



Annual Energy Outlook 2023: Case Descriptions

March 2023

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Overview

Our *Annual Energy Outlook 2023* (AEO2023), with projections through 2050, considers factors such as economic growth, future oil prices, the ultimate size of domestic energy resources, and technological changes that are often uncertain. To illustrate some of these uncertainties, we run side cases, compared with our Reference case, to show how the model responds to changes in key input variables. This document describes the nine core cases and four new combination cases in AEO2023:

- Reference
- High Economic Growth
- Low Economic Growth
- High Oil Price
- Low Oil Price
- High Oil and Gas Supply
- Low Oil and Gas Supply
- High Zero-Carbon Technology Cost
- Low Zero-Carbon Technology Cost
- Combination cases:
 - Low Economic Growth and Low Zero-Carbon Technology Cost
 - High Economic Growth and Low Zero-Carbon Technology Cost
 - Low Economic Growth and High Zero-Carbon Technology Cost
 - High Economic Growth and High Zero-Carbon Technology Cost

[Table 1](#) provides the formal case names, scenario names, and datekeys. Results for all AEO2023 cases are available in the [AEO table browser](#).

In addition to the 13 cases listed above, AEO2023 also includes:

- An analytic report, *Issues in Focus —Inflation Reduction Act Cases in the AEO2023*, on the impact of the Inflation Reduction Act of 2022 (IRA), which was passed in August 2022. This report includes descriptions of the No IRA, Low Uptake, and High Uptake cases.
- A separate *Issues in Focus* that varies the amount of liquefied natural gas (LNG) exports.

Summary of Cases

Table 1. Summary of *Annual Energy Outlook 2023* cases (released March 16, 2023)

| Case name | Scenario name | Datekey |
|-----------------------------------------------------------|---------------|----------|
| Reference | ref2023 | d020623a |
| Low Economic Growth | lowmacro | d020623a |
| High Economic Growth | highmacro | d020623a |
| Low Oil Price | lowprice | d020623a |
| High Oil Price | highprice | d020623a |
| Low Oil and Gas Supply | lowogs | d020623a |
| High Oil and Gas Supply | highogs | d020623a |
| Low Zero-Carbon Technology Cost | lowZTC | d020623a |
| High Zero-Carbon Technology Cost | highZTC | d020623a |
| Low Economic Growth and Low Zero-Carbon Technology Cost | lowmaclowZTC | d020623a |
| High Economic Growth and Low Zero-Carbon Technology Cost | himaclowZTC | d020623a |
| Low Economic Growth and High Zero-Carbon Technology Cost | lowmachighZTC | d020623a |
| High Economic Growth and High Zero-Carbon Technology Cost | himachighZTC | d020623a |

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

Note: AEO2023 = Annual Energy Outlook 2023

Macroeconomic Growth Cases

We developed the Low Economic Growth case and High Economic Growth case to reflect the uncertainty in projections of economic growth. These cases show the effects of alternative economic growth assumptions that are higher than and lower than the Reference case. Changes in assumptions for growth in population and nonfarm labor productivity yield changes in the growth in nonfarm employment, real disposable income, and real GDP, among other macroeconomic concepts. [Table 2](#) shows the average compound annual growth rates of these model parameters in the Reference case and in the macroeconomic side cases.

Table 2. Macroeconomic growth rates in the *Annual Energy Outlook 2023* Low Economic Growth, Reference, and High Economic Growth cases (2022-2050)

| Model parameter | Low Economic Growth case | Reference case | High Economic Growth case |
|-----------------------------------|--------------------------|----------------|---------------------------|
| Population | 0.2% | 0.4% | 0.6% |
| Nonfarm labor productivity | 1.0% | 1.9% | 2.4% |
| Nonfarm employment | 0.2% | 0.4% | 0.6% |
| Real disposable income per capita | 1.7% | 2.0% | 2.1% |
| Real gross domestic product | 1.4% | 1.9% | 2.3% |

Data source: U.S. Energy Information Administration, AEO2023 National Energy Modeling System, runs: ref2023.d020623a, highmacro.d020623a, and lowmacro.d020623a

Note:

AEO2023 = Annual Energy Outlook 2023

Minor discrepancies with published data are a result of independent rounding.

