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2016 Standard Scenarios Report: A U.S. Electricity Sector Outlook

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NREL Forward-looking Power Sector Work

1. **Annual Technology Baseline (ATB)**: detailed cost and performance projections for electricity generating technologies
2. **Standard Scenarios:** Power sector modeling using ATB inputs on a standardized set of scenarios

Both include projections through 2050 for the U.S. electricity sector

Standard Scenarios: U.S. Electricity Sector Outlook

Objective: identify a range of possible futures for the U.S. electricity sector that illuminate specific electricity system issues by:

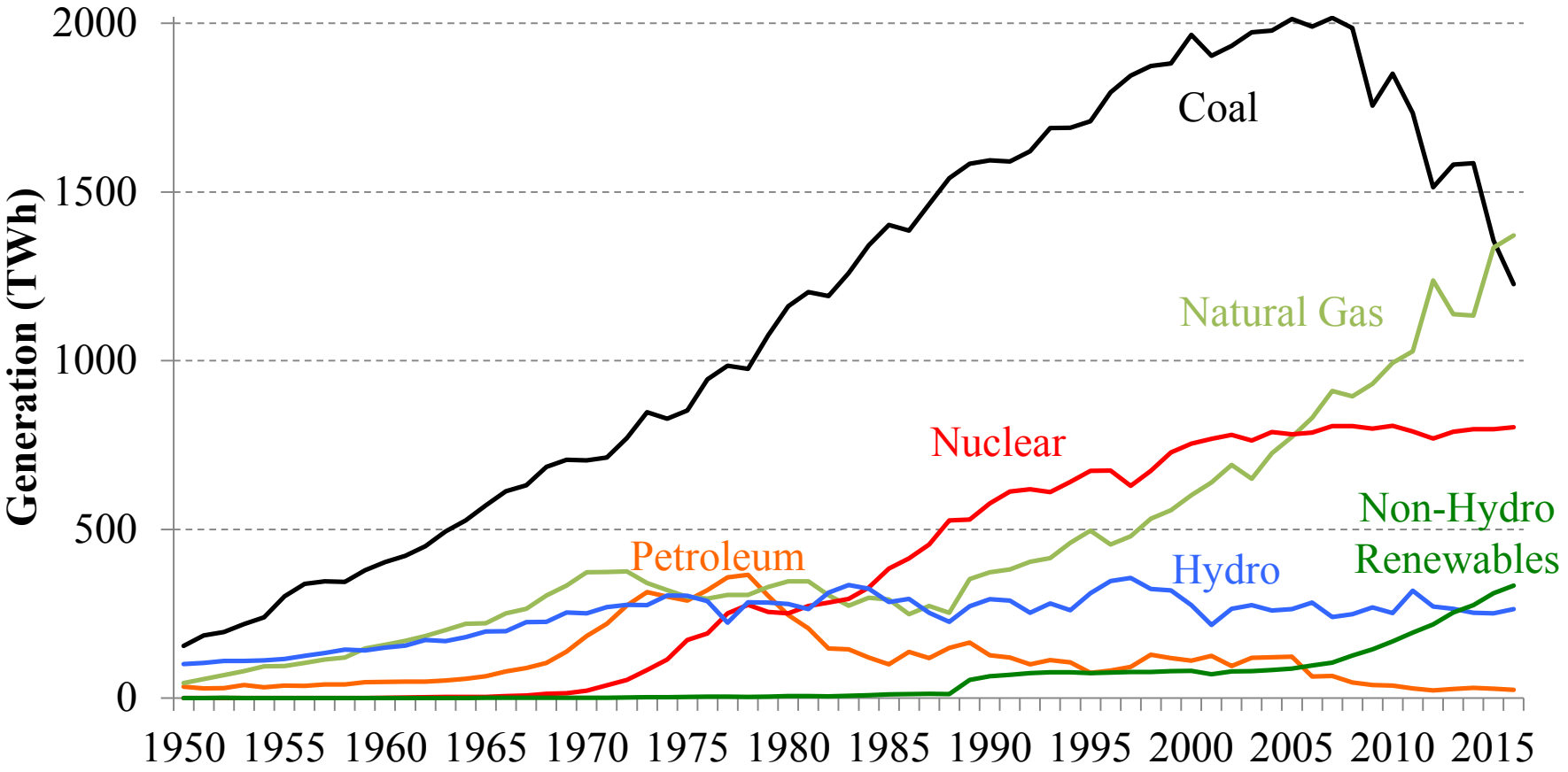
1. Defining a set of prospective scenarios that bound ranges of technology, market, and policy assumptions
2. Assessing the range of resulting outcomes, including deployment and generation, energy prices, and carbon dioxide (CO_2) emissions
3. Identifying key areas in the evolution of power sector

Changes to 2016 Standard Scenarios Report

- Standard Scenarios 2015
  - 88-page report
  - No significant analysis, just reporting on scenario results
  - ~40 pages of ReEDS documentation
  - Limited uptake and impact
- Standard Scenarios 2016
  - Shorter report (30 pages + appendices)
  - Online scenario results viewer
  - Use scenario results to present original analysis/discussion around four storylines

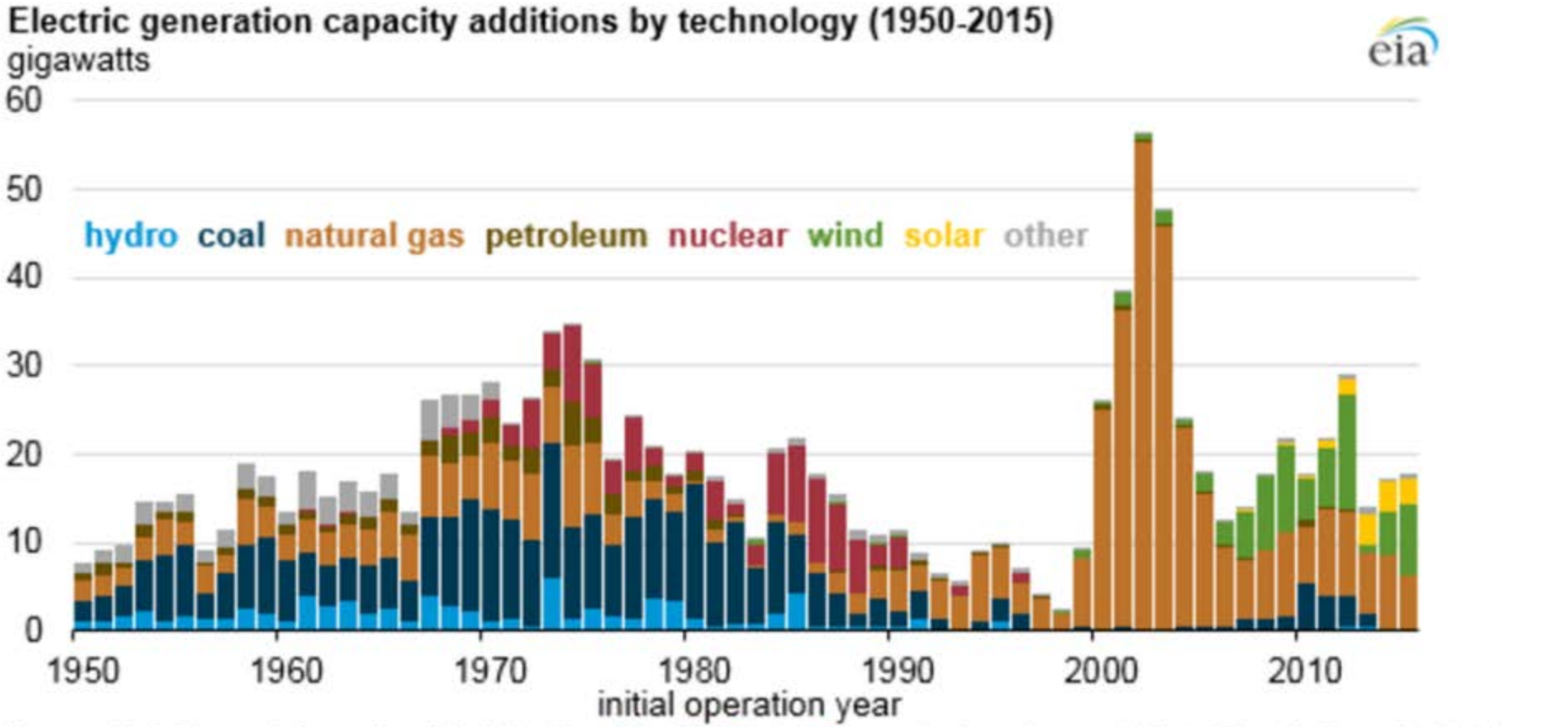
The Power Sector has Experienced Rapid Transformation

