economic Outlook, Volume 1*.

10. WEFA Group, *Asia Economic Outlook*.

11. Energy Information Administration, *Nuclear Power Generation and Fuel Cycle Report.*

12. Energy Information Administration, *Annual Energy Review.*

13. Energy Information Administration, *International Petroleum Statistics Report.*

14. PlanEcon, *Energy Outlook for Eastern Europe and the Former Soviet Republics*.

15. PlanEcon, *Review and Outlook for Eastern Europe and the Former Soviet Republics.*

16. United Nations, *World Population Prospects*.

17. International Energy Agency, *World Energy Statistics and Balances, 1971-1987* (Paris, France, 1989).

3. Technical Description

Overview

This chapter provides detailed descriptions of the data sources and computations used to produce each of the World Energy Projection System (WEPS) outputs. The purpose of the chapter is to provide sufficient information for a third party economic analyst to replicate WEPS projections. This chapter is organized as follows: total energy consumption subsystem, oil subsystem, nuclear subsystem, coal-natural gas-other subsystem, carbon emissions subsystem, and the electricity module. Each of these units is discussed separately under the major component heading.

Total Energy Consumption Subsystem

The components of the total energy subsystem are displayed in Figure 3. The estimated reference case value for total energy consumption in quadrillion Btu (TOTQUAD) is computed in five-year intervals over the 2000-2020 time period for each country and region represented in WEPS, by the equation:

$$TOTQUAD_t = TOTQUAD_{(t-5)} * (((GDPGR_t * ELAST_t)/100)+1)^5 \quad (1)$$

where GDPGR is the average annual economic growth rate measured by gross domestic product (GDP); ELAST is the ratio that determines the energy growth rate given the GDP growth rate, and t refers to a given year.

$TOTQUAD_{1995}$ represents the historical data for each country and region, computed as the sum of oil, natural gas, coal, nuclear, and hydroelectricity and other renewable consumption data, all expressed in quadrillion Btu. To determine total consumption for the first projection year, 2000, the formula applied would be:

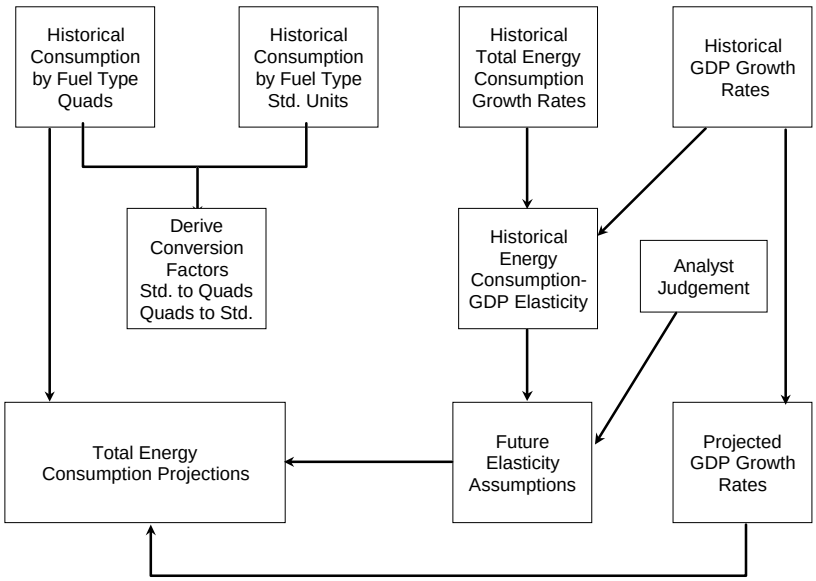
$$TOTQUAD_{2000} = TOTQUAD_{1995} * (((GDPGR_{2000} * ELAST_{2000})/100+1)^5 \quad (2)$$

The historical data are entered into WEPS as exogenous data from the Energy Information Administration, *International Energy Annual*.

The country- and region-specific five-year average annual growth rates for domestic product, GDPGR, for 2000 through 2020 are derived from the WEFA Group *World Economic Outlook* publications. The system also incorporates 1970 to 1995 historical data for GDPGR from the WEFA Group.

The energy elasticities are defined as the percent change in energy consumption per percent change in GDP. Estimates for these elasticities are developed by EIA staff and entered for the 2000 to 2020 time period. The elasticity assumptions are based upon historical elasticity trends and expectations about future improvements in energy intensity, among other things.

Figure 3. Total Energy Consumption Subsystem



GDP = Gross Domestic Product
Quads = Quadrillion Btu
Std. = Standard Physical Units

Oil Subsystem

WEPS provides projections of energy consumption for oil, natural gas, coal, nuclear, and hydroelectricity and other renewable sources by country and region for the 2000 to 2020 forecast horizon. Oil and nuclear consumption are computed by models independent of WEPS. Natural gas, coal, and hydroelectricity and other renewables are computed by the coal-natural gas- other allocation subsystem based on projected values of total, oil, and nuclear consumption.

Oil consumption projections are provided to WEPS by the exogenous International Energy Module, a module of the National Energy Modeling System. EIA's modeling of the near- to mid-term world oil market depends on two key assumptions: (1) oil is the marginal fuel and (2) the Organization of Petroleum Exporting Countries (OPEC) produces the marginal supply at prices that tend to inhibit the market penetration of new technologies, particularly technologies producing synthetic fuels. Under these assumptions, world oil prices are computed to provide a balance of supply and demand for crude oil in the international market as a function of OPEC production decisions, supply of non-OPEC oil, and international demand for oil, which depends upon worldwide economic growth. Under the assumption that oil is the marginal fuel, competition between oil and other fuels can be ignored, because switching between fuels is assumed to be too

small to affect the world oil price. The second assumption means that the price of oil is not allowed to go so high as to induce the market penetration of new technology that would reduce the demand for oil sufficiently to produce substantial downward pressure on its price. U.S. import supply curves for several qualities of crude oils are generated as a function of the world oil price, production sources, transportation rates, and the utilization and/or expansion of worldwide refining capacity.

WEPS receives the reference case international oil consumption projections for 2000 to 2020 in standard units (million barrels per day). These units are converted to annual quadrillion Btu's by the transformation:

$$QUAD_{t,\,oil} = STD_{t,\,oil} * (QUAD_{1995,\,oil} / STD_{1995,\,oil}) \quad (3)$$

where $QUAD_{t,\,oil}$ represents consumption of oil in quadrillion Btu in forecast year "t" and $QUAD_{1995,\,oil}$ represents oil consumption in quadrillion Btu for the latest available historical year, 1995. Similarly, $STD_{t,\,oil}$ represents oil consumption in million barrels per day in forecast year "t" and $STD_{1995,\,oil}$ represents oil consumption in million barrels per day for 1995. This conversion is applied across all countries and regions of the WEPS model. Historical values between 1980 and 1995 are provided in both standard units and quadrillion Btu from the EIA, *International Energy Annual*.

