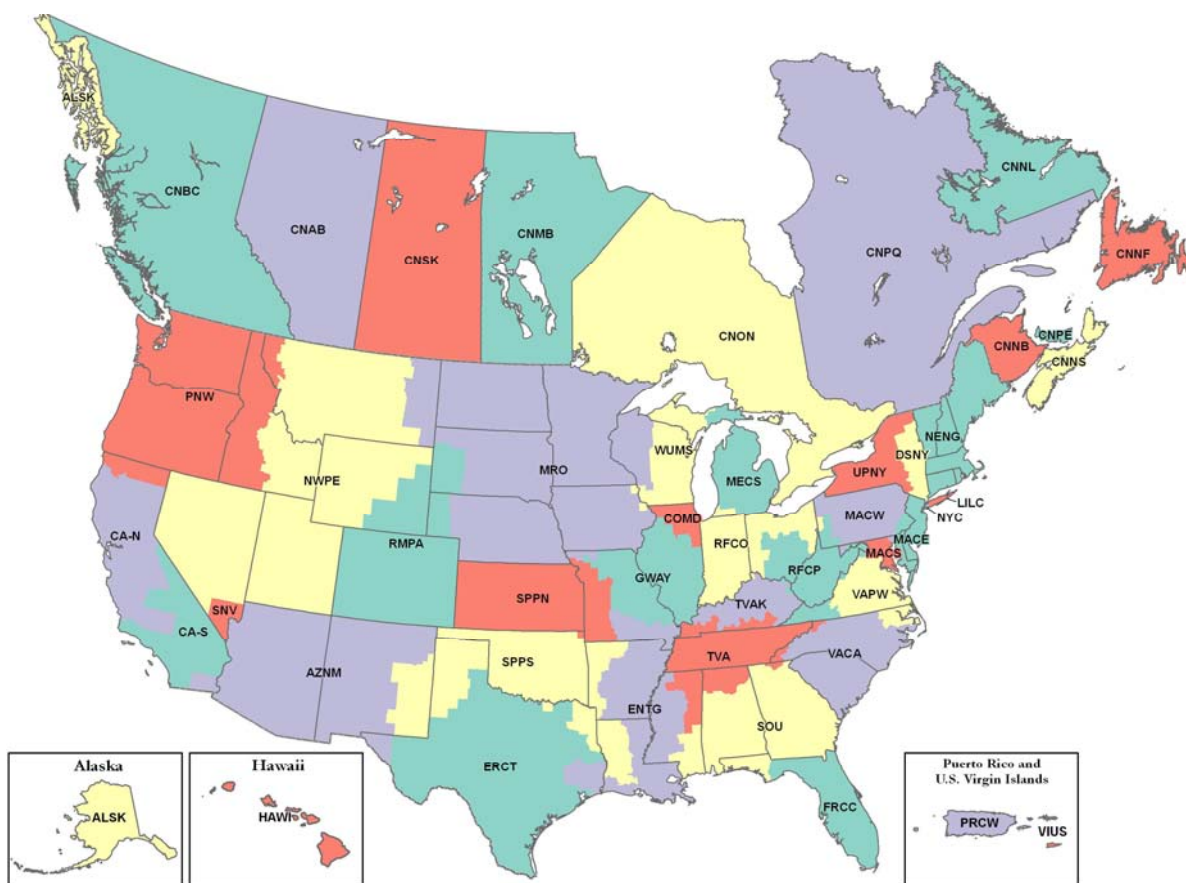


Documentation for EPA Base Case v.4.10 Using the Integrated Planning Model



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.

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

**U.S. Environmental Protection Agency
Clean Air Markets Division
1200 Pennsylvania Avenue, NW (6204J)
Washington, D.C. 20460
(www.epa.gov/airmarkets)**

August 2010

Acknowledgment

This document was prepared by U.S. EPA's Clean Air Markets Division, Office of Air and Radiation. ICF Services Company, L.L.C. provided technical support under EPA Contract EP-W-08-018.

