American Clean Power Association (ACP)

Renewable energy and infrastructure policy scenario analysis

December 2020

Trusted Power and Renewables Intelligence

woodmac.com

About Wood Mackenzie

We provide commercial insight and access to our experts, leveraging our integrated proprietary metals, energy and renewables research platform.

Wood Mackenzie is ideally positioned to support consumers, producers and financers of the new energy economy.

- Acquisition of MAKE, Greentech Media (GTM) and Genscape
- Leaders in renewables, EV demand and grid-connected storage
- Over 500 sector-dedicated analysts and consultants globally, including 75 specifically to power and renewables
- Located close to clients and industry contacts

Wood Mackenzie offices
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1. Executive Summary

Executive summary

01

Administrative action can enable doubling of renewable energy penetration in the next decade

- Administrative action can accelerate transmission infrastructure expansion in order to unlock wind and solar
- Under administrative actions, renewable energy can grow from ~19% to ~37% due to technological advancement, transmission expansion, and better access to federal lands and waters
- Achieving 50%+ renewable energy will require additional legislative polices to require and/or incentivize clean energy, accelerate the retirement of entire US coal fleet, significantly increase energy storage capacity, and massively improve grid infrastructure

02

Transmission-focused policies will be critical to unlocking renewable potential

- Transmission line upgrades are needed to alleviate congestion in regions with high renewable penetration
- Western wind and solar require new transmission infrastructure to provide low-cost power to demand centers
- Offshore wind requires significant transmission upgrades along the coast to bring power to market
- Transmission investment is estimated to be over $70-90 Billion for prioritized lines
- 50% renewables (Scenario 2) requires administrative action outlined in Scenario 1 to unlock renewables

03

Administrative and legislative actions driving 50% renewable energy by 2030 can be a major source of economic stimulus

- 50% renewables by 2030 will catalyze nearly 1 million direct, high-paying direct jobs in construction, installation, operations, manufacturing and supply chain
- Average wholesale prices will remain stable throughout this 10-year period due to injection of low-cost renewables
- Grid reserve margins and reliability are preserved by significant additions of grid-level energy storage
- Total capital investment to reach 50% renewables approaches $1 trillion by 2030.

Wood Mackenzie developed three scenarios to study US renewable energy evolution

Scenarios are sequentially built upon the Base Case, which represents a significant expansion of renewables

Base Case

Wood Mackenzie

Long Term Outlook

Base case scenario is defined by Wood Mackenzie's 1st Half 2020 Long Term Outlook (LTO)

LTO is released twice per year to Wood Mackenzie subscription clients as the North American Power Service

Federal Carbon case was utilized due to timing and availability. Carbon pricing does not begin until 2028, so has minimal impact on study

Provides overview of power market fundamental development over a 30-year outlook (2020-2050)

Data and analysis included: Capacity development, retirements, wholesale pricing

Limited tariff impact on cost due to robust global supply chain; major impacts on labor costs not considered

Scenario 1

Administrative Action

Scenario 1 built upon the Base Case by adding infrastructure and renewable capacity:

- Onshore wind and solar on BLM land, informed by development projects that are in permit stage and available land
- Offshore wind expansion driven by acceleration of BOEM leases and accelerated permitting
- Defined transmission expansion, driven by known development projects, accelerated timelines for completion of 2030+ projects
- Generic transmission expansion, driven by observed congestion, price disparity and provide access to new renewable capacity

Scenario 2

50% renewables

Scenario 2 built upon Scenario 1 to meet a nationwide objective of 50% renewables by 2030

- Accelerated retirement of all existing coal capacity nationwide
- Installation of new gas-fired capacity was halted, other than known late-stage development projects
- Replacement of retired fossil plants with sufficient renewable capacity to meet supply/demand imbalance
- Renewable geographic distribution driven by relative economics, effective load carrying capacity (ELCC) and supply/demand imbalance
- Addition of energy storage sufficient to ensure grid reliability and maintain target reserve margins

Source: Wood Mackenzie

Scenario definitions, variables and constant assumptions

	Base Case	Scenario 1 – Administrative action	Scenario 2 – Nationwide renewable target

Description	• This case was **developed using Woodmac's 2020 H1 Federal Carbon Case** (2020 H1 FC).
	• Can be viewed as WoodMac's most likely scenario, given current policy structure and outlook
		• Federal government administrative action to enable:
		  • Transmission expansion
		  • Renewable expansion in federal land/water
		  • Accelerated permitting and removal of trade barriers
			• Nationwide 50% Renewable Energy Standard
			• Administrative action included in Scenario 1:
			  • Transmission expansion
			  • Renewable expansion in federal land/water

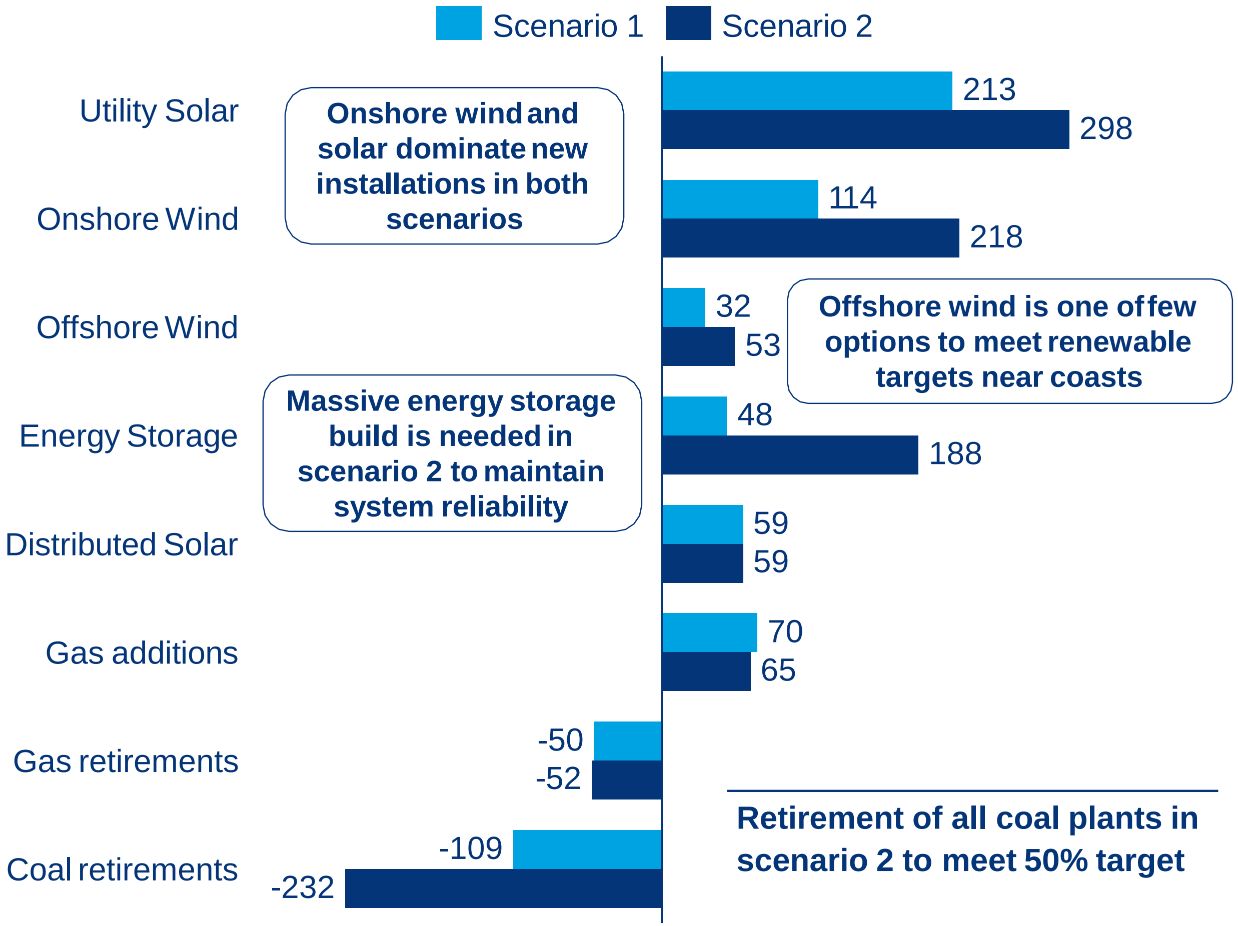
Capacity buildout	• Future capacity build was the same as Woodmac's 2020 H1 FC Case
	• Nuclear retirements were assumed as per NRC license expiry dates in NYISO and PJM
	• Coal retirements are based on announced projects and economic analysis
		• Wind and solar capacity on land leased by Bureau of Land Management (BLM)
		• Acceleration of offshore wind installations
		• Transmission expansion:
		  • Accelerate planned transmission projects
		  • Provide access to new renewable build
		  • Ease congestion and high price disparity
			• Nationwide constraint
			  • No less than 50% renewable energy by 2030
			• Retirement of all remaining coal capacity by 2030
			• Slowed capacity build for new gas capacity
			• Future capacity build was changed and system rebalanced to reflect a reserve margin similar to the Base Case.

Carbon price	• RGGI floor prices were the same as Woodmac's 2020 H1 NFC Case • Virginia was not assumed to be part of the RGGI program for this analysis • A modest federal carbon price was assumed starting in 2028 across the NERC footprint	• Same as Base Case	• Same as Base Case
Fuel price	• Future fuel prices were assumed the same as Woodmac's 2020 H1 FC Case	• Future fuel prices were assumed the same as Woodmac's 2020 H1 FC Case	• Future fuel prices were assumed the same as Woodmac's 2020 H1 FC Case
Electricity Demand	• Future electricity demand was assumed the same as Woodmac's 2020 H1 FC Case	• Future electricity demand was assumed the same as Woodmac's 2020 H1 FC Case	• Future electricity demand was assumed the same as Woodmac's 2020 H1 FC Case

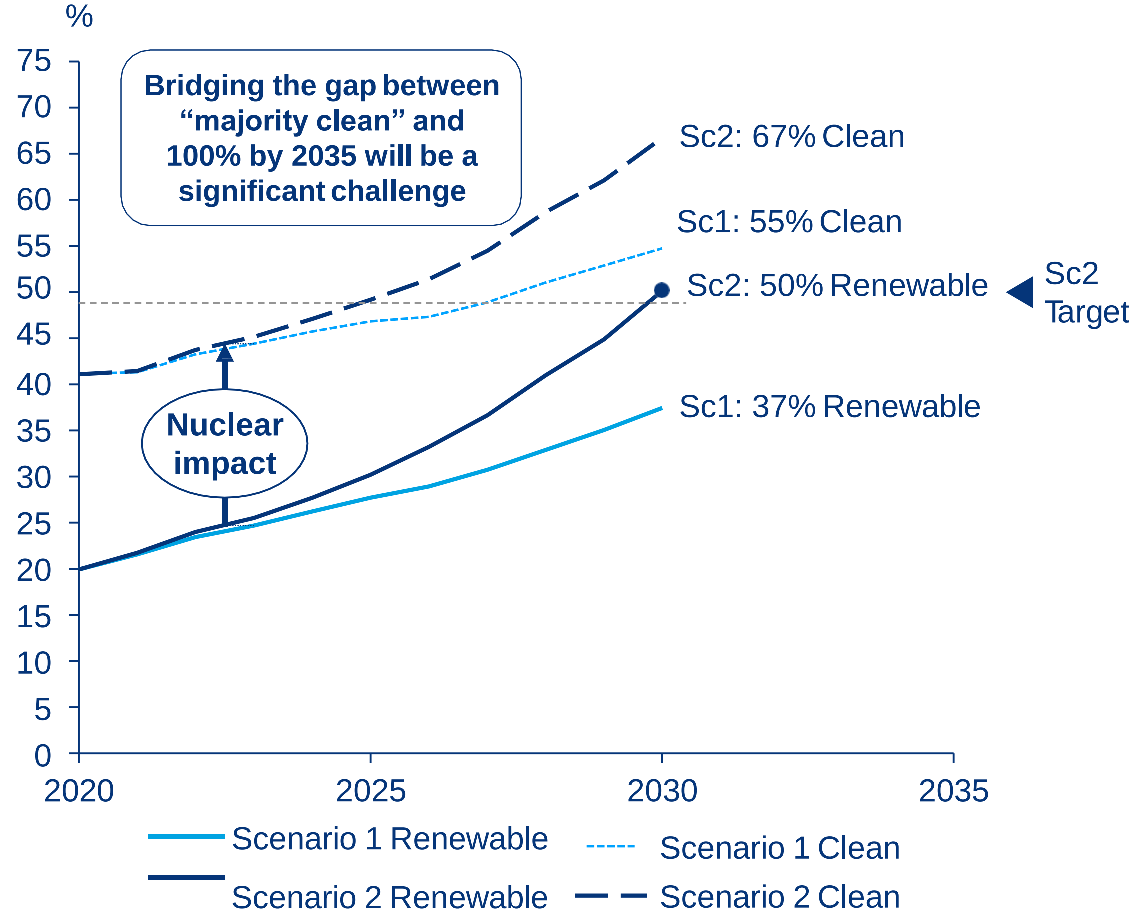
Massive renewable energy expansion was analyzed alongside significant fossil fuel retirements

Both scenarios make progress towards a greener grid, and a significant overhaul is required to reach 100% clean energy

Scenario capacity changes – 2020-2030 cumulative GW change



US renewable energy and clean energy penetration, US % of generation

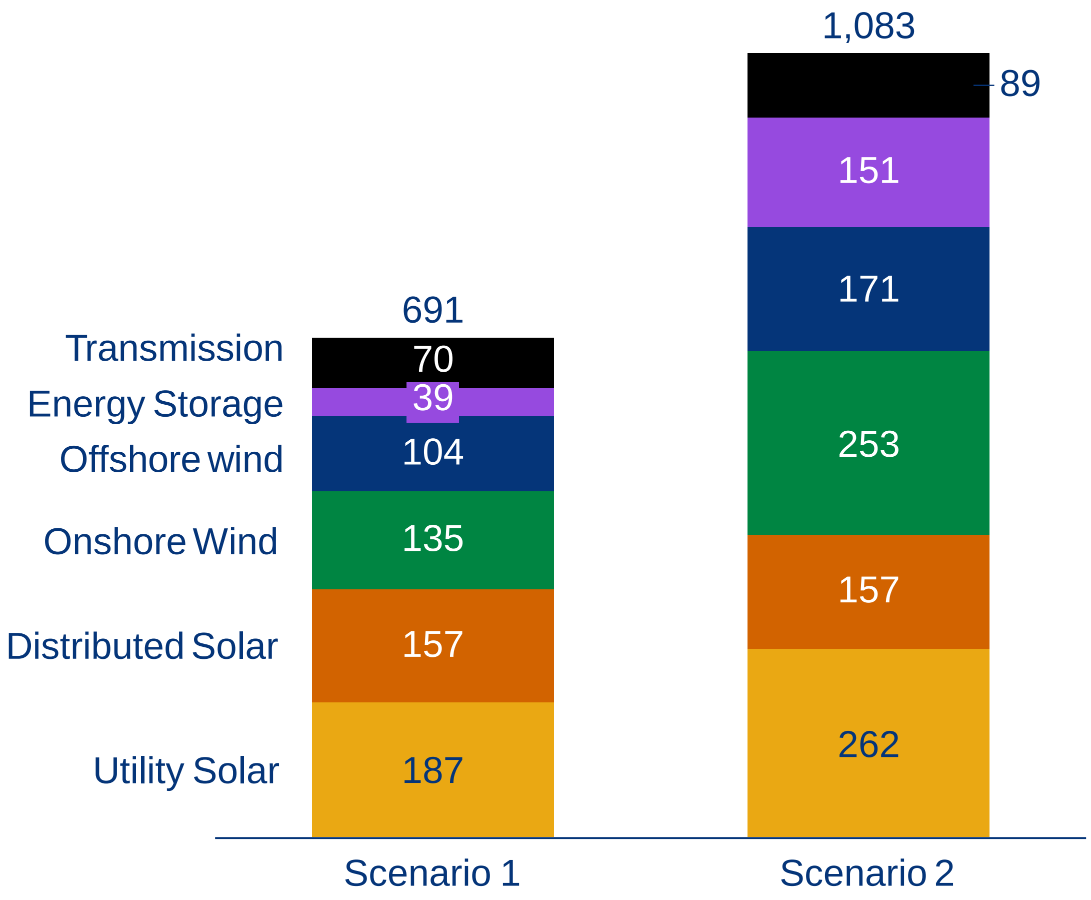


Source: Wood Mackenzie

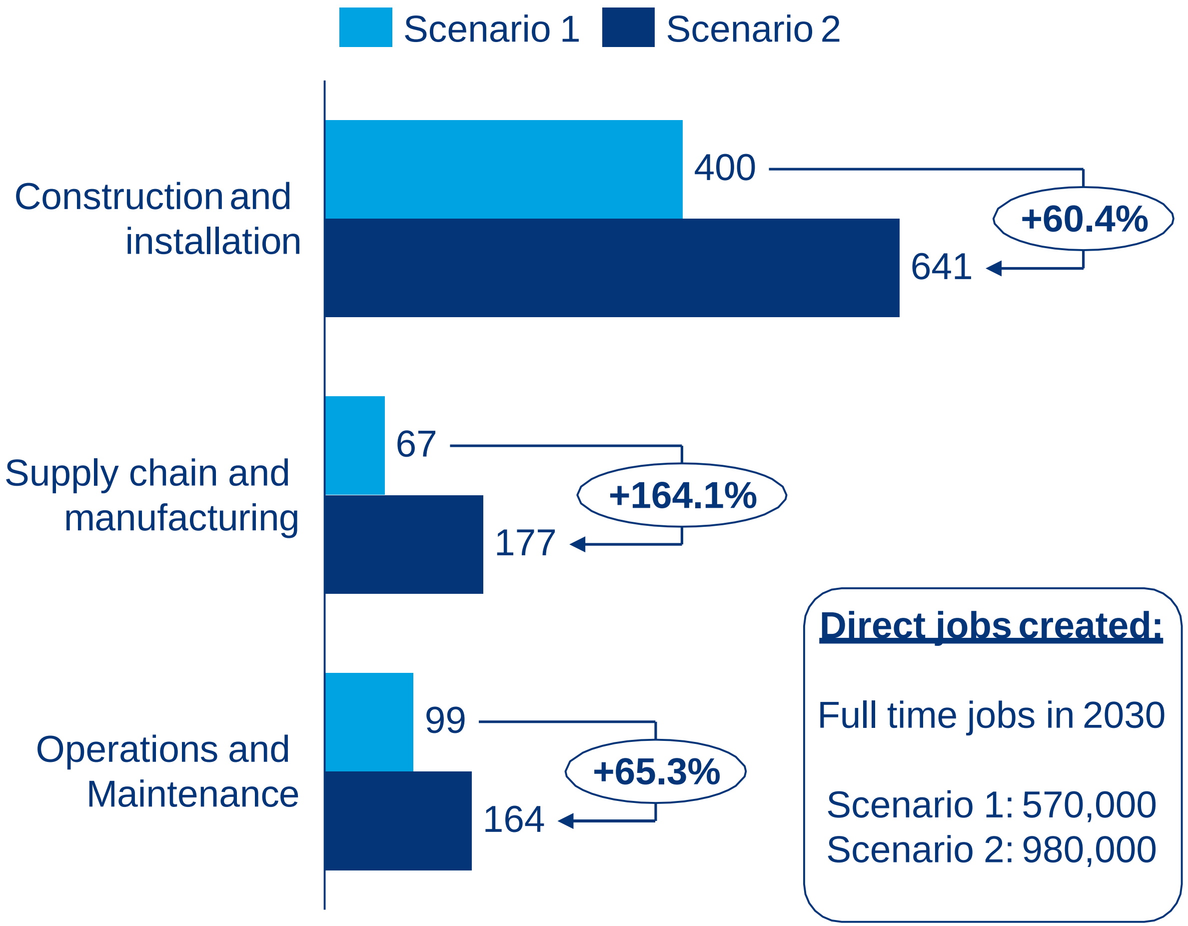
Capital spend required to reach 50% renewables within the next decade to exceed $1 trillion

Nearly 1 million new direct jobs created by 2030 are related directly to construction, manufacturing and maintenance

Total capital spend – US $ billions, 2020-2030



Direct job creation – thousands of full time direct jobs, annual in 2030



Direct jobs created:

Full time jobs in 2030

Scenario 1: 570,000
Scenario 2: 980,000

Note: Capital cost includes cost of construction and installation only
Job estimates created using NREL JEDI Tools and include direct jobs only
Source: Wood Mackenzie

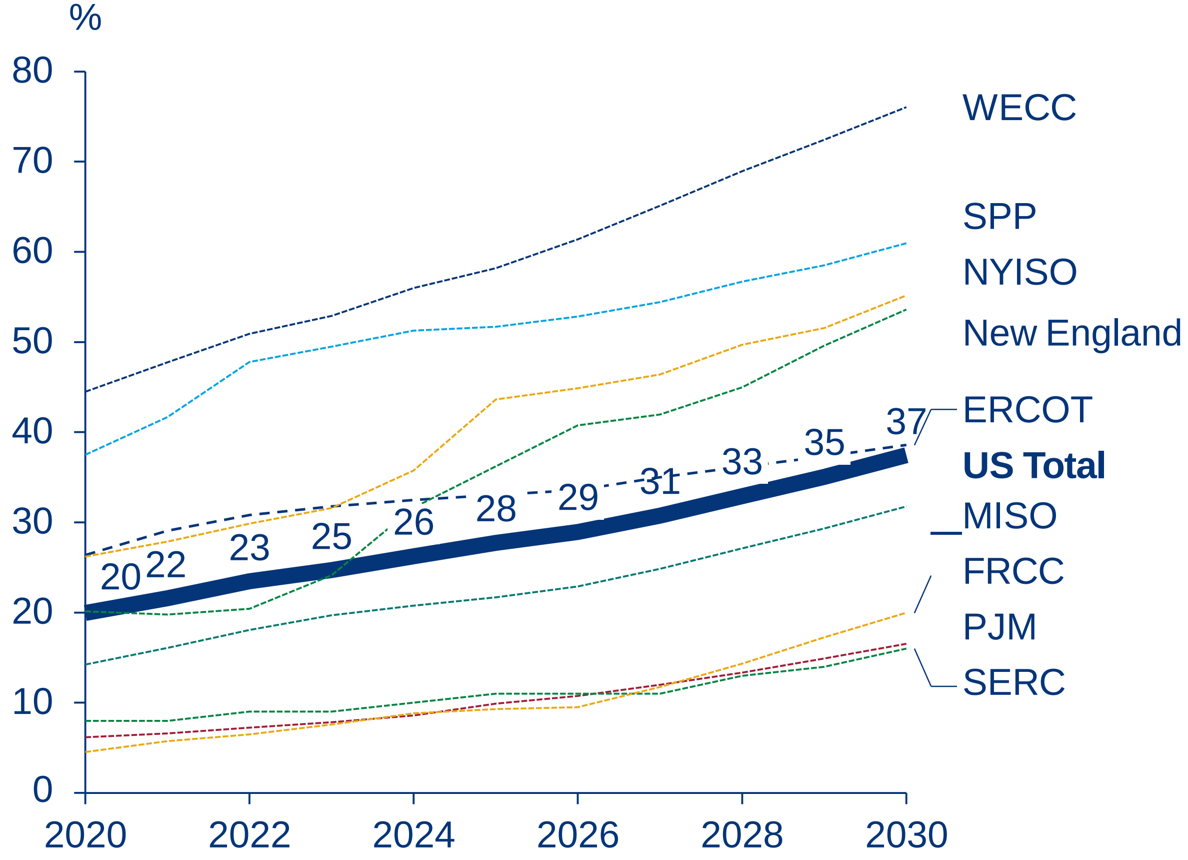
2. Scenario 1 – Administrative Action

Bold actions by the presidential administration can unlock renewable energy

Administrative action can enable doubling of renewable energy penetration by adding transmission and leveraging renewable resources on federal lands and water

Direct action by the federal administration can accelerate renewable energy expansion

Renewable energy penetration, by region – Scenario 1, %



The federal government can use administrative authority to expand renewable buildout, to achieve ~37% renewable energy nationally within the next decade.

Prioritized actions:

- **Transmission expansion** – Improve planning and cost allocation for new transmission lines, increase interregional coordination for more cost-effective lines across seams, upgrade existing lines to increase capacity, and establish corridors to allow for federal siting of interstate lines
- **Permitting** - Expediting environmental review timelines for renewable energy projects by adopting reasonable reforms to NEPA, accelerating permitting of renewables on public lands and waters, and creating fast-tracked "general permits" for low-risk renewable projects for wildlife permits.
- **Federal land for renewables build** – Set a federal target for BLM and BOEM to authorize leases and grant permits for renewables on public lands and waters, respectively.
- **Federal procurement -** Commit the federal government to purchase renewable energy as a significant portion of its electricity supply by 2030.
- **Increase competitiveness -** Reform wholesale markets to allow renewables to compete fairly, remove undue trade barriers for renewable energy products, and support electrification of other sectors to increase demand for renewables.

Note: Renewable energy includes wind, solar, hydro, landfill gas, geothermal, biomass, municipal solid waste and pumped storage

ISO/TSO abbreviations: WECC = Western Electricity Coordinating Council, SPP = Southwest Power Pool, NYISO = The New York Independent System Operator, PJM = PJM Interconnection

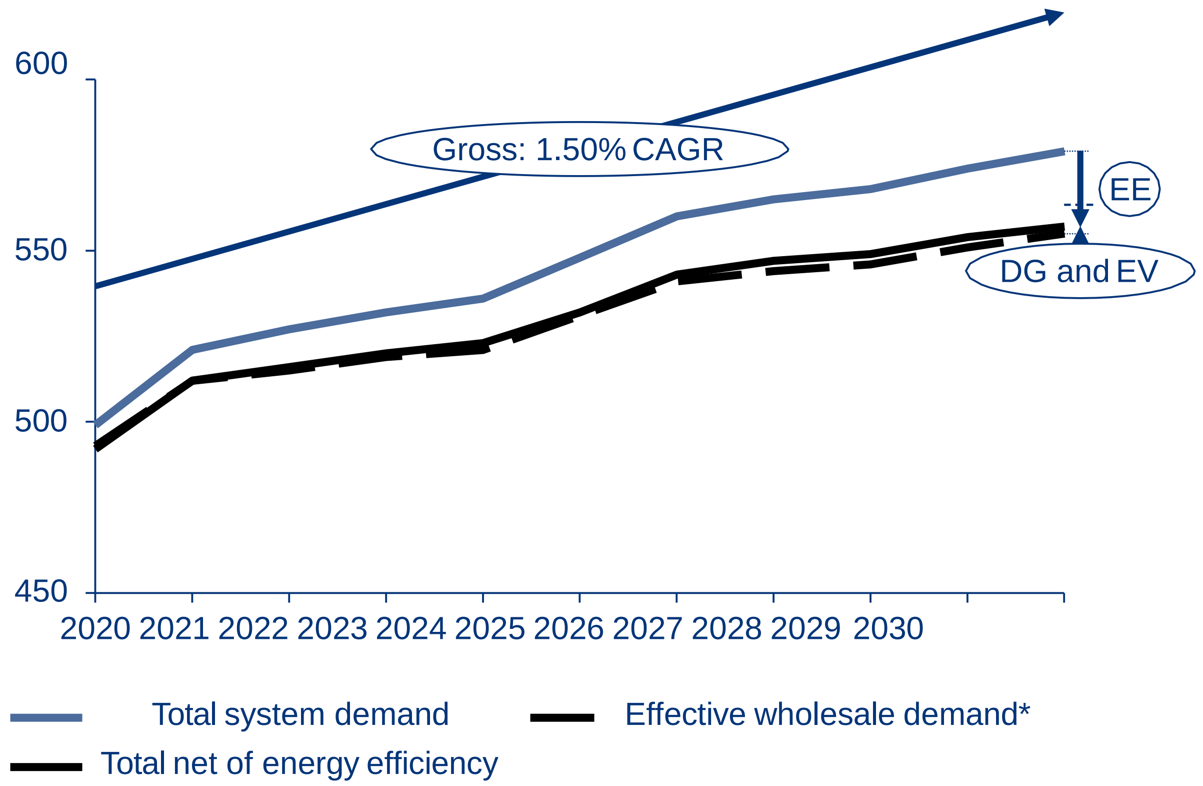
ERCOT = Electric Reliability Council of Texas, MISO = Midcontinent Independent System Operator, FRCC = Florida Reliability Coordinating Council, SERC = SERC Reliability Corporation

Source: Wood Mackenzie

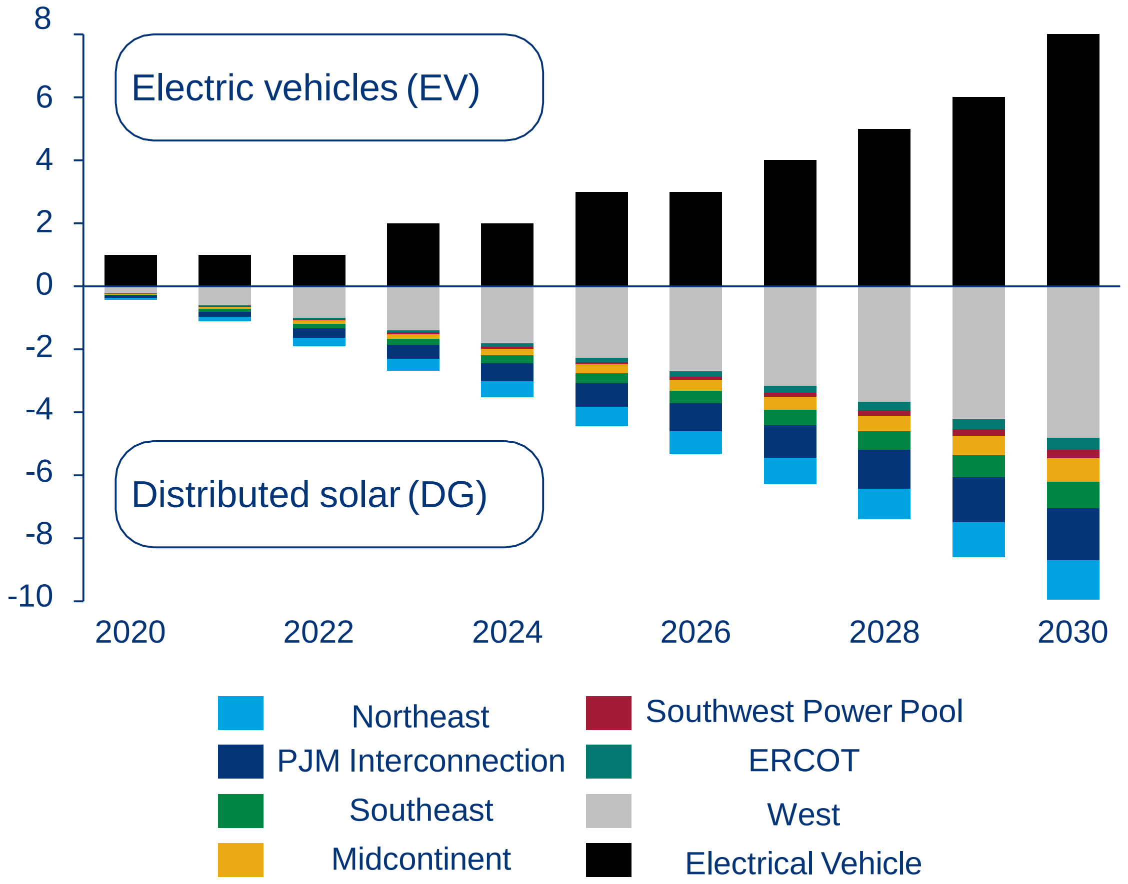
Energy demand growth from EV's largely offset by increases in distributed generation

