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NATIONAL RENEWABLE ENERGY LABORATORY

2018 Standard Scenarios Report: A U.S. Electricity Sector Outlook

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November 15, 2018

NREL/PR-6A20-72839

W. Cole et al., "2018 Standard Scenarios Report: A U.S. Electricity Sector Outlook," NREL/TP-6A20-71913, 72 pp. (October 2018).

What are the “Standard Scenarios?”

- Suite of 42 forward-looking scenarios (projections) of the U.S. power sector
- NREL report that identifies themes from the scenarios
  - Uses the 42 scenarios to provide an outlook of the power sector
- Companion product of the Annual Technology Baseline
  - https://atb.nrel.gov/

Why do we do the Standard Scenarios?

- Internal Value
  - Consistency across analyses
  - Improved efficiency
- External Value
  - Share our input assumptions and model results
  - Provide an additional perspective on power sector evolution
  - Inform stakeholder decision-making

Changes from last year

- More scenarios
  - Extended lifetimes scenario for coal and nuclear
  - Individual low renewable energy technology cost scenarios
  - Combination scenarios between technology costs and fuel prices
- Clean Power Plan scenario no longer included
- Model and policy updates
  - See Appendix A.2 of the report

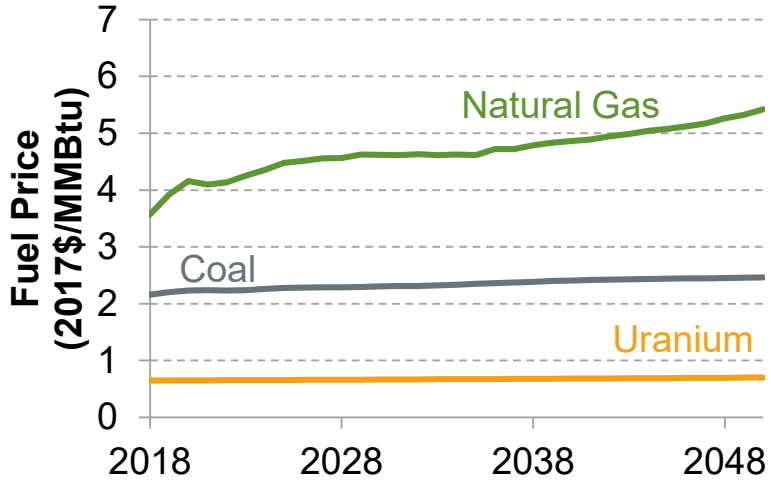
Webinar Outline

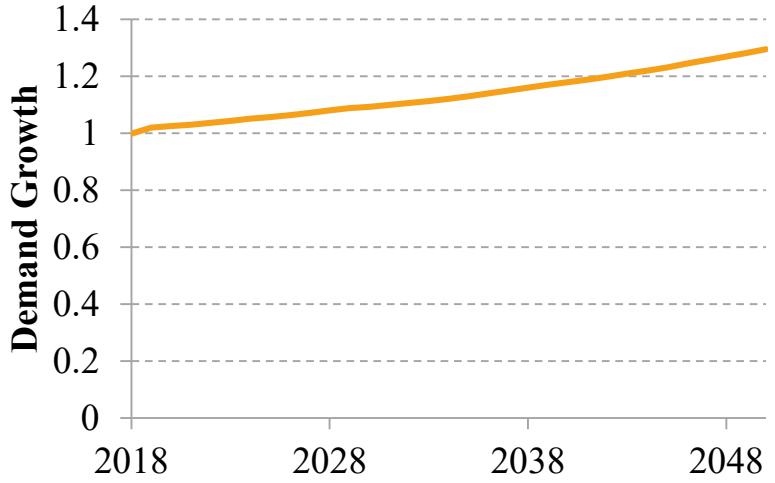
- Summary of the Standard Scenarios
- Insights and perspectives from the 2018 Standard Scenarios (i.e., what is in the report)
- How to access the scenario data

The Standard Scenarios

The Mid-case Scenario

- Fuel prices: EIA Annual Energy Outlook (AEO) 2018
- Demand growth: AEO 2018
- Technology cost and performance: 2018 Annual Technology Baseline (ATB)
- Current policies as of spring 2018
- Current fleet characteristics: ABB Ability Velocity Suite





Summary of the Standard Scenarios

Non-Policy Scenarios

Fuel Cost

- High Oil & Gas Resource (AEO 2018)
- Low Oil & Gas Resource (AEO 2018)

Demand

- Low Demand
- High Demand
- Vehicle Electrification

Other

- Extended Cost Recovery
- Climate Change Impacts
- Reduced RE Resource
- Transmission Expansion Barriers
- Restricted Cooling Water

Mid-case

- Reference or Mid-level Assumptions

Technology Cost

- Low RE Cost
- High RE Cost
- Low Wind Cost
- Low PV Cost
- Low Geo Cost
- Low CSP Cost
- Low Hydro Cost
- Low Offshore Wind Cost
- Nuclear Breakthrough
- Low Battery Cost
- High Battery Cost

Combinations

- Low/High NG Price with
  - Low/High RE Cost
  - Low/High Geo Cost
  - Low/High CSP Cost
  - Low/High Hydro Cost
  - Low/High Offshore Wind Cost

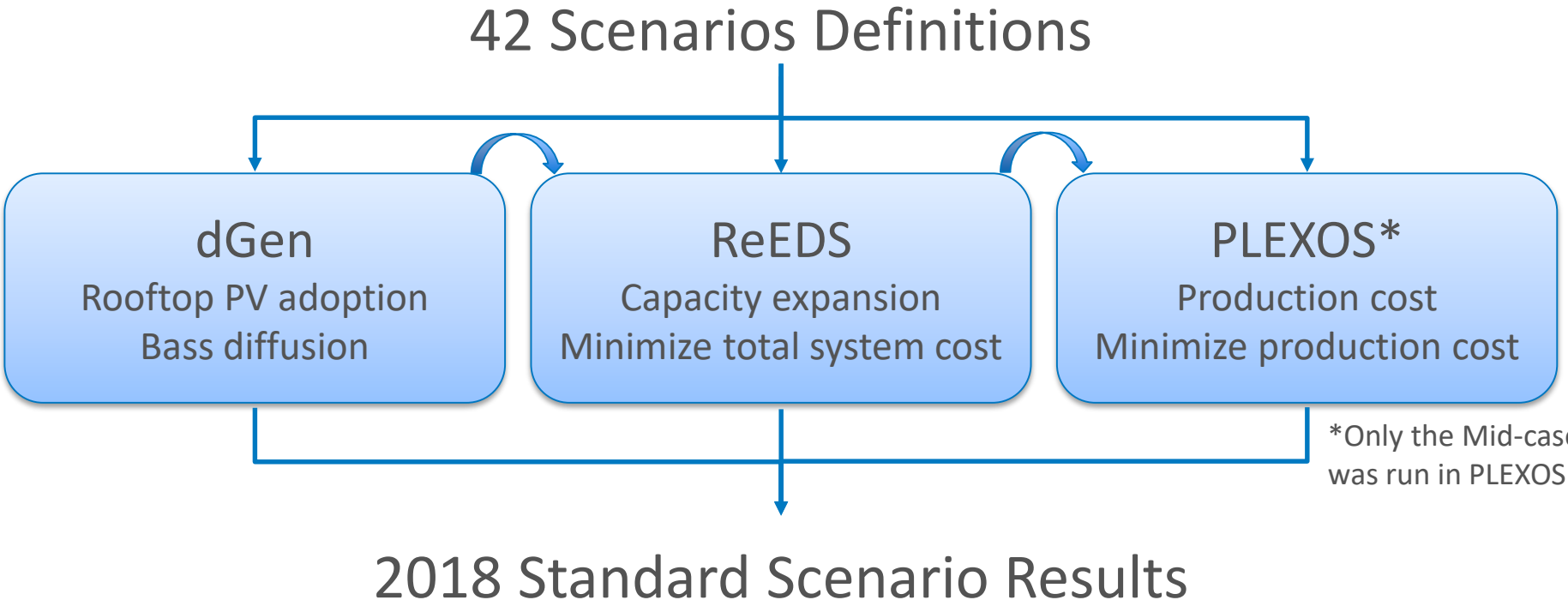
Retirements

- 80 Year Nuclear
- 60 Year Nuclear
- Accelerated Nuclear Retirement
- Accelerated Retirements
- Extended Lifetimes

Policy

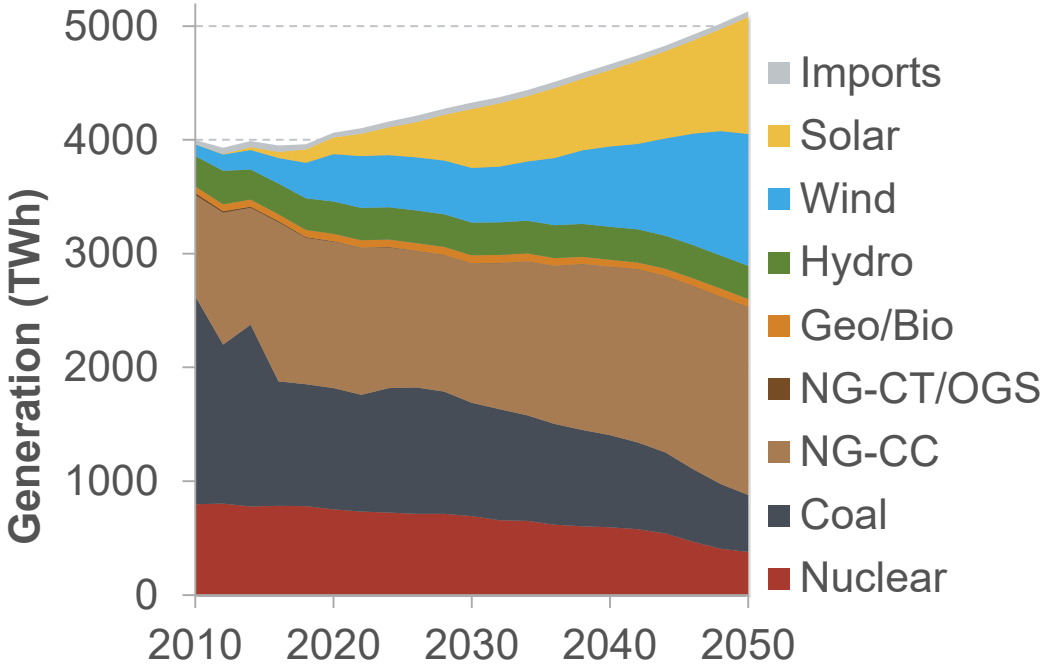
- National 80% RPS by 2050
- 83% CO_2 Reduction by 2050
- ITC & PTC Extension to 2030