- Strong coal-to-gas switching
- High relative growth in renewable energy



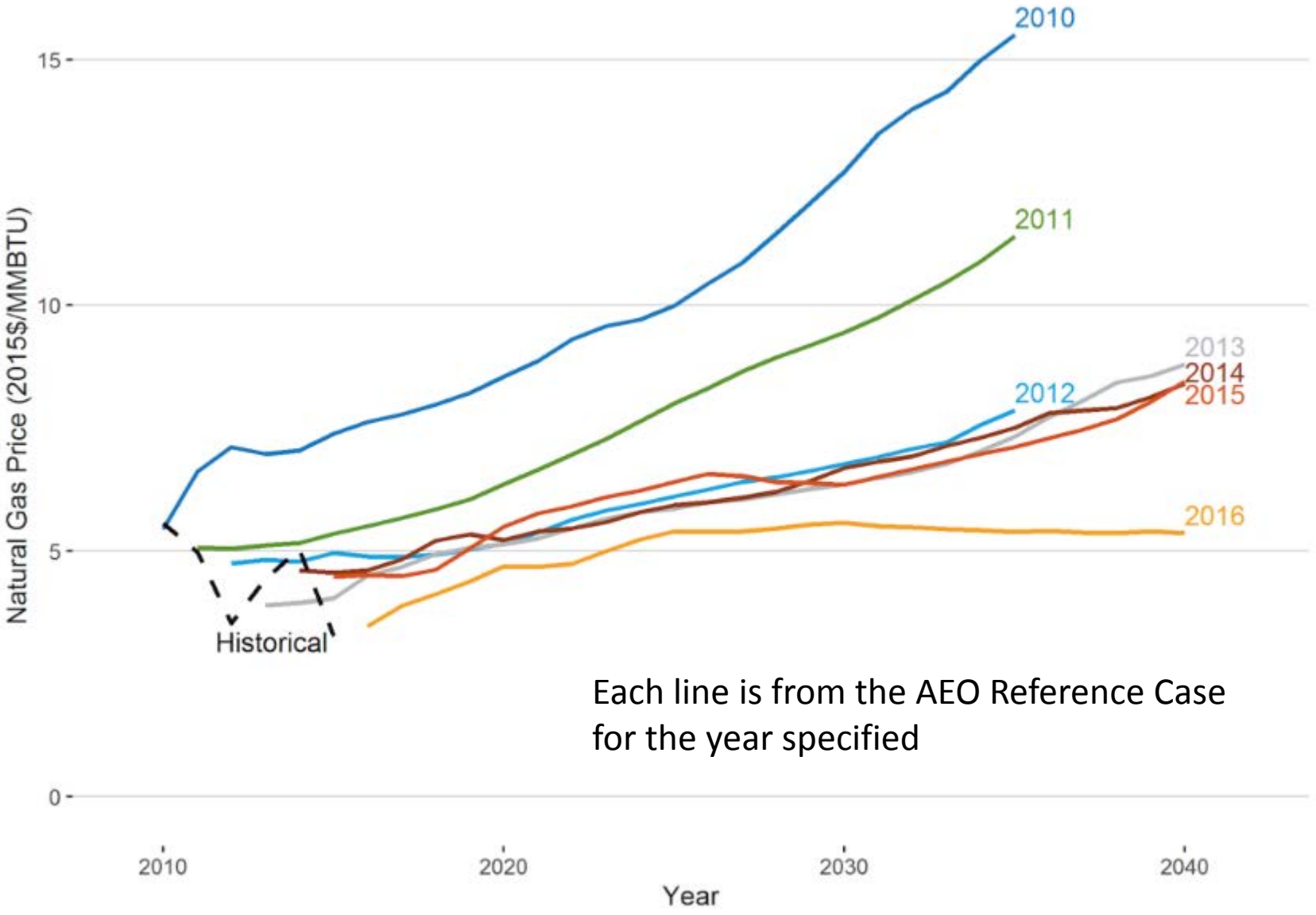
Historical Capacity Additions

- Coal plants are generally old
- Much of the natural gas capacity has been added since ~2000



Source: U.S. Energy Information Administration, *Monthly Electric Generator Inventory*, and Platts Electric Capacity Database

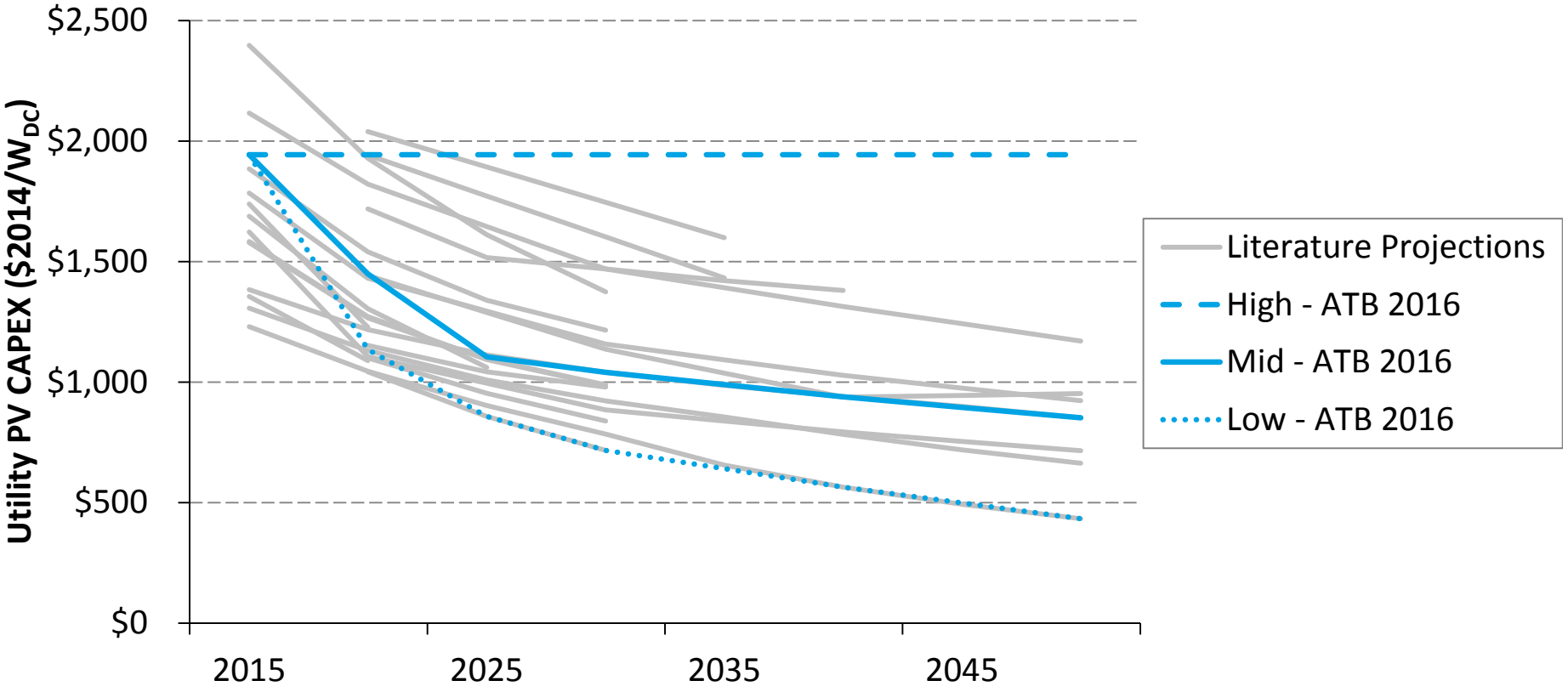
Natural Gas Prices are a Major Driver of Change



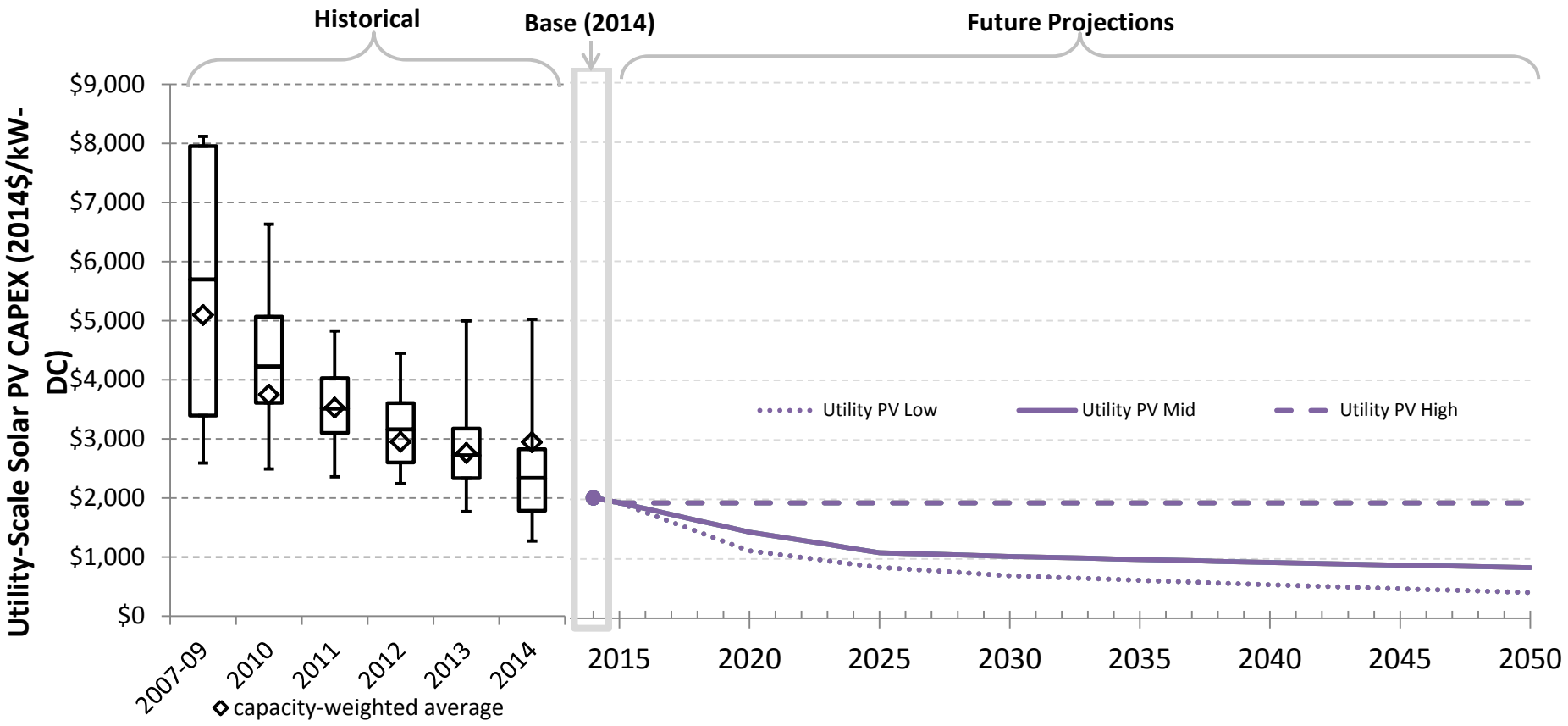
Each line is from the AEO Reference Case for the year specified