Distributed generation resources and energy efficiency measures effectively reduce net demand

Avg. hourly system load and net load (GWa**)



Electrical Vehicles and Distributed Generation (GWa**)



- Baseline demand grows at a moderate rate but is reduced by energy efficiency
- Net load reduces due to renewable generation, but offset by EV growth

* "Effective wholesale demand" is net of Energy Efficiency (EE), Electric Vehicles (EV), and Distributed Generation (DG); "Net load" is effective wholesale demand available to be served by non-renewable sources i.e. thermal resources

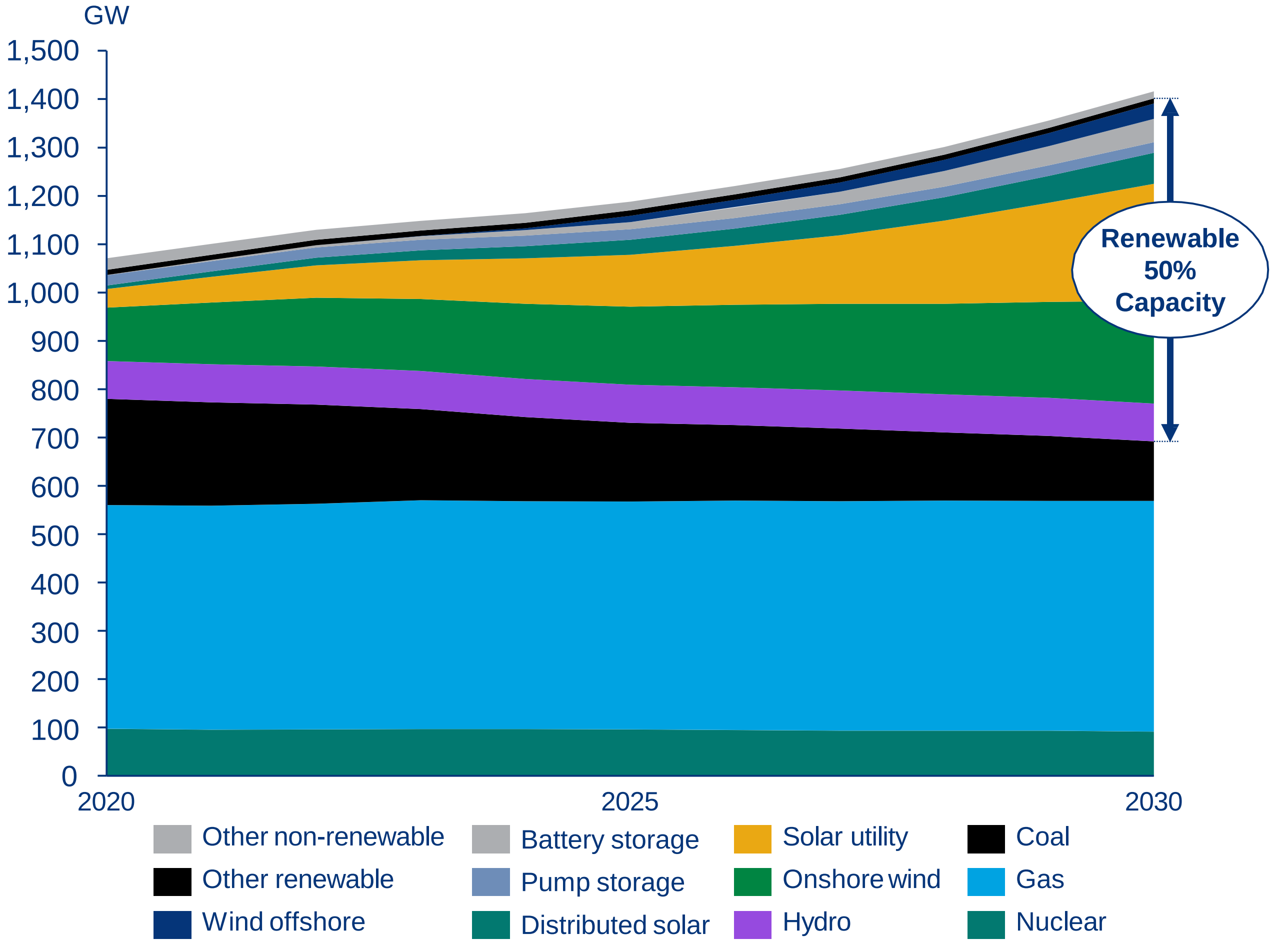
** GWa = Annual GWh / number of hours in a year

Souce: Wood Mackenzie

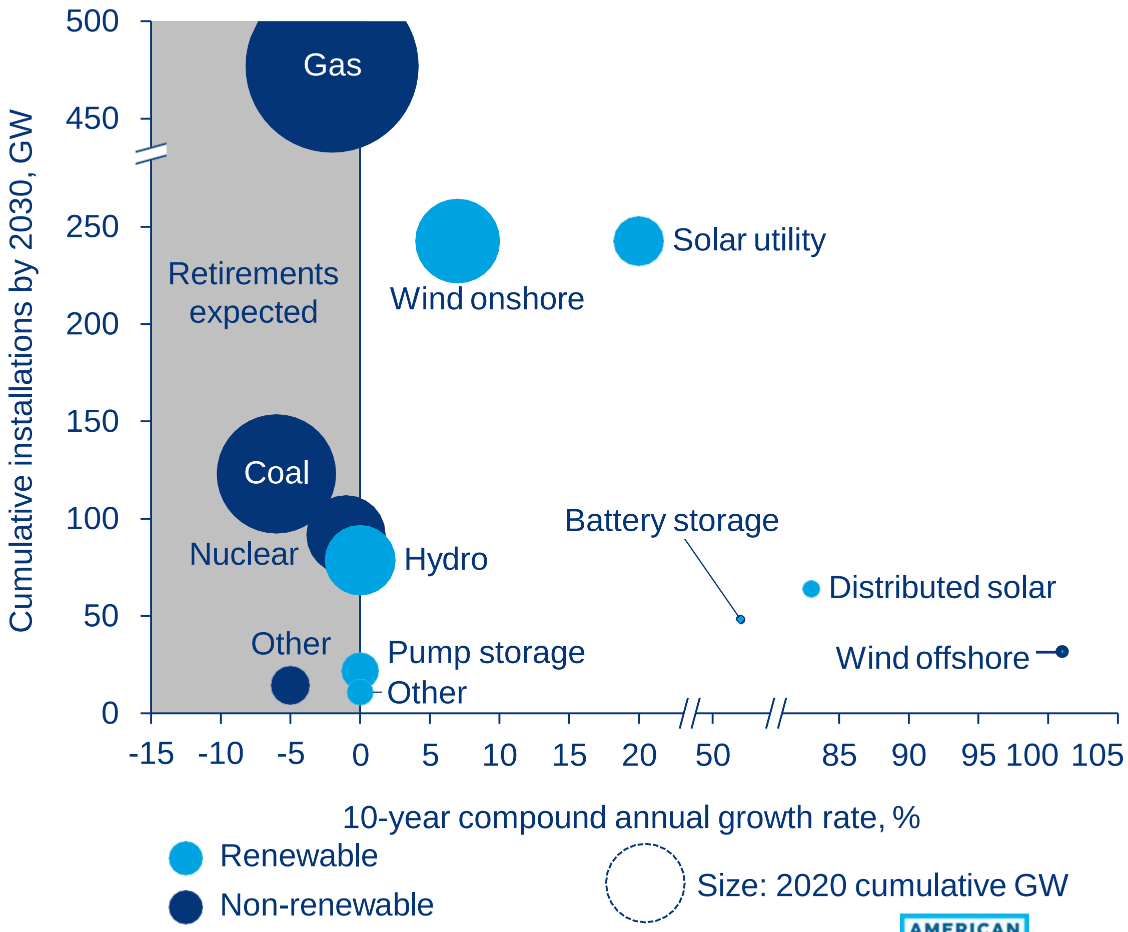
Renewable energy installations to consume nearly all new construction and erode share of fossil plants

Significant growth in offshore wind and battery storage from nascent technologies to integral parts of US power grid

Total cumulative capacity by technology, Scenario 1, GW



Growth rates of technologies – 2020-30, Scenario 1

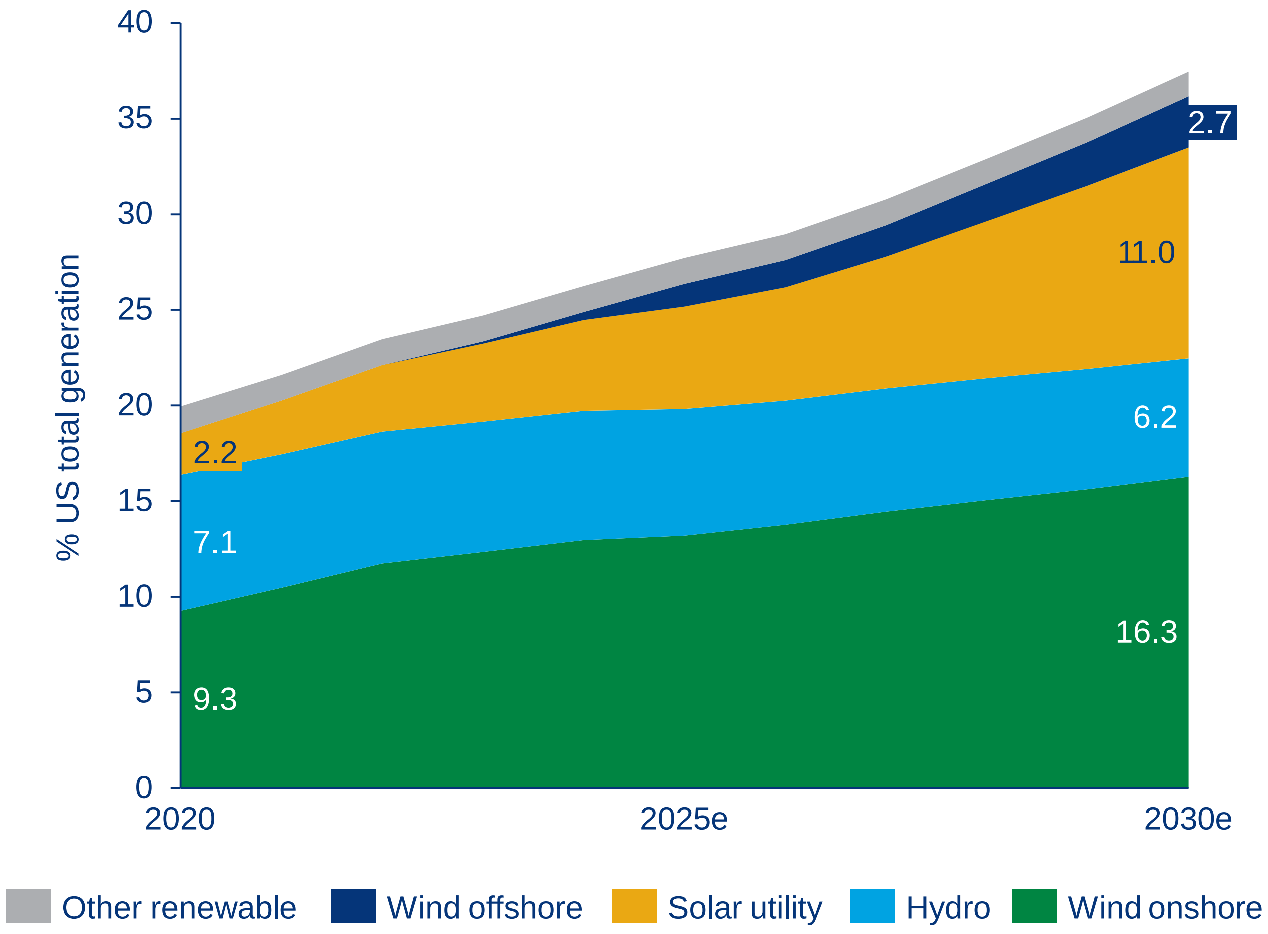


Source: Wood Mackenzie

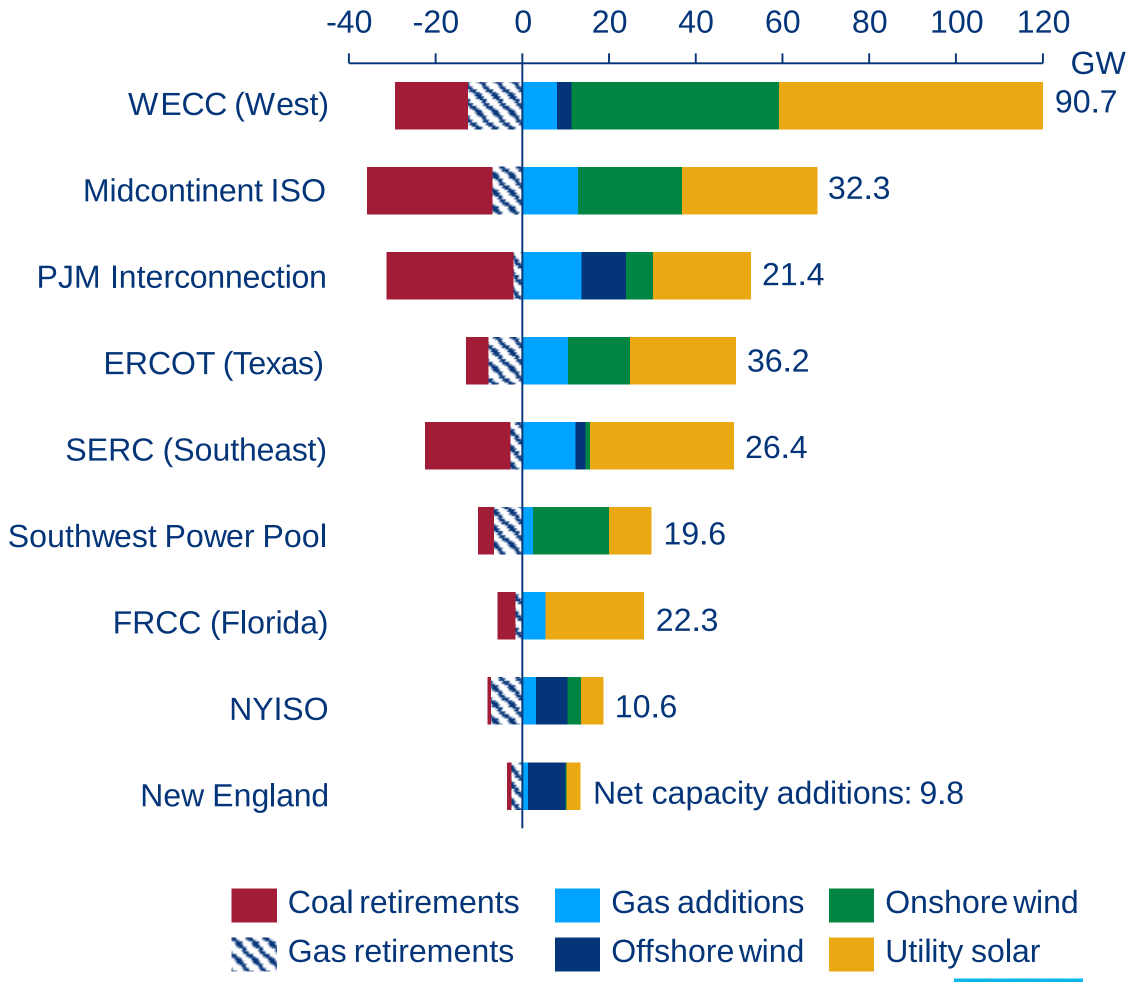
Renewable energy contributions driven by expansion of onshore wind, solar and offshore wind

Significant expected coal retirements in PJM and MISO expected to be largely replaced by wind and solar

Renewable penetration by technology – Scenario 1



Distribution of installations and retirements, Scenario 1, GW (2020-2030)C

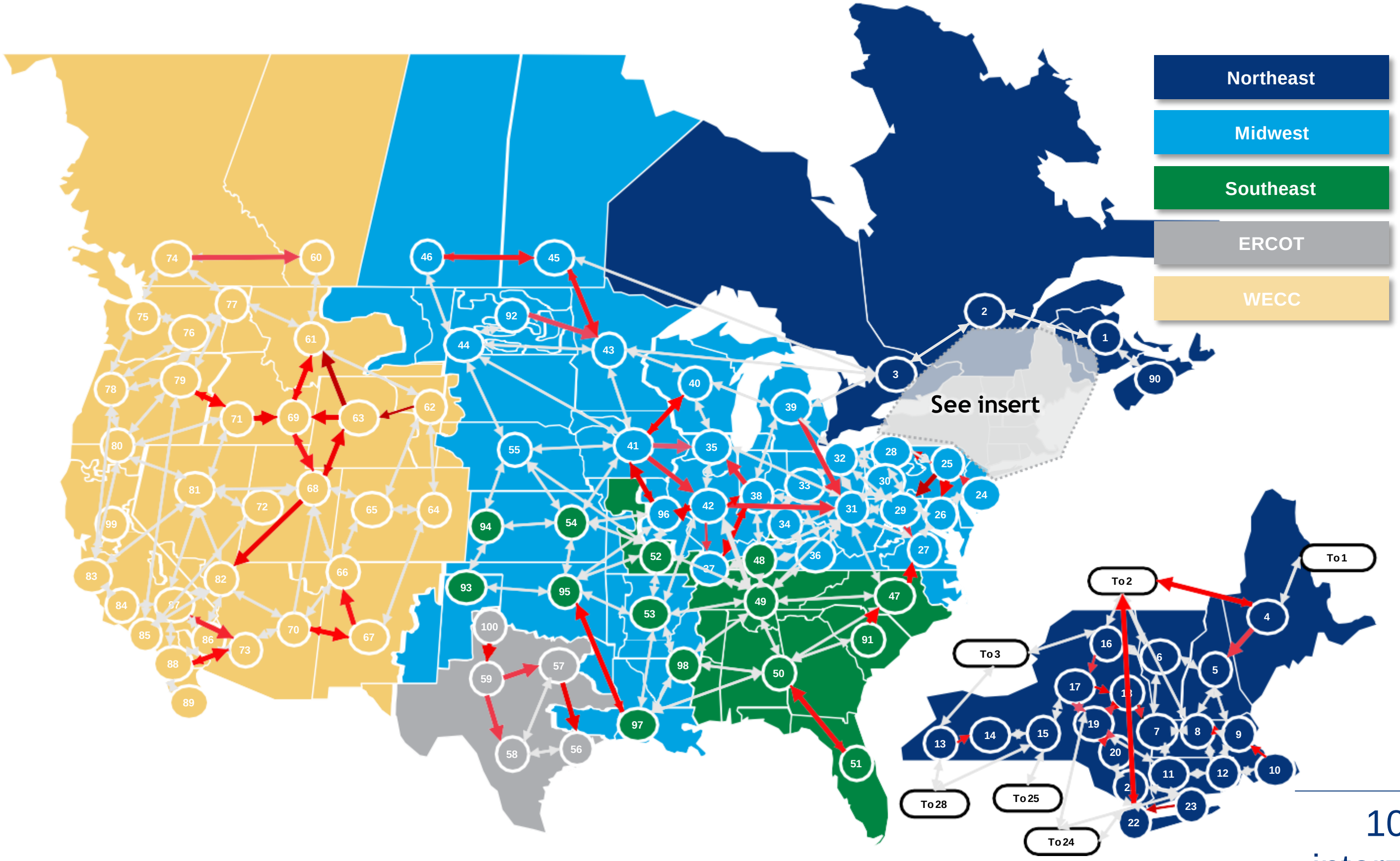


Note: Other renewables include landfill gas, biomass, municipal solid waste and geothermal

Electric transmission infrastructure expansion is key to achieving higher renewable energy goals

Transmission expansion represents over 70 new or upgraded lines, representing over 10,000 miles and $70B in capital

Identified transmission improvements in Scenario 1, including base case



Interzonal transmission Upgrades

10,000+ miles of interzonal transmission

USD $70B cost estimate

Note: Costs include the identified interzonal transmission projects, in addition to transmission upgrades required within zones to accommodate additional capacity

Source: Wood Mackenzie

Example transmission projects

Wyoming renewables

Multiple significant transmission projects in development phases to transport wind and solar energy from Wyoming to market in California

Midwestern wind

Increased connection between 'wind belt' of Chicago and other population centers

Southwestern renewables

Transmission projects to link New Mexico and Arizona renewable energy to demand centers

West Texas renewables

Upgrades to relieve congestion between ERCOT West, North and South

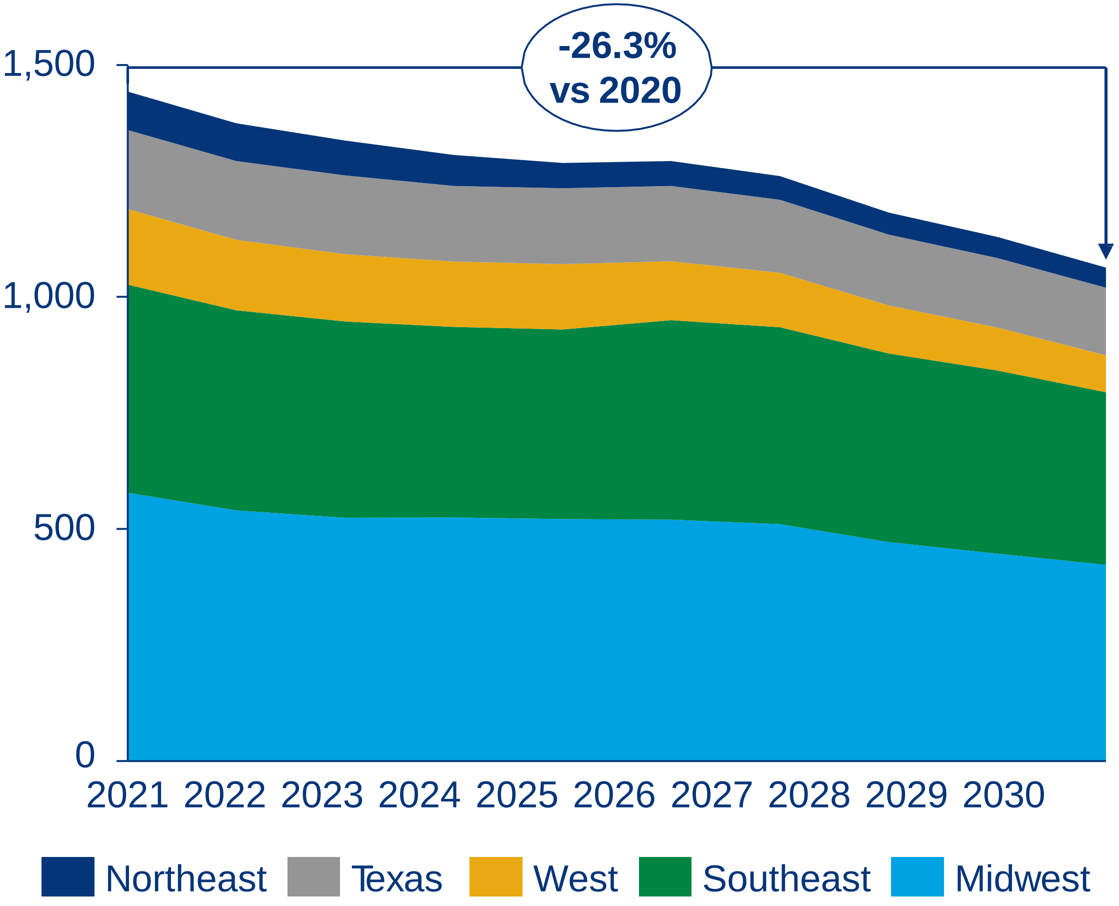
New England Offshore Wind

New lines to distribute massive offshore wind build-out from Northeast cost into western portions of ISO-NE, NYISO and PJM

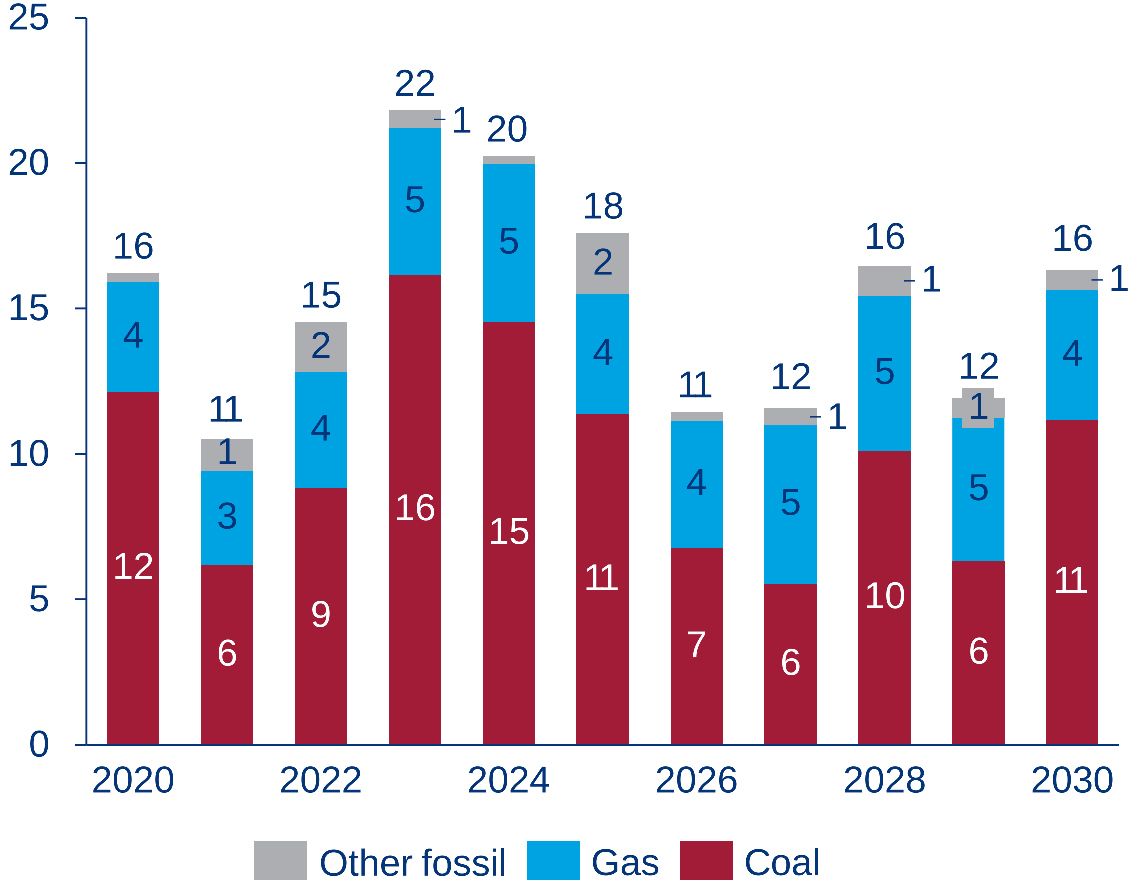
Significant reduction in emissions driven by renewable energy displacing aging fossil plants

25%+ drop in carbon emissions from electricity generation puts the US on track for CPP targets

