

# NUCLEAR WORKING GROUP

## *Electricity Market Module Overview*



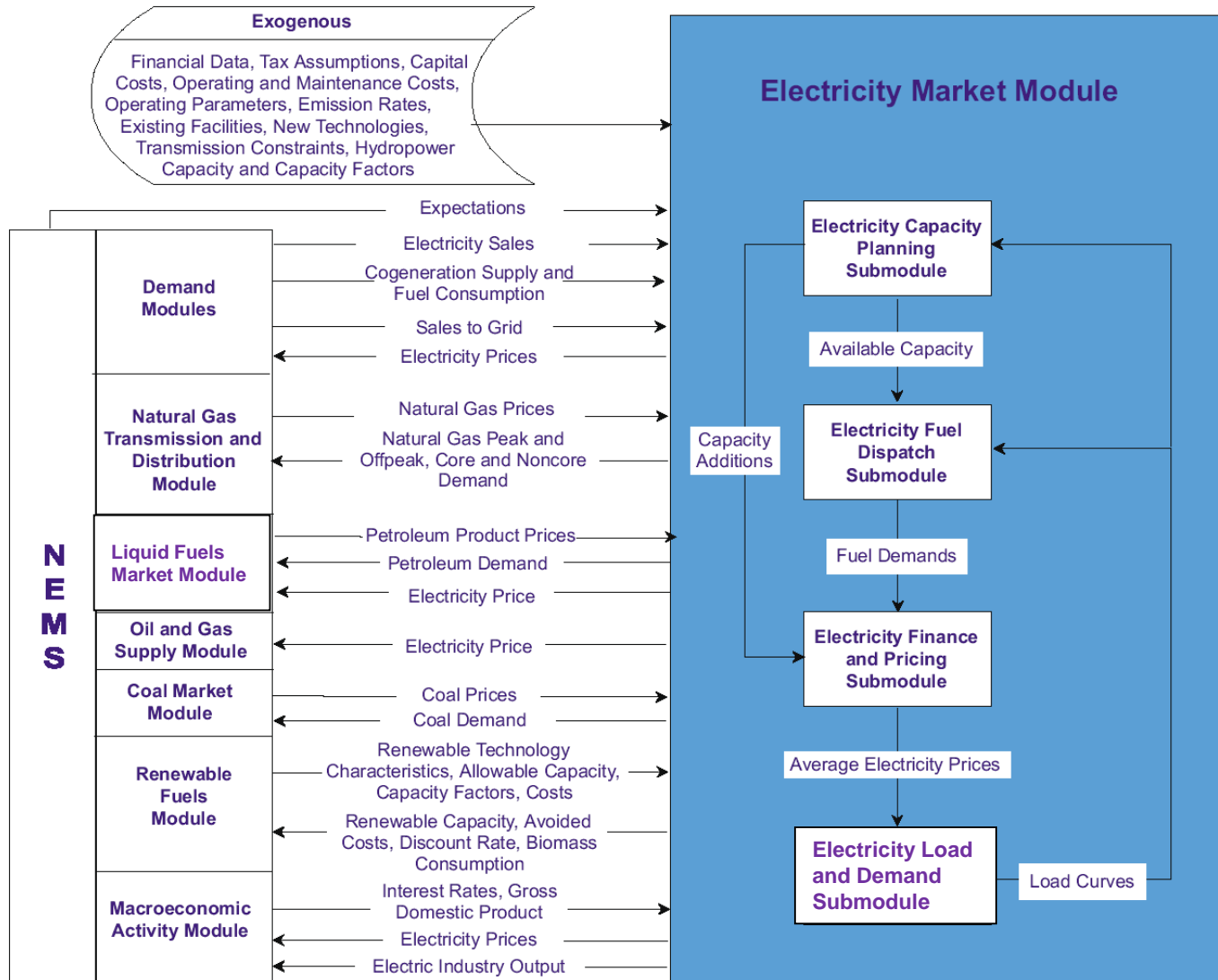
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*March 7, 2017| Washington, DC*

