

Annual Energy Outlook 2023

with projections to 2050



Annual Energy Outlook 2023 Release at Resources for the Future

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What does EIA do?

The U.S. Energy Information Administration (EIA) is the statistical and analytical agency within the U.S. Department of Energy.

EIA is the nation's premier source of energy information.

By law, our [data, analyses, and forecasts](#) are independent of approval by any other officer or employee of the U.S. government.

Our *Annual Energy Outlook 2023* explores long-term energy trends in the United States.

What's new in the 2023 *Annual Energy Outlook*?

- A focus on the narrative
- Technical notes
- Emphasis on the range of results
- New combination cases

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The electricity mix in the United States shifts from fossil fuels to renewables

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In this section, we cover the displacement of fossil fuels by renewables in the electric power sector and explore the effects on natural gas consumption.

Renewables displace fossil fuels in the electric power sector due to declining renewable technology costs and subsidies for renewable power

Economic growth paired with increasing electrification of the end-use sectors results in stable growth in U.S. electric power demand through 2050 in all cases. Declining capital costs for solar panels, wind turbines, and battery storage, as well as government subsidies such as those included in the IRA, result in renewables becoming increasingly cost-effective compared to the alternatives when building out new power capacity.

Power demand is increasingly met by renewables throughout the projection period.

Power demand is increasingly met by renewables throughout the projection period (Figure 2). The share of natural gas, coal, and nuclear generation declines. Nuclear power is outcompeted by renewable power even in the Low Zero-Carbon Technology Cost (ZTC) case, which assumes more aggressive cost declines for nuclear and renewables than the Reference case. Most natural gas-fired generation comes from combined-cycle power plants as opposed to natural gas turbines. Uncertainty in natural gas prices across cases leads to various projections for the operation of combined-cycle units in the short term, but in the long term natural gas demand from the power sector stabilizes across all cases.



The AEO2023 includes cases that vary technical and economic assumptions, including combination cases that extend the bounds of uncertainty

All cases reflect current laws and regulations as of November 2022, including the Inflation Reduction Act.

Reference	1.9% annual GDP growth; Brent = \$101 per barrel (b) in 2050
Economic Growth	Low: 1.4% annual GDP growth High: 2.3%
Oil Price	Low: Brent = \$51/b in 2050 High: Brent = \$190/b in 2050
Oil and Gas Supply	Low: 50% lower oil and gas resource recovery and 50% higher drilling costs relative to the Reference case High: 50% higher oil and gas resource recovery and 50% lower drilling costs relative to the Reference case
Zero-Carbon Technology Cost (electric power sector)	Low: About 40% reduction in cost by 2050 High: No reduction in costs
Combination	Combinations of Economic Growth and Zero-Carbon Technology Cost cases

AEO2023 *Issues in Focus*: Inflation Reduction Act

- Inflation Reduction Act *Issues in Focus* released today
 - No IRA case
 - High Uptake case
 - Low Uptake case
- Detailed IRA assumptions available on the AEO website



IRA-related caveats to keep in mind

- The IRA contains a complex package of incentives, many of which are challenging to model.
- We do not explicitly include certain IRA provisions in AEO2023 for three general reasons:
 - Guidance is not yet available on how a provision will be enacted or how agencies will implement it.
 - Provisions requiring significant model modifications that were not possible to implement this year.
 - Provisions that do not align with our analytic resolution, for example “energy communities.”
- *As a result, all energy system impacts of the IRA are not represented in AEO2023.*
- We have documented our modeling assumptions related to all IRA provisions, which are available with today’s AEO2023 release.
- We will refine our estimates over time as IRA implementation details become available and we update our modeling capability.

AEO2023 Highlights

- Energy-related CO₂ emissions fall across all AEO2023 cases because of increased electrification, higher equipment efficiencies, and more zero-carbon electricity generation.
- Renewable generating capacity grows in all regions of the United States in all AEO2023 cases, supported by growth in installed battery capacity.
- Technological advancements and electrification drive projected decreases in demand-side energy intensity.
- The United States remains a net exporter of petroleum products and of natural gas through 2050 in all AEO2023 cases.

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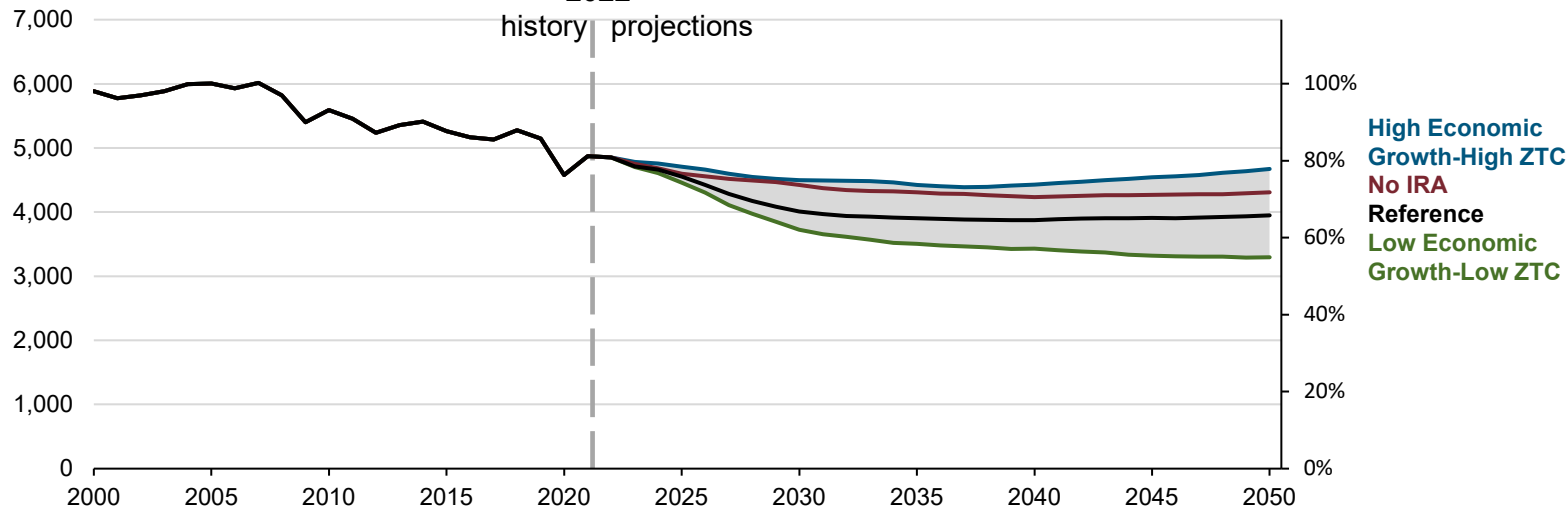
By 2030, energy-related CO₂ emissions fall 25% to 38% below 2005 levels

