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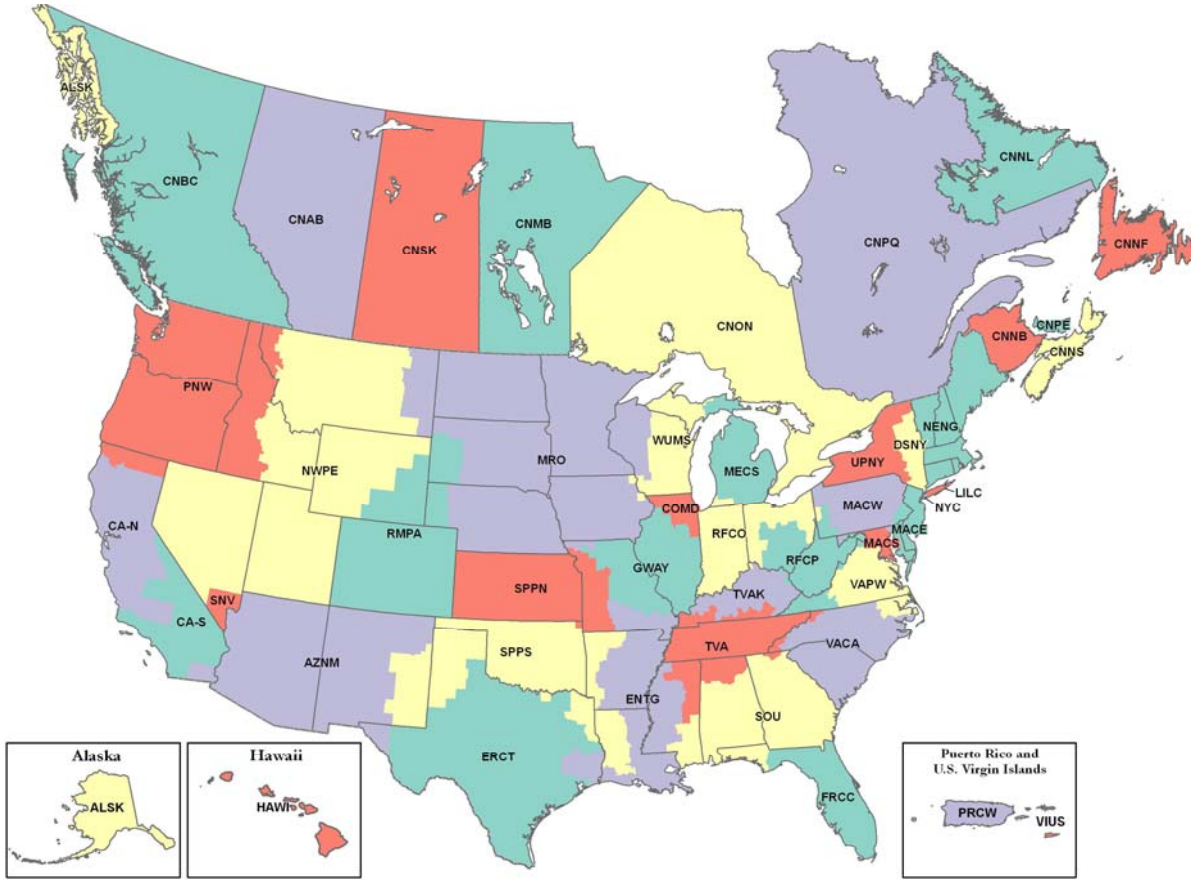
Documentation for EPA Base Case v.4.10 Using the Integrated Planning Model



Cover: EPA Base Case v.4.10 and associated policy cases are used by the U.S. Environmental Protection Agency to project the impact of emissions policies on the electric power sector in the 48 contiguous states and the District of Columbia in the lower continental U.S. Representation of the electric power sector in Canada, Alaska, Hawaii, Puerto Rico, and U.S. Virgin Islands is also included for purposes of integrated projections. The map appearing on the cover shows the 32 model regions used to characterize the operation of the U.S. electric power system in the lower continental U.S., 11 model regions in Canada, and the 4 self-contained model regions in Alaska, Hawaii, Puerto Rico, and U.S. Virgin Islands. EPA Base Case v.4.10 was developed by EPA's Clean Air Markets Division with technical support from ICF International, Inc. The IPM modeling platform is a product of ICF International, Inc and is used in support of its public and private sector clients. IPM® is a registered trademark of ICF Resources, L.L.C.

