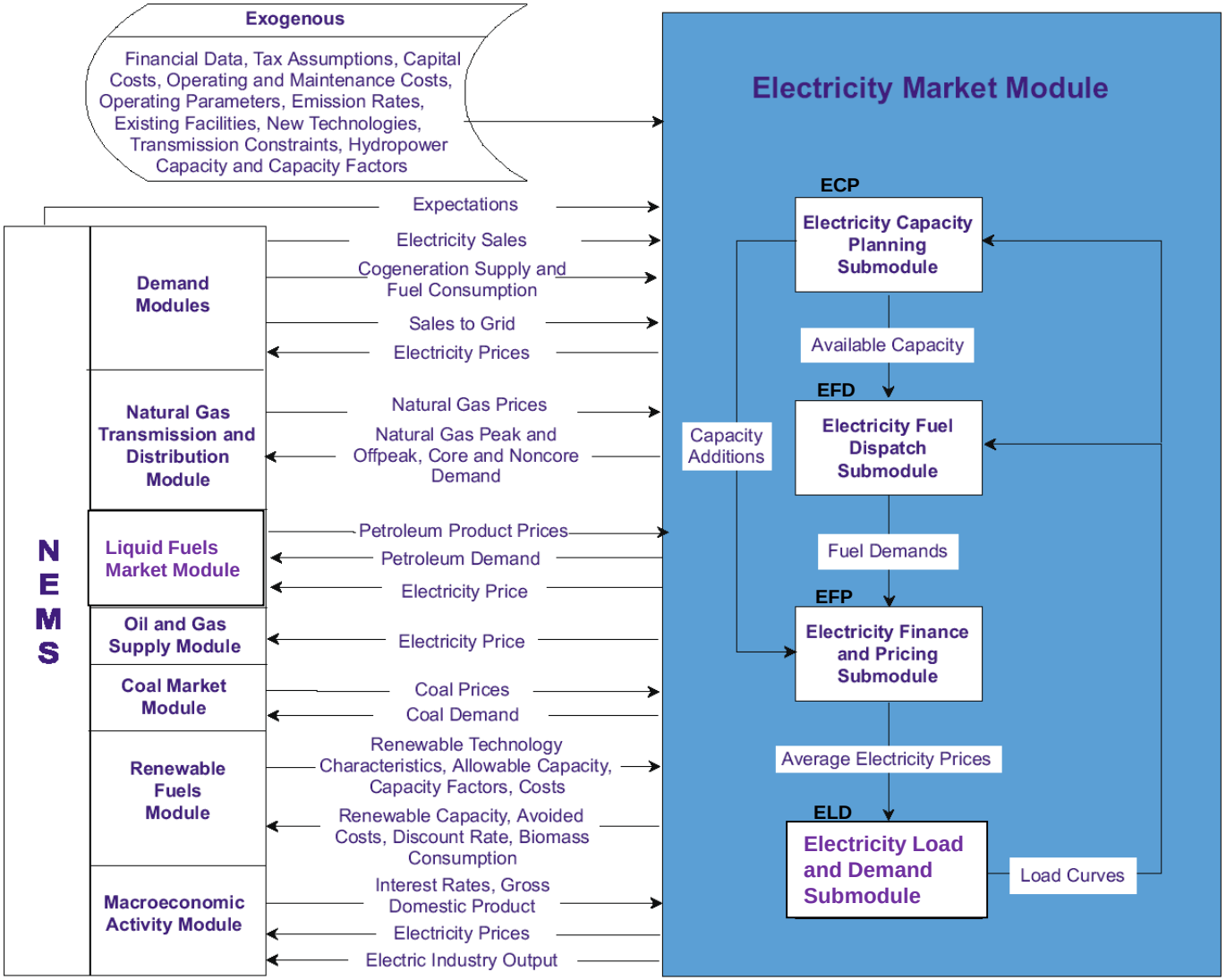
NEMS Modeling of Coal Plants

Office of Electricity, Coal, Nuclear, and Renewable Analysis
Laura Martin
June 14, 2016 Washington, DC