# NEMS and EMM are modular structures



# EMM regions are based on NERC subregions



# A range of existing and new technologies are modeled in EMM

Fossil fuel fired	Nuclear	Renewables
<ul style="list-style-type: none"> <li>Existing Coal without FGD<sup>1</sup></li> <li>Existing Coal with FGD<sup>1</sup></li> <li>New pulverized coal<sup>2</sup></li> <li>Advanced clean coal technology (IGCC)<sup>2</sup></li> <li>New Coal with sequestration (partial/full)</li> <li>Coal steam converted to natural gas</li> <li>Gas/oil steam</li> <li>Conventional gas/oil combined cycle</li> <li>Advanced combined cycle</li> <li>Advanced combined cycle with sequestration</li> <li>Conventional combustion turbine</li> <li>Advanced combustion turbine</li> <li>Fuel cells</li> <li>Distributed generation (Base and Peak)</li> </ul>	<ul style="list-style-type: none"> <li>Conventional nuclear</li> <li>Advanced nuclear</li> </ul>	<ul style="list-style-type: none"> <li>Conventional hydropower</li> <li>Geothermal</li> <li>Solar-thermal</li> <li>Solar-photovoltaic</li> <li>Wind – onshore and offshore</li> <li>Wood</li> <li>Municipal solid waste/Landfill gas</li> </ul>

Conventional nuclear  
Advanced nuclear

Currently modeling AP1000  
Evaluating potential for SMR as an additional choice

(FGD = flue gas desulfurization)

<sup>1</sup>The EMM represents 32 different types of existing coal steam plants, based on the different possible configuration of NOx, particulate and SO2 emission control devices, as well as future options for controlling mercury and carbon.

<sup>2</sup>The AEO2017 assumes new coal plants without CCS cannot be built, due to emission standards for new plants. These technologies exist in the modeling framework, but are not assumed available to be built in the projections.

# New Technology Assumptions – AEO2017

Technology	First available year	Size (MW)	Lead time (years)	Base overnight cost in 2016 (2016 \$/kW)	Project Contingency Factor	Technological Optimism Factor <sup>3</sup>	Total overnight cost in 2016 (2016 \$/kW)	Variable O&M (2016 \$/MWh)	Fixed O&M (2016\$/kW/yr)	Heat rate in 2016 (Btu/kWh)	nth-of-a-kind heat rate (Btu/kWh)
Coal with 30% carbon sequestration	2020	650	4	4,586	1.07	1.03	5,030	7.06	69.56	9,750	9,221
Coal with 90% carbon sequestration	2020	650	4	5,072	1.07	1.03	5,562	9.54	80.78	11,650	9,257
Conv Gas/Oil Comb Cycle	2019	702	3	923	1.05	1.00	969	3.48	10.93	6,600	6,350
Adv Gas/Oil Comb Cycle (CC)	2019	429	3	1,013	1.08	1.00	1,094	1.99	9.94	6,300	6,200
Adv CC with carbon sequestration	2019	340	3	1,917	1.08	1.04	2,153	7.08	33.21	7,525	7,493
Conv Comb Turbine <sup>7</sup>	2018	100	2	1,040	1.05	1.00	1,092	3.48	17.39	9,920	9,600
Adv Comb Turbine	2018	237	2	640	1.05	1.00	672	10.63	6.76	9,800	8,550
Fuel Cells	2019	10	3	6,252	1.05	1.10	7,221	44.91	0.00	9,500	6,960
Adv Nuclear (AP1000)	2022	2,234	6	5,091	1.10	1.05	5,880	2.29	99.65	10,459	10,459
Distributed Generation - Base	2019	2	3	1,463	1.05	1.00	1,536	8.10	18.23	8,981	8,900
Distributed Generation - Peak	2018	1	2	1,757	1.05	1.00	1,845	8.10	18.23	9,975	9,880
Biomass	2020	50	4	3,540	1.07	1.00	3,790	5.49	110.34	13,500	13,500
Geothermal	2020	50	4	2,586	1.05	1.00	2,715	0.00	117.95	9,510	9,510
MSW - Landfill Gas	2019	50	3	8,059	1.07	1.00	8,623	9.14	410.32	18,000	18,000
Conventional Hydropower	2020	500	4	2,220	1.10	1.00	2,442	2.66	14.93	9,510	9,510
Wind	2019	100	3	1,576	1.07	1.00	1,686	0.00	46.71	9,510	9,510
Wind Offshore	2020	400	4	4,648	1.10	1.25	6,391	0.00	77.30	9,510	9,510
Solar Thermal	2019	100	3	3,908	1.07	1.00	4,182	0.00	70.26	9,510	9,510
Photovoltaic	2018	150	2	2,169	1.05	1.00	2,277	0.00	21.66	9,510	9,510

