

Appendix L

Models Used To Generate the *IEO2010* Projections

The *IEO2010* projections of world energy consumption and supply were generated from EIA's World Energy Projections Plus (WEPS+) model. WEPS+ consists of a system of individual sectoral energy models, using an integrated iterative solution process that allows for convergence of consumption and prices to an equilibrium solution. It is used to build the Reference case energy projections, as well as alternative energy projections based on different assumptions for GDP growth and fossil fuel prices. It can also be used to perform other analyses.

WEPS+ produces projections for 16 regions or countries of the world, including North America (United States, Canada, and Mexico), OECD Europe, OECD Asia (Japan, South Korea, and Australia/New Zealand), Russia, other non-OECD Europe and Eurasia, China, India, other non-OECD Asia, Brazil, and other Central and South America. Currently, the projections extend to 2035.

The WEPS+ platform allows the various individual models to communicate with each other through a common, shared database and provides a comprehensive, central series of output reports for analysis. In the individual models, the detail also extends to the subsector level. In WEPS+, the end-use demand models (residential, commercial, industrial, and transportation) project consumption of the key primary energy sources: several petroleum products, other liquids, natural gas, coal, nuclear power, hydropower, wind, geothermal, and other renewable sources. These models also provide intermediate consumption projections for electricity in the end-use demand sectors.

The end-use model projections generally depend on retail supply prices, economic activity as represented by GDP (or gross output in the industrial sector), and population. The transformation models (power generation and district heat) satisfy electricity and heat requirements and also project consumption of primary energy sources at resulting price levels. The supply models (petroleum, natural gas, and coal) generate supply and wholesale price projections for the key supply sources corresponding to the primary consumption sources. The refinery model makes retail price projections for a variety of petroleum products corresponding to the world oil price. The main model in the WEPS+ system monitors the convergence sequence for all the models and projects energy-related carbon dioxide emissions from fossil fuels (including emissions from the use of

petrochemical feedstocks but excluding flared natural gas) at the regional level.

Several model enhancements were implemented in this year's version of the WEPS+ model, including improvements to the modeling platform and improvements in the individual models:

- The residential and commercial demand models now use dynamic simulations with additional product detail, in which the projections are built up over the projection horizon based on changes in GDP, retail prices, consumption in the previous year, and a trend.
- There is a distinct district heat model, and the supply models now provide improved retail price feedback.
- The industrial model now includes consumption in eight industries using a stock/flow approach.
- The transportation sector model includes an extensive level of detail for modes and vehicle types.
- Last year, a new electric power generation model was added to WEPS+. It is a technology-based stock/flow model using a least-cost solution technique. The generation model has been expanded and enhanced for *IEO2010*.
- A new interface with the International Natural Gas Model (INGM) has also been incorporated into the WEPS+ model.

The new detailed regional industrial model incorporated into WEPS+ for *IEO2010* looks at industrial energy use in each of 8 industries in each of the 16 WEPS+ regions. The overall energy activity in each of the 8 industries is driven by regional forecasts of gross output for each industry from the macroeconomic model, which in turn are calibrated to the overall level of GDP in each region. The new model uses a stock/flow approach, looking at the energy intensity and fuel mix distinctions between industrial capacity that is existing (and retired over time) versus capacity that is newly built and added in each year.

WEPS+ now includes a detailed model of the world's transportation sector, which provides projections by the four transport modes: road, rail, water, and air. In addition, a variety of submodes are represented, such as light-duty vehicles and freight trucks. The model separates service demand (e.g., passenger-miles for cars, ton-miles for trucks) from service intensity (e.g., miles

per gallon) and bases the service demand projections on economic and/or population growth and fuel prices.

The detailed regional power generation model that was new to WEPS+ last year has been significantly improved. It uses a stock/flow approach, keeping track of electricity generating capacity, generation, and consumption within remaining, new, and added vintages. The model is technology-based, with a wide variety of technologies for fossil fuels along with their characteristics, such as costs and heat rates. The slate of technologies has been updated and regionalized. The model solves for new capacity and generation in each year, based on the new generation requirements from the end-use demand models, after accounting for transmission and distribution losses. The solution technique is a least-cost market share, using levelized costs for each technology within various load segments based on the system load shape. The overall system load shape is built from sectoral load shapes fitted to annual loads from each of the demand models.

A new refinery model determines the regional retail prices for a variety of products by sector, based on the world oil price. The new refinery model uses the concept of marginal refineries in three international regions. The marginal refineries determine the refinery-gate (wholesale) prices for a variety of products, based on the price of crude oil entering the refinery. Wholesale prices for the WEPS+ regions are determined on the basis of transportation cost, and historical markups are then used to determine retail prices for each sector in each region.

The Reference case reflects the underlying relationships incorporated in the complete set of models interacting with each other in supply/demand relationships communicated through macroeconomic variables, prices, and consumption. The system of models is run iteratively to a point at which prices and consumption have converged to a reasonable equilibrium. Accumulated knowledge from the results of other complex models that focus on specific supply or demand issues and analysts' expert judgments also are taken into account and incorporated into the final projections. After the Reference case has been established, WEPS+ is used to run alternative cases that reflect different assumptions about future economic growth and energy prices. WEPS+ also can be used for other analyses, such as the effects of carbon prices.