EMM Structure



Model inputs for coal plants

- Existing coal plants – plant specific inputs
  - Fixed and variable operating and maintenance costs, annual capital additions
  - Retrofit costs (capital and O&M) – FGD, DSI, SCR, SNCR, CCS, FF
  - Cost to convert to natural gas-fired steam plant
  - Cost to implement heat rate improvement
  - Average heat rate and capacity factor, based on historical data
- All existing coal plants are assumed to have same annual cost adder after 30 years to address aging
- New coal plants – only one new technology that is 111(b) compliant is modeled for AEO2016
  - Overnight cost, heat rate, operating costs, carbon removal (30%)

Existing coal configurations

Sulfur dioxide	Particulate	NO_X post-combustion control	Existing capacity (MW)
none	baghouse	Any (or none)	16,308
wet FGD	baghouse	Not SCR	19,758
wet FGD	baghouse	SCR	15,774
dry FGD	baghouse	Any (or none)	28,655
none	cold-side ESP	Any (or none)	67,305
wet FGD	cold-side ESP	Not SCR	38,722
wet FGD	cold-side ESP	SCR	89,823
dry FGD	cold-side ESP	Not SCR	3,808
none	other (i.e. hot-side ESP) or none	Any (or none)	6,212
wet FGD	other/None	Not SCR	3,902
wet FGD	other/None	SCR	2,847

- No plants are assumed to have existing dry-sorbent injection (DSI), but after 2016 in the model, any plant remaining in the 'unscrubbed' category will have had a DSI added.
- Plants will switch configurations during a model run as equipment is projected to be added.
- Additional plant types representing adding supplemental fabric filter or carbon capture are also modeled.

Capacity Factor and Capital Cost Assumptions

- Maximum Capacity Factor Assumptions
  - In the first model year, the maximum capacity factor a coal unit may run at is set to the greater of either the actual, previous 5-year average capacity factor or 60%
  - If the maximum capacity factor in the first year is less than or equal to 75%, it increases linearly each year towards 75% by 2025, where it remains through 2040
  - If the actual, previous 5-year average capacity factor is already at or above 75%, the maximum capacity is set to that value and stays there throughout the forecast
- Annual Capital Cost Assumptions (in 2015 dollars)
  - The average annual capital additions for existing plants are $20 per kilowatt (kW)-year for coal plants, $8 per for oil and gas steam plants, and $23 for nuclear plants regardless of age
  - Beyond 30 years of age an additional $7 per kW-year capital charge for fossil plants and $34 for nuclear plants is included in the retirement decision to reflect further investment to address the impacts of aging

Environmental rules modeled in AEO2016

- Mercury and Air Toxics Standard (MATS)
  - Enforced in 2016, model requires coal plants to have a scrubber or a DSI/FF combination to meet HCl and particulate controls
  - Combinations of environmental controls and/or activated carbon injection can be used to meet mercury removal requirements
  - If plants do not have sufficient equipment, or it is uneconomic to invest in required equipment, they are retired
- Cross State Air Pollution Rule
  - Regional SO_2 and NO_X constraints, generally non-binding due to MATS
- Regional greenhouse gas rules
  - RGGI – Northeast states
  - AB32 - California

Clean Power Plan included in AEO2016

- Clean Power Plan is implemented in the EMM at the electricity region levels, assuming cooperation within a region
- Model can implement either EPA's average emission standard (rate-based) targets or mass-based targets; AEO2016 Reference case assumes all regions use mass-based targets, including new sources to avoid leakage
- Alternative cases will be available in final AEO2016 that use rate-based standard, assume greater cooperation among regions, and that vary the allowance allocation assumption

