

Appendix A

Modifications to the Reference Case

At the request of the House Science Committee, this analysis of the Kyoto Protocol is based upon the assumptions and methodology of the *Annual Energy Outlook 1998 (AEO98)*.¹¹⁴ Although the reference case in this report is similar to the reference case from *AEO98*, there are some small differences. Modifications were made in order to permit additional flexibility in the National Energy Modeling System (NEMS) in response to higher energy prices or to include certain analyses previously done offline directly within the modeling framework. In addition, some assumptions were modified to reflect more recent assessments of technological improvements and costs. This appendix describes (1) those changes in assumptions and methodologies that cause a change to the reference case of *AEO98*, and (2) other model changes that were implemented in preparing the carbon reduction cases.

Modifications to the Reference Case

Industrial

In *AEO98*, coke imports were incorrectly reported. In 2020, the reference case forecast for coke imports is 260 trillion Btu compared with 82 trillion Btu reported in *AEO98*.

Due to a revision in the methodology for representing the non-energy-intensive industries, the reference case forecast for electricity consumption in 2020 is 220 trillion Btu, or 4.7 percent, less than in *AEO98*. The modification results in an improved representation of the non-energy-intensive industries.

Electricity Generation

Electricity sales are lower by 1.6 percent, or 68 billion kilowatthours, in 2020 compared with *AEO98*, primarily due to the revision in industrial demand noted above.

The ratio of peak load to base load was recalibrated to recent data, resulting in lower projections of peak demands and reducing capacity requirements in the early years of the forecast. This modification reduced the projection of turbine builds by almost 55 gigawatts in the pre-2000 period and by almost 34 gigawatts by 2020, compared with *AEO98*.

In *AEO98*, generating plant retirements were developed offline to the model based on an analysis of when high-cost units would become uneconomic. Retirement decisions for fossil units and pumped storage are now developed internal to the model based on two criteria. First, fossil units that are candidates for retirement must have going-forward costs greater than the total costs of building a replacement over the forecast years for capacity

planning. Second, such units must have short-run costs greater than revenues in the year it is scheduled for retirement. This impacts all fossil-fired units. In the revised reference case, only 5 gigawatts of coal units retire from 1996 through 2020 compared to 29 gigawatts in *AEO98*. Total oil and gas retirements from 1996 through 2020 are 13 gigawatts lower than in *AEO98*, with the reduction in retirements most pronounced around 2005.

Nuclear retirements were also based on an offline analysis in *AEO98*. The retirement decision is now made internal to the model. After 30 years, if the going-forward cost of the unit (including all capital expenditures necessary to continue operation) is greater than that of the full levelized cost of a replacement unit, the unit is retired. This represents the point in time when many plants need to replace their turbine generators. This modification results in about 1 gigawatt of additional nuclear retirements by 2020 relative to *AEO98*.

Oil and Gas

Lower 48 natural gas reserves are lower in the revised reference case than in the *AEO98* reference case, resulting in lower levels of domestic production and slightly higher prices. For this analysis, the initial finding rates, success rates, and the assumed level of technically recoverable resources in the shallow waters of the Gulf of Mexico were revised. The initial finding and success rates were updated using new drilling data published by EIA and resulted in significantly lower natural gas reserve additions from conventional sources. The resources for the shallow waters of the Gulf of Mexico were made consistent with the technically recoverable resource levels estimated by the Minerals Management Service. This change also lowers the overall level of reserves, particularly in the later part of the projection period. Both of these changes put upward pressure on prices.

Cellulose-derived ethanol was added for this analysis, based on updated information about this source of ethanol. This supply represents ethanol derived from cellulose biomass such as agricultural crop residuals, switch gas, and other agricultural wood crops, supplementing the corn-derived ethanol supply curves. Capital and operating cost estimates for the cellulose ethanol production were obtained from the Office of Energy Efficiency and Renewable Energy and decline by 20 percent linearly throughout the forecast for all cases except the high technology sensitivities, for which the costs decline by 50 percent. Consumption of ethanol for gasoline blending and E85 production is higher in the revised reference case than in *AEO98* due to higher demands for E85 and the availability of attractively-priced cellulose-based ethanol. The additional availability of cellulose-

¹¹⁴Energy Information Administration, *Annual Energy Outlook 1998*, DOE/EIA-0383(98) (Washington, DC, December 1997).

based ethanol reverses the downward trend in the blending of ethanol in gasoline in *AEO98*. Additional blending of ethanol in gasoline rises above the levels in *AEO98* starting in 2005 and maintains this level, even though the subsidy for ethanol is declining through 2020. The additional availability of cellulose-based ethanol also reduces prices in the latter half of the forecast period.

