3002026229

IMPACTS OF INFLATIONARY DRIVERS AND UPDATED POLICIES ON U.S. DECARBONIZATION AND TECHNOLOGY TRANSITIONS

TABLE OF CONTENTS

UNIQUE FEATURES OF EPRI ANALYSIS

- Integrated modeling framework representing energy supply, conversion, storage, and demand
- Broad coverage of existing and emerging technologies informed by EPRI technological cost and performance assessments
- Detailed temporal, spatial, and technological resolution to capture system operations and investments
- Energy demand model includes differences across households and businesses to account for both behavioral and financial drivers of technology adoption

EXECUTIVE SUMMARY

The world has changed since the U.S. announced in April 2021 the goal to reduce economy-wide greenhouse gas (GHG) emissions by 50% below 2005 levels by 2030 ("50x30") and achieve net-zero economy-wide emissions by 2050 ("2050 Net-Zero"). EPRI has previously published detailed analysis of 50x30 pathways (*2021 EPRI 50x30 white paper*) and strategies to achieve net zero by 2050 (*2022 EPRI Net-Zero white paper*). As energy leaders examine strategies to a net-zero future, they must confront new challenges and balance goals related to energy affordability, reliability, equity, and security.

Rapid developments spanning energy technologies, markets, and policy are impacting the pathways to a low-carbon future, particularly the challenges in achieving the near-term, interim 2030 target. This analysis updates earlier EPRI analysis of 50x30 pathways accounting for new challenges and near-term uncertainties that have arisen since 2021, including:

- Increased costs and delays for energy technologies due to supply chain issues and inflation;
- Federal incentives in the Inflation Reduction Act (IRA) and updated state-level policies;
- Higher costs of some fossil fuels due to global geopolitical disruptions; and
- Rebound in economy-wide carbon dioxide (CO_2) emissions amid easing pandemic restrictions.

The need to update so many scenario variables over just a couple years is a reminder of the value of regular re-assessments along with adaptive frameworks for investments and policies.

The updated analysis uses EPRI's REGEN energy-economic model (https://us-regen-docs.epri.com/), which offers several unique features (box). Scenario analysis applies this integrated modeling framework to examine how recent changes could impact the U.S.'s ability to reach the 50x30 target, including an updated reference scenario with current state and federal policies leading up to and including IRA incentives.

Key Findings

1. **The rate and scope of change must increase to meet 2030 targets, but core decarbonization pathways remain similar.**
   - **Accelerating 4x Reduction: Reaching a 50% by 2030 target means rapidly increasing decarbonization.** Due to the 2021 rebound in emissions, achieving the U.S. target would require immediate and sustained economy-wide

GHG reductions at four times the historical rate, even faster than the three times rate outlined in EPRI's 2021 assessment.

- **Countering Emerging Challenges: IRA could offset certain inflationary and supply chain impacts.** New government funding could alter investment outlooks for key technologies such as wind and solar power, carbon capture, battery storage, existing nuclear power, electric vehicles, and heat pumps.
- **Enabling Proven Solutions: Significant energy system improvements are essential to fully leverage clean electricity, energy efficiency, and rapid electrification (Figure 1).** Realizing rapid emissions reductions without compromising reliability, affordability, or security demands reexamining energy production, transmission, delivery, use, and oversight. Supporting the transition would involve innovation and investment in grid delivery and controls systems, market designs and rate structures, and grid operations as well as planning processes and tools. As in the 2021 analysis, the power sector is positioned to lead all others in total emissions reductions (Figure 2).

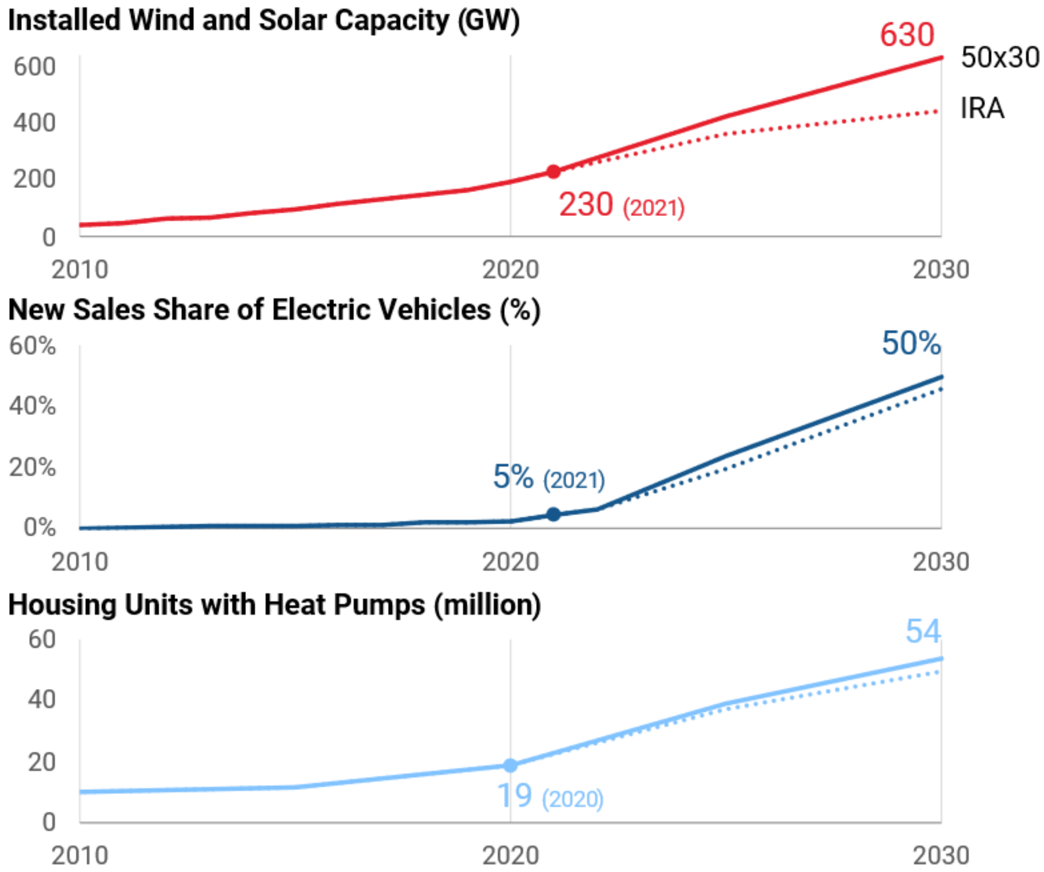

Figure 1
Summary of low-emitting technology deployment over time. *Values are shown for the Higher Costs scenarios with current policies including IRA incentives ("IRA" in dotted lines) and scenarios that combine 50x30 policies with IRA incentives ("50x30" with solid lines).*[1]

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[1] More detailed scenario descriptions are provided in the "Scenarios Assumptions" section and appendix. The Higher Costs scenarios assume that fuel prices and supply-side costs remain elevated, while Lower Costs scenarios assume that costs decline to reach their reference projections by 2030. Impacts on other power sector resources (e.g., nuclear, carbon-captured-equipped capacity, energy storage) are discussed in the "Results" section.

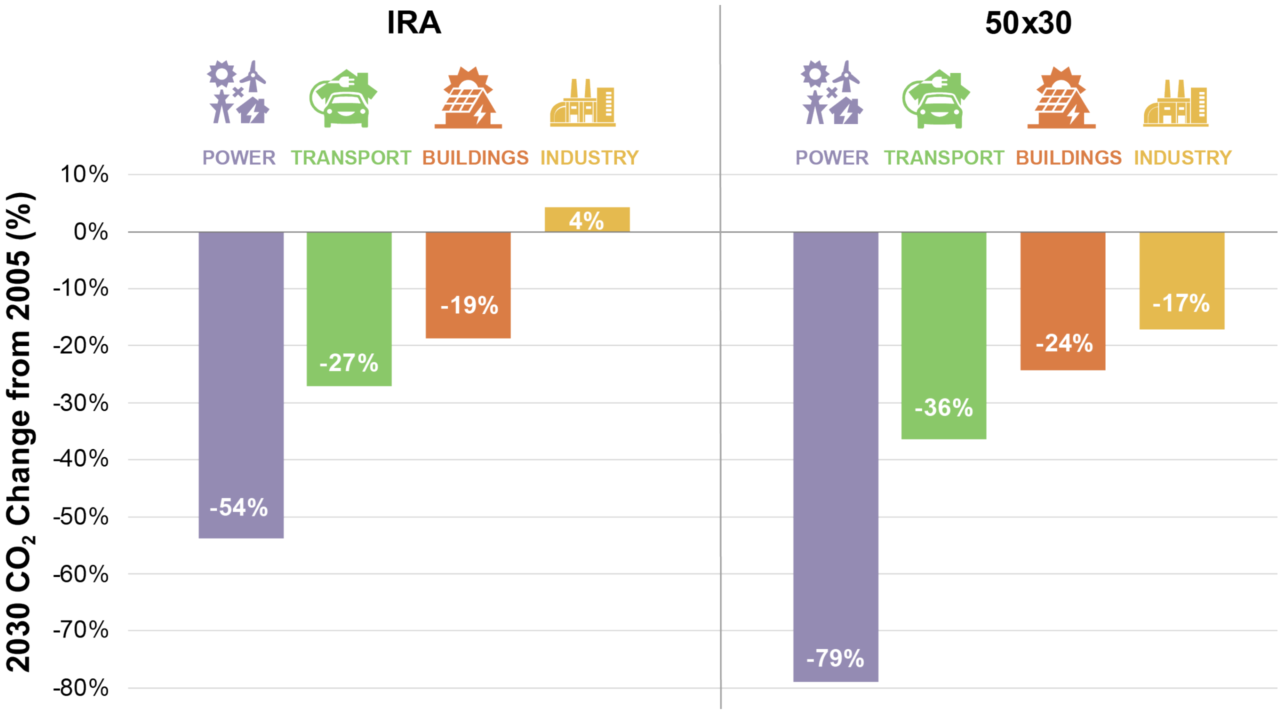

Figure 2
2030 U.S. energy CO_2 emissions change from 2005 by sector. *Values are shown for the Higher Costs scenarios with current policies including IRA incentives ("IRA" on left) and scenarios that combine 50x30 policies with IRA incentives ("50x30" on right).*

2. **Existing government incentives and policies alone are insufficient to reach the 50% target.**
   - **Driving Clean Electricity: Existing policies and government incentives could drive 290-330 GW of new low-carbon capacity by 2030 and nearly double those capacity additions by 2035.** IRA incentives support technologies experiencing rapid deployment in recent years (e.g., wind, solar, batteries) and accounting for large shares of emissions-free electricity in the current mix (e.g., existing nuclear). State and federal policies may catalyze new markets for technologies beyond 2030 (e.g., carbon capture, new nuclear, hydrogen, biofuels). Larger IRA-supported transformations could occur after 2030 due to extensions of technology-neutral production and investment credits, continued cost declines for low-emissions technologies, and more stringent state policies. These changes involve large accelerations in clean energy technology deployment relative to historical levels (Figure 1), including capacity additions in the power sector that are more than twice their current annual levels.
   - **Closing the Gap: IRA incentives and other existing policies could reduce economy-wide emissions 33% by 2030 from 2005 levels.** Moving from 33% to 50% reductions by 2030 requires an additional billion metric tons of CO_2 mitigation per year. This gap may be filled by regulatory, subnational, private sector, and consumer actions, which could contribute toward the 50x30 goal. Future federal regulations, state policies, and company pledges could help, particularly if IRA lowers the cost of adopting lower-emitting options.
   - **Powering Electrification: IRA incentives make half of new passenger vehicle sales electric by 2030 in addition to improving the economics of other electric end-use options such as heat pumps.** By 2030, load grows 12-13% over current levels in scenarios with IRA and 18-22% with 50x30 policies. A combination of clean electricity, electrification, and energy efficiency, incented by IRA, could lower annual net energy costs by $180 to $790 per household, compared to current levels.

- **Improving Air Quality: Economy-wide emissions of SO_2 and NO_x are nearly halved by 2030 in many scenarios in this analysis.** Air quality benefits from electrification and decarbonization could be distributed widely across households and regions, including socially and economically disadvantaged communities that are disproportionately impacted by air pollution and energy cost burdens today. Historical and projected SO_2 reductions largely come from the power sector, while lower NO_x, CO, and VOC come from transportation.

3. **Widespread changes to energy supply, demand, infrastructure, and policy underpin progress toward the 2030 goal.**

- **Mitigating Cost and Deployment Challenges: High supply and fuel costs increase economy-wide energy service costs by up to $250 billion annually in 2030.** Delays from policy implementation, siting, and permitting are already complicating the transition, and additional cost pressures and myriad deployment challenges threaten the 2030 target's feasibility.[2] Minimizing transition costs requires clarity on technology options, certainty on development processes and timing, and access to the materials and workforce needed to build and operate new resources. By 2030, electrician labor demand could increase by 10% to support accelerated electric vehicle charging deployment under a 50x30 scenario.
- **Deploying New Technologies at Scale: Many low-emitting supply- and demand-side technologies must scale simultaneously to reach the 50x30 goal (Figure 1).** Achieving a 50% reduction would involve technology development and deployment at unprecedented speed. Multiple new technologies would deploy at scale for the first time as part of adding 570-670 GW of low-carbon capacity through 2030. This would require accelerating deployment from historical and current levels, more than doubling 2021's annual record of solar, wind, and battery storage deployment each year through 2030. Transmission expansion is also a key element of decarbonization scenarios, as inter-regional transfer capacity increases by nearly 10% in IRA and 50x30 scenarios by 2030. Extensive industry and government collaboration would be required to condense the typically decades-long energy technology commercialization process to a matter of years.
- **Delivering the Value of Optionality: Technological diversity and optionality can lower the costs of meeting the 2030 target by 50%.** This reduction in costs depends on retaining the option to build new natural gas and carbon-capture-equipped capacity and operate existing nuclear, expanding supporting infrastructure such as electricity transmission, and decreasing costs for renewables, energy storage, and emerging technologies. If new natural gas, carbon capture, nuclear, and transmission are restricted, the costs of meeting the 2030 goal could double.

Interpreting the 50x30 Modeling Results

The power sector is challenged to preserve and improve affordability, security, reliability, and resiliency through the transition to a low-carbon economy. Minimizing the cost and duration of the clean energy transition rests on demonstrating the electric sector's continued ability to reliably serve society's energy needs, while deploying emerging technologies. Key considerations for stakeholders and decision-makers include the following:

- **Prepare today for new low-carbon resources beyond 2030:** EPRI has partnered with GTI Energy to accelerate low-carbon energy technology deployments required for deep decarbonization through the Low-Carbon Resources Initiative (LCRI). EPRI's recent LCRI analysis of approaches to economy-wide net zero by 2050 complements this work by providing longer-term views of decarbonization. The analysis shows that the path to 2030 does not look the same as strategies after 2030. Innovation and investment to deploy new clean energy technologies beyond 2030 are already underway. Advancement of technologies such as low-emissions hydrogen, advanced nuclear, carbon capture utilization and storage, and others that may play a significant role to achieve net zero by 2050 must occur in parallel with deploying existing clean energy technologies for achieving GHG reductions by 2030.
- **Strengthen electric system reliability and resiliency through the transition:** Energy system modeling for identifying technology deployment pathways does not include all detailed reliability requirements or advances in associated operational reliability capability and market structures. The EPRI REGEN model used for this analysis balances hourly supply and demand with a reserve margin for each model region subject to technical, market, and policy constraints. However, more detailed analyses of resource adequacy, reliability, stability, and resiliency are important with retirements of existing fossil capacity, additions of variable and energy-limited supply resources, and end-use electrification. Several previous and ongoing research efforts across EPRI have investigated these issues in

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[2] The term "inflationary drivers" is used in this report to describe a range of factors leading to upward pressure on energy prices, including supply chain constraints, rising demand, materials and fuel costs, labor market adjustments, and interest rates.

detail, including the 2021 white paper on "Enhancing Energy System Reliability and Resiliency in a Net-Zero Economy" (3002023437), research on reliability under deep decarbon-ization (3002025269), EPRI's Resource Adequacy Initiative (https://www.epri.com/resource-adequacy), and EPRI's In-tegrated Strategic System Planning (ISSP) Initiative (https://www.epri.com/issp).