Electricity model components

- Electricity Capacity Planning (ECP) – multi-year linear programming structure
  - Solves each model year, optimizing over 30 years for planning of long term investment decisions
  - Makes build, retrofit and retirement decisions for next future year
  - Includes expectations for future demand, fuel prices and environmental regulations if appropriate
  - Uses plant specific inputs, but can aggregate into larger groups to minimize model size
- Electricity Fuel Dispatch (EFD) – single year linear program
  - Solved every iteration of every model year, to respond to changes in demand, fuel prices and other information passed from other parts of NEMS
  - Models dispatch at more detailed plant level than ECP
  - Environmental regulations that are heavily dependent on re-dispatch options are modeled directly in both the EFD and ECP (CPP, regional CO_2 and SO_2)
  - Rules that are more reliant on build/investment decisions are modeled as constraints only in the ECP, and costs are passed to the EFD (renewable portfolio standards, NO_X constraints)
  - Provides final projections for generation and consumption

ECP – Objective Function

- Minimizes total discounted present value of construction, operating (fuel/O&M), and transmission costs of meeting demand while complying with environmental regulations for a given model year. The objective function is in millions of nominal dollars
- Construction costs evaluated over 30 year economic life, assuming financing with 45% debt/55% equity; roughly 8% nominal discount rate
- Retrofit costs are evaluated over 20 year economic life, using regulated cost of capital inputs that can vary by region
- Annual operating costs and capital additions are fixed over time, other than the one time increase for aging (which is then held constant)
- Fuel price expectations based on previous model run are used for fuel costs in projected years

ECP retirement decision

- MATS compliance – in 2016 the ECP must determine whether a plant is compliant with MATS, and if not, what controls or level of activated carbon injection must be used; alternate model vectors are created for each configuration of the plant, with the appropriate costs added to the objective function. If a MATS compliant configuration is not chosen by the LP solution, then the plant is retired.

- In later projection years, the ECP continues to evaluate plant retirements based on economics. The ECP contains constraints for demand, capacity reserve margins and operating reserves, and coal plants can contribute to each. If an existing coal plant is no longer needed to meet these constraints (i.e. enough other lower-cost capacity is available or it is cheaper to build something new), then it is retired. The plant must also have been marked by the EFD in the previous year as not covering costs with revenues.

EFD – Objective function and demand requirements

- Minimizes total operating (fuel and variable O&M) costs of meeting annual demand while complying with environmental regulations for a given model year.
  - Fixed costs and investment costs are not included in the EFD linear program
  - Available capacity and plant configurations are updated each model year based on the ECP decisions

- Demand is characterized by a load curve of 9 time slices, solved simultaneously
  - Three seasons, of four months each
  - Each season contains three segments of varying lengths of time to represent both peak, intermediate and baseload demand periods
  - Coal plants cannot operate in peak-only time slice, but may be dispatched in the peak / intermediate, or peak / intermediate / base combinations
  - Additional operating modes created to contribute to spinning reserves that can result in load-following behavior or minimum generation output
  - Current operating costs and heat rate is constant for a plant regardless of operating mode, this is being evaluated for future modification

EFD – Dispatch decisions

- Demand: electricity demand must be met in each time slice and region, through allocating existing plants in the region or trading with neighboring regions

- Spinning reserves: specific levels of operating plants must be available to provide spinning reserves in each time slice and region

- Emission constraints – SO_2 and CO_2: Emission caps on these pollutants are modeled as strict constraints in the EFD. Detailed fuel supply curves are incorporated in the LP to allow for fuel switching between coal types, or from coal plants to natural gas-fired plants, as needed to meet the constraint. Costs of complying with the constraints will flow through directly to the energy cost of meeting demand.

- Emission constraints - NO_X: Because complying with NO_x is primarily a capital cost decision, the EFD does not model NO_x caps directly. The allowance price calculated by the ECP is passed to the EFD, and the cost is added to the operating cost of a plant, based on its emission rate.

- Renewable portfolio standards: Similarly, the ECP builds renewable capacity to meet RPS requirements, and passes the EFD the credit price, which is added to the operating costs for plant types that need to purchase credits

NEMS EMM operating mode-variant heat rate feature (currently under development)

- NEMS EMM is not capable of capturing performance impacts associated with cycling behaviors exhibited by many coal plants today under various operating modes, which can affect projections of capacity factor, fuel consumption, and emission. NEMS uses generator specific five-year averaged annual heat rates which do not vary over different operating modes available.

