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Alternative Policies – 50% Carbon-Free Generation

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50% Carbon-Free Generation

Carbon-free generation standards have been established in several states and are usually a modification or extension of existing renewable portfolio standards (RPS). These standards are detailed in Appendix 1. Carbon-free generating technologies include nuclear, existing large-scale hydropower (also referred to as legacy hydro), and fossil generation with carbon capture and sequestration technologies as well as resources commonly allowed to qualify for RPS policies, such as new and small-scale hydroelectric, geothermal, biogenic municipal solid waste, solar photovoltaic, solar thermal, onshore wind, and offshore wind.

To illustrate the effects of existing RPS policies in the Reference case and the potential effects of extending carbon-free generation standards to all states, EIA developed two alternative cases, the 50% Carbon-Free Generation case and the RPS Sunset case.

Methodology

The 50% Carbon-Free Generation case assumes that states individually achieve a minimum 50% of state-wide electricity sales by 2050 using zero- or low-carbon generating technologies.[1] EIA assumes that carbon-free generation standards will supplement or extend existing RPS policies as follows:

- States that currently have an existing RPS policy designed to reach at least 50% carbon-free generation within the projection period maintain their existing RPS targets with no change to the suite of qualifying technologies.
- States with an RPS target of less than a 50% share from renewable generation before 2050 continue with their current RPS path to its terminal target year and then are assumed to adopt a new policy, switching to a linear path that achieves 50% carbon-free generation by 2050. States that have alternative compliance payments (ACP) as an option in their existing RPS legislation continue the ACP when the state adopts a standard of 50% carbon-free generation by 2050.
- For all other states, including states without any RPS policy and states that have an RPS policy with a terminal RPS year before 2020, are assumed to adopt a standard of 50% carbon-free generation by 2050 using the suite of carbon-free and renewable generation technologies described above, starting in 2025 with a linear progression. States with non-binding renewable portfolio goals or similar policies that are not modeled in the Reference case are included in this category.

A full index of current RPS policies for each state and their path under the 50% Carbon-Free Generation case is provided in Appendix 1.

[1] The 50% Carbon-Free Generation case as modeled requires each individual state to achieve a minimum of 50% carbon-free generation by 2050. Although trading of physical generation (subject to transmission constraints) may be used to achieve targets in any given state, there is no national target and thus no ability to trade *carbon-free generation credits* across regions to facilitate compliance.

The RPS Sunset case assumes that all states with an existing RPS policy terminate their programs in 2020 and that no new RPS or carbon-free generation standard policies are enacted. This case is intended to illustrate the effects current RPS policies have in the Reference case.

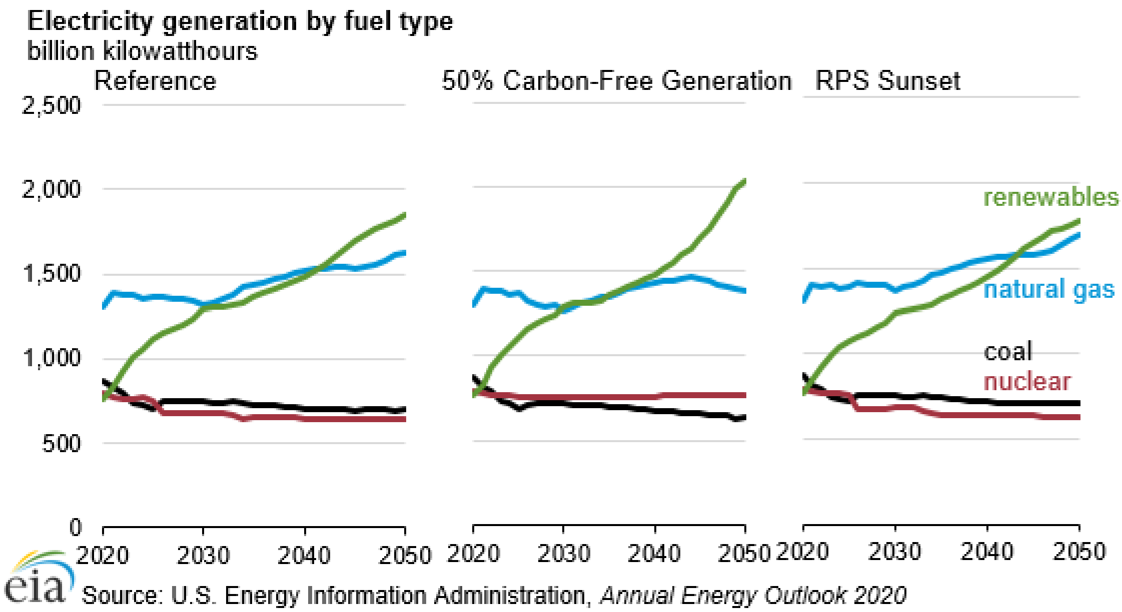
Results

Electricity generation

The assumptions in the 50% Carbon-Free Generation case and the RPS Sunset case affect the evolution of the electricity generation fuel-mix over time. Figure 1 shows electricity generation by fuel type for the Reference, 50% Carbon-Free Generation, and RPS Sunset cases.