- **Develop the workforce to support the transition:** These supply- and demand-side transitions have key implications for workforce development. A complementary white paper based on 2021 50x30 scenario outputs illustrates potential power sector impacts (3002023229).
- **Overcome supply chain constraints on technology deployment:** EPRI published a white paper in 2022 to investigate generation and storage technology supply chain risks to support decarbonization (3002023228). EPRI has follow-on research underway to understand potential supply chain costs and constraints.
- **Advance grid design to account for changing climate and weather extremes:** EPRI launched a new, multi-year initiative, Climate READi™: Power (REsilience and ADaption initia-tive), to convene global thought leaders and industry stake-holders to develop a comprehensive and consistent approach to physical climate risk assessment (https://www.epri.com/re-search/sectors/readi).

Important Caveats on Model Interpretation

The scenarios in this report provide cost-optimized pathways for energy supply and demand given alternate assumptions about technology costs, markets, and policies. Model results should be interpreted as indicative rather than predictive due to uncertain-ties associated with policy implementation, siting and permitting lags, scaling supply chains and workforce, readiness for emerg-ing technologies, and ramping up infrastructure investments (e.g., transmission). Difficult-to-model dynamics associated with implementation, technological change, economic incidence of subsidies, and policy feedbacks imply that model results should be understood as indicative that the scenario-specific policy drivers create strong economic incentives for adoption and that non-financial barriers may shape the rate of real-world deployment relative to modeled results.

INTRODUCTION

Background

In April of 2021, the U.S. announced a new target to reduce economy-wide net greenhouse gas (GHG) emissions 50-52% by 2030 from 2005 levels. Later that year, EPRI completed an analysis of potential economically efficient pathways to achieve this target as part of the updated U.S. Nationally Determined Contribution (NDC) under the Paris Agreement.[3] Since then, several new challenges and near-term uncertainties have emerged, including:

- **Emissions rebound:** Emissions have rebounded since 2020, due to increased activity as COVID-19 pandemic restrictions eased. This means reaching a 50% economy-wide target by 2030 entails faster decarbonization compared to EPRI's 2021 assessment. This implies approximately quadrupling the historical rate of decarbonization (Figure 3) from an average economy-wide GHG reduction of 1.1 percentage points per year from 2005-2021 to 4 percentage points annually to reach the 50x30 target.
- **Inflationary drivers and supply chain issues:** Increases in materials, shipping, labor, and fuel costs create uncertainty about prospective technology costs. From 2021 to 2022, costs for construction labor increased 4%, materials increased 34%, and specialty metals and rare earth elements increased as well.[4]
- **Elevated fossil fuel prices:** Supply chain disruptions, Russia-Ukraine war, and pandemic recovery increased fossil fuel prices. Energy costs have been a large driver of inflation in the U.S., and despite recent declines, significant uncertainty in mid- and long-run fuel price outlooks remains.

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[3] See Bistline, et al. (2021). "Strategies and Actions for Achieving a 50% Reduction in U.S. Greenhouse Gas Emissions by 2030." EPRI Report 3002023165 (link). For a multi-model comparison, see Bistline, et al. (2022). "Actions for Reducing U.S. Emissions at Least 50% by 2030." Science, 376(6596): 922-924 (link).

[4] See Kern, Bedilion, and Gorgian (2022). "2022 Energy System Technology Cost and Performance Summary: Market Trends & Technology Insights." EPRI Report 3002024231 (link).

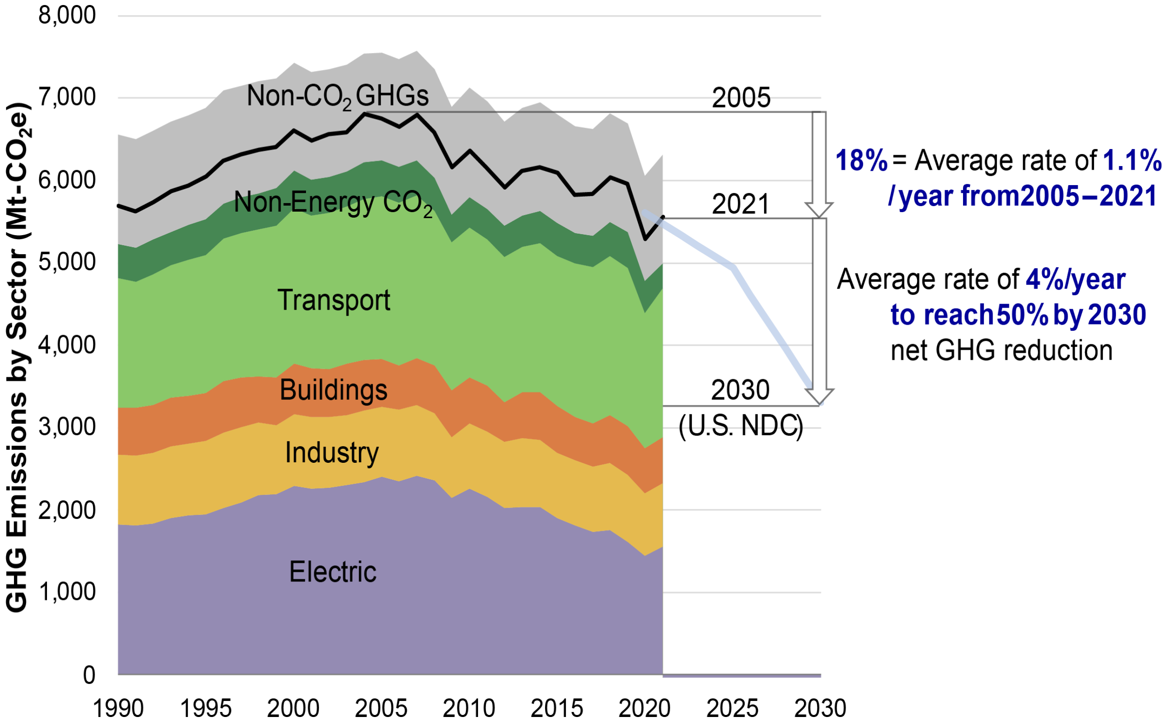

Figure 3

Greenhouse gas emissions trends by sector relative to future targets. *Historical levels come from U.S. EPA's "[Inventory of U.S. Greenhouse Gas Emissions and Sinks](#)" with 2021 data from the U.S. EIA's "[Monthly Energy Review](#)." "Other CO_2" refers to non-energy CO_2 emissions. The gray line shows U.S. NDC targets.*

In addition to these major shifts since the 2021 EPRI analysis, a fourth factor poised to play an important role is policy. The Inflation Reduction Act (IRA) of 2022, Infrastructure Investment and Jobs Act, CHIPS and Science Act, and changes to state policies[5] have increased incentives for decarbonization. IRA adopts an investment-based approach to climate policy and primarily leverages tax credits, estimated to provide over $350 billion for clean energy investments across nearly every segment of the energy sector, including:

- **Power:** Extensions of production and investment credits through at least 2032 (becoming technology-neutral in 2025), increased flexibility and transferability of credits, and production credits for existing nuclear.
- **Industry and Fuels:** Extension of credits for captured CO_2, production credits for clean hydrogen, and extension of credits for advanced energy projects.
- **Buildings:** Residential clean energy credits, and energy efficiency credits for homes and commercial buildings.
- **Transportation:** Credits for clean vehicles, sustainable aviation fuels, and extensions of incentives for biofuels.

However, while IRA has been lauded as the most significant climate bill in U.S. history, its complexity means that its impacts on emissions and energy systems are uncertain.

Objectives and Scope

This analysis addresses the following topics:

- How do recent macroeconomic and policy changes impact the challenge to reduce U.S. economy-wide emissions 50% by 2030? What are the sectoral shares of reductions across electricity, industry, buildings, and transport for achieving the 2030 target?
- What are the implications of updated policies and incentives on technology pathways, investments, and costs?

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[5] State-level policies and incentives in the modeling are summarized in the full documentation (link), which are based on the DSIRE database (link). This analysis focuses on IRA incentives and changes to state clean energy and emissions policies given their larger anticipated changes in near-term emissions and energy system outcomes.

- How could uncertainty about supply-side costs and fuel prices shape the actions needed to reach the 2030 target?
- What do these pathways imply for customers and communities?

This analysis illustrates implications of alternate pathways for reaching the 50x30 target and how intervening factors over the past year have changed the nature of the challenge. The analysis also models scenarios with current policies, including the updated and expanded IRA incentives, to assess the emissions gap in reaching the 2030 climate target.

EPRI published several companion white papers following last year's 50x30 report that provide deep dives on key topics in navigating this transition, including on enhancing reliability (3002023437), workforce development (3002023229), and supply chains (3002023228). The Low-Carbon Resources Initiative (LCRI) also released a report examining longer-term transitions to meet net-zero emissions by midcentury (3002024882).

SCENARIOS AND MODELING

This section summarizes the modeling framework and scenario assumptions for this analysis.

US-REGEN Model Overview

The analysis uses EPRI's U.S. Regional Economy, Greenhouse Gas, and Energy (REGEN) model. This framework integrates a detailed model of power sector capacity expansion and an economic model of non-electric sectors that represents end-use technology tradeoffs (Figure 4). EPRI technology performance and assessment research underpins this energy system modeling.

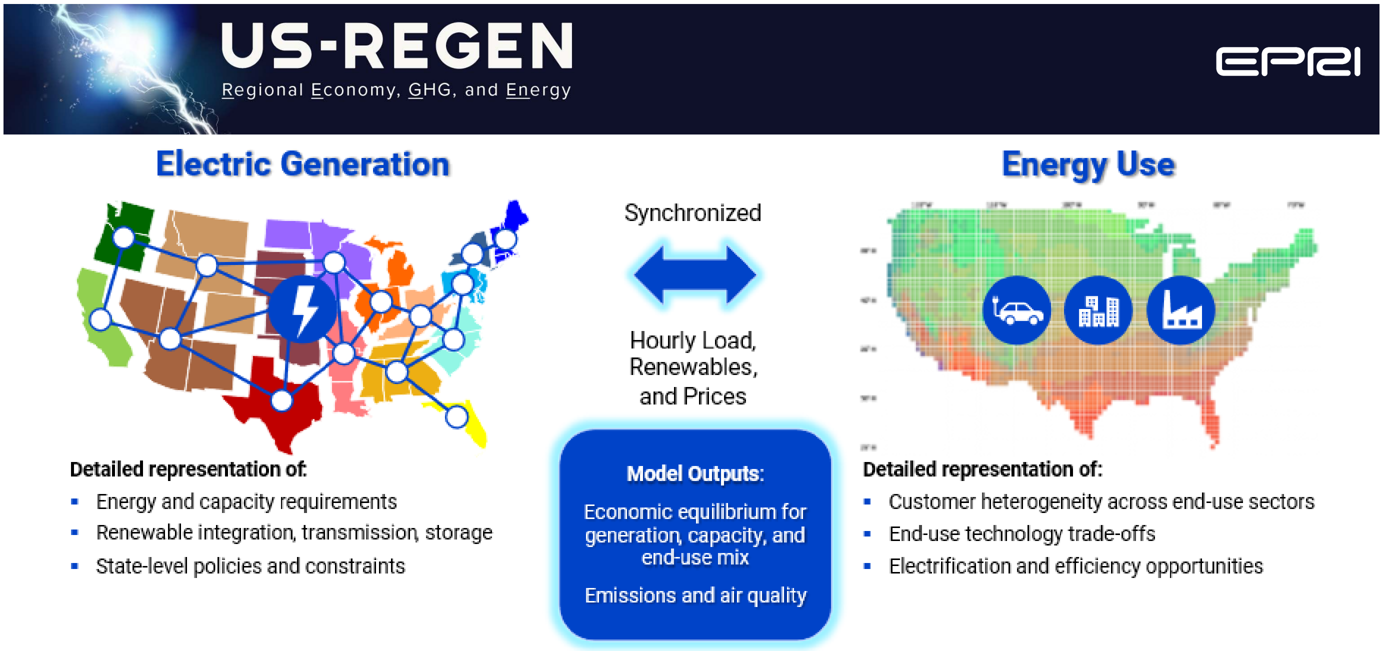


Figure 4

Overview of EPRI's US-REGEN energy systems model. *Full model documentation can be found at https://us-regen-docs.epri.com/. Recent reports and peer-reviewed publications using US-REGEN can be found at https://esca.epri.com/.*

Scenario Assumptions

The four core scenarios for the analysis vary assumptions about the policy environment and inflationary drivers, as shown in Table 1. There are two scenarios that investigate policy uncertainty:

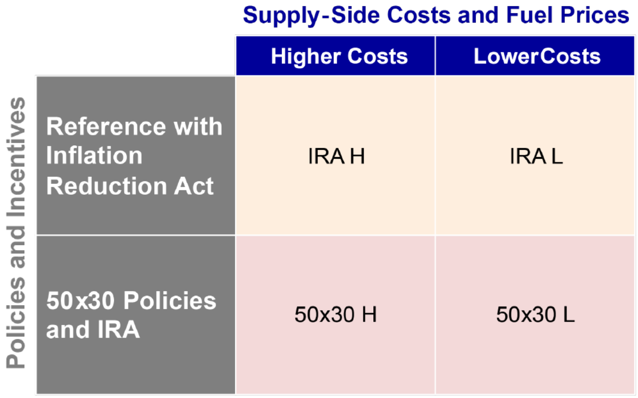
- **Reference scenario with the Inflation Reduction Act (“IRA”):** This scenario is designed to capture the economic incentives in the U.S. energy sector following the passage of the IRA. The outputs of this scenario represent the potential evolution of the energy sectors through 2050, based on input assumptions about technology and resource costs, end-user behavioral assumptions, and existing state and federal policies, as described in the documentation.[6]
- **50x30 scenario with IRA incentives (“50x30”):** This scenario starts with the same set of input assumptions as in the reference scenario with IRA, but adds the 50x30 goal to reduce net GHG emissions by 50% by 2030 relative to 2005. The 50x30 goal is represented by capping economy-wide emissions in 2030.[7] This scenario also adds the NDC goal “to reach 100 percent carbon pollution-free electricity by 2035,” which is implemented by requiring the electricity sector to achieve net-zero CO_2 emissions by 2035.