Total energy-related carbon dioxide emissions

million metric tons

2022

percentage relative to 2005



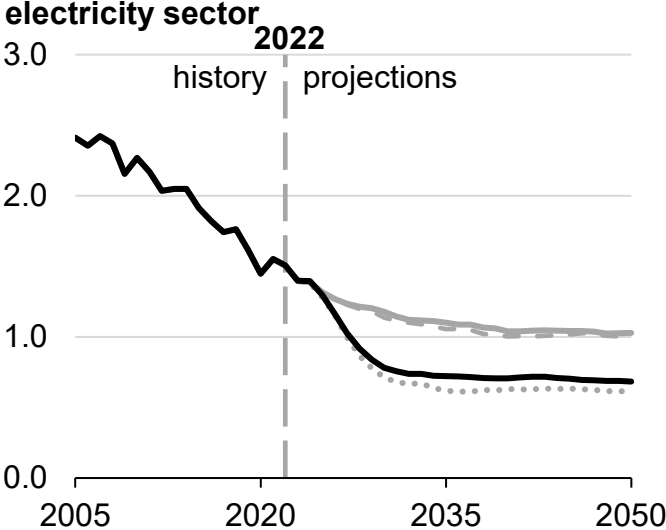
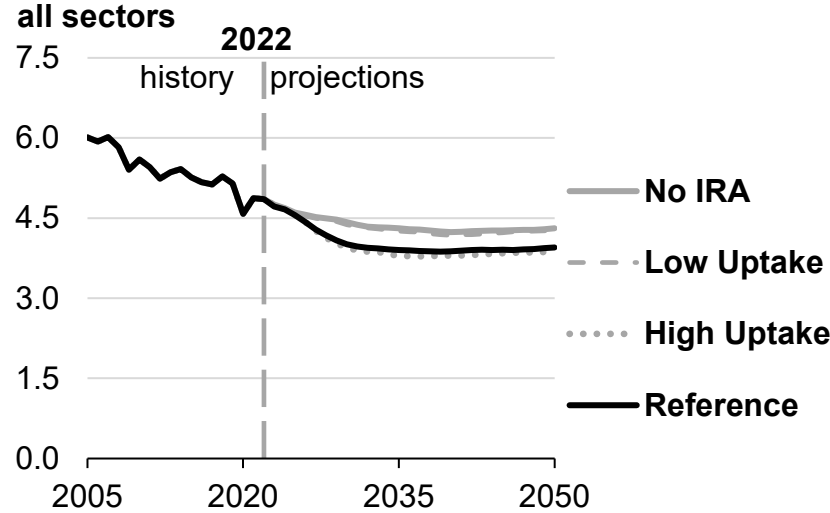
Data source: U.S. Energy Information Administration, *Annual Energy Outlook 2023* (AEO2023)

Note: Shaded regions represent maximum and minimum values for each projection year across the AEO2023 Reference case and side cases. ZTC=Zero-Carbon Technology Cost; IRA=Inflation Reduction Act.

In the No IRA and Low Uptake cases, U.S. CO₂ emissions fall 26% and 27%, respectively, by 2030 from 2005. The Reference and High Uptake cases go further and reach reductions of about 33% and 34%, respectively.