TABLE OF CONTENTS

1	INTRODUCTION	1-1
2	MODELING FRAMEWORK	2-1
2.1	IPM OVERVIEW	2-1
2.1.1	Purpose and Capabilities	2-1
2.1.2	Applications	2-2
2.2	MODEL STRUCTURE AND FORMULATION	2-2
2.2.1	Objective Function	2-2
2.2.2	Decision Variables	2-3
2.2.3	Constraints	2-4
2.3	KEY METHODOLOGICAL FEATURES OF IPM	2-4
2.3.1	Model Plants	2-4
2.3.2	Model Run Years	2-6
2.3.3	Cost Accounting	2-6
2.3.4	Modeling Wholesale Electric Markets	2-6
2.3.5	Load Duration Curves (LDC)	2-7
2.3.6	Dispatch Modeling	2-9
2.3.7	Reliability Modeling	2-9
2.3.8	Fuel Modeling	2-10
2.3.9	Transmission Modeling	2-10
2.3.10	Perfect Competition and Perfect Foresight	2-10
2.3.11	Air Regulatory Modeling	2-10
2.4	HARDWARE AND PROGRAMMING FEATURES	2-11
2.4.1	Data Parameters for Model Inputs	2-11
2.4.2	Model Outputs	2-12
	Appendix 2-1 Load Duration Curves Used in EPA Base Case v.4.10	2-1
3	POWER SYSTEM OPERATION ASSUMPTIONS	3-1
3.1	MODEL REGIONS	3-1
3.2	ELECTRIC LOAD MODELING	3-1
3.2.1	Demand Elasticity	3-4
3.2.2	Net Internal Demand (Peak Demand)	3-4
3.2.3	Regional Load Shapes	3-5
3.3	TRANSMISSION	3-5
3.3.1	Inter-regional Transmission Capability	3-5
3.3.2	Joint Transmission Capacity and Energy Limits	3-9
3.3.3	Transmission Link Wheeling Charge	3-10
3.3.4	Transmission Losses	3-11
3.4	INTERNATIONAL IMPORTS	3-11
3.5	CAPACITY, GENERATION, AND DISPATCH	3-11
3.5.1	Availability	3-11
3.5.2	Capacity Factor	3-12
3.5.3	Turndown	3-13
3.6	RESERVE MARGINS	3-13
3.7	POWER PLANT LIFETIMES	3-15
3.8	HEAT RATES	3-17

3.9	EXISTING ENVIRONMENTAL REGULATIONS	3-17
3.9.1	SO ₂ Regulations	3-17
3.9.2	NO _x Regulations	3-18
3.9.3	CO ₂ Regulations and Renewable Portfolio Standards.....	3-20
3.9.4	State Specific Environmental Regulations	3-20
3.9.5	New Source Review (NSR) Settlements.....	3-20
3.9.6	Emission Assumptions for Potential (New) Units.....	3-20
3.10	CAPACITY DEPLOYMENT CONSTRAINTS	3-21
	Appendix 3-1 NO _x Rate Development in EPA Base Case v.4.10	3-1.1
	Appendix 3-2 State Power Sector Regulations included in EPA Base Case v.4.10	3-2.1
	Appendix 3-3 New Source Review (NSR) Settlements in EPA Base Case v.4.10	3-3.1
	Appendix 3-4 State Settlements in EPA Base Case v.4.10	3-4.1
	Appendix 3-5 Citizen Settlements in EPA Base Case v.4.10.....	3-5.1
	Appendix 3-6 Renewable Portfolio Standards in EPA Base Case v.4.10	3-6.1
	Appendix 3-7 Capacity Deployment Limits for Advanced Coal with CCS and New Nuclear in EPA Base Case v.4.10.....	3-7.1
	Appendix 3-8 Nuclear Capacity Deployment Constraint in EPA Base Case v.4.10.....	3-8.1
	Appendix 3-9 Complete Availability Assumptions in EPA Base Case v.4.10.....	3-9.1
4	GENERATING RESOURCES.....	4-1
4.1	NATIONAL ELECTRIC ENERGY DATA SYSTEM (NEEDS)	4-1
4.2	EXISTING UNITS	4-1
4.2.1	Population of Existing Units	4-1
4.2.2	Capacity	4-4
4.2.3	Plant Location	4-5
4.2.4	Online Year	4-5
4.2.5	Unit Configuration	4-5
4.2.6	Model Plant Aggregation.....	4-5
4.2.7	Cost and Performance Characteristics of Existing Units	4-9
4.2.8	Life Extension Costs for existing units	4-10
4.3	PLANNED-COMMITTED UNITS	4-13
4.3.1	Population and Model Plant Aggregation.....	4-13
4.3.2	Capacity.....	4-17
4.3.3	State and Model Region	4-17
4.3.4	Online and Retirement Year	4-18
4.3.5	Unit Configuration and Cost-and-Performance.....	4-18
4.4	POTENTIAL UNITS	4-18
4.4.1	Methodology Used to Derive the Cost and Performance Characteristics of Conventional Potential Units	4-18
4.4.2	Cost and Performance for Potential Conventional Units.....	4-19
4.4.3	Short-Term Capital Cost Adder.....	4-21
4.4.4	Regional Cost Adjustment	4-21
4.4.5	Cost and Performance for Potential Renewable Generating and Non-4- Conventional Technologies	4-25
4.5	NUCLEAR UNITS	4-44
4.5.1	Existing Nuclear Units.....	4-44
4.5.2	Potential Nuclear Units	4-45
	Appendix 4-1 Representative Wind Generation Profiles in EPA Base Case v.4.10.....	4-1.1
	Appendix 4-2 Representative Solar Generation Profiles in EPA Base v.4.10.....	4-2.1
	Appendix 4-3 Characteristics of Existing Nuclear Units	4-3.1
5	EMISSION CONTROL TECHNOLOGIES	5-1