In addition to varying the policy environment, scenarios also examine alternate assumptions about the persistence of near-term inflationary drivers, including technological costs and fuel prices:

- **Higher Costs:** This scenario assumes that supply-side costs and fuel prices remain elevated through 2030. Figure 5 shows historical trends in capital costs of four key electric sector technologies and how the Higher Costs scenario assumes that costs remain at these 2022 levels through 2030.[8]
- **Lower Costs:** This scenario assumes that supply-side costs decline linearly to reach their reference projections by 2030 (i.e., returning to pre-pandemic trends). Fuel prices in this scenario start at their current levels and decline initially before gradually rising (natural gas prices in 2030 are about $4/MMBtu instead of $6/MMBtu in the Higher Costs scenario).

Table 1

Scenario definitions and abbreviations. *Supplemental power-focused sensitivities are discussed in latter sections.*



	Supply-Side Costs and Fuel Prices	
Policies and Incentives	Higher Costs	LowerCosts
Reference with Inflation Reduction Act	IRA H	IRA L
50x30 Policies and IRA	50x30 H	50x30 L

Figure 5 illustrates how 2022 year-on-year cost increases are highest for battery storage. With these recent inflationary trends, costs for solar, wind, and battery storage are similar to 2018 and 2019 levels but are still much lower than a decade ago. Note that, in all cases, what matters most is the *change in cost in real dollar terms* (i.e., after accounting for broader inflation).

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[6] The appendix includes further discussion of the REGEN representation of IRA. Note that the complexity of IRA provisions imply that the simplifications discussed in the results sections and appendix make additional implementation sensitivities an important area of follow-on research. Both scenarios include announced and planned capacity additions for power sector resources through Form EIA-860 data.

[7] This goal is implemented in REGEN as an economy-wide emissions cap but also could be interpreted as a suite of policies and incentives at federal and subnational levels consistent with a least-cost approach for achieving the 50x30 goal. Carbon payments in these scenarios are assumed to be distributed on a lump-sum basis to households.

[8] 2022 cost data come from: Kern, Bedilion, and Gorgian (2022). “2022 Energy System Technology Cost and Performance Summary: Market Trends & Technology Insights.” EPRI Report 3002024231 (link). Since these scenarios were developed in mid-2022, prices for several materials and components have declined (link) or remained flat (link), and supply-side costs are projected to decline for many technologies in the years ahead (e.g., solar, battery storage).

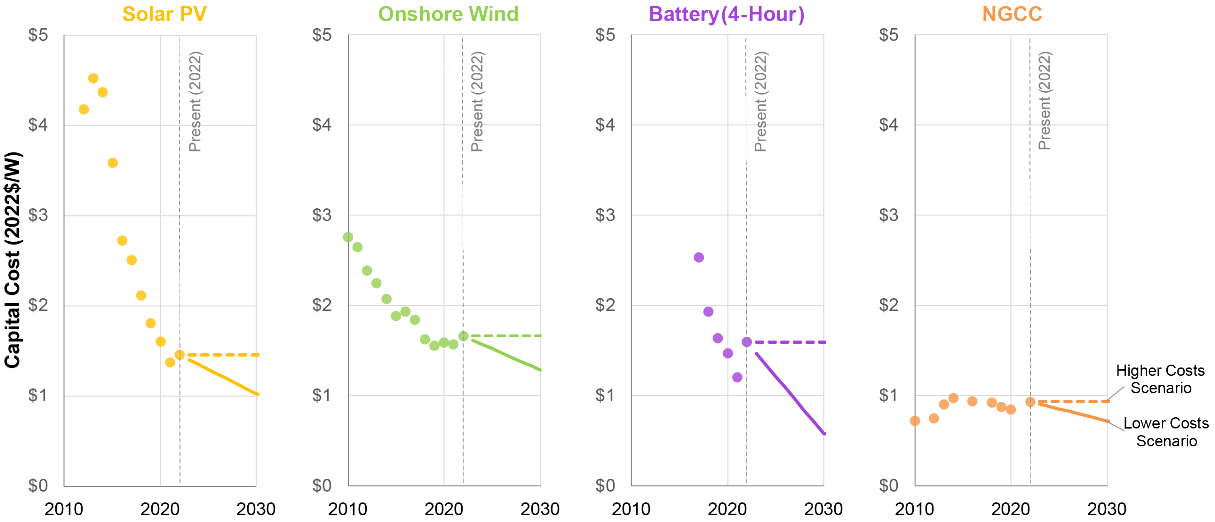

Figure 5

Capital costs of key electric sector generation and energy storage technologies over time. *Values are shown in real 2022 U.S. dollar terms before accounting for IRA subsidies. Historical data are shown in dots through 2022, the Higher Costs scenario is shown in the dashed line, and the Lower Costs scenario is shown in the solid line. Historical values are based on data from the Lawrence Berkeley National Laboratory for wind (link) and solar (link) as well as BloombergNEF for battery storage (link). 2022 costs are based on EPRI Report 3002024231 (link)[9] and show total capital required (i.e., including total plant costs, owner's costs, and financing). Solar capacity is shown in $/W$_{AC}$ terms.*

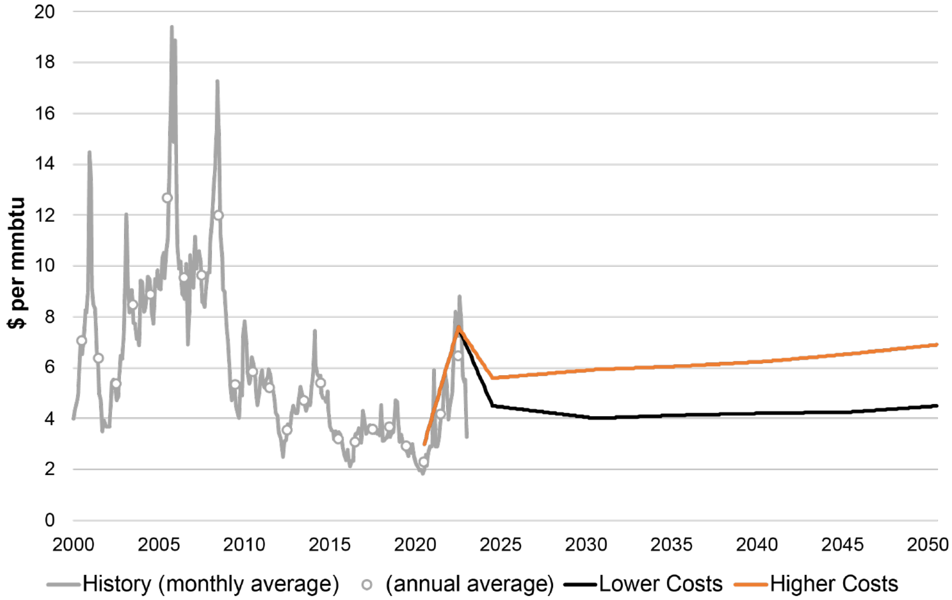

Figure 6

Natural gas price trajectories relative to historical levels. *Prices are shown in real 2022 U.S. dollar terms.*

These scenarios also vary fuel prices. In the Lower Costs scenario, fuel prices decline to 2024 and remain flat (in real terms) to 2030, as shown for natural gas prices in Figure 6. The Higher Costs scenario assumes an initial decline with rising costs (in real dollar terms) through 2030, when the difference between the scenarios spans $2/MMBtu. Petroleum and coal prices similarly vary in these scenarios.[10]

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[9] Solar costs are based on utility-scale monofacial c-Si with single-axis tracking. Battery costs are based on a 100 MW lithium-ion system with four-hour duration.

[10] Vehicle cost escalation is incorporated by applying markups to all new vehicle purchases consistent with the observed 12-month percentage change between June 2021 and June 2022 for new vehicle relative to all items in the Consumer Price Index (11.4% - 9.1% = 2.3%). The Higher Costs scenario assumes these markups persist through 2030, and the Lower Costs scenario assumes this markup reaches 0% by 2030.

The analysis uses EPRI inputs for technology cost and performance assumptions and U.S. Energy Information Administration assumptions on economic growth, fuel prices, and service demand.

Additional power sector sensitivities are discussed in later sections.

S-REGEN's scope includes energy CO_2 emissions only. Land sink, non-CO_2 GHGs, and non-energy CO_2 reductions are assumed to evolve similar to other 50x30 studies.[11] These assumptions about mitigation outside of the energy systems mean that a 50% reduction in energy CO_2 relative to 2005 would be needed to reach the 50x30 target (Figure 7).

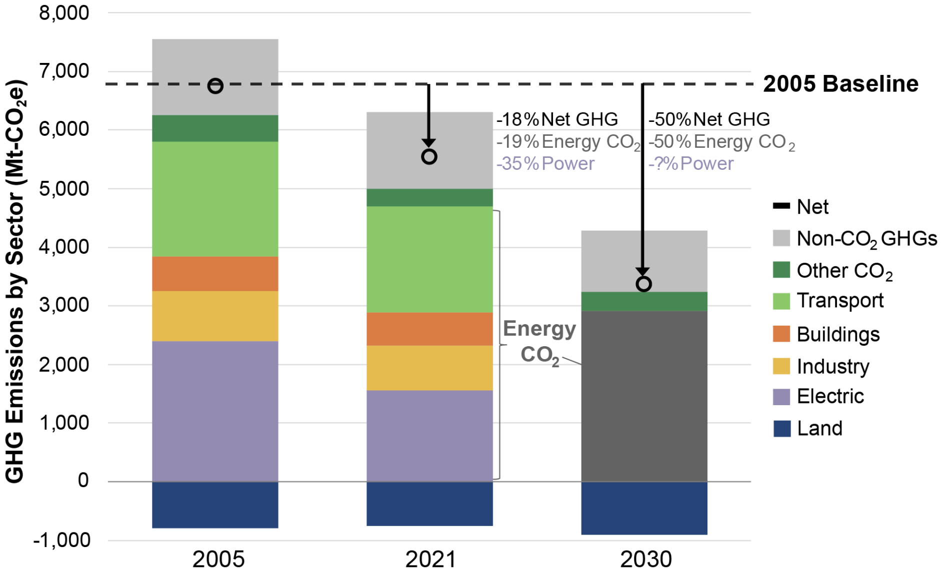

Figure 7

Historical greenhouse gas emissions by sector and 2030 target. *Historical levels come from U.S. EPA's "[Inventory of U.S. Greenhouse Gas Emissions and Sinks](#)" with 2021 data from the U.S. EIA's "[Monthly Energy Review](#)." "Other CO_2" refers to non-energy CO_2 emissions.*

Caveats

Scenarios in this report provide cost-optimized pathways for energy supply and demand with alternate assumptions about technology costs, markets, and policies. Model results should be interpreted as indicative rather than predictive due to uncertainties associated with policy implementation, siting and permitting lags, scaling supply chains and workforce, readiness for emerging technologies, and ramping up infrastructure investments (e.g., transmission). Difficult-to-model dynamics associated with implementation, technological change, and policy feedbacks imply that model results should be understood as indicative that the scenario-specific policy drivers create strong economic incentives for adoption and that non-financial barriers may shape the rate of real-world deployment relative to modeled results.

Examples of omitted dynamics include:

- IRA scenarios include other current policies but do not account for potential IRA-induced changes in federal regulations, state policies, and company pledges. Federal funding from IRA may accelerate such policies and pledges, which may help to close the 2030 emissions gap.
- Irreducible uncertainties about the future pace technological change, demographic changes, global energy markets, macroeconomic conditions, and policy implementation mean that decisions today are made under uncertainty about the future. Such hedging behavior is not captured in the cost-optimizing pathways examined here, nor are fuel diversity benefits arising from energy security and other drivers. In addition, IRA incentives combined with those in the Infrastructure Bill may drive additional innovation to make longer-term emissions reductions and amplify IRA impacts.
- Non-economic barriers and various frictions may slow the rate of real-world deployment relative to modeled results. These barriers could include expanding networks and infrastructure to support growth, siting and permitting, interconnection

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[11] See Bistline, et al. (2022). "Actions for Reducing U.S. Emissions at Least 50% by 2030." *Science*, 376(6596): 922-924 ([link](#)).

times,[12] scaling up the workforce, as well as the availability and cost of critical materials. Various provisions in the IRA and Infrastructure Bill are aimed at aligning financial incentives toward overcoming such non-financial barriers, but their effectiveness remains uncertain.

- This modeling balances hourly supply and demand with a reserve margin for each model region subject to technical, market, and policy constraints. The analysis does not explicitly represent detailed ancillary services markets or operational dynamics (e.g., inertia). As discussed in the Executive Summary, EPRI has undertaken more detailed analysis focusing on resource adequacy, reliability, and resiliency. In addition, load management is incorporated through deferrable electric vehicle charging, but additional work would be valuable on the broader role that flexible demand could play in future energy systems, including uncertainties associated with transport-related electricity demand profiles.
- It is challenging to model the supply chain impacts of IRA (and the CHIPS and Science Act). On one hand, these bills will provide significant new funding in domestic supply chains. On the other hand, onshoring requirements and siting delays could create frictions in supply chains that are already under stress.
- Deploying supply- and demand-side technologies with lower technology readiness levels takes appropriate financial incentives and time to scale from pilot projects and first-of-a-kind installations to nth-of-a-kind and multiple gigawatt levels by 2030. Examples of power sector technologies with more limited deployment to date but with considerable economic incentives through IRA and Infrastructure Bill include carbon capture and sequestration (CCS), advanced nuclear reactors, hydrogen, and long-duration energy storage.

These limitations suggest that results should be used for qualitative insights rather than as quantitative predictions about how the future will unfold.

RESULTS

Economy-Wide Emissions

The IRA, combined with other existing policies and technology trends, could drive energy CO_2 emissions down 32-33% below 2005 levels by 2030, positioning the U.S. within about 1 Gt-CO_2 of the 50x30 target (Figure 8). Larger reductions of 45-46% are achieved by 2035 under IRA. Scenarios that reach the 50x30 target lower emissions by 63-64% by 2035.[13] Inflationary pressures in the energy system and fuel costs have more limited CO_2 impacts, as there are countervailing impacts on wind and solar deployment from higher capital costs and natural gas prices.

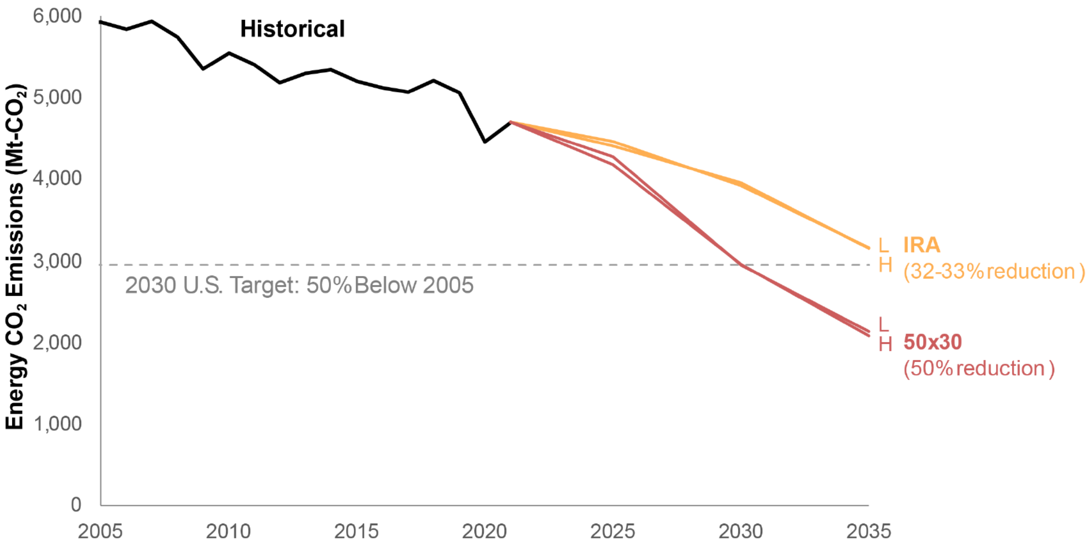

Figure 8

U.S. energy CO_2 emissions over time. *Historical levels come from U.S. EPA's "Inventory of U.S. Greenhouse Gas Emissions and Sinks."*

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[12] A recent study by LBNL indicates that interconnection wait times are increasing, with the typical time from a connection request to commercial operation rising "from ~2.1 years for projects built in 2000-2010 up to ~3.7 years for those built in 2010-2021" (link).

