1.   Introduction

1.1   Executive Summary

This document describes the nature, structure, and capabilities of the Integrated Planning Model (IPM) and the assumptions underlying the EPA's Power Sector Modeling Platform version 6 (EPA Platform v6) that was developed by the U.S. Environmental Protection Agency (EPA) with technical support from ICF, 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, 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), mercury (Hg), and HCl from the electric power sector.

This introduction chapter summarizes the key modeling capabilities and major data elements that are described in greater detail in the subsequent chapters.

EPA Platform v6 incorporates important structural improvements and data updates with respect to the previous version (v5.13). A new version number (moving from v5 to v6) indicates a substantial change to the architecture (such as this version's significantly more detailed representation of the load segments and seasons). EPA Platform v6's November 2018 Reference Case uses Energy Information Agency's (EIA) Annual Energy Outlook (AEO) 2018 demand projections.

EPA Platform v6 documentation includes assumptions and data values that were used to produce the November 2018 Reference Case; for subsequent runs that examine various future scenarios, we include separate documentation that makes clear where any assumptions or data values differ from the November 2018 Reference Case conditions shown in this core documentation for Platform v6. EPA Platform v6 November 2018 Reference Case serves as the starting point against which key drivers of the power system dynamics (such as level of fuel prices, high or low costs for generation technologies and high or low demand growth) are compared and analyzed. EPA Platform v6 is coupled with a Results Viewer to facilitate easy comparison of different scenario projections and linking them with historical data.

When policy analysis is conducted using EPA Platform v6, relevant assumptions and documentation will be provided elsewhere accordingly.

EPA Platform v6 November 2018 Reference Case 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 as documented in Section 3.9. Section 3.9 contains a detailed discussion of the environmental regulations included in EPA Platform v6, which are summarized below.

- EPA Platform v6 includes the Cross-State Air Pollution Rule (CSAPR) Update Rule, a federal regulatory measure affecting 22 states to address transport under the 1997 and 2006 National Ambient Air Quality Standards (NAAQS) for ozone and fine particles.

- EPA Platform v6 reflects the Standards of Performance for Greenhouse Gas Emissions from New, Modified, and Reconstructed Stationary Sources: Electric Utility Generating Units.[1]

- EPA Platform v6 includes the Mercury and Air Toxics Rule (MATS),[2] which was finalized in 2011. MATS establishes National Emissions Standards for Hazardous Air Pollutants (NESHAP) for the "electric utility steam generating unit" source category.

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[1] 80 FR 64510

[2] 82 FR 16736

- EPA Platform v6 reflects current and existing state regulations. A summary of these state regulations can be found in Table 3-23.

- EPA Platform v6 reflects the final actions EPA has taken to implement the Regional Haze Regulations and Guidelines for Best Available Retrofit Technology (BART) Determinations Final Rule[3]. This regulation requires 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 and 1977. Since 2010, EPA has approved SIPs or, in a very few cases, put in place regional haze Federal Implementation Plans for several states. The BART limits approved in these plans (as of summer 2017) that will be in place for EGUs are represented in the EPA Platform v6.

- EPA Platform v6 also includes three non-air federal rules affecting EGUs: National Pollutant Discharge Elimination System-Final Regulations to Establish Requirements for Cooling Water Intake Structures at Existing Facilities and Amend Requirements at Phase I Facilities, Hazardous and Solid Waste Management System; Disposal of Coal Combustion Residuals From Electric Utilities; and the Effluent Limitation Guidelines and Standards for the Steam Electric Power Generating Point Source Category.[4]

Table 1-1 lists key updates included in EPA Platform v6 incremental to the previous major platform (v5) with the corresponding data sources. Highlighted items are the updates incremental to the previous release of EPA's v6 Platform (May 2018). The updates are listed in the order in which they appear in the documentation.

