Replacement Energy Cost Estimates for Nuclear Power Plants: 2020-2030

Public Meeting

November 18, 2020

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Purpose

- Present updated information on replacement energy forecasts for short- and long-term shutdowns of U.S. nuclear electricity generating units
- Facilitate public comment on the draft NUREG for forecasting replacement energy costs

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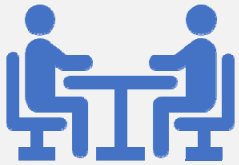
Logistics and Ground Rules

Category 3 public meeting

Questions are encouraged



Please identify yourself and the organization you represent (if any) before speaking

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Agenda

- Background
- Approach
  - Assumptions
  - Methodology
- Results
- Next Steps

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Background

- SRM-SECY-12-0110, “Consideration of Economic Consequences in the NRC’s Regulatory Framework”
- SECY-14-0002, “Plan for Updating NRC’s Cost-Benefit Guidance”
- NUREG/BR-0058, “Regulatory Analysis Guidelines of the U.S. Nuclear Regulatory Commission”

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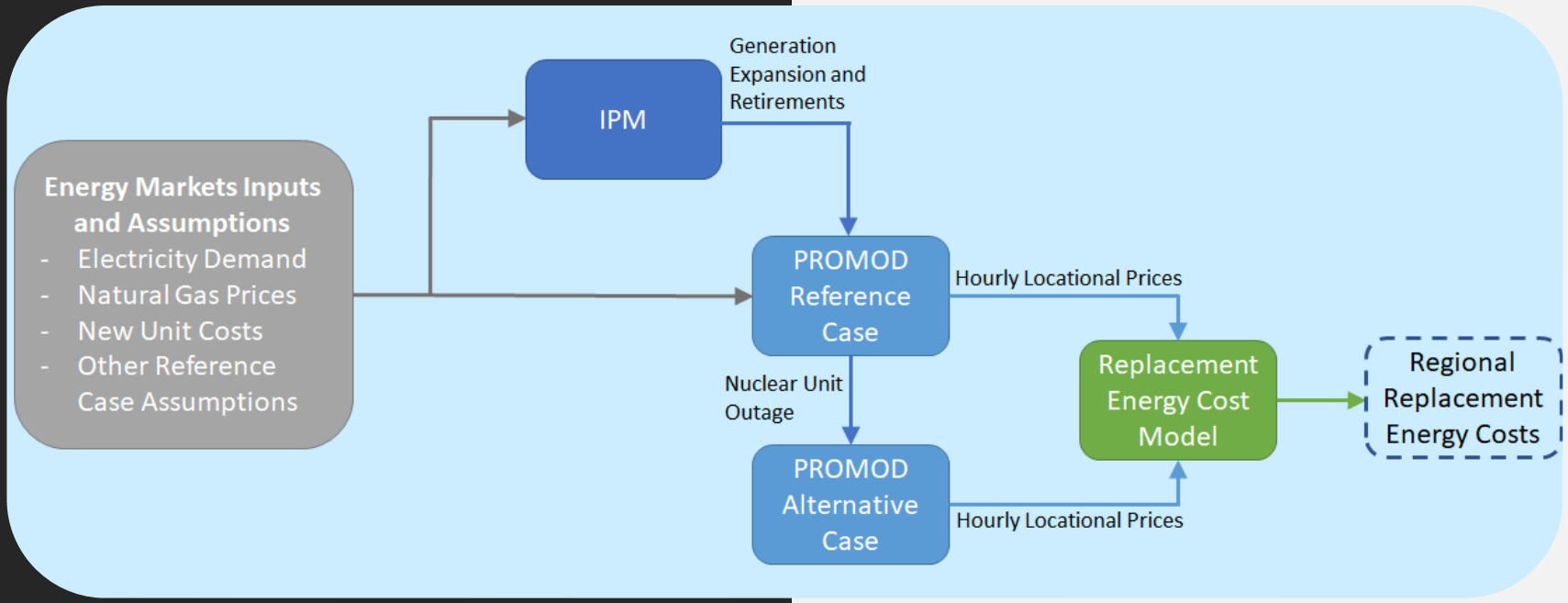
Background (cont.)

