TABLE OF CONTENTS

Acknowledgment 1-1

1. Introduction 1-1

1.1 Executive Summary 1-1

1.2 Review and Ongoing Improvement of the Integrated Planning Model 1-6

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 2-3
2.2.2 Decision Variables 2-3
2.2.3 Constraints 2-4

2.3 Key Methodological Features of IPM 2-5

2.3.1 Model Plants 2-5
2.3.2 Model Run Years 2-6
2.3.3 Cost Accounting 2-7
2.3.4 Modeling Wholesale Electricity Markets 2-7
2.3.5 Load Duration Curves (LDCs) 2-7
2.3.6 Fuel Modeling 2-10
2.3.7 Transmission Modeling 2-10
2.3.8 Operating Reserves Modeling 2-11
2.3.9 Perfect Competition and Perfect Foresight 2-11
2.3.10 Scenario Analysis and Regulatory Modeling 2-11

2.4 Hardware and Programming Features 2-12

2.5 Model Inputs and Outputs 2-12

2.5.1 Data Parameters for Model Inputs 2-12
2.5.2 Model Outputs 2-13

3. Power System Operation Assumptions 3-1

3.1 Model Regions 3-1

3.2 Electric Load Modeling 3-2

3.2.1 Distributed Solar Photovoltaics 3-6
3.2.2 Demand Elasticity 3-7
3.2.3 Net Internal Demand (Peak Demand) 3-7
3.2.4 Regional Load Shapes 3-8

3.3 Transmission 3-8

3.3.1 Inter-regional Transmission Capability 3-8
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 3-10
3.3.5 New Transmission Builds 3-11

3.4 International Imports 3-12

3.5 Capacity, Generation, and Dispatch 3-12

3.5.1 Availability 3-12
3.5.2 Capacity Factor 3-13

3.5.3 Turndown 3-15
3.6 Reserve Margins 3-15
3.7 Operating Reserves 3-16
3.7.1 Operating Reserve Requirements 3-17
3.7.2 Generation Characteristics 3-18
3.8 Power Plant Lifetimes 3-19
3.9 Heat Rates 3-19
3.10 Existing Legislations and Regulations Affecting Power Sector 3-20
3.10.1 Inflation Reduction Act 3-20
3.10.2 SO_2 Regulations 3-20
3.10.3 NO_x Regulations 3-21
3.10.4 Multi-Pollutant Environmental Regulations 3-24
3.10.5 CO_2 Regulations 3-28
3.10.6 Non-Air Regulations Impacting EGUs 3-30
3.10.7 State-Specific Environmental Regulations 3-31
3.10.8 New Source Review (NSR) Settlements 3-32
3.10.9 Emission Assumptions for Potential (New) Units 3-32
3.10.10 Renewable Portfolio Standards and Clean Energy Standards 3-32
3.11 Emissions Trading and Banking 3-35
3.11.1 Intertemporal Allowance Price Calculation 3-35
3.12 45Q – Credit for Carbon Dioxide Sequestration 3-37
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 4-6
4.2.6 Model Plant Aggregation 4-6
4.2.7 Cost and Performance Characteristics of Existing Units 4-11
4.2.8 Life Extension Costs for Existing Units 4-17
4.3 Planned-Committed Units 4-18
4.3.1 Population and Model Plant Aggregation 4-18
4.3.2 Capacity 4-18
4.3.3 State and Model Region 4-18
4.3.4 Online and Retirement Year 4-18
4.4 Potential Units 4-19
4.4.1 Methodology for Deriving the Cost and Performance Characteristics of Conventional Potential Units 4-19
4.4.2 Cost and Performance for Potential Conventional Units 4-19
4.4.3 Short-Term Capital Cost Adder 4-20
4.4.4 Regional Cost Adjustment 4-20
4.4.5 Cost and Performance for Potential Renewable Generating and Non-Conventional Technologies 4-25
4.5 Inflation Reduction Act Impacts on New Units 4-39
4.6 Nuclear Units 4-42