Annual Technology Baseline Cost Projections

- Cost projection are based on a collection of published values
- Similar type of methodology used for other technologies



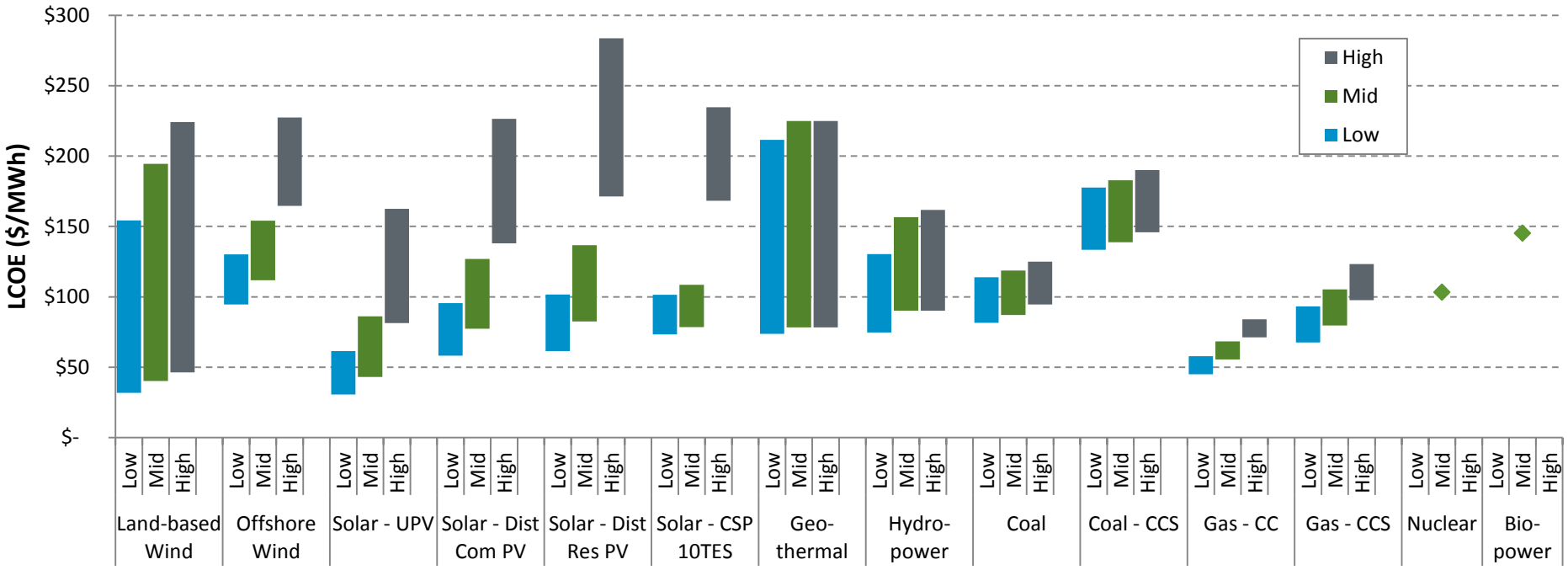
Projections Are Benchmarked Against Historical Values



- Utility PV cost projections show significant declines both in historical and projected costs (shown above)
- Wind has also seen considerable cost reductions, which are coupled with performance improvements

LCOE Projections in 2030

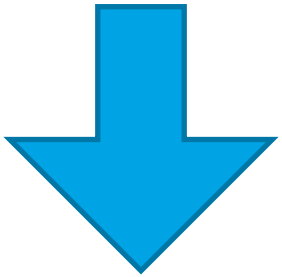
- LCOE depends on CAPEX, financing assumptions, O&M, performance & resource quality, and fuel prices



The ATB Data Are Inputs for Standard Scenarios

Annual Technology Baseline (ATB)

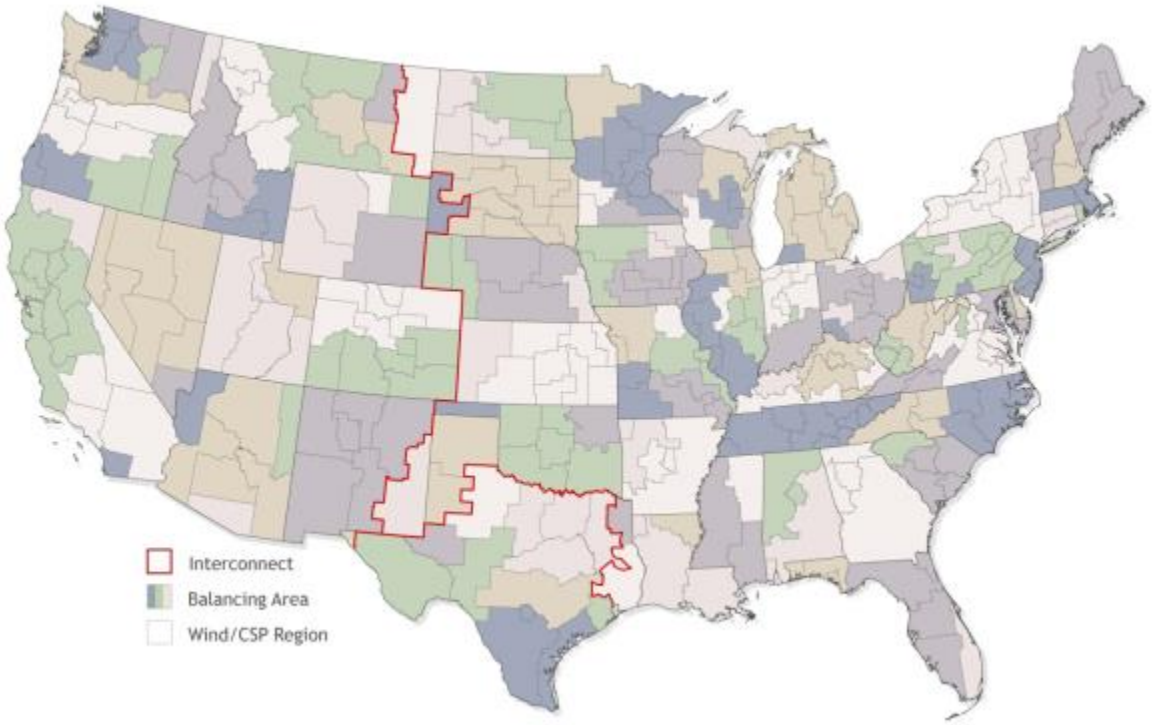
(Cost and performance assumptions for renewable and conventional technologies)



Standard Scenarios

(Ensemble of future scenarios of the U.S. electric power sector)

Regional Energy Deployment System (ReEDS) Model



- Central-planning optimization model of U.S. Electricity Sector
- 134 Balancing Areas
- 356 Wind/CSP regions
- Explicit consideration of RE integration issues

- Solves combined capacity expansion and dispatch out to 2050 under different assumptions
  - Economic
  - Technology
  - Policy

Scenarios (1 of 2)

Bidirectional Scenarios

	High	Mid-case	Low
RE Cost	ATB High	ATB Mid	ATB Low
Natural Gas Price	AEO 2016 Low Oil & Gas Resource	AEO 2016 Reference	AEO 2016 High Oil & Gas Resource
Demand	AEO 2016 High Economic Growth	AEO 2016 Reference	AEO 2016 Low Economic Growth
Retirements	Accelerated Coal Retirements	Existing	Nuclear License to 80 Years

Additional Non-Bidirectional Scenarios

Demand	Vehicle Electrification	PEV/PHEV adoption reaches 30% of sales by 2050; 45% of charging utility-controlled, 55% opportunistic
Technology Cost	Nuclear Breakthrough	50% reduction in nuclear capital costs