In the 50% Carbon-Free Generation case, nuclear generation in 2050 is 124.2 billion kilowatthours (bkWh), 19.3% more than in the Reference case. There are fewer nuclear plant retirements as nuclear generation and renewables help meet the carbon-free generation requirements and limit natural gas-fired generation growth. The 50% Carbon-Free Generation case projects 244.8 bkWh (15%) less natural gas-fired generation and 57.7 bkWh (8.2%) less coal-fired generation in 2050 when compared with the Reference case.

Figure 1. Electricity generation by fuel type, 2019–2050, and changes from the Reference case in the 50% Carbon-Free Generation and RPS Sunset cases



EIA models the requirement of 50% carbon-free generation of the total share of an individual state's electricity sales, but it does not impose any requirements for the balance of generation. In the AEO2020, dispatch decisions are made on economic grounds subject to the constraints of the case. In the 50% Carbon-Free Generation case, newly added carbon-free generation displaces the most expensive generation sources first. This is largely yet-to-be-built fossil-fuel (i.e., natural gas) capacity and existing natural gas generators used to provide energy at peak demand times.

Coal-fired generation between the 50% Carbon-Free Generation case and the Reference case remains largely unchanged because coal-fired generation under the 50% Carbon-Free Generation case does not face a cost for its emitted carbon, as it would under a carbon fee policy. As a result, existing coal plants operating at relatively high capacity factors with capital costs already amortized may continue to operate if their generation is less expensive than building new natural gas-fired capacity or operating natural gas-fired generation peakers.

Projected levels of nuclear generation differ between the Reference case and the 50% Carbon-Free Generation case (Figure 2). This difference is primarily the result of nuclear plants that would otherwise retire for economic reasons in the Reference case but do not retire in the 50% Carbon-Free Generation case.[2] In the side case, they are eligible to contribute to carbon-free generation and receive additional revenue[3] for doing so, making nuclear plants more economical to operate.[4] The effect of not supplying this additional revenue is most apparent after 2025 when, in the Reference case and RPS Sunset case, nuclear generation drops by 69 bkWh in the Reference case and 78 bkWh in the RPS Sunset case, with 8.8 gigawatts (GW) of retirements projected at the end of 2025 in the Reference case. Under the 50% Carbon-Free Generation case, these plants continue to operate. Small increases in nuclear generation in the later years are due to modeled uprates of the remaining nuclear fleet, which slightly increase the overall capacity of and generation from each remaining plant.

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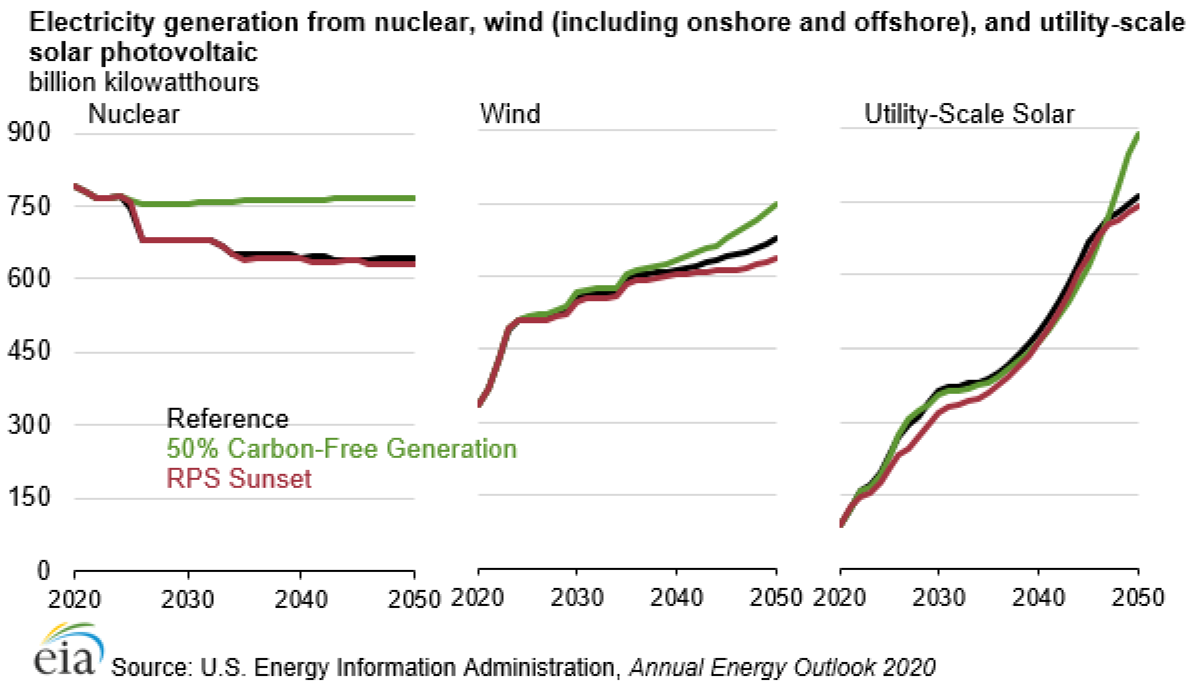
[2] No new nuclear plants are built in either of these cases.

[3] Under most existing renewable portfolio standards, qualifying generation may receive additional payments in the form of renewable energy credits (REC), or in this case carbon-free generation credits, that represent the incremental cost of the generation needed to meet the target. In proposals for national generation standards, this REC payment may be tradable among states or regions of the country, but the case analyzed here assumes that these credits are not tradable and that physical generation within each state is required.