Table 1-1 Key Updates in the EPA Platform v6 November 2018 Reference Case

Description	For More Information
Modeling Framework	
Modeling time horizon out to 2050 with eight model run years (2021, 2023, 2025, 2030, 2035, 2040, 2045, 2050)	Table 2-1
Incorporation of three seasons	Section 2.3.5
Increasing the number of load segments to 72 per year	Section 2.3.5
All costs and prices are in 2016 dollars	
Power System Operation	
Updates based on recent data from EIA, NERC, and FERC	Chapter 3
Updated inventory of state emission regulations	Section 3.9
CSAPR, MATS, and BART are reflected	Section 3.9.3
Updated RPS standards for CT and NJ	Table 3-19
Updated inventories of NSR, state, and citizen settlements (as of May 2018)	Table 3-24, Table 3-25, and Table 3-26
Updated transmission Total Transfer Capability's (TTC) and regional reserve margins (2015-2016 ISO/RTO NERC Reports)	Table 3-5 and Table 3-21
AEO 2018 NEMS region level electricity demand is disaggregated to IPM model region level. IPM model region level peak load projection is based on the future load factors from NERC 2017 ES&D and AEO 2018	Section 3.2
Implemented the NY minimum oil burn rule through facility level minimum generation constraints	Table 3-13

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[3] 70 FR 39104

[4] 79 FR 48300, 80 FR 21302, 80 FR 67838

Description	For More Information
Updated ELG costs	Section 3.9.5
Generating Resources	
Updates to NEEDS planned units, retirements, and emission control configurations (July 2018 EIA Form 860m, 2017 EIA Form 860 ER, AEO 2018, AMPD 2017 and recent lists of deactivations from PJM, MISO, and ERCOT)	Table 4-1
Updates to unit level NO_x rates (EPA ETS 2017, 2016 CARB, and 2014 NEI)	Section 3.9.2
Providing life extension costs to allow existing nuclear units to continue operation over the extended 80 year life (Sargent & Lundy 2017)	Section 4.5.1
Updated cost and performance characteristics for potential (new) conventional, renewable, and nuclear generating units (AEO 2017 and NREL ATB 2017)	Table 4-13 and Table 4-16
Wind and solar technologies have revised cost and resource base estimates, capacity credit calculation methodology, hourly generation profiles, and time of day based load segments to improve curtailment modeling (NREL 2017)	Section 4.4.5
Implemented energy storage options based on AEO 2018 cost and performance assumptions. Included the energy storage mandates for CA, NY, NJ, OR and MA.	Table 4-35 and Table 4-36
Emission Control Technologies	
Complete update of cost and performance assumptions for SO_2, NO_x, Hg, HCl and CO_2 emission controls based on engineering studies by Sargent & Lundy	Chapter 5
Inclusion of cost and performance assumptions for coal-to-gas conversion and capability to model heat rate improvement technologies	Section 5.7
Carbon Capture, Transport, and Storage	
Updated CO_2 storage cost curves based on a $75 crude oil price, average EOR efficiency of 10 Mcf of CO_2 per incremental barrel of crude oil and adjustment to geologic storage curve for industrial uses of storage capacity	Table 6-4
Updated CO_2 transportation cost adders	Table 6-5
Coal	
Complete update of coal supply curves and transportation matrix (Wood Mackenzie 2016 and Hellerworx 2016)	Table 7-25 and Table 7-26
Natural Gas	
Natural gas assumptions modeled through annual gas supply curves and IPM region level seasonal basis differentials (ICF 2017)	Section 8.6
Other Fuels	
Incorporation of biomass supply curves at a state and IPM region level (DOE 2016)	Section 9.2
Update of price assumptions for fuel oil, nuclear fuel, and waste fuel (AEO 2017)	Chapter 9
Financial assumptions	
Update of discount and capital charge rate assumptions based on a hybrid capital cost model of utility and merchant finance structures for new units	Chapter 10
Use of separate capital charge rates for retrofits based on utility and merchant finance structures	Section 10.4.2
Cost adder for new non-peaking fossil units associated with future CO_2 emissions	Section 10.7.3
Incorporated the implications of the Tax Reform Bill in the discount rate and capital charge rate calculations	Section 10.3

Table 1-2 lists the types of plants included in the EPA Platform v6.