US carbon emissions from power generation, Scenario 1 - mm metric tons



Fossil fuel plant retirement outlook – GW per year, Scenario 1

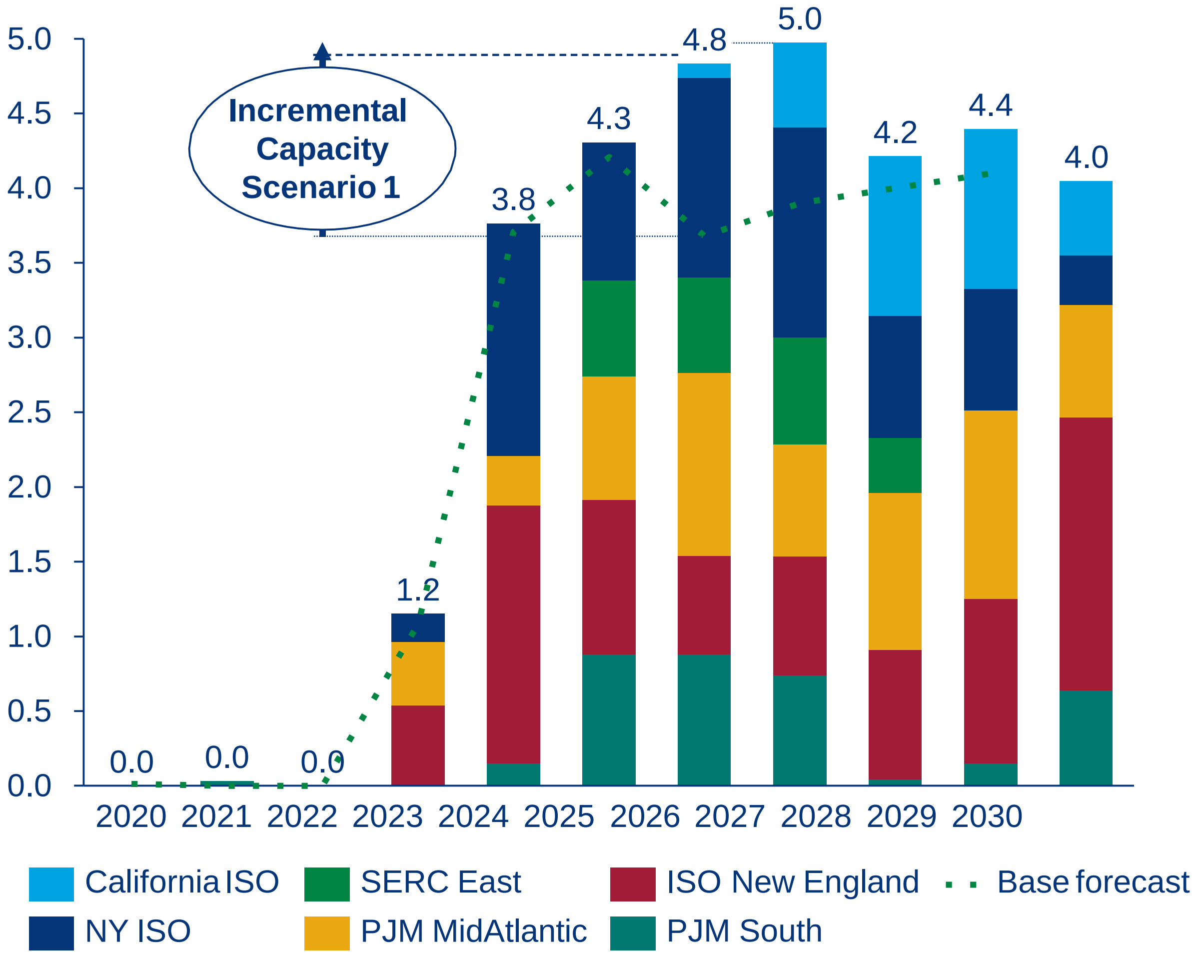


Source: Wood Mackenzie

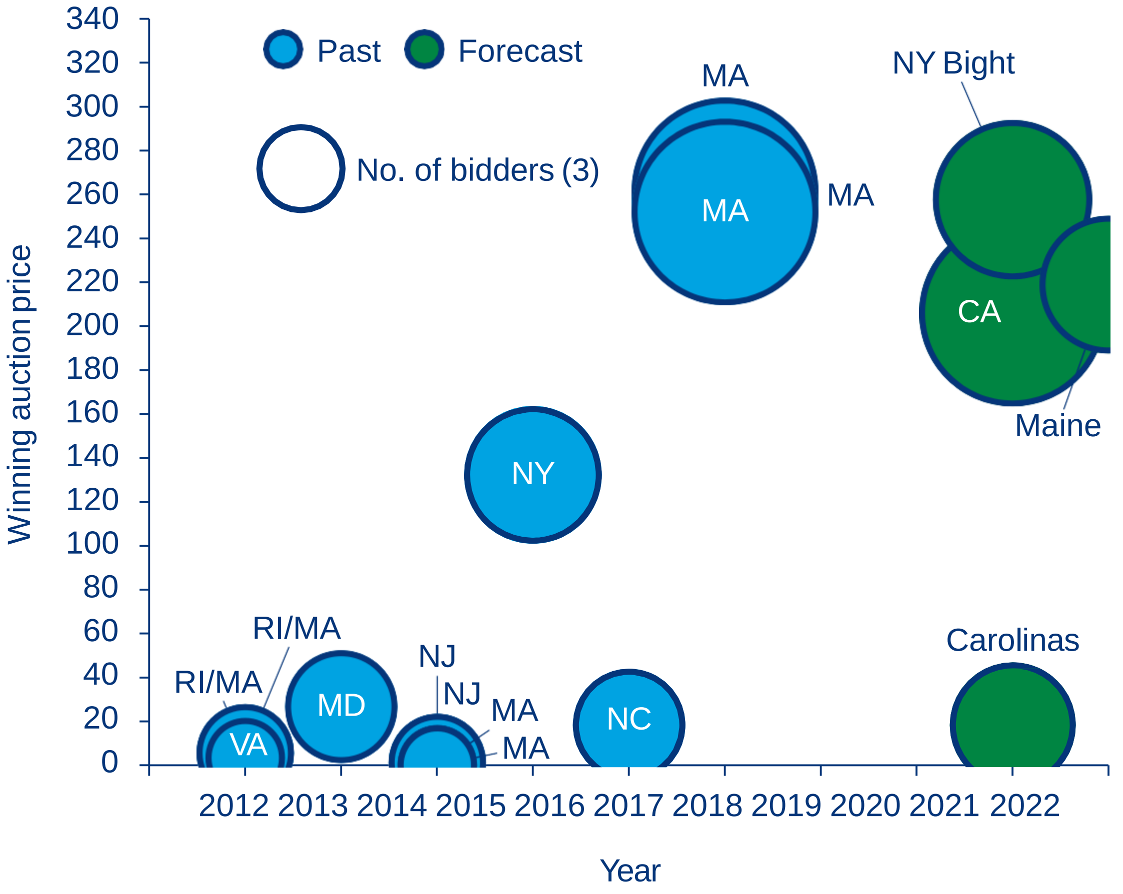
Administrative action through BOEM can open leases and streamline permitting for offshore wind

Additional BOEM leases could deliver up to $2B to the US Treasury, based on recent significant escalation in auction prices

Potential offshore wind expansion, Scenario 1, GW



Historical BOEM auction winning price and future forecast ('000 $/km²)



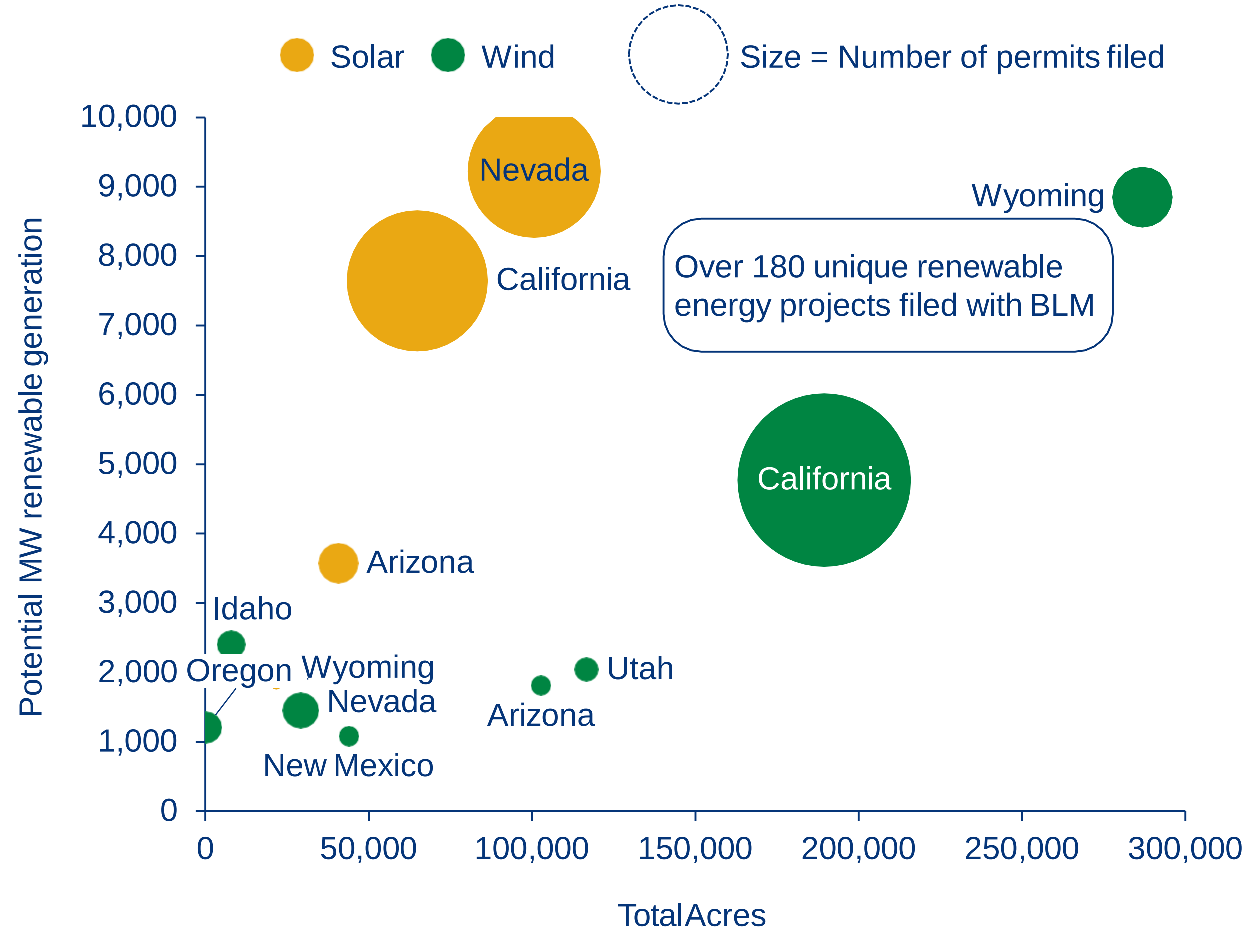
Note: Forecasted BOEM prices estimated based on previous auction prices and state-level policy initiatives

Source: Wood Mackenzie

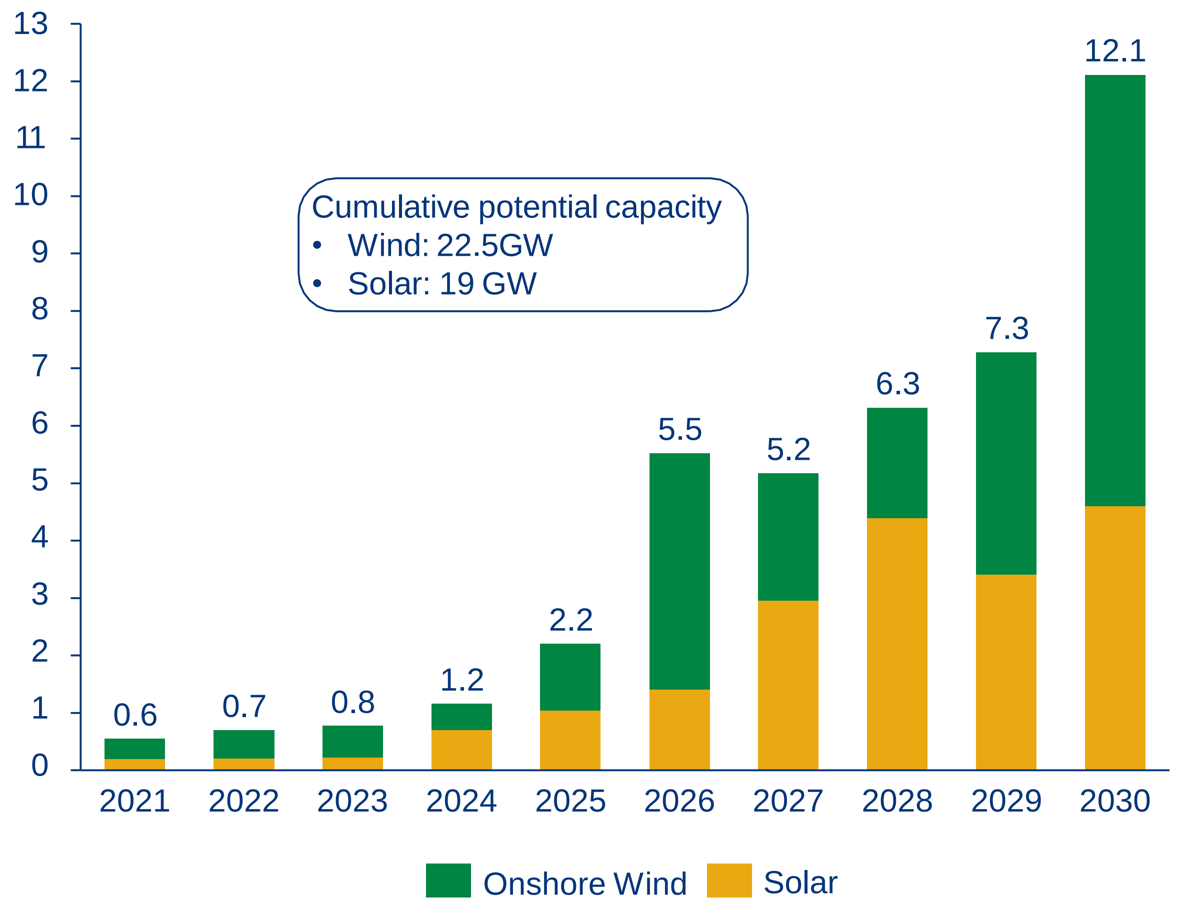
BLM land is prime for renewables, but requires lease mechanism, transmission and streamlined permitting

Access to transmission will also be a pacing item for new development. Environmental permitting may present the biggest hurdle for renewable development on federal land.

Filed permits on Bureau of Land Management land and estimated capacity



Potential BLM capacity additions, Scenario 1, GW



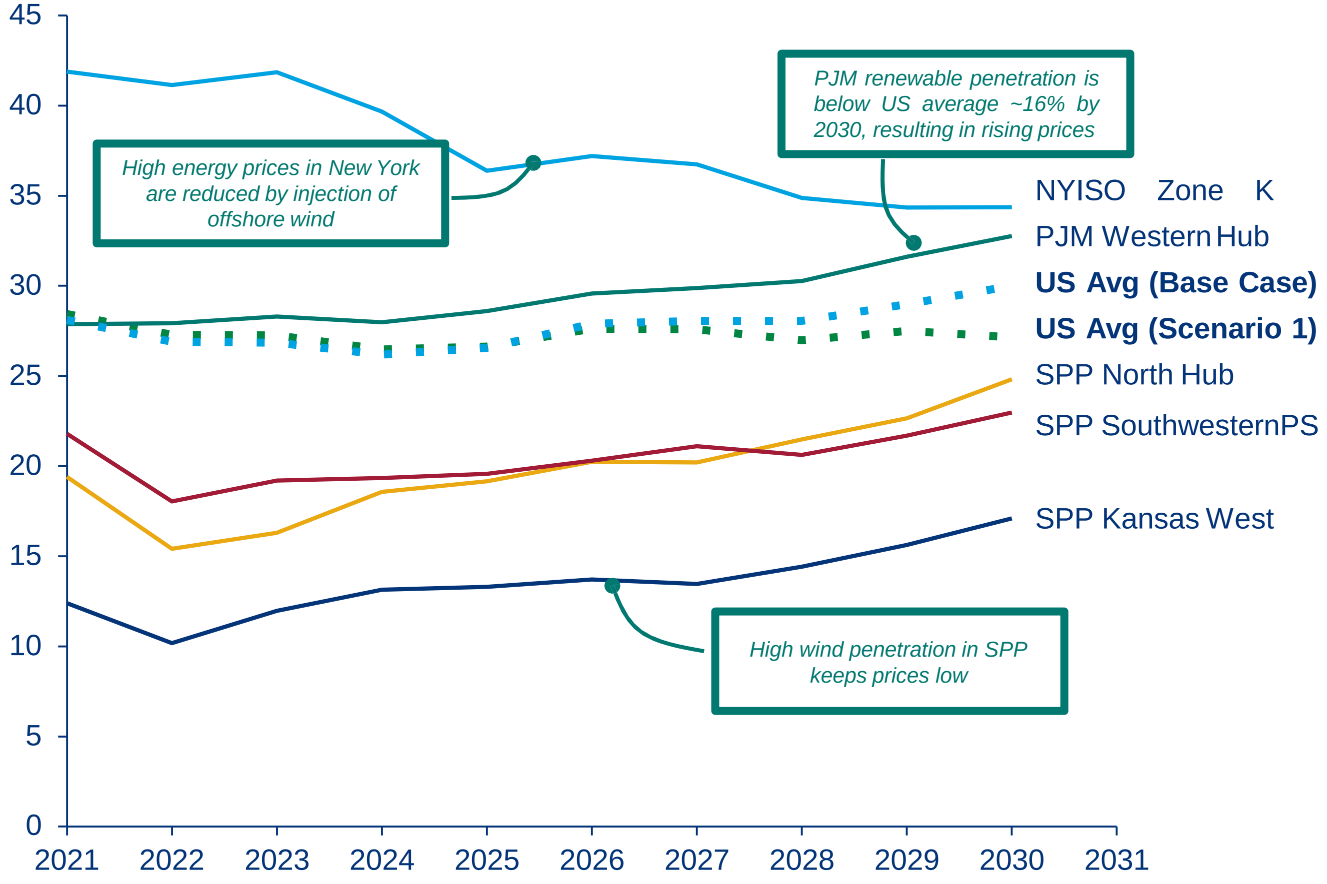
Note: BLM land permits based on filed permits, estimated capacity based on stated capacity, acreage and regional impacts

Source: Wood Mackenzie

Power price trends: Wholesale power prices stabilize due to renewable energy injection

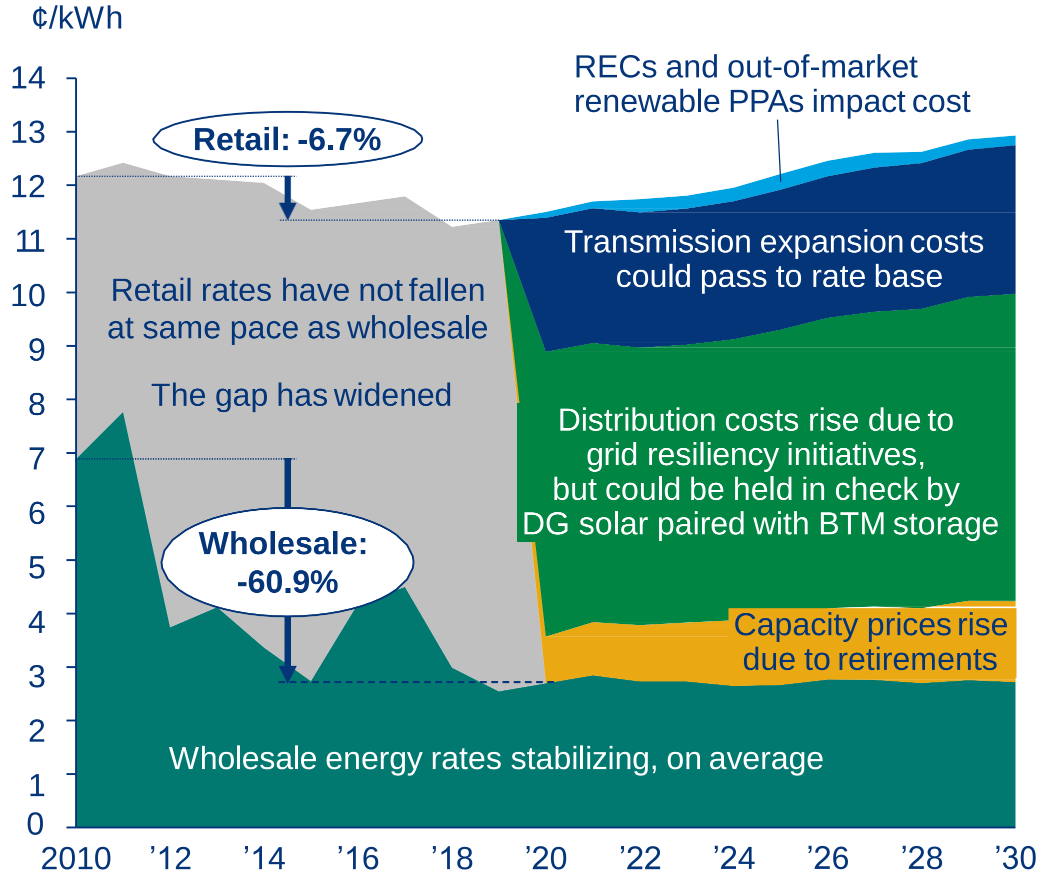
Retail rates exposed to utility recovery of added costs of transmission, distribution, retirements and capacity prices. Federal programs to absorb or fund these additional investments can help to mitigate impact to retail customers

Annual average power prices – wholesale hub price (real 2020 $/MWh)



Note: Annual average energy-only pricing at wholesale power hubs
Annual averages do not reflect seasonal or daily price volatility due to higher renewable penetration
Source: Wood Mackenzie , LBNL

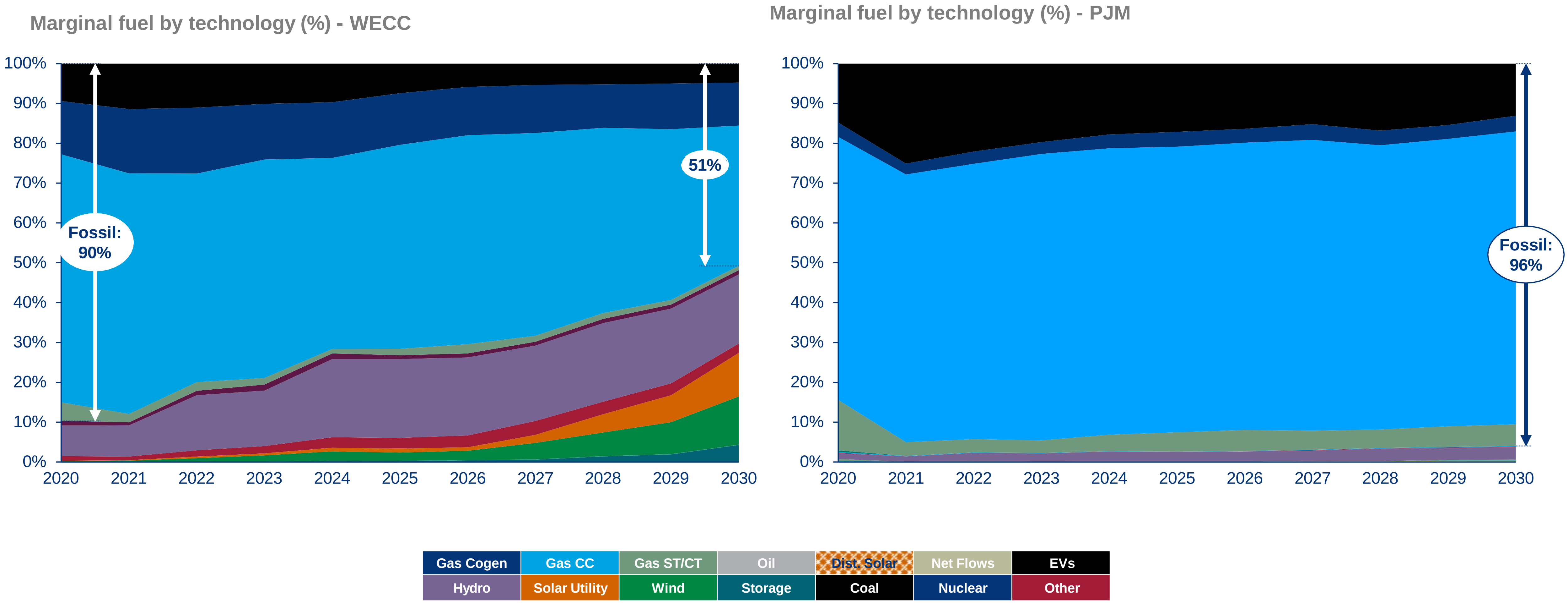
Expected impact on retail prices, real 2020 ¢/kWh, US average



Note: Historic data from Lawrence Berkley National Labs
Future retail forecast is illustrative only
Retail rates and price setting can vary substantially by market
Source: Wood Mackenzie , LBNL

Fossil fuels remain on the margin and will ultimately drive power price trends

Some markets will transition to pricing driven by zero-marginal cost renewables, but gas still plays a prominent role

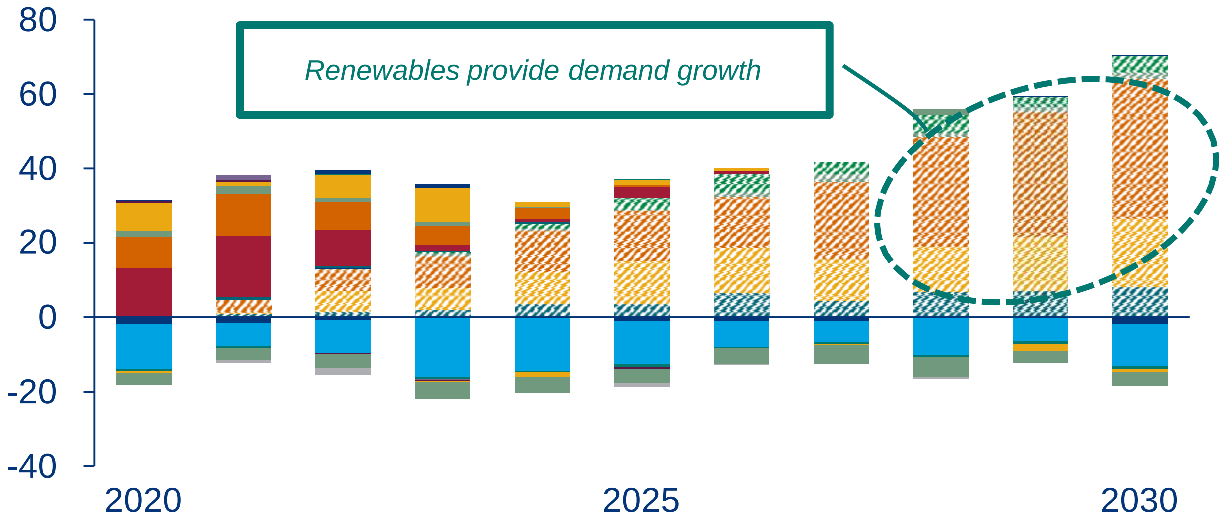


Source: Wood Mackenzie

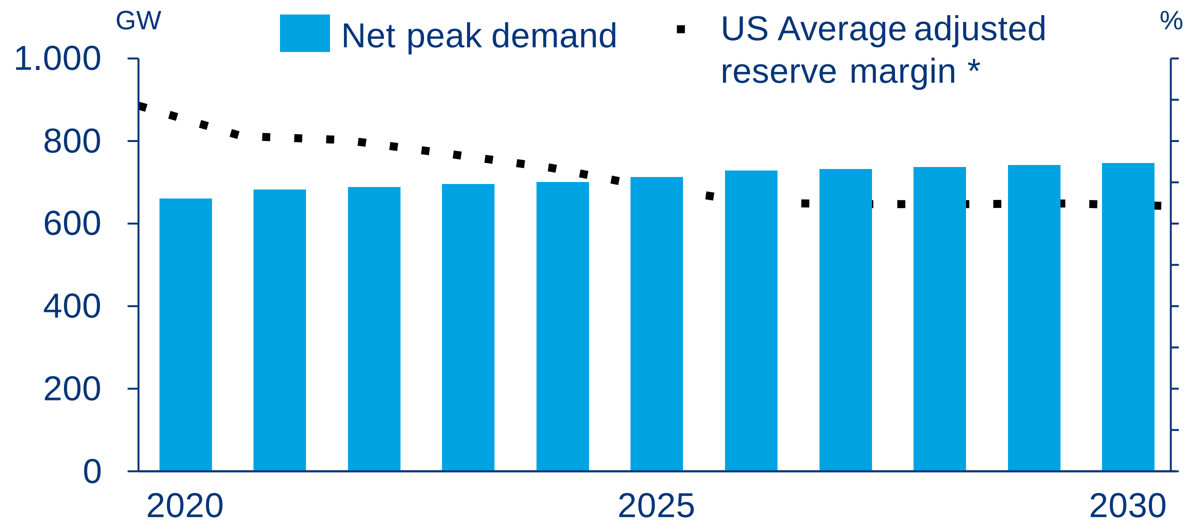
Reserve margin becomes tighter with future coal and nuclear retirements as net peak demand grows

Renewable additions maintain reserve margin to consistently be above system planning reserve margin

Installed capacity changes (GW)** – Scenario 1



Peak Demand (GW) *left axis*, **Reserve Margin** (%) *right axis - Scenario 1*



- Storage, solar and wind additions form majority of new future additions

- Reserve margin gets tighter even though there are substantial renewable additions owing to decreasing effective load carrying capability (ELCC) for solar

*Adjusted Reserve margin = (Reliable Capacity + Supply Side Adjustments)/(Net Peak Demand + Demand Side Adjustments) – 1