- Replacement energy cost estimates are used in regulatory analyses to quantify the costs associated with reactor outages; these analyses support NRC's regulatory decisions
- Estimates for long-term and short-term, plant-specific replacement energy costs are provided in:
  - NUREG/CR-6080, dated October 1993
  - NUREG/CR-4012, dated September 1997
- Changes that affected replacement energy costs since the 1990s include:
  - Deregulation of electricity generation markets
  - Federal Energy Regulatory Commission (FERC) rules impacting electricity transmission costs
  - Natural gas and renewable energy pricing

Approach

Approach



IPM- Integrated Planning Model
PROMOD – Production Cost Model

Assumptions– Key Data Sources

Key Data Sources

- U.S. Energy Information Administration (EIA) Annual Energy Outlook 2019 Reference Case
- North American Electric Reliability Corporation (NERC) Electricity Supply and Demand Projections, December 2018
- Environmental Protection Agency (EPA) Power Sector Modeling Platform v6
- National Renewable Energy Laboratory (NREL) Annual Technology Baseline (ATB), 2018
- EIA Form 860M, February 2019

Data Source Characteristics

- National in scope
- Pricing information covers all lower 48 states
- Data and assumptions are documented in sufficient detail to allow for national level modeling with regional/power pool level detail
- Publicly available

Assumptions - Key Parameters for Determining Replacement Energy Costs

- Regional Definitions
- Electricity Demand
- Natural Gas Prices
- Energy and Environmental Policies
- Recent and Firm Generation Builds/Retirements
- Technology Cost and Performance

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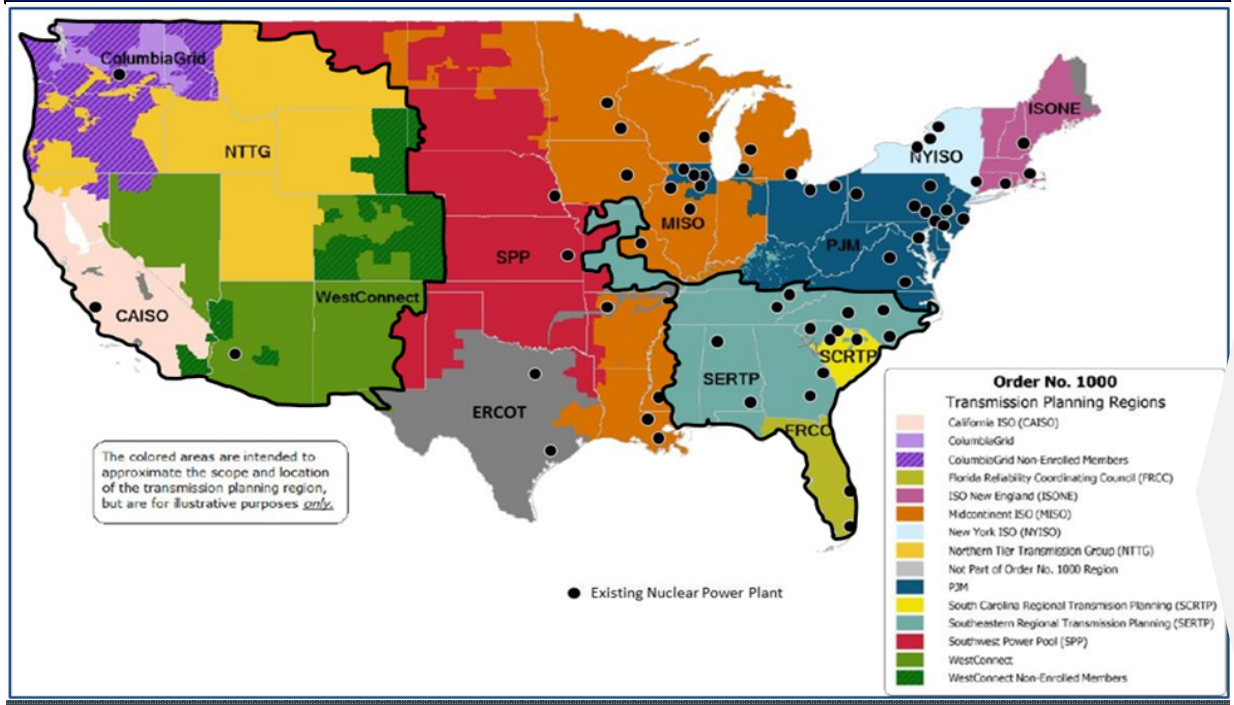
Map of Model Regions



Source: Derived from FERC Order No. 1000 Transmission Planning Regions.