# EMM inputs based on historical data, assumptions and information from other modules of NEMS

- Available capacity by plant type
- Plant characteristics – heat rate, emission rate, O&M cost, capacity factor – for existing plants and new technologies (for planning)
- Fossil fuel data – price curves, sulfur, carbon, and mercury content
  - Fuel price expectations for future years (30 year time horizon) for planning submodule
- Demand – electricity load by season and time slice
  - 30 year expectations are needed for planning submodule
- Transmission data – constraints on interregional trade, transmission and distribution loss factors
- Financial inputs – cost of capital / capital structure/ discount rate for new builds; existing plant investment and recovery for regulated pricing
- Required reserve margins by EMM region

# EMM provides outputs based on electricity capacity expansion and dispatch results

- Decisions for the next model year: new capacity builds, environmental retrofits, retirements
- Allowance prices for environmental constraints
- Credit prices for renewable portfolio standards
- Total fuel and operating costs based on dispatch solution
- Marginal costs of generation
- Cost and quantities of electricity trade
- Fuel generation and consumption, emissions
- Retail electricity prices by end-use sector

# AEO2017 continues to include the Clean Power Plan

- Clean Air Act Section 111b – new source CO<sub>2</sub> emissions standards
  - Fossil steam: 1400 lbs/Mwh
  - New coal requires carbon capture and sequestration (CCS) to comply
- Clean Air Act Section 111d – existing source CO<sub>2</sub> emission standards (Clean Power Plan)
  - Performance standards for existing fossil steam and combined cycle plants
  - Rate-based or mass-based targets
  - Leakage from existing to new sources not permitted
  - Implemented in AEO2017 as a mass-based program covering new and existing sources, and met at the electricity region level



# Current federal and state programs on emissions are explicitly represented

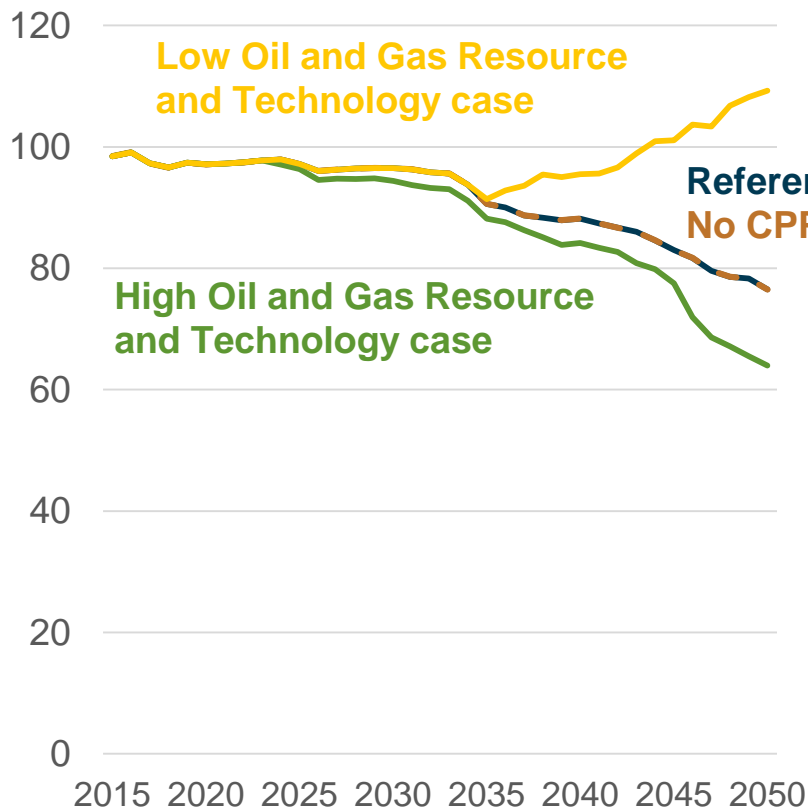
- Cross-State Air Pollution Rule (CSAPR), which was vacated in August 2012, has been reinstated to replace the Clean Air Interstate Rule (CAIR) (NO<sub>x</sub> and SO<sub>2</sub>)
- Mercury and Air Toxics Standards (MATS) issued in December 2011 are represented
  - Requires 90% removal of uncontrolled mercury emissions
  - Requires Flue Gas Desulfurization or Fabric Filter/Dry Sorbent Injection to control air toxics
- State/Regional Greenhouse Gas Regulations
  - Regional Greenhouse Gas Initiative (RGGI) – CO<sub>2</sub> cap for 9 states in the Northeast, emissions limit typically not binding in EMM
  - California Senate Bill 32 (SB 32) – cap and trade program covering multiple sectors, includes emissions offsets and allowance allocations