4.6.1 Existing Nuclear Units 4-42
4.6.2 Potential Nuclear Units 4-43
5. Emission Control Technologies 5-1
5.1 Sulfur Dioxide Control Technologies - Scrubbers 5-1
5.1.1 Methodology for Obtaining SO_2 Controls Costs 5-2
5.1.2 SO_2 Controls for Units with Capacities from 25 MW to 100 MW (25 MW ≤ capacity < 100 MW) 5-3
5.2 Nitrogen Oxides Control Technology 5-5
5.2.1 Combustion Controls 5-5
5.2.2 Post-combustion NO_x Controls 5-5
5.2.3 Methodology for Obtaining SCR and SNCR Costs for Coal Steam Units 5-6
5.2.4 Methodology for Obtaining SCR Costs for Oil/Gas Steam Units 5-8
5.3 Biomass Co-firing 5-9
5.4 Mercury Control Technologies 5-9
5.4.1 Mercury Content of Fuels 5-9
5.4.2 Mercury Emission Modification Factors 5-10
5.4.3 Mercury Control Capabilities 5-13
5.4.4 Methodology for Obtaining ACI Control Costs 5-17
5.5 Hydrogen Chloride (HCl) Control Technologies 5-17
5.5.1 Chlorine Content of Fuels 5-17
5.5.2 HCl Removal Rate Assumptions for Existing and Potential Units 5-19
5.5.3 HCl Retrofit Emission Control Options 5-19
5.6 Fabric Filter (Baghouse) Cost Development 5-21
5.7 Coal-to-Gas Conversions 5-23
5.7.1 Boiler Modifications for Coal-To-Gas Conversions 5-23
5.7.2 Natural Gas Pipeline Requirements for Coal-To-Gas Conversions 5-24
5.8 Natural Gas Co-firing 5-25
5.9 Retrofit Assignments 5-26
6. CO_2 Capture, Storage, and Transport 6-1
6.1 CO_2 Capture 6-1
6.1.1 CO_2 Capture for Potential EGUs 6-1
6.1.2 CO_2 Capture for Existing EGUs with CCS Retrofit 6-2
6.1.3 Coal-Fired Units Installing CCS Retrofit by 2030 6-3
6.2 CO_2 Storage 6-3
6.2.1 Unit Costs for Geologic Storage 6-4
6.2.2 Levelized Costs for Geologic Storage 6-5
6.2.3 Aggregated Storage Cost Curves 6-5
6.3 CO_2 Transport 6-6
7. Coal 7-1
7.1 Coal Market Representation 7-1
7.1.1 Coal Supply Regions 7-2
7.1.2 Coal Demand Regions 7-3
7.1.3 Coal Quality Characteristics 7-3
7.1.4 Coal Emission Factors 7-4
7.1.5 Coal Grade Assignments 7-10

7.2 Coal Supply Curves 7-10
7.2.1 Nature of Supply Curves Developed for EPA 2023 Reference Case 7-10
7.2.2 Cost Components in the Supply Curves 7-11
7.2.3 Procedures Employed in Determining Mining Costs 7-12
7.2.4 Procedure Used in Determining Mine Productivity 7-13
7.2.5 Procedure to Determine Total Recoverable Reserves by Region and Type 7-13
7.2.6 New Mine Assumptions 7-14
7.2.7 Other Notable Procedures 7-14
7.2.8 Cumulative Supply Curve Development 7-16
7.2.9 EPA 2023 Reference Case Assumptions and Outlooks for Major Supply Basins 7-18
7.3 Coal Transportation 7-19
7.3.1 Coal Transportation Matrix Overview 7-20
7.3.2 Overview of Rail Rates 7-22
7.3.3 Truck Rates 7-26
7.3.4 Barge and Lake Vessel Rates 7-26
7.3.5 Transportation Rates for Imported Coal 7-26
7.3.6 Other Transportation Costs 7-27
7.3.7 Long-Term Escalation of Transportation Rates 7-27
7.3.8 Market Drivers Moving Forward 7-29
7.3.9 Other Considerations 7-31
7.4 Coal Exports, Imports, and Non-Electric Sectors Demand 7-32
8. Natural Gas 8-1
8.1 GMM 8-3
8.2 Translating GMM Results to IPM Natural Gas Supply Curves 8-5
8.2.1 Supply Curves for EPA 2023 Reference Case 8-7
8.2.2 Basis 8-8
8.2.3 Delivered Price Adders 8-9
8.3 GMM Assumptions 8-9
8.3.1 GMM Resources Data and Reservoir Description 8-9
8.3.2 Oil Prices 8-12
8.3.3 Gas Production 8-12
8.3.4 Demand Assumptions 8-13
8.3.5 LNG Exports and Pipeline Exports to Mexico 8-14
9. Other Fuels and Fuel Emission Factor Assumptions 9-1
9.1 Fuel Oil 9-1
9.2 Biomass Fuel 9-2
9.3 Nuclear Fuel 9-3
9.4 Waste Fuels 9-3
9.5 Hydrogen Fuel 9-4
9.6 Fuel Emission Factors 9-4
10. Financial Assumptions 10-1
10.1 Introduction and Summary 10-1
10.2 Introduction to Risk 10-1
10.2.1 Deregulation - Market Structure Risks 10-2
10.3 Federal Income Tax Law Changes 10-3
10.4 Calculation of the Financial Discount Rate 10-4