Energy-related CO₂ emissions

billion metric tons



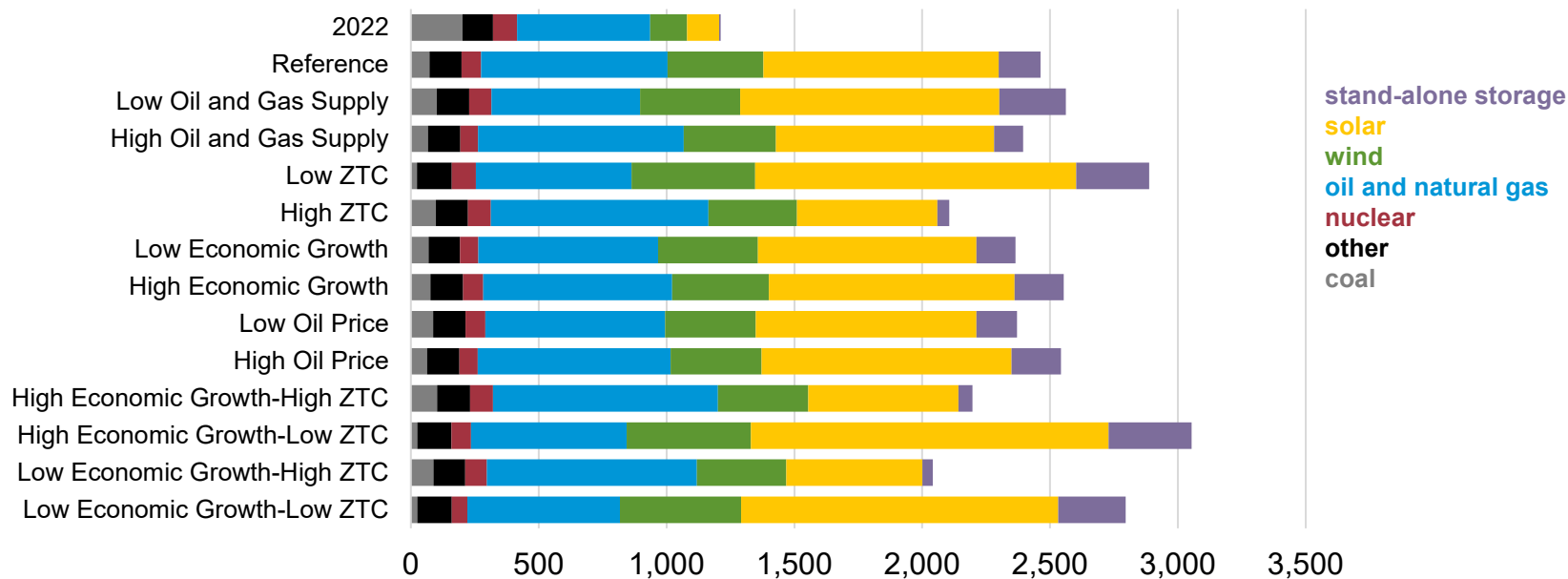
Data source: U.S. Energy Information Administration, *Annual Energy Outlook 2023* (AEO2023)
 Note: Charts include CO₂ emissions from fossil fuel and industrial feedstock uses. This scope excludes industrial process emissions, agriculture, waste, land use, and other greenhouse gases such as methane and hydrofluorocarbons. Industrial emissions include combined-heat-and-power plants that have a non-regulatory status and small on-site generating systems.

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Total installed generating capacity more than doubles across most scenarios

Total installed capacity in all sectors, 2022 (history) and 2050
gigawatts



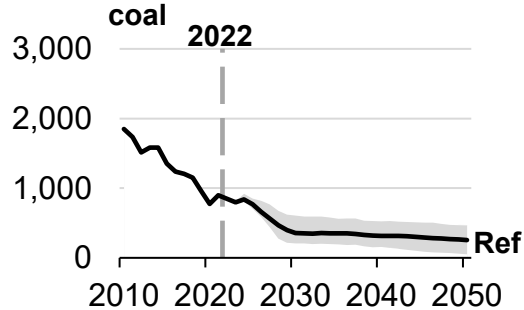
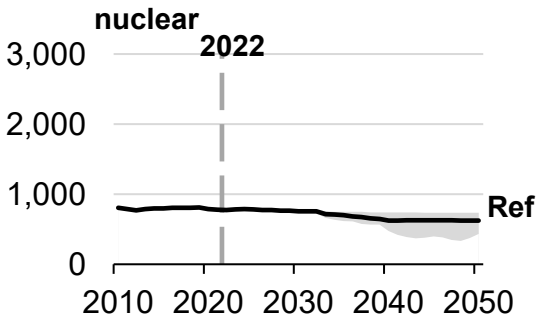
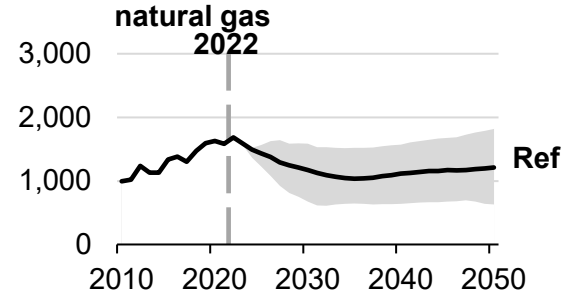
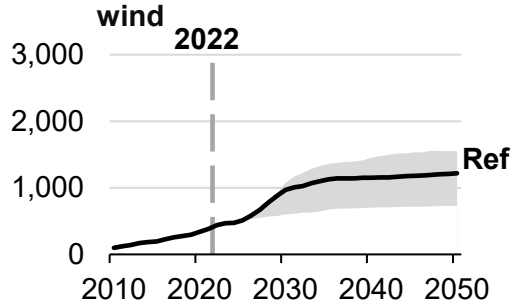
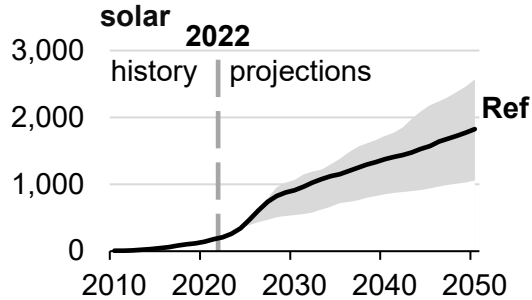
Data source: U.S. Energy Information Administration, *Annual Energy Outlook 2023* (AEO2023)

Note: ZTC=Zero-Carbon Technology Cost; other=geothermal, biomass, municipal waste, fuel cells, hydroelectric, pumped hydro storage

Power demand is increasingly met by renewables

U.S. electricity generation by select technologies for all cases

billion kilowatthours



Data source: U.S. Energy Information Administration, *Annual Energy Outlook 2023* (AEO2023)

Note: Shaded regions represent maximum and minimum values for each projection year across the AEO2023 Reference case and side cases.