# The AEO2017 projections provide a Reference case and side cases to reflect areas of uncertainty

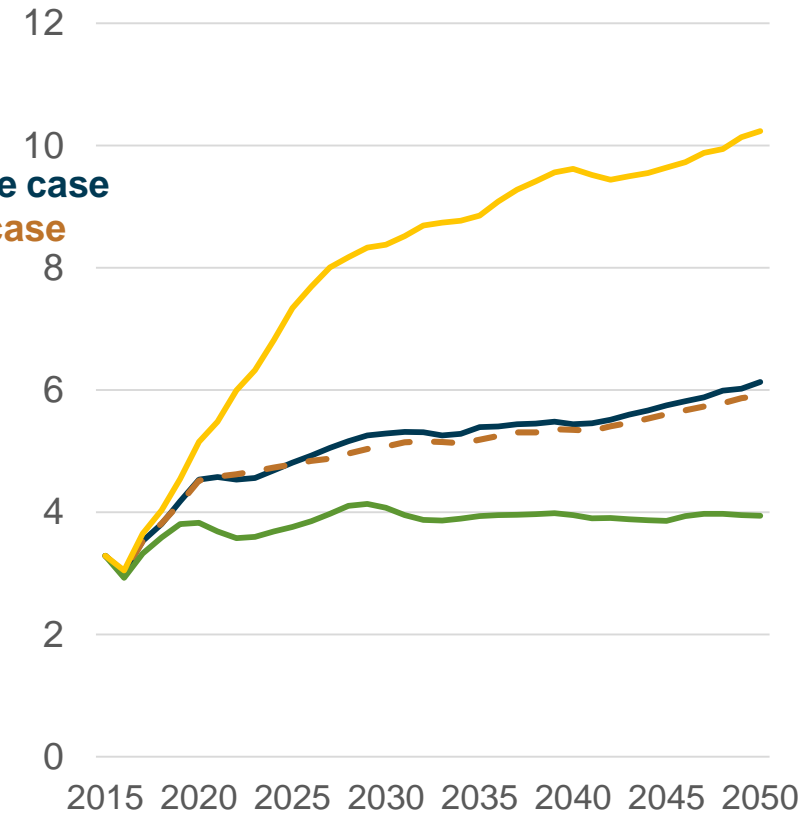
- The Reference case projection assumes trend improvement in known technologies, along with a view of economic and demographic trends reflecting the current central views of leading economic forecasters and demographers. It generally assumes that current laws and regulations affecting the energy sector, including sunset dates for laws that have them, are unchanged throughout the projection period. The potential impacts of proposed legislation, regulations, or standards are not reflected in the Reference case.
- A case that assumes that the Clean Power Plan (CPP) is not implemented can be compared to the Reference case to show how that policy could affect energy markets and emissions.
- In the High Oil and Gas Resource and Technology case, lower costs and higher resource availability than in the Reference case allows for increased levels of production at lower prices. In the Low Oil and Gas Resource and Technology case, more pessimistic assumptions about resources and costs are applied.

