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Overview

Uncertainty surrounds economic growth, future oil prices, the ultimate endowment of domestic energy resources, and technological change. To capture that uncertainty, EIA ran sensitivity cases to show how the model responds to changes in key input variables compared with the Reference case. The seven sensitivity cases covered in the *Annual Energy Outlook 2018* (AEO2018) are described in this document:

- Reference
- High Economic Growth
- Low Economic Growth
- High Oil Price
- Low Oil Price
- High Oil and Gas Resource and Technology
- Low Oil and Gas Resource and Technology

All seven of the core cases were run with and without the Clean Power Plan (CPP) included.

Table 1 provides the formal case names, scenario names, and date keys. Results for all AEO2018 cases are available on the AEO table browser.

In addition, because AEO2018 was a full edition of the AEO (which occurs every other year), EIA ran additional cases to support *Issues in Focus* analysis on specific topics, also described in this document:

- Nuclear power costs
- Alternative policies
- Arctic National Wildlife Refuge
- Autonomous vehicles

Macroeconomic growth cases

The Low Economic Growth and High Economic Growth cases were developed to reflect the uncertainty in projections of economic growth. These cases show the effects of alternative growth assumptions that are higher than and lower than the Reference case energy market projections. In the Reference case, population (including armed forces overseas) grows by an average rate of 0.6%/year, nonfarm employment by 0.7%/year, and productivity by 1.6%/year from 2017 to 2050. Economic output as measured by real gross domestic product (GDP) increases by 2.0%/year from 2017 through 2050, and growth in real disposable income per capita averages 2.2%/year.

The Low Economic Growth case assumes lower average annual growth rates for population (0.5%/year) and nonfarm labor productivity (1.2%/year), resulting in lower growth in nonfarm employment (0.5%/year), higher prices and interest rates, and lower growth in industrial output. In the Low Economic Growth case, economic output as measured by real GDP increases by 1.5%/year from 2017 through 2050, and growth in real disposable income per capita averages 2.0%/year.

The High Economic Growth case assumes higher average growth rates for population (0.8%/year) and productivity (2.0%/year), resulting in higher nonfarm employment (0.9%/year). With higher productivity gains and employment growth, inflation and interest rates are lower than in the Reference case for most years, and as a result, economic output, as measured by real GDP, grows at a higher rate (2.6%/year) than in the Reference case (2.0%/year). Real disposable income per capita grows by 2.5%/year.

Oil price cases

The historical record shows substantial variability in oil prices and even more uncertainty about long-term future prices. AEO2018 considers three oil price cases (Reference, Low Oil Price, and High Oil Price) to assess alternate views on the future course of oil prices. The benchmark crude oil price in AEO2018 is based on the spot price for North Sea Brent crude oil, which is an international standard for light sweet crude oil prices. Data tables also include West Texas Intermediate (WTI) prices—a critical reference point for the value of growing oil production in the U.S. Midcontinent—as well as the imported refiner acquisition cost for crude oil. The WTI spot price is generally lower than the North Sea Brent price. With the price spread between Brent and WTI estimated to have been $2.75/barrel (b) in 2017, EIA expects the price spread in the Reference and Low Oil Price cases to range between $3/b and $5/b from 2018 through 2050, and between $3/b and $7/b in the High Oil Price case. The December 2015 decision by the U.S. Congress to remove restrictions on U.S. crude oil exports has the potential to narrow the spread between the Brent price and the price of domestic production streams under certain cases involving high levels of U.S. crude oil production.

In the Reference case, real oil prices (2017 dollars) steadily rise from $52/b in 2017 to almost $114/b by 2050. The Reference case Brent spot price path is based on an increasing trend projection for both global oil supply and demand. Global petroleum and other liquids consumption increases steadily throughout the Reference case, in part because of an increase in the number of vehicles across the world—which 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 over the projection period, and some substitution away from liquid fuels in the industrial sector occurs. The market share of total liquids production by the Organization of the Petroleum Exporting Countries (OPEC) rises from 40% in 2017 to 42% in 2040 and then to 43% in 2050.