10.4.1 Introduction to Discount Rate Calculations 10-4
10.4.2 Summary of Results 10-5
10.5 Discount Rate Components 10-6
10.6 Market Structure: Utility-Merchant Financing Ratio 10-7
10.7 Capital Structure: Debt-Equity Share 10-7
10.7.1 Introduction and Shares for Utilities and IPPs 10-7
10.7.2 Utility and Merchant 10-8
10.7.3 Merchant by Technology 10-8
10.8 Cost of Debt 10-9
10.8.1 Merchant Cost of Debt 10-9
10.8.2 Utility Cost of Debt 10-10
10.9 Return on Equity (ROE) 10-10
10.9.1 Introduction and Beta 10-10
10.9.2 Risk-Free Rate and Equity Risk Premium 10-11
10.9.3 Beta 10-11
10.9.4 Equity Size Premium 10-12
10.9.5 Nominal ROEs 10-12
10.9.6 WACC/Discount Rate 10-13
10.10 Calculation of Capital Charge Rate 10-13
10.10.1 Introduction to Capital Charge Rate Calculations 10-13
10.10.2 Capital Charge Rate Components 10-14

LIST OF TABLES

Table 1-1 Key Updates and Specifications in the EPA 2023 Reference Case 1-2
Table 1-2 Plant Types in the EPA 2023 Reference Case 1-4
Table 1-3 Emission Control Technologies in the EPA 2023 Reference Case 1-5
Table 2-1 Model Run Year and Year Mapping in the EPA 2023 Reference Case 2-6
Table 2-2 Load Curves used in EPA 2023 Reference Case 2-13
Table 3-1 Mapping of NERC Regions and NEMS Regions with the EPA 2023 Reference Case Model Regions 3-3
Table 3-2 Electric Load Assumptions in the EPA 2023 Reference Case 3-5
Table 3-3 Regional Electric Load Assumptions in the EPA 2023 Reference Case 3-5
Table 3-4 National Non-Coincidental Net Internal Demand in the EPA 2023 Reference Case 3-7
Table 3-5 Annual Joint Capacity and Energy Limits to Transmission Capabilities between Model Regions in the EPA 2023 Reference Case 3-9
Table 3-6 International Electricity Imports (billions kWh) in the EPA 2023 Reference Case 3-12
Table 3-7 Availability Assumptions in the EPA 2023 Reference Case 3-13
Table 3-8 Seasonal Hydro Capacity Factors (%) in the EPA 2023 Reference Case 3-13
Table 3-9 Planning Reserve Margins in the EPA 2023 Reference Case 3-16
Table 3-10 Operating Reserve Requirement Assumptions by Type in the EPA 2023 Reference Case 3-17
Table 3-11 Operating Reserve Regions in the EPA 2023 Reference Case 3-18
Table 3-12 Operating Reserve Contribution Assumptions by Technology in the EPA 2023 Reference Case 3-18
Table 3-13 Lower and Upper Limits Applied to Heat Rate Data in the EPA 2023 Reference Case 3-19
Table 3-14 State-of-the-Art Combustion Control Configurations by Boiler Type in the EPA 2023 Reference Case 3-24
Table 3-15 Ozone-Season NO_x Emission Caps (Tons) for Fossil Units greater than 25MW in the EPA 2023 Reference Case 3-25
Table 3-16 G1 and G2 CSAPR Update State Budgets, Variability Limits, and Assurance Levels for Ozone-Season NO_x (Tons) – 2021 through 2054 3-26
Table 3-17 Revised CSAPR Update State Budgets, Variability Limits, and Assurance Levels for Ozone-Season NO_x for G3 states (tons) 3-26
Table 3-18 Renewable Portfolio Standards in the EPA 2023 Reference Case 3-32
Table 3-19 State RPS Solar Carve-outs in the EPA 2023 Reference Case 3-33
Table 3-20 Clean Energy Standards in the EPA 2023 Reference Case 3-33
Table 3-21 Offshore Wind Mandates in the EPA 2023 Reference Case 3-33
Table 3-22 Fossil Generation Limits (GWh) in the EPA 2023 Reference Case 3-34
Table 3-23 Trading and Banking Rules in the EPA 2023 Reference Case 3-35
Table 3-24 Emission and Removal Rate Assumptions for Potential (New) Units in the EPA 2023 Reference Case 3-36
Table 3-25 Recalculated NO_x Emission Rates for SCR Equipped Units Sharing Common Stacks with Non-SCR Units in the EPA 2023 Reference Case 3-37
Table 3-26 Regional Net Internal Demand in EPA 2023 Reference Case 3-37
Table 3-27 Annual Transmission Capabilities of U.S. Model Regions in EPA 2023 Reference Case 3-37
Table 3-28 Turndown Assumptions for Coal Steam Units in EPA 2023 Reference Case 3-37
Table 3-29 State Power Sector Regulations included in EPA 2023 Reference Case 3-37
Table 3-30 New Source Review (NSR) Settlements in EPA 2023 Reference Case 3-37
Table 3-31 State Settlements in EPA 2023 Reference Case 3-38
Table 3-32 Citizen Settlements in EPA 2023 Reference Case 3-38
Table 3-33 Availability Assumptions in EPA 2023 Reference Case 3-38