[4] The only nuclear retirements in this case are plants that have already reported their impending retirement to EIA as of October 2019.

Figure 2. Electricity generation from nuclear, wind (including onshore and offshore), and utility-scale photovoltaic in the Reference, 50% Carbon-Free Generation, and RPS Sunset cases



As seen in Figure 2, wind generation in the 50% Carbon-Free Generation case remains unchanged relative to the Reference case until 2035, when growth accelerates and reaches a level in 2050 that is 10.3% higher than in the Reference case. Photovoltaic solar generation, including both utility-scale and end-use solar, similarly remains unchanged relative to the Reference case until 2045. After 2045, utility-scale solar generation increases until it is 16.7% more than in the Reference case in 2050.

In the RPS Policies Sunset case, there is 65.5 bkWh (3.6%) less generation from renewables than in the Reference case in 2050, which is largely offset by a 61.9 bkWH (3.8%) increase in natural gas-fired generation. In the Reference case, RPS eligible generation, as shown in Figure 3, exceeds the total renewable generation requirement through 2050 suggesting that it is largely being built for economic reasons. Under the 50% Carbon-Free Generation case, this excess renewable generation, as well as generation from existing nuclear and large-scale hydroelectric plants, is more than sufficient to meet the early year targets.

Figure 3. AEO2020 Reference case and 50% Carbon-Free Generation case total qualifying renewables generation required for combined state renewable portfolio standards and projected total generation from compliant technologies, 2020–2050

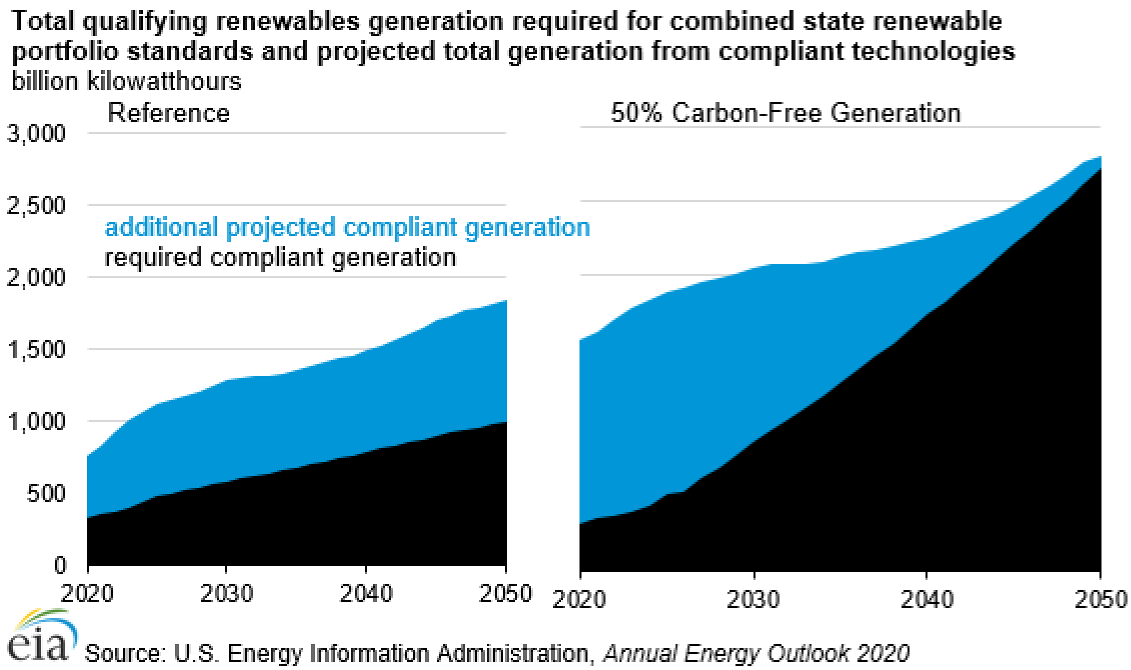
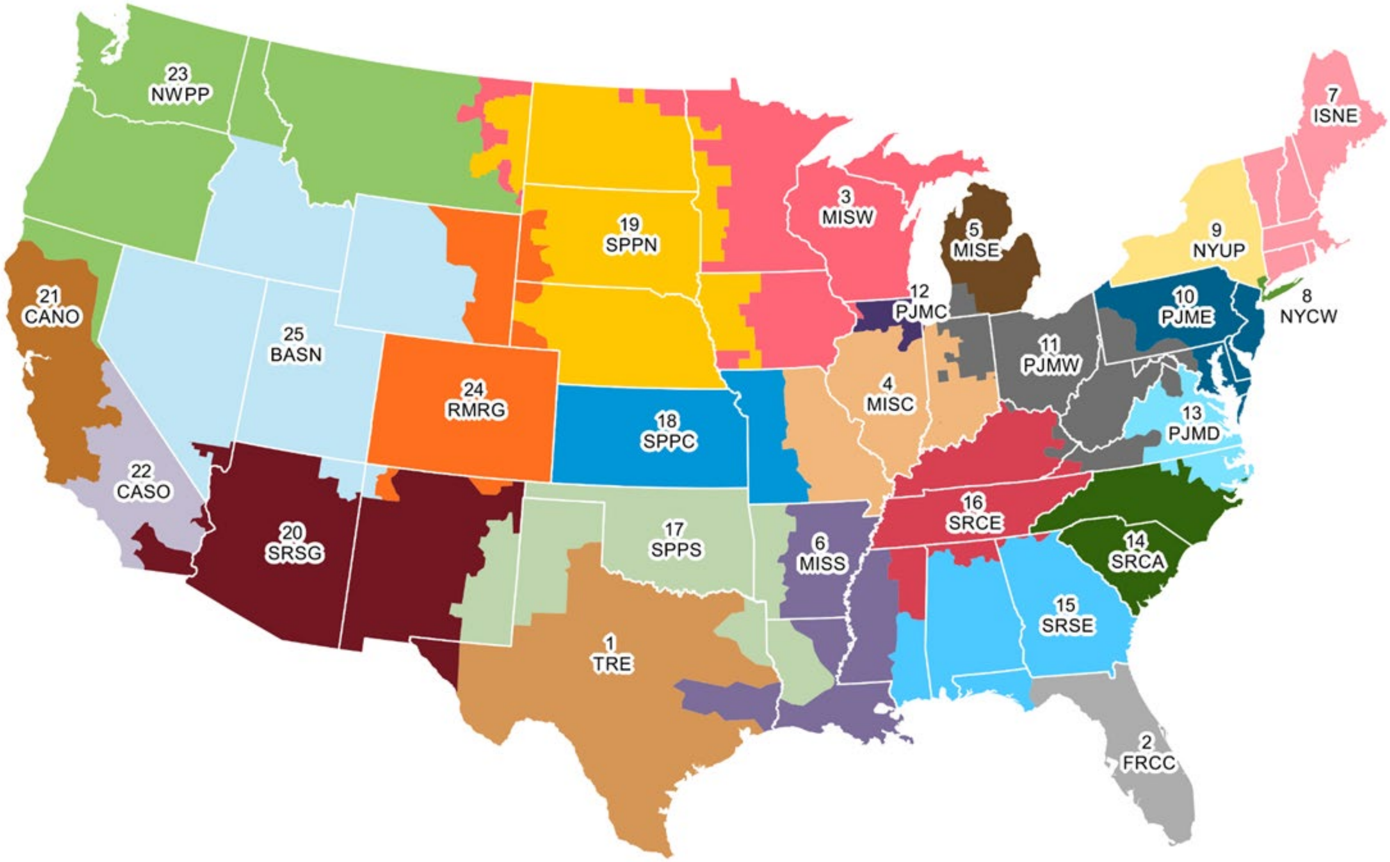