Nuclear Energy Subsystem

The International Nuclear Model (INM), PC version (INM-PC) is the nuclear subsystem of the WEPS model and provides reference case nuclear generation forecasts from which nuclear consumption is derived by region for WEPS. INM-PC is a deterministic model used to project domestic and international nuclear energy requirements. INM-PC projects aggregate spent fuel discharges, fuel cycle requirements, on-line and year-end capacities, and electricity generation for domestic and foreign nuclear reactors on an annual basis, using a simple accounting technique. The model can be used to produce projections for any country in the world for any specified time period. Currently eight different country groups are projected through the year 2015. To produce the forecasts, EIA develops a set of operational assumptions for capacity factors, full power days, reactor size, and reload quantities. These assumptions are derived statistically from historical operating data and from utilities' projected fuel management schemes and are incorporated into fuel management plans. Estimates of nuclear fuel cycle trends are determined by surveying utilities, fuel vendors, and other industry experts. WEPS derives high and low economic growth scenarios for nuclear consumption, which are discussed below.

Annual nuclear consumption projections between 2000 and 2020 are delivered in standard units (billion kilowatthours) for each country that has or expects to develop a nuclear power program over the 20 year time horizon. The by-country projections are aggregated, where necessary, to match WEPS regions. The projections are then converted from standard units into quadrillion Btu, similarly to the oil subsystem. That is,

$$QUAD_{t,\ nuclear} = STD_{t,\ nuclear} * (QUAD_{1995,\ nuclear} / STD_{1995,\ nuclear}) \quad (4)$$

where $QUAD_{t,\ nuclear}$ represents consumption of nuclear in quadrillion Btu in forecast year "t" and $QUAD_{1995,\ nuclear}$ represents nuclear consumption in quadrillion Btu for the latest available historical year, 1995. Similarly, $STD_{t,\ nuclear}$ represents nuclear consumption in billion kilowatthours in forecast year "t" and $STD_{1995,\ nuclear}$ represents nuclear consumption in billion kilowatthours for 1995. This conversion is applied across all countries and regions of the WEPS model. Historical values from 1980 through 1995 are provided in both standard units and quadrillion Btu from the EIA, *International Energy Annual*.

Coal-Natural Gas-Other Allocation Subsystem

WEPS projects annual consumption of coal, natural gas, and hydroelectricity and other renewable sources ("other") in 5-year increments between 2000 and 2020. The procedure used to accomplish this is one that combines historical data with assumed allocation shares of the change in total energy after changes in the consumption of oil and nuclear have been subtracted. The structure of this subsystem is shown in Figure 4. Separate consumption amounts of coal, natural gas, and "other " for each forecast year and every country and region represented in WEPS are determined by the equation:

$$QUAD_{t,\ i} = QUAD_{t-5,\ i} + RESCHG_t * SHARE_{t,\ i} / 100 \quad (5)$$

The initial value for year, t-5, is the exogenous historical data for each primary energy type. The subscript, i, denotes successively: coal, natural gas, and "other." The variable, $SHARE_{t,\ i}$ is an exogenously determined assumption regarding the percent of energy type i (coal, gas, or "other") allocated from the residual growth of total energy consumption (RESCHG). The change in energy consumption for each country or region is defined as:

$$RESCHG_t = TOTQUAD_t - TOTQUAD_{t-5} - (QUAD_{t,\ oil} - QUAD_{t-5,\ oil}) - (QUAD_{t,\ nuclear} - QUAD_{t-5,\ nuclear}) \quad (6)$$

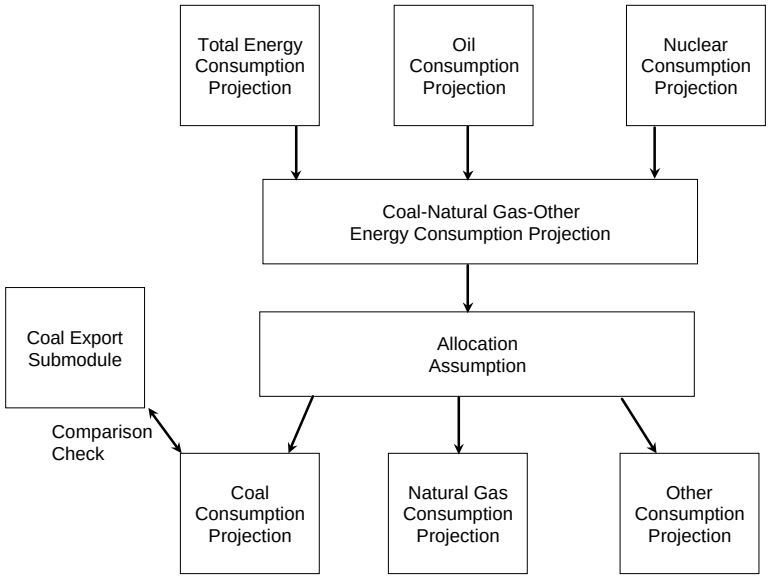
for each country or region represented in the WEPS model.

Projected energy consumption for coal, natural gas, and "other" is then computed as:

$$QUAD_{t,\ i} = QUAD_{t-5,\ i} + RESCHG_t * (SHARE_{t,\ i}/100) \quad (7)$$

To obtain standard physical units from each of the coal and natural gas ("other" is only expressed

Figure 4. Coal-Natural Gas-Other Allocation Subsystem



in quadrillion Btu) estimates, the following translation is applied:

$$STD_{t,i} = QUAD_{t,i} * (STD_{1995,\,i} / QUAD_{1995,\,i}) \quad (8)$$

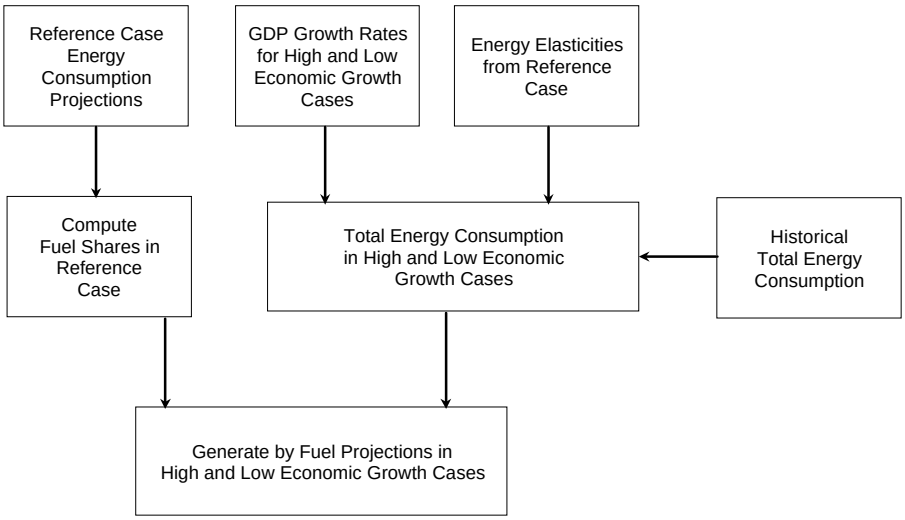
where coal in quadrillion Btu is converted into million short tons and natural gas in quadrillion Btu is converted into trillion cubic feet.