Table 3-34 BART Regulations included in EPA 2023 Reference Case 3-38
Table 4-1 Data Sources for NEEDS 4-2
Table 4-2 Rules Used in Populating NEEDS 4-2
Table 4-3 Summary Population (through 2023) of Existing Units in NEEDS 4-4
Table 4-4 Hierarchy of Data Sources for Capacity in NEEDS 4-4
Table 4-5 Capacity-Parsing Algorithm for Steam Units in NEEDS 4-5
Table 4-6 Data Sources for Unit Configuration in NEEDS 4-6
Table 4-7 Aggregation Profile of Model Plants as Provided at Set up of the EPA 2023 Reference Case 4-7
Table 4-8 VOM Assumptions in the EPA 2023 Reference Case 4-12
Table 4-9 FOM Assumptions in the EPA 2023 Reference Case 4-14
Table 4-10 Life Extension Cost Assumptions Used in the EPA 2023 Reference Case 4-17
Table 4-11 Summary of Planned-Committed Units in NEEDS 4-18
Table 4-12 Performance and Unit Cost Assumptions for Potential (New) Capacity from Conventional Technologies in the EPA 2023 Reference Case 4-21
Table 4-13 Short-Term Capital Cost Adders for New Power Plants in the EPA 2023 Reference Case (2022$) 4-22
Table 4-14 Regional Cost Adjustment Factors for Conventional and Renewable Generating Technologies in the EPA 2023 Reference Case 4-22
Table 4-15 Performance and Unit Cost Assumptions for Potential (New) Renewable and Non-Conventional Technologies in the EPA 2023 Reference Case 4-24
Table 4-16 Offshore Fixed Regional Potential Wind Capacity (MW) by Wind Class, Resource Class, and Cost Class in the EPA 2023 Reference Case 4-25
Table 4-17 Offshore Floating Regional Potential Wind Capacity (MW) by Wind Class, Resource Class, and Cost Class in the EPA 2023 Reference Case 4-26
Table 4-18 Offshore Fixed Average Capacity Factor by Wind Class and Resource Class in the EPA 2023 Reference Case 4-27
Table 4-19 Offshore Floating Average Capacity Factor by Wind Class and Resource Class in the EPA 2023 Reference Case 4-28
Table 4-20 Onshore Reserve Margin Contribution by Wind Class in the EPA 2023 Reference Case ... 4-29
Table 4-21 Offshore Fixed Reserve Margin Contribution by Wind Class in the EPA 2023 Reference Case 4-29
Table 4-22 Offshore Floating Reserve Margin Contribution by Wind Class in the EPA 2023 Reference Case 4-29
Table 4-23 Capital Cost Adder (2022$/kW) for New Offshore Fixed Wind Plants in the EPA 2023 Reference Case 4-30
Table 4-24 Capital Cost Adder (2022$/kW) for New Offshore Floating Wind Plants in the EPA 2023 Reference Case 4-30
Table 4-25 Example Calculations of Wind Generation, Reserve Margin Contribution, and Capital Cost for Onshore Wind in WECC_CO for Wind Class 7, Resource Class 5, and Cost Class 1. 4-31
Table 4-26 Solar Photovoltaic Reserve Margin Contribution by PV Class in the EPA 2023 Reference Case 4-32
Table 4-27 Regional Assumptions on Potential Geothermal Capacity in the EPA 2023 Reference Case .4-33
Table 4-28 Potential Geothermal Capacity and Cost Characteristics by Model Region in the EPA 2023 Reference Case 4-33
Table 4-29 Potential Non-Powered Dam in the EPA 2023 Reference Case 4-35
Table 4-30 Potential New Stream Development in the EPA 2023 Reference Case 4-37
Table 4-31 Bounds and Reserve Margin Contribution for Potential (New) Battery Storage in the EPA 2023 Reference Case 4-38
Table 4-32 Energy Community Tax Credit Increment for Solar and Wind Units 4-40