Figure 4. Electricity Market Module regions



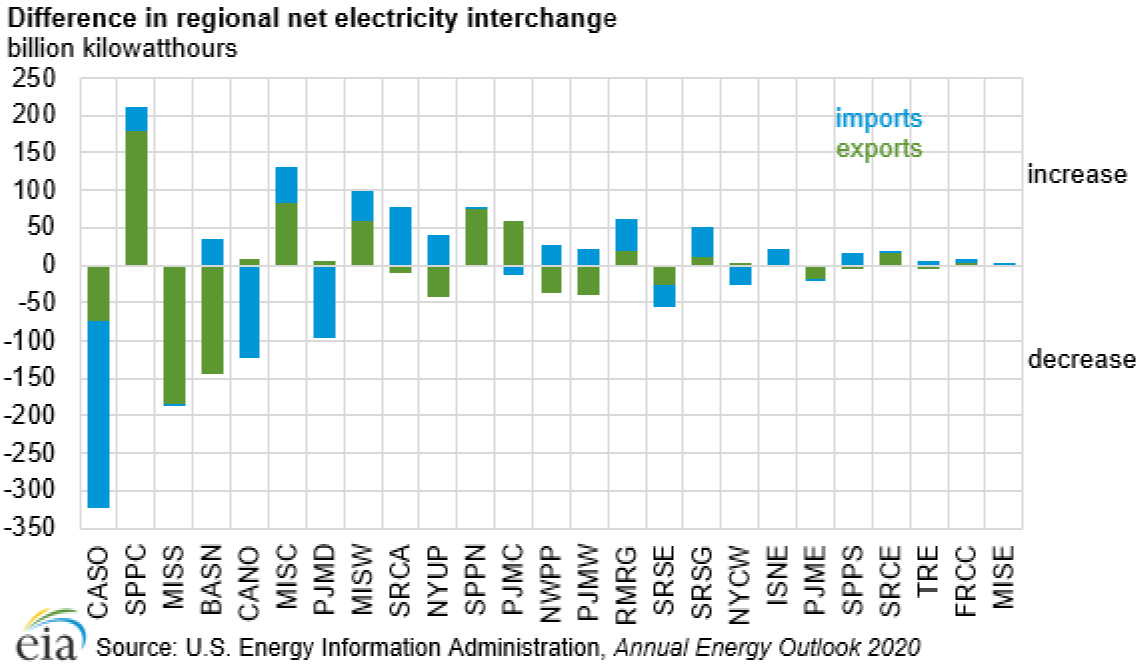
Region ID	NERC/ISO subregion	Geographic name*	Region ID	NERC/ISO subregion	Geographic name*
1- TRE	Texas Reliability Entity	Texas	14- SRCA	SERC Reliability Corporation/East	Carolinas
2- FRCC	Florida Reliability Coordinating Council	Florida	15- SRSE	SERC Reliability Corporation/Southeast	Southeast
3- MISW	Midcontinent ISO/West	Upper Mississippi Valley	16- SRCE	SERC Reliability Corporation/Central	Tennessee Valley
4- MISC	Midcontinent ISO/Central	Middle Mississippi Valley	17- SPPS	Southwest Power Pool/South	Southern Great Plai
5- MISE	Midcontinent ISO/East	Michigan	18- SPPC	Southwest Power Pool/Central	Central Great Plains
6- MISS	Midcontinent ISO/South	Mississippi Delta	19- SPPN	Southwest Power Pool/North	Northern Great Plai
7- ISNE	NPCC/ New England	New England	20- SRSG	WECC/Southwest	Southwest
8- NYCW	NPCC/NYC & Long Island	Metropolitan New York	21- CANO	WECC/CA North	Northern California
9- NYUP	NPCC/Upstate NY	Upstate New York	22- CASO	WECC/CA South	Soutshern Californi
10- PJME	PJM/East	Mid-Atlantic	23- NWPP	WECC/Northwest Power Pool	Northwest
11- PJMW	PJM/West	Ohio Valley	24- RMRG	WECC/Rockies	Rockies
12- PJMC	PJM/Commonwealth Edison	Metropolitan Chicago	25- BASN	WECC/Basin	Great Basin
13- PJMD	PJM/Dominion	Virginia			