[13] For analysis of reaching an economy-wide net-zero CO_2 target by midcentury, see EPRI (2022). "Net-Zero 2050: U.S. Economy-Wide Deep Decarbonization Scenario Analysis." EPRI Report 3002024882 (link).

As found by EPRI's 2021 report and the broader energy system decarbonization literature, power, electrification, and efficiency-driven emissions reductions are key to reaching the 2030 target. The power sector and transportation lead emissions declines in the IRA and 50x30 scenarios (Figure 9). IRA and existing policies account for two-thirds of the work needed to hit the 2030 target. Additional reductions, potential from regulatory, subnational, company actions, and innovation, would be needed to fill the remaining gap.

Many low-emitting supply- and demand-side technologies must scale, all simultaneously, which requires accelerating deployment from historical and current levels. IRA encourages deployment and lowers (perceived) costs. The largest CO_2 reductions arise from accelerating deployment of low-emitting electricity and vehicles.

Figure 9

U.S. energy CO_2 emissions change from 2005 by sector. *Values are shown for the Higher Costs scenario. Historical levels come from U.S. EPA's "Inventory of U.S. Greenhouse Gas Emissions and Sinks."*

Additional reductions from all sectors help to meet the 2030 target (Figure 10). The largest absolute reductions beyond those in the IRA scenarios come from the electric sector, which accounts for about 70% of 2030 reductions. Industry and buildings have smaller reductions due to their higher service demand growth and higher abatement costs.

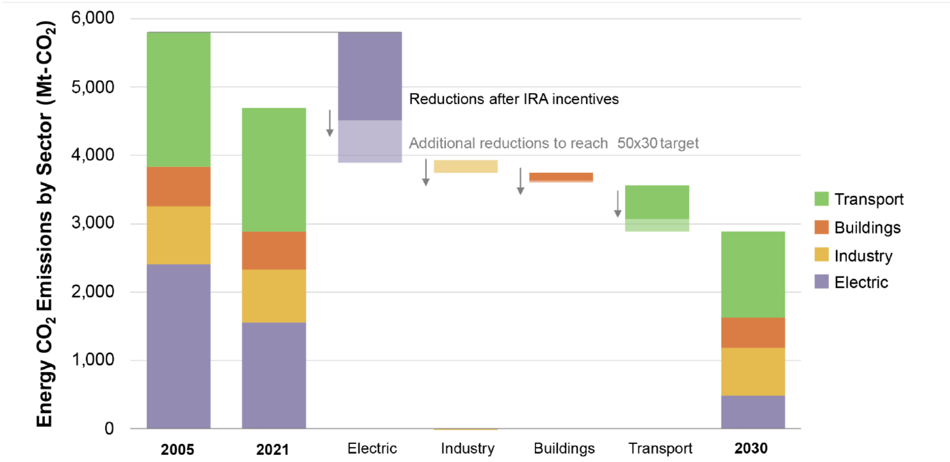

Figure 10

Waterfall of U.S. energy CO_2 emissions from 2005 by sector. *Darker colors show emissions reductions in the IRA scenario by 2030 relative to 2005 (some of these reductions have already happened, while others are due to technology and policy trends before considering IRA), and incremental changes to meet the 50x30 target are shown in lighter colors. Values are shown for the Higher Costs scenario.*

In addition to CO_2 reductions, these energy system transitions also lower emissions of SO_2, NO_x, and others. Reductions in these pollutants have benefits for air quality and human health.[14] Electrification yields immediate emissions reductions that increase over time as electricity decarbonizes. There are substantial reductions in these criteria pollutant emissions relative to 2015 in the reference scenario with IRA (i.e., the difference between the dashed and solid lines in each panel) and policy-induced changes in the 50x30 scenarios relative to the reference (i.e., the difference between the solid and dotted lines). SO_2 emissions are lower in the Lower Costs scenario, because lower natural gas prices displace SO_2-intensive coal generation in the power sector.

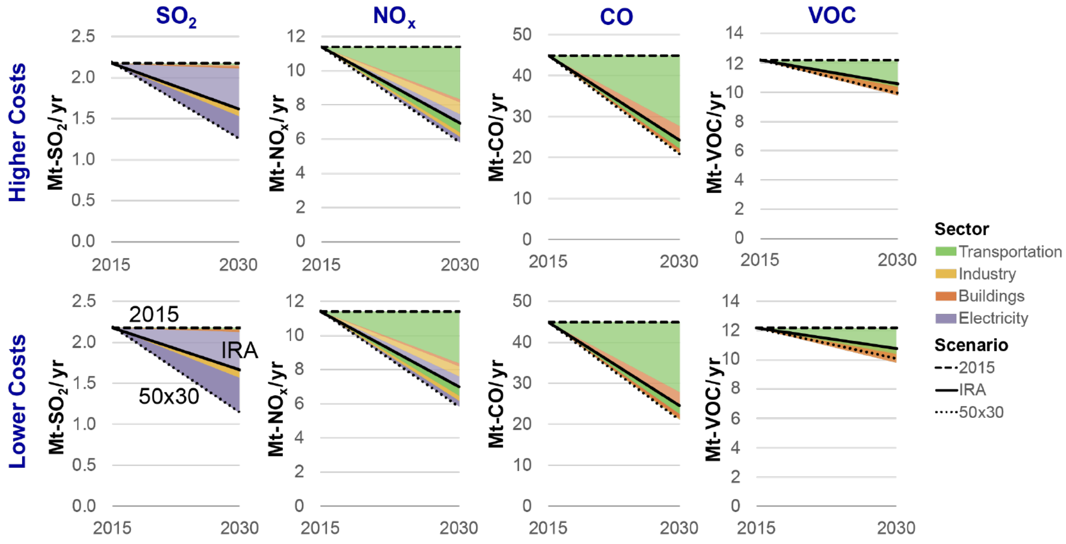

Figure 11

Economy-wide emissions from 2015 and 2030 by sector, pollutant (columns), and scenarios (rows). *The top black line in each panel represents emissions changes in the reference scenario with IRA, and the lower dotted line represents policy changes under the 50x30 scenario.*

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[14] Earlier EPRI-led research quantifies the substantial air quality benefits from electrification: Knipping, Bistline, and G. Blanford (2020). "Efficient Electrification in California: Assessment of Energy System and Air Quality Impacts." EPRI Report 3002019494 (link). Bistline, et al. (2022). "Economy-Wide Evaluation of CO_2 and Air Quality Impacts of Electrification in the United States." *Nature Communications* (link).

Figure 11 illustrates how historical and projected SO_2 reductions largely arise from the power sector (specifically from coal generation). In contrast, changes in NO_x, CO, and VOC from 2015 are dominated by reductions in transportation, with industry, buildings, and power playing relatively smaller roles. However, these other sectors contribute a larger share of projected emissions reductions over time in the 50x30 scenarios relative to the IRA scenarios.

Energy Services and Household Costs

To compare costs associated with pathways to the 2030 target, we first look at economy-wide energy service costs. Energy service costs include retail energy costs (e.g., costs of generating and delivering electricity to retail customers), tax credit payments, and expenditures for purchase and maintenance of energy-using equipment by households and businesses. Figure 12 compares these expenditure categories across scenarios in 2030 and provides a comparison with current spending.

On an absolute basis, energy service expenditures are projected to increase through 2030 from current levels; however, these increases (2-20%) are lower than GDP and service demand increases of the same period (24% and 12%, respectively), which leads to declining costs on a normalized basis. Annual spending on energy services increases $70 billion to $300 billion from current levels by 2030 under IRA and $370 billion to $620 billion under 50x30 policies. Cost increases are partially offset by tax credits through IRA. Although these subsidies are small on a relative basis, government outlays on tax credits can be large on an absolute basis:

- Under the IRA scenarios, 2030 annual fiscal costs of tax credits total about $60B/yr for end-use incentives (mostly for transport) and $20B to $30B/yr for power sector incentives, which are discussed in detail in the next section.
- Under the 50x30 scenarios, given the large-scale deployment of IRA-subsidized resources to meet emissions targets, tax credit outlays rise to $80B to $90B/yr for end-use sectors and $50B to $60B/yr for the power sector.

Figure 12

Economy-wide energy service costs by category and scenario. *Values are shown net of carbon payments in the 50x30 scenarios assuming 100% recycling and before subtracting subsidies. "Non-Energy" represents all non-fuel-related expenditures (e.g., equipment, maintenance).*

Non-energy costs of buying and maintaining equipment is a large share of current spending, as nearly half of the $3 trillion annually spent on energy services is devoted to transport. These non-energy costs still dominate in 2030, though expenditure shares from end-use fuels increase, especially in the Higher Costs scenarios. High supply costs could increase energy service costs by up to $250B annually in 2030.

Figure 13 illustrates how household energy expenditures vary by scenario. There is a reduction in total energy service costs per household as a result of electrification, even with higher electricity prices and spending. This finding aligns with the economy-wide service costs from Figure 12, where electric system costs rise from $340B/year now to $440B to $700B/year in 2030. Under IRA scenarios, net costs decline by $180 to $790 per household from current levels (depending on inflationary drivers). Under 50x30 scenarios, fuel spending increases but may be offset by recycled carbon payments. Note that this figure only includes direct energy expenditures by households but does not show increases in costs for non-households (which would impact prices for goods and services purchased by households) or non-energy costs, which are shown in Figure 12.

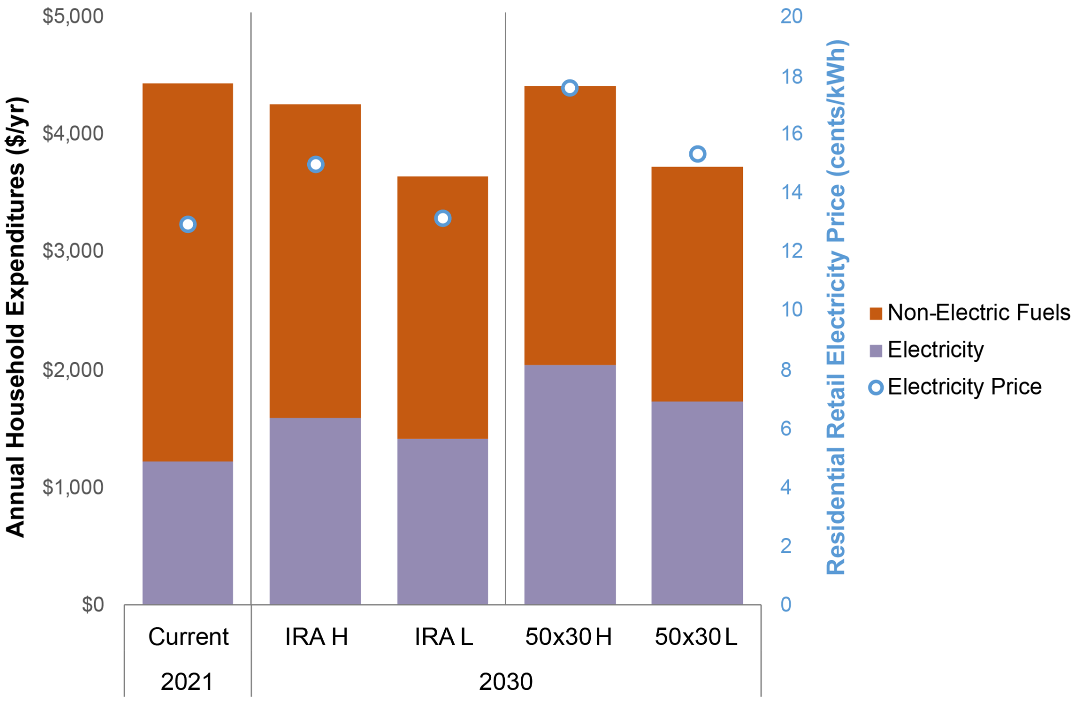

Figure 13

Household energy expenditures by scenario. *Non-electric fuel costs are shown net of carbon payments, which are assumed to be distributed on a lump-sum basis to households. Electricity prices implicitly include IRA subsidies and carbon pricing. Average residential retail electricity prices are shown on the secondary axis.*

Electric Sector

IRA and 50x30 policies entail a rapid buildout of the grid in all scenarios (Figure 14). 2021 was a record year for solar, wind, and battery storage deployment, with 31 GW of new capacity.[15] The extended tax incentives in IRA are projected to increase low-emitting electricity deployment even further with 29-33 GW/yr of wind, solar, storage, and CCS-equipped capacity through 2030 and retain existing nuclear capacity. Model results suggest that reaching 50x30 targets could bring more wind and solar deployment, more CCS (especially for new natural gas-fired units), and accelerated coal retirements, which nearly doubles low-emitting capacity deployment to 57-67 GW/yr. Alternate pathways, varying limits on emerging technologies and other assumptions, are explored later in the section, especially since longer lead times of CCS, new nuclear, and other emerging technologies may limit

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[15] The ten-year average from 2010 to 2020 was 13 GW/yr.

their contributions by 2030. These sensitivities illustrate how the costs of meeting the 2030 target are lower if the option to build new natural gas-fired capacity is retained, if supporting infrastructure such as electricity transmission can expand, and with innovation that drives down the cost of renewables, energy storage, and emerging technologies.