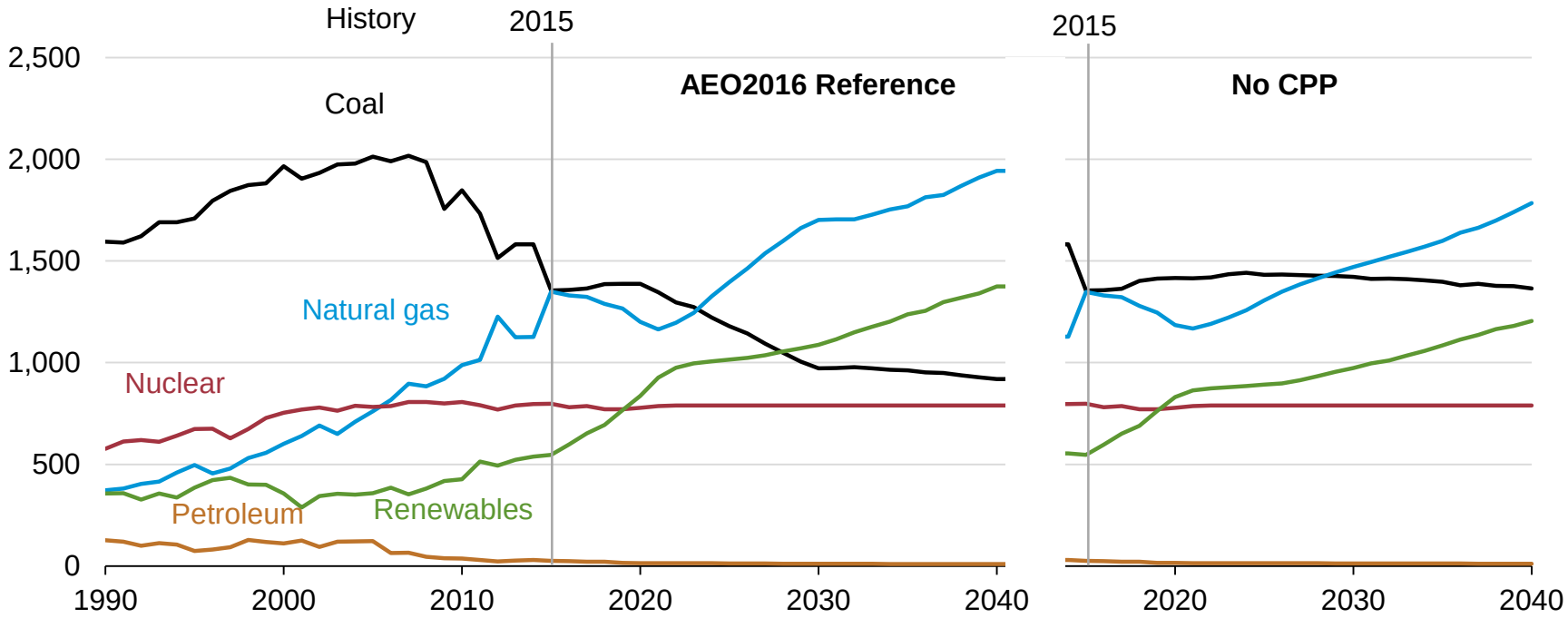
- A study was conducted in 2015 by Leidos to develop a methodology to calculate operating mode-variant heat rates based on thermal efficiency in conjunction with studying actual hourly data found in data source such as the EPA CEMS database.
  - The study was focused on 35 coal units in Georgia and New York, and found that daily cycling modes for individual units was evident in data from 2011-2014
  - The study found that the effect of daily average gross load on the predicted inverse heat rates is relatively clear

- A follow-up task with OnLocation has been started to implement algorithms to calculate heat rate adjustment factors for the different operating modes within the EMM
  - Likely implementation level will be by EMM region and coal plant configuration