5.1	SULFUR DIOXIDE CONTROL TECHNOLOGIES.....	5-1
5.1.1	Methodology for Obtaining SO ₂ Controls Costs.....	5-2
5.2	NITROGEN OXIDES CONTROL TECHNOLOGY.....	5-7
5.2.1	Combustion Controls	5-7
5.2.2	Post-combustion Controls.....	5-8
5.2.3	Methodology for Obtaining SCR Costs for Coal Units	5-9
5.2.4	Methodology for Obtaining SCR Costs for Oil/Gas Steam units.....	5-12
5.2.5	Methodology for Obtaining SNCR Costs	5-12
5.2.6	SO ₂ and NO _x Controls for Units with Capacities from 25 MW to 100 MW (25 M ≤ capacity < 100 MW).....	5-13
5.3	BIOMASS CO-FIRING	5-14
5.4	MERCURY CONTROL TECHNOLOGIES.....	5-15
5.4.1	Mercury Content of Fuels.....	5-16
5.4.2	Mercury Emission Modification Factors	5-17
5.4.3	Mercury Control Capabilities.....	5-18
	Appendix 5-1 Example Cost Calculation Worksheets for SO ₂ Control Technologies in EPA Base Case v.4.10	5-1
	Appendix 5-2 Example Cost Calculation Worksheets for NO _x Post-Combustion Control Technologies in EPA Base Case v.4.10.....	5-1
6	CO₂ CAPTURE, TRANSPORT, AND STORAGE.....	6-1
6.1	CO₂ CAPTURE	6-1
6.2	CO₂ STORAGE.....	6-2
6.3	CO₂ TRANSPORT	6-5
	Appendix 6-1 CO ₂ Storage Cost Curves in EPA Base Case 4.10	6-1.1
	Appendix 6-2 CO ₂ Transportation Matrix in EPA Base Case v.4.10	6-2.1
7	SET-UP PARAMETERS AND RULES	7-1
7.1	RUN YEAR MAPPING	7-1
7.2	RETROFIT ASSIGNMENTS	7-1
7.3	TRADING AND BANKING.....	7-3
7.4	POST-2030 MODELING ASSUMPTIONS AND CAPABILITIES.....	7-4
8	FINANCIAL ASSUMPTIONS.....	8-1
8.1	SUMMARY OF KEY FINANCIAL PARAMETERS.....	8-1
8.1.1	Capital Charge Rate, Book Life, and Discount Rate for Capital Expenditures	8-1
8.1.2	ARRA Production and Investment Tax Credit (PTC and ITC) for Renewables	8-2
8.1.3	Discount Rate for Non-Capital Expenditures	8-3
8.1.4	Inter-temporal Allowance Price Calculation	8-3
8.1.5	Nominal and Real Dollars	8-3
8.2	DEVELOPMENT OF THE FINANCIAL ASSUMPTIONS FOR EPA BASE CASE V.4.10	8-3
8.2.1	Introduction	8-3
8.2.2	Method for Deriving Discount Rate and Capital Charge Rate in EPA Base Case v 4.10	8-4
8.2.3	Calculation of the Hybrid Capital Charge Rates	8-7
8.2.4	Development of Merchant Financing Parameters.....	8-8
8.2.5	Development of Utility Financing Parameters.....	8-10
8.2.6	Development of Other Parameters	8-10
9	COAL	9-1