Assumptions – Regional Definitions

Definitions

The U.S. electricity markets were grouped into eight regions based on existing planning regions:

1. Electric Reliability Council of Texas (ERCOT)
2. ISO New England (ISO-NE)
3. Midcontinent Independent System Operator (MISO)
4. New York Independent System Operator (NYISO)
5. PJM Interconnection (PJM)
6. Southwest Power Pool (SPP)
7. Southeast – Florida Reliability Coordinating Council (FRCC), South Carolina Regional Transmission Planning (SCRTP), and Southeastern Regional Transmission Planning (SERTP)
8. Western Electricity Coordinating Council (WECC) – California Independent System Operator (CAISO), ColumbiaGrid, Northern Tier Transmission Group (NTTG) and WestConnect

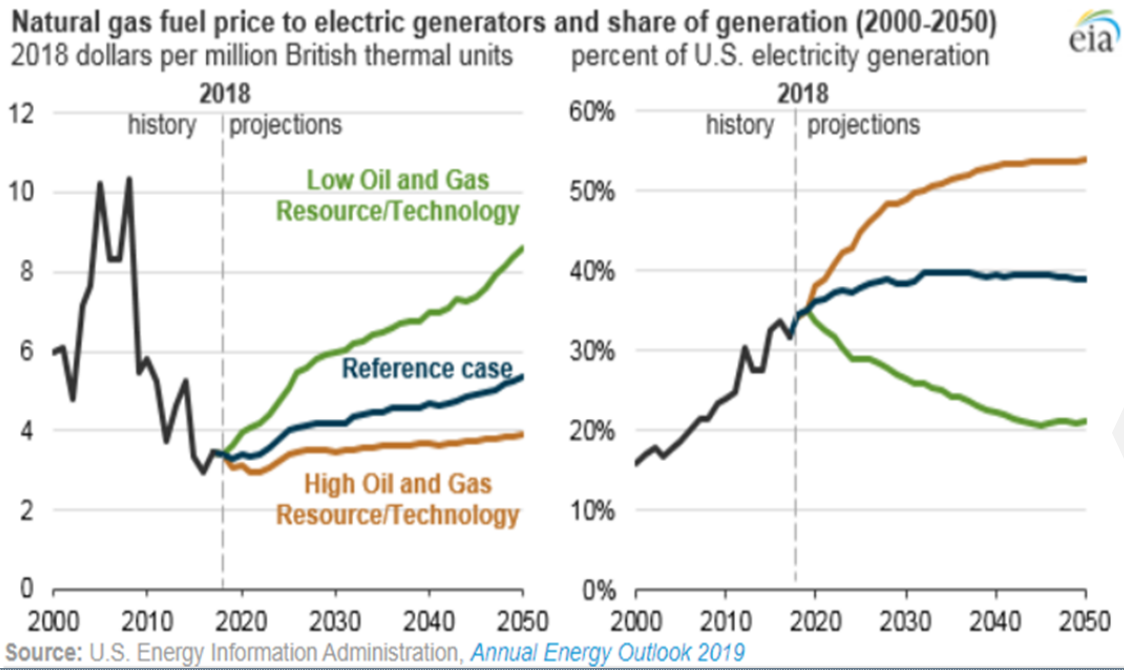
Assumptions – Peak and Energy Demand

Region (Assessment Area)	Net Internal Peak Demand (MW)				Net Energy for Load (GWh)			
	2020	2025	2030	CAGR (percent)	2020	2025	2030	CAGR (percent)
FRCC (FRCC)	45,608	48,290	50,534	1.03	236,779	245,769	253,486	0.68
Midwest Reliability Organization [MRO] (MISO)	119,303	121,289	122,842	0.29	669,881	681,949	694,663	0.36
Northeast Power Coordinating Council [NPCC] (New England)	24,878	24,239	24,190	-0.28	120,395	115,594	113,400	-0.60
NPCC (New York)	31,759	31,429	31,559	-0.06	155,567	153,454	153,518	-0.13
ReliabilityFirst Corporation [RF] (PJM)	144,287	147,118	151,070	0.46	808,638	824,140	849,551	0.49
SERC Reliability Corporation (SERC-East)	42,907	44,930	47,361	0.99	214,026	221,904	233,819	0.89
SERC (SERC-North)	39,935	40,477	41,121	0.29	214,064	214,084	215,733	0.08
SERC (SERC-Southeast)	45,983	47,201	46,764	0.17	247,542	253,679	253,860	0.25
SPP (SPP)	52,044	53,965	55,603	0.66	259,341	274,090	281,854	0.84
Texas Reliability Entity, Inc. [TRE] (ERCOT)	73,706	80,677	87,666	1.75	392,609	439,094	487,269	2.18
WECC (Northwest Power Pool-United States [NWPP]-US)	49,075	50,767	52,343	0.65	294,092	301,503	308,586	0.48
WECC (Rocky Mountain Reserve Group [RMRG])	12,637	13,549	14,394	1.31	69,671	74,874	80,099	1.40
WECC (Southwest Reserve Sharing Group [SRSG])	24,298	26,650	28,788	1.71	111,351	121,139	129,981	1.56
WECC (WECC California/Mexico [CAMX])	50,132	51,584	52,031	0.37	267,722	271,314	272,334	0.17