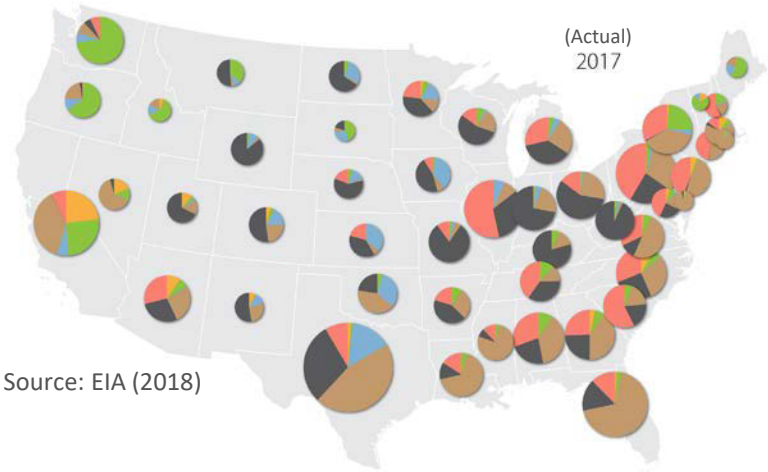
Tools & Method



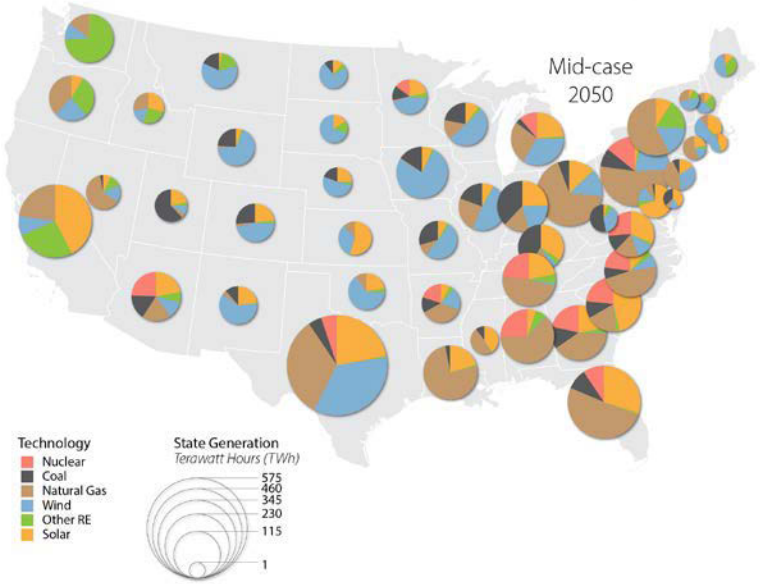
The Mid-case Scenario

2018 Mid-case: Growth in Renewable Energy and Natural Gas



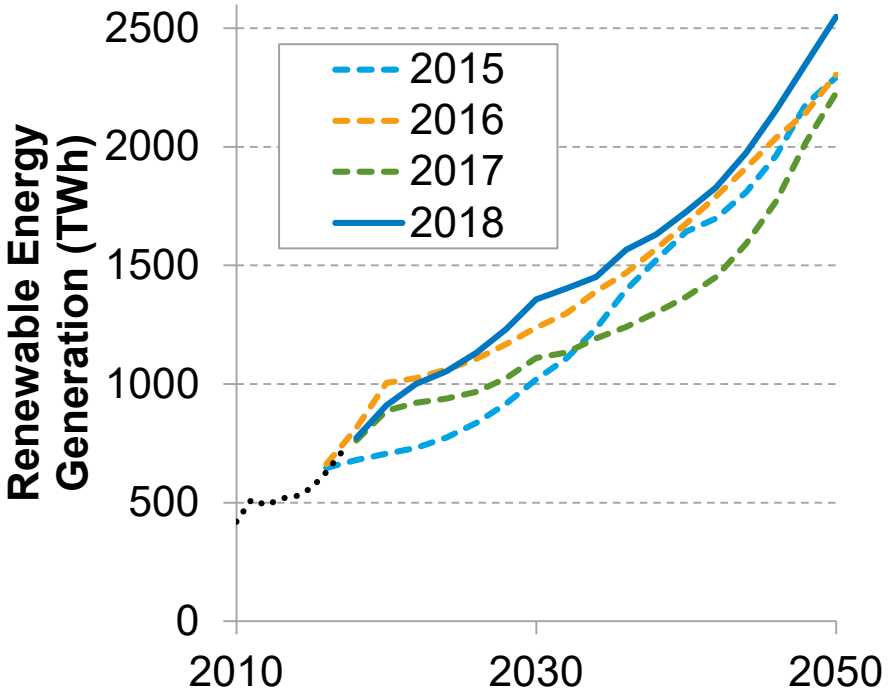


Source: EIA (2018)

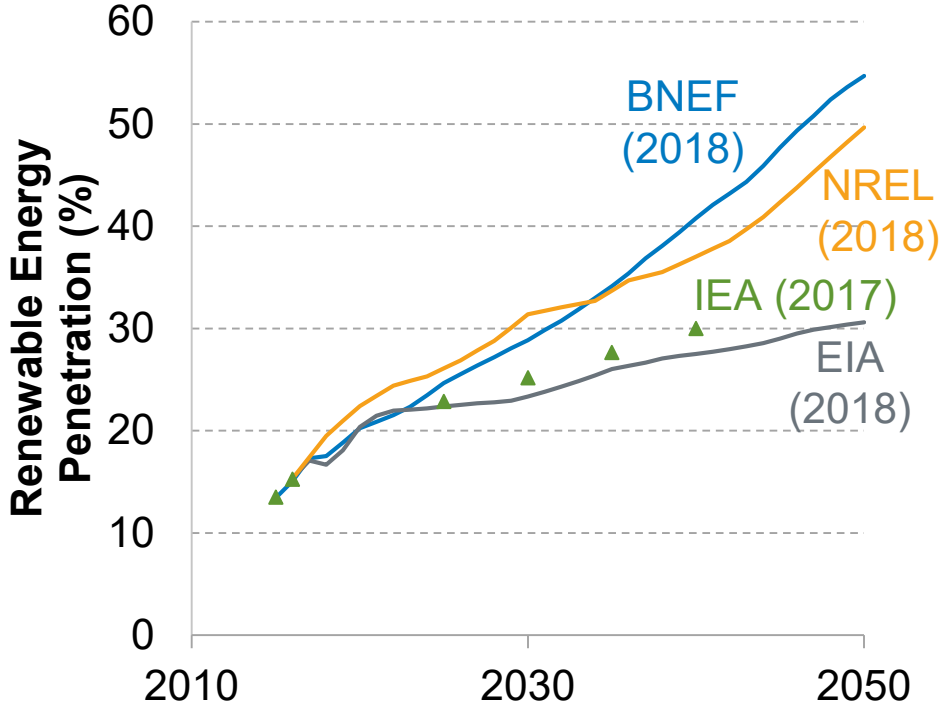


NREL Mid-case in Context

NREL Standard Scenarios Mid-case Over Time



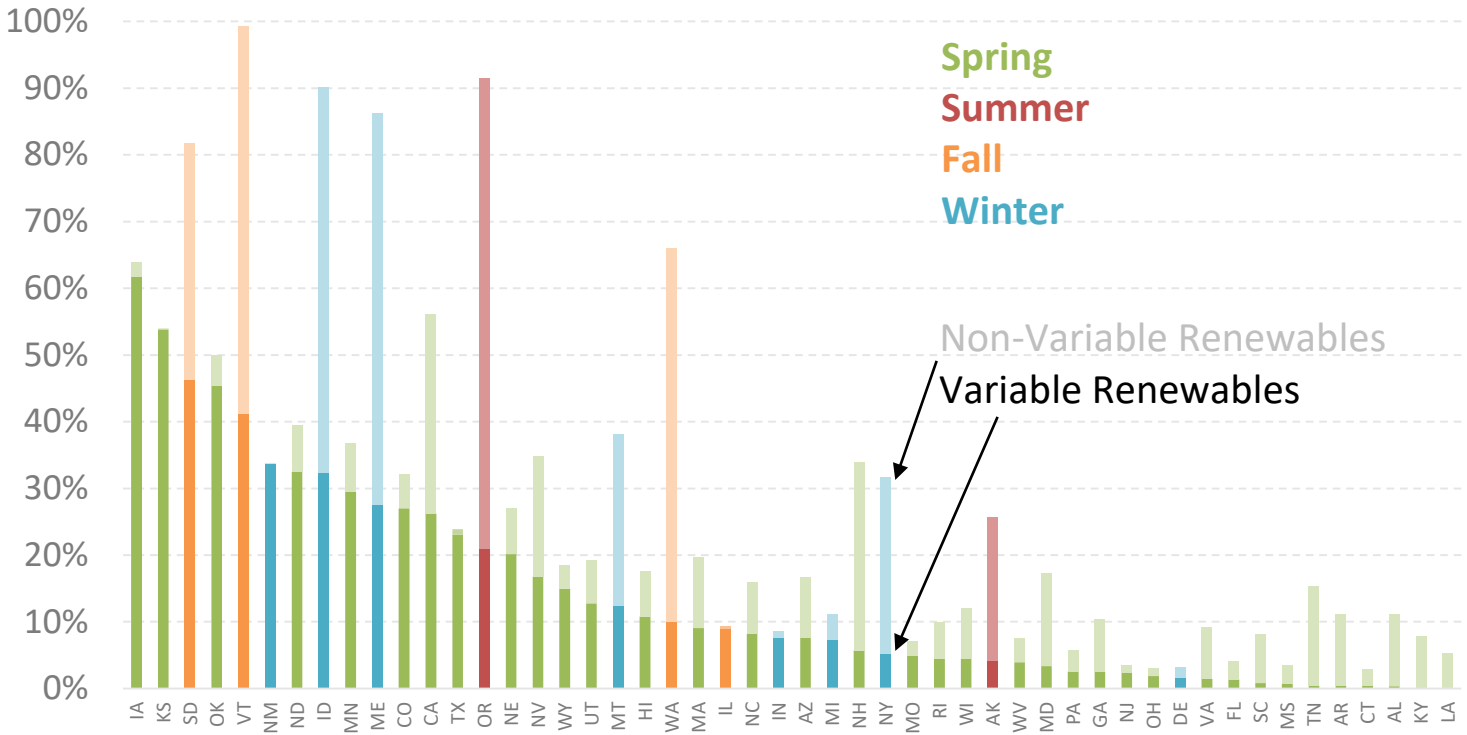
Recent "Reference Case" Scenarios



Theme #1:

The impacts on system operation from increasing shares of variable renewable energy

Maximum Monthly Observed Penetration Levels



2 States:
>50% VRE in a single month

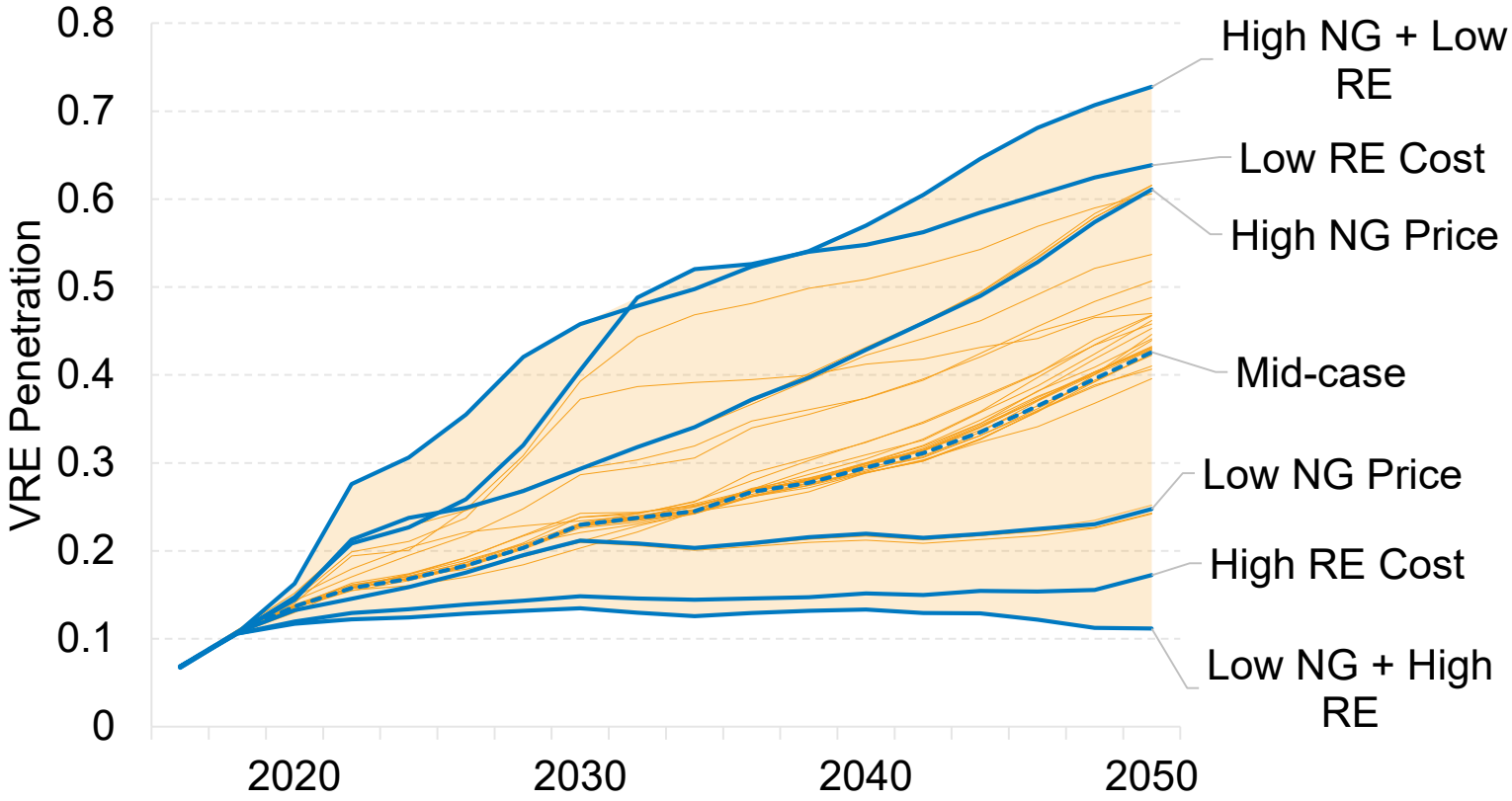
15 States:
>20% VRE in a single month

Source: EIA (2018)