AEO2016 electricity results

Natural gas generation falls through 2021; both gas and renewable generation surpass coal by 2030 in the Reference case, but only natural gas does so in the No CPP case

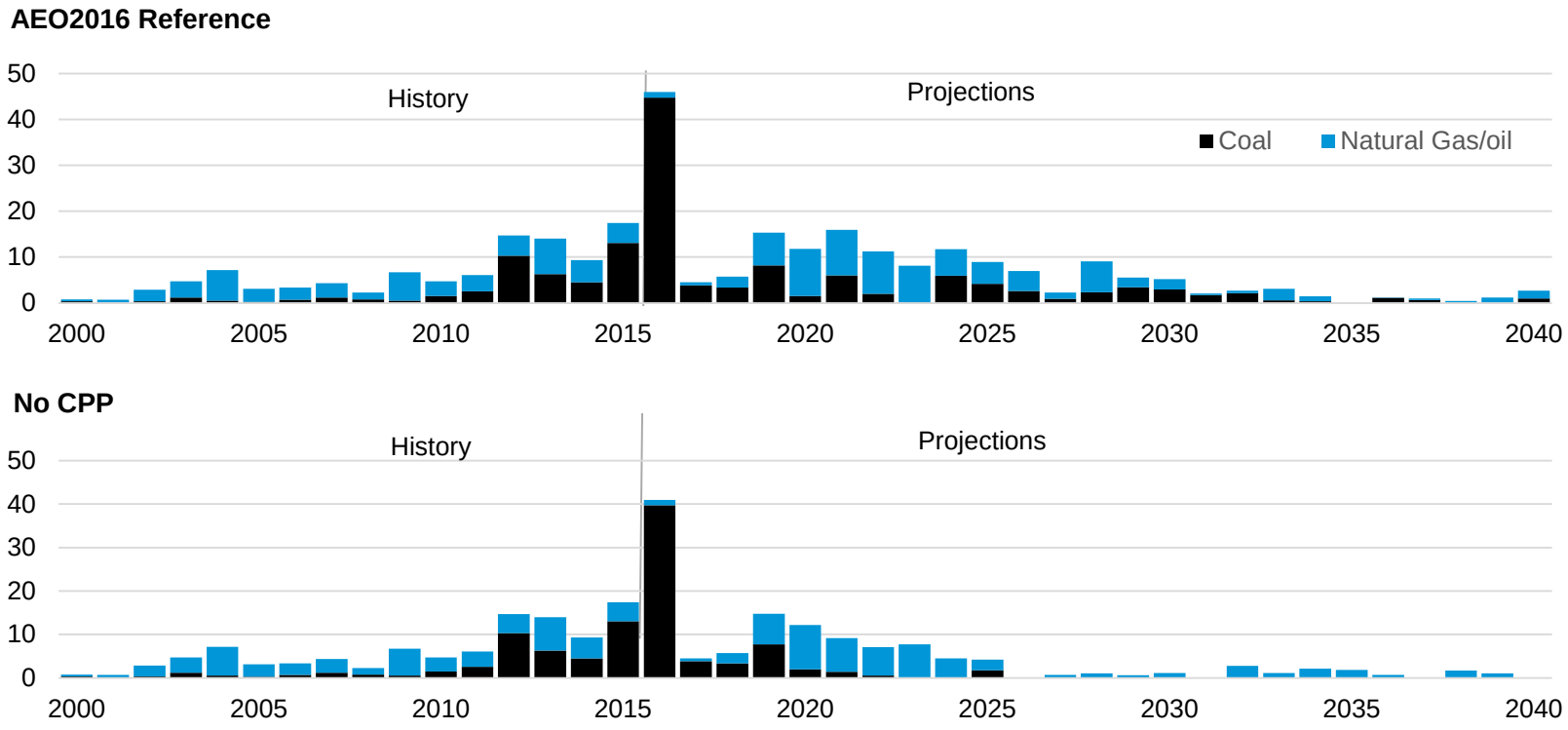
net electricity generation
billion kilowatthours