9.1	COAL MARKET REPRESENTATION IN EPA BASE CASE v.4.10	9-1
9.1.1	Coal Supply Regions	9-2
9.1.2	Coal Demand Regions	9-3
9.1.3	Coal Quality Characteristics	9-9
9.1.4	Emission Factors	9-10
9.1.5	Coal Grade Assignments	9-15
9.2	COAL SUPPLY CURVES	9-16
9.2.1	Nature of Supply Curves Developed for EPA Base Case v.4.10	9-16
9.2.2	Procedure Employed in Determining Mining Costs	9-17
9.2.3	Supply Curve Development	9-20
9.2.4	Data Sources Used to Build the Curves	9-21
9.2.5	Procedure Used In Determining Mine Productivity	9-22
9.2.6	Procedure to Determine Total Recoverable Reserves by Region and Type	9-22
9.2.7	New Mine Assumptions	9-23
9.2.8	Other Notable Procedures	9-23
9.2.9	Region Specific Assumptions and Outlooks	9-23
9.2.10	Explanation of Coal Supply Curve Extensions to 2040	9-25
9.3	COAL TRANSPORTATION	9-25
9.3.1	Coal Transportation Matrix Overview	9-26
9.3.2	Calculation of Supply/Demand Region Distances	9-26
9.3.3	Overview of Rail Rates	9-27
9.3.4	Truck rates	9-30
9.3.5	Barge and Lake Vessel Rates	9-30
9.3.6	Transportation Rates for Imported Coal	9-31
9.3.7	Other Transportation Costs	9-32
9.3.8	Long-Term Escalation of Transportation Rates	9-32
9.3.9	Market Drivers Moving Forward	9-34
9.3.10	Other Considerations	9-36
9.4	COAL EXPORTS, IMPORTS, AND NON-ELECTRIC SECTORS DEMAND	9-36
	Appendix 9-1. Illustrative Example of Wood Mackenzie Costing Procedure Used in Developing EPA's Coal Supply Curves	9-1.1
	Appendix 9-2 New Mines Included in 2040 Curves	9-2.1
	Appendix 9-3 Coal Transportation Matrix in EPA Base Case v.4.10	9-3.1
	Appendix 9-4 Coal Supply Curves in EPA Base Case v.4.10	9-4.1
10	NATURAL GAS	10-1
10.1	OVERVIEW OF IPM'S NATURAL GAS MODULE	10-1
10.2	KEY COMPONENTS OF THE NEW IPM NATURAL GAS MODULE	10-4
10.2.1	Note on the Modeling Time Horizon and Pre- and Post-2030 Input Assumptions	10-6
10.3	RESOURCE CHARACTERIZATION AND ECONOMIC EVALUATION	10-7
10.3.1	Resource and Reserves Assessment	10-8
10.3.2	Frontier Resources (Alaska and Mackenzie Delta)	10-10
10.3.3	Use of the HSM resource and reserves data in EPA Base Case using IPM v.4.10 Natural Gas Module	10-12
10.3.4	Undiscovered Resource Appreciation	10-13
10.4	EXPLORATION, DEVELOPMENT, AND PRODUCTION COSTS AND CONSTRAINTS	10-14
10.4.1	Exploration and Development Cost	10-14
10.4.2	Resource Discovery and Drilling Constraints	10-17
10.4.3	Reserves-to-Production (R/P) Ratio	10-19
10.4.4	Variable Costs, Natural Gas Liquid Share, and Crude Oil Share	10-19
10.4.5	Lease and Plant Gas Use	10-20

10.5 LIQUEFIED NATURAL GAS (LNG) IMPORTS	10-20
10.5.1 Liquefaction Facilities and LNG Supply	10-20
10.5.2 Regasification Facilities	10-21
10.5.3 LNG Regasification Capacity Expansions	10-22
10.6 END USE DEMAND	10-23
10.6.1 Step 1: Developing Sector Specific Econometric Models of Non-Power Sector Demand.....	10-23
10.6.2 Step 2: Use projections based on the GMM econometric models to produce monthly gas demand curves by sector and demand node.....	10-25
10.6.3 Step 3: Develop non-electric sector natural gas demand curves that correspond to the seasons and segments in the load duration curves used in IPM.....	10-25
10.7 PIPELINE NETWORK	10-27
10.7.1 Network Structure	10-27
10.7.2 Pipeline Transportation Costs.....	10-28
10.7.3 Pipeline Capacity Expansion Logic.....	10-29
10.8 GAS STORAGE.....	10-30
10.8.1 Storage Capacity and Injection/Withdrawal Constraints	10-33
10.8.2 Variable Cost and Fuel Use	10-33
10.8.3 Storage Capacity Expansion Logic.....	10-34
10.9 FUEL PRICES.....	10-35
10.9.1 Crude Oil and Natural Gas Liquids Prices	10-35
10.9.2 Natural Gas Prices.....	10-36
10.10 OUTPUTS AND PROXY NATURAL GAS SUPPLY CURVES	10-36
10.10.1 Outputs from the New IPM Natural Gas Module.....	10-36
10.10.2 Proxy Natural Gas Supply Curves	10-36
Appendix 10-1 EPA Base Case v.4.10 with AEO Gas Resource Assumptions.....	10-1.1
11 OTHER FUELS AND FUEL EMISSION FACTOR ASSUMPTIONS	11-1
11.1 FUEL OIL.....	11-1
11.2 BIOMASS	11-2
11.3 NUCLEAR FUEL.....	11-3
11.4 WASTE FUELS	11-3
11.5 FUEL EMISSION FACTORS	11-5
Appendix 11-1 Biomass Supply Curve in EPA Base Case v.4.0	11-1