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1 Introduction

This document describes the nature, structure, and capabilities of the Integrated Planning Model (IPM) and the assumptions underlying the base case (designated EPA Base Case v.4.10) that was developed by the U.S. Environmental Protection Agency (EPA) with technical support from ICF Consulting, Inc. IPM is a multi-regional, dynamic, deterministic linear programming model of the U.S. electric power sector. It provides forecasts of least cost capacity expansion, electricity dispatch, and emission control strategies while meeting energy demand and environmental, transmission, dispatch, and reliability constraints. IPM can be used to evaluate the cost and emissions impacts of proposed policies to limit emissions of sulfur dioxide (SO_2), nitrogen oxides (NO_x), carbon dioxide (CO_2), and mercury (Hg) from the electric power sector.

Base cases, like EPA Base Case v.4.10, serve as the starting point against which policy scenarios are compared. It is a projection of electricity sector activity that takes into account only those Federal and state air emission laws and regulations whose provisions were either in effect or enacted and clearly delineated at the time the base case was finalized in August 2010. (Chapter 3 contains a detailed discussion of the environmental regulations included in EPA Base Case v.4.10.) Regulations, mandated under the Clean Air Act Amendments of 1990 (CAAA), but whose provisions either have not yet been finalized or will expire due to Court action, were not included in the base case. These include.

- *Ozone and Particulate Matter (PM) Standards*: EPA Base Case v.4.10 does not include the provisions of the Clean Air Interstate Rule (CAIR), a Federal regulatory measure for achieving the National Ambient Air Quality Standards (NAAQS) for ozone (8-hour standard of 0.08 ppm) and fine particles (24-hour average of 65 µg/m3 or less and annual mean of 15 µg/m3 for particles of diameter 2.5 micrometers or less, i.e., PM 2.5). Originally issued on March 10, 2005, CAIR was remanded back to EPA by the U.S. Court of Appeals for the District of Columbia Circuit in December 2008 and EPA was required to correct legal flaws in the regulations that had been cited in a ruling by the Court in July 2008. Until EPA's work was completed, CAIR was temporarily reinstated. However, although CAIR's provisions were still in effect when EPA Base Case v.4.10 was released, it is not included in the base case to allow EPA Base Case v.4.10 to be used to analyze the regulations proposed to replace CAIR.
- *EPA Base Case v.4.10* includes ozone and particulate matter standards to the extent that some of the state regulations included in EPA Base Case v.4.10 contain measures to bring non-attainment areas into attainment. A summary of these state regulations can be found in Appendix 3-2 below. Apart from these state regulations, individual permits issued by states in response to ozone and PM standards are only captured (a) to the extent that they are reflected in the NO_X rates reported to EPA under Title IV and the NO_X Budget Program which are incorporated in the base case and (b) to the extent that SO_2 permit limits are used in the base case to define the choice of coal sulfur grades that are available to specific power plants.

- *Regional Haze*: On July 1, 1999, EPA issued Regional Haze Regulations to meet the national goal for visibility established in Section 169A of the CAAA, which calls for "prevention of any future, and the remedying of any existing, impairment of visibility in Class I areas [156 national parks and wilderness areas], which impairment results from manmade air pollution." The regulations required states to submit revised State Implementation Plans (SIPs) that include (1) goals for improving visibility in Class I areas on the 20% worst days and allowing no degradation on the 20% best days and (2) assessments and plans for achieving Best Available Retrofit Technology (BART) emission targets for sources placed in operation between 1962-1977. The revised SIPs were to be submitted between 2004-2006 for areas designated as "attainment" and "unclassified" and between 2006-2008 for "nonattainment" areas. They are represented in EPA Base Case v.4.10 to the extent that SO_2 permit limits derived from the SIPs are used in the base case to define the choice of coal sulfur grades that are available to specific power plants. As discussed in chapter 3, however, the base case includes the sulfur dioxide emission cap (144.7 MTons for all affected fossil fired generating units larger than 25 MW), adopted by the Western Regional Air Partnership states of Arizona,

New Mexico, Oregon, Utah, and Wyoming in response to Section 309 of the federal Regional Haze Rule.

In effect, EPA Base Case v.4.10 offers a projection of the electric sector assuming that the only future environmental regulations are those that were in place at the time the base case was finalized and that have a high likelihood of remaining in force. This simplifying assumption ensures that the base case is policy neutral with respect to prospective, future environmental policies. Table 1-1 lists the types of plants included in the EPA Base Case v.4.10. Table 1-2 lists the emission control technologies available for meeting emission limits in EPA Base Case v.4.10.