Finally, projections for coal consumption are compared for consistency with world coal trade flows generated by the Coal Export Submodule (CES), a separately documented submodule of the National Energy Modeling System. The CES is a linear program that determines world coal trade distribution by minimizing overall costs for coal, subject to U.S. coal supply prices and a number of constraints. Supply costs (mining and preparation plus transportation) for each coal export region, coal type, and end use compete in two demand sectors (coking and steam). CES also takes into account limits on sulfur dioxide emissions and concerns about diversity of coal sources.

High and Low Economic Growth Cases

Figure 5 depicts the process of generating low and high economic growth case projections of energy consumption (total and by fuel).

Figure 5. High and Low Economic Growth Case Subsystems



The process associated with generating total energy consumption in the two cases is straightforward: high and low economic growth rates are determined and applied to the WEPS model in the same way as the reference case to generate the side cases. The energy elasticities are not changed from reference case assumptions. That is, for the high economic growth case:

$$TOTQUAD\_H_t = TOTQUAD\_H_{t-5} * \{[(GDPGR\_H_t * ELAST_t)/100]+1\}^5 \quad (9)$$

and for the low economic growth case:

$$TOTQUAD\_L_t = TOTQUAD\_L_{t-5} * \{[(GDPGR\_L_t * ELAST_t)/100]+1\}^5 \quad (10)$$

where $TOTQUAD\_H_t$ and $TOTQUAD\_L_t$ are the total energy consumption in quadrillion Btu in the high economic growth case and low economic growth case in forecast year t, respectively. Similarly, $GDPGR\_H_t$ and $GDPGR\_L_t$ are the assumed economic growth rates in forecast year t for the high and low cases, respectively. $ELAST_t$ is the energy elasticity at forecast year t.

For each of the side cases, low and high economic growth rates are computed for each country and region represented by WEPS based upon adding or subtracting percentage points to the reference case GDP growth rate assumptions. These amounts vary according to region as well as scenario according to the amount of uncertainty analysts feel is present in a specific region. They are summarized in Table 2.

Table 2. Percentage Points Added to/Subtracted from Reference Case Gross Domestic Product Growth Rates by Region and Scenario

Scenario	Industrialized	EE/FSU	China	Rest of the World
High Economic Growth . .	+0.5	+3.0	+1.5	+1.5
Low Economic Growth . .	-0.5	-1.5	-3.0	-1.5

Note: EE/FSU = Eastern Europe and the former Soviet Union

By-fuel projections for the high and low economic growth cases are computed by assuming that the share of any particular fuel relative to total energy consumption will remain the same as in the reference case forecasts. So, for the high economic growth case,

$$QUAD\_H_{t,i} = TOTQUAD\_H_t * (QUAD_{t,i} / TOTQUAD_t) \quad (11)$$

$$QUAD\_L_{t,i} = TOTQUAD\_L_t * (QUAD_{t,i} / TOTQUAD_t) \quad (12)$$

where $QUAD\_H_{t,i}$ and $QUAD\_L_{t,i}$ are consumption of energy source i in quadrillion Btu in forecast year t in the high and low economic growth cases, respectively. $QUAD_{t,i}$ and $TOTQUAD_t$ are the reference case projections in year t of energy consumption of fuel i and total energy consumption, both in quadrillion Btu.

Electricity Forecasts

Figure 6 shows the structure of the electricity consumption subsystem. Net electricity consumption (generation plus imports minus exports minus distribution losses) is projected as a share of total energy consumption. That is,

$$ELEC\_Q_t = PCT\_ELEC_t * TOTQUAD_t \quad (13)$$

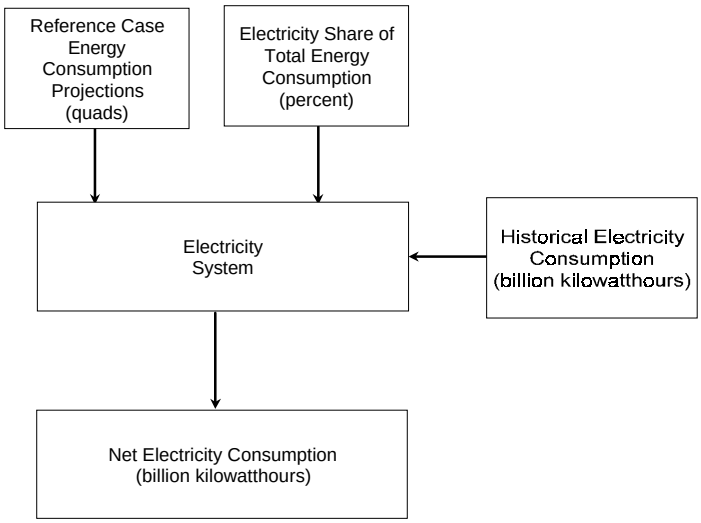
where $ELEC\_Q_t$ is the electricity consumption at time t expressed in quadrillion Btu, PCT_ELEC_t is the electricity share of total consumption at time t (see Table 3), and $TOTQUAD_t$ is the total energy consumption projection for time t expressed in quadrillion Btu.

Next, to convert the consumption into standard physical units (here billion kilowatthours),

$$ELEC\_STD_t = ELEC\_Q_t * (10^6/3412) \quad (14)$$

where $ELEC\_STD_t$ is net electricity consumption in billion kilowatthours.

Figure 6. Electricity Consumption Subsystem



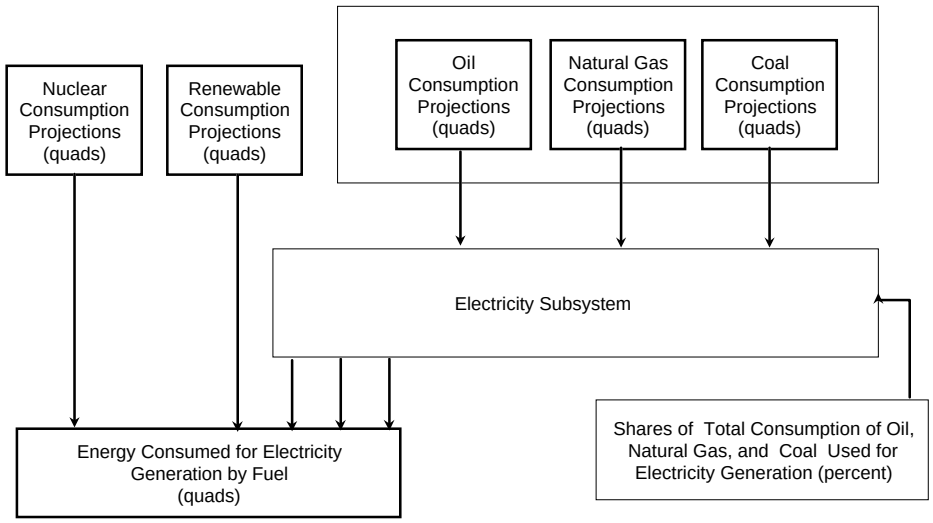
quads = quadrillion Btu

Energy use for the purpose of electricity generation is also projected in the electricity subsystem by fuel (Figure 7). Reference case projections of consumption by energy source are input into the electricity system. The quantity of each fossil fuel used at the electric utility is determined as:

$$ELECF\_Q_{t,\,i} = PCT\_FUEL_{t,\,i} * QUAD_{t,\,i} \quad (15)$$

where $PCT\_FUEL_{t,\,i}$ is the share of fossil fuel i used to generate electricity in year t, $QUAD_{t,\,i}$ is reference case consumption of fossil fuel i in quadrillion Btu projected for year t, and $ELECF\_Q_{t,\,i}$ is the resulting fossil fuel i used for electricity generation in year t in quadrillion Btu. The model assumes that all consumption of nuclear power and all renewables are for the purpose of electricity generation.

Figure 7. Energy Consumed for Electricity Generation (Part of Electricity Subsystem)



quads = quadrillion Btu

Low and high economic growth estimates of net electricity consumption and energy used for electricity generation are determined in the same way as the reference case estimates. For each side case, total energy consumption and consumption by energy source are input into the electricity subsystem. The shares used in the reference case are also used to determine high and low economic growth scenarios.

That is, for net electricity consumption:

$$ELEC\_Q\_L_t = PCT\_ELEC_t * TOTQUAD\_L_t \quad (16)$$

$$ELEC\_Q\_H_t = PCT\_ELEC_t * TOTQUAD\_H_t \quad (17)$$

where _L is the suffix for low economic growth and _H is the suffix for high economic growth. Similarly, for energy consumed for electricity generation by fuel :

$$ELECF\_Q\_L_{t,\,i} = PCT\_FUEL_{t,\,i} * QUAD\_L_{t,\,i} \quad (18)$$

$$ELECF\_Q\_H_{t,\,i} = PCT\_FUEL_{t,\,i} * QUAD\_H_{t,\,i} \quad (19)$$

Table 3. Electricity Share of Total Energy Consumption, 1995-2020
(Percent of Total)

	1995	2000	2005	2010	2015	2020
Canada	13.27	12.76	12.58	12.76	13.01	13.27
Mexico	7.99	8.61	9.25	9.92	10.61	11.35
Japan	14.40	14.96	15.41	15.77	16.05	16.34
United Kingdom	10.47	10.86	11.25	11.63	12.00	12.38
France	13.20	14.17	15.03	15.77	16.40	17.05
Germany	12.86	13.82	14.73	15.57	16.33	17.13
Italy	12.28	13.29	14.33	15.40	16.50	17.67
Netherlands	8.06	8.65	9.22	9.77	10.29	10.85
Other Europe	13.80	14.44	14.99	15.70	16.40	17.13
Australasia	14.65	16.00	17.14	18.07	18.81	19.57
Former Soviet Union	8.88	8.88	8.89	8.89	8.89	8.89
Eastern Europe	8.99	9.58	10.12	10.63	11.09	11.57
China	7.30	7.97	8.69	9.45	10.25	11.12
India	11.76	12.56	13.30	13.97	14.57	15.19
Other Asia	9.74	9.89	9.95	9.98	9.99	10.00
Middle East	6.45	6.79	7.02	7.18	7.29	7.40
Africa	9.83	10.53	11.24	11.96	12.69	13.46
Central & South Ameri	11.66	11.95	12.31	12.38	12.30	12.37
Brazil	15.23	16.22	17.28	18.41	18.41	19.61

Source: Energy Information Administration, World Energy Projection System (1998)

Note: Australasia = Australia, New Zealand, and the U.S. Territories. U.S. electricity consumption projections are not derived using the World Energy Projection System. They are instead produced by EIA's National Energy Modeling System for the report, Annual Energy Outlook.

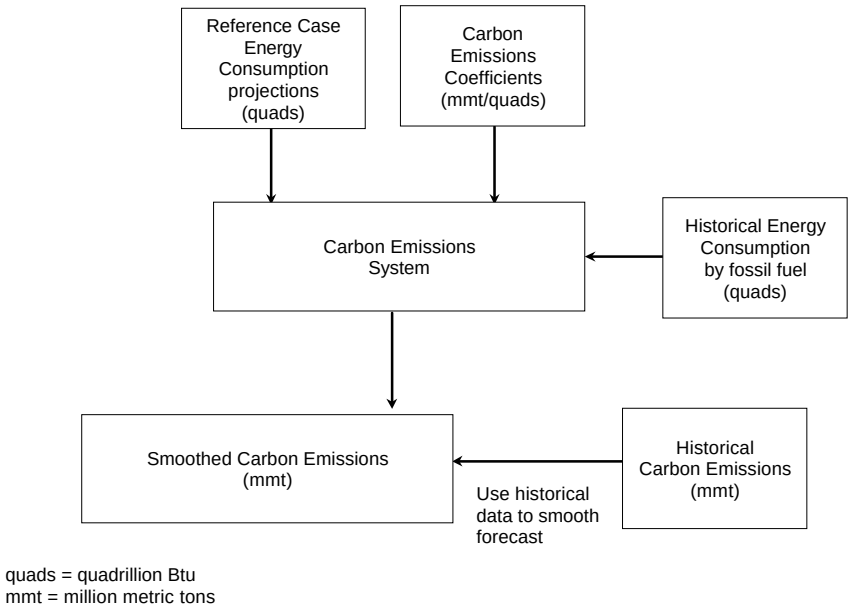
Carbon Emissions Forecasts

Carbon emissions projections in the reference case are estimated from reference case projections of energy consumption by fossil fuel. The emissions subsystem is presented in Figure 8. Emissions are computed as the product of carbon emissions coefficients at full combustion (million metric tons of carbon per quadrillion Btu) and oil, natural gas, and coal consumption expressed in quadrillion Btu from 1970 through 2020:

$$EMIT_{t,i} = QUAD_{t,i} * COEF_i \quad (20)$$

where $EMIT_{t,i}$ represents carbon emissions in million metric tons for forecast year t and fossil fuel I; $QUAD_{t,i}$ represents the reference case consumption of fuel i (oil, gas, or coal) in forecast year t; and $COEF_i$ the carbon coefficient corresponding to fossil fuel i.