Ref=Reference case

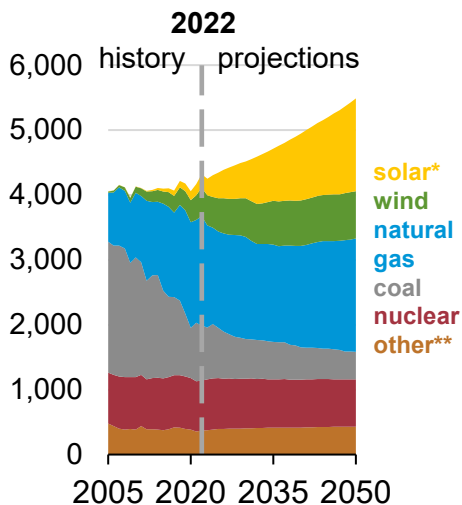
Solar and wind generate a majority of U.S. electricity by 2050 in the Reference and High Uptake cases



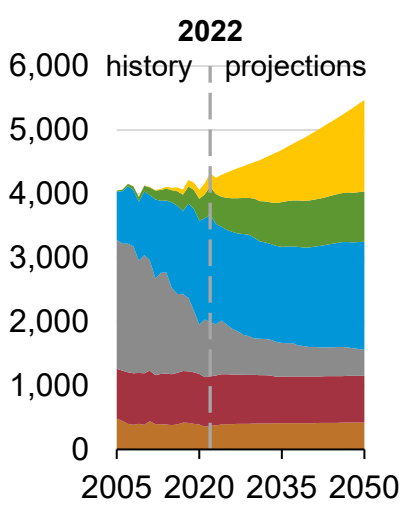
U.S. net electricity generation by fuel

billion kilowatthours

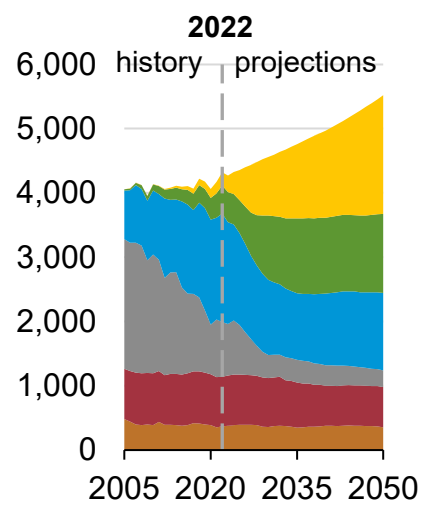
No IRA



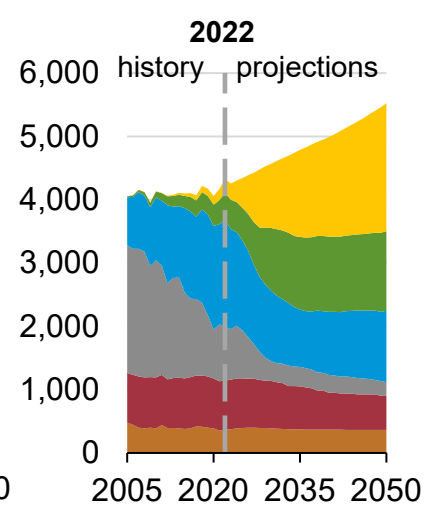
Low Uptake



Reference



High Uptake



Data source: U.S. Energy Information Administration, *Annual Energy Outlook 2023* (AEO2023)

Note: IRA=Inflation Reduction Act

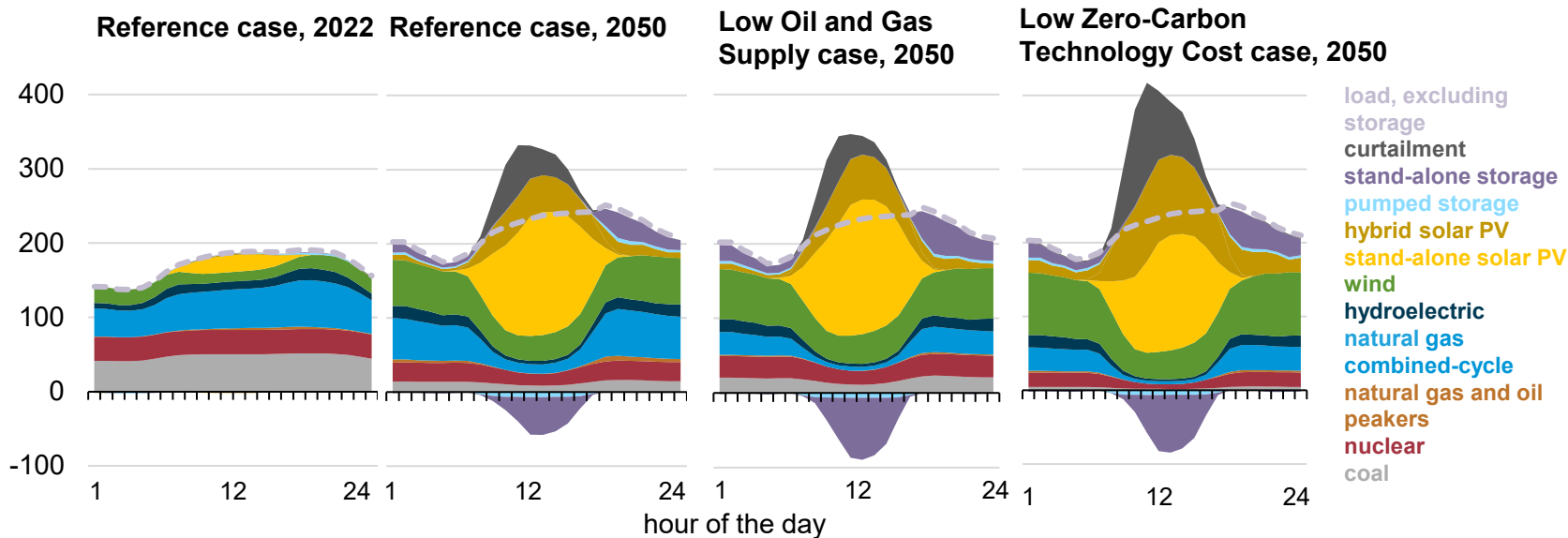
*Includes utility-scale and end-use photovoltaic generation and excludes off-grid photovoltaics.