Table 1-2 Plant Types in EPA Platform v6

Conventional Technologies
Coal Steam
Oil/Gas Steam
Combustion Turbine
Combined-Cycle Combustion Turbine
Integrated Gasification Combined-Cycle (IGCC) Coal
Ultra-Supercritical Coal with and without Carbon Capture
Fluidized Bed Combustion
Nuclear
Renewables and Non-Conventional Technologies
Hydropower
Pumped Storage
Energy Storage
Biomass
Onshore Wind
Offshore Wind
Fuel Cells
Solar Photovoltaics
Solar Thermal
Geothermal
Landfill Gas
Other[1]

Note:

[1] Included are fossil and non-fossil waste plants.

Table 1-3 lists the emission control technologies available for meeting emission limits in EPA Platform v6.

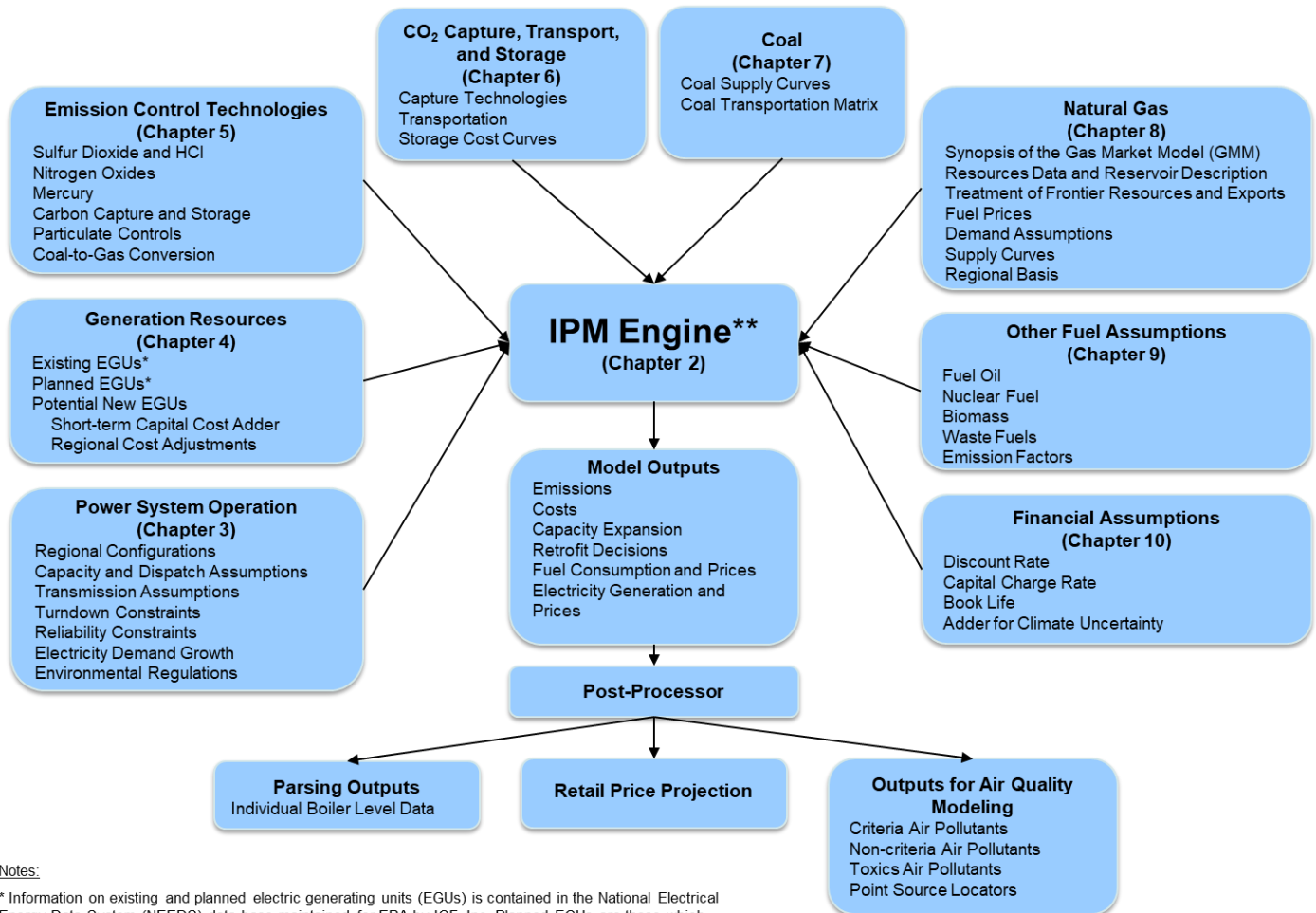**Table 1-3 Emission Control Technologies in EPA Platform v6**