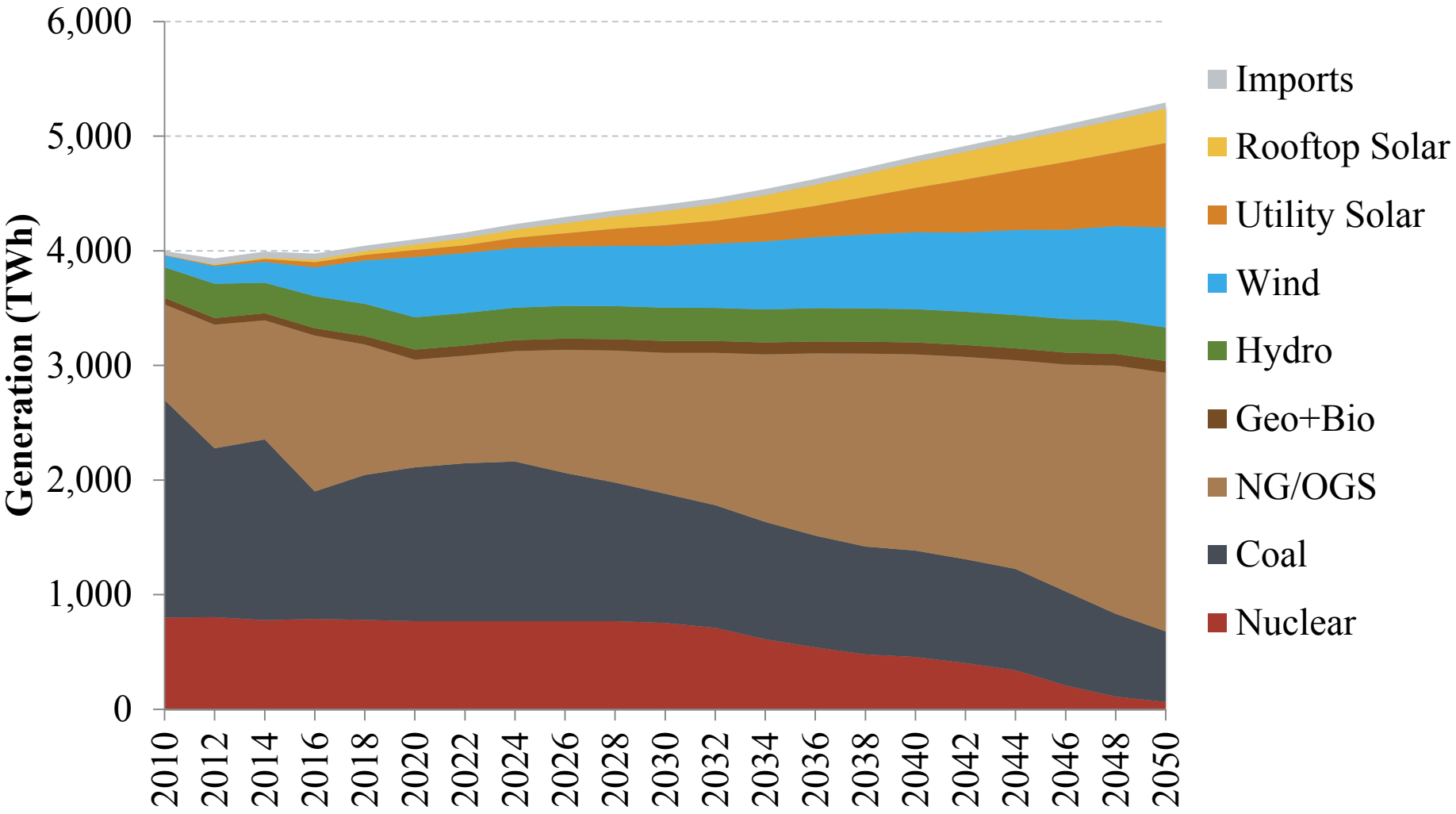
Scenarios (2 of 2)

Additional Non-Bidirectional Scenarios

Policy	Extended Incentives for RE	Extend ITC/PTC through 2030 for eligible technologies
	National Renewable Portfolio Standard (RPS)	43% of generated electricity from renewables by 2030, 80% by 2050
	Power Sector CO_2 Cap	Power sector emissions 17% below 2005 levels by 2020, 83% by 2050
Earth System Feedback	Impacts of Climate Change	Temperature impacts on generators, transmission, and load; derived from IGSM-CAM climate scenario
Resource and System Constraints	Reduced RE Resource	25% cut to resource in input supply curves
	Barriers to Transmission System Expansion	3x transmission capital cost No new AC-DC-AC interties 2x transmission loss factors
	Restricted Cooling Water Use	New construction may not use freshwater for cooling

Mid-case Scenario – Generation

Used as a point of comparison for other scenarios

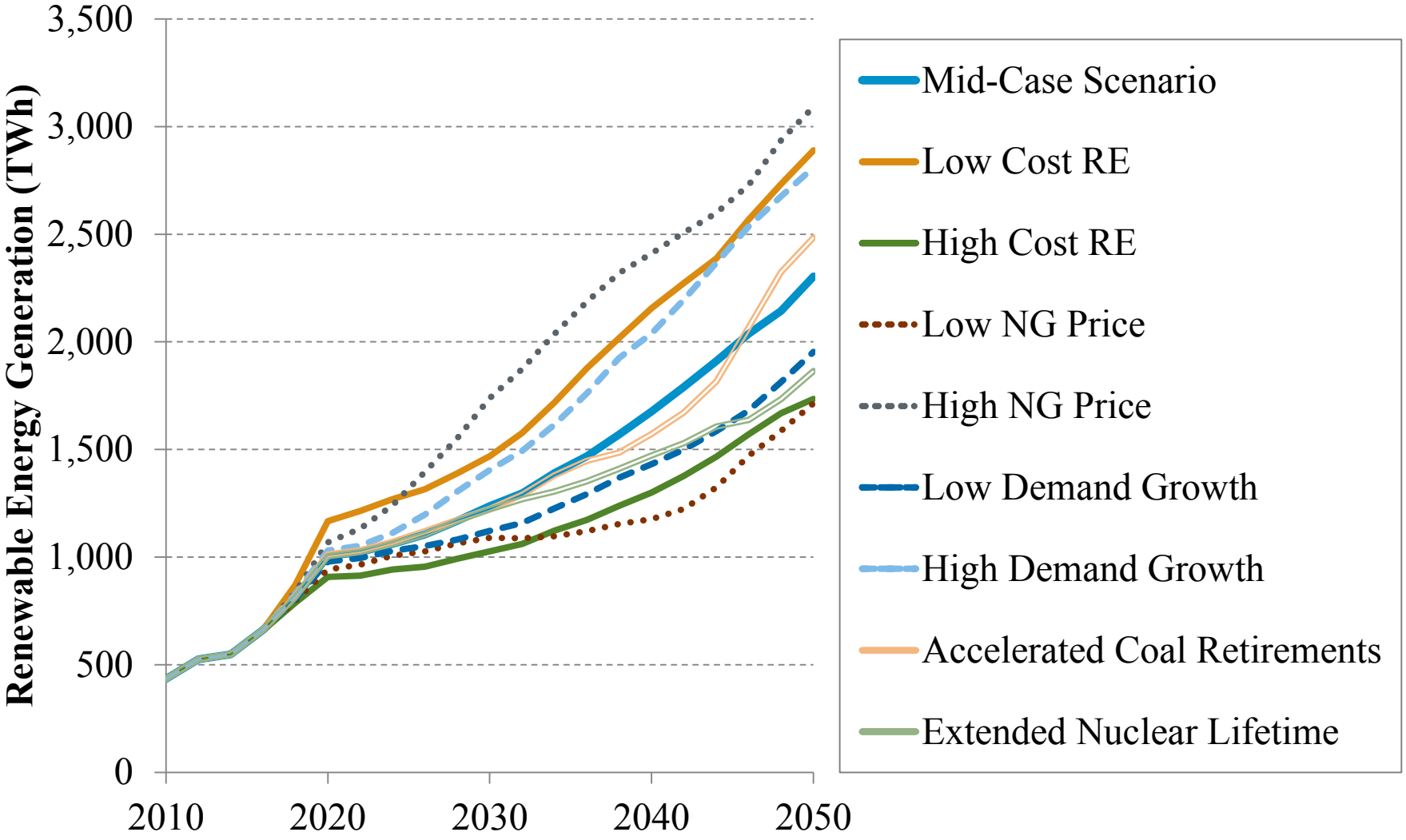


2016 Areas of Focus

Focus on four central storylines

1. **Renewable Deployment:** driven by cost reductions, highly dependent on relative costs & natural gas price
2. **Natural Gas:** projected to grow unless price exceeds expectations or more stringent GHG policies enacted
3. **Distributed PV (DPV):** deployment heavily dependent on cost reductions, rate structures, net metering, and other supporting policies
4. **Decarbonization:** significant but not sufficient to meet climate targets