The Generate World Oil Balance (GWOB) application is used to create a "bottom up" projection of world liquids supply—based on current production capacity, planned future additions to capacity, resource data, geopolitical factors, and oil prices—and to generate conventional crude oil production cases. The scenarios (Oil Price cases) are developed through an iterative process of

examining demand levels at given prices and considering price and income sensitivity on both the demand and supply sides of the equation. Projections of conventional liquids production for 2009 through 2015 are based on analysis of investment and development trends around the globe. Data from EIA's *Short-Term Energy Outlook* are integrated to ensure consistency between short- and long-term modeling efforts. Projections of unconventional liquids production are based on exogenous analysis.

Ten major streams of liquids production are tracked on a volume basis: (1) crude oil and lease condensate, (2) natural gas plant liquids, (3) refinery gains, (4) Canadian oil sands, (5) extra-heavy oils, (6) coal-to-liquids, (7) gas-to-liquids, (8) shale oils, (9) ethanol, and (10) biodiesel. Biofuels are tracked on both a volume basis and an oil equivalent basis. All liquid fuels are reported in physical volumes, unless otherwise stated.

The *IEO2010* projections of global natural gas production and trade were generated from EIA's INGM, which estimates natural gas production, demand, and international trade for 60 detailed regions globally. It combines estimates of natural gas reserves, natural gas resources and resource extraction costs, energy demand, and transportation costs and capacity in order to estimate future production, consumption, and prices of natural gas.

INGM incorporates regional by-fuel energy consumption projections from the WEPS+ model, as well as more detailed U.S. projections from EIA's National Energy Modeling System (NEMS), which is used to generate U.S. energy projections for the *Annual Energy Outlook* (AEO). An iterative process between INGM and WEPS+ is used to balance world natural gas markets, with INGM providing supply curves to WEPS+ and receiving demand estimates developed by WEPS+. INGM uses regional natural gas demand estimates from NEMS for the United States rather than those computed as part of the WEPS+ output, so that the final output for the United States is consistent with projections that appear in the AEO.

INGM uses a linear program to simulate the global natural gas and LNG markets. The linear program combines multiple activities at different locations and optimizes them to determine a market equilibrium for each year of the simulation, while maximizing the cumulative discounted sum of producer and consumer surplus. Regions that currently show noncompetitive features or have internal constraints that will affect future markets are captured by limiting their ability to increase key asset capacities in the future. Restricting assets provides hard constraints on a region's ability to produce and export natural gas.

Appendix M

Regional Definitions

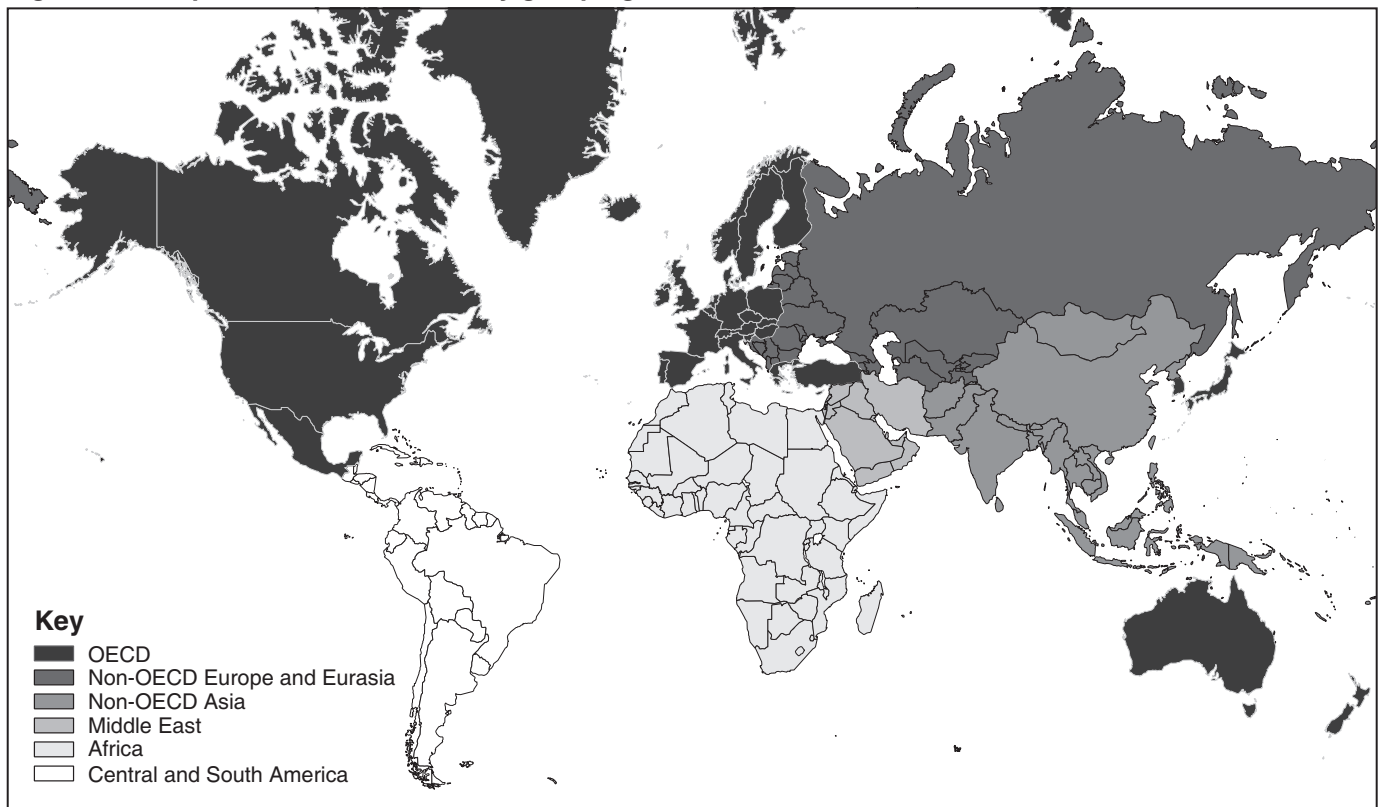
The six basic country groupings used in this report (Figure M1) are defined as follows:

- **OECD** (18 percent of the 2010 world population):
North America—United States, Canada, and Mexico; **OECD Europe**—Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Luxembourg, the Netherlands, Norway, Poland, Portugal, Slovakia, Spain, Sweden, Switzerland, Turkey, and the United Kingdom. **OECD Asia**—Japan, South Korea, Australia, and New Zealand.⁴⁰
- **Non-OECD** (82 percent of the 2010 world population):
 - **Non-OECD Europe and Eurasia** (5 percent of the 2010 world population)—Albania, Armenia, Azerbaijan, Belarus, Bosnia and Herzegovina, Bulgaria, Croatia, Cyprus, Estonia, Georgia, Kazakhstan, Kyrgyzstan, Latvia, Lithuania, Macedonia, Malta,

Moldova, Montenegro, Romania, Russia, Serbia, Slovenia, Tajikistan, Turkmenistan, Ukraine, and Uzbekistan.

- **Non-OECD Asia** (53 percent of the 2010 world population)—Afghanistan, American Samoa, Bangladesh, Bhutan, Brunei, Cambodia (Kampuchea), China, Cook Islands, Fiji, French Polynesia, Guam, Hong Kong, India, Indonesia, Kiribati, Laos, Macau, Malaysia, Maldives, Mongolia, Myanmar (Burma), Nauru, Nepal, New Caledonia, Niue, North Korea, Pakistan, Papua New Guinea, Philippines, Samoa, Singapore, Solomon Islands, Sri Lanka, Taiwan, Thailand, Timor-Leste (East Timor), Tonga, U.S. Pacific Islands, Vanuatu, Vietnam, and Wake Islands.
- **Middle East** (3 percent of the 2010 world population)—Bahrain, Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia, Syria, the United Arab Emirates, and Yemen.

Figure M1. Map of the six basic country groupings



Source: Energy Information Administration, Office of Integrated Analysis and Forecasting.

⁴⁰For consistency, OECD includes all members of the organization as of March 1, 2010, throughout all the time series included in this report. Chile became a member on May 7, 2010, but its membership is not reflected in *IEO2010*.

- **Africa** (14 percent of the 2010 world population)—Algeria, Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Cape Verde, Central African Republic, Chad, Comoros, Congo (Brazzaville), Congo (Kinshasa), Côte d’Ivoire, Djibouti, Egypt, Equatorial Guinea, Eritrea, Ethiopia, Gabon, The Gambia, Ghana, Guinea, Guinea-Bissau, 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** (7 percent of the 2010 world population)—Antarctica, Antigua and Barbuda, Argentina, Aruba, The Bahamas, Barbados, Belize, Bolivia, Brazil, 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, Paraguay, Peru, Puerto Rico, St. Kitts-Nevis, St. Lucia, St. Vincent/Grenadines, Suriname, Trinidad and Tobago, Turks and Caicos Islands, Uruguay, U.S. Virgin Islands, and Venezuela.

In addition, the following commonly used country groupings are referenced in this report:

- **European Union (EU):** Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, and the United Kingdom.
- **Organization of the Petroleum Exporting Countries (OPEC):** Algeria, Angola, Ecuador, Iran, Iraq, Kuwait, Libya, Nigeria, Qatar, Saudi Arabia, the United Arab Emirates, and Venezuela.
- **Persian Gulf Countries:** Bahrain, Iran, Iraq, Kuwait, Oman, Qatar, Saudi Arabia, and the United Arab Emirates.
- **Arabian natural gas producers:** Bahrain, Kuwait, Oman, United Arab Emirates, and Yemen.
- **Non-OECD Developed Asia:** Hong Kong, Macau, Singapore, and Taiwan.
- **Non-OECD Asia LNG exporters:** Brunei, Indonesia, Malaysia, and Papua New Guinea.
- **Central and South America northern producers:** Colombia, Ecuador, Trinidad and Tobago, and Venezuela.