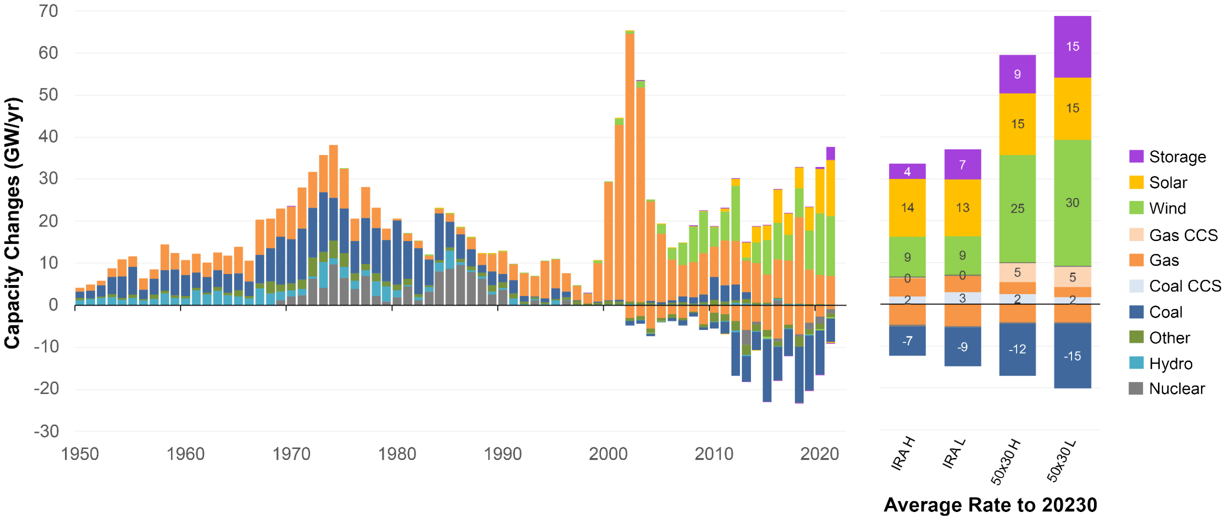

Figure 14

Historical and projected capacity additions and retirements by technology. *Projections show the average annual build rate between 2021 and 2030 in the reference electrification scenario ("50x30"). Historical values through 2021 come from Form EIA-860 data.*[16]

Inflationary drivers have offsetting effects on wind and solar deployment, which lead to higher capital costs of these technologies but also higher fuel prices. Higher natural gas prices, in particular, put upward pressure on electricity prices and consequently increase revenues for new renewables and other assets. In absolute and percentage terms, battery storage deployment is the resource that is most impacted by inflationary drivers, given the magnitudes of observed cost inflation (Figure 5).

CCS retrofits for existing coal are projected to be economic for some capacity, primarily due to the enhanced 45Q tax credits. The updated bonus rate of \$85/t-CO_2 combined with the higher emissions intensities for these units translate to levelized subsidies of about \$70 to \$90/MWh (Appendix, Figure 30). Even with assumed CCS retrofit costs of \$2,800/kW to \$3,900/kW, a 500 MW unit could receive \$3-4 billion in subsidies over the 12-year eligibility period.[17] New natural gas-fired capacity with CCS is primarily Allam cycle plants that use supercritical CO_2 power and capture 98% of their CO_2. While CCS is projected as economic in some scenarios with up to 70 GW of new gas with CCS and coal retrofits in cases that reach the 50x30 target, non-economic barriers may constrain such deployment by 2030, including technology maturity, liability risks, and political economy considerations. Sensitivities precluding CCS described later in this section address how these barriers could impact deployment of other technologies.

Policies and inflationary drivers impact power sector technology shares (Figure 15). IRA and 50x30 policies lead to higher low-emitting electricity shares.[18] Larger IRA transformations occur by 2035 due to lower wind and solar costs, higher fuel costs, and more stringent state policies. Under IRA scenarios, low-emitting generation shares reach 79-81% in 2035 (58-60% in 2030). Under 50x30 scenarios, these shares are 76-78% by 2030 and 97-99% by 2035 (due to these scenarios incorporating the net-zero-by-2035 power sector constraint in this period).

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[16] Both scenarios include announced and planned capacity additions for power sector resources through Form EIA-860 data.

[17] These scenarios do not explicitly account for potential permitting concerns, execution risks, regulatory risks, and long-term liability issues.

[18] Low-emitting generation shares include renewables, nuclear, and CCS-equipped generation.

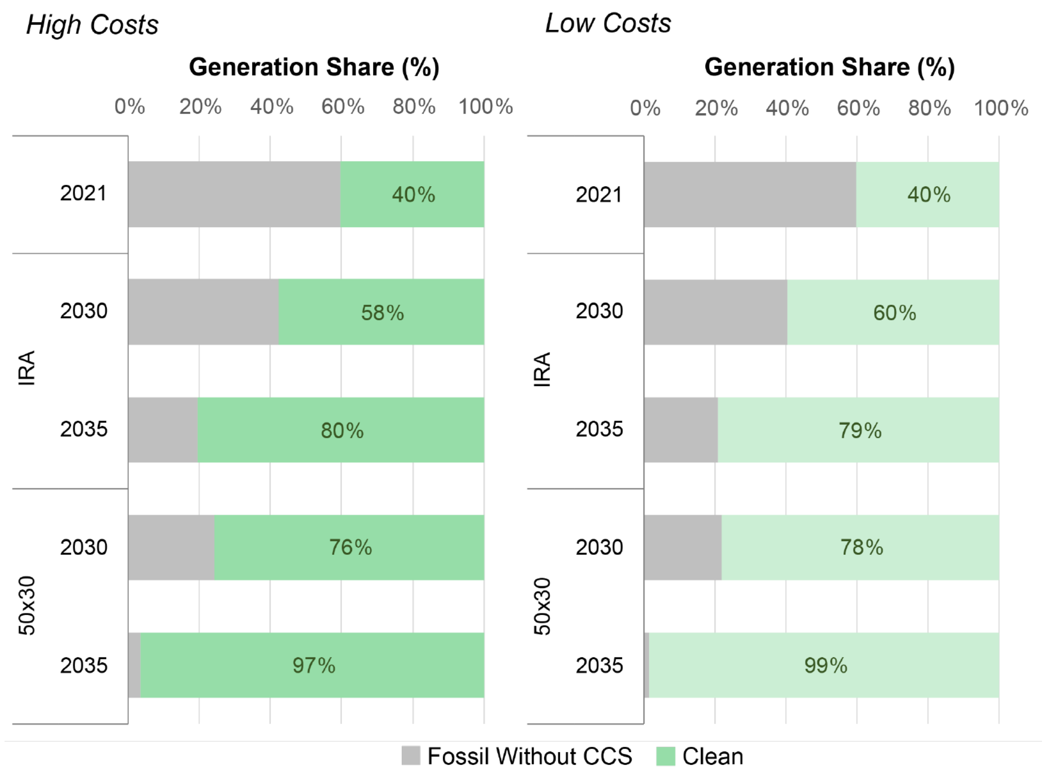

Figure 15

Generation shares by year and scenario. *Low-emitting generation includes renewables, nuclear, and CCS-equipped generation. The left (right) panel shows the Higher (Lower) Costs scenarios.*

Figure 16 illustrates these larger transformations across longer time horizons in terms of capacity additions and retirements. Additions of wind, solar, and energy storage more than double on an annual basis between 2030 and 2035.

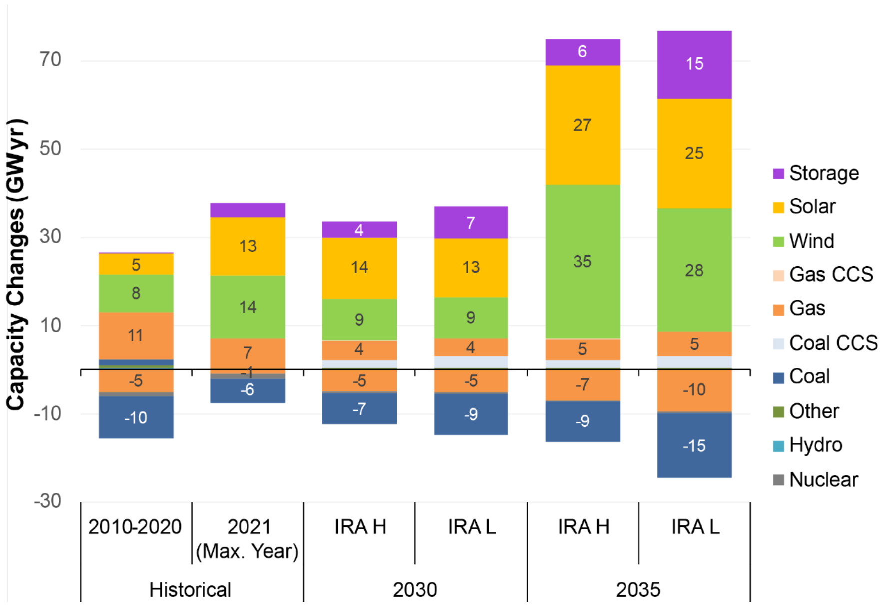

Figure 16

Historical and projected capacity additions and retirements by technology. *Projections show the average annual build rates through 2030 (middle) and 2035 (right) across IRA scenarios. Historical values come from Form EIA-860 data.*

Figure 17 shows 2030 generation shares by technology. All scenarios project lower coal generation and much higher wind and solar shares than today.

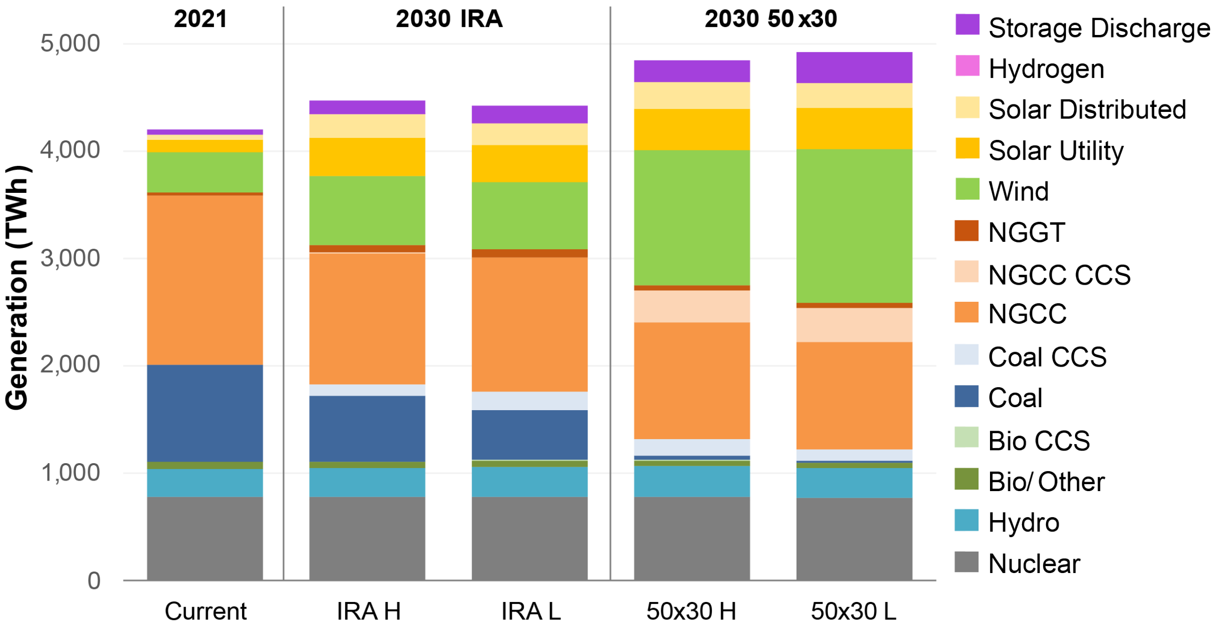

Figure 17

Generation by technology and scenario in 2030. *Bars show the electric sector mix under the reference with IRA and 50x30 scenario under Higher Costs ("H") and Lower Costs ("L").*

The analysis also conducts a wide range of sensitivities to examine how assumptions about electric sector technology costs and availability alter cost-optimized 50x30 decarbonization pathways. Table 2 in lists these scenarios, and Figure 18 shows generation and capacity.[19]

Table 2

Electric sector sensitivities and assumptions.

SCENARIO	ABBR.	SENSITIVITY ASSUMPTIONS
Reference	50x30	Reference 50x30 assumptions from earlier sections
No New NGCC Capacity	NoGas	No new NGCC capacity
No Carbon Capture	NoCCS	No new CCS-equipped capacity
No New NGCC or CCS	NoGasCCS	No new NGCC or CCS
Flat $8 Natural Gas Prices	Gas8	Flat $8/MMBtu natural gas prices in real dollar terms
Transmission Constraints	TrCons	Inter-regional transmission capacity constrained to base year values; higher costs for intra-regional transmission to support wind/solar expansion
Limited Options	Limited	Combines restrictions on new NGCC capacity, CCS-equipped capacity, nuclear, and inter-regional transmission

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[19] In interpreting the sensitivities, it is important to consider that model results are intended to be directionally informative, given assumed technological costs and policy constraints. Model outputs should not be interpreted as predictions or statements about feasibility.

These sensitivities show how the generation mixes can vary but contain many robust near-term elements and insights across scenarios:

- **High wind and solar shares:** Wind and solar generation shares are 30% to 50% nationally across these 50x30 sensitivities with high regional and intra-annual variability.
- **Lower coal generation:** Unabated coal generation in 2030 is 1-5%, but coal including CCS-equipped generation ranges from 1-9%.
- **Adequate firm back-up capacity:**
  - Natural gas capacity is a key system resource for providing dispatchable capacity as the system grows with increased electrification, even though capacity factors for unabated natural gas-fired plants drop with deeper decarbonization.[20]
  - The clean firm capacity portfolio varies by scenario. 45Q incentivizes coal CCS retrofits and new natural gas CCS with reference assumptions, which are amplified with constraints on new unabated natural gas capacity. Restricting CCS leads to greater renewables, battery storage, and nuclear builds.
- **Greater rate of capacity change:** Additions and retirements are near their historical maximum each year through 2030 with incentives. Capacity deployments are highest under the 50x30 scenarios with lower renewables and storage costs.
- **Expanded grid to maintain reliability with high wind and solar and electrification of other sectors:** Transmission expansion is a key element of decarbonization scenarios. As shown in Figure 19, there is currently 110,000 GW-mi of transmission nationally, and the IRA and 50x30 scenarios add about 14,000 GW-mi by 2030. When inter-regional transmission is constrained and intra-regional transmission costs are higher, wind and solar deployment is lower, and the cost to reach the 2030 target increases.
- **Optionality enables affordability:** Scenarios indicate that expanded technological portfolios can lower decarbonization costs and that, conversely, limiting options increases costs to achieve the 50x30 target. A “Limited Options” scenario—which combines restrictions on new NGCC capacity, CCS, nuclear, and transmission—doubles the costs of reaching the 2030 target in the power sector. This constrained portfolio leads to considerably more capacity deployment of wind, solar, and battery storage to reach emissions reductions targets.

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[20] See Bistline and Young (2022). “The Role of Natural Gas in Reaching Net-Zero Emissions in the Electric Sector.” Nature Communications, 13: 4743 (link).