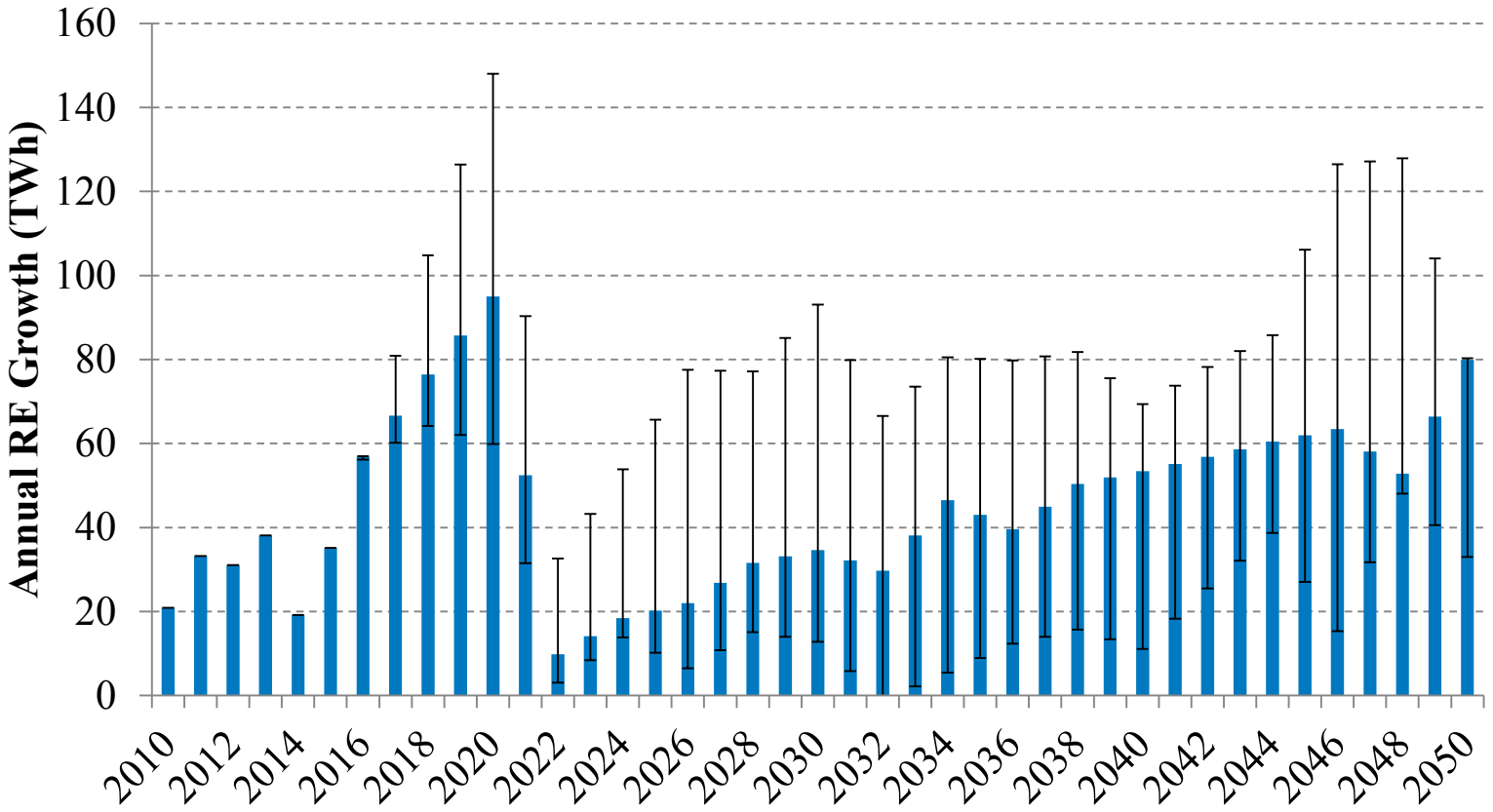
1. Renewable Growth



Continued cost reductions are projected to drive growth in renewable generation. Natural gas prices bound range of outcomes.

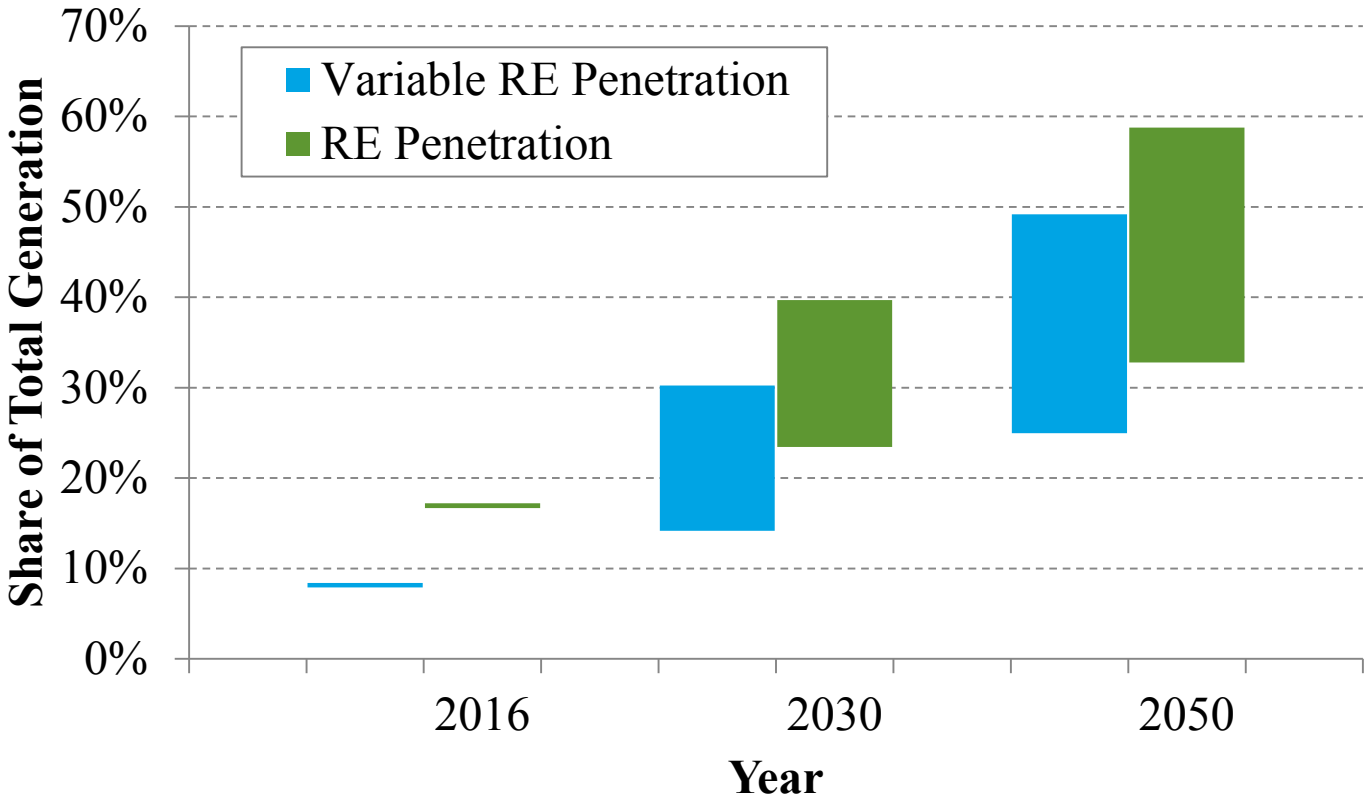
Annual Deployment Highest in Near-term

- Declining RE costs, increasing natural gas prices, and RE tax credits create a favorable near-term environment for renewable energy technologies



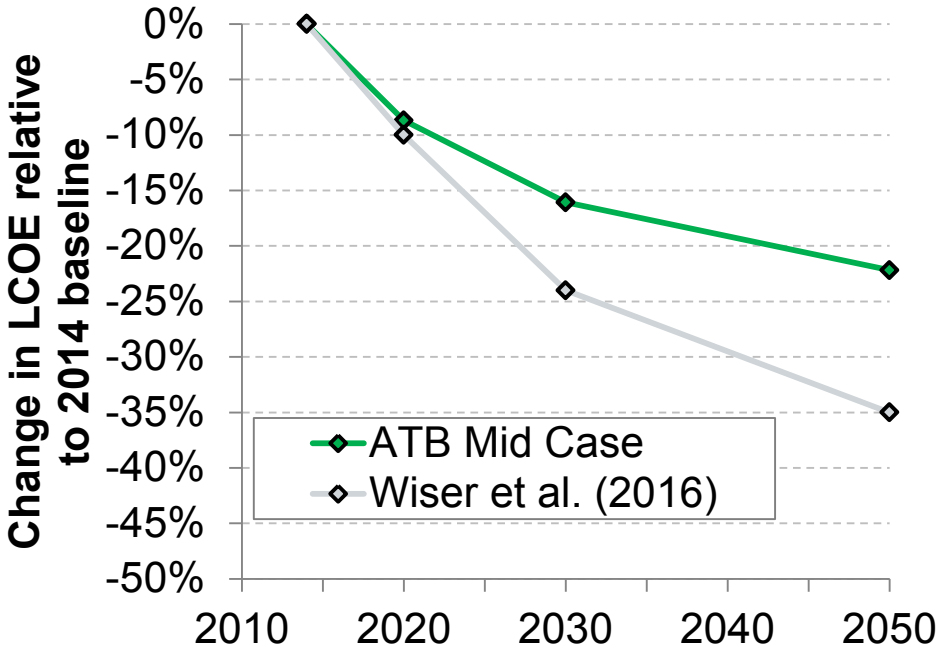
Scenarios Reach Substantial RE Penetration Levels