NPCC = Northeast Power Coordinating Council, WECC = Western Electricity Coordinating Council

* Names are intended to be approximately descriptive of location. Exact regional boundaries do not necessarily correspond to state borders or to other regional naming conventions.

Source: U.S. Energy Information Administration.

Figure 5. Difference in regional net electricity interchange from Reference case by region for 50% Carbon-Free Generation case in 2050



Because EIA's assumptions in the 50% Carbon-Free Generation case are modeled on a state level rather than through implementing a single national policy, carbon-free credits (similar to renewable energy credits) cannot be used to facilitate compliance between regions with low-cost carbon-free generation options and those with higher costs. However, physical electricity trading occurs among regions and between states and is affected by the 50% carbon-free generation target by 2050.

The model allows physical electricity trading among regions and between states. Regions that have higher RPS targets in the Reference case generally see their imports decrease as neighboring regions use their own qualifying generation to meet their respective RPS goals under the 50% Carbon-Free Generation case. Regional trading changes in the 50% Carbon-Free Generation case generally involve a decrease in exports from regions that either have no or low RPS in the Reference case, because those states use the qualifying generation they produce to meet their own targets instead in the 50% Carbon-Free Generation case.

A map of the 25 regions is provided in Figure 4. Changes in imports and exports between the Reference case and the 50% Carbon-Free Generation case are shown in Figure 5. In the Southern Great Plains (SPPC), exports increase by 178 bkWh between the Reference case and the 50% Carbon-Free Generation case. In the Mississippi Delta (MISS), exports decline the most out of any region, decreasing by 185 bkWh. In Northern California (CANO) and Southern California (CASO) (comprising most of California), imports significantly decrease by 124 bkWh and 248 bkWh, respectively, between the Reference case and the 50% Carbon-Free Generation case. In Virginia (PJMD), imports also decrease by 96 bkWh between the Reference case and 50% Carbon-Free Generation case.

Electricity prices, natural gas use, and carbon

All-sector average electricity prices vary minimally, between 9.86 to 9.90 cents/kWh (2019 dollars) across the Reference case, 50% Carbon-Free Generation case, and RPS Sunset case. The deviations grow in the later years, as additional renewables penetration lowers the generation cost component, which is only partly offset by higher transmission costs (Figure 6).

Figure 6. U.S. average electricity prices in the Reference, 50% Carbon-Free Generation and RPS Sunset cases, 2019–2050