The Low and High Oil Price cases reflect a wide range of potential price paths, resulting from variation in global demand and supply of petroleum and other liquid fuels. The Low Oil Price case assumes conditions under which global liquids demand is low and supply is high, and the High Oil Price case assumes the opposite. Both cases show shifts in global supply and demand that offset one another, which makes liquids consumption close to Reference case levels although prices are substantially different.

In the Low Oil Price case, crude oil prices fall to an average of $27/b (2017 dollars) in 2018 and remain lower than $50/b until 2048, and the Brent crude oil price in 2050 is almost $52/b. Relatively low global demand compared with the Reference case occurs as a result of several factors:

- Economic growth that is relatively slow compared with historical trends
- 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 use of natural gas or electricity

- Efficiency improvement in nonmanufacturing industries in the non-Organization for Economic Cooperation and Development countries
- Industrial fuel switching from liquids to natural gas feedstocks for production of methanol and ammonia

Low oil prices also result from lower costs of production and relatively abundant supply from both OPEC and non-OPEC producers. However, lower-cost supply from OPEC producers eventually begins to replace supply from relatively more expensive non-OPEC sources. In the Low Oil Price case, OPEC's market share of liquids production rises steadily from 40% in 2017 to 48% in 2030 and to 57% in 2050.

In the High Oil Price case, Brent crude oil prices average almost $230/b (2017 dollars) in 2050. A lack of global investment in the oil sector is the primary cause of higher prices, which eventually leads to higher production from non-OPEC producers relative to the Reference case. Higher prices stimulate increased supply of more costly resources, including tight oil and bitumen, and also lead to significant increases in production of renewable liquid fuels as well as gas-to-liquids and coal-to-liquids compared with the Reference case. Increased non-OPEC production, starting in 2019, crowds out OPEC oil, and OPEC's share of world liquids production decreases to less than 33% in 2030 then rises to almost 36% in 2050. The main reason for increased demand in the High Oil Price case is higher economic growth, particularly in developing countries, than in the Reference case. In the developing countries, consumers demand greater personal mobility and more consumption of goods. Fewer efficiency gains occur in the industrial sector, while growing demand for fuel in the non-manufacturing sector continues to be met with liquid fuels.

Clean Power Plan cases

The CPP cases assume compliance with the CPP through mass-based standards modeled with cooperation across states at the regional level, with all allowance revenues rebated to taxpayers. All seven core cases can be compared with or without the CPP.

Oil and gas resource and technology cases

Estimates of technically recoverable tight/shale crude oil and natural gas resources are particularly uncertain and change over time as new information is gained through drilling, production, and technology experimentation. Over the past decade, as more tight/shale formations have gone into production, the estimate of technically recoverable tight oil and shale gas resources has increased. However, these increases in technically recoverable resources are based on many assumptions that might not prove to be true over the long term and over the entire tight/shale formation. For example, these resource estimates assume that crude oil and natural gas production rates achieved in a limited portion of the formation are representative of an entire formation, even though neighboring well production rates can vary by as much as a factor of three within the same play. Additionally, the tight/shale formation can vary 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 the development of crude oil and natural gas resources that have not been identified yet, and thus are not included in the Reference case.

The sensitivity of the AEO2018 projections to changes in assumptions regarding domestic crude oil and natural gas resources and technological progress is examined in two cases. These cases do not represent a confidence interval for future domestic oil and natural gas supply, but rather they provide a framework to examine the effects of higher and lower domestic supply on energy demand, imports, and prices. Assumptions associated with these cases are described below.

In the Low Oil and Gas Resource and Technology case, the estimated ultimate recovery per tight oil, tight gas, or shale gas well in the United States and undiscovered resources in Alaska and the offshore Lower 48 states is assumed to be 50% lower than in the Reference case. 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. The total unproved technically recoverable resource of crude oil is reduced to 156 billion barrels, and the natural gas resource is reduced to 1,269 trillion cubic feet (Tcf), as compared with unproved resource estimates of 249 billion barrels of crude oil and 2,155 Tcf of natural gas as of January 1, 2016, in the Reference case.