Figure 8. Carbon Emissions Subsystem



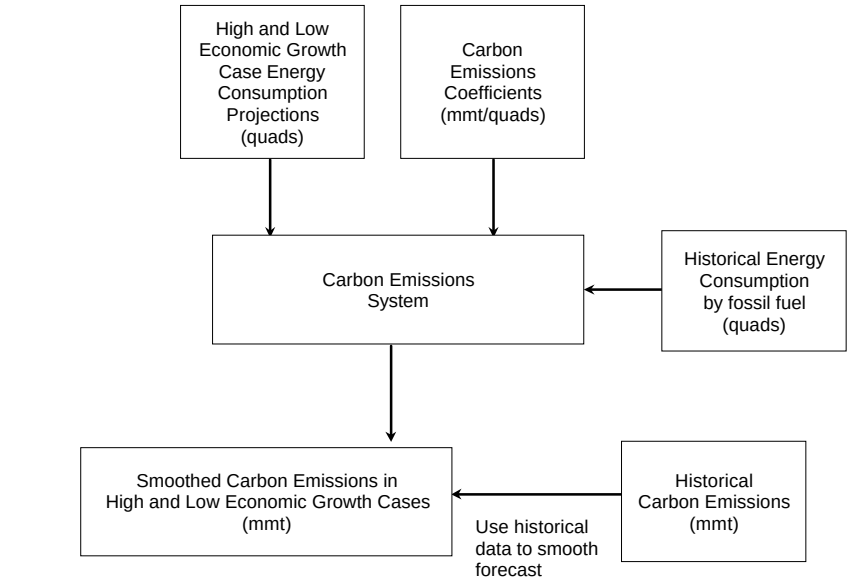
Then, to smooth emissions estimates for consistency with historical measures:

$$SM\_EMIT_{t,i} = EMIT_{t,i} * (H\_EMIT_{1995,i} / EMIT_{1995,i}) \quad (21)$$

where $SM\_EMIT_{t,i}$ = smoothed emissions for forecast year t and fossil fuel i and $H\_EMIT_{1995,i}$ is the historical estimate of emissions for 1995 and fossil fuel i.

High and low economic growth case emissions are similarly generated, but using the high and low economic growth case energy consumption numbers in place of the reference case numbers (Figure 9).

Figure 9. High and Low Carbon Emissions Subsystems



So that,

$$EMIT\_H_{t,i} = QUAD\_H_{t,i} * COEF_i \quad (22)$$

$$EMIT\_L_{t,i} = QUAD\_L_{t,i} * COEF_i \quad (23)$$

where $QUAD\_H_{t,i}$ represents energy consumption of fuel i (oil, gas, or coal) in forecast year t for the high economic growth case , $QUAD\_L_{t,i}$ represents energy consumption in the low economic growth case, and $COEF_i$ the carbon coefficient corresponding to fossil fuel i.

Then, to smooth emissions estimates for consistency with historical measures:

$$SM\_EMIT\_H_{t,i} = EMIT\_H_{t,i} * (H\_EMIT_{1995,i} / EMIT_{1995,i}) \quad (24)$$

$$SM\_EMIT\_L_{t,i} = EMIT\_L_{t,i} * (H\_EMIT_{1995,i} / EMIT_{1995,i}) \quad (25)$$

where $SM\_EMIT\_H_{t,i}$ = smoothed emissions for forecast year t and fossil fuel i in the high economic growth case, $SM\_EMIT\_L_{t,i}$ = smoothed emissions for forecast year t and fossil fuel i in the low economic growth case, $H\_EMIT_{1995,i}$ is the historical estimate of emissions for 1995 and fossil fuel i from the Office of Energy Markets and End Use, and $EMIT_{1995,i}$ is the reference case estimate of emissions in 1995 from WEPS.

Appendix A

System Abstract

A. Model Name:	World Energy Projection System
B. Acronym:	WEPS
C. Description:	WEPS is an integrated set of personal-computer-based spreadsheets containing data compilations, assumption specifications, descriptive analysis procedures, and projection models. Projections of the WEPS accounting framework incorporates projections from independently documented models and assumptions about the future energy intensity of economic activity (ratios of total energy consumption divided by gross domestic product [GDP]) and about the rate of incremental energy requirements met by natural gas, coal, and renewable energy sources (hydroelectricity, geothermal, solar, wind, and other renewable sources). WEPS provides projections of total world primary energy consumption, as well as projections of energy consumption by primary energy type (oil, natural gas, coal, nuclear, and hydroelectric and other renewable sources), and projections of net electricity consumption. Carbon emissions resulting from fossil fuel use are derived from the energy consumption projections. All projections are computed in 5-year intervals through 2020. For both historical series and projections series, WEPS provides analytical computations of energy intensity and energy elasticity (the percentage change in energy consumption per percentage change in GDP).
D. Model Update Information:	The spreadsheet files are updated annually. The last update was on October 1997.
E. Sub-model References:	Subsystems and models within WEPS include: Total Energy Consumption Subsystem, High and Low Economic Growth Subsystem, Oil Subsystem, Nuclear Energy Subsystem, Coal-Natural Gas-Other Allocation System,

	Carbon Emissions Subsystem, High and Low Carbon Emissions Subsystem, Electricity Consumption Subsystem, and High and Low Electricity Consumption Subsystem.
F. Model Interface:	Oil consumption projections are accepted from the International Energy Module (IEM) of the National Energy Modeling System (NEMS). Nuclear generation projections are accepted from the International Nuclear Model (INM) PC Version. In addition, WEPS considers outputs from the World Integrated Nuclear Evaluation System (WINES) and the NEMS Coal Export Submodule (CES) which is used to derive flows in international coal trade. WEPS is not part of another model.
G. Official Model Representatives:	Office: Office of Integrated Analysis and Forecasting Division: International, Economic, and Greenhouse Gases Division, EI-81 Model Contact: Linda E. Doman Telephone: 202/586-1041 E-mail: linda.doman@eia.doe.gov
H. Documentation Reference:	Energy Information Administration, *World Energy Projection System Model Documentation* (Washington, DC, 1997).
I. Archive Information:	World Energy Projection System (1998) — May 1998
J. Purpose of the Model:	The purpose of the WEPS model is to project total primary energy consumption, energy consumption by primary energy source (oil, natural gas, coal, nuclear, and hydroelectricity and other renewable sources), net electricity consumption, and carbon emissions. High and low economic growth case estimates are also generated in WEPS. The model is used to provide an accounting framework that produces consistent world energy consumption balances from diverse sources of information.
K. Energy System:	Oil, natural gas, coal, nuclear, hydroelectricity and other renewable sources, and net electricity.
L. Coverage:	World by selected countries and major regions. Projections of consumption by five-year intervals through 2020. Units include million barrels per day (oil), trillion cubic feet

(natural gas), million short tons (coal), billion kilowatthours (nuclear and net electricity).