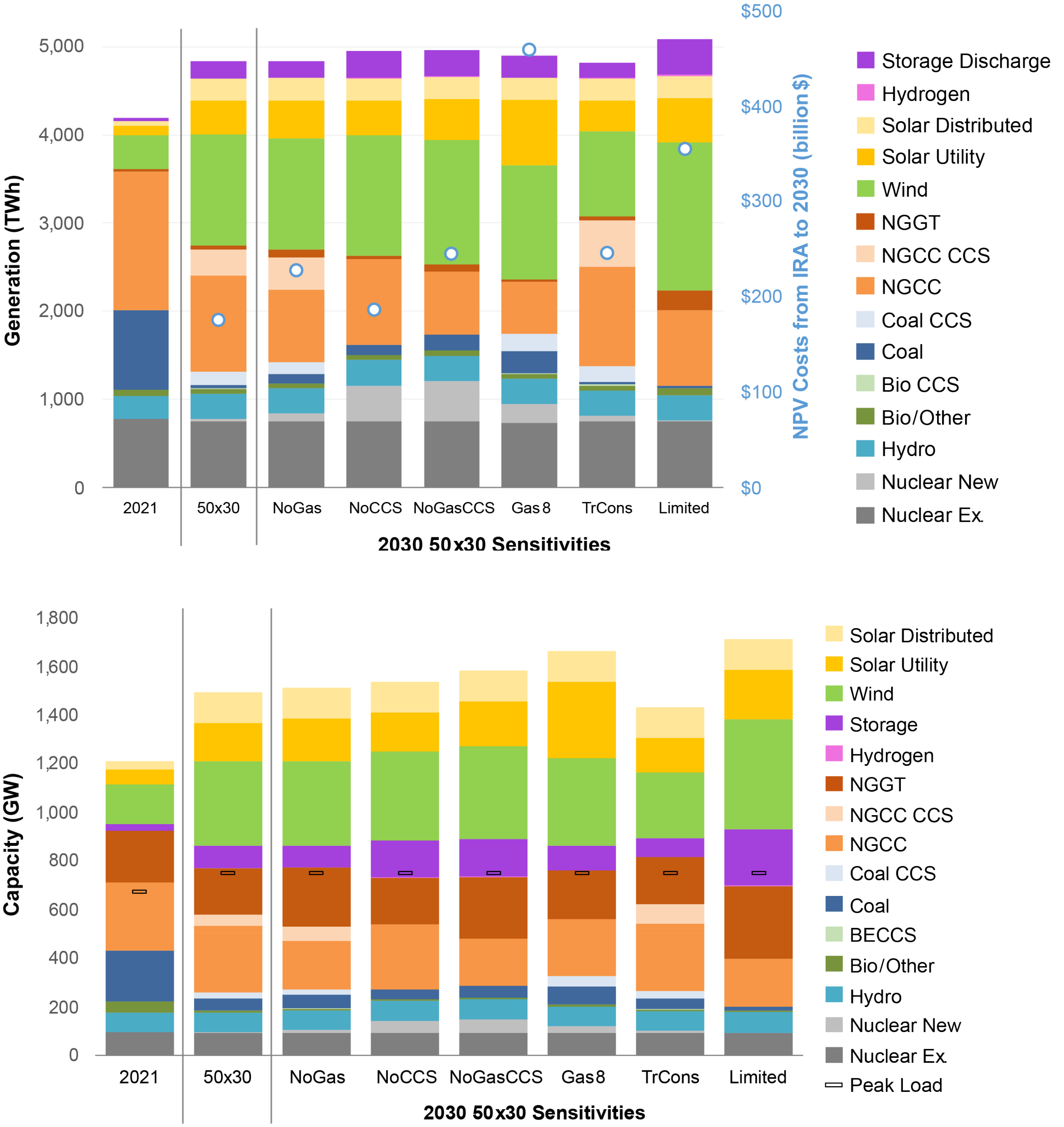

Figure 18

Generation (top panel) and capacity (bottom panel) by technology and scenario under the 50x30 scenario with Higher Costs. *The top panel also includes the net present value (NPV) of power sector costs through 2030.*

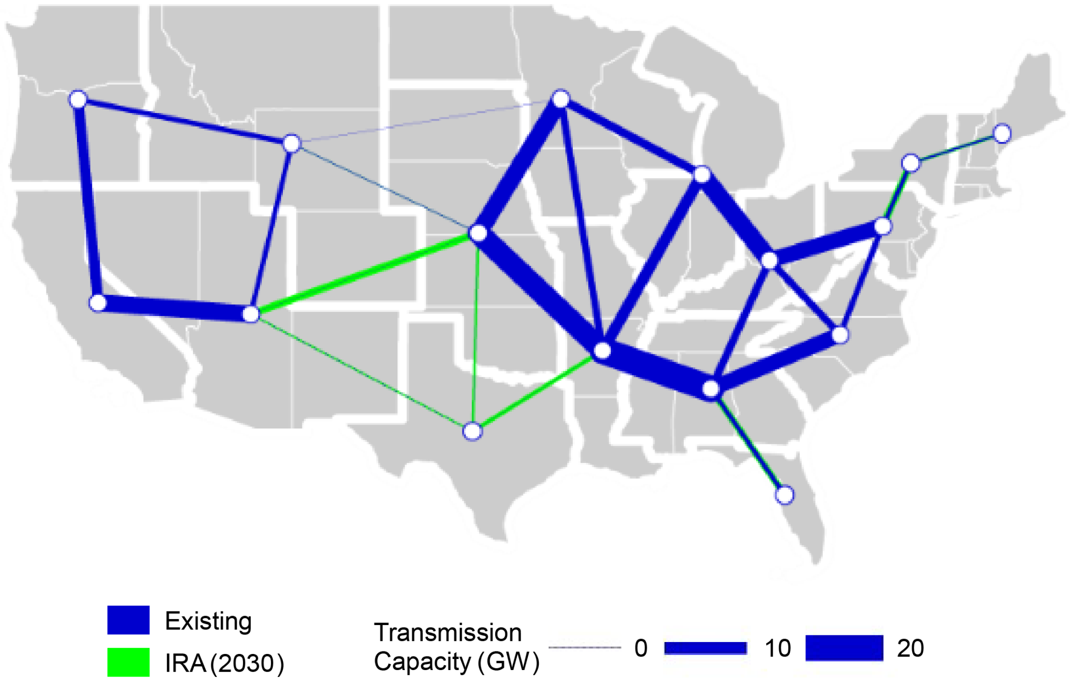

Figure 19
Transmission capacity across model regions. *Existing capacity in 2015 is shown in blue, and new capacity under the IRA scenario with Higher Costs in 2030 is shown in green.*

Emissions reductions in the IRA scenarios continue historical trends and reach 54-58% below 2005 levels by 2030 (Figure 20). The bill text of IRA indicates that technology-neutral production and investment tax credits begin to phase down either in 2032 or when power sector emissions reach 25% of their 2022 emissions, whichever is later. This threshold is reached by 2030 under the 50x30 scenario but takes until 2040 in the IRA scenario with high costs.

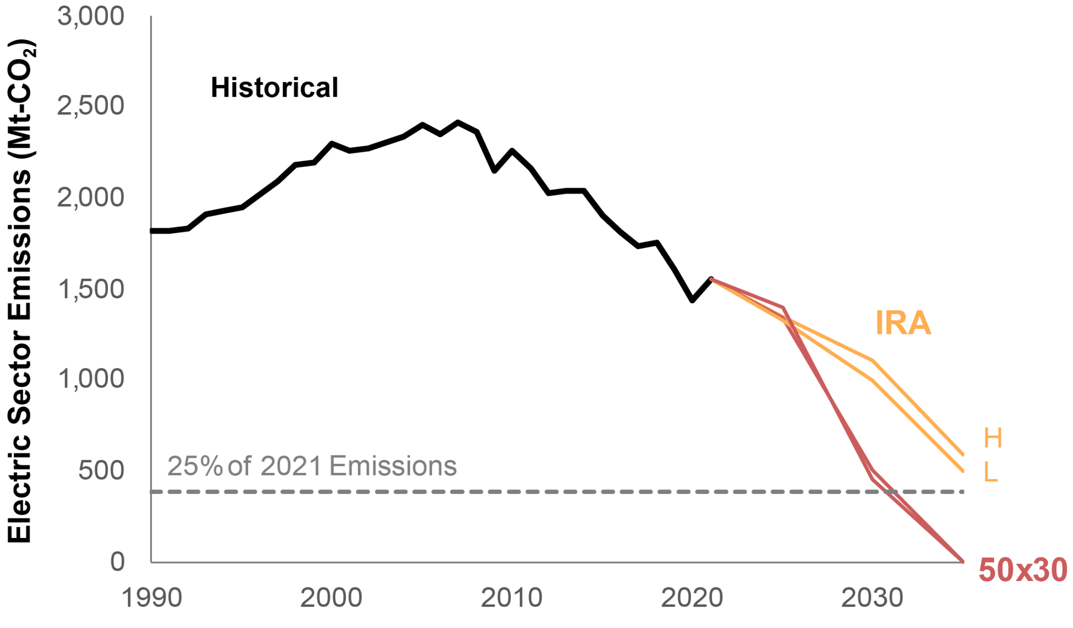

Figure 20
Power sector CO_2 emissions over time by scenario. *Historical levels come from U.S. EPA's "Inventory of U.S. Greenhouse Gas Emissions and Sinks."*

These changes have implications for electricity prices and affordability (Figure 21). IRA incentives can have large impacts on electricity markets by lowering wholesale prices and increasing prevalence of negative-priced periods, which can alter operational, investment, and retirement decisions. 50x30 scenarios lead to increases in prices across all regions and scenarios, even with IRA incentives. This difference reflects the investment-driven approach to climate policy in the IRA scenarios, which mainly relies on "carrots" to make low-emitting technologies cheaper, as opposed to carbon pricing in the 50x30 scenarios, which adds "sticks" to disincentivize emissions-intensive resources. Electricity prices increase up to 34% with higher fuel and supply costs (relative to the Lower Costs scenario).

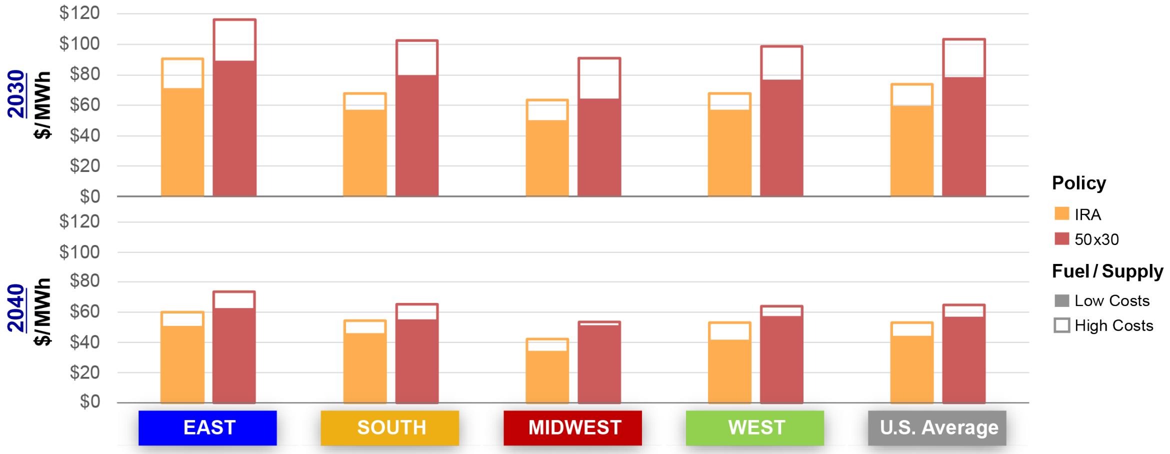

Figure 21

Regional electricity generation prices by scenario over time. *Average annual prices reflect generation and new bulk transmission but excludes intra-regional transmission and distribution costs associated with delivery to retail customers. Regional definitions are shown in Figure 29.*

Figure 22 shows cumulative budgetary effects of tax credits under the IRA scenarios. 2030 estimates suggest about $200 billion in subsidies from electric sector tax credits, which are relatively balanced across investment tax credits, production tax credits, and 45Q credits for captured CO$_2$. Tax expenditures increase substantially after 2030, as cumulative subsidies through 2040 approach $800 billion. Long-run expenditures by category vary by cost scenario: There are higher 45Q credits for captured CO$_2$ when natural gas prices are low, while production credits are higher when natural gas prices are high. Tax credits for existing nuclear plants are higher with lower natural gas prices owing to lower wholesale power prices and revenues to existing capacity.

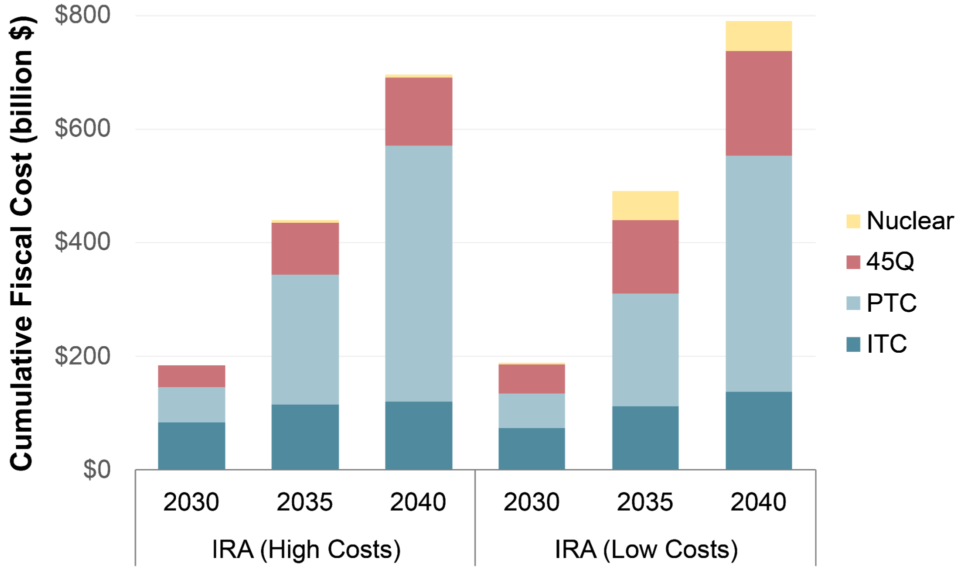

Figure 22

Estimates of cumulative budgetary effects associated with power sector IRA tax credits by provision. *Values are shown in undiscounted real dollar terms. IRA production and investment tax credits are assumed to be available until power sector CO$_2$ emissions reach 25% of their 2022 levels.*

Transport

Technological trends and consumer choice lead to increasing electrification and electricity demand over time (Figure 23), which is amplified with incentives and policies. Reaching the 50% target by 2030 entails greater electrification, but levels vary based on assumptions about inflationary drivers. By 2030, load grows 12-13% over current levels in scenarios with IRA and 18-22% with 50x30 policies.