Table 1-1 Plant Types in EPA Base Case v.4.10

Fossil Fuel Fired
Coal Steam
Oil/Gas Steam
Combustion Turbine
Combined-Cycle Combustion Turbine
Integrated Gasification Combined-Cycle (IGCC) Coal
Advanced Coal with Carbon Capture
Fluidized Bed Combustion
Non-Fossil Fuel Fired
Nuclear
Renewables and Non-Conventional Technologies
Hydropower
Pumped Storage
Biomass IGCC
Onshore Wind
Offshore Shallow Wind
Offshore Deep Wind
Fuel Cells
Solar Photovoltaics
Solar Thermal
Geothermal
Landfill Gas
Other[1]

Note:

[1] Includes fossil and non-fossil waste plants

Table 1-2 Emission Control Technologies in EPA Base Case v.4.10

Sulfur Dioxide (SO_2)	Nitrogen Oxides (NO_x)
Limestone Forced Oxidation (LSFO) Lime Spray Dryer (LSD)	Combustion controls Selective catalytic reduction (SCR) Selective non-catalytic reduction (SNCR)
Mercury (Hg)	**Carbon Dioxide (CO_2)**
Combinations of SO_2, NO_x, and particulate control technologies Activated Carbon Injection	Carbon Capture and Sequestration

Notes:
1. Though not listed in Table 1-2, biomass co-firing, which is offered as a fuel option in EPA Base Case v.4.10, is also used as a CO_2 emission control option. See section 5.3 in Chapter 5 for a description of the implementation of biomass co-firing in EPA Base Case v.4.10.
2. Fuel switching between coal types and to natural gas is also a compliance option for reducing emissions in EPA Base Case v.4.10

Figure 1-1 provides a schematic of the components of the modeling and data structure used for EPA Base Case v.4.10. This report devotes a separate chapter to all the key components shown in Figure 1-1. Chapter 2 provides an overview of IPM's modeling framework (sometimes referred to as the "IPM Engine"), highlighting the mathematical structure, notable features of the model, programming elements, and model inputs and outputs. The remaining chapters are devoted to different aspects of EPA Base Case v.4.10. Chapter 3 covers the power system operating characteristics captured in EPA Base Case v.4.10. Chapter 4 explores the characterization of electric generation resources. Emission control technologies (chapter 5) and carbon capture, transport and storage (chapter 6) are then presented. Chapter 7 describes certain set-up rules and parameters employed in EPA Base Case v.4.10. Chapter 8 summarizes the base case financial assumptions. The last three chapters discuss the representation and assumptions for fuels in the base case. Coal is covered in chapter 9, natural gas in chapter 10, and other fuels (i.e., fuel oil, biomass, nuclear fuel, and waste fuels) in chapter 11 (along with fuel emission factors).