**Includes petroleum, conventional hydroelectric power, geothermal, wood and other biomass, pumped storage, non-biogenic municipal waste in the electric power sector, refinery gas, still gas, batteries, chemicals, hydrogen, pitch, purchased steam, sulfur, and miscellaneous technologies.

More intermittent renewables lead to more curtailment and usage of battery storage

Hourly U.S. electricity generation and load by fuel for selected cases and representative years

billion kilowatthours



Data source: U.S. Energy Information Administration, *Annual Energy Outlook 2023* (AEO2023)

Note: Negative generation represents charging of energy storage technologies such as pumped hydro and battery storage. Hourly dispatch estimates are illustrative and are developed to determine curtailment and storage operations; final dispatch estimates are developed separately and may differ from total utilization as this figure shows. Standalone solar photovoltaic (PV) includes both utility-scale and end-use PV electricity generation.

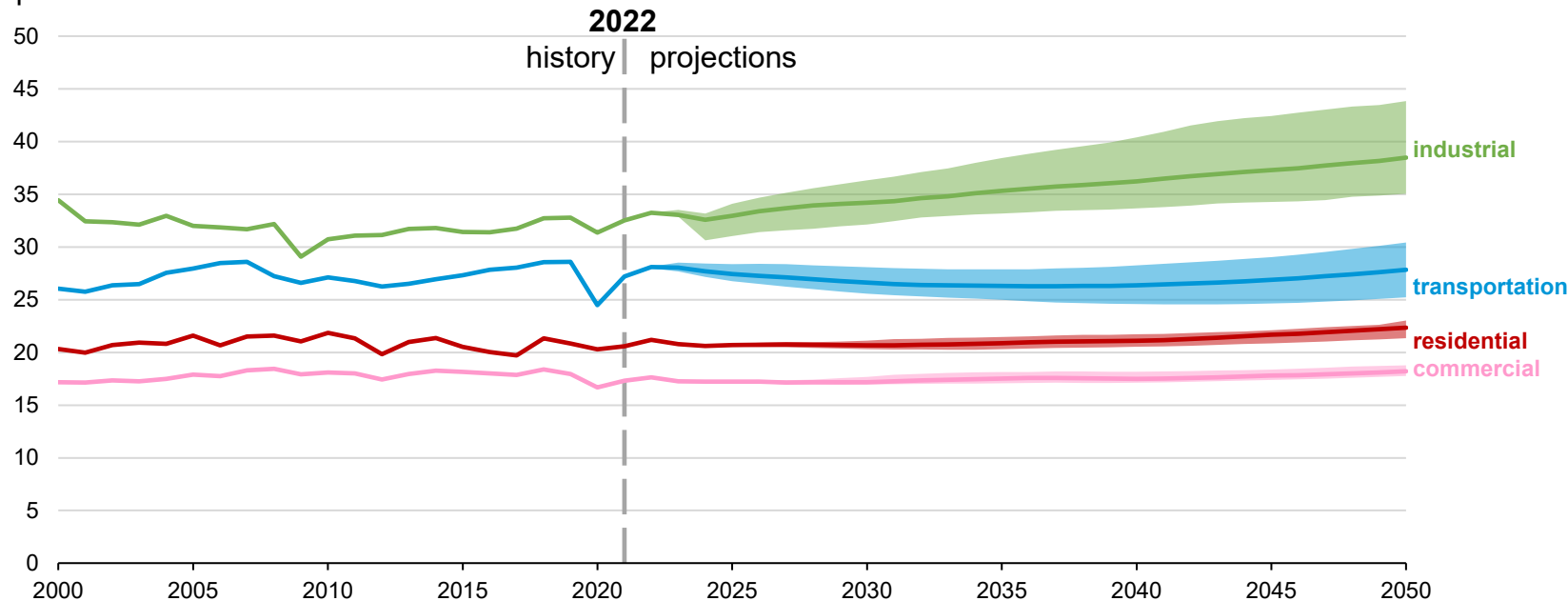
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U.S. energy consumption increases to 2050, and electricity plays an increasingly larger role



Total energy consumption by end-use sector
quadrillion British thermal units



Data source: U.S. Energy Information Administration, *Annual Energy Outlook 2023* (AEO2023)

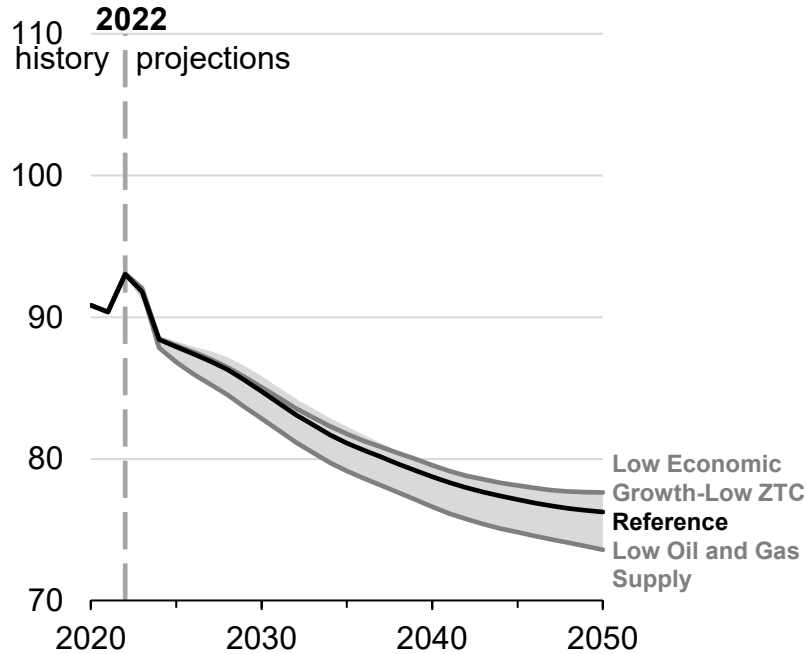
Note: Total consumption in end-use sectors includes purchased electricity and electricity-related losses. Each line represents AEO2023 Reference case projections. Shaded regions represent maximum and minimum values for each projection year across the AEO2023 Reference case and side cases.