Source: NERC, "Electricity Supply and Demand (ES&D)," December 2018

CAGR – compound annual growth rate

Henry Hub Gas Price Forecast and Projected Gas Share



Source: U.S. Energy Information Administration, *Annual Energy Outlook 2019*

Assumptions – Natural Gas Price Forecast

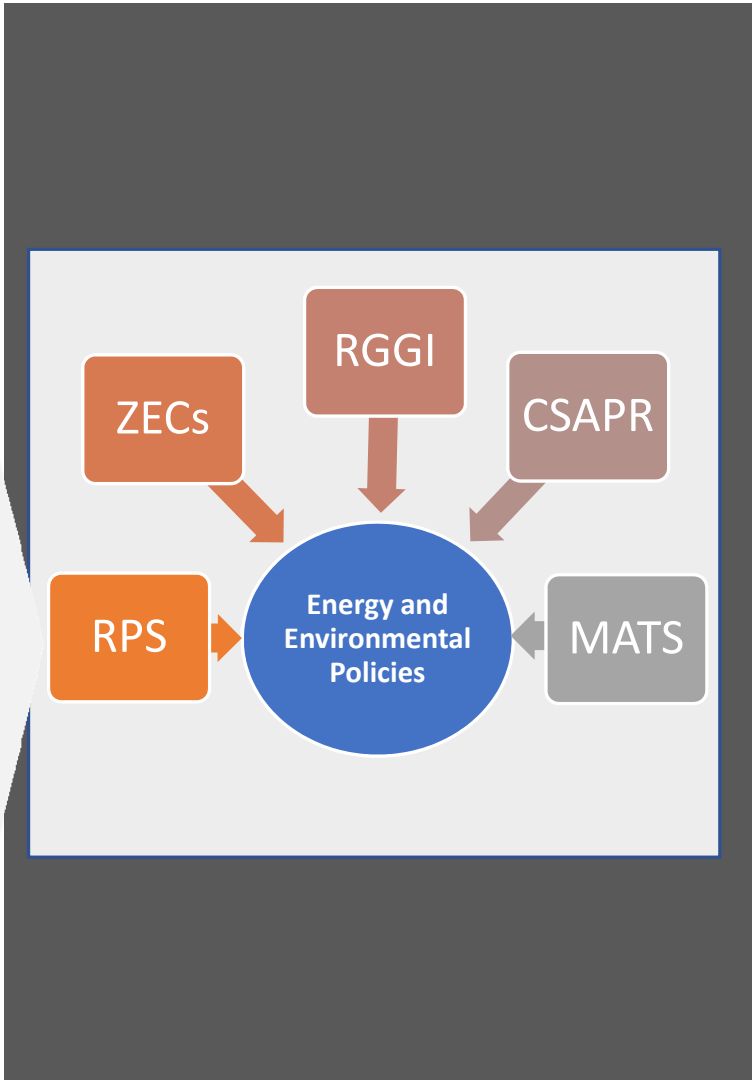
Notes

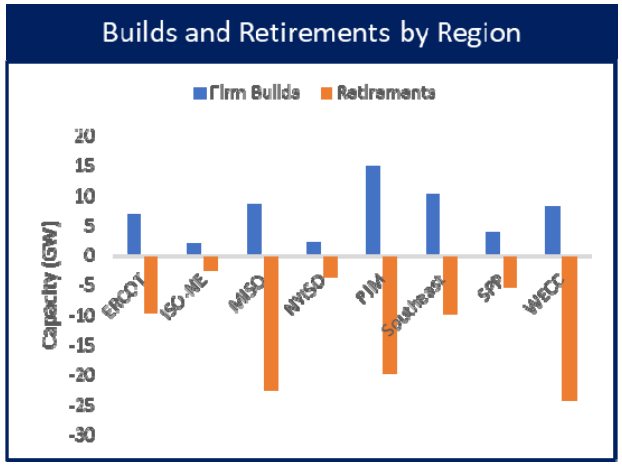
- Natural gas surpassed coal in 2016 as the fuel most used to generate electricity in the U.S.
- EIA projects natural gas share to grow to approximately 40% by 2030 and remain between 39% and 40% through 2050