** Only includes firm and generic retirements and additions

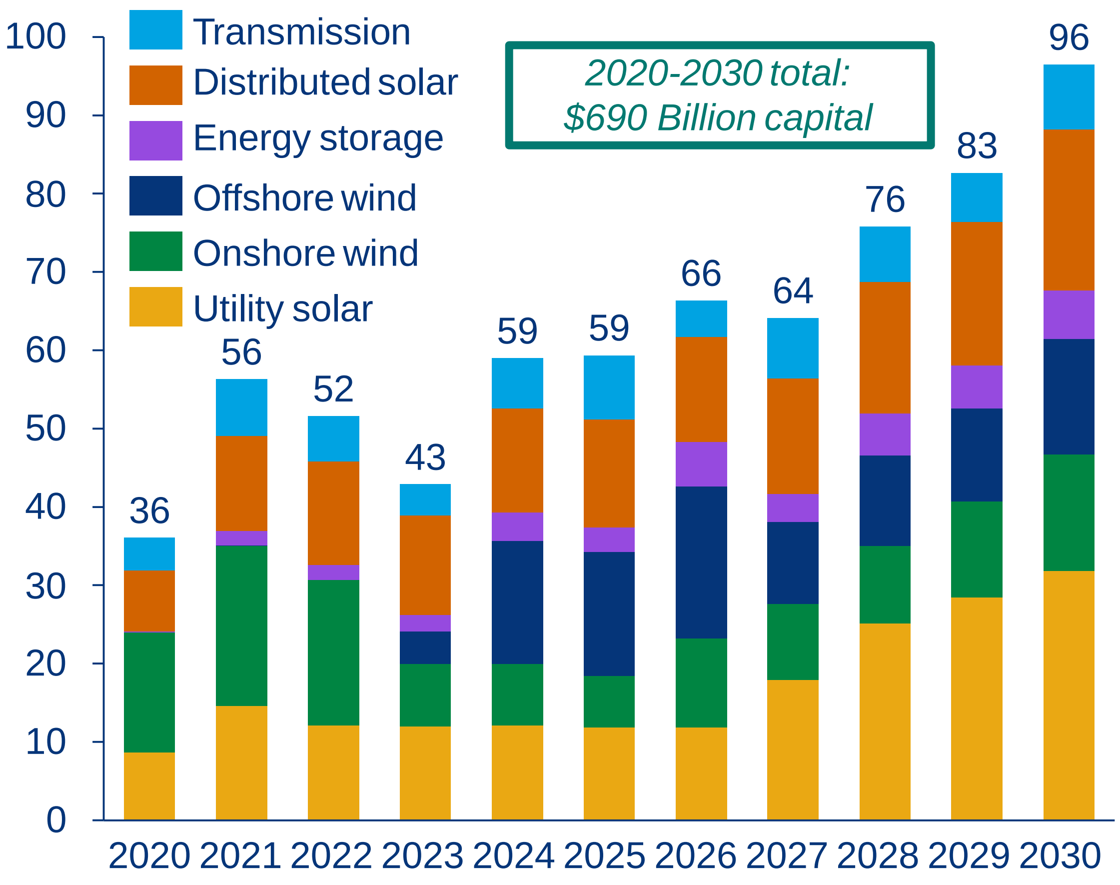
Souce: Wood Mackenzie

Scenario 1 economic development opportunity

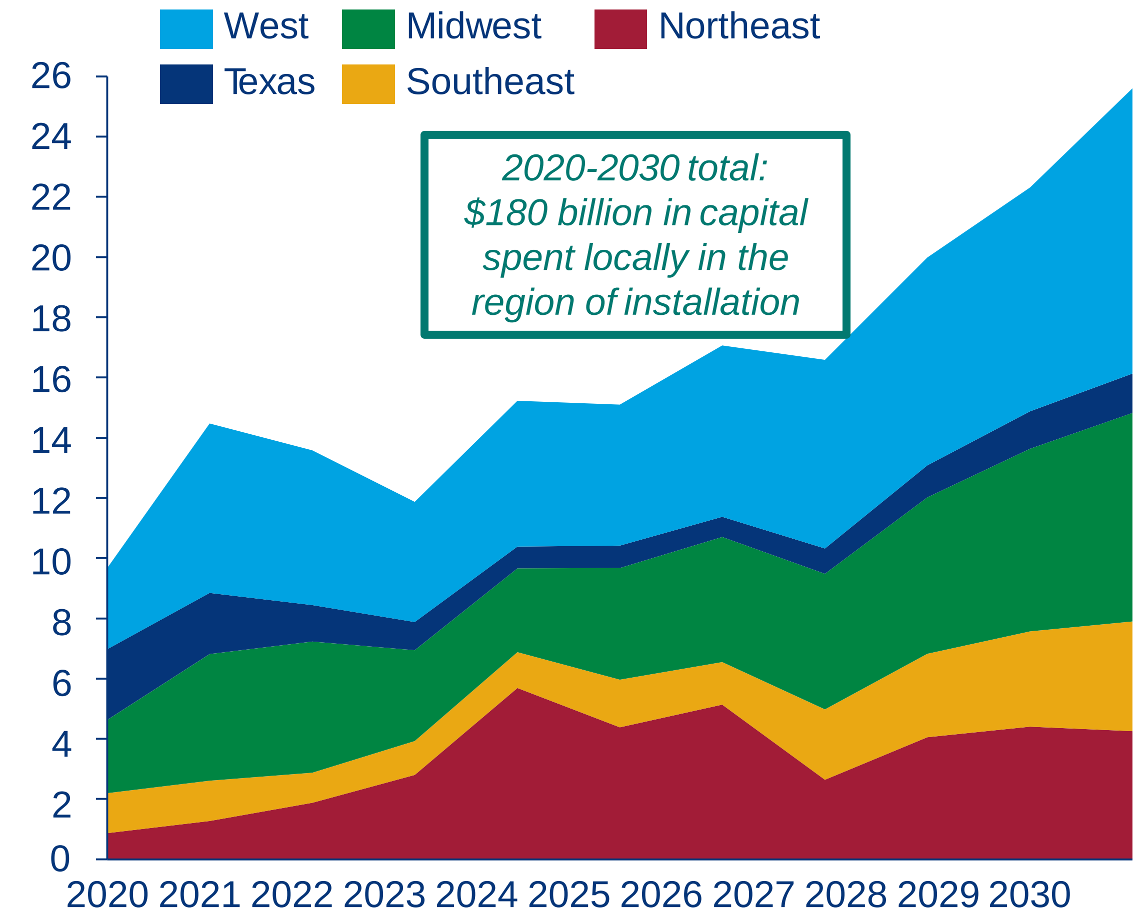
Total capital investment within the US from renewable energy and transmission expansion

Renewable build-out will deploy $690 billion in capital over 10 years, with ~25% spent local to the installation region
Additional impacts to local economies include tens of billions in local tax payments and land lease payments

Total capital investment, USD Billions – Scenario 1



Estimated local region capital investment – Scenario 1



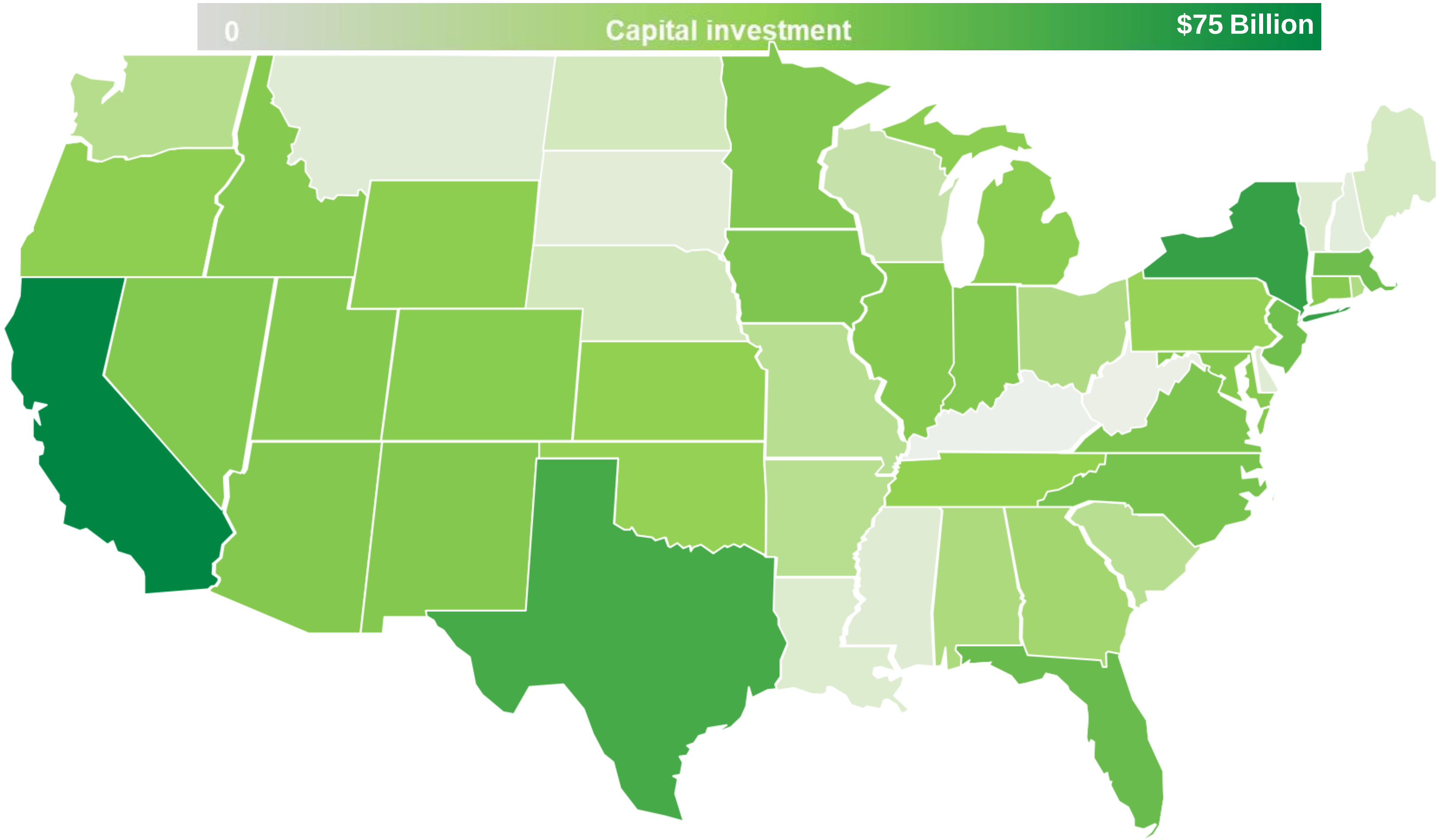
Note: Capital includes construction of power plants and transmission, but does not include induced affects or other benefits to local economies

Source: Wood Mackenzie, NREL JEDI tools

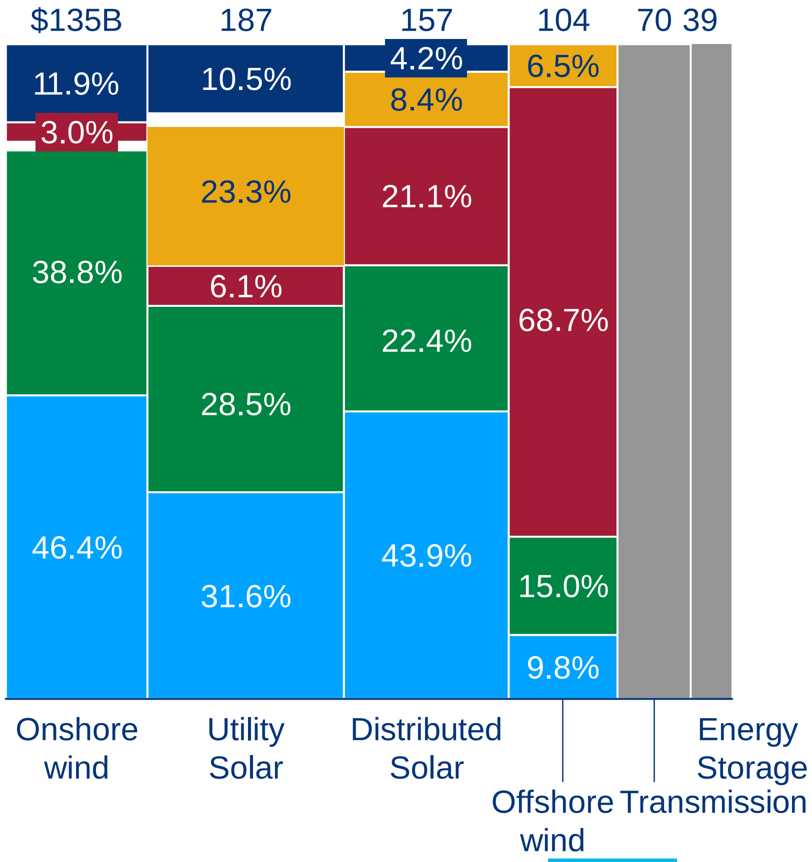
Total capital investment across all wind and solar distributed across the country

States with renewable energy targets lead investment, while regions with abundant renewable resources see growth

Total investment wind and solar – Cumulative capital investment, 2020-2030, Scenario 1



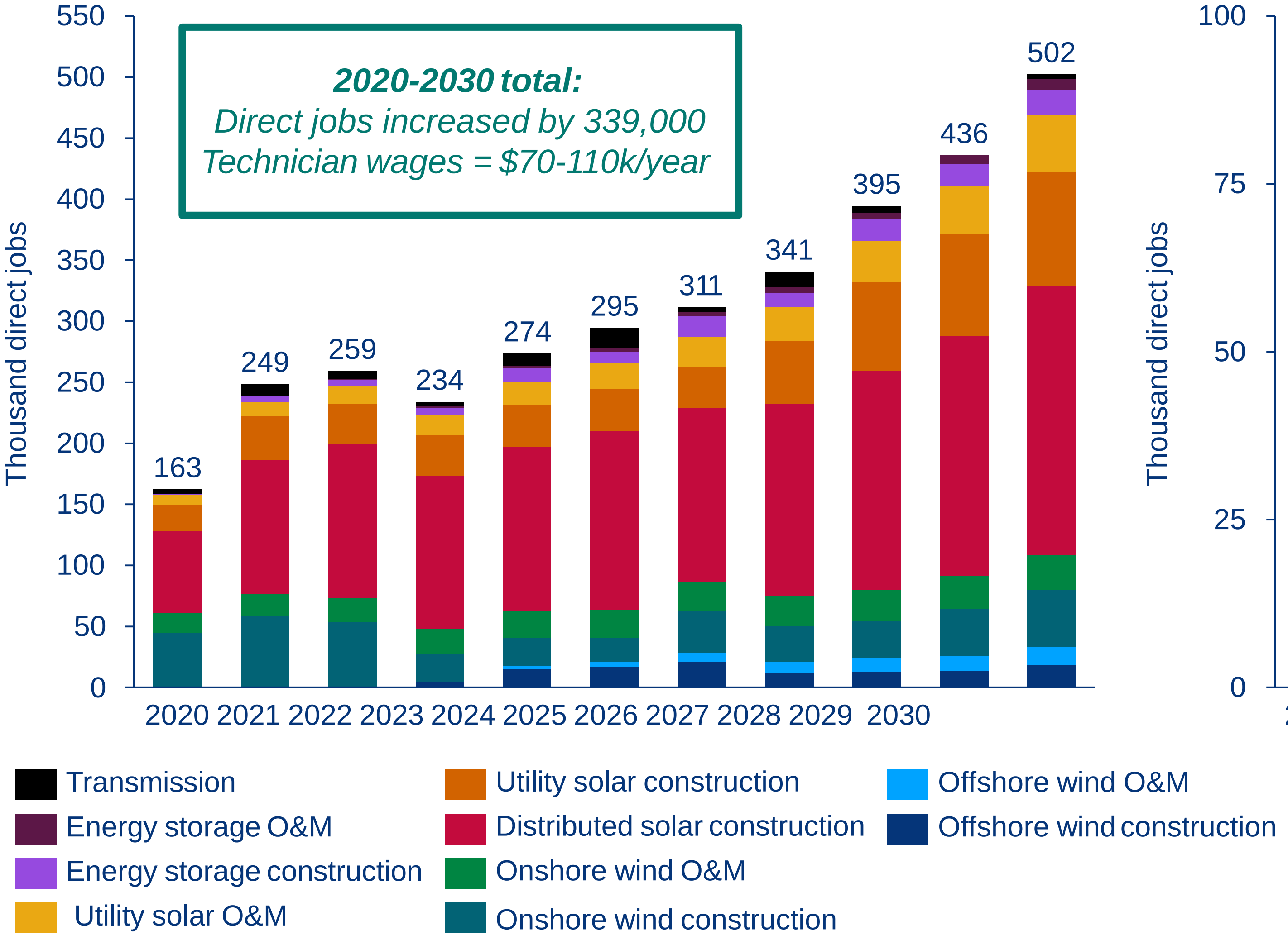
Capital investment, by region and technology



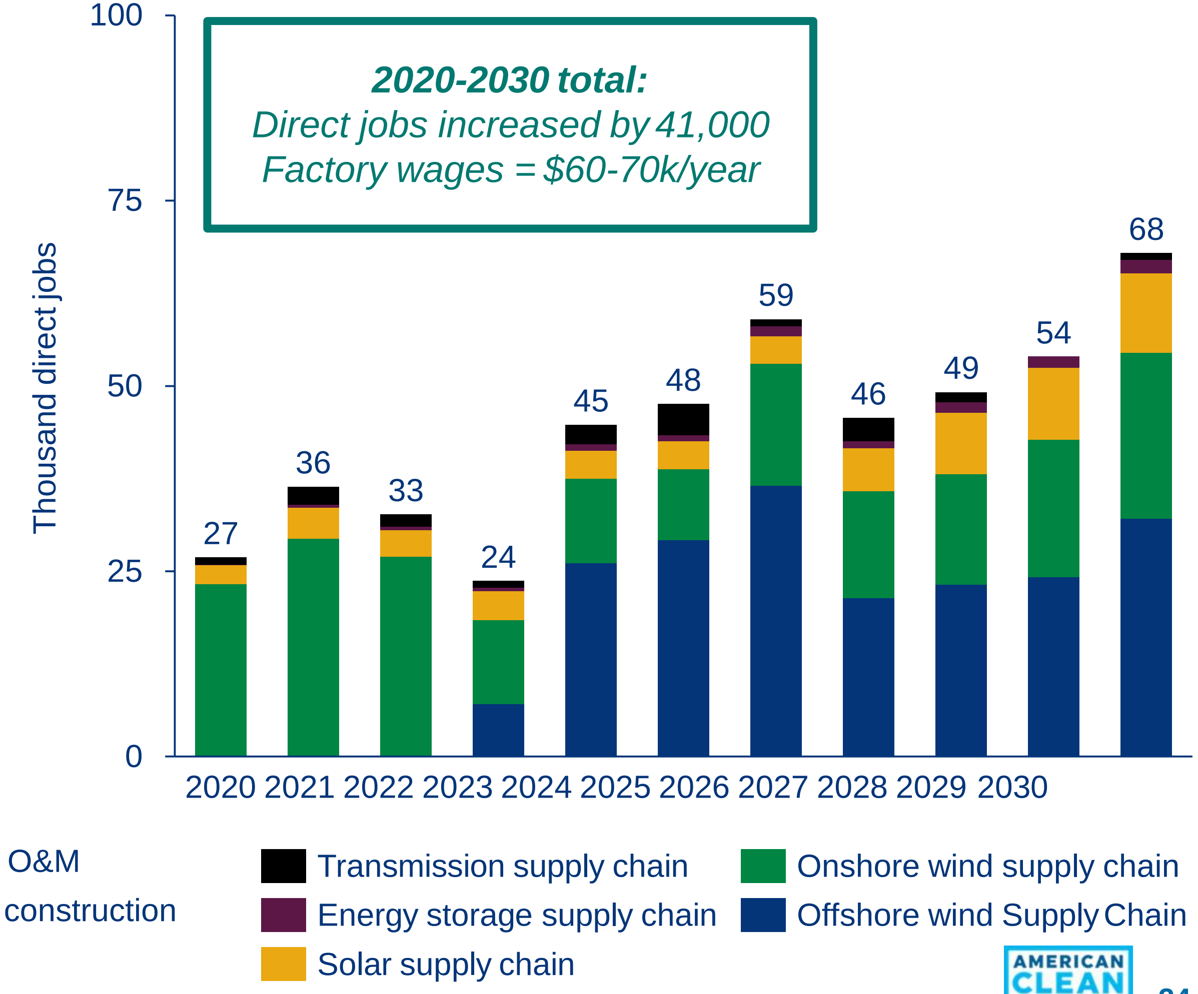
Nationwide direct jobs impact from renewable energy increases – Scenario 1

Renewable growth has potential for hundreds of thousands of new direct jobs related to construction, O&M and supply chain
Indirect jobs not quantified include induced jobs within local economies

Construction / technicians – Annual direct jobs, construction and O&M – Sc1



Supply chain – Annual direct jobs in factories, distribution and development, Sc1

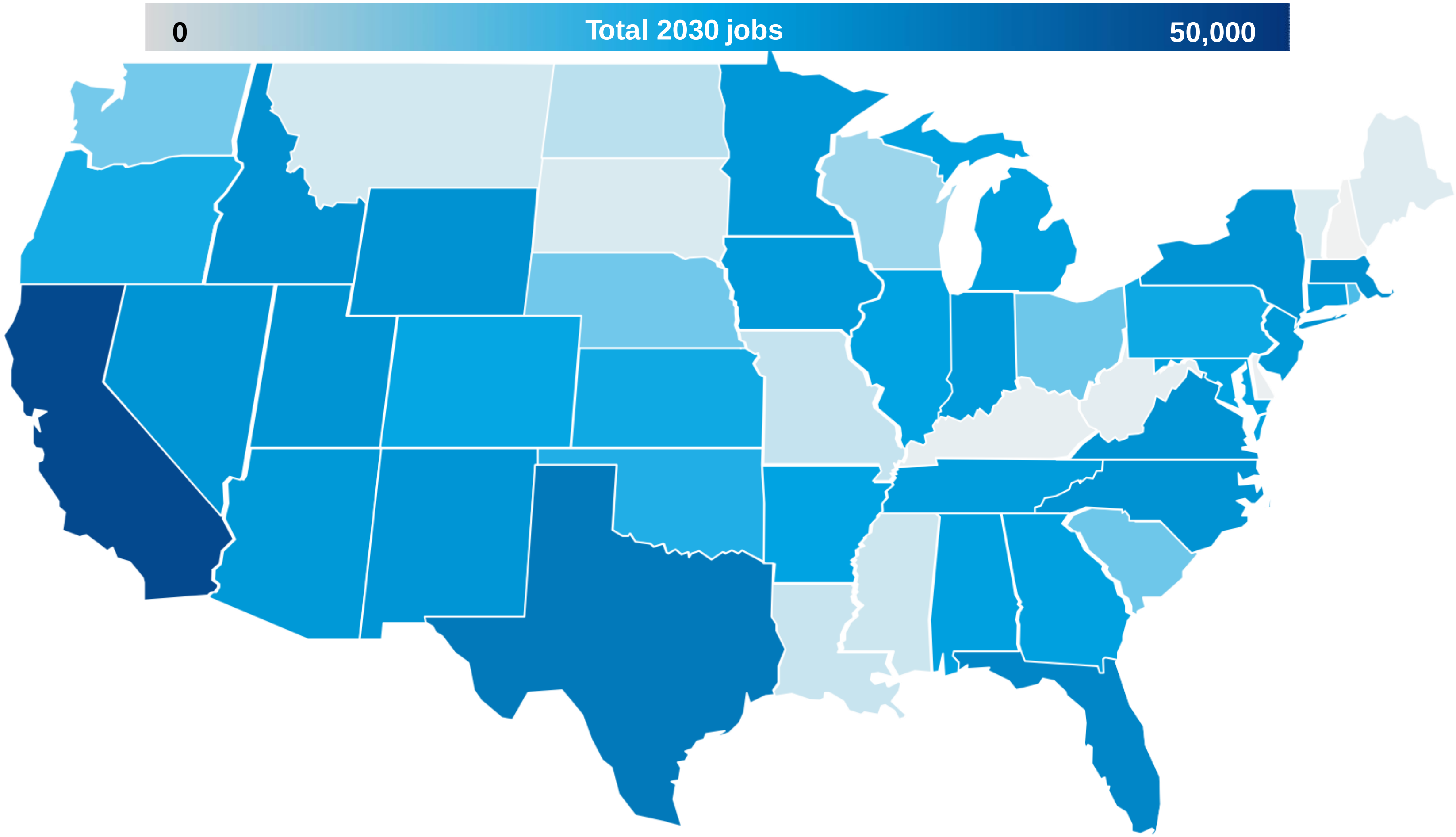


Source: Wood Mackenzie, NREL JEDI tools

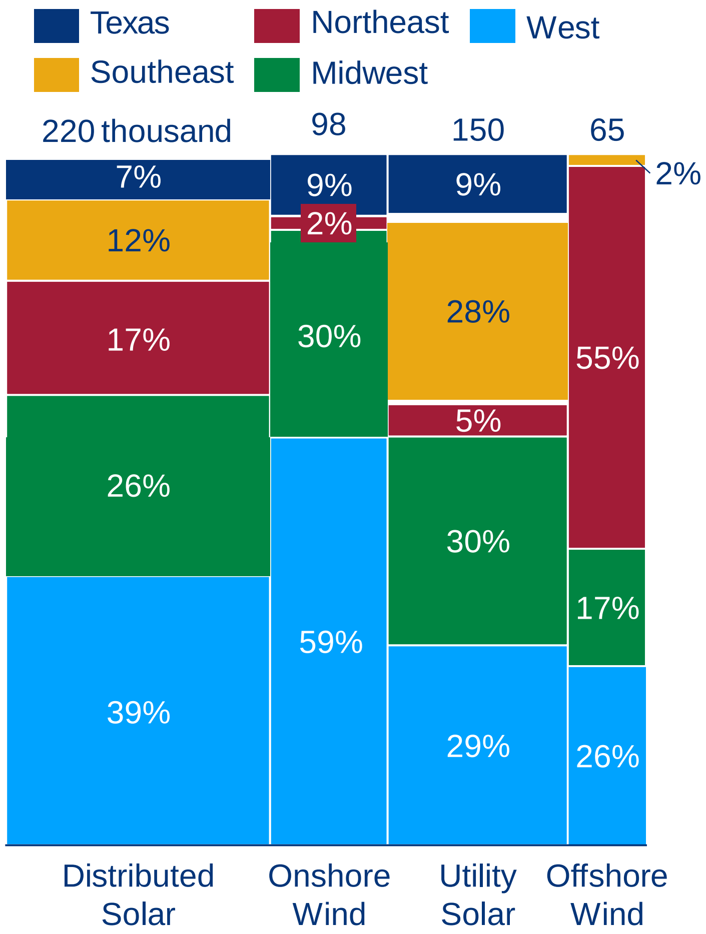
Total job growth is highly focused locally to installation centers

Distributed solar presents the highest potential for job growth in Scenario 1, due to widespread adoption

2030 direct jobs, wind and solar – Direct job creation, 2030 annual, Scenario 1



Total direct jobs, 2030, region and technology



Source: Wood Mackenzie

3. Scenario 2 – Nationwide 50% Renewable Energy Target

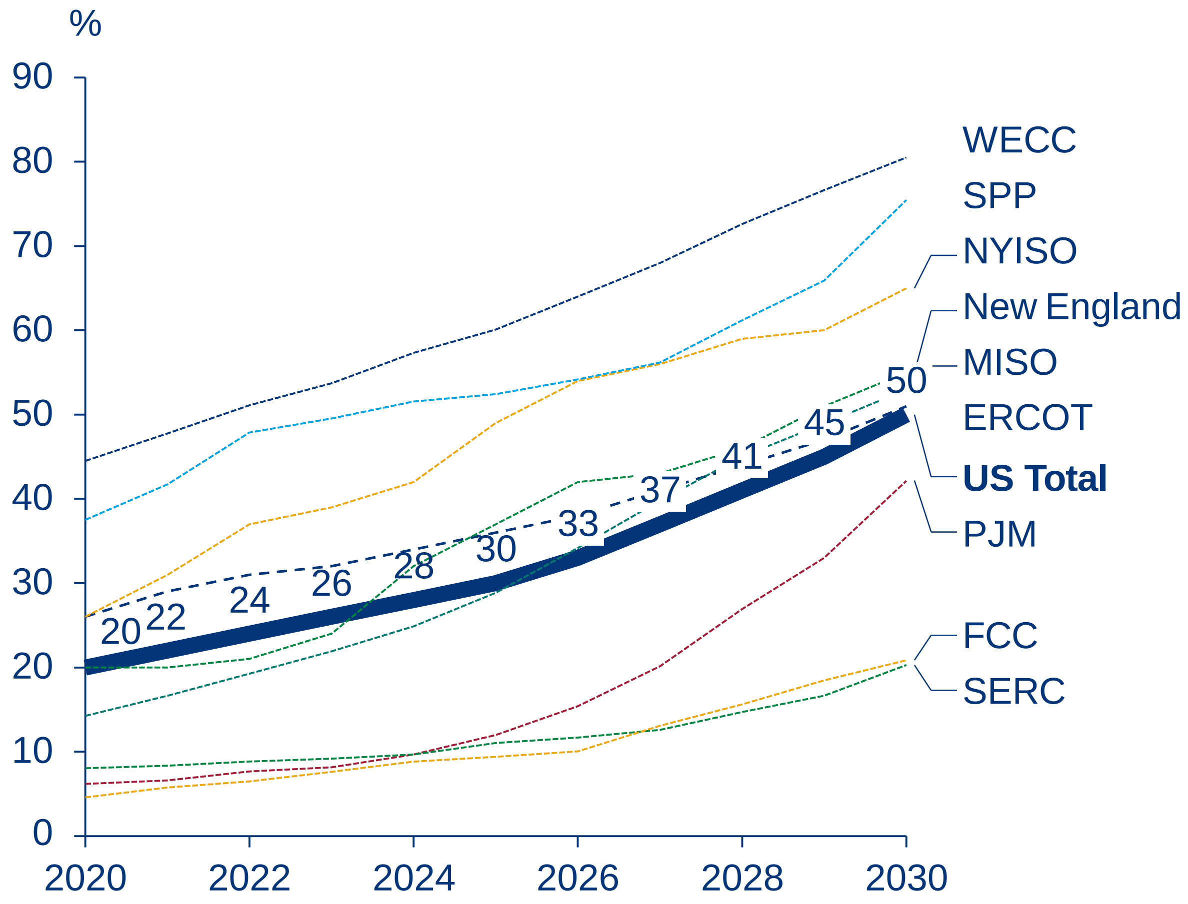
Setting a nationwide 50% renewable energy goal presents many challenges and opportunities

Scenario 1 (administrative action and transmission expansion) is incorporated in Scenario 2

50% renewable goal is attainable with additional policy anchored on strong administrative action

Imposing a 50% nationwide renewable target will have diverse regional affects and will require policy that favors renewables

Renewable energy penetration, by region – Scenario 2, %



Note: Renewable energy includes wind, solar, hydro, landfill gas, geothermal, biomass, municipal solid waste and pumped storage