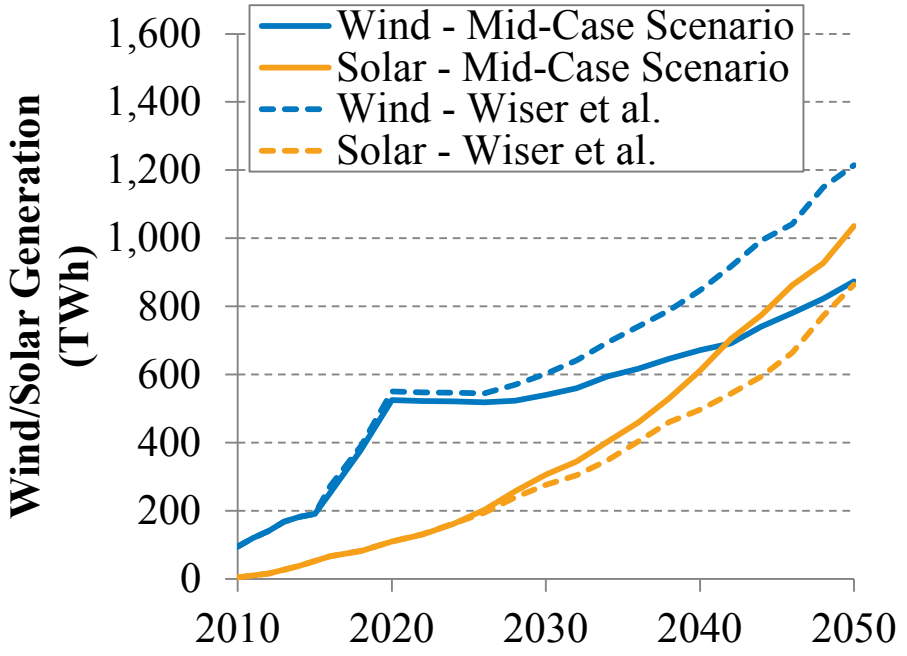
- Regional results vary even more considerably, and are sensitive to additional assumptions such as cost of transmission and amount of available RE resource



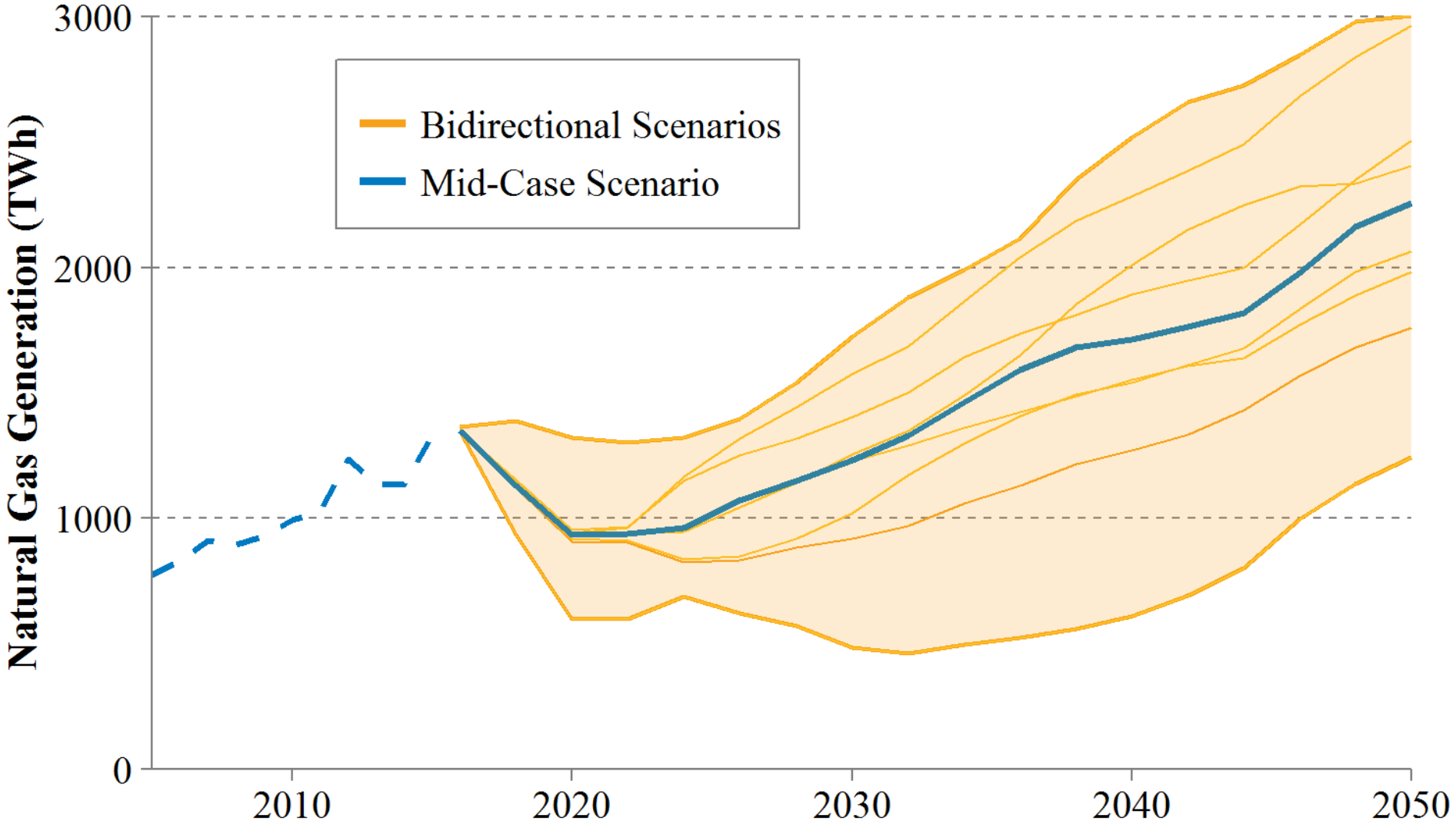
Wind/Solar Trade-off

- The LCOE for Solar and Wind are very close to one another in most scenarios
- A relatively small change in cost can significantly change the wind/solar mix