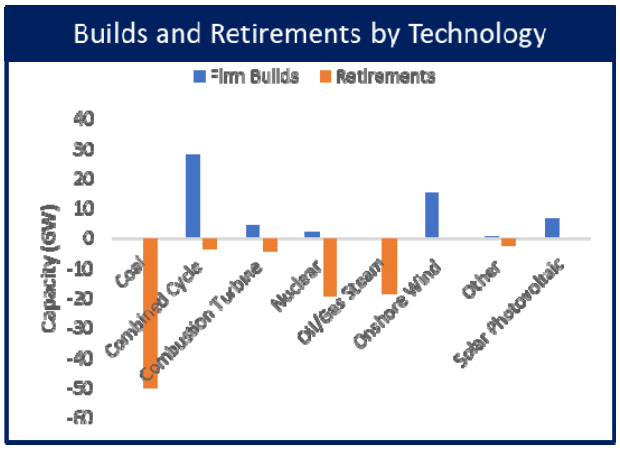
Assumptions – Energy and Environmental Policies

Key Energy and Environmental Policies Modeled

- Renewable Portfolio Standards (RPS) and tax credits for new solar and wind units
- Clean energy legislation that provides price support in the form of Zero Emission Credits (ZECs) for nuclear units that are at risk of early closure because of declining profitability, including programs in Illinois, New York, and New Jersey
- Environmental regulations approved and enacted
  - Regional Greenhouse Gas Initiative (RGGI), Cross-State Air Pollution Rule (CSAPR), and Mercury and Air Toxic Rule (MATS)
  - Policies under discussion but not enacted were not modeled







	Recent and Firm Builds (MW)								Recent and Firm Retirements (MW)							
Technology	ERCOT	ISO-NE	MISO	NYISO	PJM	Southeast	SPP	WECC	ERCOT	ISO-NE	MISO	NYISO	PJM	Southeast	SPP	WECC
Coal									5,583	383	12,906		11,417	8,529	1,546	9,416
Combined Cycle	232	1,230	4,725	1,721	13,065	5,480		1,235		34	424		430	121		2,268
Combustion Turbine	329	629	729	124	371	155	409	1,425	26	25	1,798	99	777	371	237	737
Nuclear						2,200			1,205	1,928	5,181	3,260	5,361			2,240
Oil/Gas Steam									1,692		2,098		1,394	364	3,241	9,090
Onshore Wind	5,166	33	2,858	158	959		3,423	2,531								
Other	11	16		21		215	1	373	1,010	2	183	2	242	255	169	437
Solar Photovoltaic	1,032	7	109	10	437	2,109	15	2,554								

Source: U.S. Energy Information Administration, "Form 860M," February 2019.

Assumptions – Recent and Firm Generation Builds/Retirements

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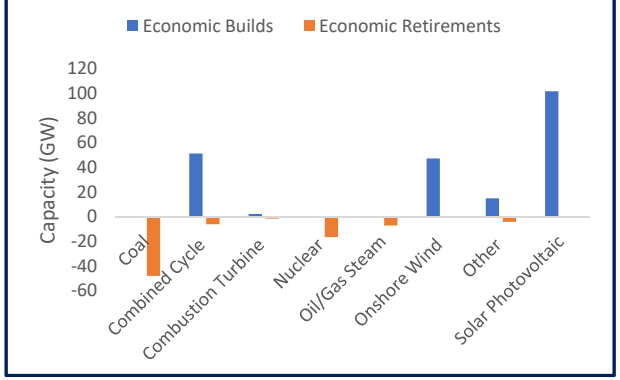
Builds and Retirements by Region

Builds and Retirements by Technology



	Recent and Firm Builds (MW)								Recent and Firm Retirements (MW)							
Technology	ERCOT	ISO-NE	MISO	NYISO	PJM	Southeast	SPP	WECC	ERCOT	ISO-NE	MISO	NYISO	PJM	Southeast	SPP	WECC
Coal									815	534	9,505	723	12,514	22,860		1,193
Combined Cycle	13,242		7,974	519	6,123	12,117		11,250		1,576		1,519		110		2,975
Combustion Turbine					673			1,409		148		54	40	8		1,424
Nuclear											5,456	853	1,590	5,526	1,947	1,180
Oil/Gas Steam										1,723	202	2,297	2,236	130	536	34
Onshore Wind		3,692	3,589	5173	8341	330	229	25,835								
Other		43	4,026	1,507	3,224	2,428	680	2,985	118	547	724	74	210	1,558		949
Solar Photovoltaic	14,895		5,430	2,828	36,963	15,767	4,694	21,105								

Source: U.S. Energy Information Administration, "Form 860M," February 2019.