Reaching 50% renewable energy requires widespread fossil retirements

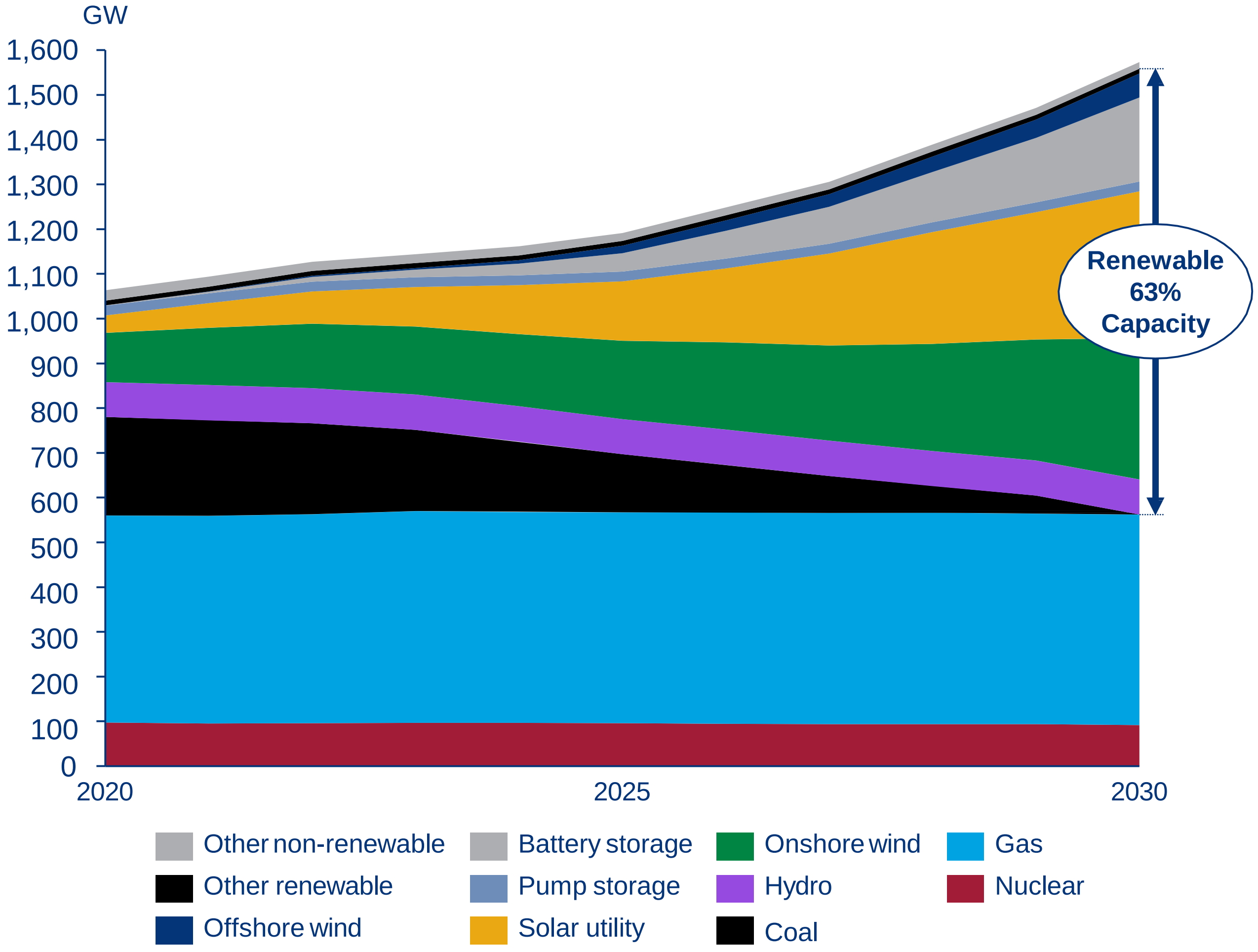
- Nearly all coal plants must be retired nationwide by 2030 to reach 50% target
- New gas plants are delayed, other than advanced-stage projects
- Federal policy initiatives to accelerate retirements and eliminate new gas construction are needed to reach 50% nationwide renewable energy
- Significant expansion of renewable capacity will require policies that streamline permitting, development and provide favorable economics to renewable assets

- **PJM** (Mid-Atlantic) – will require over 50GW of coal retirements
  - Fossil fuels replaced with over 120GW of wind and solar
  - Over 60GW of energy storage capacity required to maintain reliability
- **MISO** (Midwest) – Nearly 60GW of coal plants retirements required
  - Renewable energy capacity additions of over 100GW, 30GW of storage
- **WECC (West)** – Western region renewable penetration to grow to nearly 80%
  - Nation's highest levels of renewable penetration only expected to grow with fossil retirements and additional renewable additions
- **Southeast** – FERC (Florida) and Southeast (SERC) remain at the bottom of renewable energy penetration, despite over 70GW of solar capacity addition
  - Over 50GW of coal is retired, but significant amount of nuclear remains

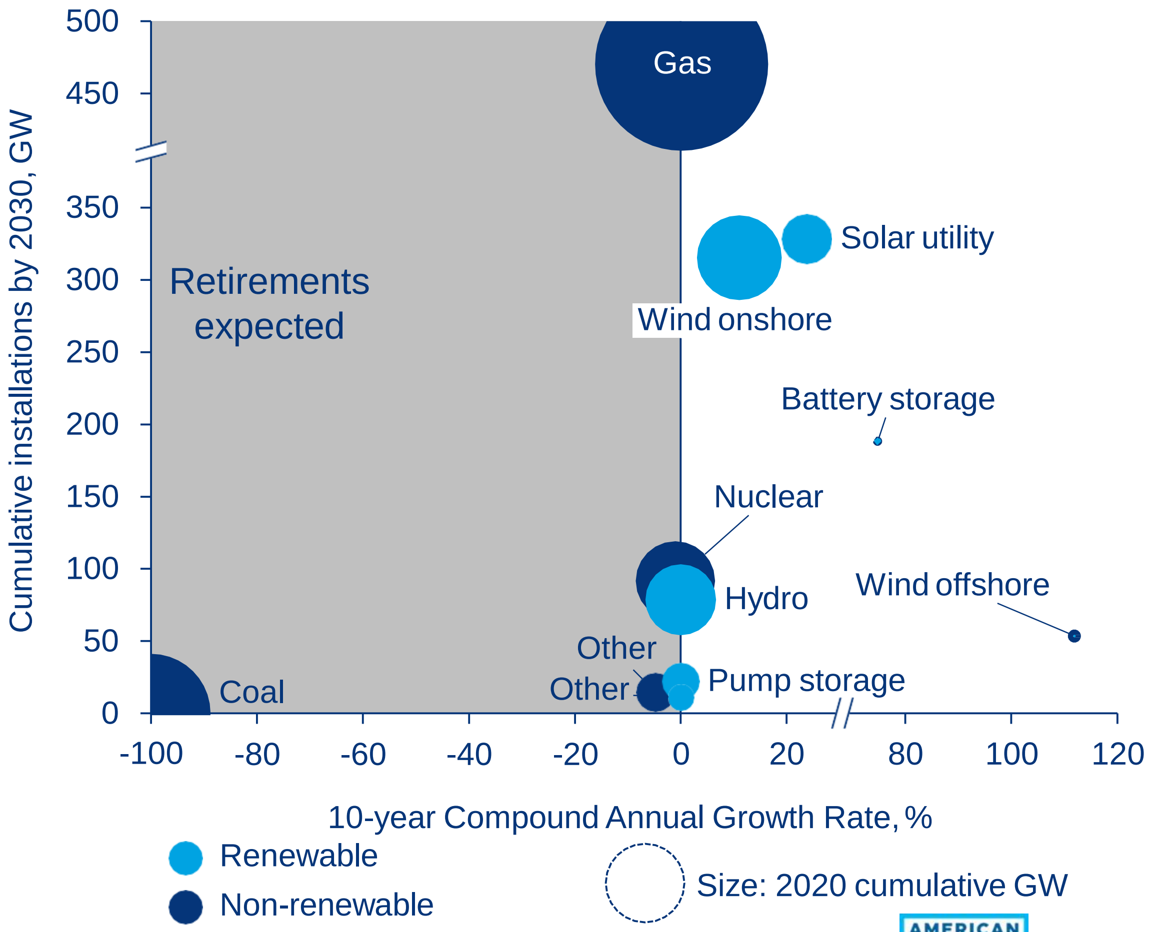
Widespread coal retirements and slowed gas additions are necessary to reach 50% renewables target

Phase-out of coal is critical to reaching majority renewables, in addition to significant growth in battery storage for reliability

Total cumulative capacity by technology, Scenario 2, GW



Growth rates of technologies – 2020-30, Scenario 2

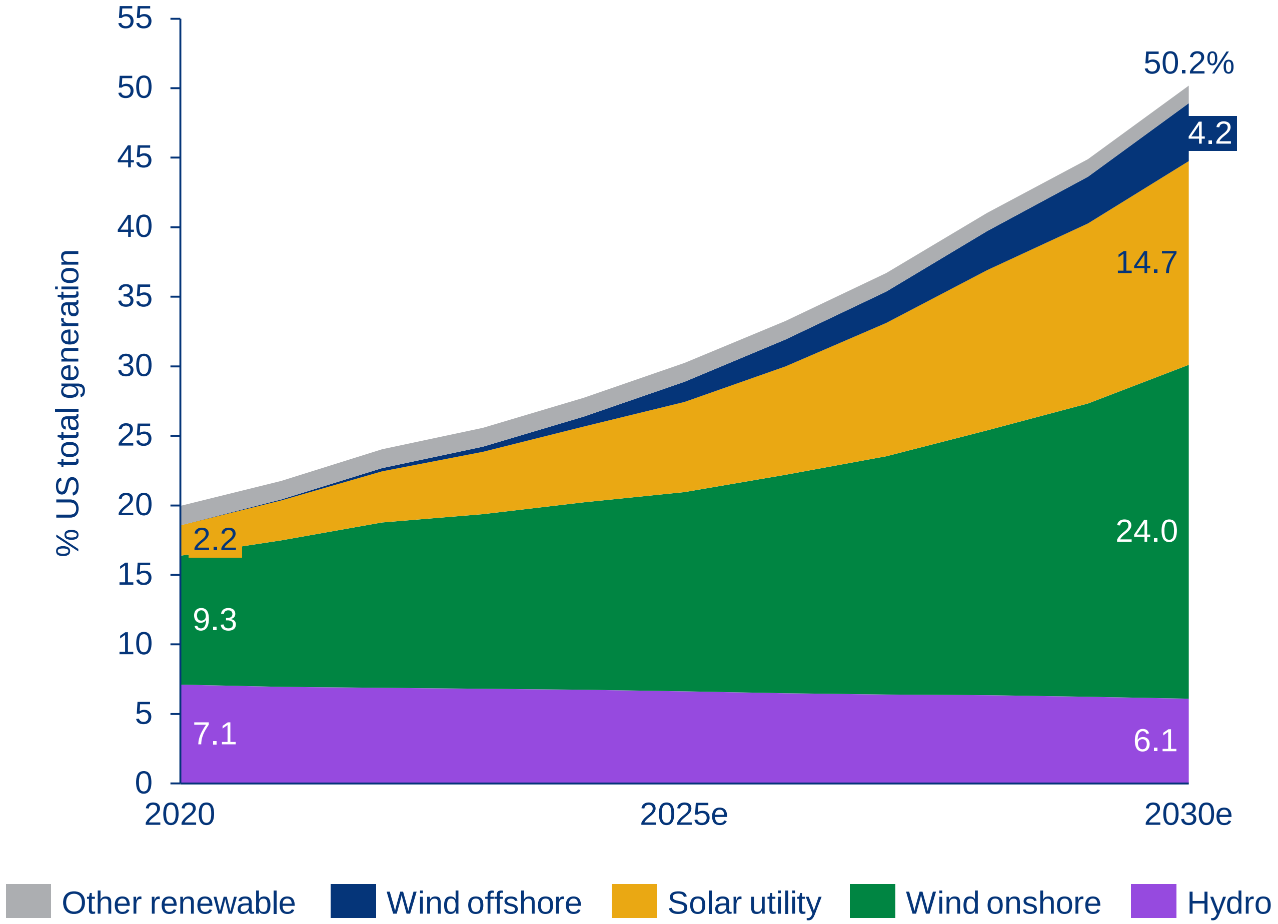


Source: Wood Mackenzie

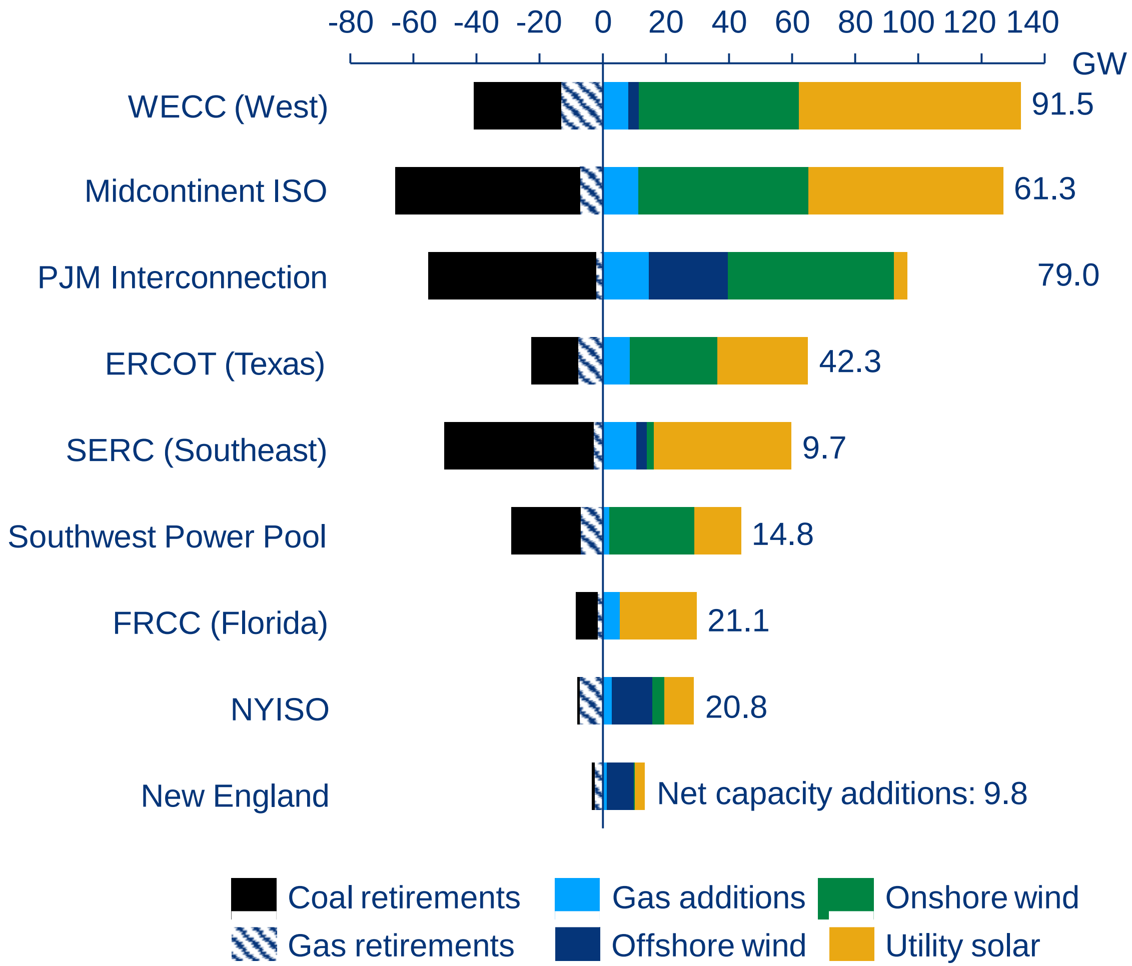
Renewable energy contributions driven by expansion of onshore wind, solar and offshore wind

Significant expected coal retirements in PJM and MISO are expected to be largely replaced by wind and solar

Renewable penetration by technology – Scenario 2



Distribution of installations and retirements, Scenario 2, GW (2020-2030)



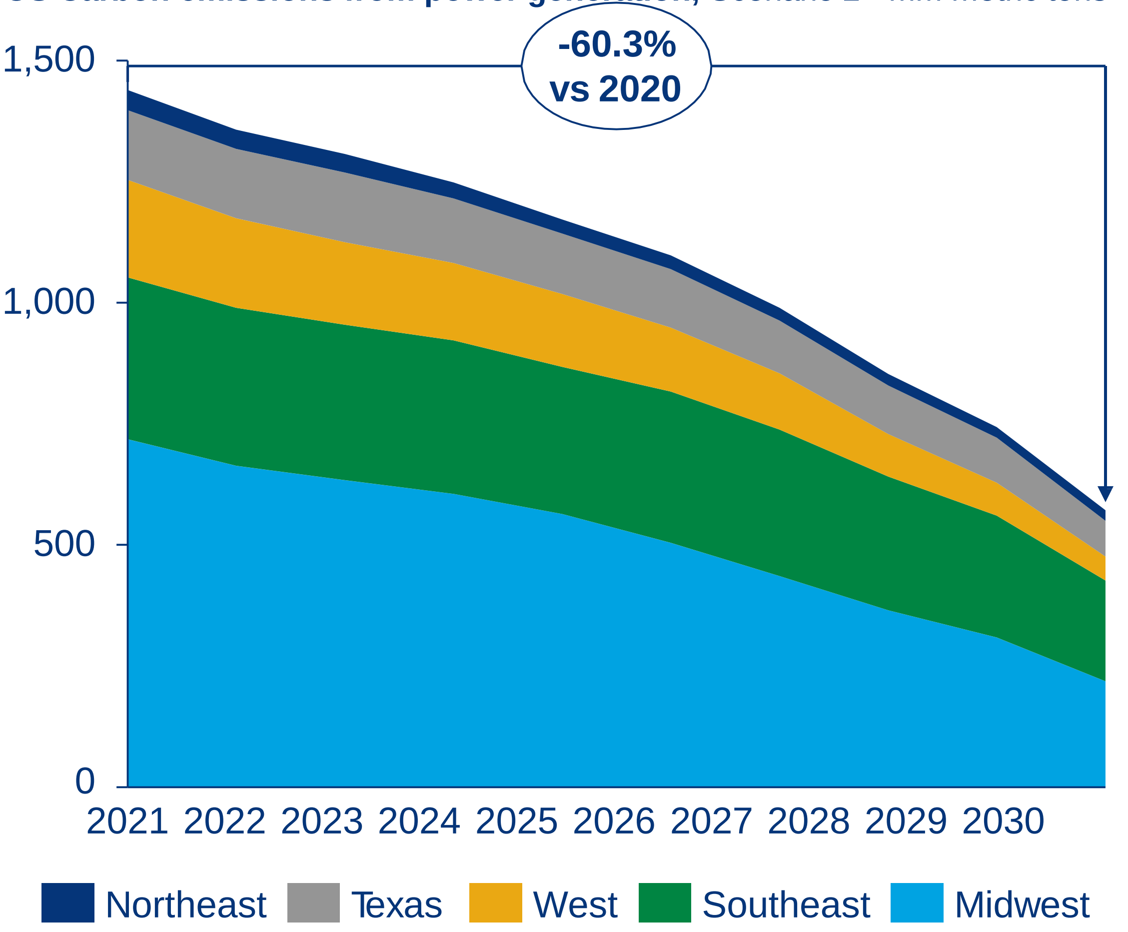
Note: Other renewables include landfill gas, biomass, municipal solid waste and geothermal

Source: Wood Mackenzie

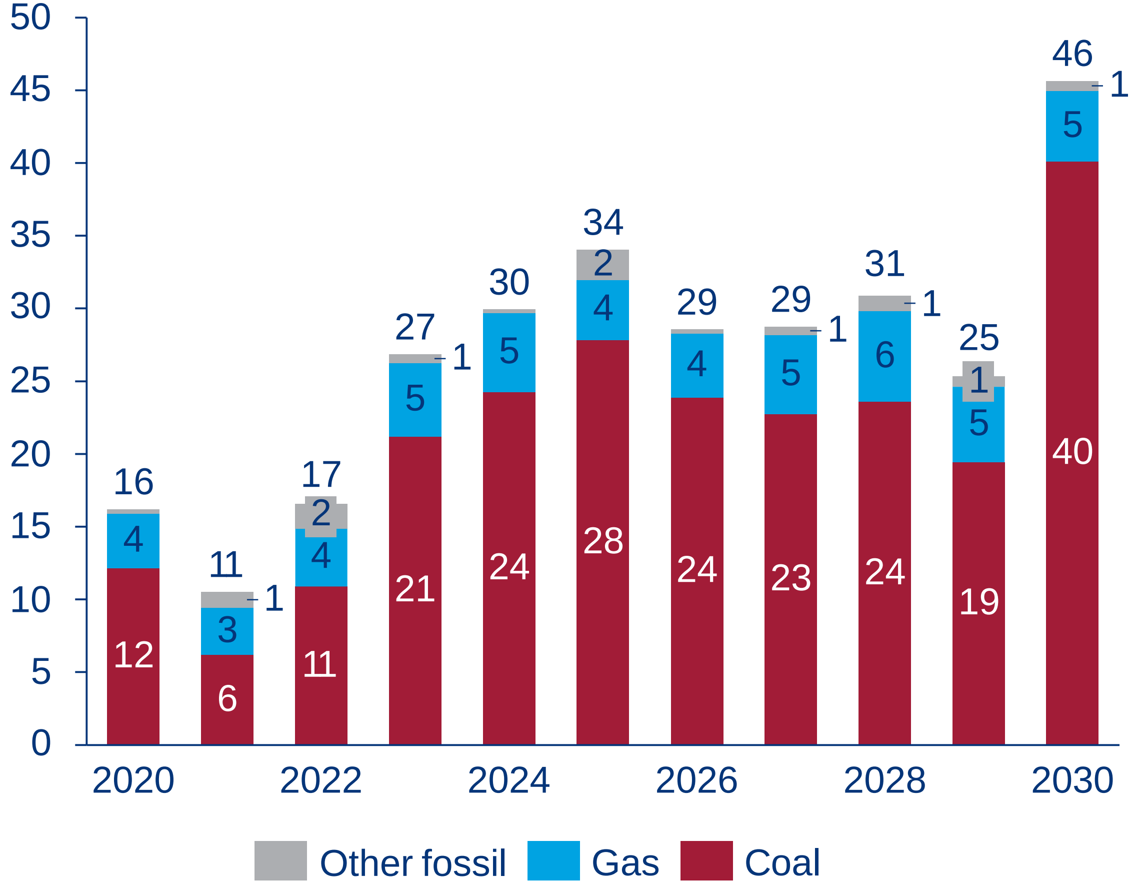
Significant reduction in emissions driven by renewable energy displacing aging fossil plants

Over 60%+ drop in carbon emissions is due to widespread coal retirements and renewable energy build

US Carbon emissions from power generation, Scenario 2 - mm metric tons



Fossil fuel plant retirement outlook – GW per year, Scenario 2

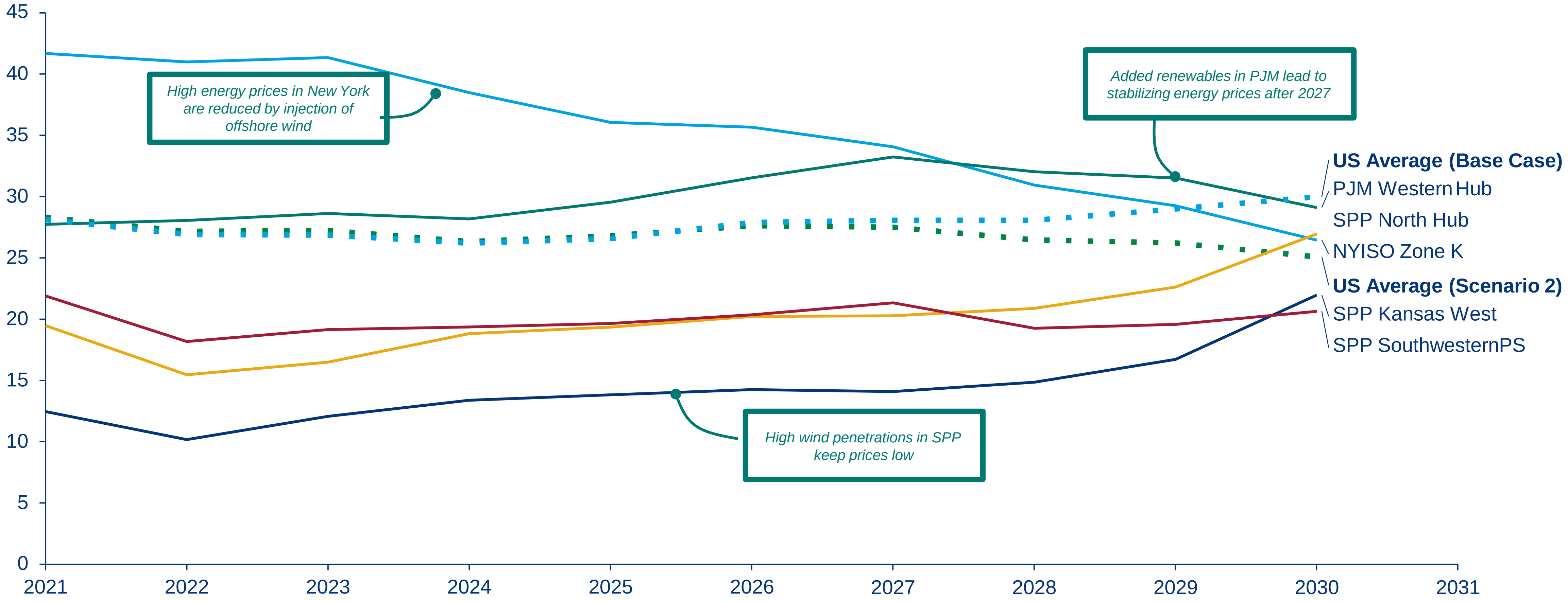


Source: Wood Mackenzie

Power price trends: Average wholesale power prices stabilize due to renewable energy injection

Wholesale prices are lower on average due to higher penetration of low-cost renewable sources, but volatility in daily and seasonal prices will likely rise due to increased supply of variable generation

Annual average power prices – wholesale hub price (real 2020 $/MWh)

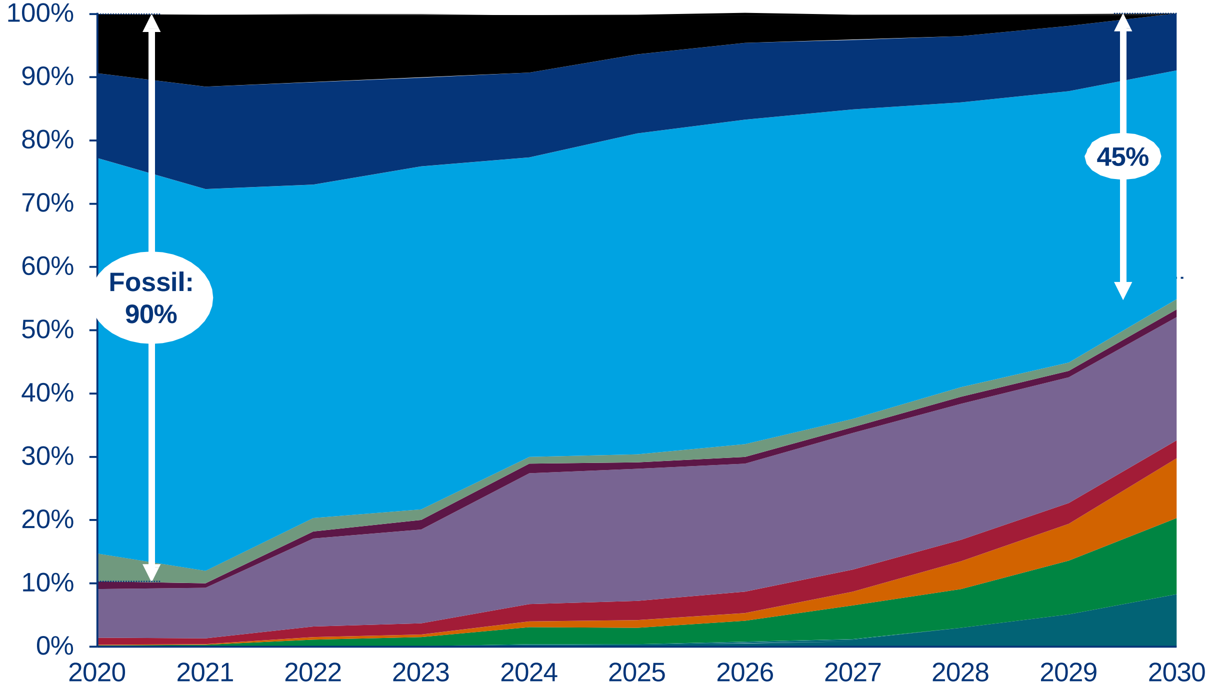


Note: Annual average energy-only wholesale power prices
Does not reflect hourly or seasonal price volatility that may be imposed by higher renewable energy penetration levels
Source; Wood Mackenzie

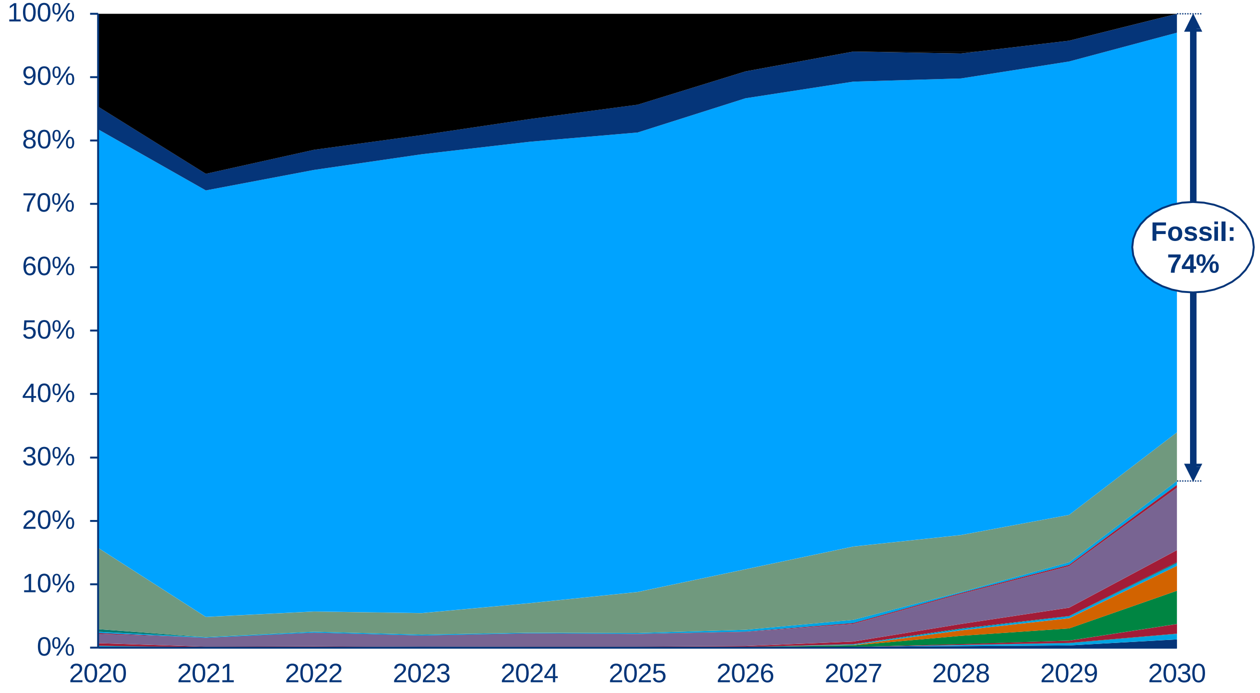
Coal retirements will create expanded role for gas in many markets for setting marginal prices