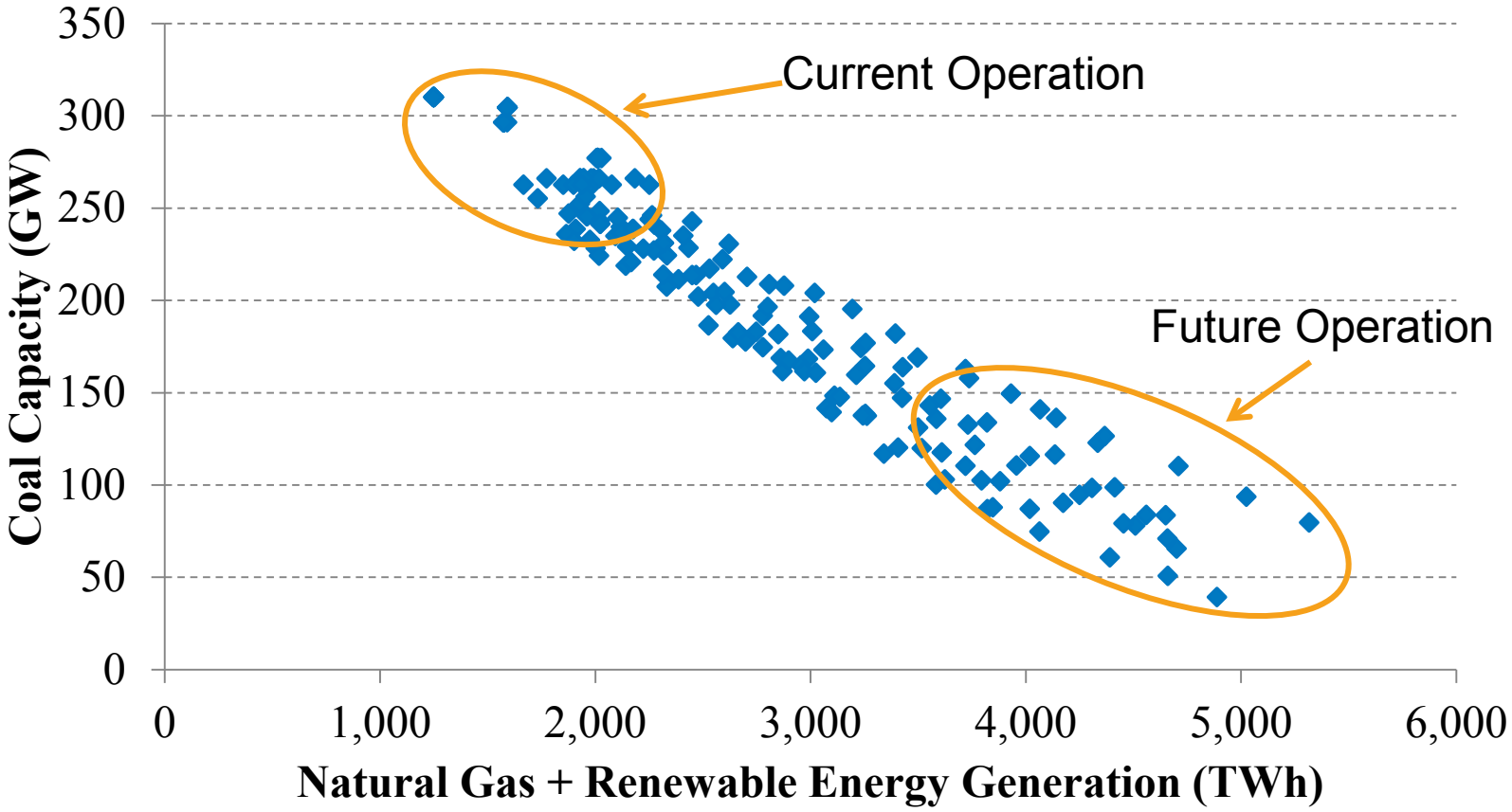


2. Natural gas is projected to grow unless prices exceed projections or more stringent GHG emissions are enacted



Impact of Combined Growth in Natural Gas and RE

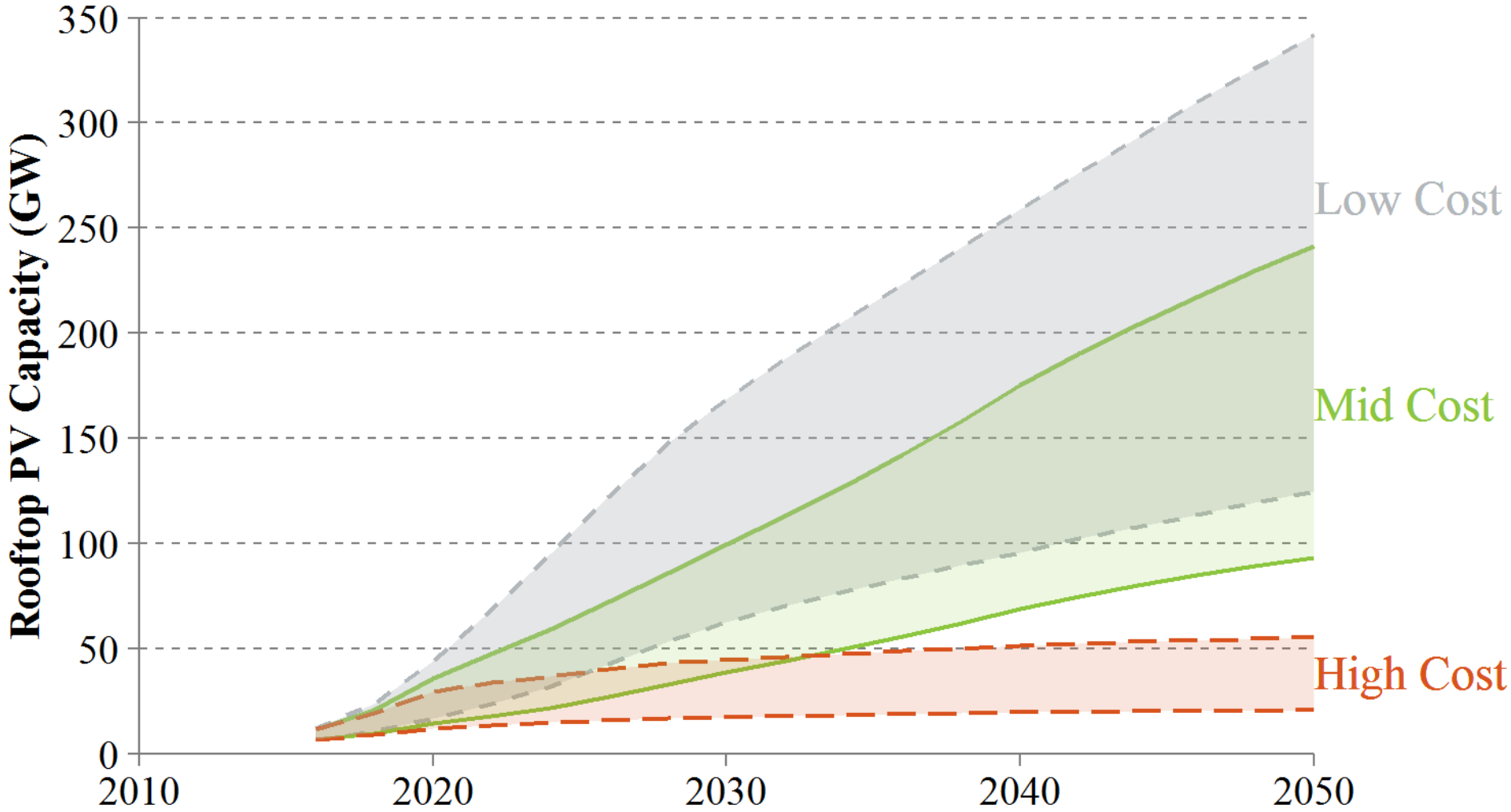
- Future systems are projected to have less traditional baseload
- With less coal capacity, there are fewer opportunities for fuel switching



Implications of Strong Growth in Natural Gas

- The projected growth in natural gas and renewables leads to a system with little traditional baseload by 2050
- Carbon Cap scenario (83% reduction from 2005 by 2050) causes long-term natural gas usage to decline
  - The only other scenario to see declines in natural gas generation is the high natural gas price scenario
- Carbon capture and sequestration has the potential to reduce or turn-around that natural gas decline

3. DPV future is heavily dependent on the evolution of rate structures, costs, net metering, and other supporting policies