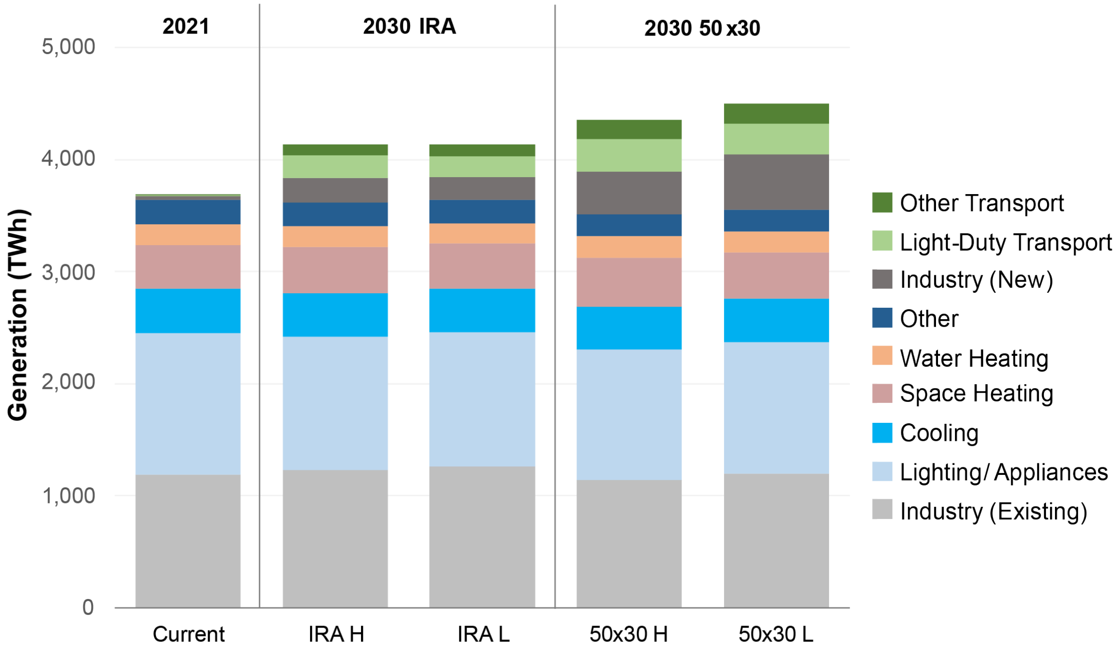

Figure 23
Electricity demand by end use across scenarios. *IRA and 50x30 policy scenarios are shown for Higher Costs scenarios ("H") and Lower Costs scenarios ("L").*

Vehicle electrification is extensive in all scenarios. Figure 24 shows projected new sales and service demand for light-duty cars and trucks, which is a leading source of load growth in the IRA scenarios. By 2030, electric vehicles are projected to be 46-50% of new sales—many times current levels (which are about 7% in 2022).[21] Declining battery costs and IRA tax incentives of up to $7,500 per vehicle drive down the purchase price of EVs, and once the lower total costs of ownership for EVs are considered, many households adopt EVs even before adding 50x30 policies. Service demand and CO_2 changes lag new sales, as shown in the bottom row of Figure 24. The additional 50x30 incentives lead to greater new sales shares of EVs (reaching 50% of new cars by 2030) and a greater share of service demand.

There is also significant electrification of non-passenger transport. Under IRA, this could contribute 100-110 TWh/yr of demand by 2030 (Figure 23), which increases to 160-170 TWh/yr under 50x30 policies. The projected electricity share of final energy across all transport is approximately 5% under IRA and 8% under 50x30 (Figure 25).

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[21] Due to the timestep resolution of the model, the 2030 new sales share represents the average value across a five-year period between 2026 and 2030.

Figure 24

Light-duty vehicle new sales share (bottom row) and service demand (top row) by technology type and policy scenario (columns). *Service demand is expressed in terms of trillion vehicle miles traveled per year. Values are shown for the Higher Costs scenario.*

Buildings

IRA incentives for heat pumps are projected to lead to up to 40% of floorspace heated or cooled by heat pumps by 2030, which increases to 43% with 50x30 policies. Water heaters are also significantly electrified. Electricity's share of final energy in buildings was 48% in 2020 (the highest sectoral share, Figure 25), which increases to 52-53% by 2030.

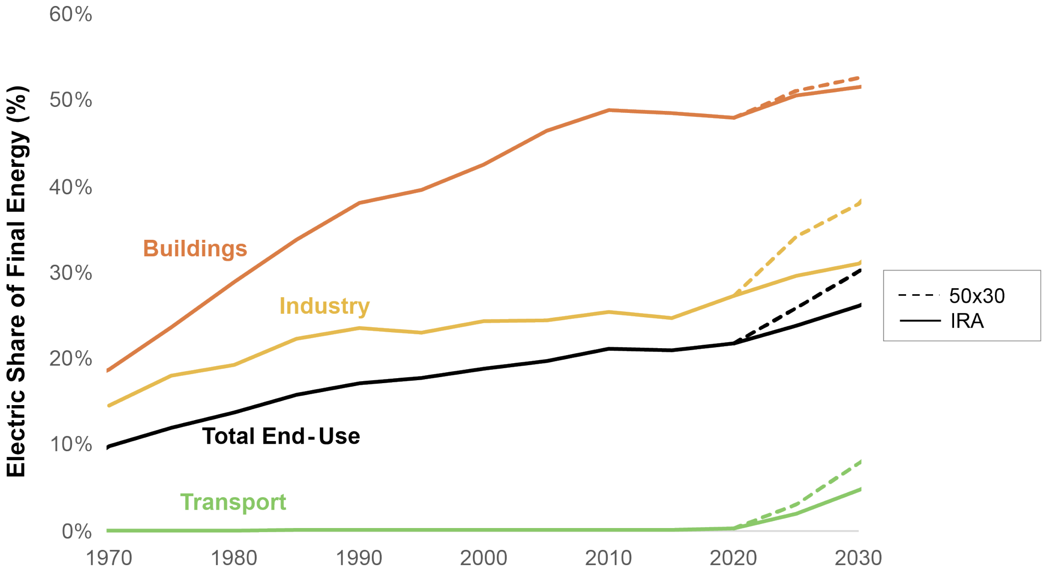

Figure 25

Electricity share of final energy by sector and scenario. *Historical values come from U.S. Energy Information's "State Energy Data System" (https://www.eia.gov/state/seds/). Values are shown for the Higher Costs scenario.*

Heat pump deployment is supported by IRA rebates up to the full cost of an average heat pump system for low-income households, with lower amounts for higher income households. Emissions declines are also supported by marginal improvements to building shell efficiency as a result of policies supporting residential and commercial energy efficiency projects.

Fuels

Technological change and market drivers are projected to drive sustained declines in fossil fuel consumption, which are amplified by IRA incentives and 50x30 policies (Figure 26). The pace and extent of these declines vary by fuel, policy scenario, and resource assumptions. Coal use exhibits a slight rebound in 2025 relative to 2020 owing to higher near-term natural gas prices, which temporarily reverses coal-to-gas switching trends in the power sector. However, this rebound is temporary, as coal consumption exhibits a structural decline beyond 2030 in all scenarios. Petroleum use is projected to drop steadily in all scenarios, decreasing 22-33% from 2021 levels by 2030 with larger declines under 50x30 policies. Natural gas consumption is projected to remain flat or decline and is strongly influenced by fuel cost assumptions.

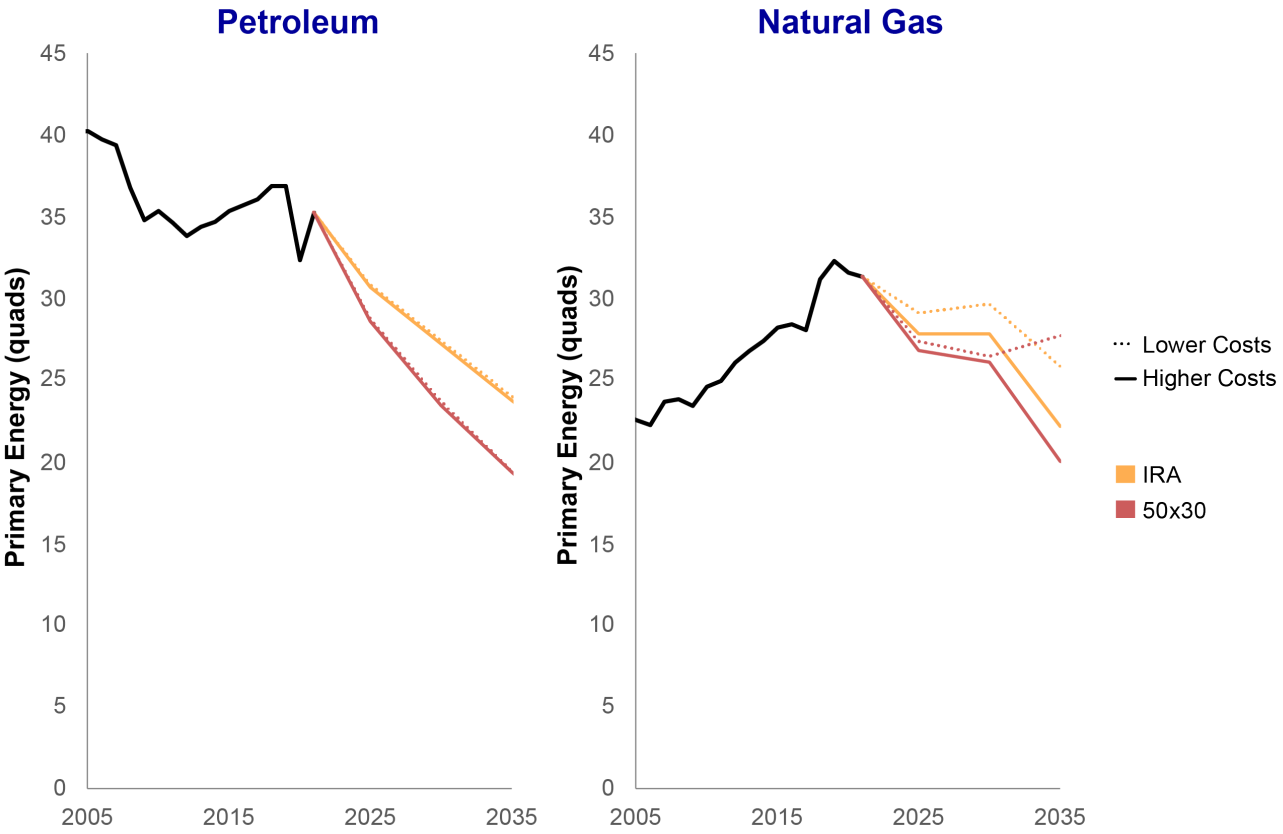

Figure 26
Primary energy from fossil fuels by scenario. *Historical data come from U.S. EIA's "Monthly Energy Review" (updated September 2022).*

Workforce Implications

These supply- and demand-side transitions have key implications for workforce development. A complementary white paper based on 2021 50x30 scenario outputs illustrates potential power sector workforce impacts.[22]

But the end-use changes under the IRA and 50x30 scenarios also alter workforce dynamics. Figure 27 shows the labor force dedicated to heat pump installations relative to the total supply of heating and cooling contractors over time. Although heat pump installation accounts for a greater share of the building heating and cooling labor force over time, overall labor impacts are tempered by the fact that existing stock turnover at the end-of-life would be irrespective of customer replacement choice. In other words, contractors would be installing heat pumps instead of gas furnaces or other heating sources, not in addition to other heating sources. This implies that changes to heating and cooling contractor needs under the IRA and 50x30 scenarios are relatively small.

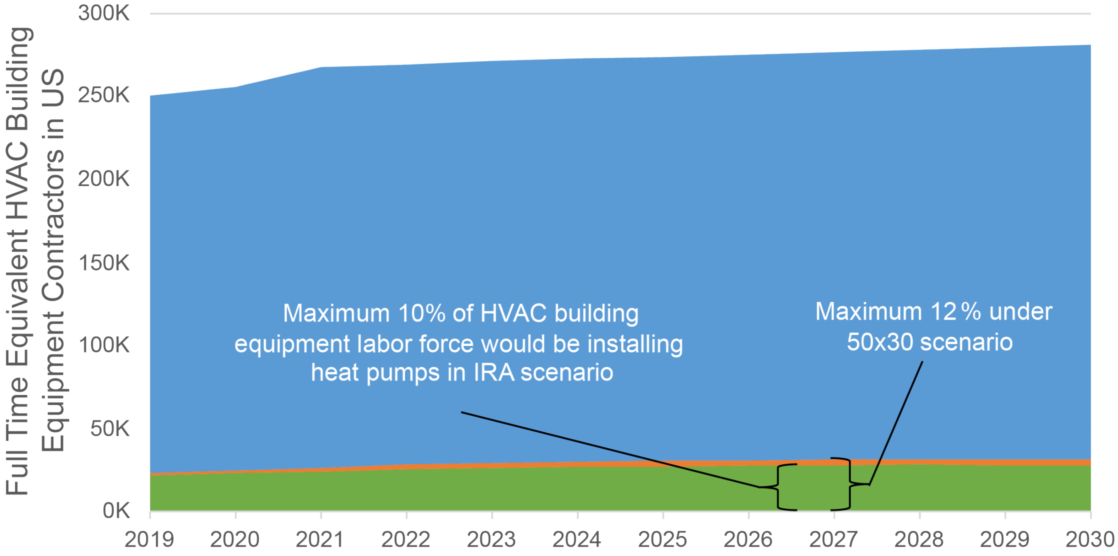

Figure 27

Labor force dedicated to heat pump adoption over time relative to total supply of contractors. *Full-time equivalent heating, ventilation, and air conditioning (HVAC) contractors are shown with labor force installing heat pumps in the IRA scenario (green) and incremental labor in the 50x30 scenario (orange). Values are shown for the Higher Costs scenario.*

Absolute and relative effects of EV charger deployment on electrician labor demand are larger than heat pump deployment (Figure 28).[23] By 2030, electrician labor demand is projected to increase by 10% (6%) under the 50x30 (IRA) scenario compared with projected electrician contractors without EV deployment, which is over 51,000 electricians under a 50x30 scenario and 31,000 under an IRA scenario.

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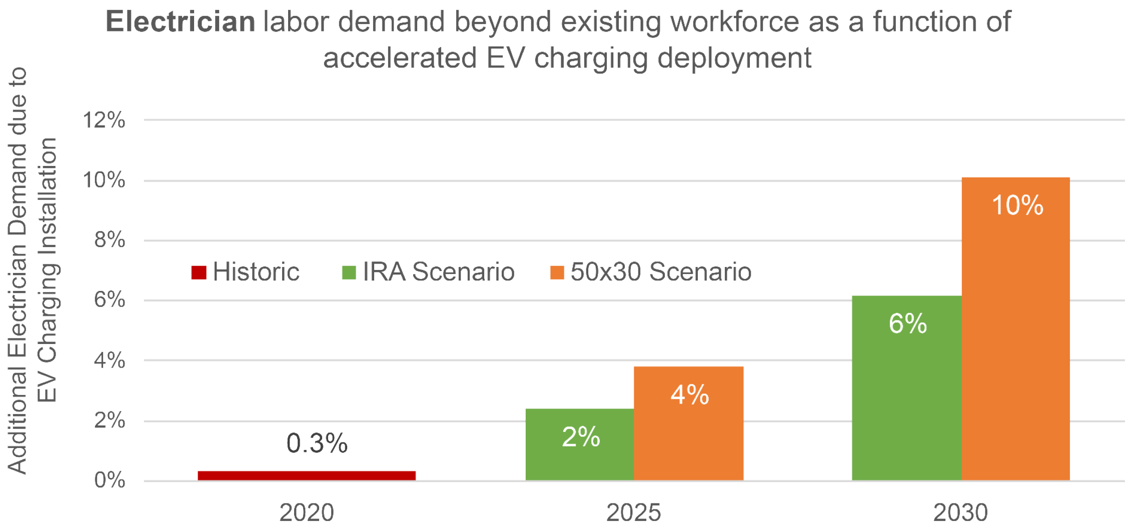
[22] See EPRI (2022). "Electric Utility Workforce Development and Decarbonization." EPRI Report 3002023229 (link).

[23] Note that these estimates assume one home charger per battery electric vehicle and a half per plug-in hybrid electric vehicle.