Canadian natural gas pipeline capacity additions were assumed to be higher in the revised reference case, particularly in the near term, given updated information on proposed pipelines. This change resulted in a higher forecast for Canadian imports and a somewhat lower domestic natural gas production forecast, even with relatively consistent consumption levels. As a result, through the latter half of the forecast, the import prices in the revised reference case exceed the national average wellhead price by a greater margin than in the *AEO98* reference case.

The forecasts for total domestic natural gas pipeline and storage capacity builds are lower in the revised reference case, mainly in the later and earlier years of the forecast, respectively. This is primarily because anticipated consumption growth was tightened in the capacity planning model. Previously, the model planned for more consumption than was realized. This change also contributed to a somewhat lower use of pipeline fuel.

Additional Model Changes

Macroeconomic Activity

- The previous methodology was a response surface representation of the Standard and Poor's Data Resources, Inc. (DRI) Macroeconomic Model of the U.S. Economy. This was replaced with a nonparametric estimation technique known as kernel regression. The kernel regression model mimics DRI results by comparing inputs from NEMS to databases of inputs and outputs from DRI model simulations of different policy and implementation strategies. The inputs include tax collections and energy prices and quantities. The outputs are 99 macroeconomic variables used in NEMS.
- As part of the analysis underlying the Kyoto service report, EIA requested that DRI examine its Federal Reserve reaction function estimated in the 1997 version of the model, which was the model used in generating *AEO98*. The DRI model used by EIA in this service report changed the structural form of the Federal Reserve reaction function to incorporate a

longer-term view of the tradeoff between inflation and unemployment changes.

Residential

- Short-term price elasticity was increased from -0.15 to -0.25 to reflect increased willingness by consumers to reduce energy services in the face of dramatically higher prices, for example, adjusting thermostats, turning off lights when leaving the room, etc. Also, a price elasticity was included for more end uses, such as water heating and clothes drying.
- The unit energy consumption values were adjusted for personal computers, color televisions, and furnace fans to reflect more recent data. Unit energy consumption values for personal computers are now higher and for televisions and furnace fans are lower.
- Technology choice consideration for both conventional lighting and torchiere lighting was added. This allows lighting efficiency levels to be determined by relative equipment costs and electricity prices.
- The responses to large price increases for shell efficiency improvements are lagged over a 5-year period, as opposed to a total response in 1 year.
- The nonfinancial part of consumer hurdle rates was made a function of energy prices. A doubling of energy prices results in about a 30-percent reduction in the nonfinancial hurdle rate, subject to a lower limit of 15 percent, the assumed financial discount rate.
- New technology databases were updated based on a report from Arthur D. Little.¹¹⁵
- Solar hot water heaters were added as a technology choice for electric hot water heating.
- Fuel switching methodology was reestimated.
- Recent Energy Star programs were incorporated that are aimed at cutting standby losses in televisions and VCRs.

Commercial

- Short-term price elasticities were added to all uses except commercial refrigeration, including "other" uses such as cogeneration and nonbuilding use. The short-term price elasticities were increased from -0.15 to -0.25 to capture a greater consumer response to increasing fuel prices, such as adjusting thermostats, turning off lights and office equipment when not in use, etc.

¹¹⁵Arthur D. Little, Inc., *EIA—Technology Forecast Updates—Residential and Commercial Building Technologies—Reference Case*, Draft Report, 37125-00 (June 16, 1998).

- The proportion of consumers who consider all fuels in equipment purchase decisions for new construction was allowed to increase. The proportion varies by building type with all proportions showing a 15-percent increase over *AEO98* reference case values.
- The nonfinancial part of consumer hurdle rates was made a function of energy prices. A doubling of energy prices results in about a 30-percent reduction in the nonfinancial hurdle rate, with a lower limit of 15 percent, the assumed financial discount rate.
- New technology databases were updated based on the Arthur D. Little report cited previously.

Industrial

- Retirement rates were made a function of price changes.
- The rate of intensity decline, the technology possibility coefficient, was made a function of price changes.
- The representation of cogeneration was revised to better reflect the incremental energy requirements of cogeneration. Biomass cogeneration was made a function of the availability of byproduct biomass, and natural gas cogeneration was made a function of the difference between the electricity price and the natural gas price.