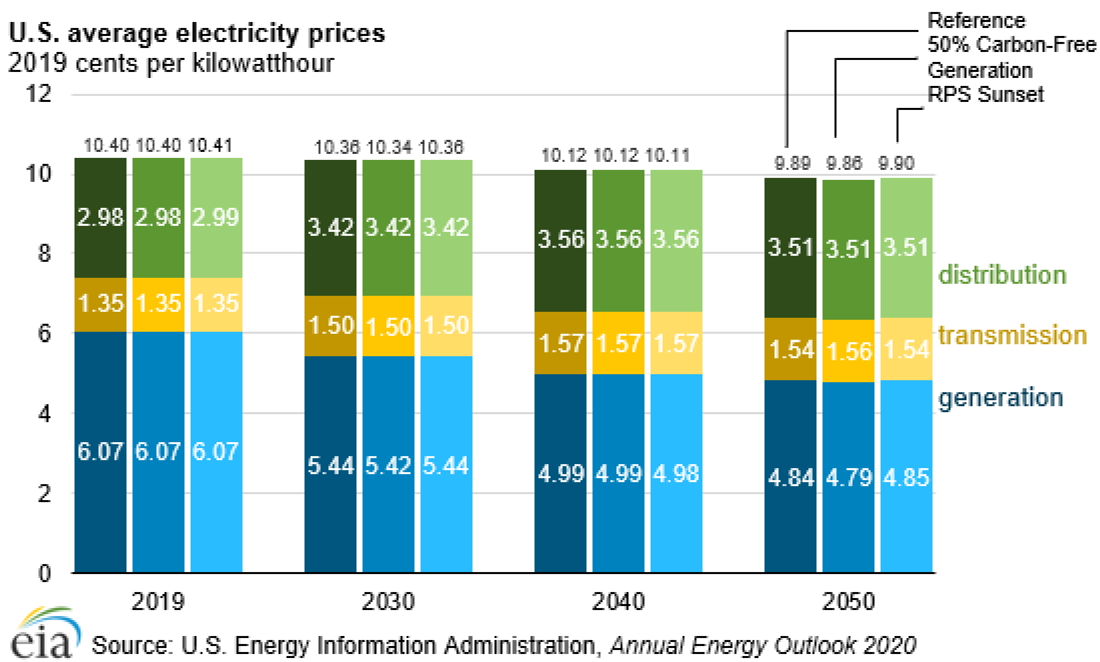
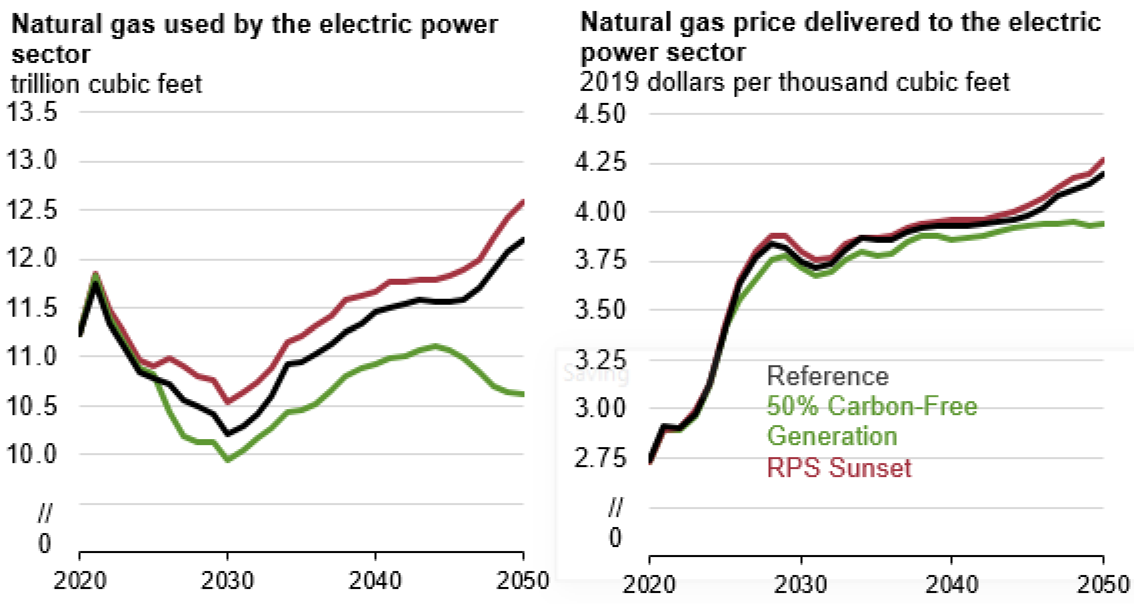


Figure 7 shows that natural gas use by the electric power sector differs across the three cases. As individual states rely on renewables and nuclear to meet their zero- or low-carbon mandates in the 50% Carbon-Free Generation case, less natural gas is used to meet electricity demand relative to the Reference case. This shift results in a 13.0% decline in natural gas used by the electric power sector in 2050 in the 50% Carbon-Free Generation case compared with the Reference case. In the RPS Sunset case, 3.2% more natural gas is used by the electric power sector compared with the Reference case by 2050.

Natural gas prices delivered to the electric power sector in the 50% Carbon-Free Generation case is $0.26 per million British thermal units (MMBtu) lower than in the Reference case. The price in the RPS Sunset case is $0.07 per MMBtu higher relative to the price in the Reference case.

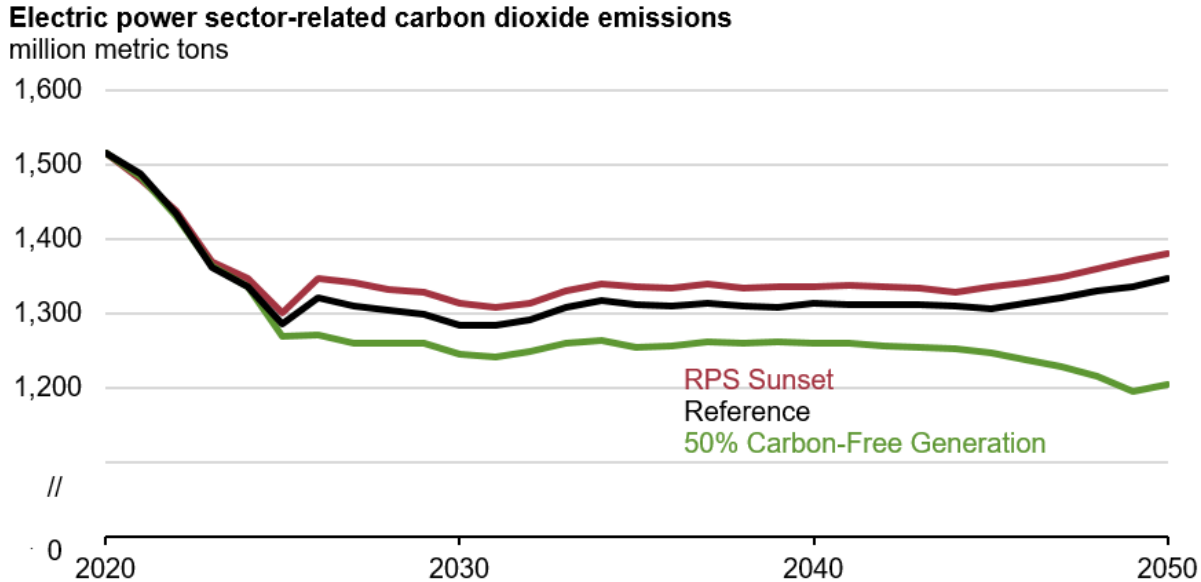
Figure 7. Natural gas consumption and price in the Reference, 50% Carbon-Free Generation, and RPS sunset cases, 2019–2050