Variable resources of wind and solar have limited contribution as a marginal fuel, despite massive capacity build-out

Marginal fuel by technology (%) – WECC – Scenario 2



Marginal fuel by technology (%) – PJM – Scenario 2



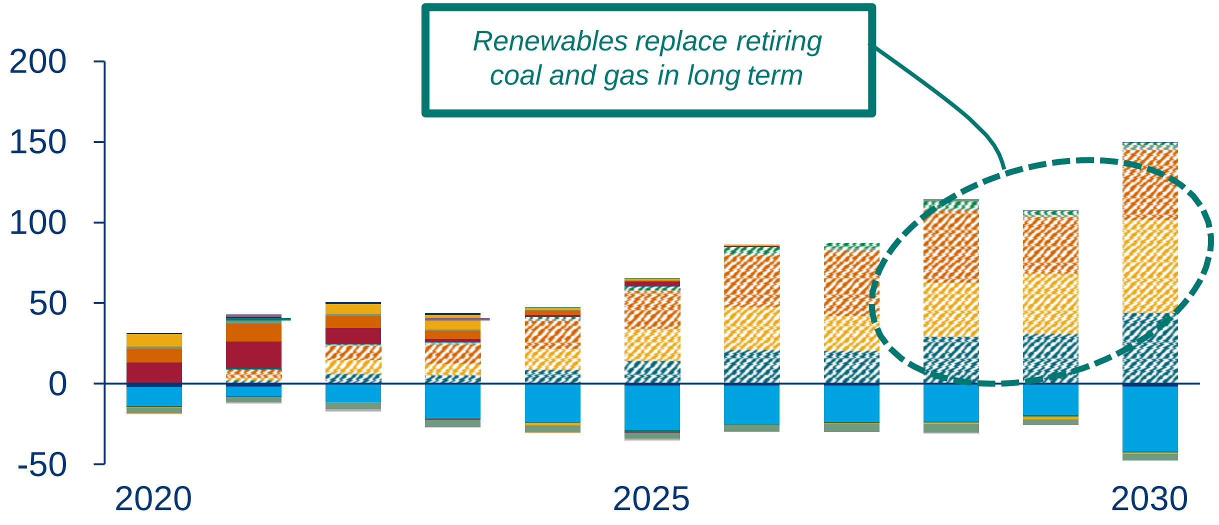
Gas Cogen	Gas CC	Gas ST/CT	Oil	Dist. Solar	Net Flows	EVs
Hydro	Solar Utility	Wind	Storage	Coal	Nuclear	Other

Source: Wood Mackenzie

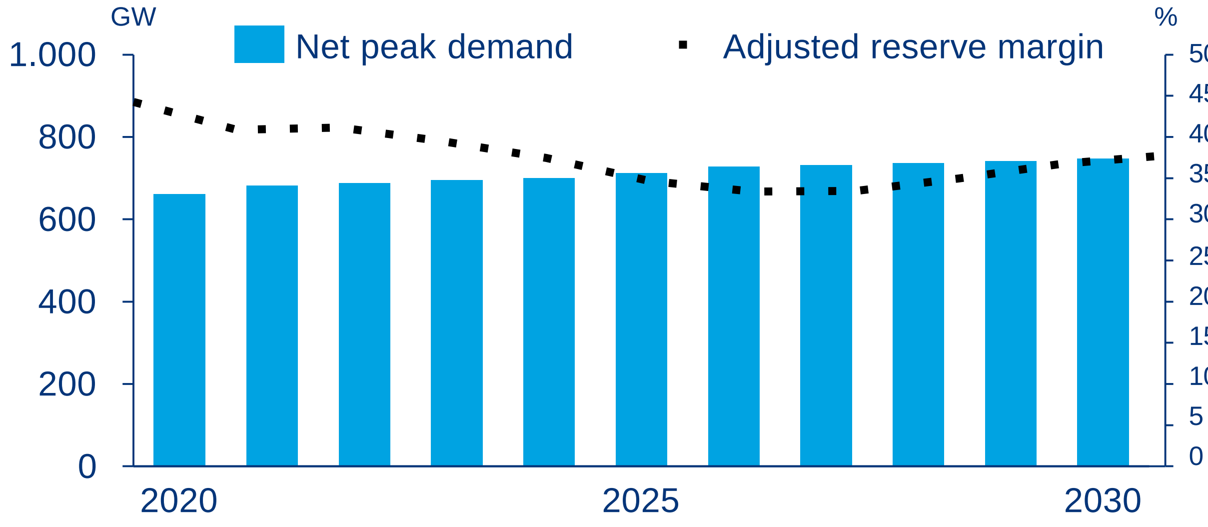
Preserving reserve margins requires significant investment in over 180 GW in energy storage

Retirement of coal plants nationwide require significant investment in renewables and energy storage to meet peak demand

Installed capacity changes (GW),** Scenario 2



Peak Demand (GW) *left axis*, **Reserve Margin** (%) *right axis - Scenario 2*



- Coal retirements are replaced by renewables and storage plants to avoid dramatic reduction in available reliable capacity
- Storage, solar and wind additions form majority of new future additions

- Reserve margin gets tighter even though there are substantial renewable additions owing to decreasing effective load carrying capability (ELCC) for solar

*Adjusted Reserve margin = (Reliable Capacity + Supply Side Adjustments)/(Net Peak Demand + Demand Side Adjustments) – 1

** Only includes firm and generic retirements and additions

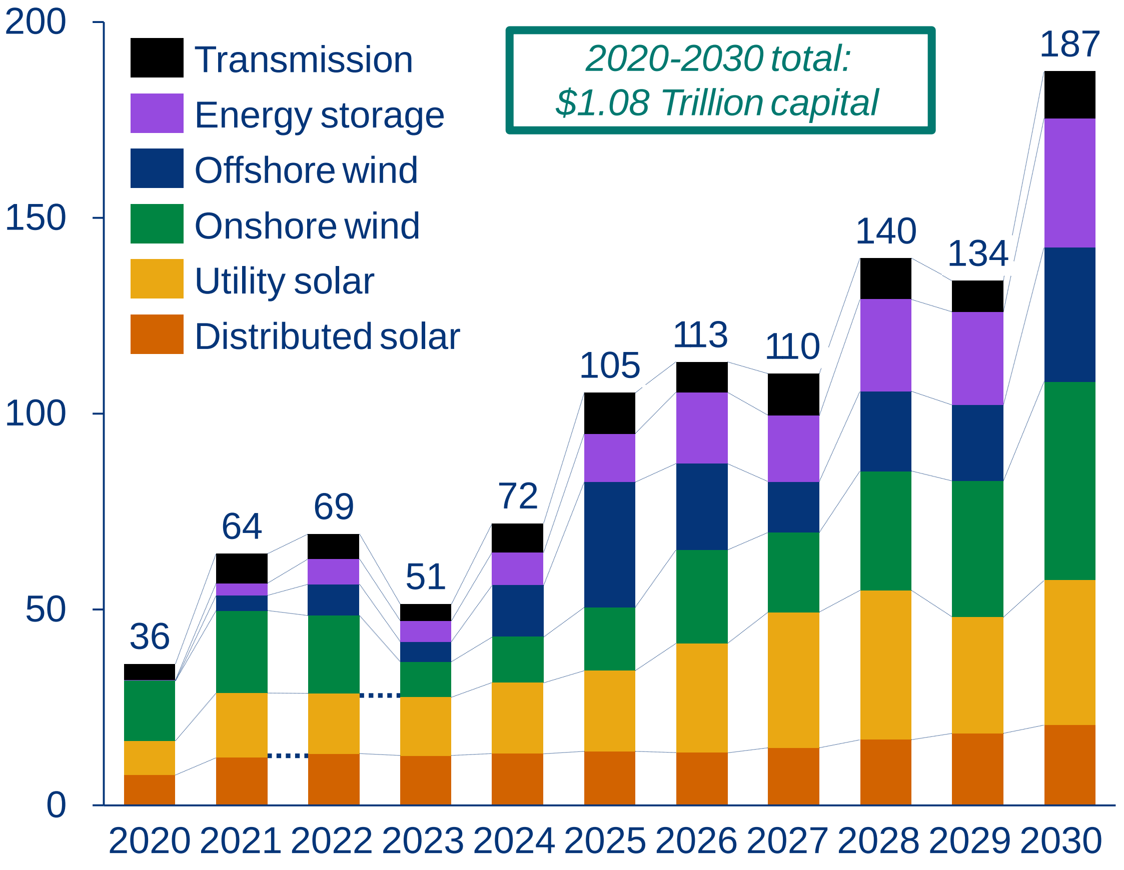
Souce: Wood Mackenzie

Scenario 2 economic development opportunity

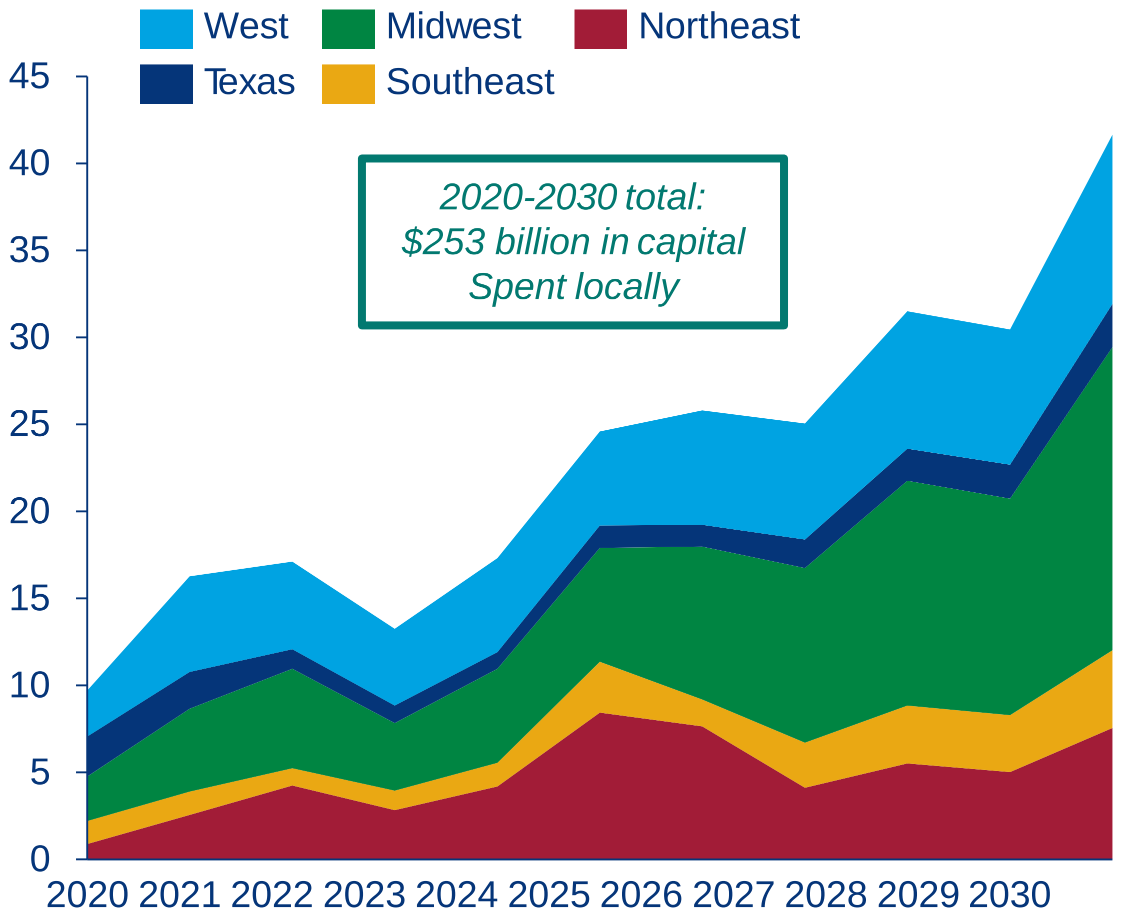
Total capital investment by technology

Renewable build-out will deploy over $1Trillion in capital over 10 years, with ~25% spent local to the installation region

Total capital investment, USD Billions – Scenario 2



Estimated local capital investment, USD Billions – Scenario 2



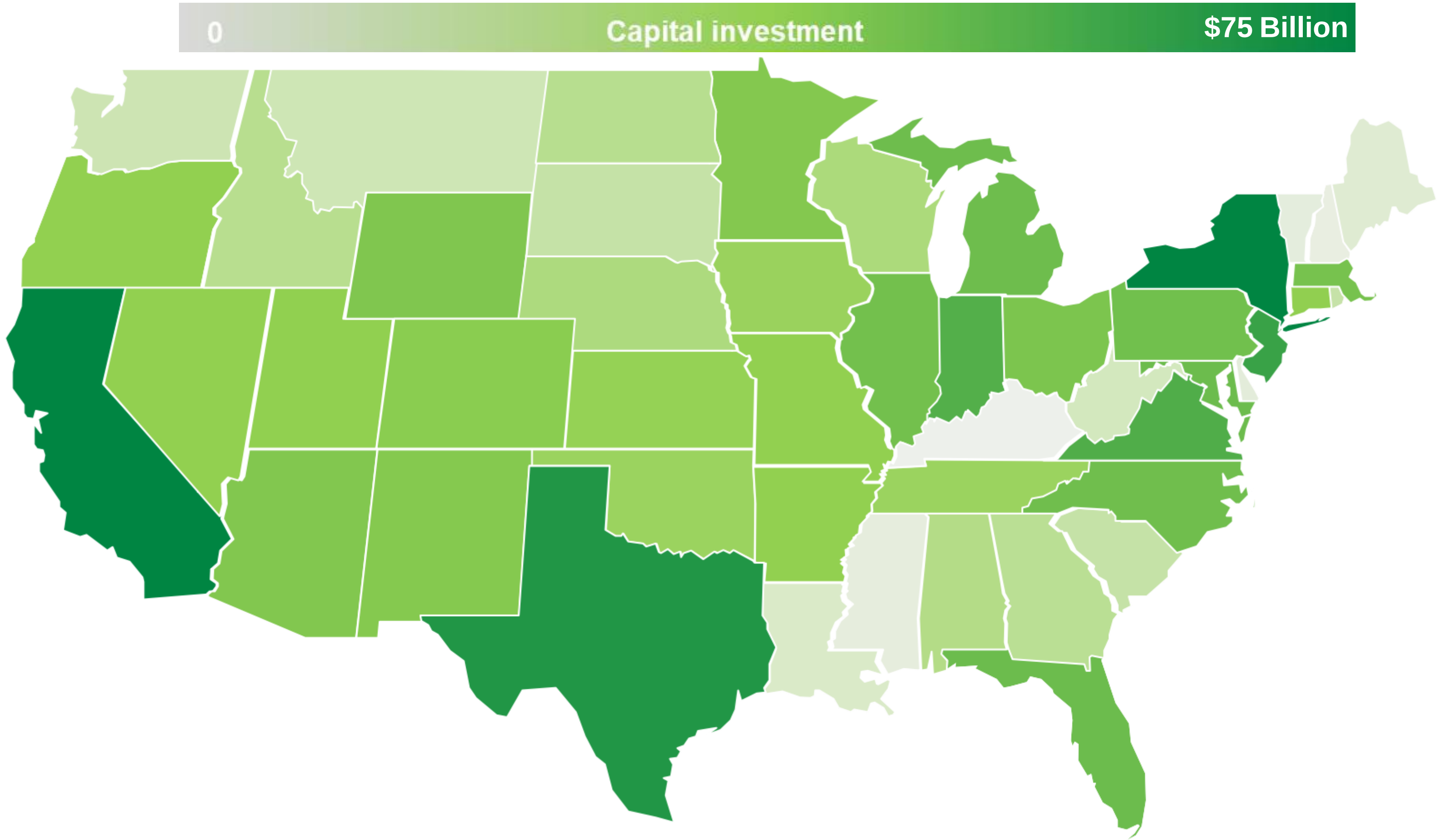
Note: Capital includes construction of power plants and transmission, but does not include induced affects or other benefits to local economies

Source: Wood Mackenzie, NREL JEDI tools

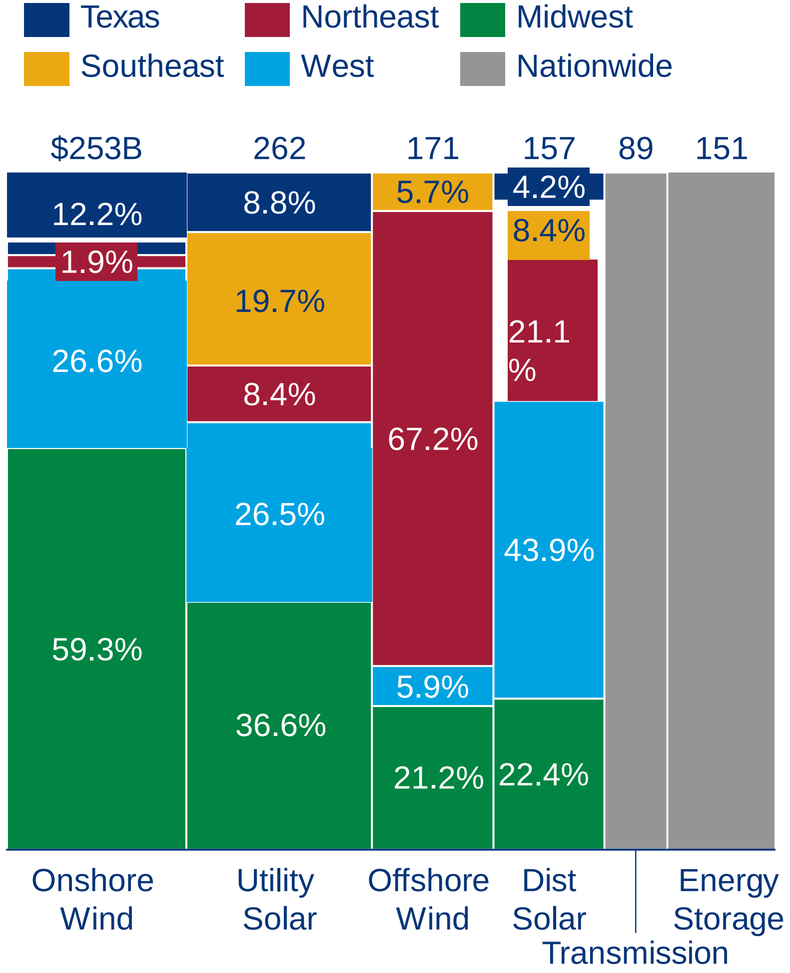
Total capital investment across all wind and solar distributed across the country

Scenario 2 shows further investment in onshore wind, utility solar and offshore wind, while regional focus remains consistent

Total investment wind and solar – Cumulative capital investment, 2020-2030, Scenario 2



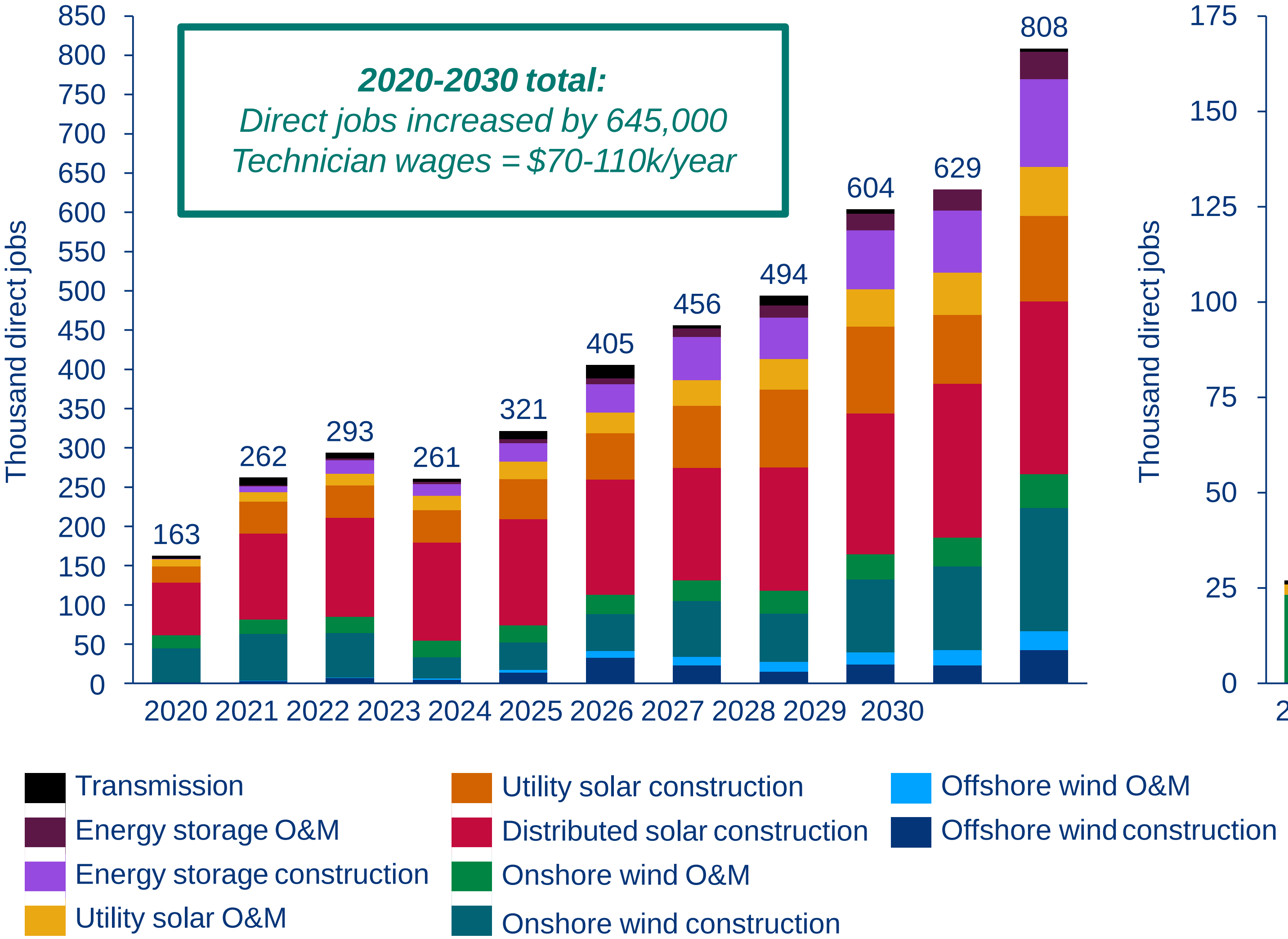
Capital investment, by region and technology



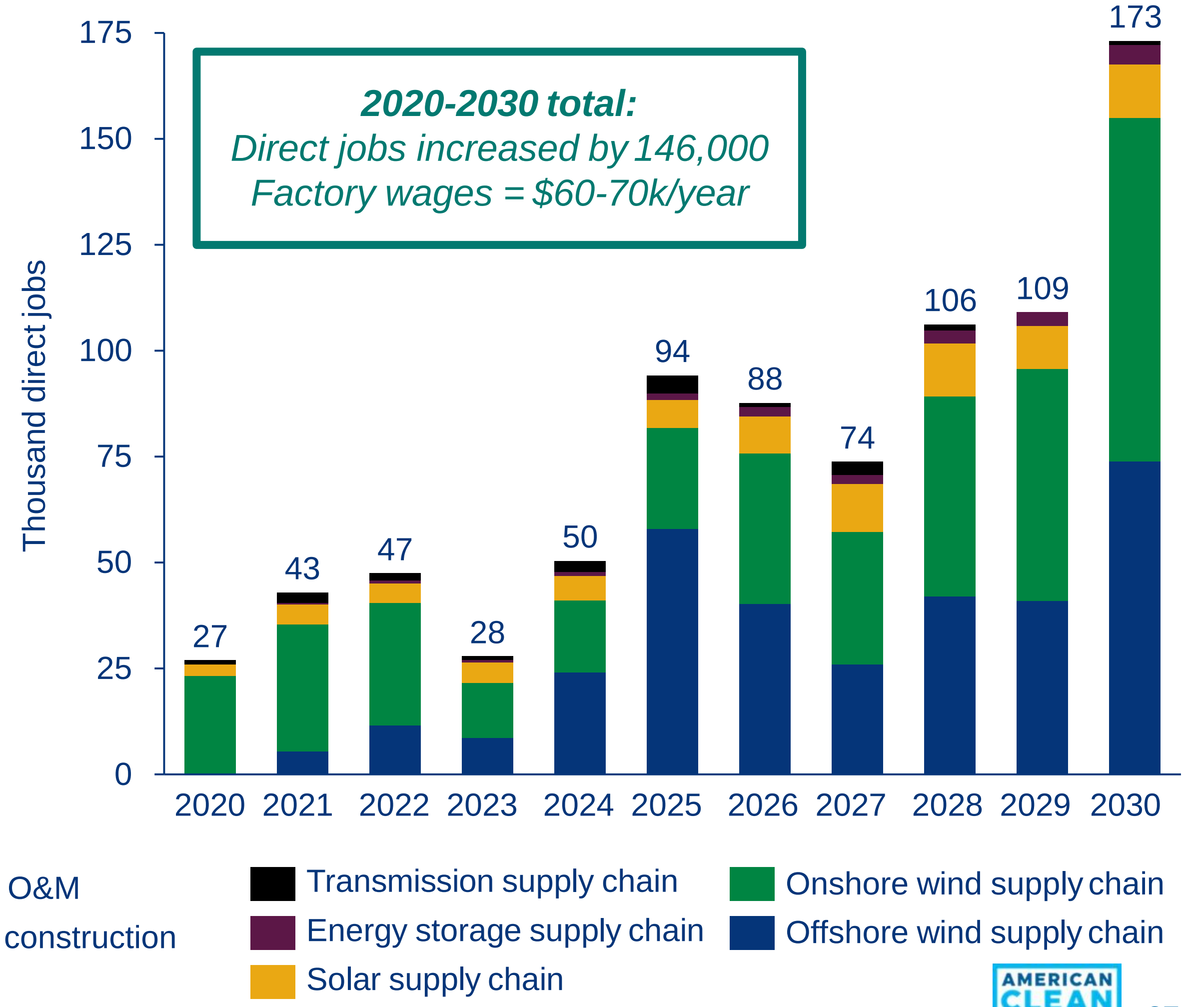
Nationwide direct jobs increase by 791,000 from renewable energy increases – Scenario 2

Reaching 50% renewable energy will foster a new industry of technicians, manufacturers and maintenance