In the High Oil and Gas Resource and Technology case, the estimated ultimate recovery per tight oil, tight gas, or shale gas well in the United States and undiscovered resources in Alaska and the offshore Lower 48 states is assumed to be 50% higher than in the Reference case. Rates of technological improvement that reduce costs and increase productivity in the United States are also 50% higher than in the Reference case. In addition, tight oil and shale gas resources are added to reflect new plays or the expansion of known plays. The total unproved technically recoverable resource of crude oil increases to 421 billion barrels, and the natural gas resource increases to 3,226 Tcf as compared with unproved resource estimates of 249 billion barrels of crude oil and 2,155 Tcf of natural gas in the Reference case as of the start of 2016.

Nuclear power cases

These sensitivity cases illustrate three different types of uncertainty surrounding the nuclear power generating capacity projections in the Reference case. The uncertainty is related to higher or lower operating and capital costs for both new and existing nuclear units, higher or lower levels of natural gas availability, and alternative levels of carbon emissions regulation, as represented by different fees on the emissions of carbon dioxide.

The first two types of uncertainty are covered by either increasing or decreasing the operating and capital costs for both new and existing nuclear units by 20% and applying those costs to the Reference case, the High Oil and Gas Resource and Technology case, and the Low Oil and Gas Resource and Technology case.

The carbon dioxide allowance fee cases assumes a cost for carbon dioxide emissions from utility-scale electricity generators beginning at either $15 or $25 (in 2017 dollars) per metric ton carbon dioxide in 2020 and increasing at 5% per year in real dollar terms.

Alternative policy cases

The AEO2018 Reference case is best described as a current laws and regulations case, because it generally assumes that existing laws and regulations remain unchanged throughout the projection period. Exceptions to this guiding principle are those current laws or regulations that include sunset dates or specific changes over time. The Reference case serves as a starting point for analysis of possible changes in legislation or regulations. The alternative cases assume changes to laws and regulations that have a history of being extended beyond their legislated sunset dates or that call for periodic updates beyond current standard levels.

The Production Tax Credit (PTC)/Investment Tax Credit (ITC) Extension case assumes that existing tax credits that have scheduled reductions and sunset dates remain at their full credit values through 2050. The PTC for eligible utility-scale electricity generating technologies retains its full credit value through 2050 as opposed to declining in value starting in 2017 (wind) or expiring at the end of 2016 (other PTC-eligible technologies, including geothermal and hydroelectric) as specified in the Reference case. The PTC provides a credit of $24 per megawatthour ($/MWh in 2017 dollars) for qualifying electricity production from wind, closed-loop biomass, geothermal, and certain waste energy facilities. The PTC also provides a half-value credit of $12/MWh for qualifying electricity production from open-loop biomass, incremental hydroelectric, marine, tidal, and certain other waste energy facilities. For solar power, the full ITC value of 30% remains in effect through 2050 for the residential, commercial, and electric power sectors. In the Reference case, the value of the ITC begins to decline in 2020, achieving a permanent 10% level for commercial and electric power sectors and phasing out completely for the residential sector by 2022. In addition, EIA assumes offshore wind projects that are eligible to claim the ITC in lieu of the PTC will opt for the ITC because of their high capital costs. In the building sectors, the ITC for solar water heaters is assumed to remain at 30% rather than being phased out in 2022 (residential systems) or declining to 10% (commercial systems).

The Early PTC/ITC Sunset case assumes existing tax credits expire completely in 2019, before their scheduled phaseouts and expirations as represented in the Reference case. All renewable generation tax credits expire in 2019, including a complete sunset of the ITC for solar photovoltaic (PV) in the residential, commercial, and electric power sectors, other ITC-eligible technologies in the power sector, and the PTC for wind and other PTC-eligible technologies. The available ITC for solar water heaters in both the residential and commercial sectors is also assumed to sunset in 2019.