Table 4-33 Energy Storage Mandates in the EPA 2023 Reference Case 4-41
Table 4-34 Planned-Committed Units by Model Region in NEEDS for EPA 2023 Reference Case 4-43
Table 4-35 Onshore Average Capacity Factor by Wind Class, Resource Class, and Vintage in EPA 2023 Reference Case 4-43
Table 4-36 Onshore Regional Potential Wind Capacity (MW) by Wind Class, Resource Class, and Cost Class in EPA 2023 Reference Case 4-43
Table 4-37 Wind Generation Profiles in EPA 2023 Reference Case (kWh of Generation per MW of Capacity) 4-43
Table 4-38 Capital Cost Adder (2022$/kW) for New Onshore Wind Plants by Resource and Cost Class in EPA 2023 Reference Case 4-43
Table 4-39 Solar Photovoltaic Regional Potential Capacity (MW) by Resource and Cost Class in EPA 2023 Reference Case 4-43
Table 4-40 Solar Thermal Regional Potential Capacity (MW) by Resource and Cost Class in EPA 2023 Reference Case 4-44
Table 4-41 Solar Photovoltaic Generation Profiles in EPA 2023 Reference Case (kWh of Generation per MW of Capacity) 4-44
Table 4-42 Solar Photovoltaic Regional Capital Cost Adder (2022$/kW) for Potential Units by Resource and Cost Class in EPA 2023 Reference Case 4-44
Table 4-43 Solar Thermal Regional Capital Cost Adder (2022$/kW) for Potential Units by Resource and Cost Class in EPA 2023 Reference Case 4-44
Table 4-44 Solar Photovoltaic Average Capacity Factor by Resource Class and Vintage in EPA 2023 Reference Case 4-44
Table 4-45 Solar Thermal Capacity Factor by Resource Class and Season in EPA 2023 Reference Case 4-44
Table 4-46 Potential Electric Capacity from New Landfill Gas Units in EPA 2023 Reference Case (MW) . 4-44
Table 4-47 Characteristics of Existing Nuclear Units in EPA 2023 Reference Case 4-44
Table 5-1 Retrofit Emission Control Options in the EPA 2023 Reference Case 5-1
Table 5-2 Retrofit SO_2 Emission Control Performance Assumptions in the EPA 2023 Reference Case . 5-2
Table 5-3 Illustrative Scrubber Costs (2022$) for Representative Capacities and Heat Rates in the EPA 2023 Reference Case 5-4
Table 5-4 Retrofit NO_x Emission Control Performance Assumptions in the EPA 2023 Reference Case .. 5-5
Table 5-5 Illustrative Post Combustion NOx Control Costs (2022$) for Coal Plants for Representative Sizes and Heat Rates under the Assumptions in the EPA 2023 Reference Case 5-7
Table 5-6 Post-Combustion NOx Controls Costs (2022$) for Oil/Gas Steam for Representative Sizes and Heat Rates under the Assumptions in the EPA 2023 Reference Case 5-8
Table 5-7 Coal Units with Biomass Co-firing Option in the EPA 2023 Reference Case 5-9
Table 5-8 Mercury Concentration Assumptions for Non-Coal Fuels in the EPA 2023 Reference Case 5-10
Table 5-9 Mercury Emission Modification Factors Used in the EPA 2023 Reference Case 5-11
Table 5-10 Definition of Acronyms for Existing Controls 5-12
Table 5-11 Key to Burner Type Designations in Table 5-9 5-13
Table 5-12 Assignment Scheme for Mercury Emissions Control Using Activated Carbon Injection in the EPA 2023 Reference Case 5-15
Table 5-13 Illustrative Activated Carbon Injection (ACI) Costs (2022$) for Representative Sizes and Heat Rates under the Assumptions in the EPA 2023 Reference Case 5-18
Table 5-14 HCl Removal Rate Assumptions for Potential (New) and Existing Units in the EPA 2023 Reference Case 5-19
Table 5-15 Retrofit HCl and SO_2 Emission Control Performance Assumptions in the EPA 2023 Reference Case 5-20
Table 5-16 Illustrative Dry Sorbent Injection (DSI) Costs (2022$) for Representative Sizes and Heat Rates in the EPA 2023 Reference Case 5-22