# Nuclear capacity retirements and new additions can vary depending on relative natural gas prices

**Nuclear electricity generating capacity**  
gigawatts



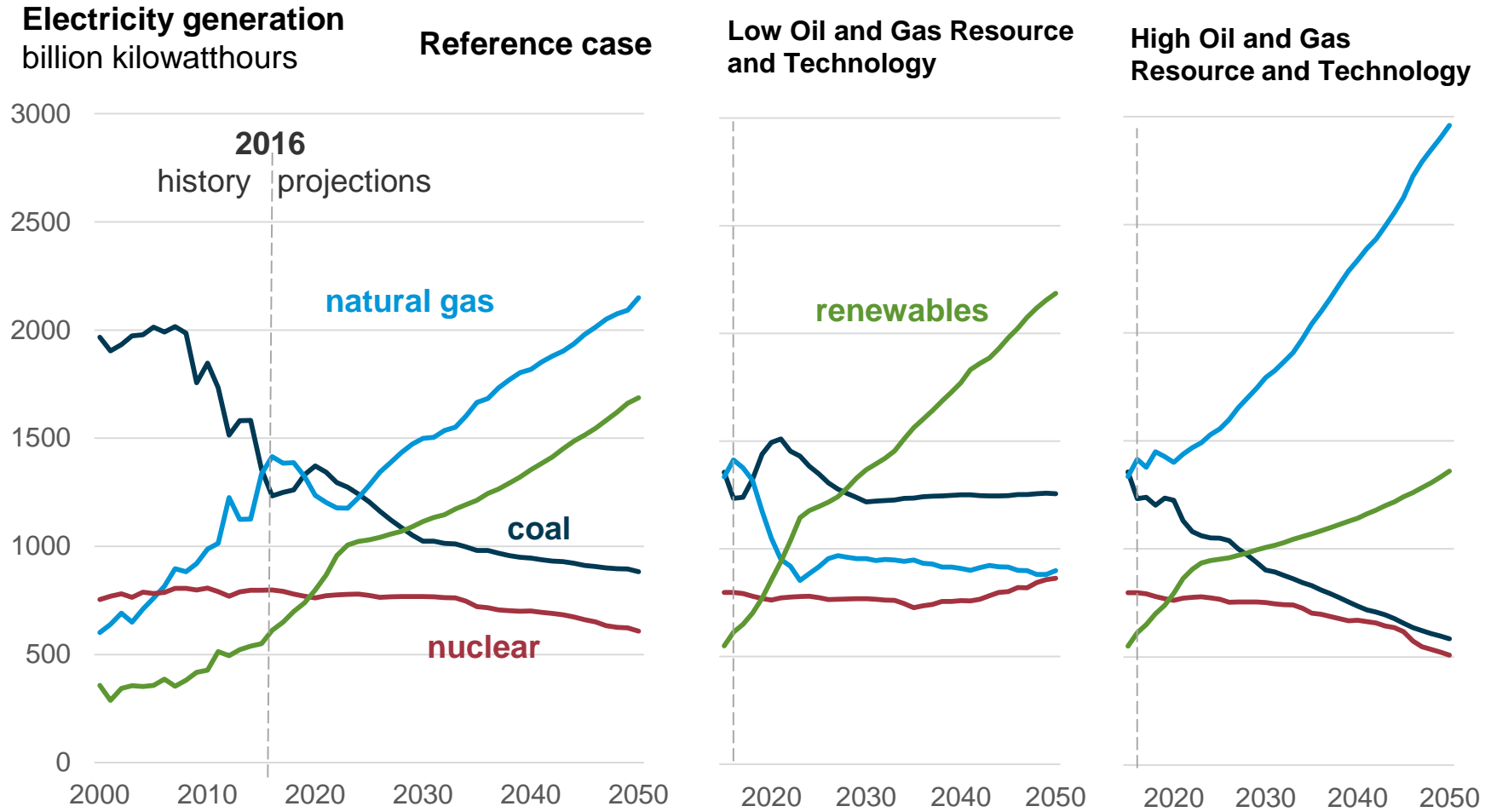
**Delivered natural gas prices**  
2016 \$/MMBtu