Sulfur Dioxide (SO$_2$)
Limestone Forced Oxidation (LSFO)
Lime Spray Dryer (LSD)
Nitrogen Oxides (NO$_x$)
Combustion controls
Selective catalytic reduction (SCR)
Selective non-catalytic reduction (SNCR)
Mercury (Hg)
Combinations of SO$_2$, NO$_x$, and particulate control technologies
Activated Carbon Injection
Hydrogen Chloride (HCl)
Dry Sorbent Injection (with milled Trona)
Carbon Dioxide (CO$_2$)
Heat rate improvement
Coal-to-gas
Carbon Capture and Sequestration

Notes:
Fuel switching between coal types is also a compliance option
for reducing emissions in EPA Platform v6.

Figure 1-1 provides a schematic of the components of the modeling and data structure used for EPA Platform v6. The document contains separate chapters devoted to all the key components shown in Figure 1-1. Chapter 2 provides an overview of IPM's modeling framework (also 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 Platform v6. Chapter 3 covers the power system operating characteristics captured in EPA Platform v6. 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. The next three chapters discuss the representation and assumptions for fuels in the EPA Platform v6. Coal is covered in chapter 7, natural gas in chapter 8, and other fuels (i.e., fuel oil, biomass, nuclear fuel, and waste fuels) in chapter 9 (along with fuel emission factors). Finally, Chapter 10 summarizes the financial assumptions.

Figure 1-1 Modeling and Data Structures in EPA Platform v6

CO₂ Capture, Transport, and Storage (Chapter 6)
Capture Technologies
Transportation
Storage Cost Curves

Coal (Chapter 7)
Coal Supply Curves
Coal Transportation Matrix

Emission Control Technologies (Chapter 5)
Sulfur Dioxide and HCl
Nitrogen Oxides
Mercury
Carbon Capture and Storage
Particulate Controls
Coal-to-Gas Conversion

Natural Gas (Chapter 8)
Synopsis of the Gas Market Model (GMM)
Resources Data and Reservoir Description
Treatment of Frontier Resources and Exports
Fuel Prices
Demand Assumptions
Supply Curves
Regional Basis

Generation Resources (Chapter 4)
Existing EGUs*
Planned EGUs*
Potential New EGUs
　Short-term Capital Cost Adder
　Regional Cost Adjustments

IPM Engine **
(Chapter 2)

Other Fuel Assumptions (Chapter 9)
Fuel Oil
Nuclear Fuel
Biomass
Waste Fuels
Emission Factors

Power System Operation (Chapter 3)
Regional Configurations
Capacity and Dispatch Assumptions
Transmission Assumptions
Turndown Constraints
Reliability Constraints
Electricity Demand Growth
Environmental Regulations