Source: U.S. Energy Information Administration, *Annual Energy Outlook 2020*

Electricity-related CO2 emissions across all three cases diverge in 2025 (Figure 8). Before 2025, electricity-related CO2 emissions decline in all cases as a result of retiring coal-fired generating plants. The retirement of coal-fired generating plants is driven by factors such as continued low natural gas prices (compared with history), compliance with the Affordable Clean Energy Rule (ACE Rule), and slow growth in electricity demand. After the ACE Rule takes full effect by 2025, electricity-related CO2 emissions increase slightly in the Reference case and RPS Sunset case because the remaining coal-fired generating plants are more efficient but have higher utilization rates, and new natural gas capacity is added to compensate for the drop in capacity from the retired coal plants under the ACE Rule. In 2050, CO2 emissions from the electricity sector in the 50% Carbon-Free Generation case are 10.5% lower than in the Reference case because additional zero- or low-carbon generation resources contribute a higher share of generation, compared with the Reference case, which projects more generation from natural gas. Continued use of natural gas and less utilization of renewables and nuclear generation in the RPS Sunset case results in electricity-related CO2 emissions that are 2.6% higher relative to the Reference case by 2050.

Figure 8. Electricity generation-related carbon dioxide emissions in the electric power sector in the Reference, 50% Carbon-Free Generation and RPS Sunset cases, 2019–2050



Source: U.S. Energy Information Administration, *Annual Energy Outlook 2020*

Appendix 1. Renewable Portfolio Standard requirements in the Reference case and 50% Carbon-Free Generation case

State[1]	Reference case target	50% Carbon-Free Generation by 2050	Reference case qualifying technologies	50% Carbon-Free Generation qualifying technologies added
AZ	15% by 2025	50% by 2050	Geothermal electric, solar thermal, solar PV, wind, biomass, hydroelectric, landfill gas, fuel cells, offshore wind	Nuclear, carbon capture and sequestration
CA	60% electricity generation by 2030, 100% carbon-free by 2045	Maintains Reference case path	Geothermal electric, solar thermal electric, solar photovoltaics, wind biomass, municipal solid waste, landfill gas, hydroelectric Carbon-free includes nuclear, carbon capture and sequestration	No additional technologies
CO	30% by 2020 for investor-owned utilities, 20% by 2020 for large electric cooperatives, 10% by 2020 for other cooperatives and municipal utilities serving more than 40,000 customers	50% by 2050, for all utilities	Geothermal electric, solar thermal, solar PV, wind, biomass, hydroelectric, landfill gas, fuel cells	Nuclear, carbon capture and sequestration
CT	48% by 2030 (44% renewables, 4% efficiency and combined heat and power)	50% by 2050	Geothermal electric, solar thermal, solar PV, wind, biomass, hydroelectric, landfill gas, fuel cells, offshore wind	Nuclear, carbon capture and sequestration
DE	25% by 2026	50% by 2050	Geothermal electric, solar thermal, solar PV, wind, biomass, hydroelectric, landfill gas, fuel cells, offshore wind	Nuclear, carbon capture and sequestration
DC	100% by 2040	Maintains Reference case path	Geothermal electric, solar thermal, solar PV, wind, biomass, hydroelectric, landfill gas, fuel cells, offshore wind	No additional technologies
IL	25% by 2026 (3,000 megawatts [MW] solar and 1,300 MW wind)	50% by 2050	Geothermal electric, solar thermal, solar PV, wind, biomass, hydroelectric, landfill gas, offshore wind	Nuclear, carbon capture and sequestration
IA	105 MW of eligible renewable resources	50% by 2050, starting in 2025	Solar thermal, solar PV, wind, biomass, hydroelectric, municipal solid waste, landfill gas, offshore wind	Nuclear, carbon capture and sequestration, geothermal
MA	35% by 2030 (and an additional 1% per year thereafter)	Maintains Reference case path. MA path ends at 50% by 2050	Geothermal electric, solar thermal, solar PV, wind, biomass, hydroelectric, landfill gas, fuel cells, offshore wind	No additional technologies
MD	50% by 2030	Maintains reference case path	Geothermal electric, solar thermal, solar PV, wind, biomass, hydroelectric, landfill gas, fuel cells, offshore wind	No additional technologies