LIST OF TABLES

Table 1-1 Plant Types in EPA Base Case v.4.10.....	1-2
Table 1-2 Emission Control Technologies in EPA Base Case v.4.10	1-3
Table 1-3 Key Updates in the EPA Base Case v.4.10	1-4
Table 3-1 Mapping of NERC Regions and NEMS Regions with EPA Base Case v.4.10 Model Regions	3-3
Table 3-2 Electric Load Assumptions in EPA Base Case v.4.10	3-4
Table 3-3 National Non-Coincidental Net Internal Demand	3-5
Table 3-4 Annual Transmission Capabilities of U.S. Model Regions in EPA Base Case v.4.10	3-6
Table 3-5 Annual Joint Capacity and Energy Limits to Transmission Capabilities Between Model Regions in EPA Base Case v.4.10	3-9
Table 3-6 International Electricity Imports in EPA Base Case v.4.10	3-11
Table 3-7 Availability Assumptions in the EPA Base Case v.4.10	3-12
Table 3-8 Seasonal Hydro Capacity Factors (%) in the EPA Base Case v.4.10	3-12
Table 3-9 Planning Reserve Margins in EPA Base Case v.4.10	3-14
Table 3-10 Lower and Upper Limits Applied to Heat Rate Data in NEEDS v.4.10	3-17
Table 3-11 Emission and Removal Rate Assumptions for Potential (New) Units in EPA Base Case v.4.10	3-23
Table 4-1 Data Sources for NEEDS v.4.10 for EPA Base Case v.4.10	4-2
Table 4-2 Rules Used in Populating NEEDS v.4.10 for EPA Base Case v.4.10.....	4-3
Table 4-3 Summary Population (through 2006) of Existing Units in NEEDSv.4.10 for EPA Base Case v.4.10	4-3
Table 4-4 Hierarchy of Data Sources for Capacity in NEEDS v.4.10.....	4-4
Table 4-5 Capacity-Parsing Algorithm for Steam Units in NEEDS v.4.10.....	4-4
Table 4-6 Data Sources for Unit Configuration in NEEDS v.4.10 for EPA Base Case v.4.10	4-6
Table 4-7 Aggregation Profile of Model Plants as Provided at Set Up of EPA Base Case v.4.10	4-7
Table 4-8 VOM Assumptions (2007\$) in EPA Base Case v.4.10	4-9
Table 4-9 FOM Assumptions Used in EPA Base Case v.4.10.....	4-11
Table 4-10 Life Extension Cost Assumptions Used in EPA Base Case v.4.10.....	4-13
Table 4-11 Summary of Planned-Committed Units in NEEDS v.4.10 for EPA Base Case v.4.10	4-14
Table 4-12 Planned-Committed Units by Model Region in NEEDS v.4.10 for EPA Base Case v.4.10.....	4-14
Table 4-13 Performance and Unit Cost Assumptions for Potential (New) Capacity from Conventional Technologies in EPA Base Case v4.10	4-20
Table 4-14 Short-Term Capital Cost Adders for New Power Plants in EPA Base Case v.4.10 (2007\$).....	4-23
Table 4-15 Regional Cost Adjustment Factors for Conventional and Renewable Generating Technologies in EPA Base Case v.4.10	4-25
Table 4-16 Performance and Unit Cost Assumptions for Potential (New) Renewable and Non-Conventional Technology Capacity in EPA Base Case v4.10	4-27
Table 4-17 Onshore Regional Potential Wind Capacity (MW) by Wind and Cost Class in EPA Base Case v.4.10	4-29
Table 4-18 Offshore Shallow Regional Potential Wind Capacity (MW) by Wind and Cost Class in EPA Base Case v.4.10	4-32