M. Modeling Features:

The model structure is an accounting framework of relationships concerning energy consumption, oil production, world oil prices, economic growth, and energy elasticities.

The major technique used in WEPS is to project total energy by region based on an assumed relationship to economic growth as measured by gross domestic product (GDP). Projections of all other energy sources are made consistent with projected total energy. Econometric techniques are not used to determine changes in relationships over the projection period.

N. Input Data (Non-DOE):

International Energy Agency, *Coal Information* (Paris)

- Total final energy consumption by fuel
- Energy consumed by end use sector by fuel

International Energy Agency, *Electricity Information* (Paris)

- Energy consumed by fuel by electric utilities

International Energy Agency, *Energy Balances of OECD Countries* (Paris)

- Consumption of energy source (oil, natural gas, coal, nuclear, other) by end use sector (industrial, building, transportation, electric utility) for OECD countries.

International Energy Agency, *Balances and Statistics of Non-OECD Countries* (Paris).

- Consumption of energy source (oil, natural gas, coal, nuclear, other) by end use sector (industrial, building, transportation, electric utility) for Non-OECD countries.

WEFA Group, *World Economic Outlook* (Eddystone, PA)

- Real Gross Domestic Product (in 1990 U.S. Dollars) projections (1995-2000)
- Average annual GDP growth rates

WEFA Group, *World Economic Outlook: 20 Year Extension* (Eddystone, PA)

- Historical (1977-1995) real GDP (in 1990 U.S. Dollars)
- GDP projections (1996-2016)

O. Input Data (DOE):

Energy Information Administration, *Annual Energy Outlook*

- U.S. consumption of energy source (oil, natural gas, coal, nuclear, other) by sector (industrial, transportation, building, and electric utility)
- World oil price path
- U.S. carbon emissions
- U.S. net electricity consumption

Energy Information Administration, *Annual Energy Review*

- GDP deflators

Energy Information Administration, *Nuclear Power Generation and Fuel Cycle Report*

- Nuclear power operating capacity

Energy Information Administration, *International Energy Annual*

- Oil consumption in quadrillion Btu and million barrels per day
- Natural gas consumption in quadrillion Btu and trillion cubic feet
- Coal consumption in quadrillion Btu and million

short tons

- Nuclear energy consumption (equated to generation) in quadrillion Btu and billion kilowatthours
- Hydroelectricity and other renewable energy consumption in quadrillion Btu
- Net electricity consumption in billion kilowatthours
- Carbon emissions in million metric tons

P. Output Data: Total energy consumption, primary energy consumption by energy source (oil, natural gas, coal, nuclear, and hydroelectricity and other renewable resources), net electricity consumption, and carbon emissions all for the reference, high and low economic growth cases.

Q. Computing Environment: Consists of spreadsheet files and directories run on an IBM compatible personal computer using Windows 95.

The world energy consumption spreadsheet programs require about 6.3 MB of hard disk space. To run the world energy consumption reference case spreadsheet requires about 640K of random access memory (RAM).

R. Independent Reviews Conducted: Model Quality Audit was conducted by the Office of Statistical Standards, December 23, 1996.

S. Status of Evaluation Efforts: No evaluation currently being undertaken

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DRI/McGraw-Hill, *The Future of the Electric Power Industry Around the World* (Lexington, MA, November 1995)

WEFA Energy, *World Power Service* (includes reports on Western Europe, Eastern Europe, Far East, Latin America, and China and Indian Subcontinent).

Appendix B

Data, Variables, and Parameter Definitions

Primary Energy Consumption Models (WEDA.XLW, LOWRNG.XLS, and HIRNG.XLS Models)

Quantity	Definition	Source	Units/Function
$TOTQUAD_t$	Total energy consumption, year t	1980-1995, EIA, *International Energy Annual 1995*; 2000-2020, computed by WEPS	Quadrillion British thermal units (Btu)
$GDPGR_t$	Average annual growth in gross domestic product (GDP), year t	1980-2000, WEFA Energy, *World Economic Service: 20 Year Extension*; 2005-2020, EIA assumptions	Percent per year
$ELAST_t$	Energy elasticity, year t	1980-1995, computed by WEPS as percent change in energy consumption divided by percent change in GDP; 2000-2020, EIA assumptions	ratio
$QUAD_{t, oil}$	Oil consumption in quadrillion Btu, year t	1980-1995, EIA, *International Energy Annual 1995*; 2000-2020, input from the International Energy Module	Quadrillion Btu

Primary Energy Consumption Models (WEDA.XLW, LOWRNG.XLS, and HIRNG.XLS Models)

Quantity	Definition	Source	Units/Function
$STD_{t, oil}$	Oil consumption in standard units, year t	1980-1995, EIA, *International Energy Annual 1995*; 2000-2020, input from the International Energy Module	Million Barrels per Day
$QUAD_{t, nuclear}$	Nuclear consumption in quadrillion Btu, year t	1980-1995, EIA, *International Energy Annual 1995*; 2000-2020, computed by WEPS	Quadrillion Btu
$STD_{t, nuclear}$	Nuclear consumption in standard units, year t	1980-1995, EIA, *International Energy Annual 1995*; 2000-2020, input from the International Nuclear Model, PC-Version	Billion kilowatthours
$QUAD_{t, coal}$	Coal consumption in quadrillion Btu, year t	1980-1995, EIA, *International Energy Annual 1995*; 2000-2020, computed by WEPS	Quadrillion Btu
$STD_{t, coal}$	Coal consumption in standard units, year t	1980-1995, EIA, *International Energy Annual 1995*; 2000-2020, computed by WEPS	Million short tons
$QUAD_{t, gas}$	Natural gas consumption in quadrillion Btu, year t	1980-1995, EIA, *International Energy Annual 1995*; 2000-2020, computed by WEPS	Quadrillion Btu

Primary Energy Consumption Models (WEDA.XLW, LOWRNG.XLS, and HIRNG.XLS Models)

Quantity	Definition	Source	Units/Function
$STD_{t, gas}$	Natural gas consumption in standard units, year t	1980-1995, EIA, *International Energy Annual 1995*; 2000-2020, computed by WEPS	Trillion cubic feet
$QUAD_{t, other}$	Hydroelectricity and other renewable sources consumption in quadrillion Btu, year t	1980-1995, EIA, *International Energy Annual 1995*; 2000-2020, computed by WEPS	Quadrillion Btu
$RESCHG_t$	Residual growth of total energy consumption, year t	1980-2020, computed by WEPS	Quadrillion Btu
$SHARE_{t, i}$	Percent of RESCHG allocated to energy source i, year t	1980-2020, computed by WEPS	Percent
_L (SUFFIX)	Denotes low economic growth scenario for associated variable.		
_H (SUFFIX)	Denotes high economic growth scenario for associated variable		

Electricity Subsystem (ELE_SH2.XLS, ELE_SHH.XLS, and ELE_SHL.XLS Models)