Average energy intensity declines through 2050 across all cases



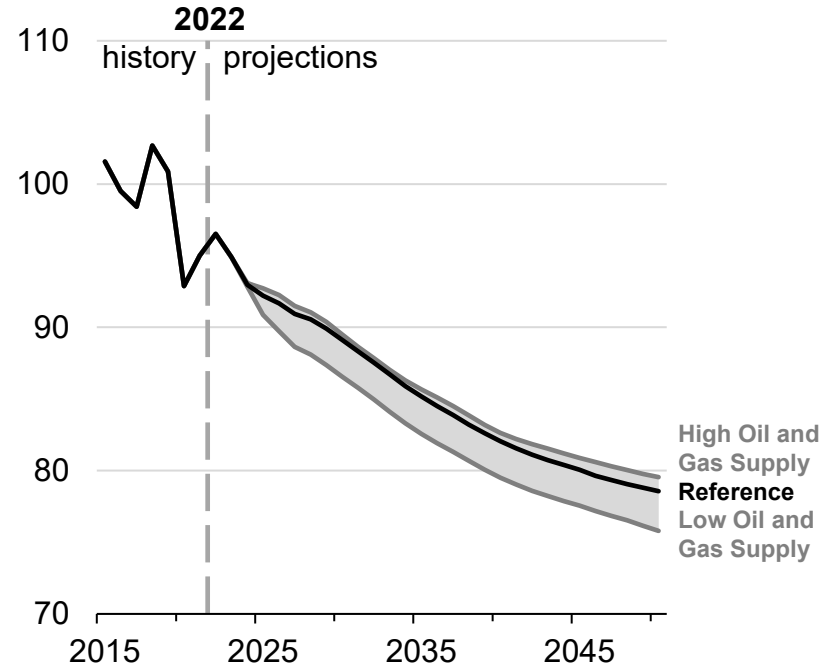
Residential delivered energy intensity

million British thermal units per household



Commercial delivered energy intensity

thousand British thermal units per square foot



Data source: U.S. Energy Information Administration, *Annual Energy Outlook 2023* (AEO2023)

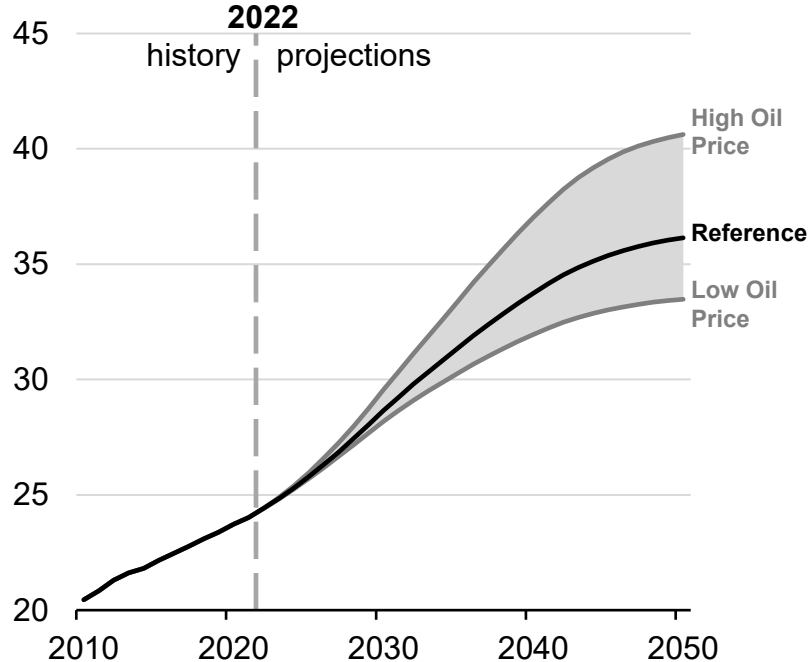
Note: Shaded regions represent maximum and minimum values for each projection year across the AEO2023 Reference case and side cases.

ZTC=Zero-Carbon Technology Cost

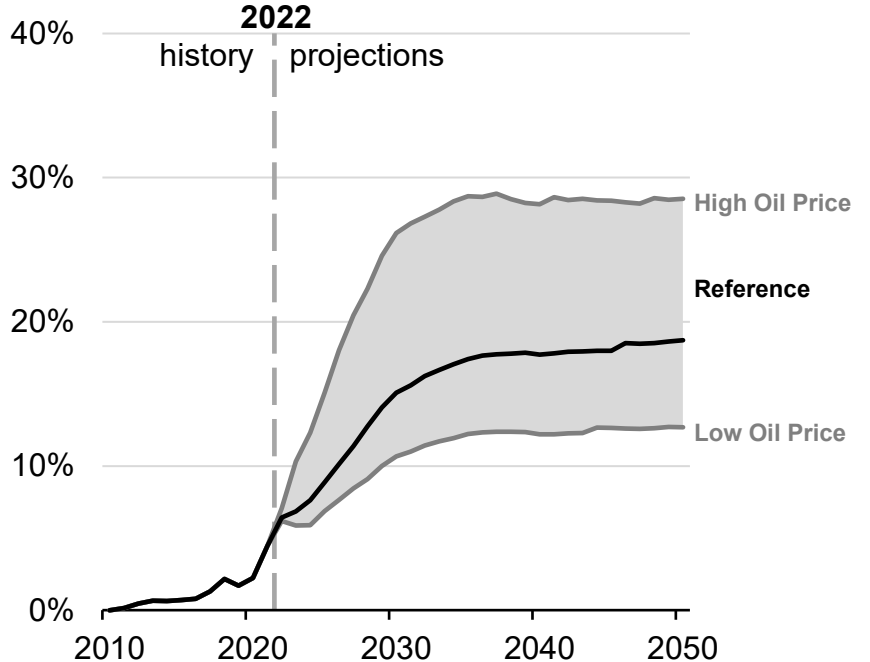
Light-duty vehicle fuel economy and electric vehicle market share increase through 2050 due to rising CAFE Standards and other incentives