Table 5-17 Illustrative Particulate Controls Costs (2022$) for Representative Sizes and Heat Rates in the EPA 2023 Reference Case 5-22
Table 5-18 Cost and Performance Assumptions for Coal-to-Gas Retrofits in the EPA 2023 Reference Case 5-23
Table 5-19 Cost and Performance Assumptions for Natural Gas Co-firing Retrofits in the EPA 2023 Reference Case 5-25
Table 5-20 First Stage Retrofit Assignment Scheme in the EPA 2023 Reference Case 5-26
Table 5-21 Second and Third Stage Retrofit Assignment Schemes in the EPA 2023 Reference Case 5-27
Table 5-22 Cost of Building Pipelines to Coal Plants in EPA 2023 Reference Case 5-29
Table 6-1 Cost and Performance Assumptions for Potential USC and NGCC with and without Carbon Capture in the EPA 2023 Reference Case 6-1
Table 6-2 Performance and Unit Cost (2022$) Assumptions for Carbon Capture in the EPA 2023 Reference Case 6-2
Table 6-3 Existing Coal-Fired Units that can Install CCS Retrofit by 2030 in the EPA 2023 Reference Case 6-3
Table 6-4 CO_2 Storage Cost Curves in EPA 2023 Reference Case 6-7
Table 6-5 CO_2 Transportation Matrix in EPA 2023 Reference Case 6-7
Table 7-1 Coal Supply Regions in EPA 2023 Reference Case 7-2
Table 7-2 Coal Rank Heat Content Ranges 7-4
Table 7-3 Coal Grade SO_2 Content Ranges 7-4
Table 7-4 Coal Quality Characteristics by Supply Region and Coal Grade in the EPA 2023 Reference Case 7-5
Table 7-5 Coal Clustering by Coal Grade – SO_2 Emission Factors (lbs/MMBtu) 7-7
Table 7-6 Coal Clustering by Coal Grade – Mercury Emission Factors (lbs/TBtu) 7-7
Table 7-7 Coal Clustering by Coal Grade – Ash Emission Factors (lbs/MMBtu) 7-8
Table 7-8 Coal Clustering by Coal Grade – HCl Emission Factors (lbs/MMBtu) 7-8
Table 7-9 Coal Clustering by Coal Grade – CO_2 Emission Factors (lbs/MMBtu) 7-9
Table 7-10 Example of Coal Assignments Made in the EPA 2023 Reference Case 7-10
Table 7-11 Basin-Level Groupings Used in Preparing the EPA 2023 Reference Case Coal Supply Curves 7-10
Table 7-12 Rail Competition Definitions 7-23
Table 7-13 Assumed Eastern Rail Rates for 2020 (2019 mills/ton-mile) 7-24
Table 7-14 Assumed Midwestern Rail Rates for 2020 (2019 mills/ton-mile) 7-24
Table 7-15 Assumed Non-PRB Western Rail Rates for 2020 (2019 mills/ton-mile) 7-25
Table 7-16 Assumed PRB Western Rail Rates for 2020 (2019 mills/ton-mile) 7-25