Quantity	Definition	Source	Units/Function
$ELEC\_Q_t$	Net electricity consumption in forecast year t	1980-1995, derived from *International Energy Annual* 2000-2020 projected by WEPS	quadrillion Btu
PCT_ELEC_t	Share of total energy that comprises energy consumption in year t	assumption	percent
$TOTQUAD_t$	Total energy consumption in year t	input from WEDA.XLW	quadrillion Btu
$ELEC\_STD_t$	Net electricity consumption in forecast year t	1980-1995, *International Energy Annual* 2000-2020 projected by WEPS	billion kilowatthours
$ELECF\_Q_{t, i}$	Energy consumed for purpose of electricity generation for i in year t	1980-1995, derived from *International Energy Annual* and data from the International Energy Agency; 2000-2020, projected by WEPS	quadrillion Btu
$PCT\_FUEL_{t, i}$	Share of energy source i used by electric utilities at time t	assumption	percent
$QUAD_{t, i}$	Energy consumption of fuel i in time t	input from WEDA.XLW	quadrillion Btu
_L (SUFFIX)	Denotes low economic growth scenario for associated variable.		

Electricity Subsystem (ELE_SH2.XLS, ELE_SHH.XLS, and ELE_SHL.XLS Models)

Quantity	Definition	Source	Units/Function
_H (SUFFIX)	Denotes high economic growth scenario for associated variable		

Carbon Emissions Subsystem (CARBONF.XLS, CARBONL.XLS, and CARBONH.XLS Models)

Quantity	Definition	Source	Units/Function
$EMIT_{t, i}$	Carbon emissions resulting from fossil fuel (oil, natural gas, coal) i, year t	1980-1995, EIA, *Annual Energy Review 1996*; 2000-2020, computed by WEPS	Million metric tons
$QUAD_{t, oil}$	Oil consumption in quadrillion Btu, year t	1980-1995, EIA, *International Energy Annual 1995*; 2000-2020, input from the International Energy Module	Quadrillion Btu
$QUAD_{t, gas}$	Natural gas consumption in quadrillion Btu, year t	1980-1995, EIA, *International Energy Annual 1995*; 2000-2020, computed by WEPS	Quadrillion Btu
$QUAD_{t, coal}$	Coal consumption in quadrillion Btu, year t	1980-1995, EIA, *International Energy Annual 1995*; 2000-2020, computed by WEPS	Quadrillion Btu

Carbon Emissions Subsystem (CARBONF.XLS, CARBONL.XLS, and CARBONH.XLS Models)

Quantity	Definition	Source	Units/Function
$COEF_i$	Coefficient used to determine emissions, fuel i (oil, natural gas, coal)	Derived using EIA, *International Energy Annual 1995* and *Emissions of Greenhouse Gases in the United States*	Million metric tons per quadrillion Btu
$SM\_EMIT_{t,i}$	Emissions smoothed according to historical estimates, fuel i, year t	Computed by WEPS	Million metric tons
$H\_EMIT_{1995, i}$	Historical estimate of carbon emissions for 1995 computed by the Office of Energy Markets and End Use, fuel i	EIA, *Annual Energy Review 1996*	Million metric tons
$EMIT_{1995, i}$	Estimate of carbon emissions for 1995 computed by WEPS, fuel i	Computed by WEPS	Million metric tons
_L (SUFFIX)	Denotes low economic growth scenario for associated variable.		
_H (SUFFIX)	Denotes high economic growth scenario for associated variable		

Appendix C

Location of Variables

Primary Energy Consumption Module (WEDA.XLW)

Variable Name in Documentation	Cell Range in Spreadsheet
$STD_{t,oil}$	A306..V342
$STD_{t,nuk}$	A489..V525
$STD_{t,gas}$	A367..V403
$STD_{t,coal}$	A428..V464
$STD_{t,other}$	A550..V586
$QUAD_{t,oil}$	X306..AS342
$QUAD_{t,nuk}$	X489..AS525
$QUAD_{t,gas}$	X367..AS403
$QUAD_{t,coal}$	X428..AS464
$QUAD_{t,other}$	X550..AS586
GDP	A62..V98
GDPGR	A1..V40
ELAST	A123..V159
TOTQUAD	A184..V220
RESCHG	X245..AS281
$SHARE_{t,i}$	X123..BA159

Low Economic Growth Case Module (LOWRNG.XLS)

Variable Name in Documentation	Cell Range in Spreadsheet
$STD\_L_{t,oil}$	Sheet 1!A331..V367
$STD\_L_{t,nuk}$	Sheet 1!A529..V499
$STD\_L_{t,gas}$	Sheet 1!A397..V433
$STD\_L_{t,coal}$	Sheet 1!A463..V499
$STD\_L_{t,other}$	Sheet 1!A595..V631
$QUAD\_L_{t,oil}$	Sheet 2!A1..L37
$QUAD\_L_{t,nuk}$	Sheet 2!A217..L253
$QUAD\_L_{t,gas}$	Sheet 2!A73..L109
$QUAD\_L_{t,coal}$	Sheet 2!A145..L181
$QUAD\_L_{t,other}$	Sheet 2!A289..L325
GDP_L	Sheet 1!A67..V103
GDPGR_L	Sheet 1!A1..V40
ELAST	Sheet 1!A133..V169
TOTQUAD_L	Sheet 1!A99..V235

High Economic Growth Case Module (HIRNG.XLS)

Variable Name in Documentation	Cell Range in Spreadsheet
$STD\_H_{t,oil}$	Sheet 1!A331..V367
$STD\_H_{t,nuk}$	Sheet 1!A529..V499
$STD\_H_{t,gas}$	Sheet 1!A397..V433
$STD\_H_{t,coal}$	Sheet 1!A463..V499

$STD\_H_{t,other}$	Sheet 1!A595..V631
$QUAD\_H_{t,oil}$	Sheet 2!A1..L37
$QUAD\_H_{t,nuk}$	Sheet 2!A217..L253
$QUAD\_H_{t,gas}$	Sheet 2!A73..L109
$QUAD\_H_{t,coal}$	Sheet 2!A145..L181
$QUAD\_H_{t,other}$	Sheet 2!A289..L325
GDP_H	Sheet 1!A67..V103
GDPGR_H	Sheet 1!A1..V40
ELAST	Sheet 1!A133..V169
TOTQUAD_H	Sheet 1!A99..V235

Net Electricity Consumption Module (ELE_SH2.XLW)

Variable Name in Documentation	Cell Range in Spreadsheet
ELEC_Q	D!A1..G21
PCT_ELEC	B!A1..G21
TOTQUAD	C!A1..G21
ELEC_STD	E!A1..J36
$ELECF\_Q_{t,oil}$	M!A1..I34
$ELECF\_Q_{t,gas}$	P!A1..I34
$ELECF\_Q_{t,coal}$	I!A1..I34
$ELECF\_Q_{t,nuk}$	J!A1..I34
$ELECF\_Q_{t,other}$	K!A1..I34
$PCT\_FUEL_{t,oil}$	L!A1..AZ21