Table 4-19	Offshore Deep Regional Potential Wind Capacity (MW) by Wind and Cost Class in EPA Base Case v.4.10	4-34
Table 4-20	Onshore Reserve Margin Contribution an Average Capacity Factor by Wind Class and Model Region.....	4-37
Table 4-21	Offshore Shallow Reserve Margin Contribution an Average Capacity Factor by Wind Class and Model Region	4-37
Table 4-22	Offshore Deep Reserve Margin Contribution an Average Capacity Factor by Wind Class and Model Region	4-38
Table 4-23	Capital Cost Adjustment Factors for New Wind Plants in Base Case v.4.10.....	4-39
Table 4-24	Example Calculations Of Wind Generation Potential, Reserve Margin Contribution, And Capital Cost For Onshore Wind In CA-N At Wind Class 7, Cost Class 2	4-40
Table 4-25	Solar Reserve Margin Contribution and Average Capacity Factor by Model Region	4-41
Table 4-26	Regional Assumptions on Potential Geothermal Electric Capacity.....	4-42
Table 4-27	Potential Geothermal Capacity and Cost Characteristics by Model Region	4-42
Table 4-28	Regional Assumptions on Potential Electric Capacity from New Landfill Gas Units (MW).....	4-43
Table 4-29	Nuclear Upgradings (MW) as Incorporated in EPA Base Case v.4.10 from AEO 2010	4-45
Table 5-1	Summary of Emission Control Technology Retrofit Options in EPA Base Case v.4.10	5-1
Table 5-2	Summary of Retrofit SO ₂ Emission Control Performance Assumptions	5-2
Table 5-3	Capital Cost Modules and Their Governing Variables for SO ₂ and NO _x Emission Controls	5-3
Table 5-4	Illustrative Scrubber Costs (2007\$) for Representative Sizes and Heat Rates under the Assumptions in EPA Base Case v.4.10.....	5-6
Table 5-5	Cost (2007\$) of NO _x Combustion Controls for Coal Boilers (300 MW Size).....	5-7
Table 5-6	Incremental Combustion NO _x Controls in EPA Base Case v.4.10.....	5-8
Table 5-7	Summary of Retrofit NO _x Emission Control Performance Assumptions	5-8
Table 5-8	Illustrative Post Combustion NO _x Controls for Coal Plants Costs (2007\$) for Representative Sizes and Heat Rates under the Assu Assumptions in EPA Base Case v.4.10	5-11
Table 5-9	Post-Combustion NO _x Controls for Oil/Gas Steam Units in EPA Base Case v.4.10	5-12
Table 5-10	Biomass Cofiring for Coal Plants	5-15
Table 5-11	Mercury Clusters and Mercury Content of Coal by IPM Coal Types.....	5-17
Table 5-12	Assumptions on Mercury Concentration in Non-Coal Fuel in EPA Base Case v.4.10	5-17
Table 5-13	Mercury Emission Modification Factors Used in EPA Base Case v.4.10.....	5-19
Table 5-14	Definition of Acronyms for Existing Controls	5-26
Table 5-15	Key to Burner Type Designations in Table 5-13	5-26
Table 5-16	Illustrative Activated Carbon Injection Costs (2007\$) for Representative Sizes under the Assumptions in EPA Base Case v.4.10.....	5-28
Table 5-17	Assignment Scheme for Mercury Emissions Control Using Activated Carbon Injection (ACI) in EPA Base Case v.4.10.....	5-29
Table 6-1	Performance and Unit Cost Assumptions for Carbon Capture Retrofits on Pulverized Coal Plants.....	6-1

Table 6-2 CO ₂ Transport Cost Calculation Example – MACS to Louisiana Onshore	6-5
Table 7-1 Run Years and Analysis Year Mapping Used in the EPA Base Case v.4.10	7-1
Table 7-2 First Stage Retrofit Assignment Scheme in EPA Base Case v.4.10.....	7-2
Table 7-3 Second Stage Retrofit Assignment Scheme in EPA Base Case v.4.10	7-3
Table 7-4 Trading and Banking Rules in EPA Base Case v.4.10	7-4
Table 7-5 Post-2030 Assumptions in EPA Base Case v.4.10.....	7-5
Table 8-1 U.S. Discount Rates and Capital Charge Rates in EPA Base Case v4.10.....	8-2
Table 8-2 Capital Structure Assumptions for EPA Base Case v4.10.....	8-6
Table 8-3 Debt Rates for EPA Base Case v4.10	8-8
Table 8-4 Book Life, Debt Life and Depreciation Schedules for EPA Base Case v. 4.10	8-11
Table 9-1 Coal Supply Regions in EPA Base Case.....	9-2
Table 9-2 Coal Demand Regions in EPA Base Case	9-3
Table 9-3 Coal Rank Heat Content Ranges.....	9-10
Table 9-4 Coal Grade SO ₂ Content Ranges	9-10
Table 9-5 Coal Quality Characteristics by Supply Region and Coal Grade	9-11
Table 9-6 SO ₂ Emission Factors of Coal Used in EPA Base Case v.4.10.....	9-13
Table 9-7 Mercury Emission Factors of Coal Used in EPA Base Case v.4.10	9-14
Table 9-8 Ash Emission Factors of Coal Used in EPA Base Case v.4.10	9-14
Table 9-9 CO ₂ Emission Factors of Coal Used in EPA Base Case v.4.10.....	9-15
Table 9-10 Example of Coal Assignments Made in EPA Base Case	9-16
Table 9-11 Basin-Level Groupings Used in Preparing v.4.0 Coal Supply Curves	9-17
Table 9-12 Rail Competition Definitions	9-28
Table 9-13 Assumed Eastern Rail Rates (2007 mills/ton-mile).....	9-29
Table 9-14 Assumed Midwestern Rail Rates (2007 mills/ton-mile).....	9-29
Table 9-15 Assumed Non-PRB Western Rail Rates (2007 mills/ton-mile)	9-30
Table 9-16 Assumed PRB Western Rail Rates (2007 mills/ton-mile)	9-30
Table 9-17 Assumed Truck Rates (2007 Real Dollars).....	9-30
Table 9-18 Assumed Barge Rates (2007 Real Dollars)	9-31
Table 9-19 Assumed Transportation Rates for Imported Coal (2007 Real Dollars).....	9-31
Table 9-20 Assumed Other Transportation Rates (2007 Real Dollars).....	9-32
Table 9-21 EIA AEO Diesel Fuel Forecast, 2012-2030 (2007 Real Dollars)	9-34
Table 9-22 ABARE Forecast of Iron Ore Prices.....	9-35
Table 9-23 Assumed Production Growth Rates	9-36
Table 9-24 Coal Exports.....	9-37
Table 9-25 Residential, Commercial, and Industrial Demand.....	9-38
Table 9-26 Coal Import Limits	9-38
Table 10-1 List of Nodes	10-5
Table 10-2 List of Gas Supply Regions.....	10-1
Table 10-3 List of Key Pipelines.....	10-3
Table 10-4 U.S. and Canada Natural Gas Resources and Reserves	10-10
Table 10-5 Exploration and Development Assumptions for EPA Base Case v.4.10	10-17
Table 10-6 North American LNG Regasification Facilities	10-21
Table 10-7 Summer and Winter Load Segments in EPA Base Case v.4.10	10-26
Table 10-8 List of Storage Nodes.....	10-31
Table 10-9 Storage Capacity and Injection/Withdrawal Rates (EOY 2010).....	10-33