Oil Price Cases

Different expectations about long-term future oil prices can significantly affect the energy system. AEO2023 considers three oil price cases (Reference, Low Oil Price, and High Oil Price) to assess the impacts of alternative views on the future course of oil prices. We base the benchmark world crude oil price in AEO2023 on historical spot prices for North Sea Brent crude oil, which is an international standard for light, sweet crude oil prices. Data tables also include the West Texas Intermediate (WTI) price—a critical reference point for the value of crude oil production in the U.S. Midcontinent—as well as the refiner’s acquisition cost for imported crude oil.

We base the Brent spot price path in the Reference case on an assumption that both global oil supply and demand will increase in the projection period and that crude oil prices will also rise steadily across the projection period starting in 2023. Global petroleum and other liquid fuels consumption increases steadily throughout the Reference case, in part, because of an increase in the number of vehicles globally. The increase in vehicles is offset somewhat by improvements in light-duty vehicle (LDV) and heavy-duty vehicle (HDV) fuel economy in developing countries and increased natural gas consumption for transportation in most regions. Economic growth is steady during the projection period. The industrial sector also uses some substitutes for liquid fuels.

The Low Oil Price and High Oil Price cases encompass a wide range of potential price paths, illustrating potential variation in global demand for and supply of petroleum and other liquid fuels. The Low Oil Price case assumes conditions under which global (worldwide, excluding the United States) liquid fuels demand is lower and supply is higher than in the Reference case. The High Oil Price case assumes the opposite. Note that assumptions about U.S. supply and demand remain the same across the cases, and U.S. liquid fuels production and consumption respond only to changes in price.

In the Low Oil Price case, relatively low global demand results from several assumptions:

- Economic growth that is relatively slow compared with historical trends, especially in the countries outside of the OECD
- Reduced consumption in developed countries as a result of adopting more efficient technologies, extending Corporate Average Fuel Economy (CAFE) standards, lowering travel demand, and increasing natural gas or electricity consumption
- Efficiency improvements in nonmanufacturing industries in non-OECD countries
- Industrial fuel switching from liquid fuels to natural gas feedstocks for methanol and ammonia production

The Low Oil Price case also assumes higher supply than the Reference case, and the higher supply results in lower production costs for both crude oil and other liquid fuels production technologies. With lower demand and higher supply, prices remain lower in the Low Oil Price case than in the Reference case throughout the projection period, but the impacts on global quantities produced and consumed are muted because the demand and supply effects somewhat offset each other at equilibrium.

In the High Oil Price case, these assumptions are largely reversed. Liquid fuel demand is higher in the High Oil Price case as a result of higher economic growth than in the Reference case. Consumers

demand greater personal mobility and consume more goods. Fewer efficiency gains occur in the industrial sector, and growing demand for fuel in the nonmanufacturing sector continues to be met with liquid fuels. Liquid fuels supply decreases due to a lack of global investment in the oil sector, which eventually leads to higher production in countries outside of OPEC relative to the Reference case. Higher prices stimulate increased production of more costly resources, including tight or shale oil and bitumen, and they also lead to significant increases in production of renewable liquid fuels, gas-to-liquids, and coal-to-liquids compared with the Reference case.

Table 3 shows assumptions of the Brent crude oil benchmark price in the most recent historical year and in the first and last years of the projection period for both oil price cases and the Reference case.

Table 3. Brent oil price in selected years in both oil price cases and the Reference case, *Annual Energy Outlook 2023*

2022 dollars per barrel

| Case name | 2022 | 2023 | 2050 |
|---------------------|----------|----------|----------|
| High Oil Price case | N/A | \$169.06 | \$190.06 |
| Reference case | \$102.13 | \$91.54 | \$101.34 |
| Low Oil Price case | N/A | \$43.28 | \$51.28 |

Data source: U.S. Energy Information Administration. *Annual Energy Outlook 2023*, National Energy Modeling System runs ref2023.d020623a, highprice.d020623a, lowprice.d020623a

Note:
AEO2023 = Annual Energy Outlook 2023
N/A = not applicable

Oil and Gas Supply Cases

Estimates of technically recoverable tight or shale oil and natural gas resources are particularly uncertain and change over time as new information is gained through drilling, production, and technology experimentation. During the past decade, as more tight or shale oil formations have gone into production, estimates of technically recoverable tight or shale oil and natural gas resources have generally increased. However, these increases in technically recoverable resources (TRR) are based on many assumptions that might not apply in the long term or for the entire tight or shale formation. For example, some resource estimates may assume that crude oil and natural gas production rates achieved in one part of the formation represent the entire formation, even though neighboring well production rates can vary greatly. In addition, the tight or shale formation can differ significantly across the petroleum basin with respect to depth, thickness, porosity, carbon content, pore pressure, clay content, thermal maturity, and water content. Technological improvements and innovations may also result in developing undiscovered crude oil and natural gas resources, but the Reference case does not include these resources (because they are currently unknown).