Assumptions – Economic Generation Builds/Retirements

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Assumptions – Technology Cost and Performance

Parameter	Advanced Combined Cycle	Advanced Combustion Turbine	Nuclear	Battery Storage	Solar Photovoltaic	Solar Thermal	Onshore Wind
Size (MWe)	1,100	237	2,234	30	150	100	100
First Year Available	2022	2021	2025	2020	2020	2022	2022
Lead Time (Years)	3	2	6	1	1	3	3
Generation Capability	Economic Dispatch	Economic Dispatch	Economic Dispatch	Economic Dispatch	Generation Profile	Economic Dispatch	Generation Profile
2021							
Heat Rate (Btu/kWh)	6,300	9,550	10,461	NA	0	0	0
Capital (2018$/kW)	768	667	5,813	1,796	939	6,675	1,460
Fixed O&M (2018$/kW-yr)	10.30	7.01	103.31	36.32	7.84	67.80	51.48
Variable O&M (2018$/MWh)	2.06	11.02	2.37	7.26	0.00	3.69	0.00
2025							
Heat Rate (Btu/kWh)	6,200	8,550	10,461	NA	0	0	0
Capital (2018$/kW)	711	600	5,550	1,573	897	6,334	1,395
Fixed O&M (2018$/kW-yr)	10.30	7.01	103.31	36.32	7.50	60.85	49.94
Variable O&M (2018$/MWh)	2.06	11.02	2.37	7.26	0.00	3.69	0.00
2030							
Heat Rate (Btu/kWh)	6,200	8,550	10,461	NA	0	0	0
Capital (2018$/kW)	658	545	5,195	1,385	844	5,909	1,329
Fixed O&M (2018$/kW-yr)	10.30	7.01	103.31	36.32	7.07	52.15	48.02
Variable O&M (2018$/MWh)	2.06	11.02	2.37	7.26	0.00	3.69	0.00

Source: U.S. Department of Energy (DOE) Energy Information Administration (EIA) Annual Energy Outlook (AEO) 2019 Reference Case and National Renewable Energy Laboratory (NREL), "Annual Technology Baseline (ATB), 2018," 2018.

Methodology – Power Sector Models

IPM – Long-Term Planning and Capacity Expansion

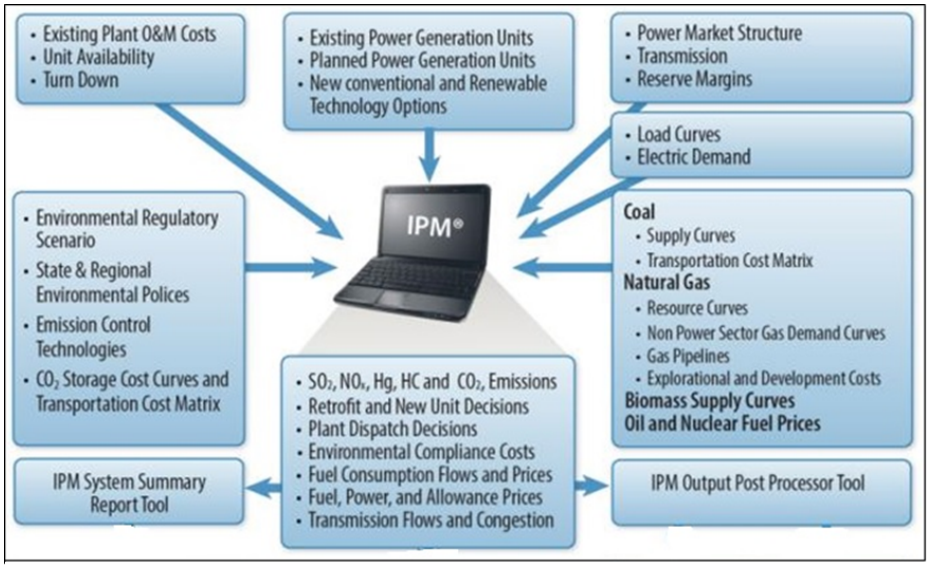
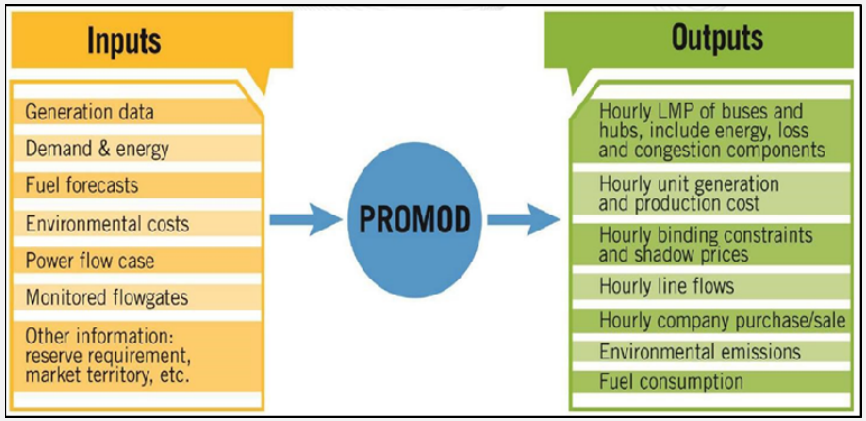