Light-duty vehicle average fuel economy
miles per gallon



Market share of electric light-duty vehicles*
percentage of sales



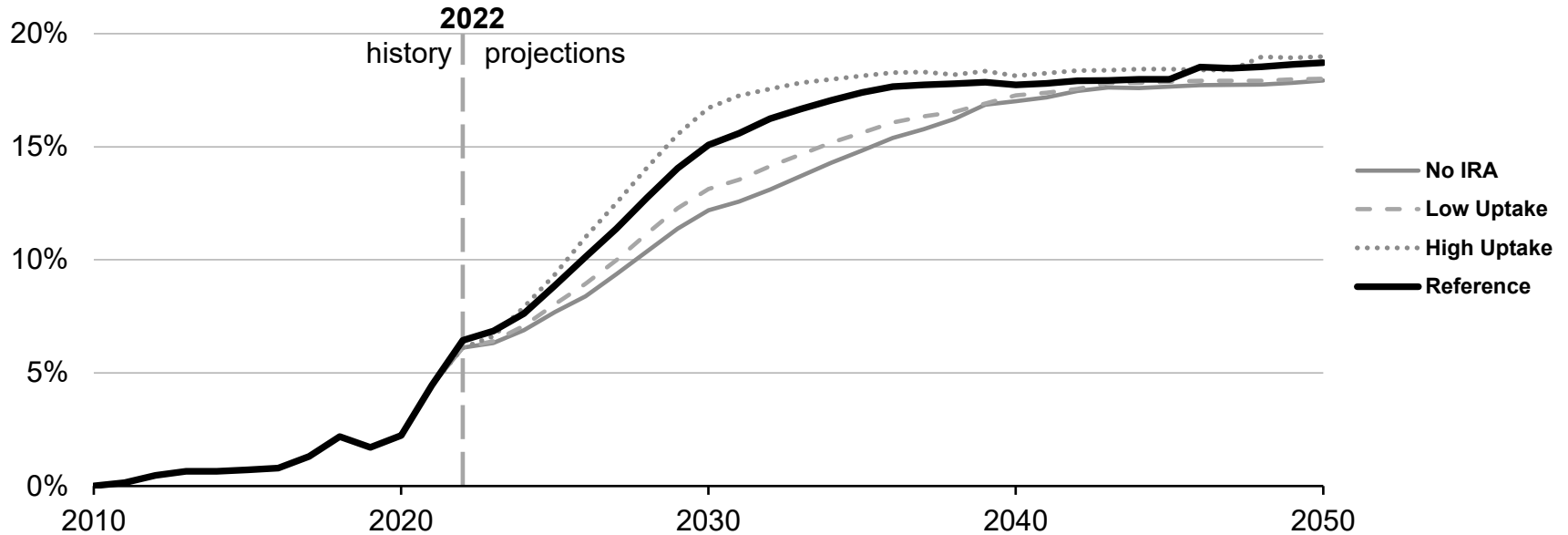
Data source: U.S. Energy Information Administration, *Annual Energy Outlook 2023 (AEO2023)*

Note: *Includes battery electric and plug-in hybrid electric vehicles. Shaded regions represent maximum and minimum values for each projection year across the AEO2023 Reference case and side cases.

IRA incentives speed growth in sales of electric vehicles



Market share of electric light-duty vehicles*
percentage



Data source: U.S. Energy Information Administration, *Annual Energy Outlook 2023* (AEO2023)
Note: *Includes battery electric and plug-in hybrid electric vehicles. IRA=Inflation Reduction Act

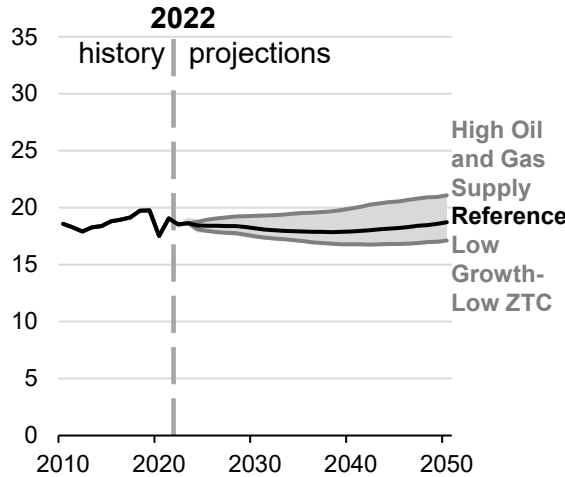
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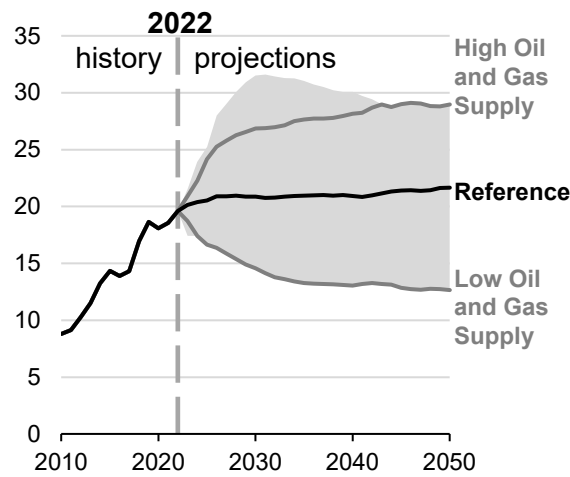
In all cases, we project that the United States will remain a net exporter of petroleum products through 2050