Table 7-17 Assumed Truck Rates for 2020 7-26
Table 7-18 Assumed Barge Rates for 2020 7-26
Table 7-19 Assumed Other Transportation Rates for 2020 7-27
Table 7-20 EIA AEO Diesel Fuel Forecast, 2020-2050 7-30
Table 7-21 Summary of Expected Escalation for Coal Transportation Rates, 2020-2050 7-31
Table 7-22 Coal Exports in the EPA 2023 Reference Case (Million Short Tons) 7-32
Table 7-23 Residential, Commercial, and Industrial Demand in the EPA 2023 Reference Case (Million Short Tons) 7-32
Table 7-24 Coal Import Limits in the EPA 2023 Reference Case (Million Short Tons) 7-33
Table 7-25 Coal Transportation Matrix in EPA 2023 Reference Case 7-35
Table 7-26 Coal Supply Curves in EPA 2023 Reference Case 7-35
Table 8-1 Delivered Price Adders 8-9
Table 8-2 Refiners' Acquisition Cost of Crude (RACC) 8-12
Table 8-3 United States and Canada Projected Dry Gas Production by Source (Bcfd) 8-13

Table 8-4 GMM United States and Canada Gas Demand Projection (Bcfd) 8-14
Table 8-5 Net LNG Export Volumes as per AEO 2023 (Bcfd) 8-15
Table 8-6 U.S. Pipeline Exports to Mexico (Bcfd) 8-15
Table 8-7 Natural Gas Basis for EPA 2023 Reference Case 8-15
Table 8-8 Natural Gas Supply Curves for EPA 2023 Reference Case 8-15
Table 9-1 Fuel Oil Prices by NEMS Region in the EPA 2023 Reference Case 9-1
Table 9-2 Waste Fuels in the EPA 2023 Reference Case 9-3
Table 9-3 Fuel Emission Factor Assumptions in the EPA 2023 Reference Case 9-4
Table 9-4 Biomass Supply Curves for EPA 2023 Reference Case 9-4
Table 10-1 Summary Tax Changes 10-4
Table 10-2 Financial Assumptions for Utility and Merchant Cases 10-5
Table 10-3 Weighted Average Cost of Capital in the EPA 2023 Reference Case 10-6
Table 10-4 Share of Annual Thermal Capacity Additions by Market 10-7
Table 10-5 Capital Structure Assumptions in the EPA 2023 Reference Case 10-8
Table 10-6 Nominal Debt Rates in the EPA 2023 Reference Case 10-9
Table 10-7 Utilities Used to Calculate Cost of Debt 10-10
Table 10-8 Estimated Annual Levered Beta for S15ELUT Utility Index Based on Daily Returns 10-11
Table 10-9 Real Capital Charge Rate – Blended (%) in the EPA 2023 Reference Case 10-13
Table 10-10 Real Capital Charge Rate – IPP (%) 10-13
Table 10-11 Real Capital Charge Rate – Utility (%) 10-14
Table 10-12 Book Life, Debt Life, and Depreciation Schedules in the EPA 2023 Reference Case 10-14