Construction/technician – Annual direct jobs in construction and maintenance



Supply chain – Annual direct jobs in factories, distribution and development

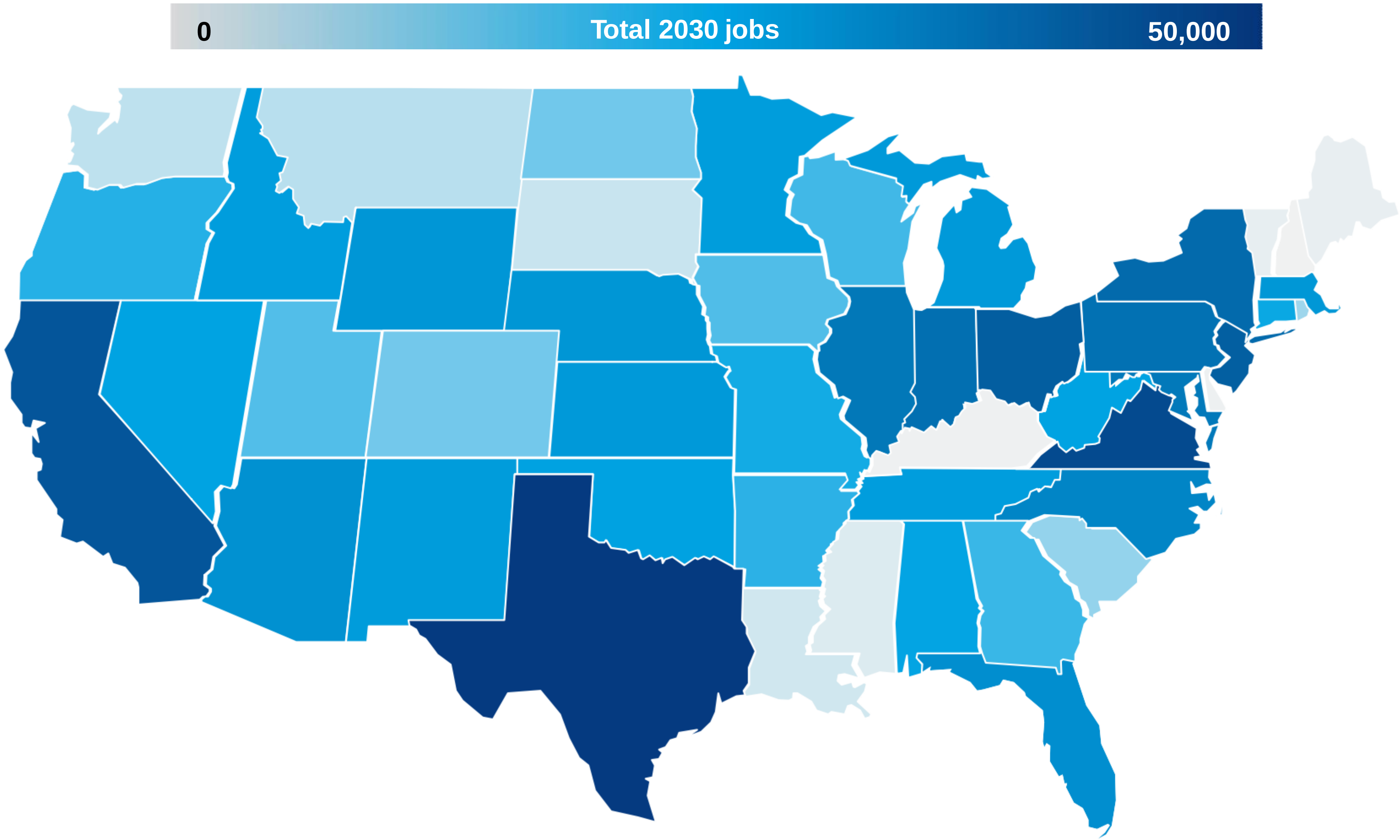


Source: Wood Mackenzie, NREL JEDI tools

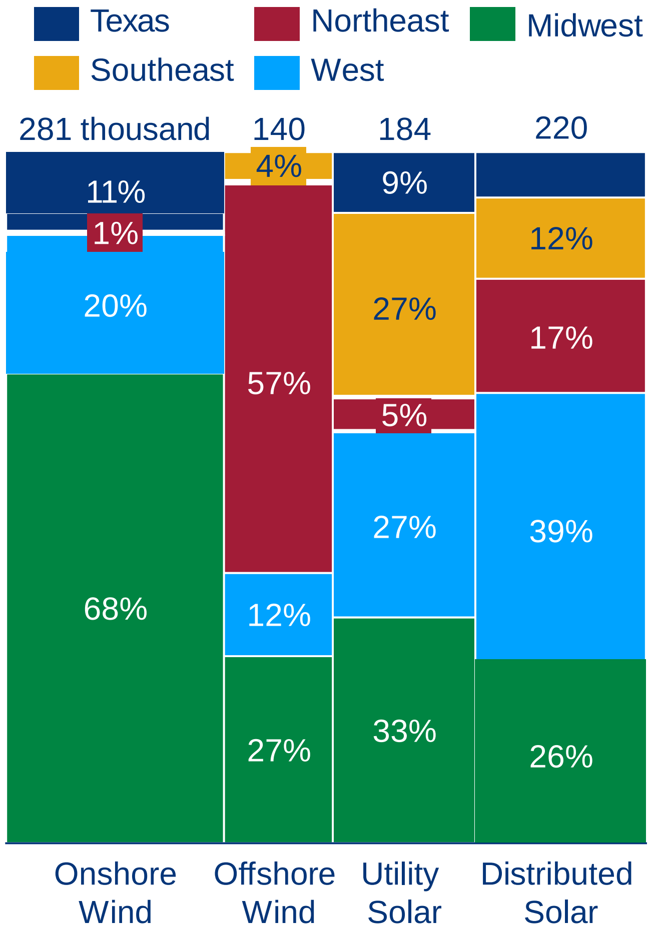
Scenario 2 acceleration of onshore wind and solar further reinforces job growth in Midwest

Reaching 50% renewables requires significant addition of onshore wind leading to a surge in job creation

2030 direct jobs, wind and solar – Direct job creation, 2030 annual, Scenario 2



Total direct jobs, 2030, region and technology



Source: Wood Mackenzie

4. Renewable energy supply chain impact

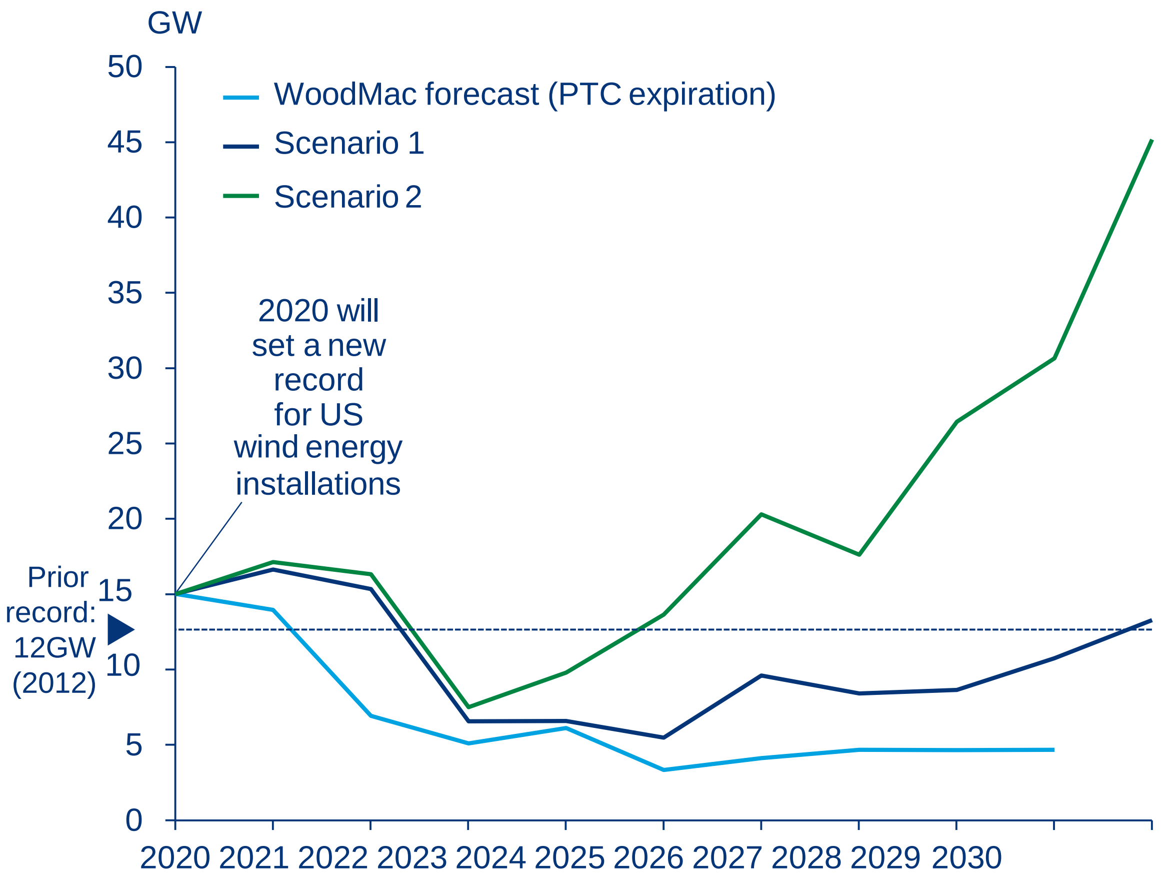
Global supply chains have matured for wind and solar manufacturing

Scenario 2 will strain US domestic supply chain and require manufacturing investment

Onshore wind supply chain is fully globalized, but will require local investment to meet goals

Scenario 1 is unlikely to attract new factories due to a mature supply chain that is delivering record installs in 2020. 50% renewable target (Scenario 2) will likely require significant investment in US factories to meet aggressive growth

Onshore wind annual installation outlook, GW



New record wind years of 2020 and 2021 set up US for success:

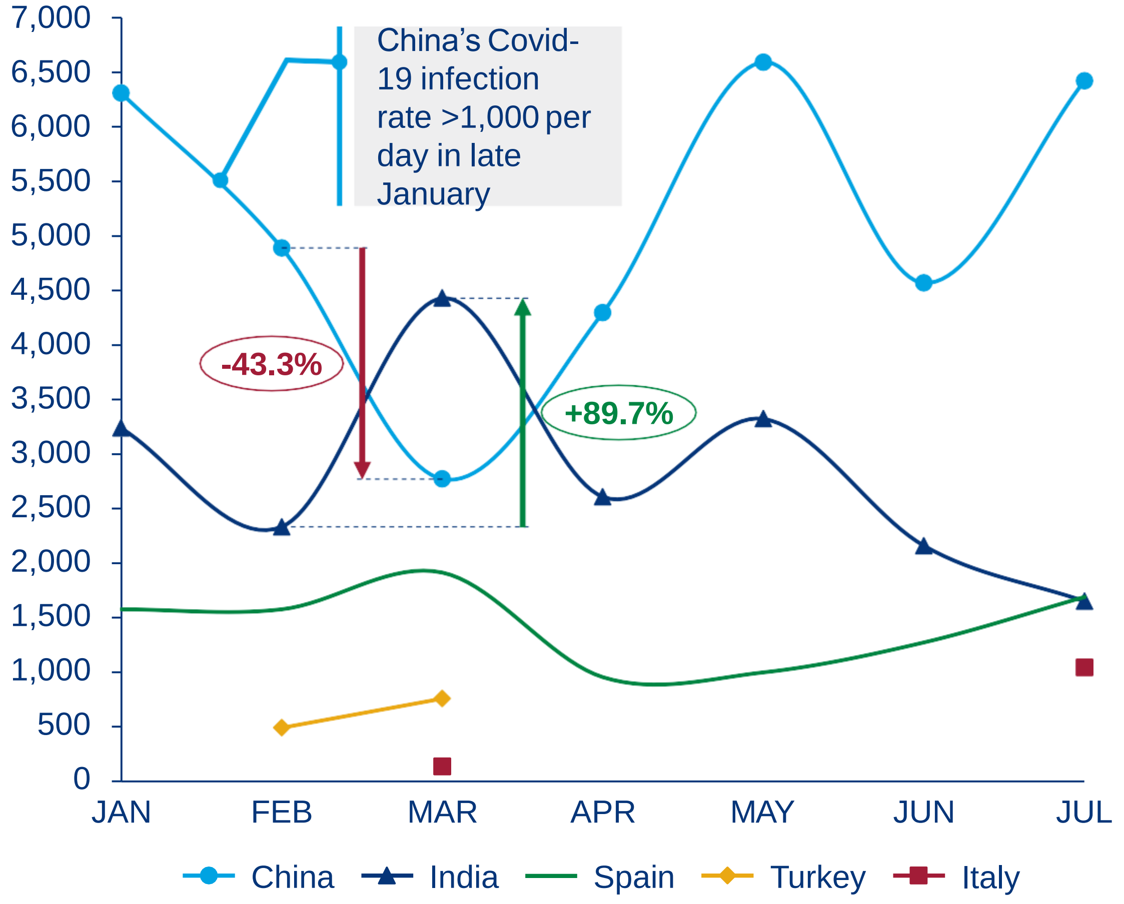
- New installations of ~15GW expected in 2020 due to expiring PTC
- Few significant project delays, despite impact of COVID on global supply chain
- Existing US wind manufacturing is focused on large components:
  - Blades – 7 Midwest US blade facilities are augmented with imports
  - Towers – Large components and logistics cost provide US advantage
  - Nacelle assembly – US factories provide assembly for nearly all nacelles
- 2nd tier of supply chain draws from a broad US supply base
  - Concrete, rolled steel, cables and bolts have solid US supply base
- Scenario 1 volumes can likely be obtained without additional factories
  - Next-generation turbines may require expansion of blade and nacelle factories
  - Scenario 1 volumes unlikely to attract sub-component suppliers
- 50% renewable target creates significant demand for onshore wind
  - Peak installs grow to nearly 3X previous record values
  - Additional manufacturing capacity may be re-opened or invested in:
    - Blade facilities – expansion or re-opening of retired plants
    - Mothballed plants may re-open – Gearbox, nacelle, tower and blade facilities that closed during the last PTC downturn may find new life

Source: Wood Mackenzie

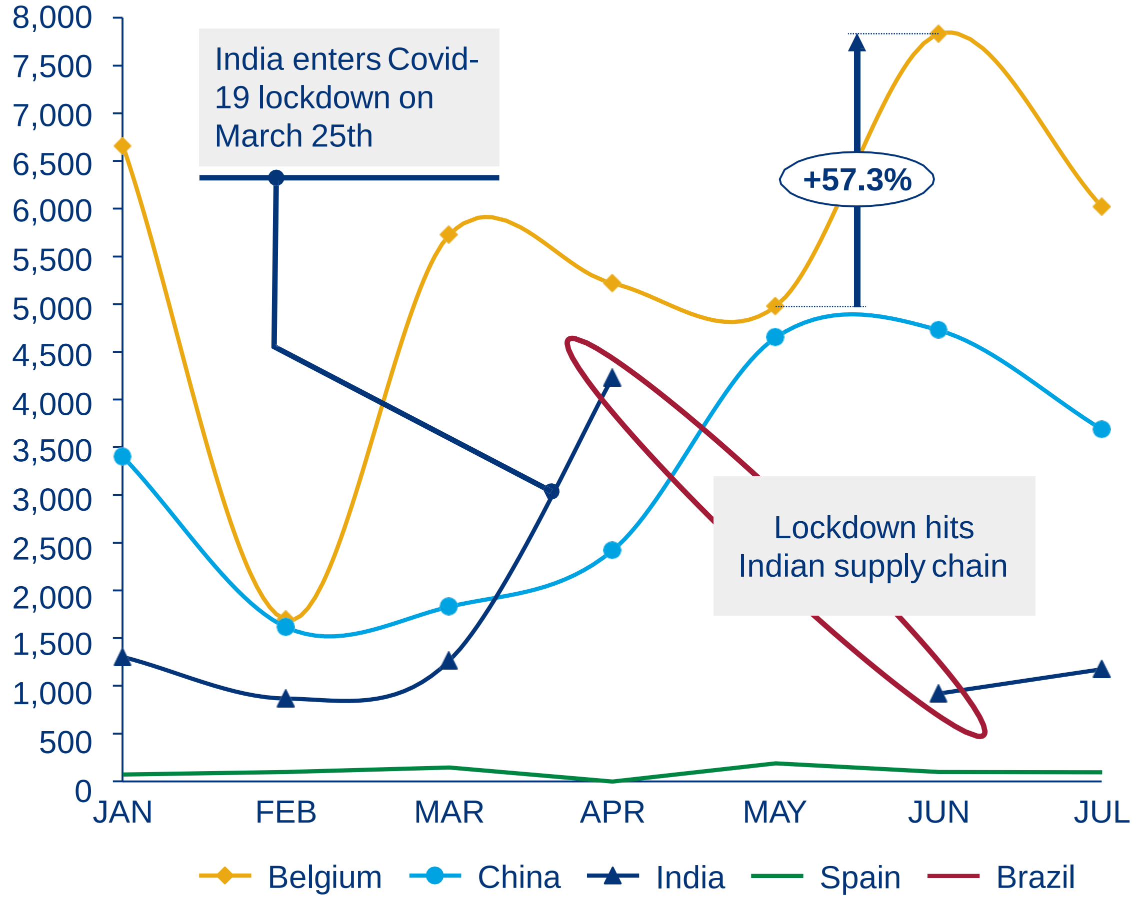
US wind supply chain has demonstrated resilience and flexibility during coronavirus pandemic

Lack of local content requirements and global supply diversification enabling record installs in the United States

US blade imports by country of origin, 2020 (metric tons)



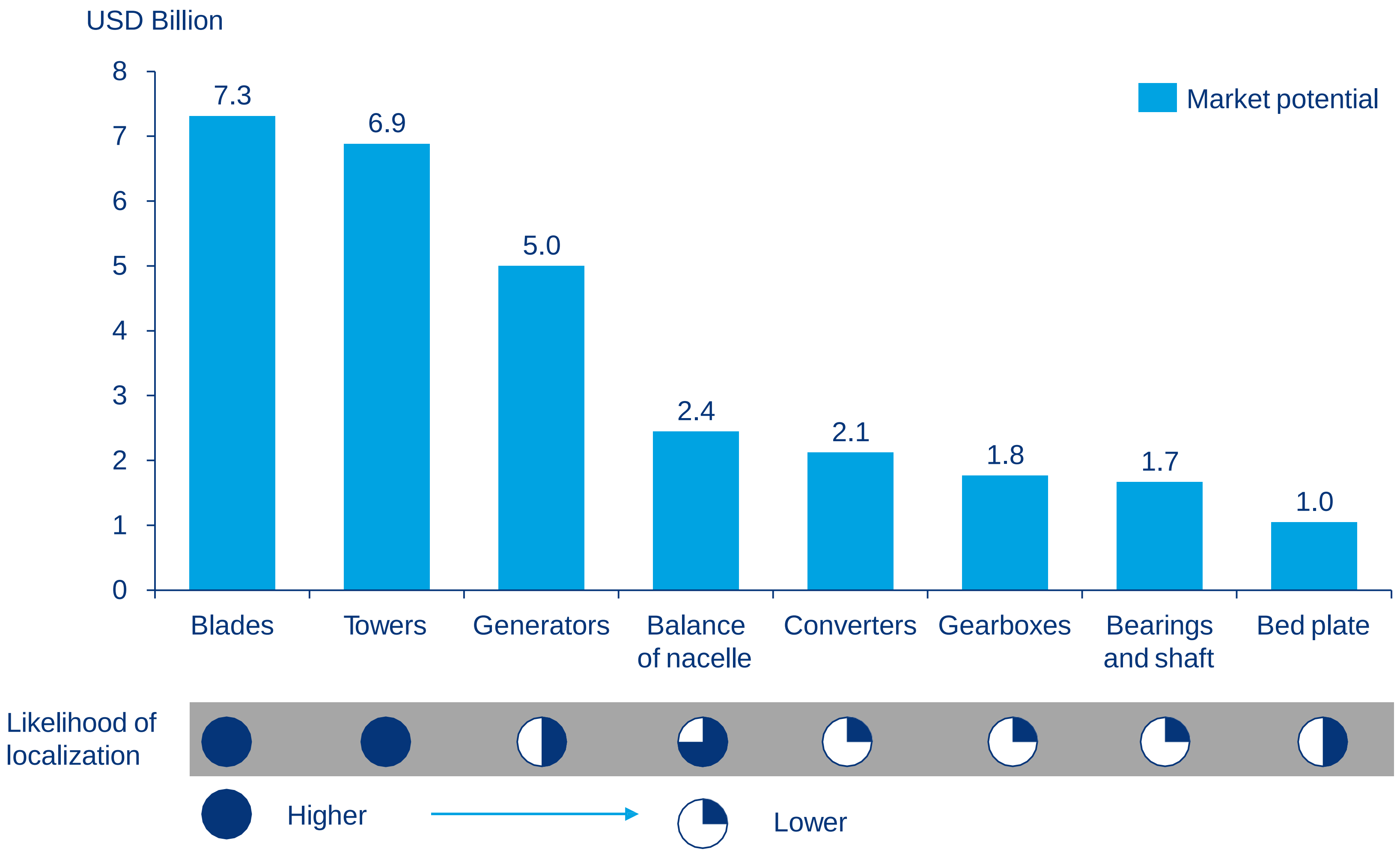
US gearbox imports by country of origin, 2020 (metric tons)



Source: Wood Mackenzie

US offshore installs will create USD 36B wind turbine supply chain opportunity, warranting new local investments

US Offshore turbine supply chain's cumulative addressable market potential, 2020-2028e



- The turbine supply chain plays a critical role in lowering offshore wind's LCOE.
- US states are working to lure developers and turbine OEMs with GW scale contracts/leases
  - Northeastern states are competing for a pivotal role in the offshore wind supply chain
  - Turbine OEMs, in conjunction with component suppliers, are expected to set up facilities in Northeastern states
- Turbines and components for early projects (2022-23) will be imported from Europe, but local investment will occur after this time
- Significant opportunity exists outside of installation regions for supply chain
  - Ship and port operations leveraging gulf coast and southeast expertise
  - Component supply chain in Southeast and MidWest

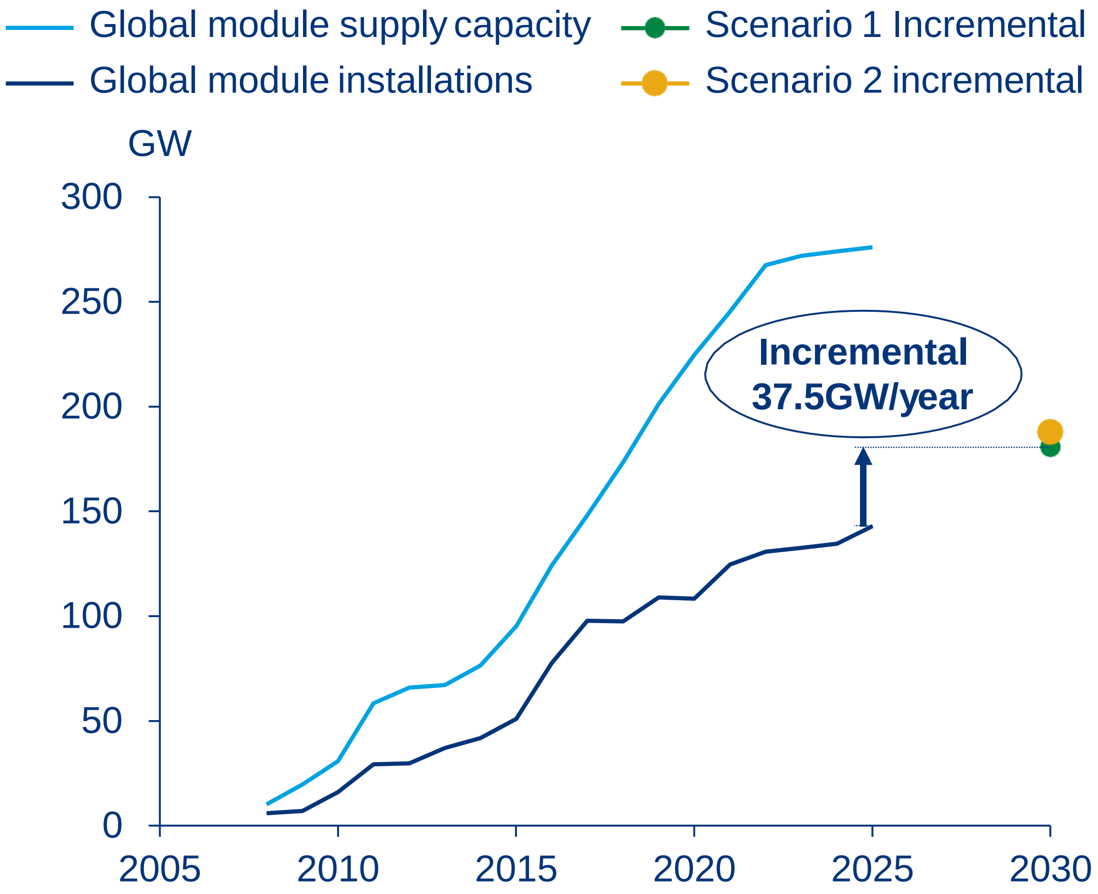
Note: The annual addressable market value includes the average turbine pricing projections inclusive of the O&M contracts for turbines and components

Source: Wood Mackenzie

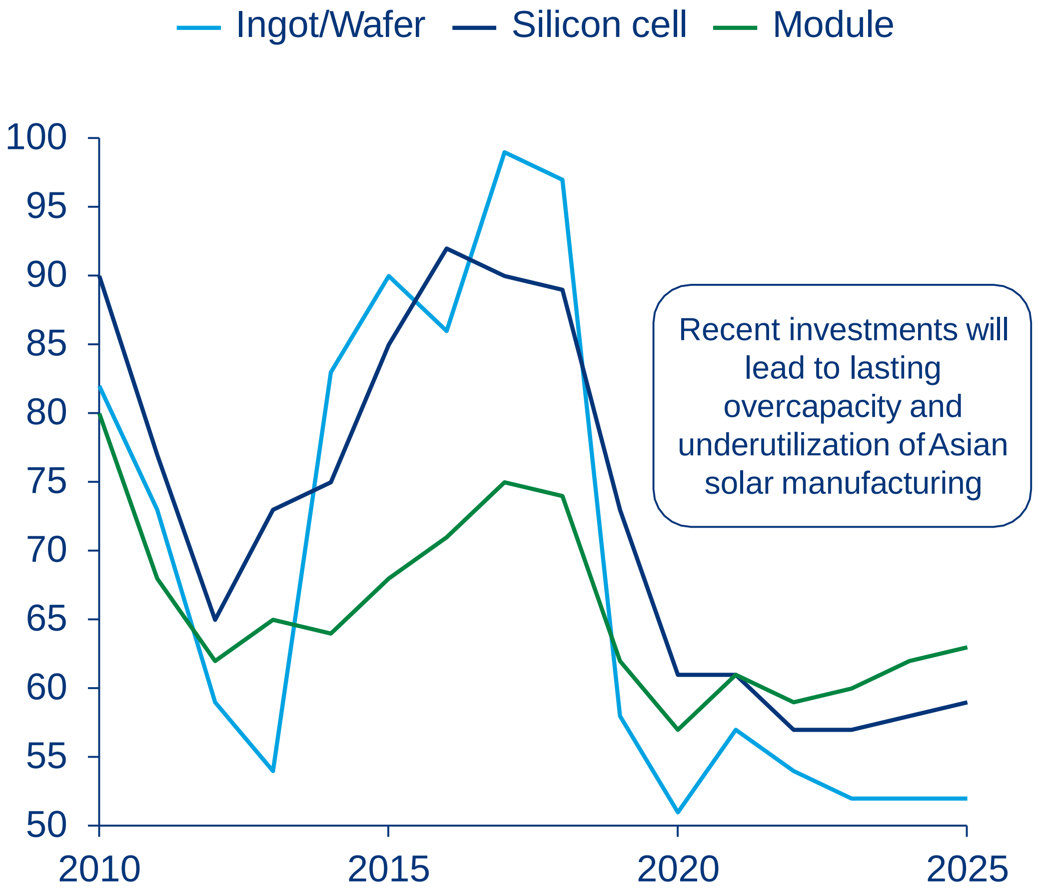
Global solar supply chain is in the midst of massive increase in manufacturing capacity to meet demand

Need for core solar PV modules and inputs will be satisfied from growing Asian supply base

Solar module supply chain global supply capacity vs demand



Global solar supply chain utilization rates, %

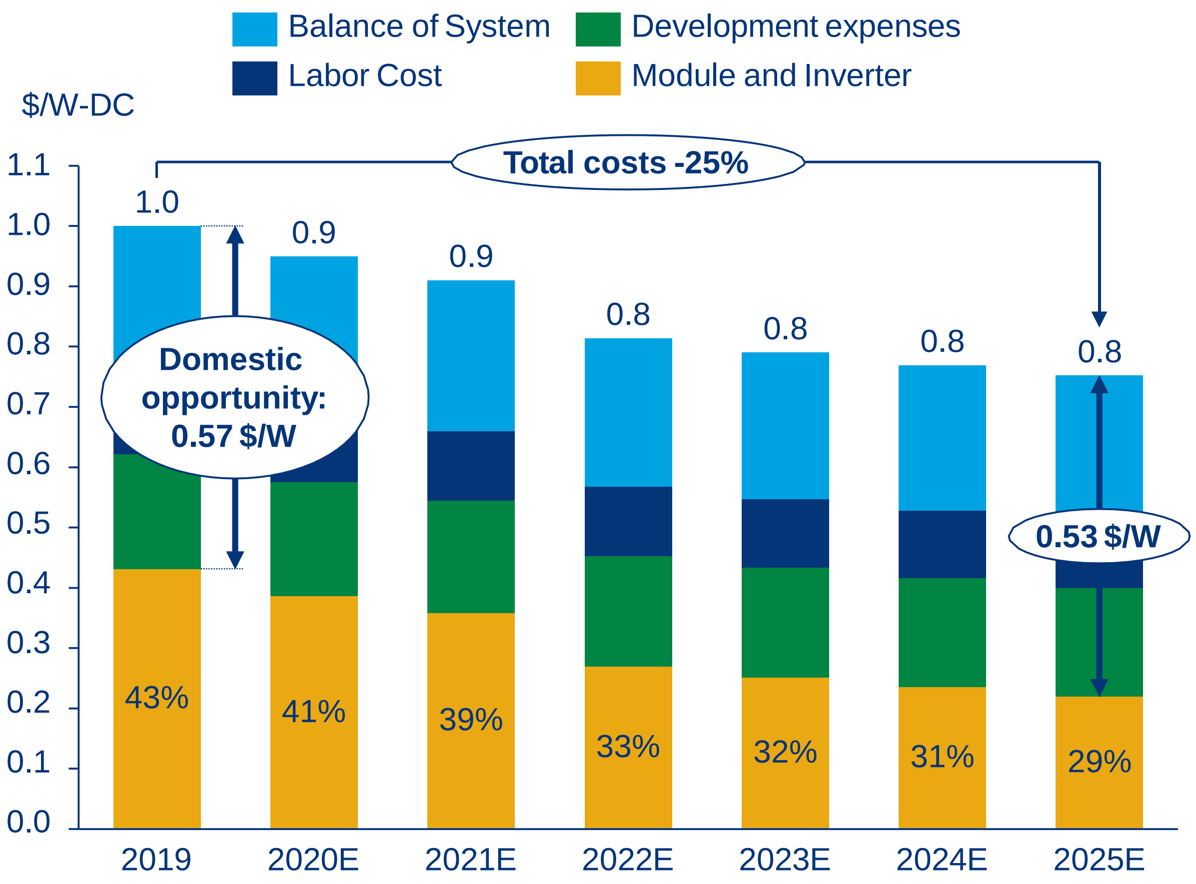


Source: Wood Mackenzie PV Pulse

Domestic opportunities exist for solar supply chain for balance of plant components and development

Modules and inverters will comprise less than 30% of cost by 2025, 'other' costs will remain stable, open to US supply

Cost contributions for utility scale solar installation, $/Watt, DC



Domestic solar supply chain opportunities are abundant

Massive increase in solar installations will require US supply chain support

- Structural components – racking systems, fencing, tracking mechanisms present strong opportunities for US-based lean manufacturing
- Civil construction – concrete, rebar, road construction will be sourced to local companies and EPC providers
- Electrical components – cabling, conduit, transformers will require both domestic manufacturers and overseas supply with US distribution channels
- Logistics – Storage, transport and distribution of modules and other components