Source: EIA, Annual Energy Outlook 2016

The Mercury and Air Toxics rule (MATS) rule and low natural gas prices are the main near-term driver of coal plant retirements; CPP increases near-term coal plant retirements modestly and adds more retirements in later years

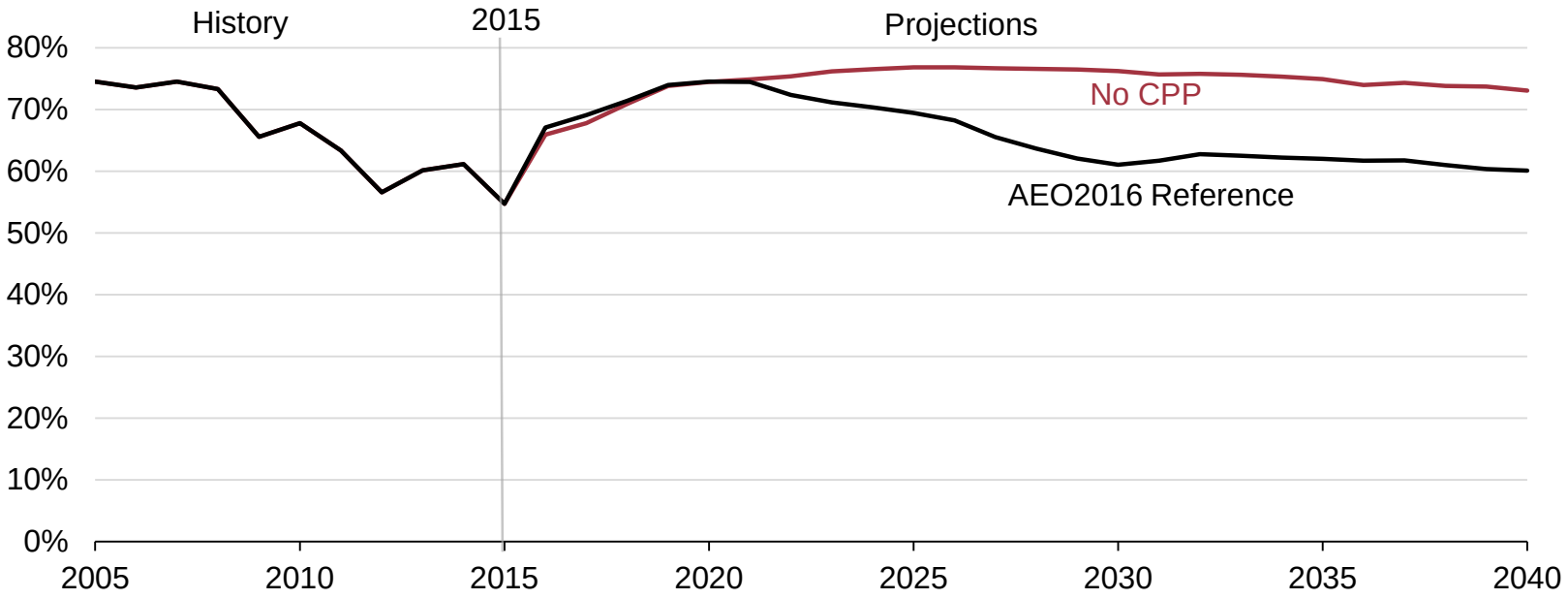
annual capacity retired, gigawatts



Source: EIA, Annual Energy Outlook 2016

Average capacity factor for coal-fired generating units falls by 15 percentage points by 2030 in the Reference case when compared with the No CPP case