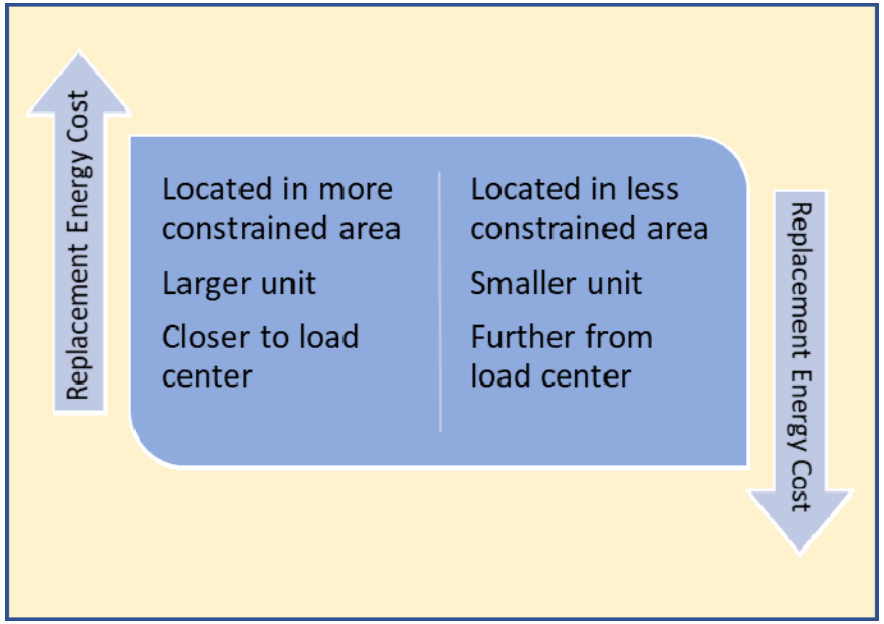
ABB PROMOD Nodal Production Cost Modeling



Source: IPM – ICF; PROMOD Graphic – PJM

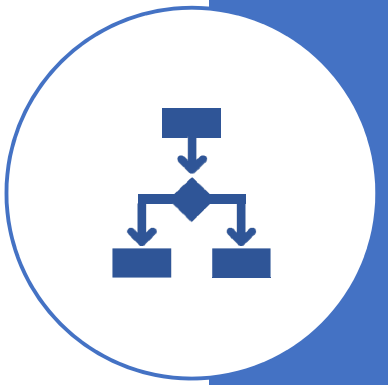
Methodology – Approach to Selecting Nuclear Outage Units for Alternative Cases

- Replacement energy costs were calculated by region
- For regions with multiple nuclear units the replacement energy cost was calculated as a range between the cost of the unit with the highest impact (Most Critical Unit) and the unit with the lowest impact (Least Critical Unit)
- Units were selected as most or least critical based on:
  - Location relative to congestion in the region
  - Size of the generating unit
  - Proximity to load centers



Methodology – Cost Calculations

- Calculated replacement energy cost for a region is the difference in annual average energy price between the Reference Case and each Alternative case
- Accounted for the effect of seasonal variations in energy prices by providing seasonal replacement energy cost. Seasons were defined as:
  - Winter: December (of prior year), January, February
  - Spring: March, April, May
  - Summer: June, July, August
  - Fall: September, October, November
- Seasonal values were calculated as the change in average energy price between the Reference Case and each Alternative Case for the months within the season