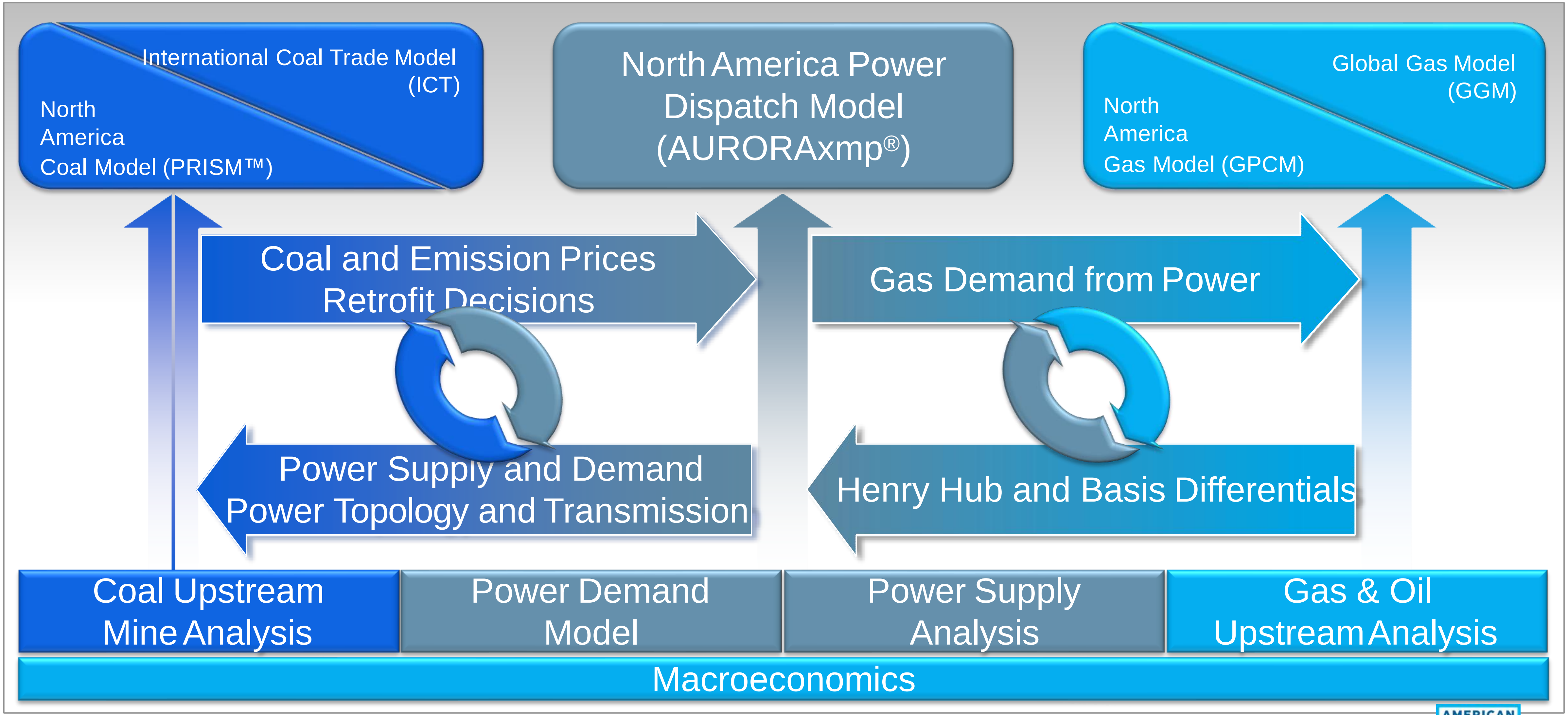
Development and labor expenses will remain in the US

- Permitting, land acquisition and other development activities will continue to be supported by local and regional teams
- Installation and service labor a significant source of direct job growth

Note: Balance of System (BOS) includes electrical BOS, structural BOS, civil costs
Development expenses include permitting, taxes, design and engineering, logistics, miscellaneous, overhead and margin
Modeled U.S. Utility Single-Axis Tracking Ground Mount System $/DC (10 MW, blended module, central inverter pricing)
Source: Wood Mackenzie

5. Methodology appendix

Wood Mackenzie power system modelling leverage significant experience across multiple commodity expertise within the WoodMac group to forecast impact on pricing, supply and demand



Power & Renewables Methodology

North American Power Market Fundamental Analysis

- Wood Mackenzie's power market modelling leverages an integrated analysis across the value chain across our North America and Global Macroeconomic and fuels market teams that provide detailed data and analytics feeding into our view of NorthAmerica Power and Renewables markets.
- Wood Mackenzie utilizes the Aurora XMP® production cost simulation tool for energy price forecasting in the North America power markets. Using Aurora XMP®, Wood Mackenzie performs a focused, plant-by-plant analysis on an hourly basis against hourly demand projections for every modelled power market zone, taking into account power plant operational characteristics and inter-zonal transmission constraints. Currently, Wood Mackenzie has broken the North American market into 99 power market zones, reflecting the inter-zonal transmission constraints. Energy market clearing prices are set at an hourly level using least cost dispatch based on generating unit marginal cost of production and operational characteristics. Zonal energy flows (imports and exports) are determined based on a combination of least cost dispatch and inter-zonal transmission path ratings.
- Wood Mackenzie’s fundamental analysis of the power markets is based on our proprietary North American power market supply and demand assumptions. These assumptions have been refined over many years relying on the knowledge and expertise of the power team as well as input from power clients that include many major industry players. Below is a description of the major forecast assumptions developed by Wood Mackenzie and continuously updated and within our simulation dataset.
  - » **Power plant cost and technical characteristics** have been developed and are continuously being updated based on historical unit performance reports (e.g. EPA CEMS and EIA reports) and typical generator characteristics given plant age, technology and manufacturer. Such characteristics include power plant location, fuel type, size, efficiency/heat rates, variable operating and maintenance (O&M) costs, emission rates, planned maintenance and forced outage rates, ramp rates, start costs and fixed O&M costs.
  - » **23 technology types covered**

Power & Renewables Methodology

North American Power Market Fundamental Analysis Continued…

Biomass	Coal Conv	Coal Conv CCS	Coal IGCC	Coal IGCC CSS	Distillate
Gas CC	Gas Cogen	Gas Peaking	Gas Steam	Geothermal	Hydro
Storage	Landfill Gas	Municipal Solid Waste	Nuclear	Other Non-Renewable	Other Renewable
Fuel Oil Steam	Hydro Pump	Wind	Solar	Batteries	

» **Named power plant entry and retirement** assumptions are being updated on a frequent basis based on continuous tracking of industry publications, regulatory permitting progress, ISO and RTO planning information, power plant developer and plant owner announcements related to new plant additions and old plant shutdowns or mothballs.

» **Long-term Generic power plant retirements** determined on semi-annual basis relying on an evaluation of the plant's age, efficiency and expected economic performance.

» **Long-term generic plant additions** assumptions also updated twice a year based on the regulatory drivers (renewable portfolio standards) and financial incentives (loan guarantees, tax credits, feed-in tariffs) promoting certain generation alternatives such as renewable and nuclear generators; plant economics - levelized costs, CONEs, Net Cone - by region and technology; and regional/sub-regional reliability (reserve margin) requirements.

» **Short-term and long-term power demand forecasts** by power zone based on a combination of a proprietary demand forecast model projecting monthly energy and peak demand and hourly load shapes calculated from actual historical hourly loads reported by load serving entities (LSEs). Long-term annual energy and peak demand forecasts are updated twice a year and short-term projections on a quarterly basis reflecting Wood Mackenzie's current economic growth and GDP assumptions and recent demand trends. Electricity demand forecasts are also adjusted based on our estimates of incremental energy efficiency and demand response based on our extensive research and analysis of ISO/RTO reports, provincial, state and LSE initiatives and other relevant sources. Wood Mackenzie proprietary demand models also incorporate incremental distributed solar and electric vehicle demand (distributed solar not embedded in historical loads), large industrial addition and losses (for e.g. start of a new ethylene or electric drive LNG liquefaction capacity or closure of large aluminium smelters). Daily shapes for these factors is embedded in the model to reflect of time of day impact.

Power & Renewables Methodology

North American Power Market Fundamental Analysis Continued…

» **Inter-zonal transmission path ratings, wheeling rates and losses** are estimated utilizing information from ISOs, RTOs, transmission coordination groups, transmission system coordinators and transmission owner OASIS websites. Transmission expansion assumptions are determined based on an evaluation of development activity in light of ISO/RTO transmission planning efforts, regulatory permitting and construction progress Wood Mackenzie also frequently evaluates the zonal configuration topology for the North American power markets to reflect inter-zonal transmission congestion, mostly affecting power prices for major hubs and zones.

» **Natural gas, oil and coal fuel prices and emission allowance price projections** based on the results of our integrated and iterative multi-commodity modelling of the North American and global energy markets.

- Coal and gas prices are modelled specific to ever asset utilizing Wood Mackenzie's North America Coal (PRISM) and Gas models (GPCM). These models interact with Global coal and gas modules to model international coal and gas market dynamics. Specific to North America, pricing for pipelines and basis is the result of detailed iterative market modelling with the final results based on the GPCM market model. Wood Mackenzie identified the specific natural gas pipelines that individual gas-fired plants are connected to, or the most likely primary gas pipeline supply if a power plant is connected to a Local Distribution Company (LDC) network instead of an interstate pipeline. This was accomplished using information from the Eastern Interconnect Planning Collaborative (EIPC) gas-electric coordination study, new reports from the Energy Information Administration, and a review of individual pipeline company electronic bulletin boards. The pipeline assignments were then used to refine and expand the assignment of “Liquid” trading hub points or “delivered” interstate/intrastate pricing points. For example, rather than using the same natural gas price point for every gas-fired plant in the PJM AEP power zone, we have several different gas hub assignments depending upon the pipelines or LDCs that plants are connected to (Appalachia, Chicago, Lebanon, MichCon, Dominion, TETCO M3).

Power & Renewables Methodology

North American Power Market Fundamental Analysis Continued…

- This update also reflects a more granular modeling of delivered natural gas prices in the Canadian provinces that captures the current distance-based transportation tariff charges along the TransCanada pipeline east of Alberta and the influence of the Emerson hub (in addition to AECO and Dawn and Iroquois) on these pricing dynamics. For example the Manitoba gas price reflects the influence of both AECO and Emerson hubs, while there are delivered multiple gas prices in the Ontario footprint rather than a single "Dawn" price.
- For gas-fired plants connected to a LDC, the modeling also includes unit-specific LDC price adders representative of power or interruptible gas transportation tariff rates for over 120 different gas LDCs in the U.S. and Canada (previously the only 3 LDCs were modeled in California).
- Coal prices are reflected on an asset level (reflecting basin prices, transport costs, coal blending ratios) utilizing the PRISM Coal Market model. More detail is provided in the Coal section.
- **CO2 Modelling**
  - Clean Power Plan Modelling: Wood Mackenzie has developed EPA targets that can be applied at any level of topology from states, to power systems/zones/areas to ISOs or NERC regions. Once the CPP caps were determined and the generators were assigned accordingly, we model the CPP constraints in the Aurora simulation model. To do this we use the Aurora emissions constraint logic, with the annual emissions caps by Interconnect beginning in 2022 declining each year through 2030, and then held constant through 2035. Wood Mackenzie worked extensively with EPIS to refine the Aurora model constrained logic to produce a true "Shadow Price" for CO_2 emissions ($/ton) that is required to keep annual emissions at or below the CPP caps in each Interconnect. The shadow price computed by Aurora is then assumed to represent the allowance cost that generators will pay in each Interconnect in order to emit CO_2, and because coal generators produce more than double the CO_2 per MWh than NGCCs, higher CO_2 prices force more coal-to-gas switching and lowers CO_2 emissions

Power & Renewables Methodology

North American Power Market Fundamental Analysis Continued…

» Regional Programs – example RGGI: Similar to the CPP CO_2 constraints, we model the Regional Greenhouse Gas Initiative (RGGI) CO_2 market explicitly in Aurora through 2021 before the Eastern Interconnect CPP constraint takes over. To do this we specified the annual RGGI cap and historical prices as well as the yearly Floor Price (Auction Reserve Price) that is the minimum price up until the Cap is reached. Once the annual cap is reached the price can rise up to the Cost Containment Reserve price at which point another 10,000,000 tons of CO_2 are available at that price. Once those allowances are consumed then the RGGI price can continue rising. This gives us to model the dynamic nature of RGGI prices under different scenarios such as a high nuclear retirement case, for example.

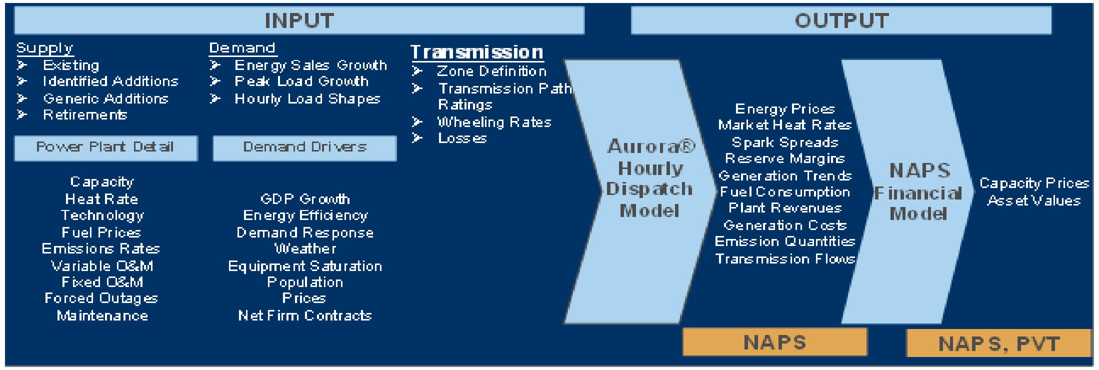
- **Renewables Modeling**

» **Hourly Solar Power Profiles**: Wood Mackenzie's solar modeling reflects significantly more granularity for 91 separate PVWatts1 weather stations. Based upon the State-Zone combination where a solar facility is located, it is assigned to one of these 91 stations with utility-scale facilities receiving a single-axis tracking profile and DG solar facilities receiving a rooftop solar profile assuming a south-facing 10 degree fixed-tilt orientation. The solar profiles also include several Canada weather stations. Each of these profiles is modeled as a 24-hour pattern that is repeated daily, but varies by month, representing the typical average solar generation day per month. The exception to the above remains California, where for utility-scale solar we reflect historical/actual hourly (8760) solar patterns for Northern and Southern California from 2012-2015, with repeating normalized patterns reflecting those historical years used during the forecast period. DG solar in California has been revised to use the new 12x24 PVWatts rooftop solar shapes.

» **Hourly Wind Power Profiles including History:** Wood Mackenzie's power modeling reflects historical hourly 8760 data at least back to 2011 and up through 2015 for Alberta, Ontario, ISO New England, MISO, PJM, SPP, and ERCOT. Since MISO recently started to provide separate wind generation reporting for MISO North and MISO Central, we have captured this additional granularity as well. Within the MISO, PJM, and SPP footprints we also "tune" the hourly profiles at the monthly level to produce the historical state-level monthly wind capacity factors based upon EIA data. For example, SPP Missouri wind farms in our modeling produce at a much lower capacity factor than SPP Nebraska wind farms even though both are tied to the same hourly profile. We also "tune" wind generation for WECC Colorado and WECC New Mexico to produce state-level capacity factors reflective of the SPP 8760 hourly profile based upon geographic proximity.

Power & Renewables Methodology

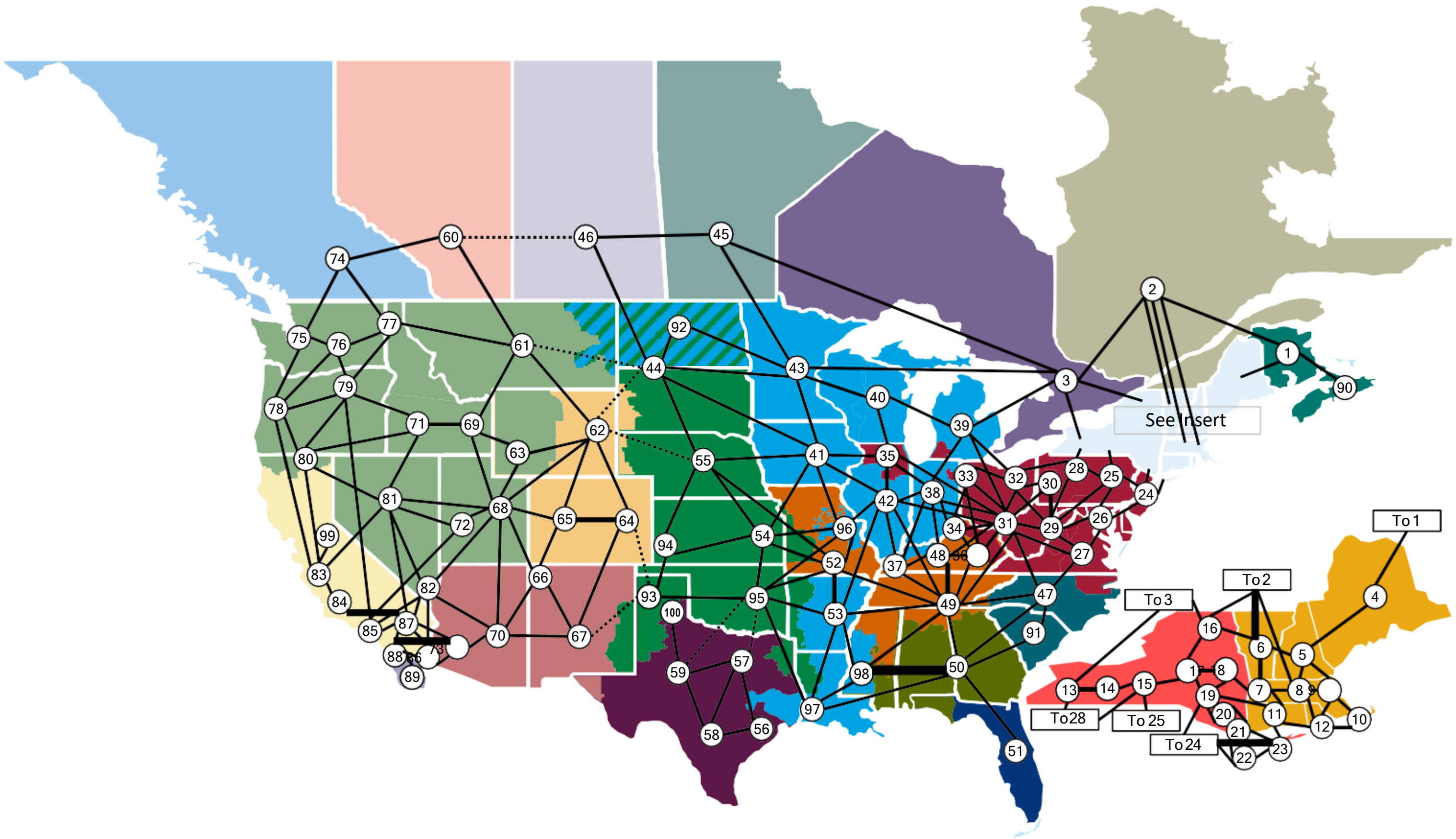
North America Power Market Analytics Framework



- **Pricing Forecast**
  - » Wood Mackenzie's North America Power Service applies a three-part price forecasting approach independently estimating the value of marginal production costs, scarcity premiums borne by market fundamentals, and capacity pricing within each simulated power market area. The general description of this three-part forecast methodology:
  - » Short run marginal costs are calculated within Aurora XMP® for every hour during the simulated study period based on the marginal cost of production of the unit setting the price including variable O&M, fuel, emission and start costs.
  - » An exogenous dispatch-to-price model is used to back-cast historical scarcity bidding that markets have exhibited. This is determined by observing the hourly market clearing heat rates versus an assumed "capped" heat rate (e.g. assuming production costs alone) level that is commensurate with peaking facilities. A regression between historical supply-demand margins and historical scarcity rents is used to forecast future scarcity based upon the fundamental reserve margin forecast. This methodology also incorporates changes to scarcity pricing rules like Operational Reserve Demand Curves (ORDCs), among other.
  - » Capacity prices are estimated reflecting current market design of centralized markets like RPM in PJM, ICAP in NYISO, FCM in ISONE, RAR in MISO. For other markets capacity prices are reflective of new entry cost compensation as reserve margins fall below long term reserve margin level. In general, Wood Mackenzie's projected capacity prices represent capacity values that generators typically extract from organized installed capacity (ICAP) markets and capacity payments in bilateral power purchase agreements (PPAs).

North America Power Market Zonal Simulation Topology

Review of Wood Mackenzie Forecasting Methodology



- Using Aurora XMP®, Wood Mackenzie performs a focused, plant-by-plant analysis on an hourly basis against hourly demand projections for every modelled power market zone, taking into account power plant operational characteristics and inter-zonal transmission constraints.
- Wood Mackenzie has broken the North American market into 99 power market zones, reflecting the inter-zonal transmission constraints.

Topology Map Key
Reporting Regions and Pricing Zone Names

Western Interconnect

Market	Region	Pricing Zones	Number
West	Alberta AESO	Alberta AESO	60
	British Columbia	British Columbia	74
	WECC NWPP PNW	California-Oregon Border (COB)	80
		Lower Columbia	79
		MidC	76
		Montana	61
		PNW Oregon West	78
		PNW Spokane	77
		PNW Washington West	75
	WECC NWPP Basin	Idaho East	69
		Idaho Southwest	71
		Nevada North	81
		Mead	82
		Utah	68
		Wyoming NWPP	63
	WECC Rockies	Wyoming RMPA	62
		Colorado East	64
		Colorado West	65
	WECC AZNM	Four Corners	66
		New Mexico	67
		Arizona	70
		Palo Verde	73
	WECC California Munis	Intermountain Power Project	72
		LADWP	85
		Imperial Irrigation District	86
		BAofNorCal TID	99
	WECC California ISO	CAISO NP15	83
		CAISO ZP26	84
		CAISO SP15	87
		CAISO SDG&E	88
	WECC Baja Mexico	Baja North	89

ERCOT Interconnection

Market	Region	Pricing Zones	Number
ERCOT	ERCOT	ERCOT Houston	56
		ERCOT North	57
		ERCOT Panhandle	100
		ERCOT South	58
		ERCOT West	59

Eastern Interconnect

Market	Region	Pricing Zones	Number
Midcontinent ISO	MISO Central	MISO BREC	37
		MISO Illinois	42
		MISO Indiana	38
		MISO Michigan	39
		MISO Missouri	96
		MISO WUMS	40
	MISO North	MISO Iowa	41
		MISO MDU	92
		MISO Minnesota	43
	MISO South	MISO Arkansas	53
		MISO Mississippi	98
		MISO Texas Louisiana	97
	MRO Manitoba	Manitoba Hydro	45
Southwest Power Pool	SPP WAUE	SPP Dakotas	44
	SPP South	SPP Kansas East	54
		SPP Kansas West	94
		SPP SouthwesternPS	93
		SPP South Hub	95
	SPP Nebraska	SPP North Hub	55
	MRO SaskPower	SaskPower	46
Southeast	FRCC	FRCC	51
	SERC East	North Carolina	47
		South Carolina	91
	SERC North	LGE-KU	48
		TVA	49
		AECI	52
	SERC Southeast	Southern	50

Market	Region	Pricing Zones	Number
Northeast	NPCC Maritimes	New Brunswick	1
		Nova Scotia	90
	NPCC Ontario	Ontario IESO	3
	NPCC Quebec	Hydro Quebec	2
	NPCC ISO New England	ISONE Maine	4
		ISONE New Hampshire	5
		ISONE Vermont	6
		ISONE Mass West	7
		ISONE Mass Hub	8
		ISONE Mass Boston	9
		ISONE Mass Southeast	10
		ISONE Connecticut	11
		ISONE Rhode Island	12
	NPCC New York ISO	NYISO Zone A	13
		NYISO Zone B	14
		NYISO Zone C	15
		NYISO Zone D	16
		NYISO Zone E	17
		NYISO Zone F	18
		NYISO Zone G	19
		NYISO Zone H	20
		NYISO Zone I	21
		NYISO Zone J	22
		NYISO Zone K	23
PJM	PJM South	PJM Dominion	27
	PJM Mid-Atlantic	PJM East	24
		PJM PPL Meted	25
		PJM BGE PEPCO	26
		PJM Penelec	28
	PJM West	PJM Allegheny Power	29
		PJM Duquesne Light	30
		PJM AEP	31
		PJM FirstEnergy	32
		PJM Dayton PL	33
		PJM Duke OHKY	34
		PJM ComEd	35
		PJM EKPC	36

Review of energy transmission lines addition methodology

Inputs previously discussed are used in the Aurora Hourly Dispatch Model

Inputs

- NERC's database of 10-year projections for new transmission line projects
  - Large database of Tx projects officially registered by NERC member transmission planning entities
  - Over 15,000 miles of transmission considered, with many lines accelerated in time from expected COD dates
- Transmission Congestion Tool
  - Summarized view of the congestion costs caused by the capacity of each link or import/export limit.
  - Identified new generic transmission required by congestion or significant price disparity

Aurora Hourly Dispatch Model

- Aurora uses a network with nodes defined by links. Each link has a nominal carrying capacity limit.
  - By adding a line connecting the nodes, we expand these carrying capacities
  - The carrying capacity of DC transmission connections are taken from project websites
- Zonal energy flows (imports and exports) are determined based on a combination of least cost dispatch and **inter-zonal transmission path ratings**

Results

Review of energy price forecast methodology

Inputs previously discussed are used in the Aurora Hourly Dispatch Model

Inputs

- Supply: Existing, identified additions, generic additions, retirements
- Demand: Energy sales growth, peak load growth
- Transmission

Aurora Hourly Dispatch Model

- Energy market clearing prices are set at a hourly level using least cost dispatch based on generating unit marginal cost of production and operational characteristics
- Zonal energy flows (imports and exports) are determined based on a combination of least cost dispatch and inter-zonal transmission path ratings

NAPS Financial Model

- Capacity prices
- Asset values

Review of energy price forecast methodology

Wood Mackenzie's North America Power Service applies a three-part price forecasting approach

Value of marginal production costs

- Short run marginal costs are calculated within Aurora XMP® for every hour during the simulated study period.
- Based on the marginal cost of production of the unit setting the price including variable O&M, fuel, emission and start costs.

Scarcity premiums borne by market fundamentals

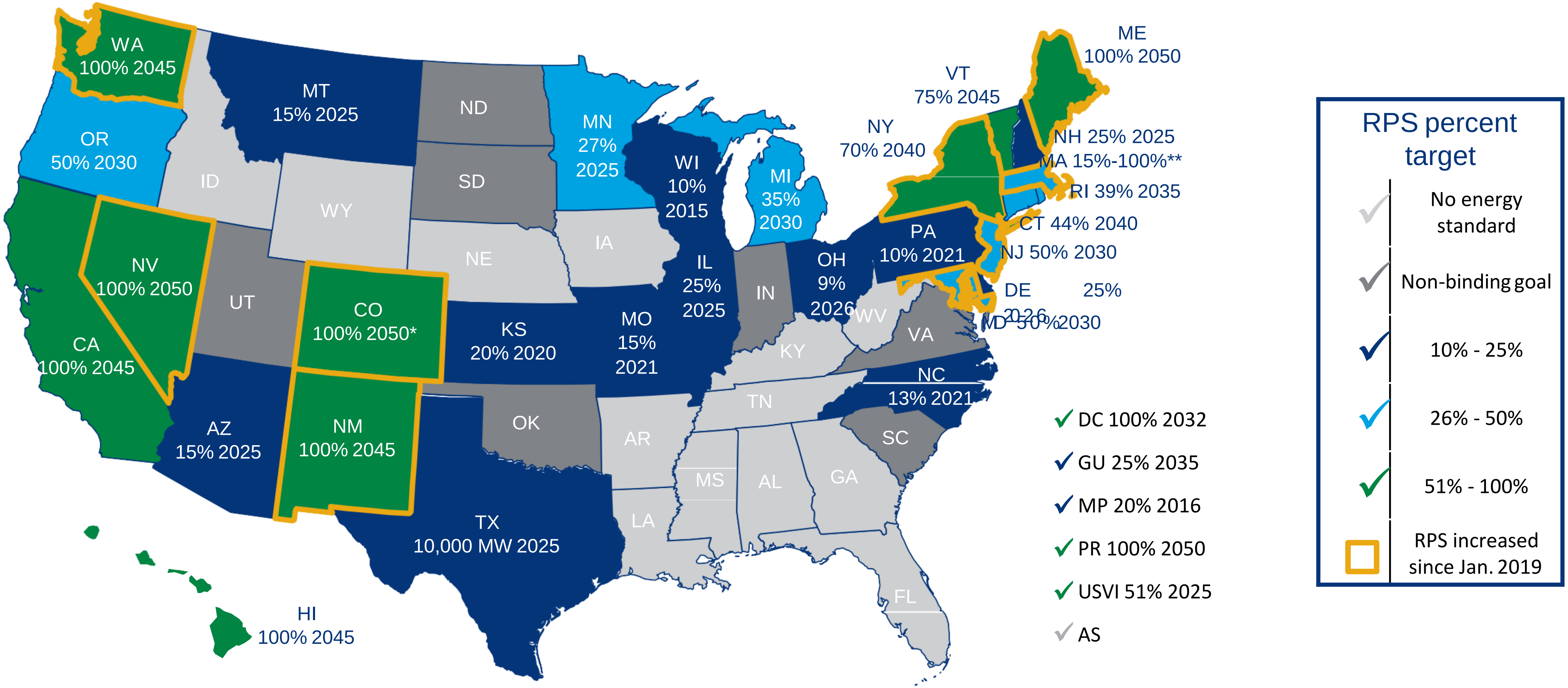
- An exogenous dispatch-to-price model is used to back-cast historical scarcity bidding that markets have exhibited.
- A regression between historical supply-demand margins and historical scarcity rents is used to forecast future scarcity based upon the fundamental reserve margin forecast.

And capacity pricing

- Wood Mackenzie's projected capacity prices represent capacity values that generators typically extract from:
  - Organized installed capacity (ICAP) markets
  - And capacity payments in bilateral power purchase agreements (PPAs).

Renewable/clean energy standards by state

Nine states have raised their goals since 2018. RPS will drive more utility scale PV in the next five years



Source: Wood Mackenzie
*CO goal of 100% clean energy requirement for qualifying retail utilities with 500k customers or more
**MA goal of 15% renewables by 2020 and an additional 1% each year after

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