U.S. Energy Information Administration, Annual Energy Outlook 2017

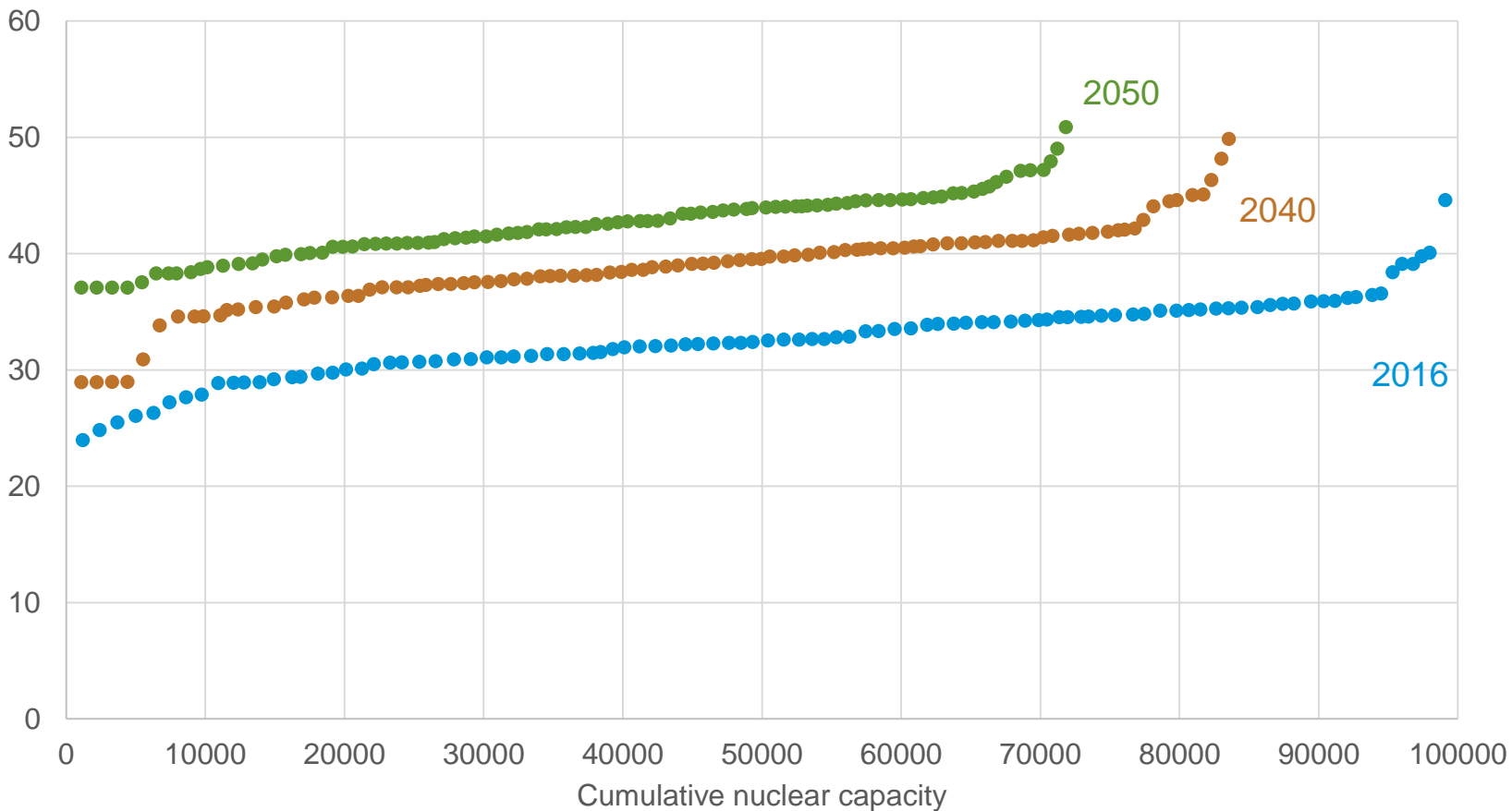
# Natural gas resource availability affects prices and plays a critical role in determining the mix of coal, natural gas, nuclear, and renewable generation