$PCT\_FUEL_{t,gas}$	O!A1..AZ21
$PCT\_FUEL_{t,coal}$	G!A1..AZ21
$QUAD_{t,oil}$	N!A1..AZ21
$QUAD_{t,gas}$	Q!A1..AZ21
$QUAD_{t,coal}$	F!A1..AZ21
$QUAD_{t,nuk}$	see $ELECF\_Q_{t,nuk}$
$QUAD_{t,other}$	see $ELECF\_Q_{t,other}$

Net Electricity Consumption, High Case Module (ELE_SHH.XLW)

Variable Name in Documentation	Cell Range in Spreadsheet
ELEC_Q_H	D!A1..G21
PCT_ELEC	B!A1..G21
TOTQUAD_H	C!A1..G21
ELEC_STD_H	E!A1..J36
$ELECF\_Q\_H_{t,\ oil}$	M!A1..I34
$ELECF\_Q\_H_{t,gas}$	P!A1..I34
$ELECF\_Q\_H_{t,coal}$	I!A1..I34
$ELECF\_Q\_H_{t,nuk}$	J!A1..I34
$ELECF\_Q\_H_{t,other}$	K!A1..I34
$PCT\_FUEL_{t,oil}$	L!A1..AZ21
$PCT\_FUEL_{t,gas}$	O!A1..AZ21
$PCT\_FUEL_{t,coal}$	G!A1..AZ21

$QUAD\_H_{t,\ oil}$	N!A1..AZ21
$QUAD\_H_{t,gas}$	Q!A1..AZ21
$QUAD\_H_{t,coal}$	F!A1..AZ21
$QUAD\_H_{t,nuk}$	see $ELECF\_Q\_H_{t,nuk}$
$QUAD\_H_{t,other}$	see $ELECF\_Q\_H_{t,other}$

Net Electricity Consumption, Low Case Module (ELE_SHL.XLW)

Variable Name in Documentation	Cell Range in Spreadsheet
ELEC_Q_L	D!A1..G21
PCT_ELEC	B!A1..G21
TOTQUAD_L	C!A1..G21
ELEC_STD_L	E!A1..J36
$ELECF\_Q\_L_{t,\ oil}$	M!A1..I34
$ELECF\_Q\_L_{t,gas}$	P!A1..I34
$ELECF\_Q\_L_{t,coal}$	I!A1..I34
$ELECF\_Q\_L_{t,nuk}$	J!A1..I34
$ELECF\_Q\_L_{t,other}$	K!A1..I34
$PCT\_FUEL_{t,oil}$	L!A1..AZ21
$PCT\_FUEL_{t,gas}$	O!A1..AZ21
$PCT\_FUEL_{t,coal}$	G!A1..AZ21
$QUAD\_L_{t,\ oil}$	N!A1..AZ21
$QUAD\_L_{t,gas}$	Q!A1..AZ21

$QUAD\_L_{t,coal}$	F!A1..AZ21
$QUAD\_L_{t,nuk}$	see $ELECF\_Q\_L_{t,nuk}$
$QUAD\_L_{t,other}$	see $ELECF\_Q\_L_{t,other}$

Carbon Emissions, Referencc Case Module (CARBONF.XLS)

Variable Name in Documentation	Cell Range in Spreadsheet
$EMIT_{t,oil}$	Oil!A1..AF36
$EMIT_{t,gas}$	Nat Gas!A1..AF36
$EMIT_{t,coal}$	Coal!A1..AF36
$QUAD_{t,\ oil}$ $QUAD_{t,gas}$ $QUAD_{t,coal}$	By country &/or region CARBONF!A1..AF372
$COEF_{oil}$	By country &/or region: CARBONF!BE5..BG281
$COEF_{gas}$	CARBONF!BK3
$COEF_{coal}$	CARBONF!BK4
$SM\_EMIT_{t,\ oil}$	Oil!AZ1..CE36
$SM\_EMIT_{t,\ gas}$	Nat Gas!AZ1..CE36
$SM\_EMIT_{t,\ coal}$	Coal!AZ1..CE36
$H\_EMIT_{1995,\ oil}$	Oil!AX1..AX36
$H\_EMIT_{1995,\ gas}$	Nat Gas!AX1..AX36
$H\_EMIT_{1995,\ coal}$	Coal!AX1..AX36

Carbon Emissions, High Case Module (CARBONH.XLS)

Variable Name in Documentation	Cell Range in Spreadsheet
$EMIT\_H_{t,oil}$	Oil!A1..AF36
$EMIT\_H_{t,gas}$	Nat Gas!A1..AF36
$EMIT\_H_{t,coal}$	Coal!A1..AF36
$QUAD\_H_{t,oil}$ $QUAD\_H_{t,gas}$ $QUAD\_H_{t,coal}$	By country &/or region CARBONF!A1..AF372
$COEF_{oil}$	By country &/or region: CARBONF!BE5..BG281
$COEF_{gas}$	CARBONF!BK3
$COEF_{coal}$	CARBONF!BK4
$SM\_EMIT\_H_{t,oil}$	Oil!AZ1..CE36
$SM\_EMIT\_H_{t,gas}$	Nat Gas!AZ1..CE36
$SM\_EMIT\_H_{t,coal}$	Coal!AZ1..CE36
$H\_EMIT_{1995,oil}$	Oil!AX1..AX36
$H\_EMIT_{1995,gas}$	Nat Gas!AX1..AX36
$H\_EMIT_{1995,coal}$	Coal!AX1..AX36

Carbon Emissions, Low Case Module (CARBONL.XLS)

Variable Name in Documentation	Cell Range in Spreadsheet
$EMIT\_L_{t,oil}$	Oil!A1..AF36
$EMIT\_L_{t,gas}$	Nat Gas!A1..AF36
$EMIT\_L_{t,coal}$	Coal!A1..AF36

$QUAD\_L_{t,\ oil}$ $QUAD\_L_{t,gas}$ $QUAD\_L_{t,coal}$	By country &/or region CARBONF!A1..AF372
$COEF_{oil}$	By country &/or region: CARBONF!BE5..BG281
$COEF_{gas}$	CARBONF!BK3
$COEF_{coal}$	CARBONF!BK4
$SM\_EMIT\_L_{t,\ oil}$	Oil!AZ1..CE36
$SM\_EMIT\_L_{t,\ gas}$	Nat Gas!AZ1..CE36
$SM\_EMIT\_L_{t,\ coal}$	Coal!AZ1..CE36
$H\_EMIT_{1995,\ oil}$	Oil!AX1..AX36
$H\_EMIT_{1995,\ gas}$	Nat Gas!AX1..AX36
$H\_EMIT_{1995,\ coal}$	Coal!AX1..AX36