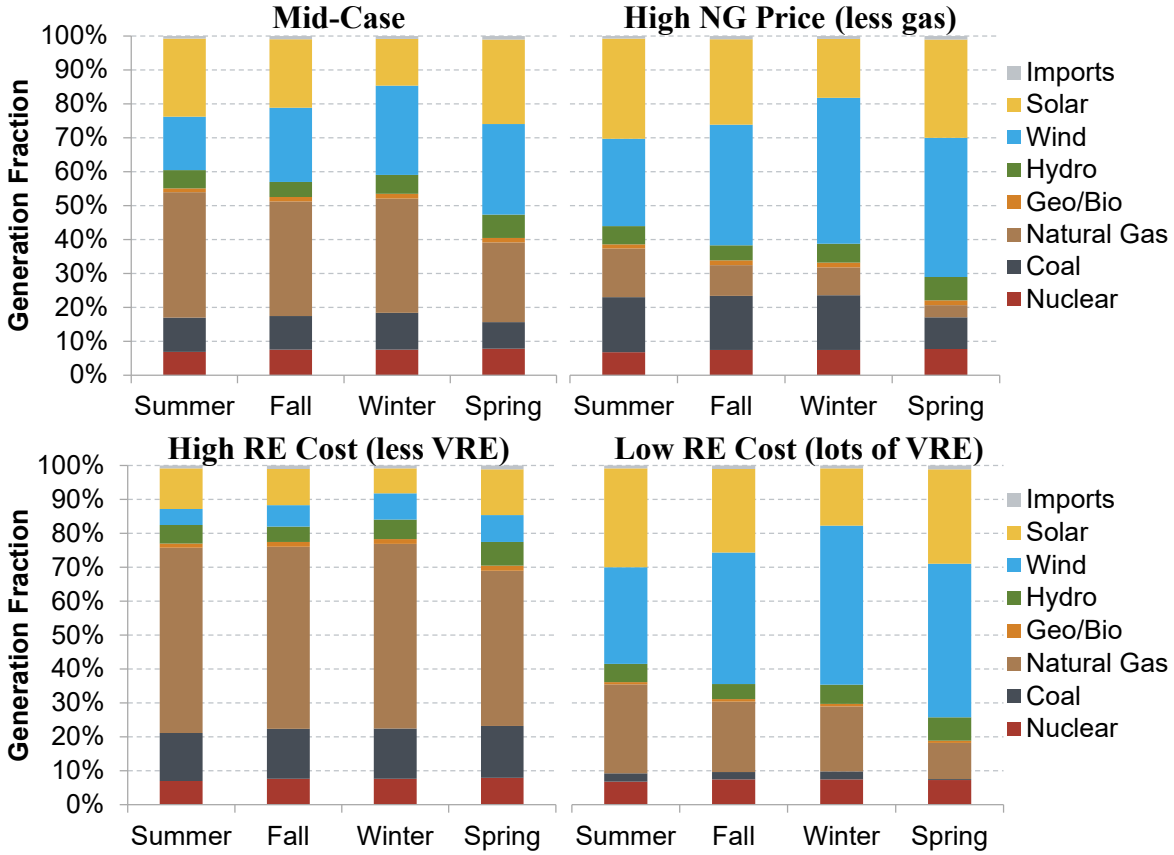
Maximum Observed Instantaneous VRE Penetration Levels

Organization	Energy Sources	Instantaneous Penetration	Total Power (GW)	Date	Source
CAISO	Wind and solar	64.6%	10,739 MW PV (June 29, 12:33 p.m.) 5,139 MW wind (June 8, 9:05 p.m.)	May 26, 2018 2:28 p.m.	July 2018 CAISO California Energy Commission report (CAISO 2018)
SPP	Wind	62.1%	14,500 MW	March 31, 2018	RTO Insider (Kleckner 2018)
MISO	Wind	Not Reported	15,600 MW	March 31, 2018	S&P Global Platts (Zhou 2018)
ERCOT	Wind	54%	17,541 MW (February 19, 2018)	October 27, 2017	ERCOT fact sheet (ERCOT 2018)
NYISO	Wind	9%	1,571 MW	January 2016	NYISO (2017)
ISO-NE	Wind and distributed PV	19.3% distributed PV 6.6% wind	3,098 MW	April 21, 2018	ISO-NE report and data (ISO Newswire 2018)
PJM	Wind	9%	6,338 MW	May 2, 2018	PJM Data Miner (PJM n.d.; ISO New England n.d.)

VRE Growth Across Scenarios

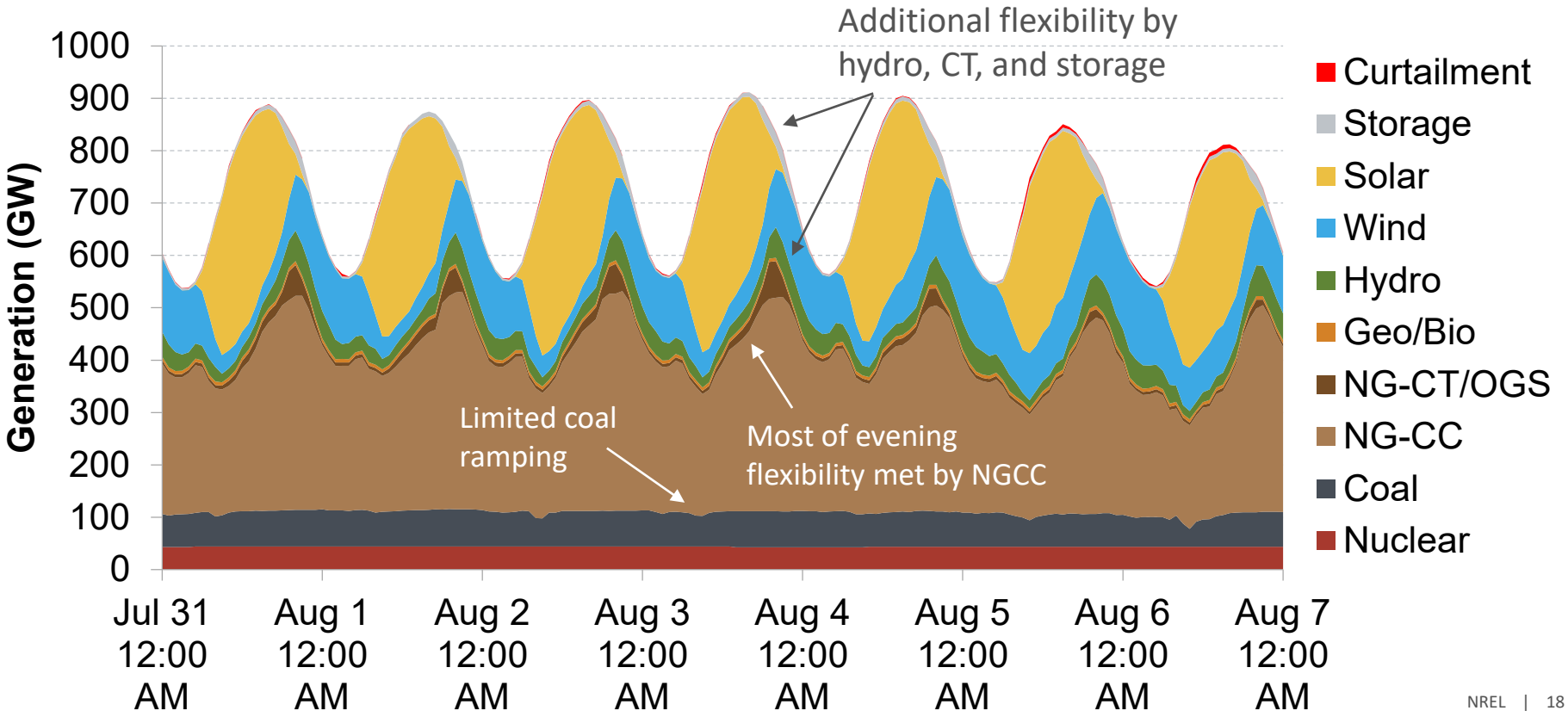


Seasonal Operation (in 2050)

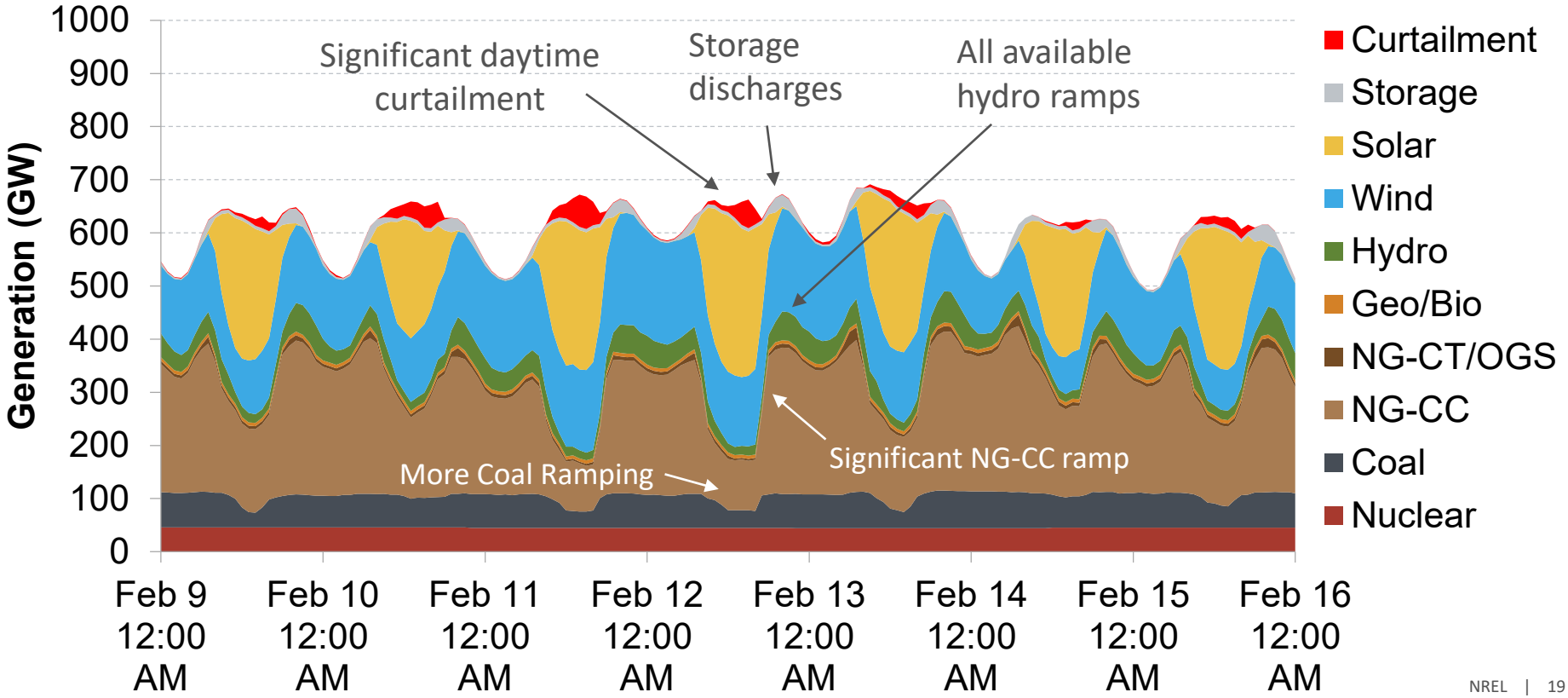


- VRE production varies across seasons
- Natural gas provides greatest amount of seasonal flexibility
- Coal provides significant amount of seasonal flexibility when VRE penetration is higher