State[1]	Reference case target	50% Carbon-Free Generation by 2050	Reference case qualifying technologies	50% Carbon-Free Generation qualifying technologies added
ME	100% by 2050	Maintains Reference case path	Geothermal electric, solar thermal, solar PV, wind, biomass, hydroelectric, landfill gas, fuel cells, offshore wind	No additional technologies
MI	15% by 2021, with specific new capacity goals for utilities that serve more than one million customers	50% by 2050 for all utilities regardless of size	Geothermal electric, solar thermal, solar PV, wind, biomass, hydroelectric, landfill gas, offshore wind	Nuclear, carbon capture and sequestration
MN	31.5% by 2020 (Xcel), 26.5% by 2025 (other investor-owned utilities), or 25% by 2025 (other utilities)	50% by 2050 for all utilities	Geothermal electric, solar thermal, solar PV, wind, biomass, hydroelectric, landfill gas, offshore wind	Nuclear, carbon capture and sequestration
MO	15% by 2021	50% by 2050, starting in 2025	Geothermal electric, solar thermal, solar PV, wind, biomass, hydroelectric, landfill gas, fuel cells, offshore wind	Nuclear, carbon capture and sequestration
MT	15% by 2015	50% by 2050, starting in 2025	Geothermal electric, solar thermal, solar PV, wind, biomass, hydroelectric, landfill gas, fuel cells, offshore wind	Nuclear, carbon capture and sequestration
NC	12.5% by 2021 for investor-owned utilities, 10% by 2018 for municipal and cooperative utilities	50% by 2050, starting in 2025, applies to all utilities	Geothermal electric, solar thermal, solar PV, wind, biomass, hydroelectric, landfill gas, offshore wind	Nuclear, carbon capture and sequestration
NH	24.8% by 2025	50% by 2050	Geothermal electric, solar thermal, solar PV, wind, biomass, hydroelectric, landfill gas, fuel cells, offshore wind	Nuclear, carbon capture and sequestration
NJ	50% by 2030 with the solar carve-out reaching 5.1% in 2021 before gradually decreasing to 1.1% by 2033	Maintains Reference case path	Geothermal electric, solar thermal, solar PV, wind, biomass, hydroelectric, landfill gas, fuel cells, offshore wind	No additional technologies
NM	80% renewable generation by 2040, 100% carbon-free by 2045	Maintains Reference case path	Geothermal electric, solar thermal, solar PV, wind, biomass, hydroelectric, landfill gas, fuel cells, offshore wind Carbon-free includes nuclear	No additional technologies
NV	50% renewable generation by 2030, 100% carbon-free by 2050	Maintains Reference case path	Geothermal electric, solar thermal, solar PV, wind, biomass, hydroelectric, landfill gas, fuel cells, offshore wind Carbon-free includes nuclear	No additional technologies
NY	70% renewable generation by 2030, 100% carbon-free by 2040.	Maintains Reference case path	Geothermal electric, solar thermal, solar PV, wind, biomass, hydroelectric, landfill gas, fuel cells, offshore wind Carbon-free includes nuclear	No additional technologies

State[1]	Reference case target	50% Carbon-Free Generation by 2050	Reference case qualifying technologies	50% Carbon-Free Generation qualifying technologies added
OH	8.5% renewable energy resources by 2026	50% by 2050	Geothermal electric, solar thermal, solar PV, wind, biomass, hydroelectric, landfill gas, fuel cells, offshore wind	Nuclear, carbon capture and sequestration
OR	50% by 2040	Maintains Reference case path	Geothermal electric, solar thermal, solar PV, wind, biomass, hydroelectric, landfill gas, offshore wind	No additional technologies
PA	18% by 2020	50% by 2050, starting in 2025	Geothermal electric, solar thermal, solar PV, wind, biomass, hydroelectric, landfill gas, fuel cells, offshore wind	Nuclear, carbon capture and sequestration
RI	38.5% by 2035	50% by 2050, starting in 2035	Geothermal electric, solar thermal, solar PV, wind, biomass, hydroelectric, landfill gas, fuel cells, offshore wind	Nuclear, carbon capture and sequestration
TX	5,880 MW by 2015	50% by 2050, starting in 2025	Geothermal electric, solar thermal, solar PV, wind, biomass, hydroelectric, landfill gas, offshore wind	Nuclear, carbon capture and sequestration
VT	75% by 2032	Maintains Reference case path	Geothermal electric, solar thermal, solar PV, wind, biomass, hydroelectric, landfill gas, fuel cells, offshore wind	No additional technologies
WA	100% carbon-free by 2045	Maintains Reference case path	Geothermal electric, solar thermal, solar PV, wind, biomass, hydroelectric, landfill gas, fuel cells, offshore wind	No additional technologies
WI	10% by 2015	50% by 2050, starting in 2025	Geothermal electric, solar thermal, solar PV, wind, biomass, hydroelectric, landfill gas, fuel cells, offshore wind	Nuclear, carbon capture and sequestration
All other states[2]	Several states included here have current renewable portfolio goals, which are non-binding and therefore not modeled in the Reference case	50% by 2050, starting in 2025	NA	Geothermal electric, solar thermal, solar PV, wind, biomass, hydroelectric, landfill gas, offshore wind, nuclear, carbon capture and sequestration

[1] Although Hawaii has a 100% renewable generation by 2045 Renewable Portfolio Standard that is implicitly accounted for in previous work, the generation in Alaska and Hawaii are not included in this analysis as the generation mix from these states is determined outside of the NEMS model because of the unique electricity supply markets in these states.

[2]*All other states* includes AL, AR, FL, GA, ID, IN, KS, KY, LA, MS, ND, NE, OK, SC, SD, TN, UT, VA, WV, WY