Table 10-10 Base Year 2011 Average Levelized Storage Capital Cost.....	10-35
Table 10-11 Proxy Natural Gas Supply Curves for EPA Base Case v.4.10.....	10-37
Table 10-12 Glossary of Natural Gas Terms Used in Documentation	10-38
Table 11-1 Fuel Oil Prices by NEMS Region in EPA Base Case v.4.10.....	11-1
Table 11-2 Non-Electric Biomass Demand by NEMS Region in EPA Base Case v.4.10	11-2
Table 11-3 Waste Fuels in NEEDS, v.4.10 and EPA Base Case v.4.10	11-4
Table 11-4 Fuel Emission Factor Assumptions in EPA Base Case v.4.10	11-5

LIST OF FIGURES

Figure 1-1 Modeling and Data Structures in EPA Base Case v.4.10	1-4
Figure 2-1 Hypothetical Chronological Hourly Load Curve and Seasonal Load Duration Curve in EPA Base Case v.4.10.....	2-7
Figure 2-2 Stylized Depiction of Load Duration Curve Used in EPA Base Case v.4.10	2-8
Figure 2-3 Stylized Dispatch Order in EPA Base Case v.4.10.....	2-9
Figure 3-1 EPA Base Case v.4.10 Model Regions	3-2
Figure 3-2 Scheduled Retirements of Existing Nuclear Capacity Under 60-Year Life Assumption	3-15
Figure 9-1 Map of the Coal Supply Regions in EPA Base Case v.4.10	9-3
Figure 9-2 Cluster Mapping Example --- BG Coal.....	9-15
Figure 9-3 Cost Calculations Included When Developing Coal Supply Curves (based on a Powder River Basin Mine Supply Curve Example).....	9-18
Figure 9-4 Illustration of Preliminary Step in Developing a Cumulative Coal Supply Curve	9-20
Figure 9-5 Illustration of Final Step in Developing a Cumulative Coal Supply Curve	9-21
Figure 9-6 Example Coal Supply Curve in Stepped Format	9-21
Figure 9-7 Calculation of Multi-Mode Transportation Costs (Example).....	9-26
Figure 9-8 Coal Demand Region with Multiple Coal Supply Regions	9-27
Figure 9-9 Rail Cost Indices Performance (2Q2003-2Q2008)	9-33
Figure 9-10 Long-Run Marginal Cost Breakdown by Transportation Mode	9-34
Figure 10-1 Modeling and Data Structure in EPA Base Case v.4.10.....	10-2
Figure 10-2 Natural Gas Module in EPA Base Case v.4.10.	10-3
Figure 10-3 Gas Transmission Network Map.....	10-5
Figure 10-4 Gas Supply Regions Map	10-8
Figure 10-5 Gas Demand Regions Map.....	10-3
Figure 10-6 Natural Gas Storage Facility Node Map	10-7
Figure 10-7 Resource Cost Curves at the End of Year 2010.....	10-13
Figure 10-8 Exploration & Development and Production Processes and Costs to Bring Undiscovered Resource into Reserves and Production	10-14
Figure 10-9 E&D and Production Technology Improvement Factor.....	10-15
Figure 10-10 Incremental E&D Cost (EOY 2010) by Percentage of Resource Found.....	10-15
Figure 10-11 Drilling Rig Speed Constraint.....	10-19
Figure 10-12 North American LNG Supply Curves	10-21
Figure 10-13 North American LNG Regasification Facilities Map	10-22
Figure 10-14 Examples of Firm Demand Curves by Electric Load Segment.....	10-26
Figure 10-15 Examples of Interruptible Demand Curves by Electric Load Segment	10-27
Figure 10-16 New England Pipeline Corridors in 2020	10-28
Figure 10-17 Example Pipeline Discount Curve.....	10-29
Figure 10-18 Pipeline Cost Growth Factor	10-29
Figure 10-19 Storage Cost Growth Factor	10-34
Figure 10-20 Example Maximum Storage Capacity Expansion	10-34
Figure 10-21 Crude Oil and NGL Prices	10-36