Hourly Operation – Peak Day (in 2050)



Hourly Operation – High Ramp Day (in 2050)



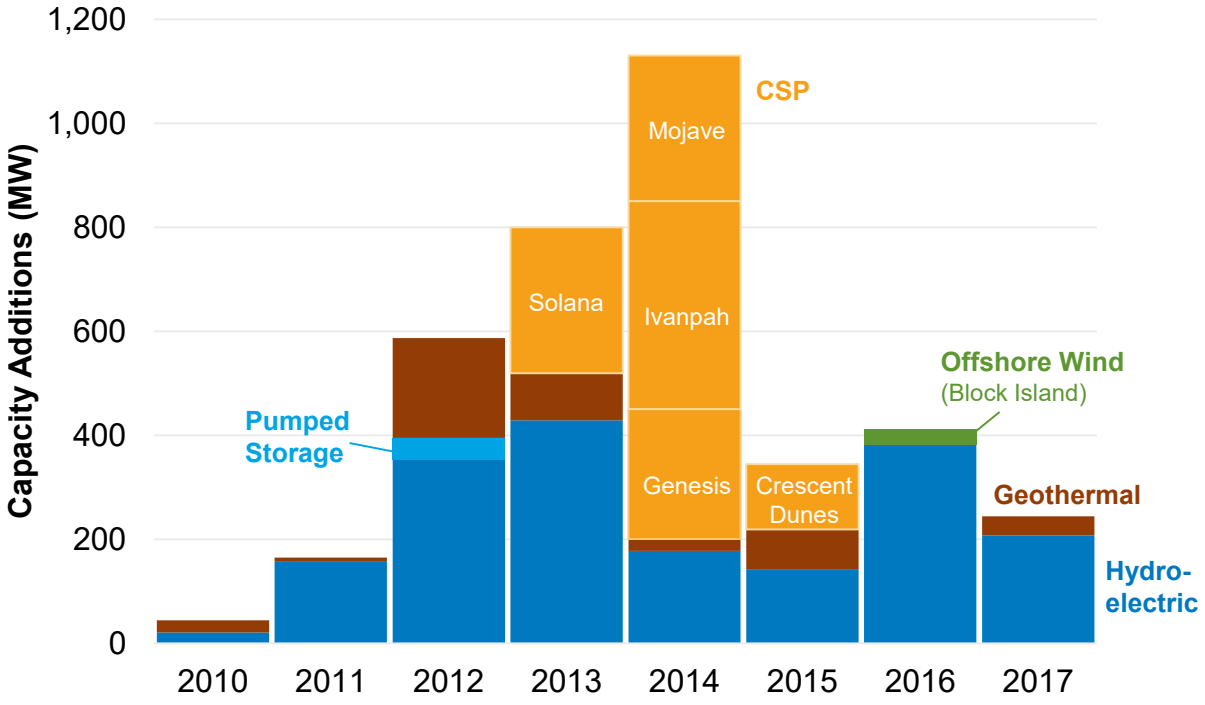
Mid-case Statistics (in 2050)

Metric	Level	Occurrence
Maximum Hourly VRE Penetration	77.2%	Mid-afternoon in April
Minimum Hourly VRE Penetration	8.2%	Early morning in September
Maximum VRE Generation	549,500 MW	Mid-afternoon in June
Minimum VRE Generation	41,400 MW	Early morning in September
Maximum VRE Curtailment	147,700 MW	Mid-afternoon in March

Theme #2:

The potential for renewable energy technologies beyond solar PV and land-based wind

Recent Capacity Additions of RE (excluding PV and land-based wind)



Note: this does not consider retired capacity due to replacement of existing generators; therefore, net capacity additions, specifically those from hydroelectric, will be smaller due to refurbishment and upgrades of generators at existing facilities.

Recent Trends

- Hydropower gross capacity additions are largely from refurbishments or upgrades of existing facilities
- CSP costs have declined, but not as rapidly as PV costs
- Geothermal has seen consistent capacity additions, but has limited capacity currently under construction
- Offshore wind has seen rapid price declines, but has seen little deployment in the U.S.

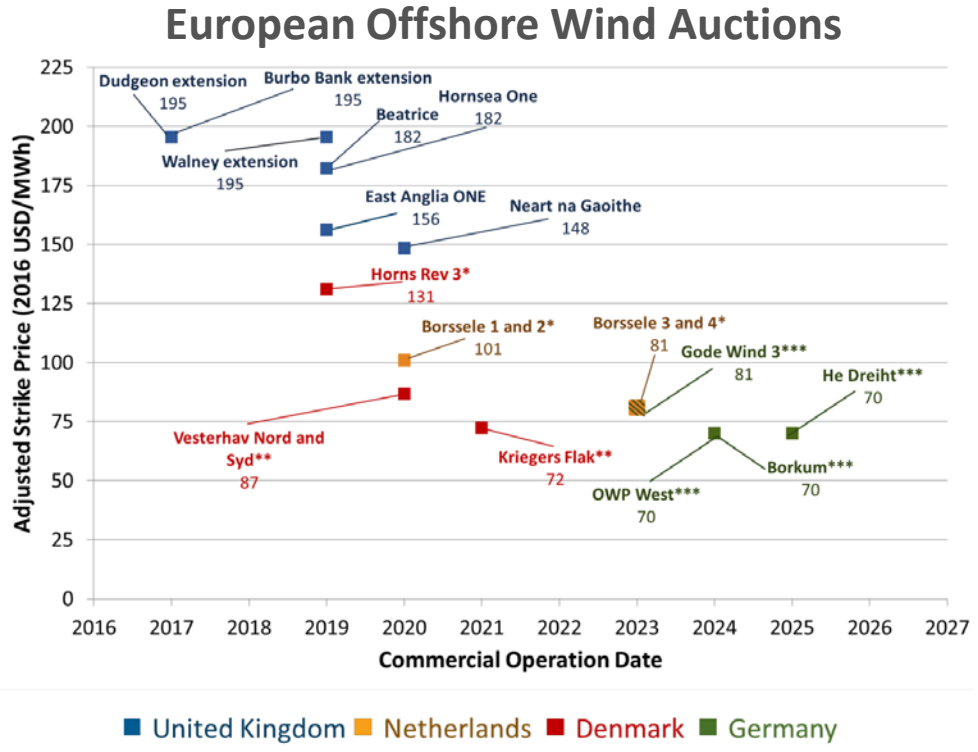
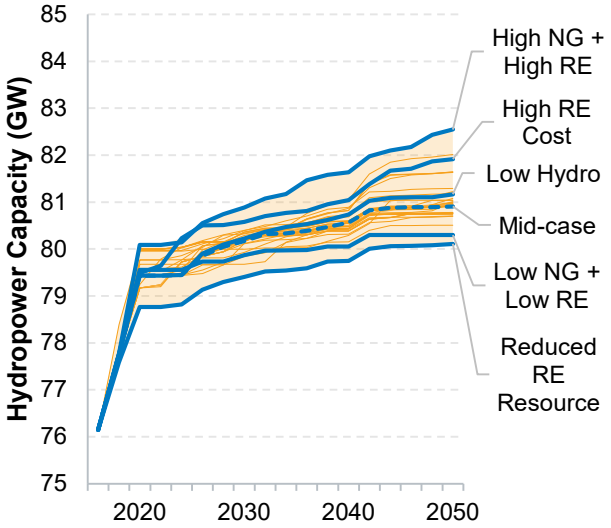
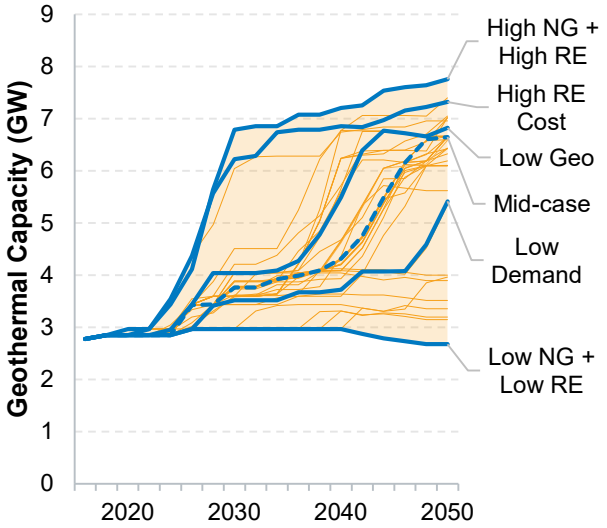


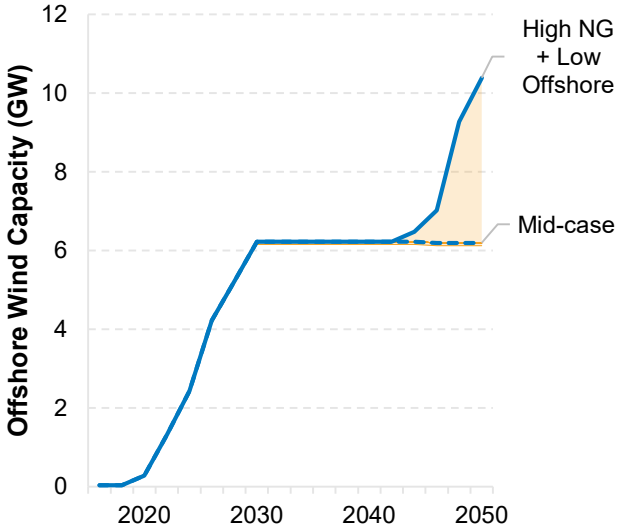
Figure from Musial et al. (2017)

Growth in Hydropower, Geothermal and Offshore Wind

Hydropower, Geothermal, and Offshore Wind Experienced Limited Growth Across Scenarios