Model Outputs
Emissions
Costs
Capacity Expansion
Retrofit Decisions
Fuel Consumption and Prices
Electricity Generation and Prices

Financial Assumptions (Chapter 10)
Discount Rate
Capital Charge Rate
Book Life
Adder for Climate Uncertainty

Post-Processor

Parsing Outputs
Individual Boiler Level Data

Retail Price Projection

Outputs for Air Quality Modeling
Criteria Air Pollutants
Non-criteria Air Pollutants
Toxics Air Pollutants
Point Source Locators

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, Inc. Planned EGUs are those which were under construction or had obtained financing at the time EPA's Platform v6 was finalized.

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

1.2　Review and Ongoing Improvement of the Integrated Planning Model

A customized, fully documented version of the data assumptions underlying IPM has been developed and used by EPA to help inform power plant air regulatory and legislative efforts for over 20 years, following the enactment of the Clean Air Act Amendments of 1990. The model has been tailored to meet the unique environmental considerations important to EPA, while also fully capturing the detailed and complex economic and electric dispatch dynamics of power plants across the country. It has been EPA's goal to thoroughly explain and document the agency's use of the model in a transparent and publicly accessible manner, while also providing for concurrent channels for improving the model's assumptions and representation by soliciting constructive feedback so that the model may be continually improved. This includes making all inputs and assumptions to the model, as well as all output files from the model, publicly available on EPA's website (and, when applied to inform a rulemaking, in the relevant publicly accessible regulatory docket).

EPA's use of IPM depends upon a variety of environmental, policy, and regulatory considerations. Generally, EPA's version of the model input assumptions has undergone significant updates and architectural improvements every 2-4 years in order to best reflect the evolving dynamics of the power sector, and smaller ongoing updates (1-2 times a year) to reflect changes in fleet composition

(retirements, new capacity builds, and installed retrofits). Currently, EPA's implementation of IPM is in its sixth major version, not including Coal and Electric Utility Model (CEUM), the model used by EPA before its use of IPM.

Federal Regulatory efforts:

EPA has used IPM for many regulatory efforts affecting the power sector, including:

- The NO_x SIP Call, the Clean Air Interstate Rule (2004-2006), the Clean Air Visibility Rule, the Clean Air Mercury Rule (2005), the Cross-State Air Pollution Rule and Updates (2010-2016), the Mercury and Air Toxics Rule (2012), the Clean Power Plan (2015), and various Ozone, PM NAAQS, and regional haze regulatory efforts.

National Legislative efforts:

EPA has used IPM to support legislative efforts that affect the power sector, including:

- The Clear Skies Act (2002-2005), the Clean Air Planning Act (2002-2005), the Clean Power Act (2002-2005), the Climate Stewardship and Innovation Act (2007), the Low Carbon Economy Act (2007-2008), the Lieberman-Warner Climate Security Act (2007-2008), and the American Clean Energy and Security Act (2008-2009).

Notable Versions and Updates/Improvements/Enhancements:

EPA Base Case using IPM - 1996

- Designed for projections covering the US with 4 run years
- Disaggregated the US into 17 IPM model regions
- Modeled coal and gas markets through coal and gas supply curves

EPA Base Case using IPM – 1998

- Updated unit inventory of power plants
- Increased the number of IPM model regions covering the US from 17 to 21
- Disaggregated New York into 4 IPM model regions
- Increased the number of run years from 4 to 6

EPA Base Case 2000 using IPM Version 2.1 (2000-2003)

- Updated unit inventory of power plants
- Increased the number of IPM model regions covering the US from 21 to 26
- Increased the modeling time horizon to 2030
- Increased the overall number of emission control technology options modeled
- Incorporated Activated Carbon Injection (ACI) retrofit options for mercury control modeling
- Expanded coal supply representation

EPA Base Case 2004 using IPM Version 2.1.9 (2004)