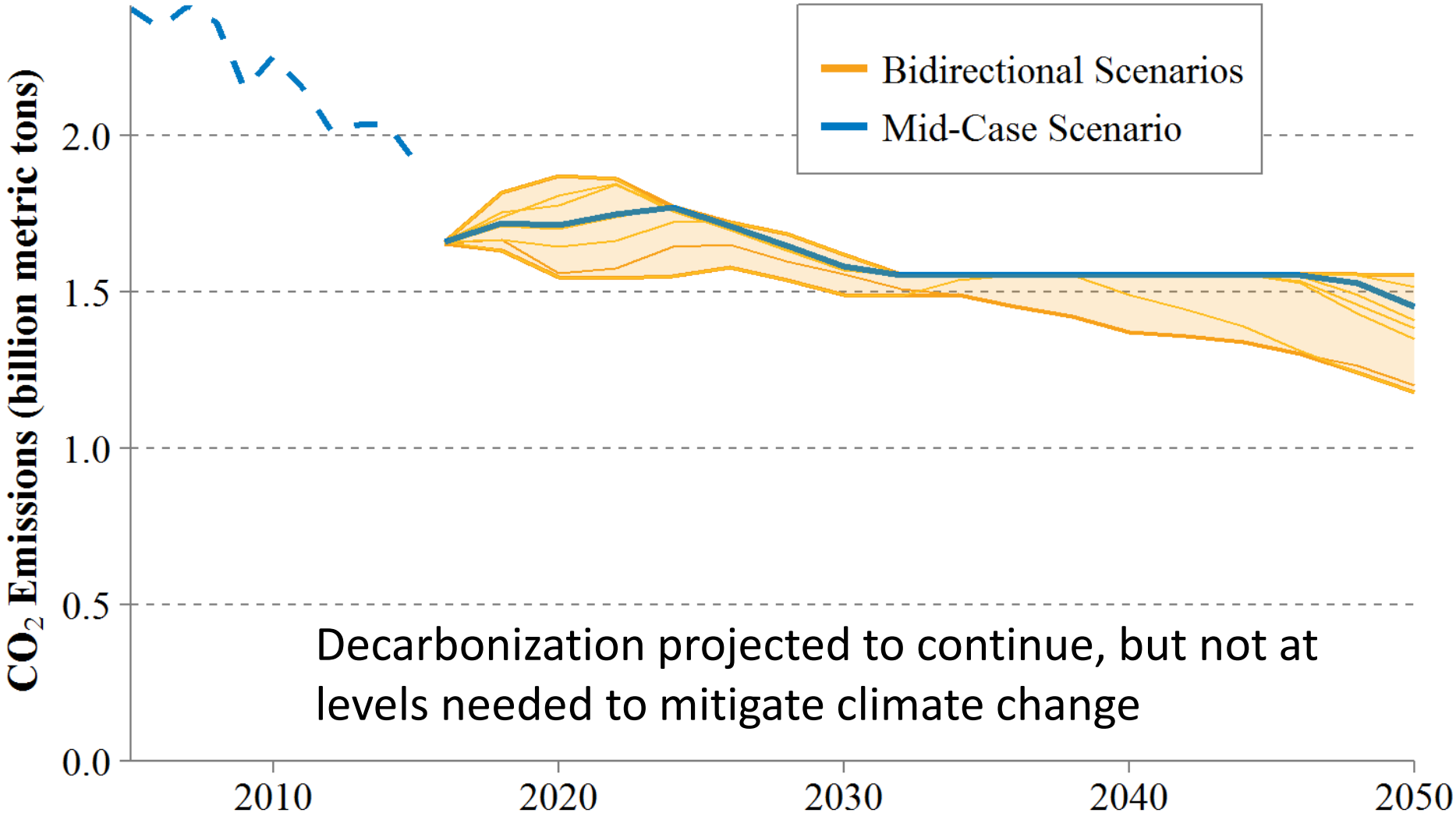


Low and high ranges driven by differences in how exported electricity is valued

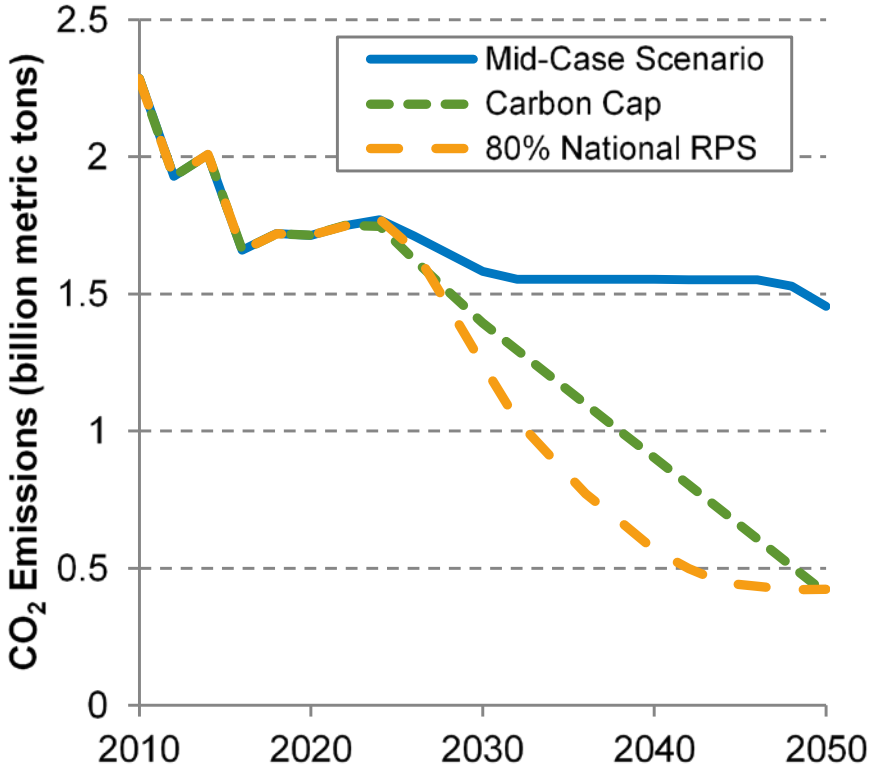
Major Uncertainties Associated with DPV

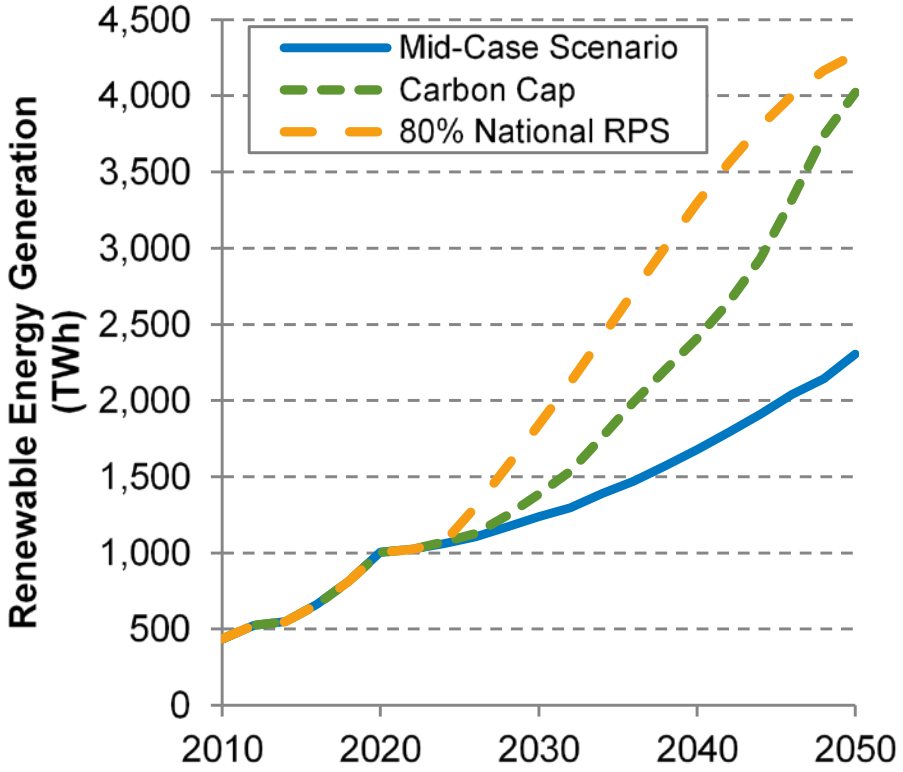
- PV experiences declining value as penetration level increases
- If distributed PV deployment continues to grow, it might put pressure on current rate designs and policies to reflect that declining value
- Evolving rates could significantly impact the deployment level, and there is large uncertainty into if/how rates would evolve

4. Decarbonization



Alternative Decarbonization Pathways





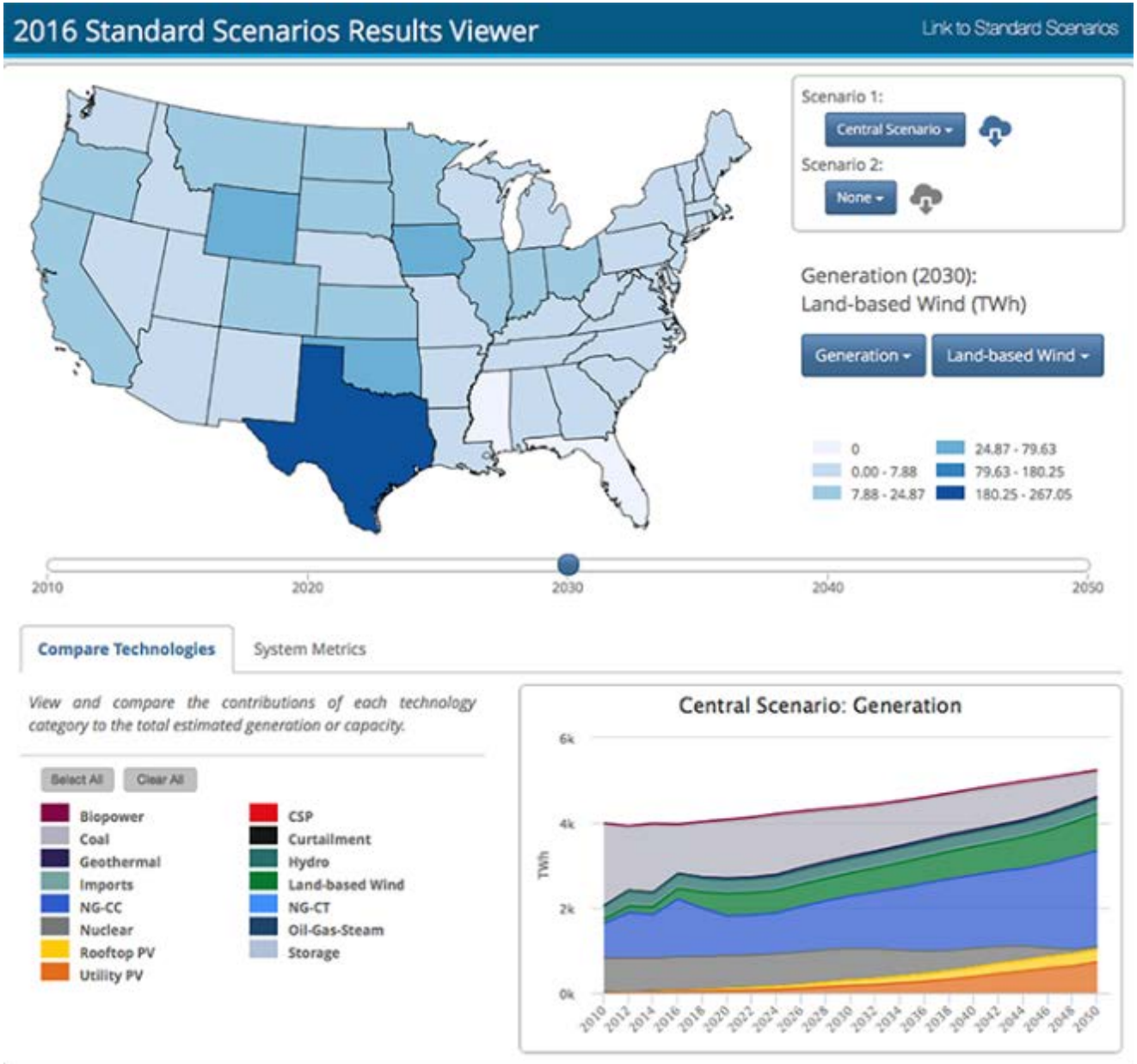
Policy scenarios:

- Carbon cap (emissions limited to 83% below 2005 by 2050) and 80% National RPS
- Generation mix more diversified, 9% lower system costs, in Carbon Cap vs. National RPS scenarios

Additional Appendix Items

- Scenario definitions
- Changes since last year
  - Model inputs
  - Model structure
  - Model outputs
- Impact of wind/solar cost inputs on Mid-Case Scenario outputs

Detailed Scenario Results Available Online



Questions or Comments?

The Standard Scenarios Report is available at
http://www.nrel.gov/analysis/data_tech_baseline.html

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