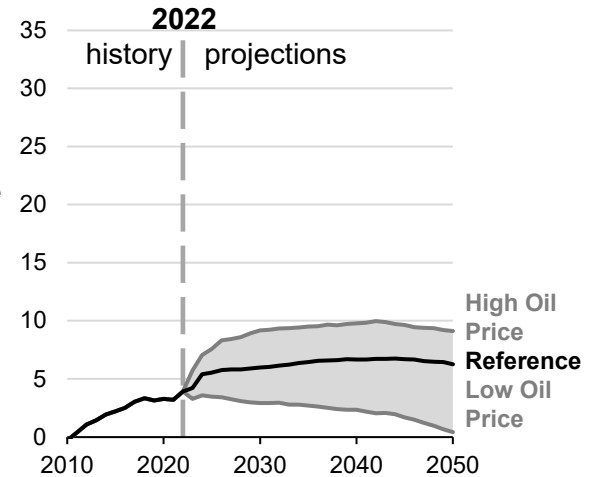
Petroleum and other liquids consumption
million barrels per day



Petroleum and other liquids production
million barrels per day



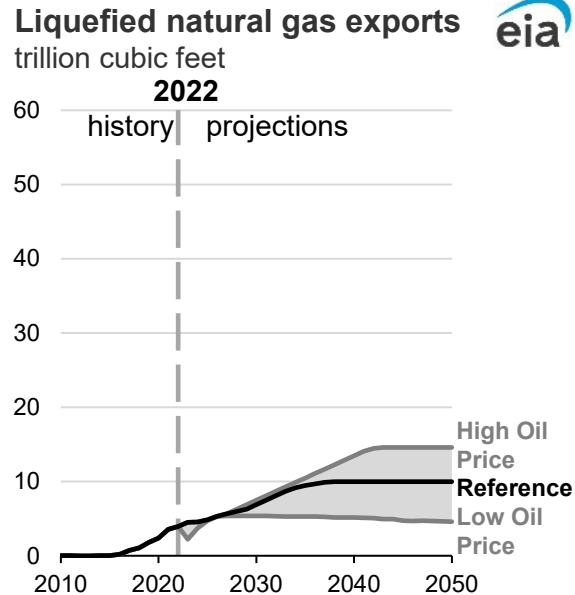
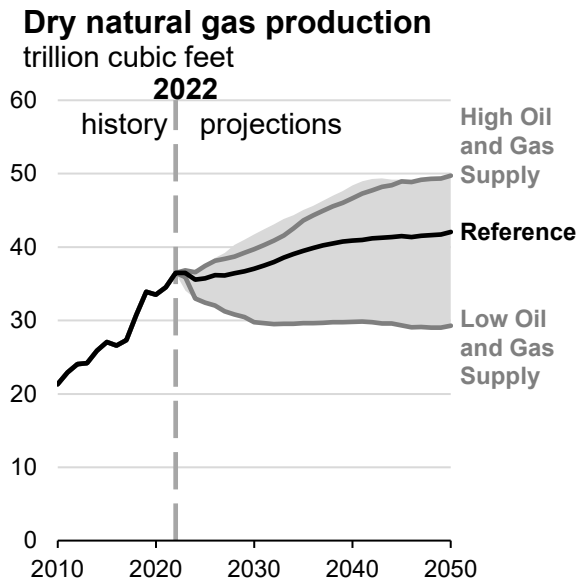
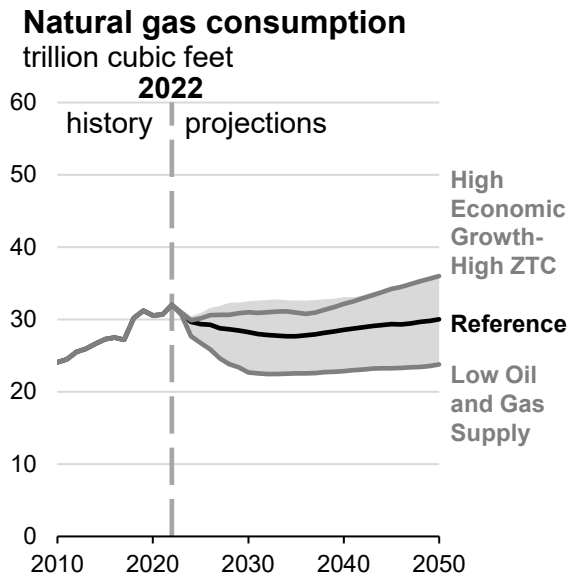
Petroleum products net exports
million barrels per day



Data source: U.S. Energy Information Administration, *Annual Energy Outlook 2023 (AEO2023)*

Note: Biofuels are not included in *petroleum and other liquids* production or consumption. Shaded regions represent maximum and minimum values for each projection year across the AEO2023 Reference case and side cases. ZTC=Zero-Carbon Technology Cost

Liquefied natural gas exports drive production; domestic consumption remains stable



Data source: U.S. Energy Information Administration, *Annual Energy Outlook 2023* (AEO2023)

Note: Shaded regions represent maximum and minimum values for each projection year across the AEO2023 Reference case and side cases. ZTC=Zero-Carbon Technology Cost

Upcoming AEO2023 *Issues in Focus*

- Liquefied Natural Gas (LNG)
Issues in Focus coming next month
 - High LNG Price case
 - Low LNG Price case
 - Fast Builds + High LNG Price case





Independent Statistics and Analysis

**U.S. Energy Information
Administration**

View the full report at eia.gov/aeo

Contact us at AnnualEnergyOutlook@eia.gov