- Updated unit inventory of power plants
- Improved the characterization of SO_2 and NO_x emissions
- Revised coal choice assumptions for individual coal units
- Updated natural gas supply curves, incorporating recommendations from the natural gas peer review

EPA Base Case 2006 using IPM Version 3 (2005-2009)

- Updated unit inventory of power plants
- Improved environmental pollution control retrofit assumptions
- Increased the number of IPM model regions covering the US from 26 to 32 to enhance regional representation
- Increased the number of load segments from 5 to 6 to enhance electric load representation
- Updated natural gas supply curves based on ICF's North American Natural Gas Systems Analysis (NANGAS) model
- Updated coal supply curves
- Enhanced electric transmission capabilities and imports/exports
- Enhanced power plant representation detail

EPA Base Case using IPM Version 4.10 (2010-2013)

- Updated unit inventory of power plants
- Integrated Canada into the modeling framework
- Incorporated HCl emissions and Dry Sorbent Injection retrofit options
- Improved resolution of Carbon Capture and Storage, including regional storage representation and transportation network
- Updated coal supply modeling with significantly more resolution of coal mine data
- Incorporated natural gas resource model for North America to reflect emerging shale resource
- Enhanced power plant representation detail to support toxic air pollutant emissions and controls

EPA Base Case using IPM Version 5 (2014-2017)

- Updated unit inventory of power plants
- Doubled the number of IPM model regions from 36 to 64
- Revised environmental pollution control retrofit assumptions for conventional pollutants and toxic emissions
- Incorporated additional technology options for new power plants
- Overhauled coal supply assumptions, with even further resolution to reflect mine-by-mine geography and coal characteristics
- Improved coal transportation network by modeling each individual coal plant as its own coal demand region
- Updated gas modeling assumptions to reflect natural gas shale supply/trends and pipeline capacity expansion

Background on EPA Base Case using IPM Review:

Peer Reviews:

EPA conducts periodic formal peer review of the EPA Base Case application of IPM. These reviews have included separate expert panels on the model itself, and EPA's key modeling input assumptions. For example, separate panels of independent experts have been convened to review IPM's coal supply and transportation assumptions, natural gas assumptions, and model formulation.

EPA Base Case v5.13 Data Assumption Review

In 2015, an independent peer review panel provided expert feedback on whether the analytical framework, assumptions, and applications of data in IPM were sufficient for the EPA's needs in estimating the economic and emissions impacts associated with the power sector. The panel identified a number of strengths associated with the model and underlying data and assumptions. For example, the report

stated that EPA's platform exceeds other model capabilities in providing a relevant feedback mechanism between the electric power model and key fuel inputs that drive simulation results[5].

Other strengths the panel identified include:

- The detail with which pollution control technology options and costs are represented
- The level of detail at which federal Clean Air Act (CAA) regulations are represented
- The ability of the model to allow for the detailed representation of a variety of potential changes in energy and environmental policies, including important features of market-based programs
- The accuracy of the emissions control costs and their relationship to retirement decisions
- The expansion of model regions from 32 to 64, which allows the model to better represent current power market operations and existing transmission bottlenecks even within regional transmission organization (RTO) regions
- Continuous updates of the representation of domestic coal and natural gas market conditions

The peer review panel has also provided several areas for investigation and additional recommendations for the EPA's consideration, including:

- Improved documentation of the input assumptions
- Changes to certain cost functions and financial assumptions
- Consideration of certain improvements to the Base Case architecture (additional seasonal representation, representation of electric demand, transmission considerations, and renewable energy representation among others)

The updated EPA Platform v6 using IPM addresses many of these recommendations (seasons, renewable energy representation, regional representation, etc.), and this peer review has also lead to additional work at EPA to further understand and better represent some of the emerging issues in the power sector. EPA intends to add more capabilities and continue to refine the modeling platform to reflect these comments, and adopt those changes at an appropriate time after further research and testing of the model.