## Electricity generation billion kilowatthours



# EMM accounts for variability in plant level costs to project dispatch and retirement decisions

Full going forward costs for nuclear plants  
2016 \$/MWh

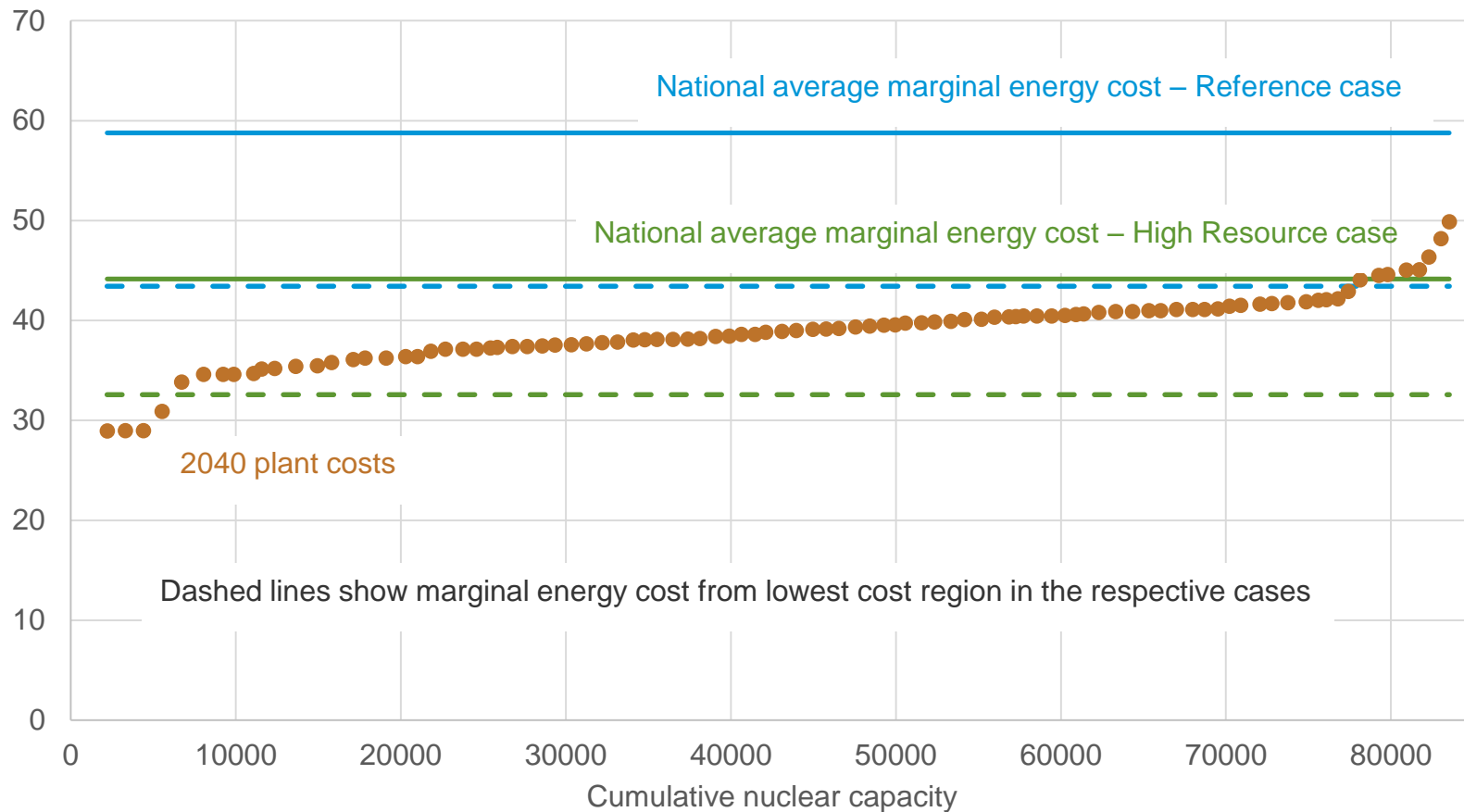


U.S. Energy Information Administration, Annual Energy Outlook 2017

# Operating costs relative to the marginal energy price, representing potential revenues, impacts model retirement decisions

Full going forward costs for nuclear plants, 2040  
2016 \$/MWh

Marginal energy cost, 2040  
2016 \$/MWh



U.S. Energy Information Administration, Annual Energy Outlook 2017

## For more information

Assumptions Document | <http://www.eia.gov/forecasts/aeo/assumptions/index.cfm>

Model Documentation |  
<http://www.eia.gov/reports/index.cfm?t=Model%20Documentation>

Annual Energy Outlook | [www.eia.gov/aeo](http://www.eia.gov/aeo)