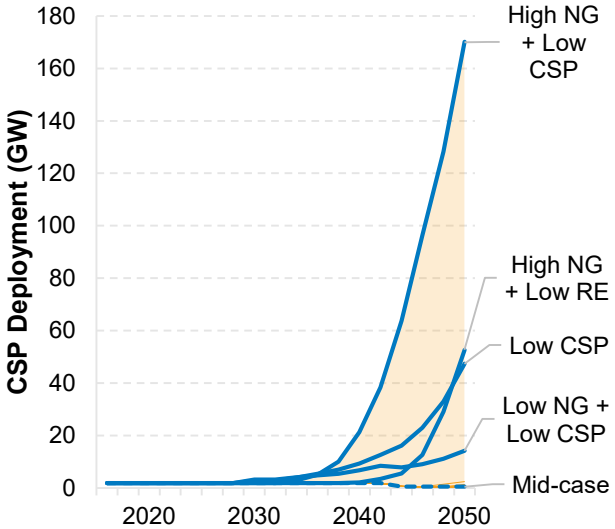


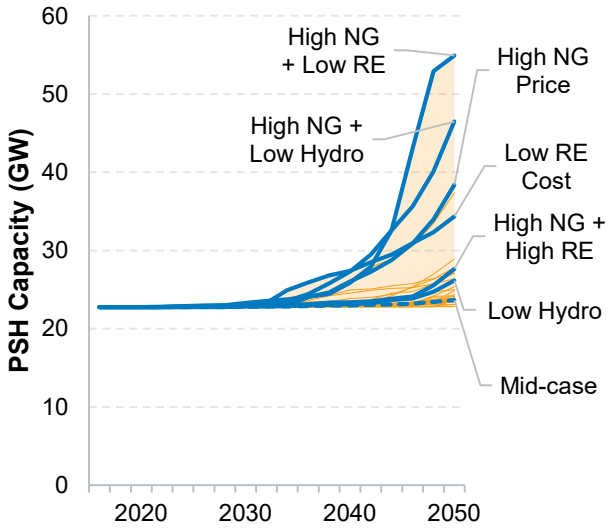


Note differences in scales

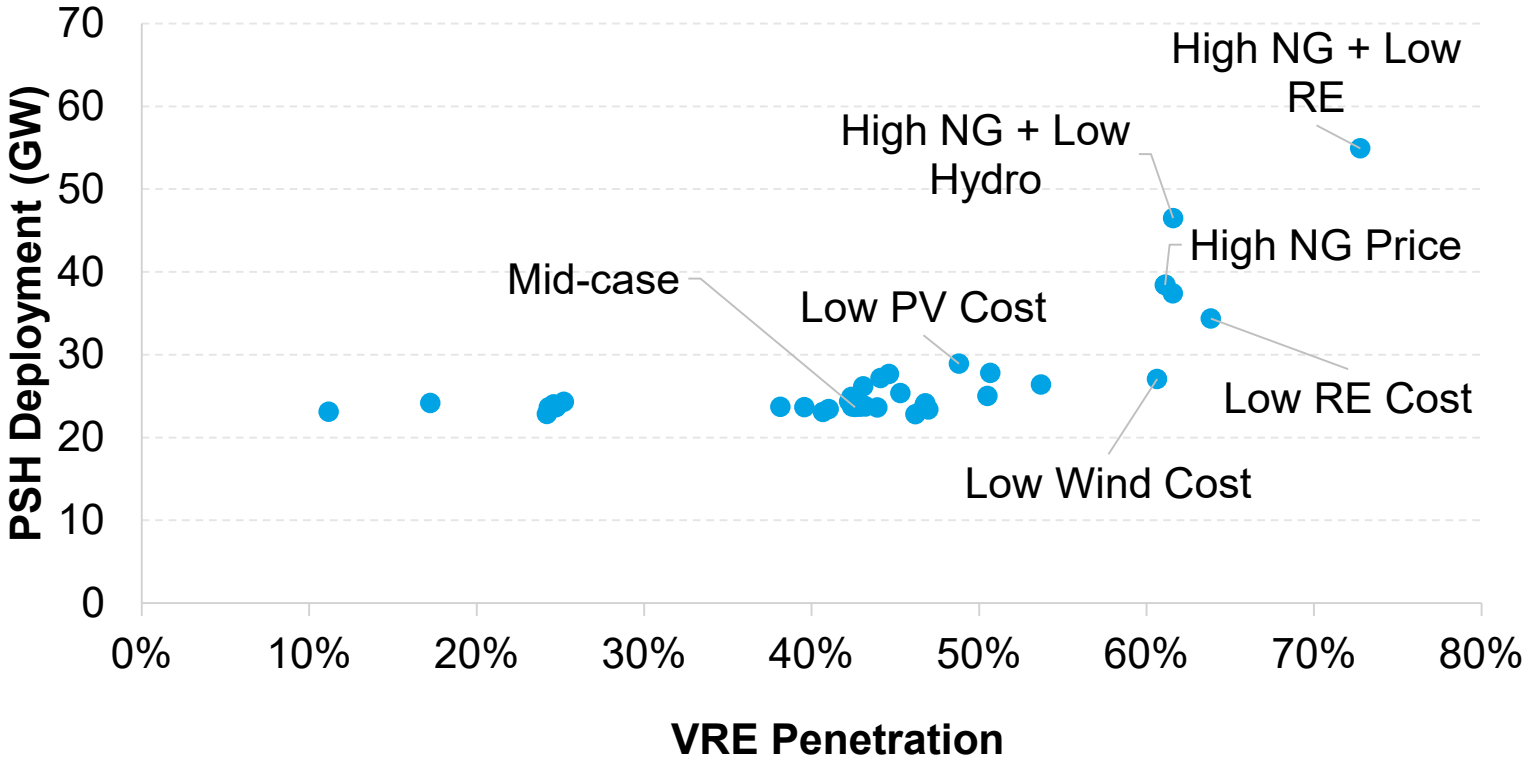
Growth in Concentrating Solar Power and Pumped-Storage Hydro

CSP and PSH experience limited growth in the Mid-Case, but show strong growth potential in several side-cases





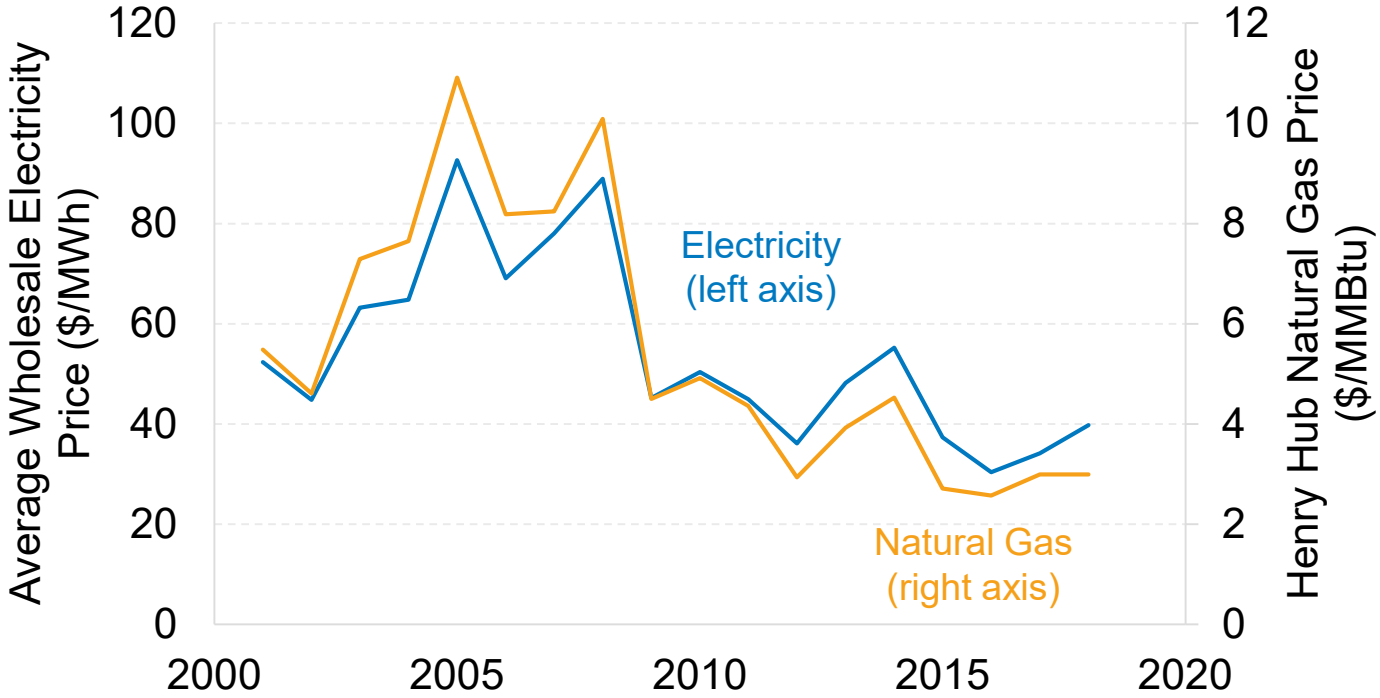
Value of Pumped-Hydro Increases with VRE Penetration



Theme #3:

The effect of continued natural gas and renewable energy deployment on power sector prices

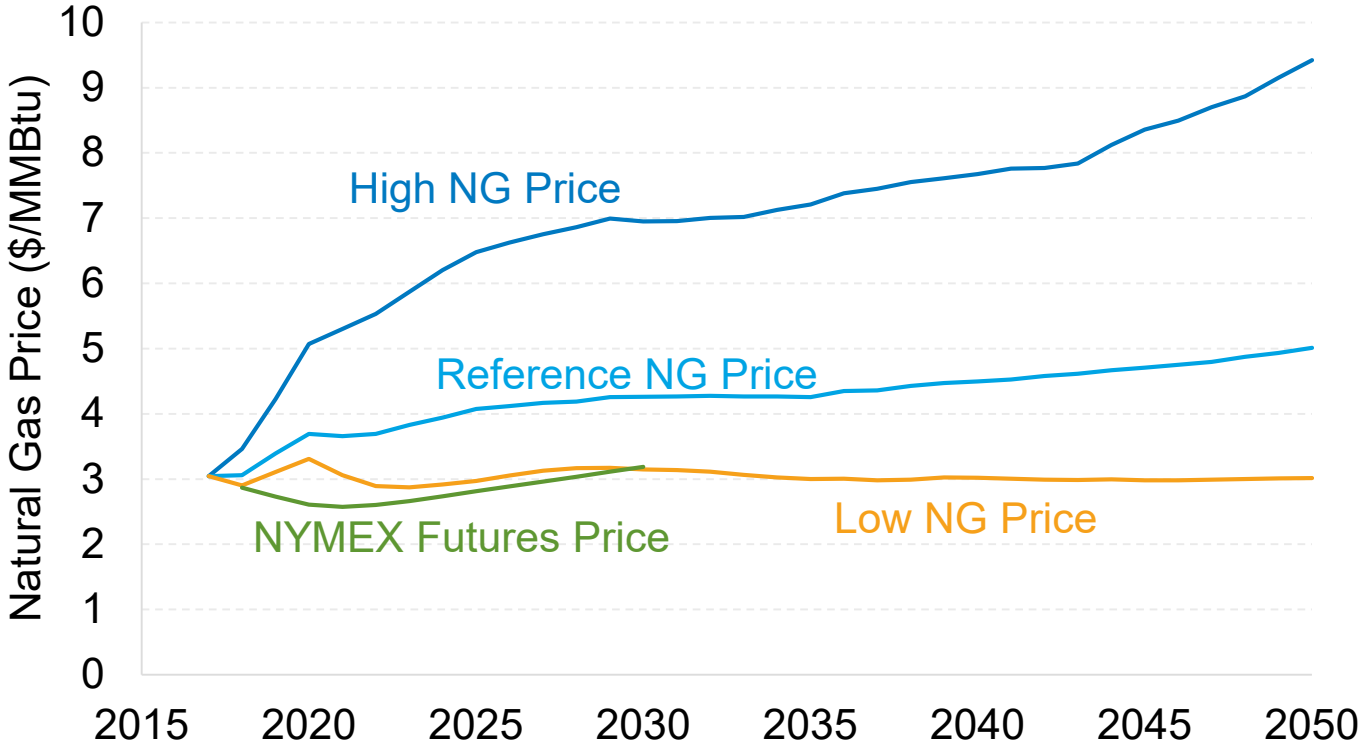
Natural Gas Prices and Wholesale Energy Prices Have Been Coupled



Source: EIA (multiple years)