Two AEO2023 side cases examine our projections' sensitivity to changes in assumptions regarding domestic crude oil and natural gas resources and technological progress ([Table 4](#)). These side cases are included to provide a framework to examine the effects of higher and lower domestic supply on energy demand, imports, and prices.

In the Low Oil and Gas Supply case, the estimated ultimate recovery per well is assumed to be 50% lower than in the Reference case for:

- Tight oil, tight gas, and shale gas in the Lower 48 states
- Undiscovered resources in Alaska
- Offshore Lower 48 states

Rates of technological improvement that reduce costs and increase productivity in the United States are also 50% lower than in the Reference case. These assumptions increase the per-unit cost of crude oil and natural gas development in the United States.

In the High Oil and Gas Supply case, we assume the estimated ultimate recovery per well to be 50% higher than in the Reference case for:

- Tight oil, tight gas, and shale gas in the Lower 48 States
- Undiscovered resources in Alaska
- Offshore Lower 48 states

Rates of technological improvement that reduce costs and increase productivity in the United States are also 50% higher than in the Reference case. The Liquid Fuels Market Module (LFMM) assumes crude oil pipeline and export capacity increases in the projection period to accommodate higher levels of domestic oil production.

Table 4. Unproved technically recoverable resource assumptions at the start of 2020, *Annual Energy Outlook 2023*

| Case | Oil (billion barrels) | Natural gas (trillion cubic feet) |
|------------------------------|----------------------------------|----------------------------------------------|
| High Oil and Gas Supply case | 463 | 3,663 |
| Reference case | 321 | 2,528 |
| Low Oil and Gas Supply case | 180 | 1,393 |

Data source: U.S. Energy Information Administration. *Annual Energy Outlook 2023*, National Energy Modeling System runs ref2023.d020623a, lowogs.d020623a, highogs.d020623a

Note: AEO2023 = Annual Energy Outlook 2023

Zero-Carbon Technology Cost Cases

To address the uncertainty in the future costs of power generation technologies that produce zero emissions, AEO2023 provides two cases: one assuming technology costs that are higher than those in the Reference case and another assuming technology costs that are lower. We applied the changes in the cost assumptions to the following technologies:

- Power sector
 - Conventional hydropower
 - Geothermal
 - Biomass
 - Solar thermal
 - Solar photovoltaic, standalone and hybrid
 - Onshore and offshore wind
 - Diurnal storage
 - Advanced and small modular reactors
- End-use sector
 - Solar photovoltaic
 - Wind

In the High Zero-Carbon Technology Cost case, the overnight capital cost is held constant at the 2022 level throughout the projection period for all of the technologies listed above. In the Low Zero-Carbon Technology Cost case, we assume overnight capital costs and fixed operating and maintenance (O&M) costs decline more rapidly than in the Reference case, falling 40% below their Reference case equivalents by 2050 for all of these technologies. Other assumptions within these two cases remain the same as in the Reference case.

Combination Cases

For AEO2023, we include cases to examine the impact of combined uncertainties in our core side cases. In particular, we combine the uncertainties surrounding economic growth projections and installed costs assumptions for electricity-generating technologies that produce zero emissions as follows:

- High Economic Growth and High Zero-Carbon Technology Cost case
- High Economic Growth and Low Zero-Carbon Technology Cost case
- Low Economic Growth and High Zero-Carbon Technology Cost case
- Low Economic Growth and Low Zero-Carbon Technology Cost case

The uncertainties surrounding economic growth projections (High Economic Growth and Low Economic Growth cases) are presented in [Table 2](#), and the uncertainties in the cost assumptions (High Zero-Carbon Technology Cost and Low Zero-Carbon Technology Cost cases) are as described in the Zero-Carbon Technology Cost cases section of this report.