Coal Market Assumptions Review

In 2003, a group of experts in the field of cost, quality, reserves, and availability of coal were selected as peer reviewers to assess whether the choice, use, and interpretation of data and methodology employed in the derivation of the IPM coal supply curves was appropriate and analytically sound. The peer reviewers were charged with:

- Evaluating the appropriateness of the overall methodology used to develop the new coal supply curves,
- Assessing the adequacy of the individual components employed in building the coal supply curves in terms of both the approach and data used,
- Assessing the technical soundness of the resulting coal supply curves for each coal type and supply region in terms of the cost/quantity relationship and the characteristics associated with the coal (e.g., sulfur, heat, and mercury content), and
- Assessing the appropriateness of the use of this set of supply curves for use in production cost models in general (of which IPM is a particular example).

The review process produced useful and specific recommendation for improvements and updates to the coal supply information that is represented in IPM, which were subsequently incorporated into the model.

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[5] https://www.epa.gov/airmarkets/response-and-peer-review-report-epa-base-case-version-513-using-ipm

Gas Market Assumptions Review

In 2003, a peer review of the natural gas supply assumptions implemented in EPA Base Case using IPM v.2.1.6 (2003) was performed. The peer reviewers were charged with evaluating the following:

- The appropriateness of the representation of all the key natural gas market fundamentals in NANGAS,
- The reasonableness of the natural gas supply curves, non-electricity demand assumptions and transportation adders, and
- The reasonableness of the iteration process between NANGAS and IPM.

The review commended the comprehensiveness of the approach used to generate the gas supply curves implemented in the EPA Base Case. The review further identified assumptions that could be revised in generating a new set of natural gas supply curves, as well as nonelectric-sector gas demand curves, for the next update of the EPA Base Case.

IPM Formulation Review

Conducted in 2008, this peer review focused on IPM's core mathematical formulation. The objective of the review was to obtain expert feedback on the adequacy of the formulation in representing the economic and operational behavior of the power sector over a modeling time horizon of 20-50 years.

The panel identified several strengths of IPM, including:

- The model's ability to compute optimal capacity that combined short-term dispatch decisions with long-term investment decisions.
- The model's integration of relevant markets, including the electric power, fuel, and environmental markets, into a single modeling framework.
- And the model's ability to represent a very detailed level of data with regard to the emissions modeling capability.

The peer review panel also provided several areas for investigation and recommendations for the EPA's consideration. These peer reviews led to concrete changes, enhancements, and updates to the IPM framework to better represent the power sector and related markets (i.e., fossil fuels).

Regulatory Review:

The formal rulemaking process provides opportunity for expert review and comment by key stakeholders. Formal comments as part of a rulemaking are reviewed and evaluated, and changes/updates are made to IPM where appropriate. Stakeholders to EPA regulatory efforts are a diverse group, including regulated entities and impacted industries, fuel supply companies, states, environmental organizations, developers of other models of the U.S. electricity sector, and others. The feedback provides a highly detailed review of input assumptions, model representation, and model results.

Other Uses and Reviews:

- IPM has been used by many regional organizations for regulatory support, including the Regional Greenhouse Gas Initiative (RGGI), the Western Regional Air Partnership (WRAP), and the Ozone Transport Assessment Group (OTAG). IPM has also been used by other Federal agencies (e.g., FERC, USDA), environmental groups, and many electric utilities,
- The Science Advisory Board reviewed EPA's application of IPM as part of the CAAA Section 812 prospective study 1997-1999.
- The President's Council of Economic Advisors (2002-2003) performed head-to-head comparison of IPM and EIA's NEMS system for use in multi-pollutant control analysis.

- IPM has been used in a number of comparative model exercises sponsored by Stanford University's Energy Modeling Forum and other organizations.

EPA Platform v6 using IPM represents another major iteration of EPA's application of IPM, with notable structural and platform improvements/enhancements, as well as universal updates to reflect the most current set of data and assumptions.