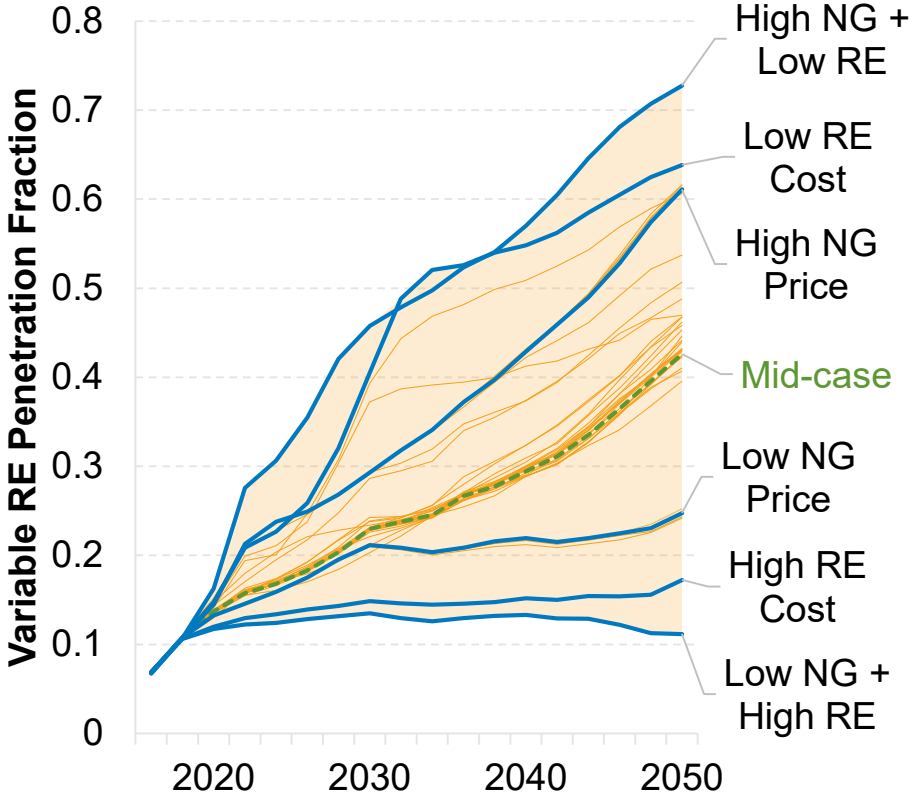
Prices were adjusted to 2017$ using the consumer price index. 2018 prices are only through July. Average wholesale electricity prices are based on the ERCOT, Indiana, Mid Columbia, Nepool, NP-15, SP-15, Palo Verde, and PJM West trading hubs.

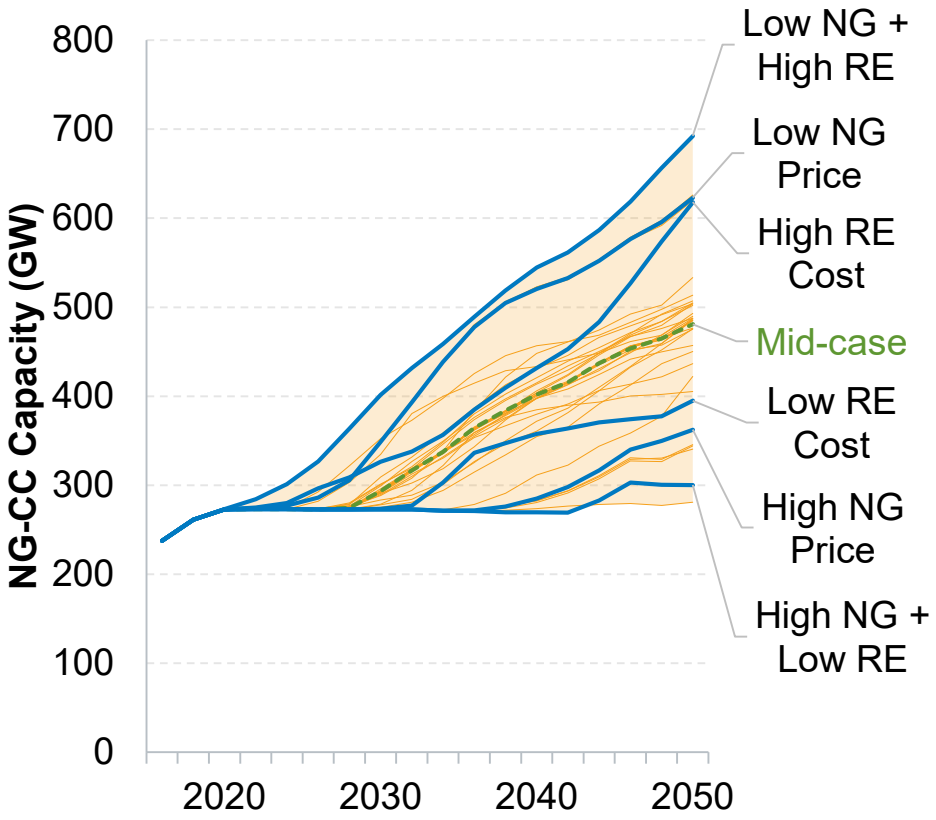
Henry Hub Price Projections (EIA and NYMEX)



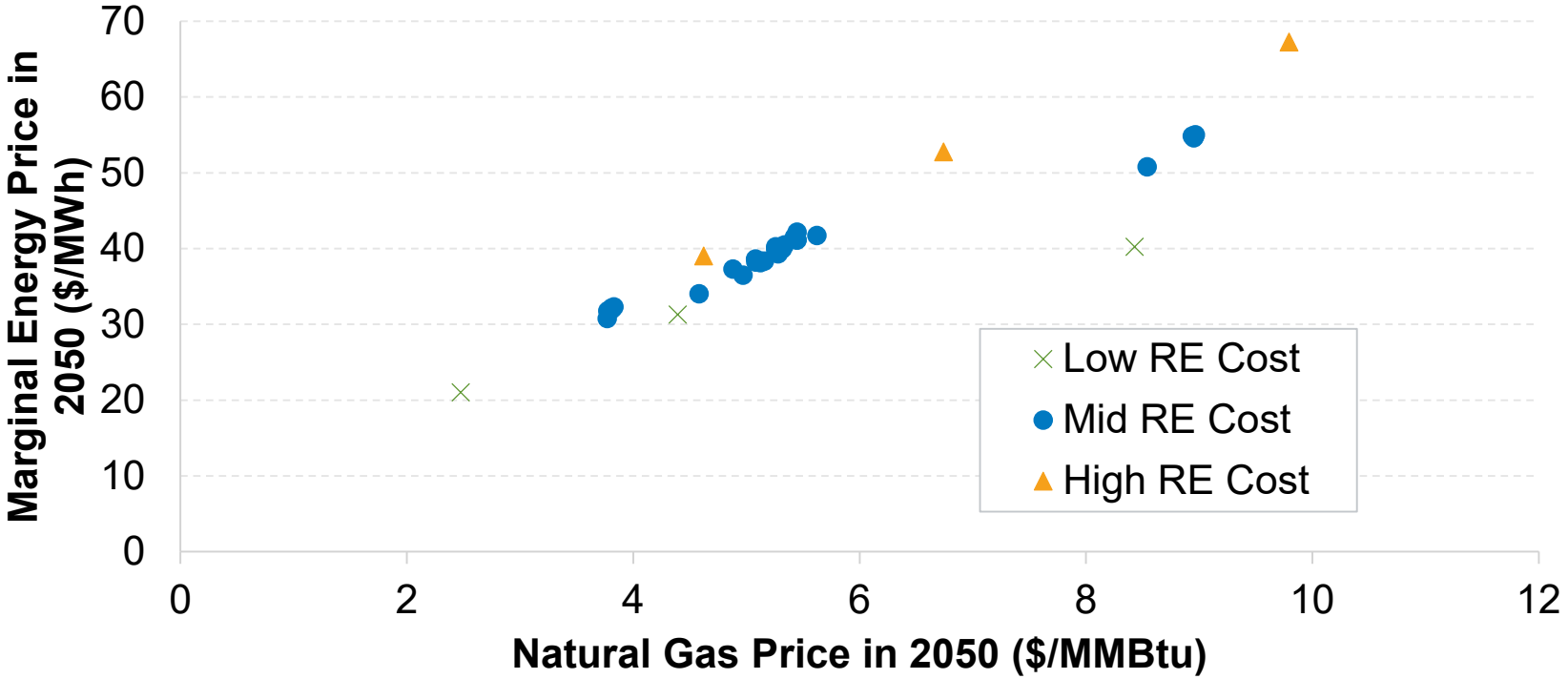
NYMEX futures prices are from August 2, 2018