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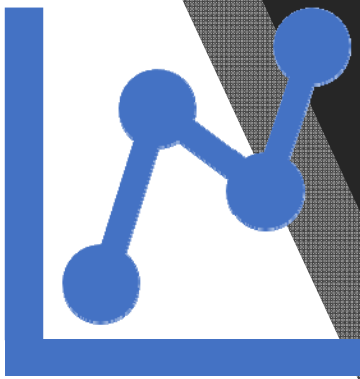
Limitations of Model and Methodology



- These projections are not predictions of what will happen, but rather modeled projections of what may happen
- Energy market projections are subject to uncertainty
- Assumes if the cost of generation is greater than the revenue produced the unit is not dispatched
- The NUREG does not consider:
  - Spikes in prices and volatility as a result of unexpected outages or errors in forecasts
  - Extreme events
  - Impact of future regulations
  - Effect of economic and other disruptions due to events such as pandemics

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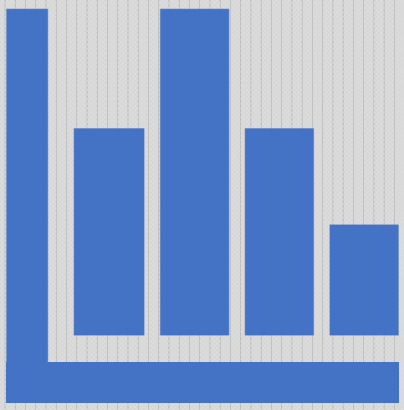
Results



Annual Market Price Impact and Replacement Energy Costs

Region	Annual Replacement Energy Costs ($/MWh)									
	2020		2021		2023		2025		2030	
	Most Impact	Least Impact	Most Impact	Least Impact	Most Impact	Least Impact	Most Impact	Least Impact	Most Impact	Least Impact
ERCOT	1.01	1.01	0.85	0.85	1.48	1.48	1.22	1.22	2.8	2.8
ISO-NE	2.36	1.68	3.00	2.13	2.96	2.13	3.42	2.38	6.12	4.35
MISO	0.13	0.01	0.23	0.03	0.30	0.03	0.37	0.09	0.17	0.00
NYISO	2.04	0.92	2.14	0.98	1.73	0.72	2.19	0.80	3.77	0.00
PJM	1.02	0.08	0.67	0.09	0.74	0.19	0.79	0.16	1.16	0.17
Southeast	0.18	0.11	0.18	0.07	0.17	0.13	0.16	0.10	0.26	0.15
SPP	0.92	0.46	0.86	0.47	0.00	0.00	0.00	0.00	0.00	0.00
WECC	1.12	0.68	1.15	0.91	1.07	0.00	0.94	0.00	1.76	0.00

Note: $0/MWh costs implies that there is no nuclear plant dispatched in the region

Observations

- Replacement energy costs in ERCOT and ISO-NE spike in 2030 because Comanche Peak Nuclear Power Plant Unit 1 and Seabrook Station are assumed to not be dispatched
- The operating license for Nine Mile Point Nuclear Station Unit 1 is modeled to expire in 2030. The impact on the NYISO annual replacement energy cost is less pronounced because it is a relatively smaller unit

- Appendix A - Overview of IPM
- Appendix B - Overview of PROMOD
- Appendix C - Selection of nuclear power plants for alternative cases (New England)
- Appendix D - Existing and committed nuclear units
- Appendix E - Determination of regional definitions for replacement cost calculations
- Appendix F - Summary of assumptions
- Appendix G - Detailed replacement energy costs: 2020-2030
- Appendix H - Studies and sources of data reviewed for assumptions development

Appendices

QUESTIONS

Next Steps

- Consider feedback from this public meeting
- Develop and publish the final NUREG with Commission approval
- Develop an appendix to NUREG/BR-0058, Rev. 5 to provide guidance for applying the replacement energy cost estimates
- Issue the appendix for public comment/public meeting
- Consider public comments and finalize the appendix
- Submit final appendix to Commission for review and approval

How to Provide Comments

- Federal Rulemaking Web Site
  - http://www.regulations.gov
  - Docket ID NRC-2020-xxxx
- NRC Contacts
  - Docket questions: Dawn Forder, 301-415-3407, Dawn.Forder@nrc.gov
  - Technical questions: Pamela Noto, 301-415-6795, Pamela.Noto@nrc.gov

How Did We Do?

There are several ways you can provide your feedback on this meeting:

- Scan QR code for NRC Public Meeting Feedback Form

Meeting ID # 20201293

- Go to the Public Meeting Schedule and click on the “Meeting Feedback” link.

References

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