Transportation

- An algorithm which switched consumer preferences toward cars and away from light trucks was added as a function of fuel price.
- The vehicle-miles traveled fuel price elasticity was increased from -0.05 to -0.2 .
- A direct injection diesel, diesel electric hybrid, and gasoline fuel cell technologies were added to the technology menu.
- Additional fuel price sensitivity was added to reflect higher consumer purchase shifting toward smaller vehicles.
- A fuel switching algorithm based on fuel price was added for flexible fuel and bi-fuel vehicles.
- Ultra-high bypass engines for aircraft were currently made available.
- Air travel coefficients were adjusted as a function of jet fuel prices to a -0.2 fuel price elasticity from -0.04 .
- Domestic load factors were increased to 69 percent for domestic flights and 72 percent for international flights by 2015 beginning in 2005.
- Technology trigger prices for freight trucks were based on a 10-percent discount rate and 20-year pay-back period.

- LE-55 and turbocompound diesel engine technologies were added to the technology menu for freight trucks.
- Time to maximum penetration for most freight truck technologies was changed to 20 years from 99 years.
- Rail ton-miles traveled was made a function of coal production and average miles traveled of east-west coal production shares.

Electricity

- For this analysis, the decision to retire nuclear plants is now made internal to the model. As noted before, a unit is retired after 30 years if the cost of continuing operation, including required capital expenditures, exceeds the cost of replacement power. For the carbon reduction cases, the status of the unit is also reviewed after 40 years, the time for relicensing. The license can be renewed for 20 years if the cost of continuing operation, including required capital expenditures, is lower than the cost of replacement power.
- With increasing competition in the electricity industry, electricity suppliers are reluctant to build excess capacity. In the revised reference case, total capacity is limited to 2 percent above the minimum reliability requirement, compared to 1 percent in *AEO98*.
- Coal-fired units in regions with sufficient biomass supplies are allowed to cofire with up to 5 percent biomass.

Renewables

- Capital costs for renewable technologies were increased to reflect impacts of expected short-term supply bottlenecks (e.g., site identification, permitting, and construction) that could result if capacity increases rapidly above existing levels. In *AEO98*, biomass, solar, and wind capacity could increase 25 percent annually without incurring higher capital costs. Costs were assumed to increase by one-half percent for every 1 percent increase of capacity in excess of 25 percent. With higher renewable penetration expected in this analysis, the supply curves were modified so that capital costs increase by 1 percent for every percent increase in capacity above 20 percent for all technologies except wind, for which the cost increase is 1.5 percent.
- Available biomass resources were updated by reestimating potential biomass resources from mill and agricultural residues, forestry products, and energy crops.
- The project life of geothermal units was reduced from 30 years to 20 years, the same as other renewable technologies, to reflect shorter cost recovery periods resulting from competition in the electricity

industry. The time period required to develop additional geothermal projects at an existing site was reduced by 1 year.

- In *AEO98*, capacity additions of hydroelectric power are limited to announced projects; however, carbon reduction targets are expected to raise the cost of fossil-fired technologies, which could attract additional hydroelectric capacity. For this analysis, regional hydroelectric supply curves based on projects identified by the Idaho National Engineering and Environmental Laboratory were included.

Oil and Gas

- The decline in flow rates for the discounted cash flow calculation was revised. The decline in flow rates is now linked to the ratio of reserve additions to production instead of to the decline in the finding rates. As a result, the decline in flow rates increases if reserve additions exceed production.
 - For *AEO98*, the annual change in onshore drilling was limited to 20 percent for 1997 through 2001, and offshore drilling was not limited. For the revised reference case, the annual increase in onshore drilling is limited to 30 percent and offshore drilling to 20 percent throughout the forecast, and the minimum drilling limit was removed.
 - The forecast of Canadian pipeline expansion in *AEO98* was modified to incorporate more recent information on historical and near-term expansions.
- In this analysis, the subsidy for both corn-based and cellulose-based ethanol is 54 cents per gallon, declining by the inflation rate throughout the forecasts. In the carbon reduction cases, the carbon fee applied to end-use product prices replaces the ethanol subsidy if the carbon fee is greater than the ethanol subsidy adjusted by inflation. Corn-based ethanol receives the full carbon fee as a subsidy because corn prices are carbon penalized through the price of diesel fuel, used in the production and harvesting of corn.
 - Refinery efficiency increases linearly throughout the forecast based on the carbon fee as refineries become more efficient to reduce the effect of lost product demand on petroleum product margins. The consumption of steam, natural gas, and electricity decreases linearly at increasing rates based on the carbon fee to a maximum of 5.1, 4.3, and 12.0 percent respectively by 2020.
 - In the reference case, the capital recovery investment decision factor for each refinery processing unit is based on a 15-percent return on investment with a 3-year construction and investment decision period and a 15-year plant life. For the carbon reduction cases, a 7.5-year plant life is used between 2000 to 2008 to reflect the additional risk from the declining market demand in that period. For the industrial migration sensitivity, refinery investment is not allowed beyond 2000, reflecting the inability of the U.S. refinery industry to compete with non-Annex I countries in energy-intensive industries.