VRE Penetration and NG-CC Capacity Across Scenarios

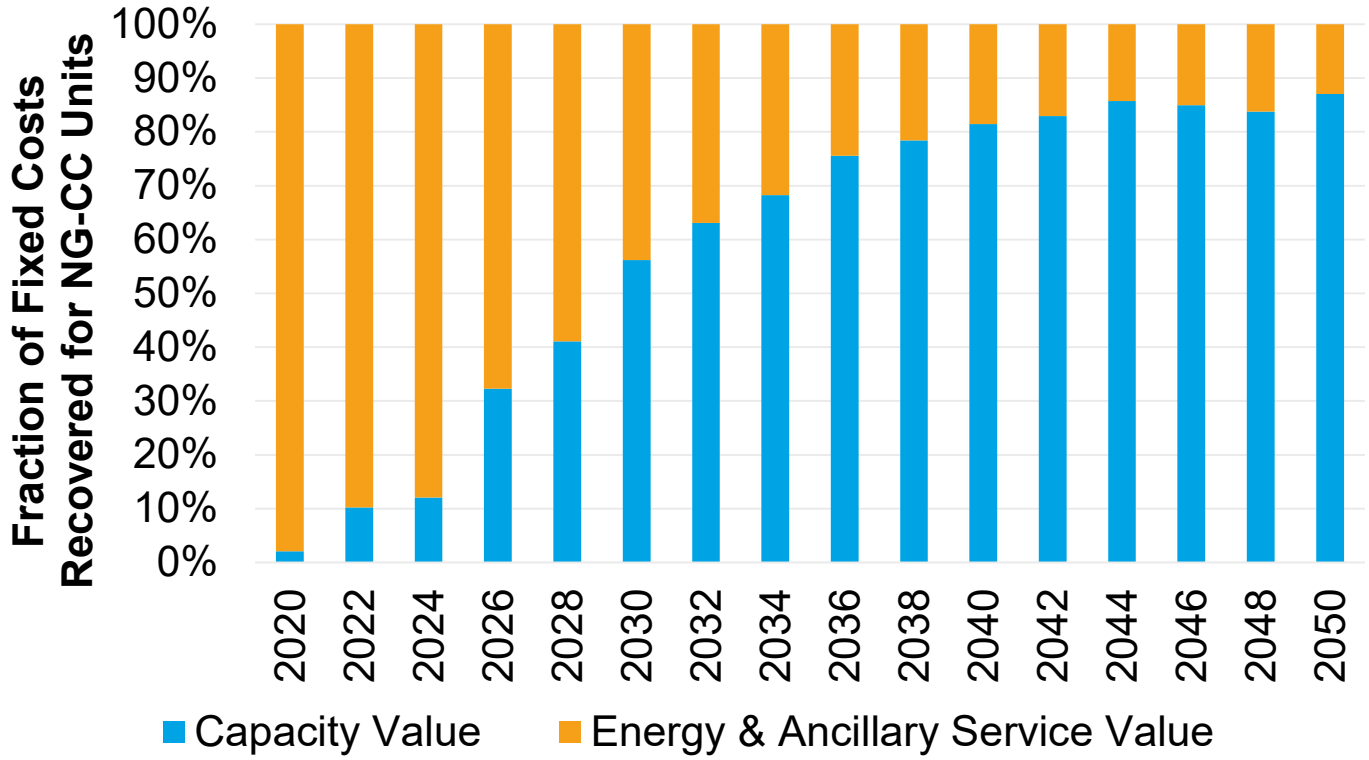




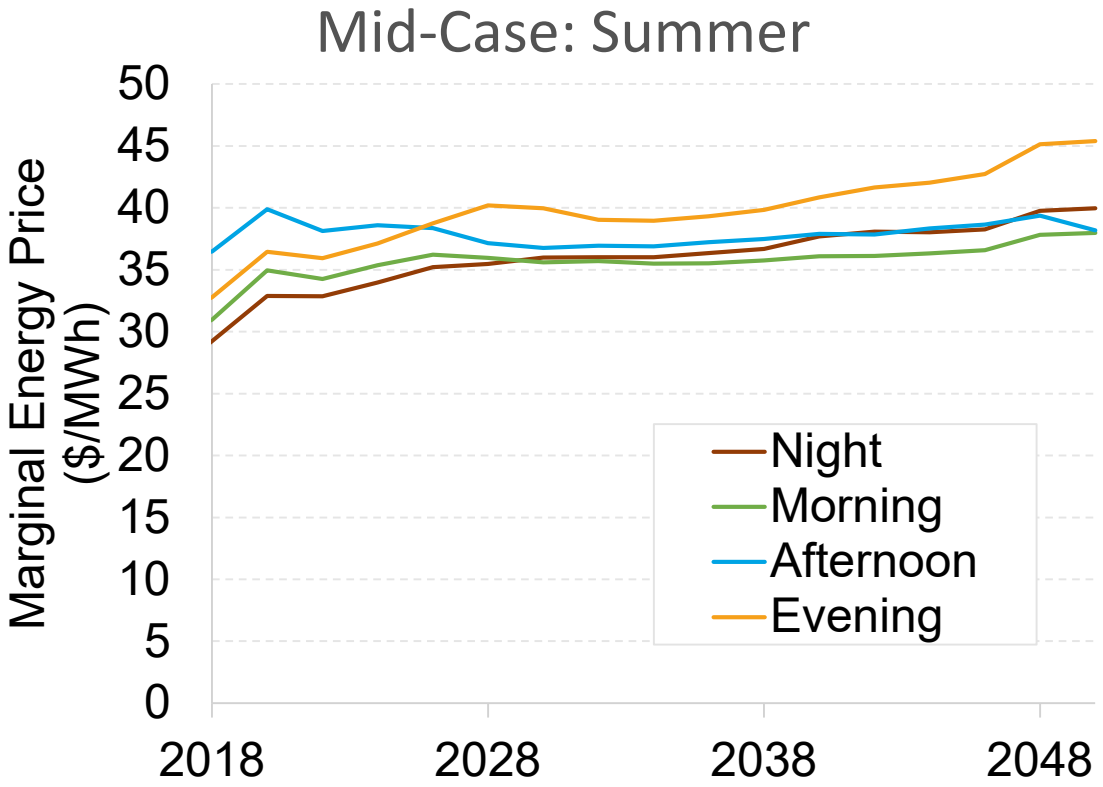
Marginal Energy Prices Remain Correlated with Natural Gas Price



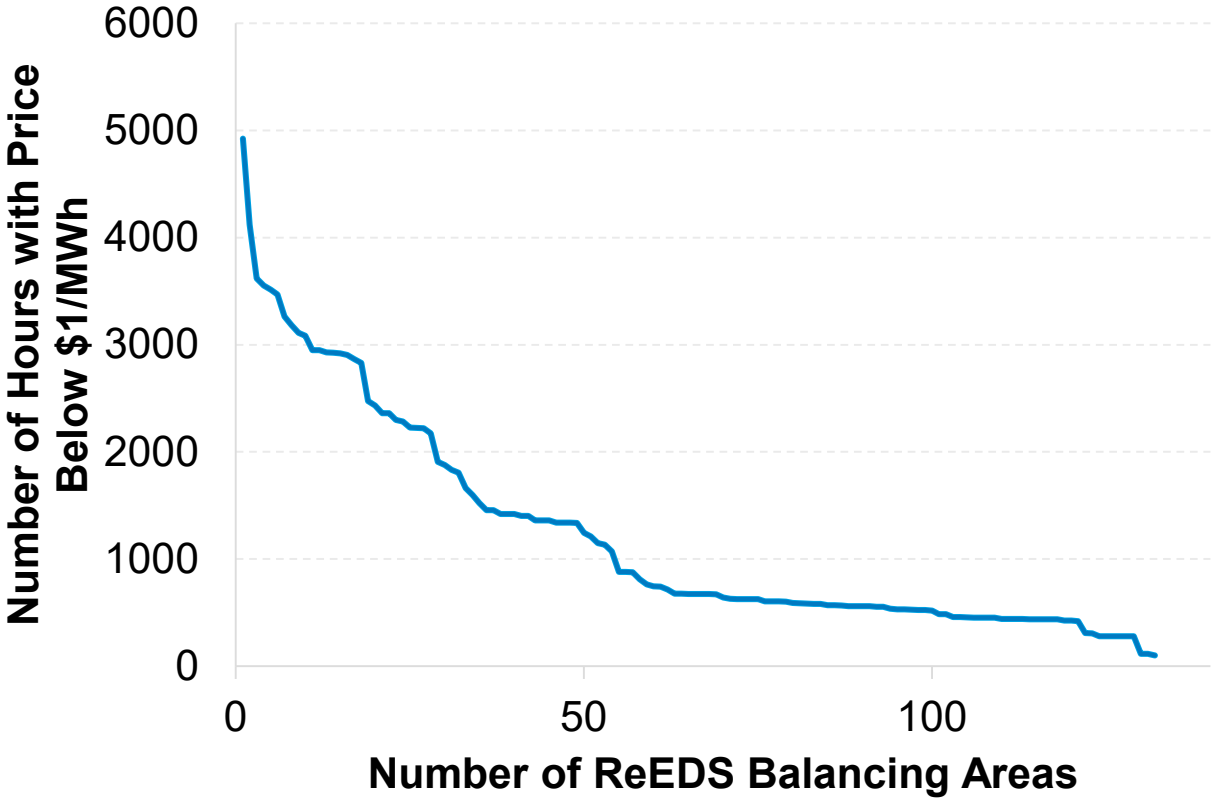
Capacity Value Grows in Importance for Natural Gas Generators



Impact on Electricity Prices



Frequency of Low-price Hours (in 2050)



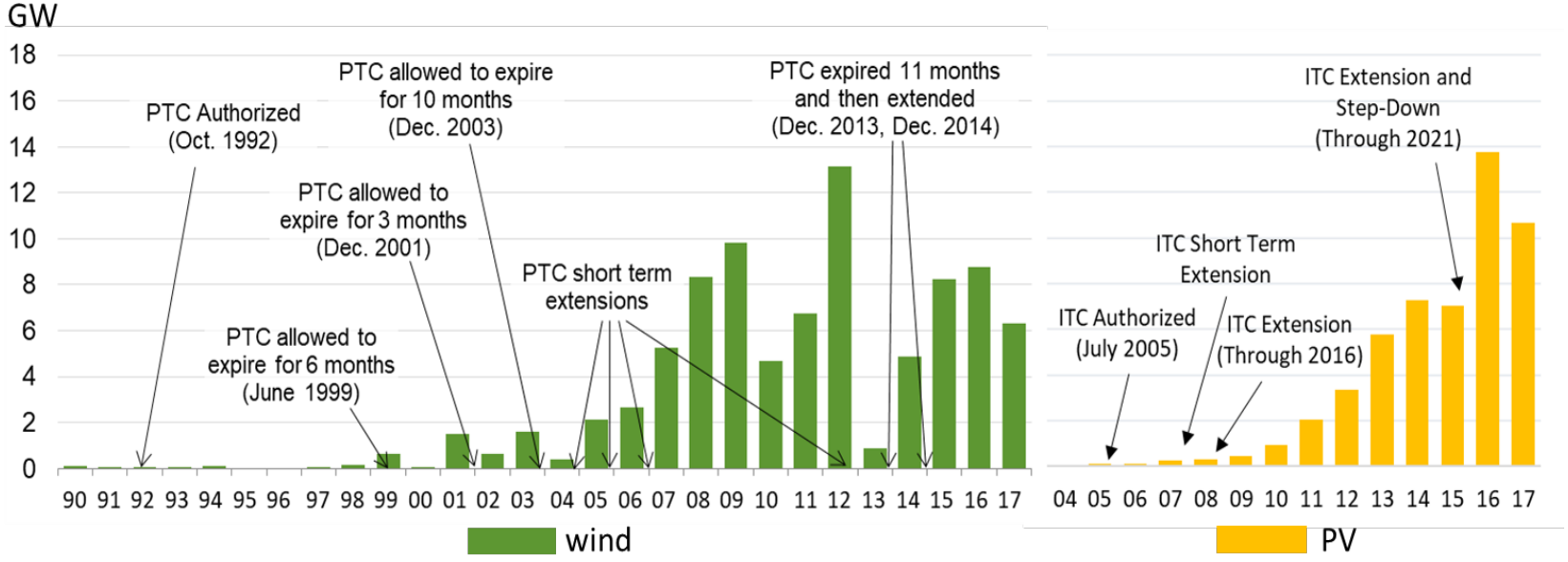
- All regions have >100 low-price hours per year
- 54 (of 134) have >1000

Theme #4:

The impact of the declining tax credits on renewable energy deployment

Production Tax Credit (PTC) and Investment Tax Credit (ITC)

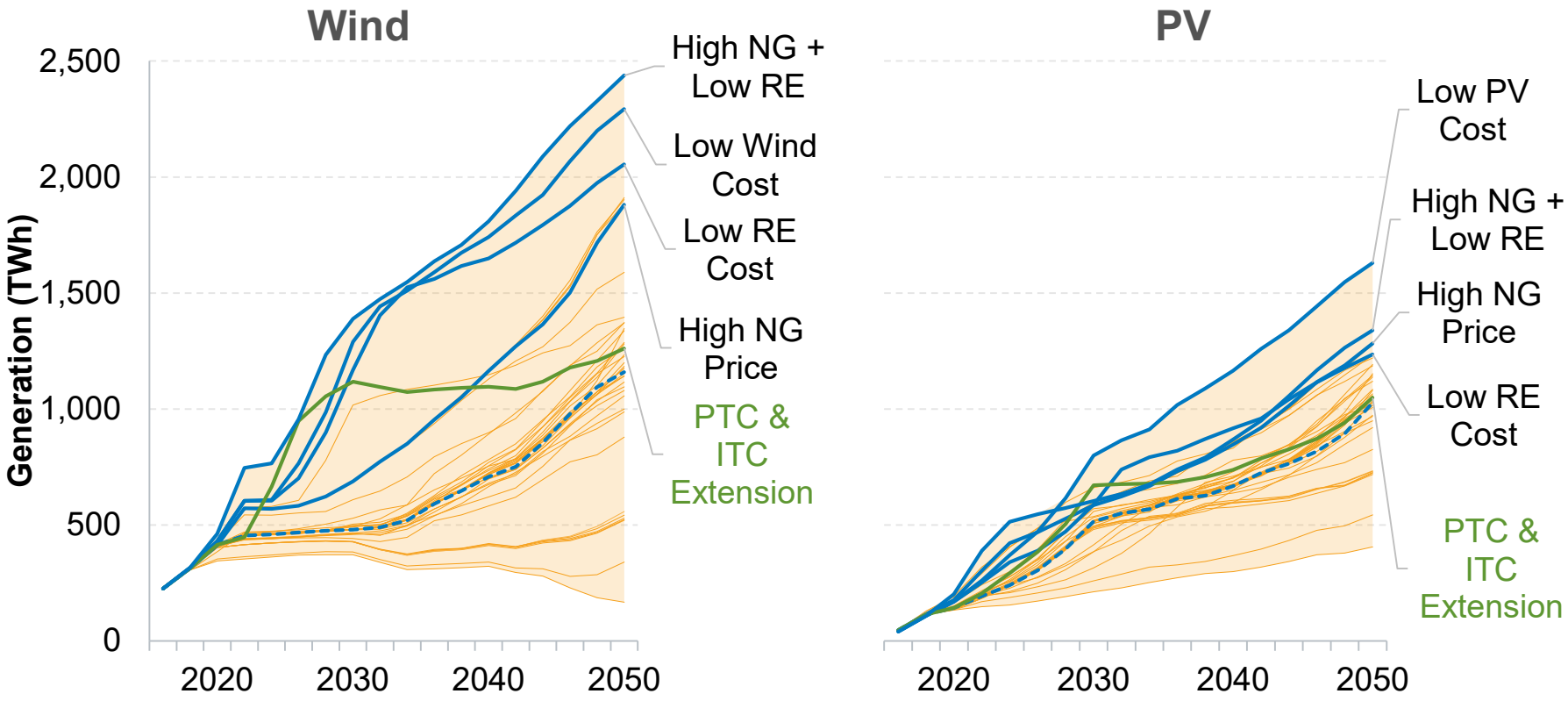
Annual Capacity Additions of Wind and PV Along With Major PTC and ITC Extension Dates