Figure 1-1 Modeling and Data Structures in EPA Base Case v.4.10

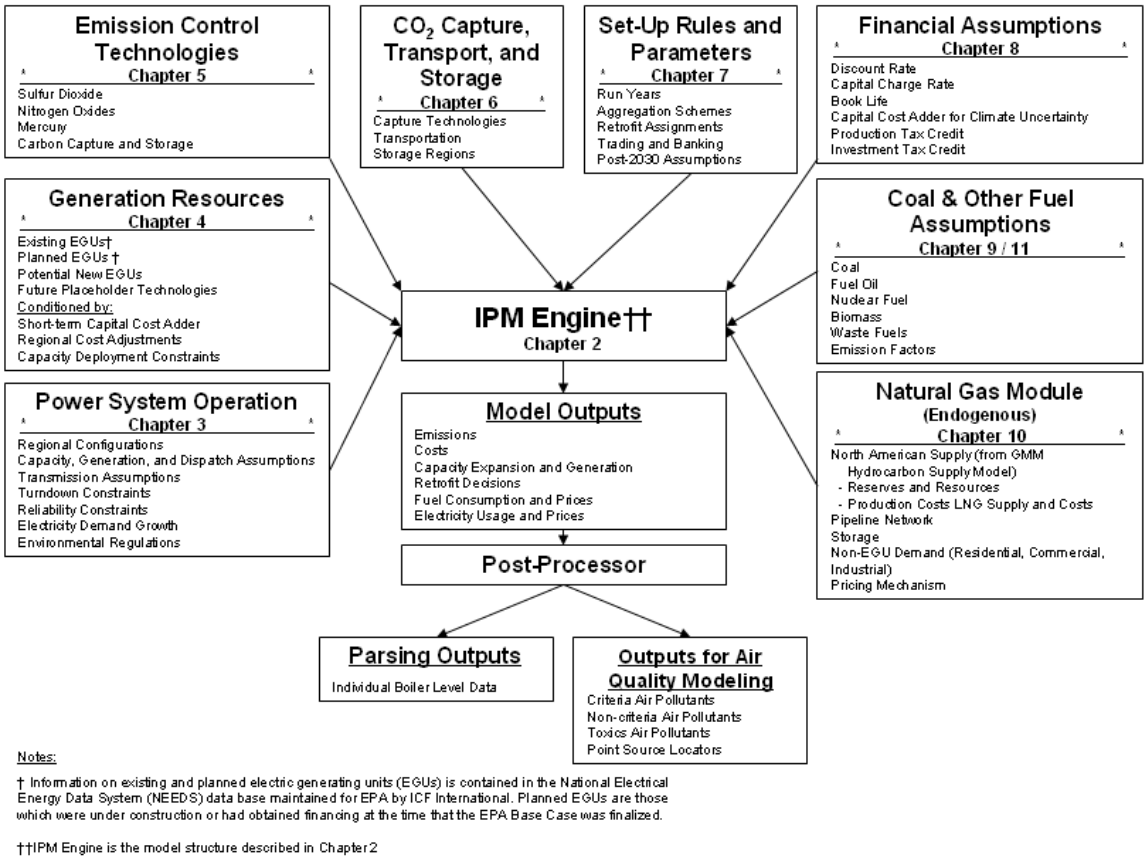

Table 1-3 lists key updates included in EPA Base Case v.4.10 listed in the order they appear in this documentation report. Noted by asterisks in the second column are updates that were "non-routine" in the sense that they constituted new modeling capabilities or notable extensions beyond the capabilities provided in previous EPA base cases or significant reviews of important assumptions. The updates that are not starred represent more routine updates. Equal in importance to the non-routine updates, the routine updates typically require substantial effort and great discipline to maintain. They are critical to the technical credibility of a detailed, bottom-up, data driven model like IPM.

Table 1-3 Key Updates in the EPA Base Case v.4.10

Description	Non-Routine (*)	For More Information
Modeling Framework		
Use of six-segment load duration curves (2012-2030) to enable differentiation of peak and super-peak generating unit dispatch		§2.3.5 - 2.3.6
Power System Operation		
Model region update and inclusion of Canada, Alaska, Hawaii, Puerto Rico, and U.S. Virgin Islands	*	§3.1
Updates based on recent data from EIA, NERC, FERC, etc.		(multiple)
Capacity deployment constraints (for new advanced coal with carbon capture, carbon capture retrofits, and new nuclear)	*	§3.10 App. 3-07 - 3-08

Description	Non-Routine (*)	For More Information
Updated inventory of state emission regulations		App.3-02
Updated inventories of NSR, state, and citizen settlements		App. 3-03 - 3-05
Nuclear retirement at age 60	*	§3.7
Generating Resources		
Updates to NEEDS, the database of existing and planned-committed units and their emission control configurations		§4.1- 4.3
Providing life extension cost option to allow existing units to continue operation over the extended 2012-2050 modeling time horizon in the new base case		§4.2.8
Updated cost and performance characteristics for potential (new) conventional and nuclear generating units, based on comparative cost analyses	*	§4.4.1 - 4.4.2
Adding biomass gasification combined cycle and offshore (shallow and deep) wind as potential (new) renewable generating options	*	§4.4.5
Expanding wind resource base to include 5 wind classes (3-7) by adding new wind classes 3 and 7 using data provided by NREL	*	§4.4.5
Emission Control Technologies		
Complete update of cost and performance assumptions for SO_2 and NO_x emission controls based on engineering studies by Sargent and Lundy	*	§5.1 - 5.2
Inclusion of cost and performance assumptions for SO_2 and NO_x emission controls for units with capacities ranging from 25-100MW	*	§5.2.6
Updated cost and performance assumptions for biomass co-firing by coal units		§5.3
Carbon Capture, Transport and Storage		
Update of the cost and performance characteristics used to represent carbon capture retrofits and new generating units with carbon capture		§6.1
CO_2 transport and storage represented through state level transportation matrix and regional storage cost curves rather than a single cost adder	*	§6.2 - 6.3
Set-Up Parameters and Rules		
Expanded modeling time horizon out to 2050 with six model run years (2012, 2015, 2020, 2030, 2040, 2050)	*	§7.1 and 7.4
Five generic placeholder future generation technologies for later use in comparative scenario analyses		§7.4
Financial assumptions		
Update of discount and capital charge rate assumptions based on a new hybrid capital cost model of utility and merchant finance structures		§8.1.1 and 8.2
Capital cost adder for climate change uncertainty		§8.1.1

Description	Non-Routine (*)	For More Information
Incorporation of latest legislation based tax credits for renewables and nuclear generation		§8.1.1 - 8.1.2
Coal		
Complete update of coal supply curves and transportation matrix	*	§9
Natural Gas		
Development of IPM natural gas module providing completely endogenous comprehensive modeling of North American natural gas system	*	§10
Major revision of unconventional gas resource base, particularly view of shale gas resources	*	§10.3
Base case variant with natural gas resource assumptions similar to AEO 2010		Appendix 10.1
Other Fuels		
Update of biomass supply curves and price assumptions for fuel oil, nuclear fuel and waste fuel	*	§11