LIST OF FIGURES

Figure 1-1 Modeling and Data Structures in the EPA 2023 Reference Case 1-6
Figure 2-1 Hypothetical Chronological Hourly Load Curve and Seasonal Load Duration Curve for Summer Season 2-8
Figure 2-2 Stylized Depiction of a Six Segment Load Duration Curve Dispatch Modeling 2-9
Figure 2-3 Stylized Dispatch Order in Illustrative Load Segments 2-10
Figure 3-1 EPA 2023 Reference Case Model Regions 3-2
Figure 3-2 Modeling Process for Obtaining Projected NO_x Emission Rates 3-22
Figure 3-3 How One of the Four NO_x Modes Is Ultimately Selected for a Unit 3-23
Figure 4-1 Derivation of Plant Fixed O&M Data 4-13
Figure 5-1 Process for Lateral Cost Estimation 5-24
Figure 6-1: Storage Regions in GeoCAT 2.0 6-4
Figure 6-2: Lower 48 Geologic Storage Supply Cost Curves 6-6
Figure 7-1 Map of the Coal Supply Regions in the EPA 2023 Reference Case 7-3
Figure 7-2 Coal Mine Productivity (2000-2019) 7-15
Figure 7-3 Average Annual Cost Growth Assumptions by Region (2021-2050) 7-15
Figure 7-4 Maximum Annual Coal Production Capacity per Year (Million Short Tons) 7-16
Figure 7-5 Illustration of Preliminary Step in Developing a Cumulative Coal Supply Curve 7-17
Figure 7-6 Illustration of Final Step in Developing a Cumulative Coal Supply Curve 7-17
Figure 7-7 Example Coal Supply Curve in Stepped Format 7-18
Figure 7-8 Calculation of Multi-Mode Transportation Costs (Example) 7-21
Figure 7-9 Rail Cost Indices Performance (1Q2016-1Q2020) 7-28
Figure 7-10 Long-Run Marginal Cost Breakdown by Transportation Mode 7-29
Figure 8-1 GMM Gas Quantity and Price Response 8-2
Figure 8-2 IPM/GMM Interaction 8-2
Figure 8-3 Geographic Coverage of GMM 8-3
Figure 8-4 Demand Region Definition 8-6
Figure 8-5 Supply Region Definition 8-6
Figure 8-6 Supply Curves for 2028, 2030, 2035, 2040, 2045, and 2050 8-8

LIST OF ATTACHMENTS

Attachment 3-1 Incremental Demand Accounting for the On-the-books EPA OTAQ GHG Rules 3-38
Attachment 3-2 NO_x Rate Development in EPA 2023 Reference Case 3-38
Attachment 4-1 Nuclear Power Plant Life Extension Cost Development Methodology in EPA 2023 Reference Case 4-44
Attachment 5-1 Wet FGD Cost Methodology.....5-29
Attachment 5-2 SDA FGD Cost Methodology.....5-29
Attachment 5-3 SCR Cost Methodology for Coal-Fired Boilers.....5-29
Attachment 5-4 SCR Cost Methodology for Oil-Gas-Fired Boilers.....5-29
Attachment 5-5 SNCR Cost Methodology for Coal-Fired Boilers 5-29
Attachment 5-6 SNCR Cost Methodology for Oil-Gas-Fired Boilers 5-29
Attachment 5-7 DSI Cost Methodology.....5-29
Attachment 5-8 Hg Cost Methodology 5-29
Attachment 5-9a PM Cost Methodology 5-29
Attachment 5-9b PM Cost Methodology 5-29
Attachment 5-10 Combustion Turbine NO_x Control Technology Methodology 5-29
Attachment 5-11 Natural Gas Co-firing Methodology 5-29
Attachment 6-1 CO_2 Reduction Retrofit Cost Development Methodology.....6-7
Attachment 7-1 Mining Cost Estimation Methodology and Assumptions 7-34