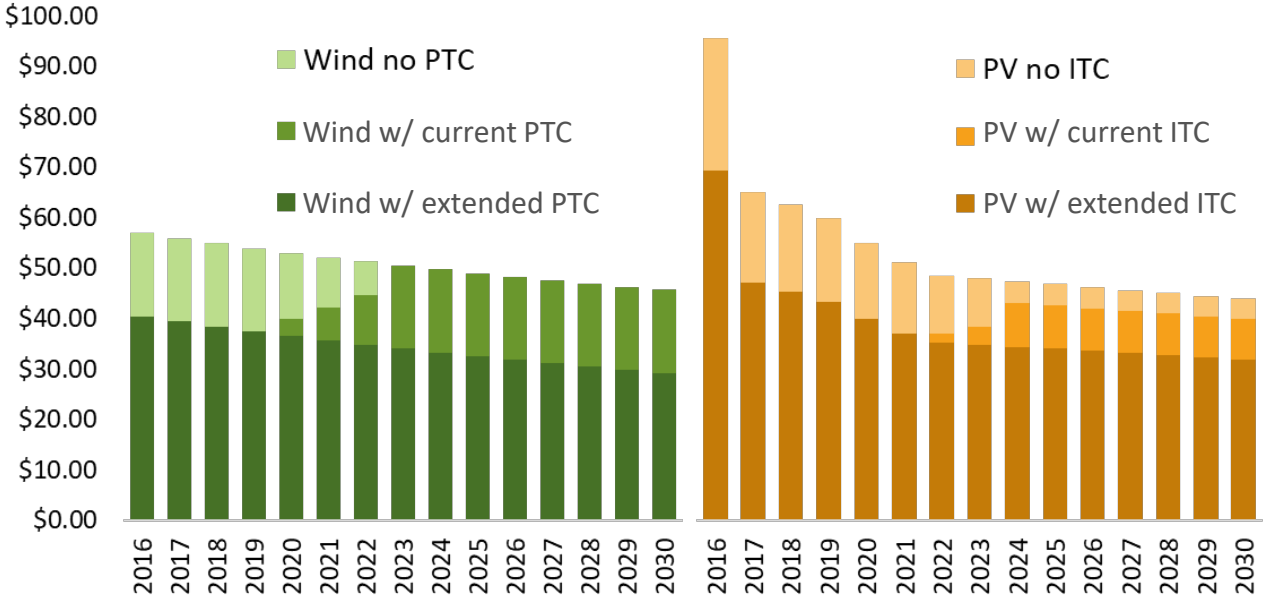
	2019	2020	2021	2022	2023	future
PTC	23$/MWh	18.40$/MWh	13.80$/MWh	9.20$/MWh	0$/MWh	0$/MWh
ITC	30%	30%	30%	26%	22%	10%

Tax credit schedule based on in-service date

Wind and PV Deployment Across Scenarios

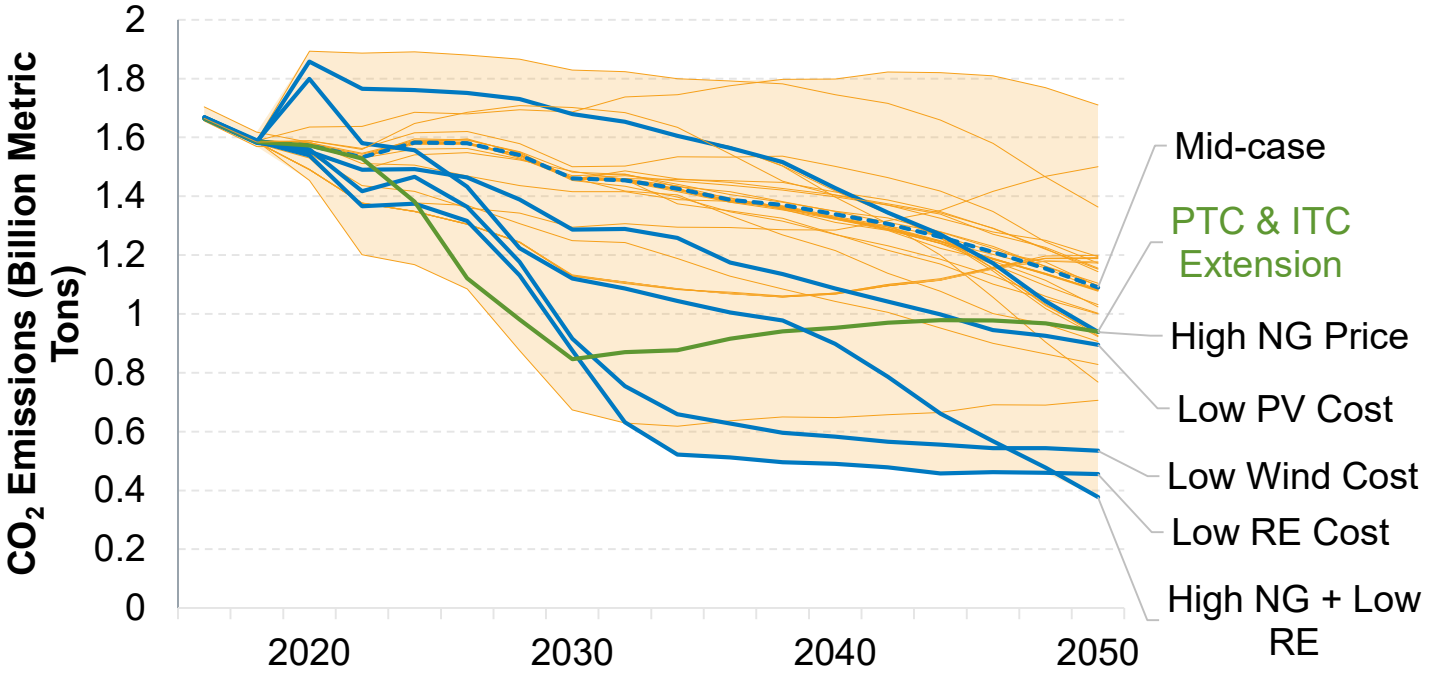


LCOE Estimates for Wind and PV With and Without PTC/ITC

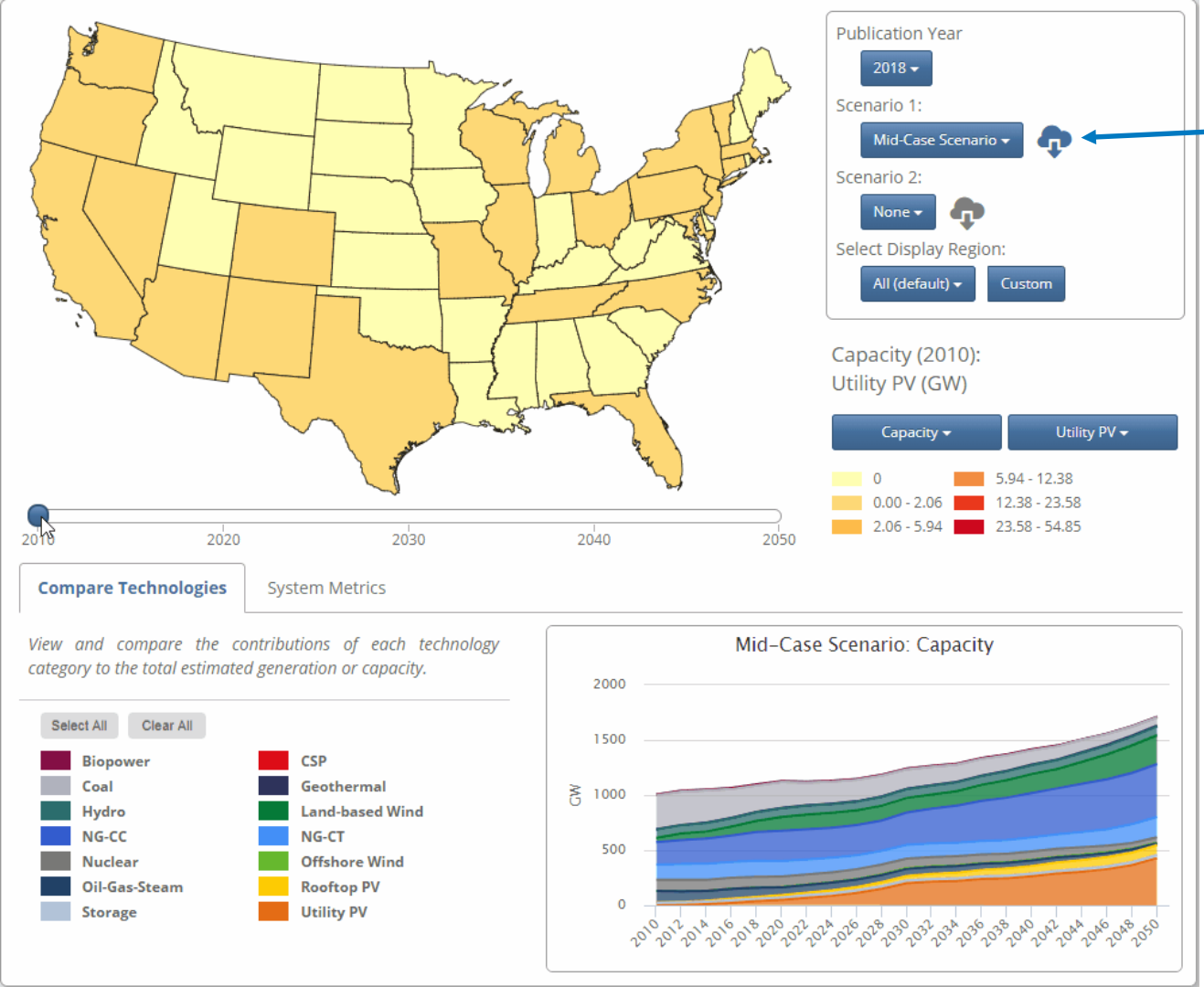


Year	2016	2030
PTC Relative Value	**29%**	**36%**
PTC Absolute Value (2017$)	$\frac{23\$}{\mathrm{MWh}}$	$\frac{23\$}{\mathrm{MWh}}$
ITC Relative Value	30%	30%
ITC Absolute Value (2017$)	$\boldsymbol{\frac{26\$}{\mathrm{MWh}}}$	$\boldsymbol{\frac{12\$}{\mathrm{MWh}}}$

CO_2 Emissions Across Scenarios



Accessing the Data



Cloud icon downloads data into csv file

Standard Scenario Results Viewer available at https://openei.org/apps/reeds/

Summary

- Standard Scenarios provides a framework to
  - Improve analysis and modeling work
  - Provide a perspective on the U.S. electricity sector evolution
  - Get access to state-level projections
- Themes from 2018:
  - The impacts on system operation from increasing shares of variable renewable energy
  - The potential for renewable energy technologies beyond solar PV and land-based wind
  - The effect of continued natural gas and renewable energy deployment on power sector prices
  - The impact of the declining tax credits on renewable energy deployment

Questions or Comments?

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www.nrel.gov

Full Report: https://www.nrel.gov/docs/fy19osti/71913.pdf

Results Viewer: https://openei.org/apps/reeds/

This work was authored by the National Renewable Energy Laboratory, operated by Alliance for Sustainable Energy, LLC, for the U.S. Department of Energy (DOE) under Contract No. DE-AC36-08GO28308. Funding provided by U.S. Department of Energy Office of Energy Efficiency and Renewable Energy Office of Strategic Programs. The views expressed in the presentation do not necessarily represent the views of the DOE or the U.S. Government.