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 (SO₂), nitrogen oxides (NO_x), carbon dioxide (CO₂), 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 SO₂ 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 SO₂ 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

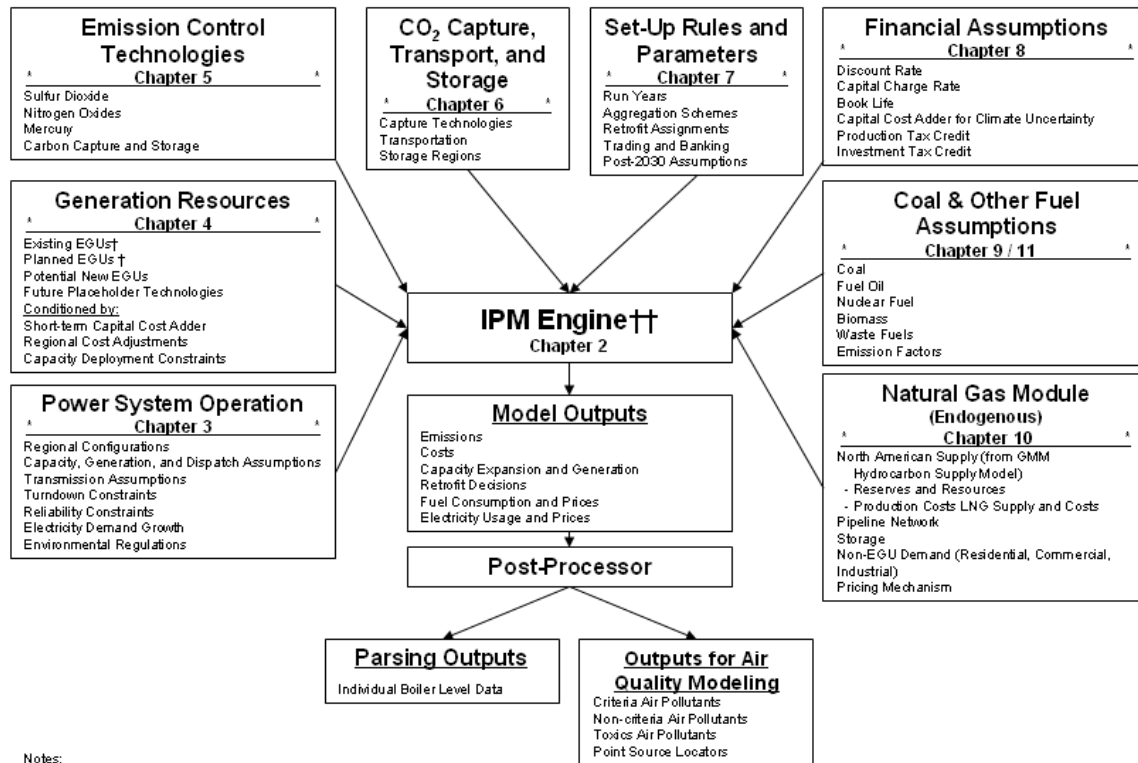
Sulfur Dioxide (SO₂)	Nitrogen Oxides (NO_x)
Limestone Forced Oxidation (LSFO) Lime Spray Dryer (LSD)	Combustion controls Selective catalytic reduction (SCR) Selective non-catalytic reduction (SNCR)
Mercury (Hg)	Carbon Dioxide (CO₂)
Combinations of SO ₂ , NO _x , and particulate control technologies Activated 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 CO₂ 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



Notes:

† Information on existing and planned electric generating units (EGUs) is contained in the National Electrical Energy Data System (NEEDS) data base maintained for EPA by ICF International. Planned EGUs are those which were under construction or had obtained financing at the time that the EPA Base Case was finalized.

††IPM Engine is the model structure described in Chapter 2

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