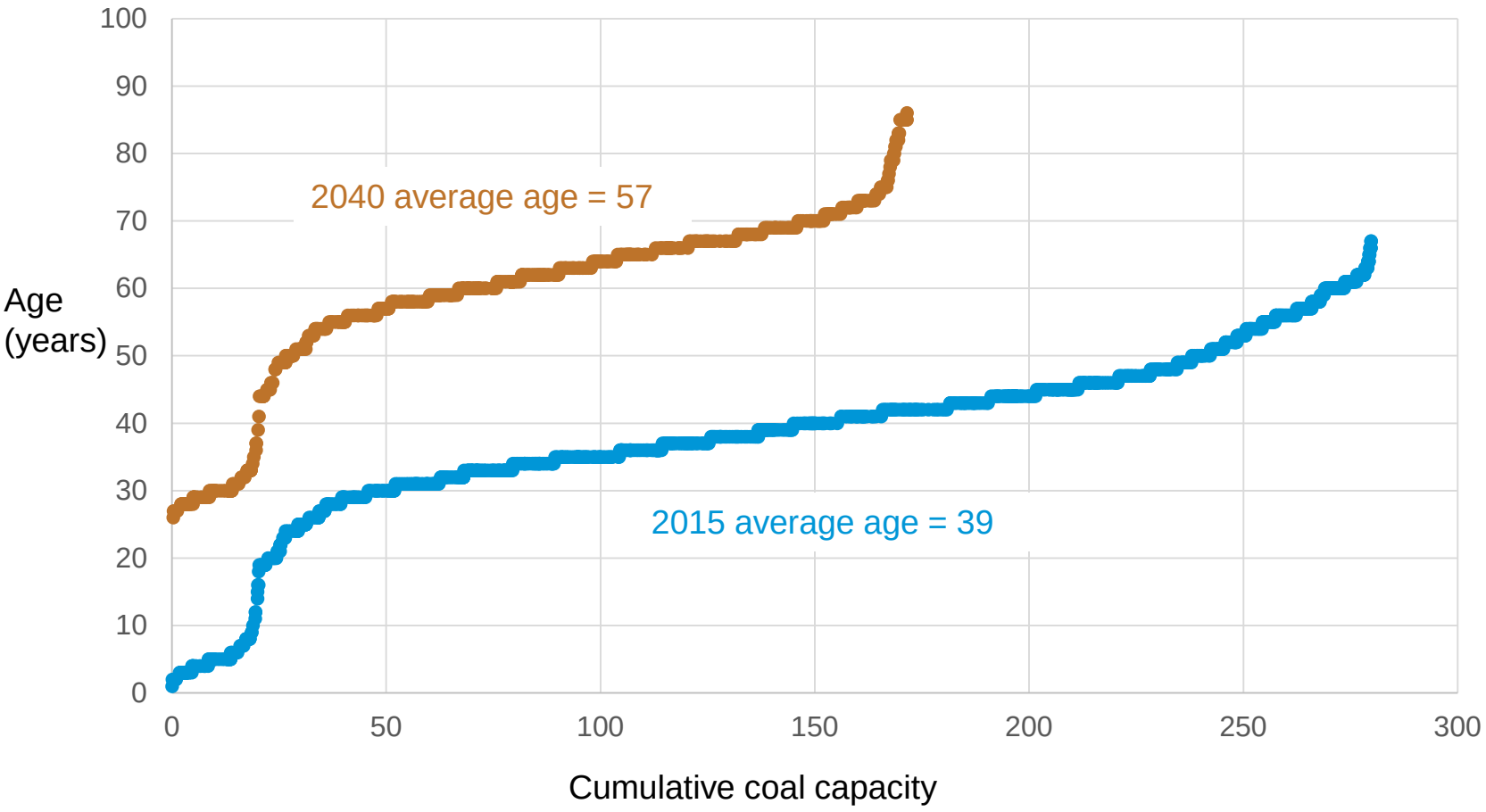
capacity factor of central station coal-fired electricity generating units
percent utilization



Source: EIA, Annual Energy Outlook 2016

Average age of coal fleet increases significantly between 2015 and 2040

Cumulative coal capacity (GW) versus age (years)



Source: EIA, Annual Energy Outlook 2016

For more information

Annual Energy Outlook www.eia.gov/aeo

Assumptions to the AEO http://www.eia.gov/forecasts/aeo/assumptions/index.cfm

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