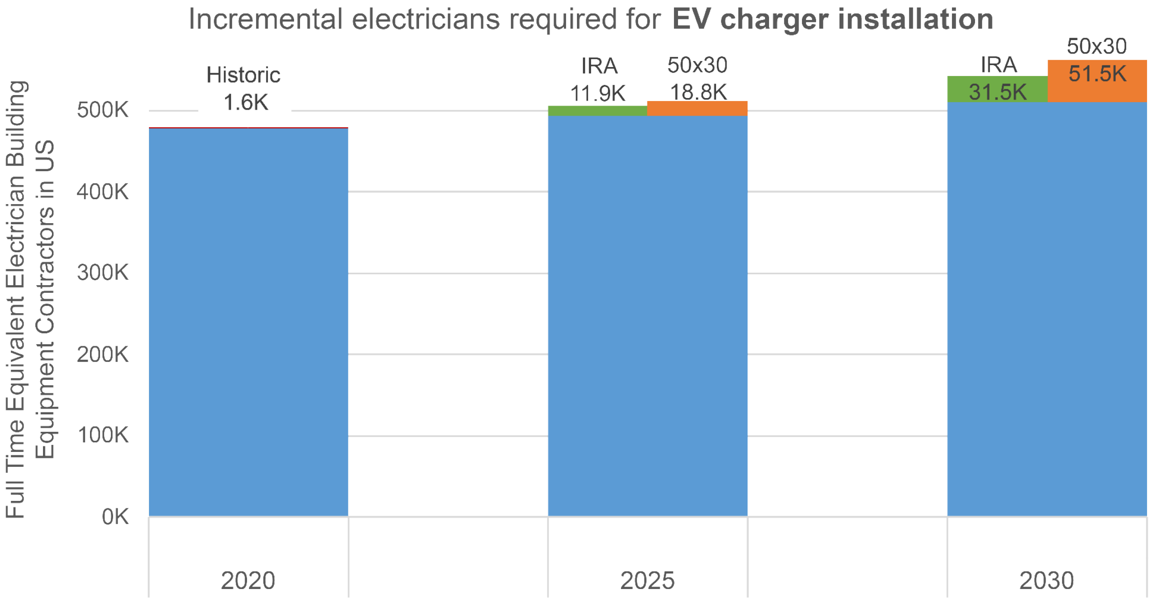


Figure 28

Labor demand from EV charging deployment relative to electricians on a relative basis (top panel) and absolute basis (bottom panel). *Figures show changes in the IRA scenario (green) and 50x30 scenario (orange) with Higher Costs.*

DISCUSSION AND NEXT STEPS

Key Insights

This white paper highlights several changes in the near-term decarbonization outlook relative to last year's assessment:

- **Reaching the 2030 target would require even faster decarbonization:** Achieving a 50% economy-wide reduction by 2030 entails faster decarbonization compared to historical rates and EPRI's 2021 assessment. Average economy-wide reductions of 1.1 percentage points per year from 2005-2021 would have to increase to 4 percentage points annually.
- **IRA incentives alter technology outlooks and counteract inflation:** IRA offers investments to decarbonize the economy, improve air quality, and lower energy costs for households. These incentives potentially alter the decarbonization challenge from primarily compliance to opportunity capture. IRA incentives alter the outlook for many existing and emerging low-emitting technologies and counteract inflationary drivers. These credits lower costs of deploying low-emitting resources, which can in turn lower barriers for agencies, subnational governments, and companies to increase their mitigation ambitions. Clean energy technology deployment across all sectors will have to accelerate to derive the benefits provided by IRA. IRA incentives could reduce economy-wide GHG emissions by 32-33% if technology deployment significantly accelerates—approximately 3 times the current emission reductions in the transport and buildings sectors and more than 1.5 times in the electric sector.
- **The inflation trajectory impacts decarbonization costs:** Higher costs of supply-side resource, end-use technologies, and fuels lead to higher decarbonization costs, but the extent of these changes depends critically on how these inflated costs change over time. Inflationary drivers have offsetting effects on wind and solar deployment, which lead to higher capital costs of these technologies but also higher fuel prices.
- **Need for new low-carbon resource technologies beyond 2030:** EPRI's recent LCRI analysis of approaches to economy-wide net zero by 2050 shows the need to deploy new clean energy technologies beyond 2030. Advancement of technologies such as green hydrogen, advanced nuclear, carbon capture utilization and storage, and others that may play a significant role to achieve net zero by 2050 will have to occur in parallel with deploying existing clean energy technologies for achieving GHG reductions by 2030.

Next Steps

This analysis suggests several opportunities for additional research:

- **Exploring IRA sensitivities:** The Inflation Reduction Act is characterized by tiered and overlapping incentives that have implications for siting, manufacturing process, and supply chains. The ability of manufacturers and consumers to capture the full value of the subsidies depends on many factors, including their affordability, feasibility, and materials availability. Understanding the ability for the supply chain to adjust to incentive requirements and the potential costs of doing so will help characterize the direct value and indirect costs of the various base and bonus requirements. Together, these have direct effects on the size and distribution of costs of transition, as well as overall deployment and emissions outcomes. Future work will investigate IRA sensitivities related to implementation questions.
- **Understanding supply chain issues:** The rapid deployment of supply- and demand-side resources alongside new incentives for domestic sourcing and manufacturing through IRA indicate the importance of additional research to understand supply chain impacts.
- **Exploring resource adequacy, reliability, and resiliency:** In light of retiring fossil capacity, deployment of variable and energy-limited supply, and other trends, detailed analyses of resource adequacy, reliability, grid stability, and resiliency implications of these transitions are important. Several previous and ongoing research efforts across EPRI have investigated these issues in detail, including the 2021 white paper on "Enhancing Energy System Reliability and Resiliency in a Net-Zero Economy" (3002023437), research on reliability under deep decarbonization (3002025269), EPRI's Resource Adequacy Initiative (https://www.epri.com/resource-adequacy), and EPRI's Integrated Strategic System Planning (ISSP) Initiative (https://www.epri.com/issp).
- **Investigating the transition to economy-wide net-zero emissions:** EPRI's recent analysis of approaches to economy-wide net zero by 2050 has shown the considerable value of optionality and role of low-carbon fuels. Just as historical emissions reductions are tied to the required rate of change to achieve 50% by 2030, so is the rate of emissions reductions required to reach net zero tied to the emissions levels in 2030. Delaying action increases the challenge of later decarbonization that may rely on uncertain and not-yet-commercialized technologies that require early investment in research and development and clear investor signals to reduce the costs of decarbonization. Future research will be aimed at merging the near-term perspective from this report and the midcentury net-zero one to look in more detail at scenarios for intermediate targets and time steps.

APPENDIX

Model Overview

More detailed documentation for the REGEN model can be found at https://us-regen-docs.epri.com/, and additional applications of the model can be found at https://esca.epri.com/. REGEN provides customizable regional resolution and accounts for differences in regional policy, resources, and demand. The model regions and reporting regions used for this analysis are shown in Figure 29.

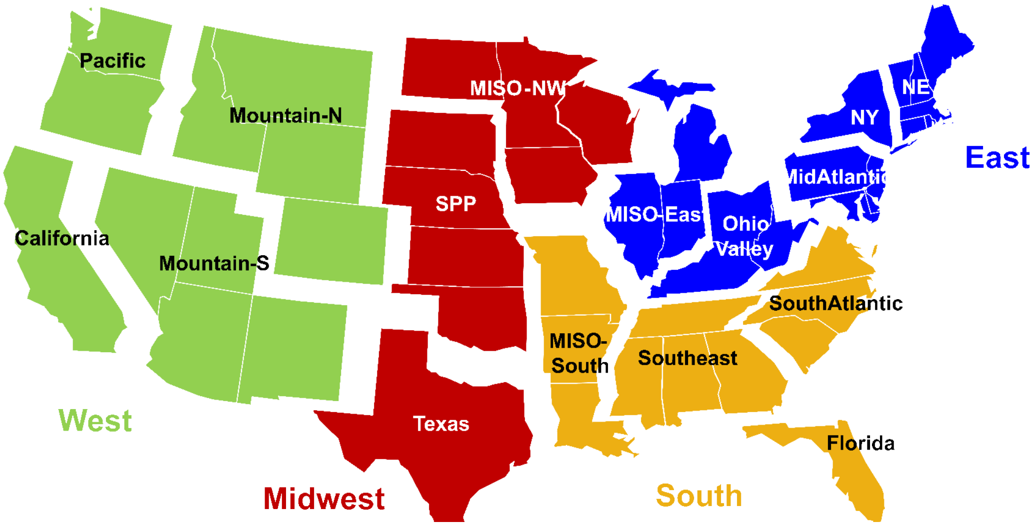


Figure 29
Regional aggregation for model regions in this analysis. *Colors illustrate configurations for reporting regions.*

Model Implementation of the Inflation Reduction Act (IRA)

Table 3 summarizes the IRA provisions that are represented in this modeling.

Table 3
Modeled provisions of the Inflation Reduction Act.

CATEGORY	SECTION	DESCRIPTION
Electricity	13101	Production tax credit (PTC) extension
	13102	Investment tax credit (ITC) extension
	13103/13702	Solar in low-income communities
	13015	Production tax credit for existing nuclear
	13701/13702	New clean electricity PTC (45Y) and clean electricity ITC (48E)
Multi-Sector	13104	Extension of credits for captured CO_2 (45Q)
	13204	Production credits for clean hydrogen (45V)
Transport	13401	Clean vehicle credit
	13403	Commercial clean vehicle credit
	13404	Alternative refueling property credit
Buildings	13302	Residential clean energy credit
	13303	Energy efficient commercial building deduction
	13304	Energy efficient home credit
	50121	Home energy efficiency credit
		High efficiency home rebate program

There are also several provisions that are not captured in this modeling, including the extension of incentives for biofuels (13201/13202), sustainable aviation credit (13203), credit for previously owned clean vehicles (13402), extension of advanced energy project credit (13501), industrial facilities deployment program (50161), and agricultural conservation and forestry provisions. The modeling also does not include loan programs to facilitate capital deployment. Additional reductions may be possible from areas that are not modeled, but it is also possible that uncaptured dynamics may imply that the scenarios overestimate emissions reductions (e.g., siting and permitting challenges, supply chain adjustments, eligibility for bonus credits, lowering the effective value of credits to reflect transaction costs to monetize tax credits without direct pay).

Power sector investment tax credit (ITC) and production tax credit (PTC) have several levels of bonus incentives for paying prevailing wages; training apprentices; using domestic produced iron, steel, and manufactured content; as well as siting in an energy community. This analysis assumes that labor bonus levels apply (i.e., that wage and apprenticeship requirements are met) but does not explicitly include the domestic content bonus.[24] Due to their siting flexibility and the expansive definition of energy communities in the IRA, the analysis assumes that 50% of solar and battery storage qualifies for the energy community bonus, and 25% of wind is eligible for these credits. Power sector tax credits become technology-neutral in 2025 and allow all eligible zero-emitting resources to claim the PTC, ITC, or 45Q credits for captured CO_2.[25] The law's text indicates that credits remain at their full levels (adjusted for inflation) until 2032 or when power sector emissions reach 25% of current levels, whichever is later.[26] The extended and enhanced 45Q credits offer \$85/t-CO_2 for captured CO_2 from power, industry, and fuels production. In the power sector, 45Q subsidies are highest for coal with CCS, given the higher CO_2 capture intensity per unit of generation (Figure 30).[27]

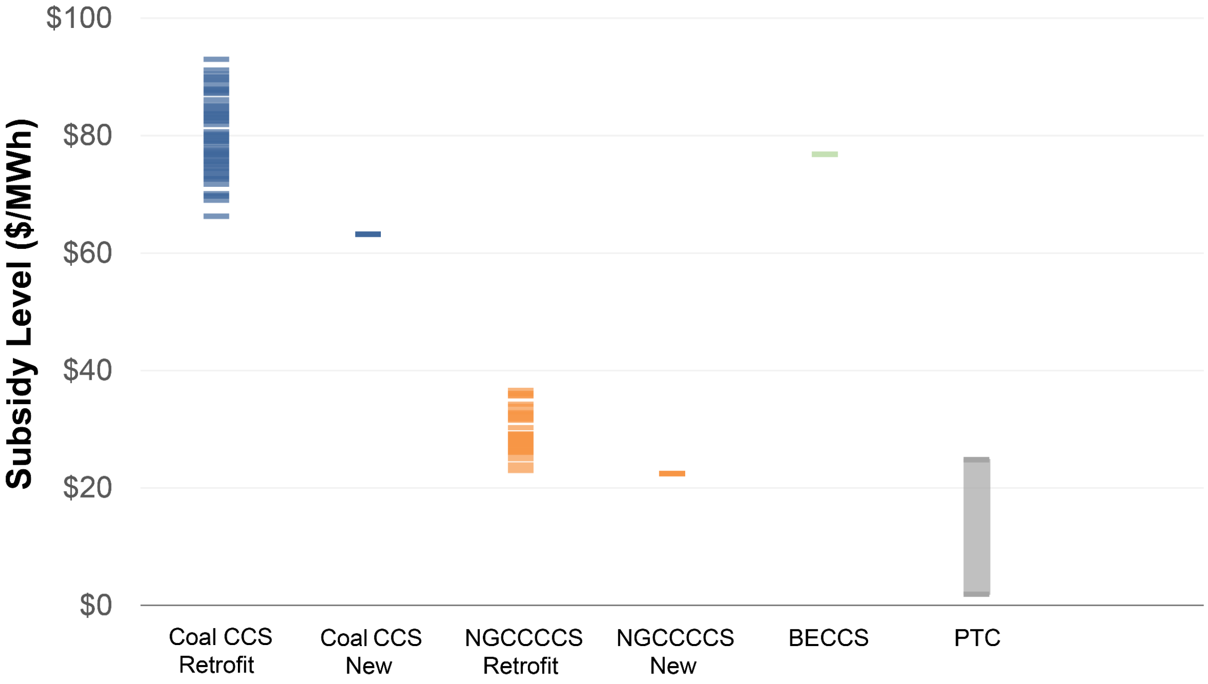


Figure 30

Implications of IRA subsidies on dispatch costs of CCS-equipped capacity. *Ranges reflect plant-specific variation in subsidy levels.*

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[24] Another interpretation of this assumptions is that domestic content bonuses apply but are offset by incremental costs of domestic supply.

[25] This analysis simplifies this tax credit selection by assuming that technologies take the applicable credit with the highest value for individual technologies. The PTC is claimed by solar, onshore wind, and geothermal; ITC by nuclear, offshore wind, and energy storage; and 45Q by CCS-equipped capacity.

[26] This analysis includes the extended eligibility of these credits to match the text of IRA.

[27] 45Q credits assume bonus credits and storage of captured CO_2 with endogenous transport and storage costs that vary by region.

The $7,500 IRA clean vehicle credit is subject to domestic materials and assembly requirements that constrain full adoption of the subsidy, with materials and assembly requirements tied to eligibility for 50% of the subsidy. Manufacturers are assumed to be able to meet the requirements of the full credit value by 2030 but are subject to limitations in intervening years as the supply chain shifts to meet the new production constraints. This analysis also captures the effect of the refueling property credit incentives for rural and low-income communities on the disutility of range anxiety.[28]

Residential home energy efficiency projects are able to claim overlapping incentives that apply on overall energy efficiency retrofits as well as new equipment purchases. This analysis assumes that the capped per-unit rebates are the most valuable credit for homeowners to claim on new equipment installations for washers, dryers, and heat pumps for home heating and cooling as well as water heating, while the energy efficiency credits lead to improvements in overall residential and commercial building efficiency. Actual heat pump rebate amounts are tied to household percent of area median income levels (<80%, 80-150%, and >150%).

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[28] Note that this scenario does not include state-level zero-emissions vehicle policies or incentives.

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