The Solar PV Tariff case assumes implementation of a declining-value tariff on imported solar modules. On January 22, 2018, the president approved a tariff of 30% on crystalline silicon (c-Si) solar PV cells and modules that are imported into the United States. The tariff is scheduled to start in 2018 and remain in effect for four years, declining by 5 percentage points annually and expiring completely after 2021. The first 2.5 gigawatts (GW) of imported solar PV cells are exempt from the tariff in each of the four years. EIA estimates that the initial 30% tariff on the module component of PV systems will increase the system cost of utility PV systems by 10%. This cost increase is reflected in this case for systems entering service in 2019. The prorated cost increase is reduced to 8.3%, 6.7%, and 5.0% for utility-scale solar PV projects entering service in 2020, 2021, and 2022, respectively. Prorated cost increases for residential solar PV equate to 4.0%, 3.1%, 2.5%, and 1.8% in 2019 through 2022, while nonresidential end-use solar PV costs increase 6.0%, 4.6%, 3.7%, and 2.8% during the same time period.

The New Efficiency Requirements case assumes that joint Corporate Average Fuel Economy (CAFE) and greenhouse gas (GHG) emissions standards for light-duty vehicles (LDVs) and the efficiency standards for residential and commercial major end-use equipment are both expanded beyond current provisions. The Reference case and the New Efficiency Requirements case include the joint attribute-based CAFE and vehicle GHG emissions standards through model year (MY) 2025 for LDVs as issued in 2012. In the Reference case, CAFE and GHG emissions standards are assumed to remain constant at MY 2025 levels in subsequent model years, although the fuel economy of new LDVs continues to improve modestly over time because of economic, consumer, and other factors. CAFE and GHG emissions standards are assumed to continue to increase at an annual average rate of 0.4% through MY 2050 for new LDVs after MY 2025. Standards for residential and commercial major end-use equipment are assumed to be updated according to the timeline in the U.S. Department of Energy's (DOE) multi-year plan at levels based on ENERGY STAR® specifications or on Federal Energy Management Program purchasing guidelines for federal agencies, as applicable. Standards also are updated for products that currently are not subject to federal efficiency standards but are covered by voluntary industry agreements or by state standards. The equipment standards assumed for the New Efficiency Requirements case illustrate the potential effects of those policies on energy consumption for buildings. No cost-benefit analysis or evaluation of impacts on consumer welfare was completed in developing the assumptions. Likewise, no technical feasibility analysis was conducted, although standards were not allowed to exceed the maximum technologically feasible levels described in DOE's technical support documents.

The No New Efficiency Requirements case assumes that joint CAFE and GHG emissions standards for LDVs and the efficiency standards for residential and commercial major end-use equipment are not increased beyond provisions effective in MY 2021 (for LDVs) or in 2018 (for end-use equipment). The joint attribute-based CAFE and vehicle GHG emissions standards are held constant at MY 2021 levels through MY 2050, although the fuel economy of new LDVs continues to rise modestly over time as a result of economic, consumer, and other factors. Standards for residential and commercial major end-use equipment are held constant at 2018 levels. Standards slated to go into effect after 2018 are removed from the projections.

Arctic National Wildlife Refuge cases

In December 2017, the passage of Public Law 115-97 required the Secretary of the Interior to establish and administer a competitive oil and natural gas program for the leasing, development, production, and transportation of oil and natural gas in and from the coastal plain (1002 Area) of the Arctic National Wildlife Refuge (ANWR). Previously, ANWR was effectively under a drilling moratorium. Uncertainty surrounds the ANWR projections because production has not yet occurred in the area. The resource bases for these cases are based on the latest (1998) levels of high (a 5% probability of being as high as 16.0 billion barrels), mean (10.4 billion barrels), and low (a 95% probability of being more than 5.7 billion barrels) assessments by the United States Geological Survey.

In these cases, the first crude oil production occurs at least 10 years after the first least sale, which is assumed to be in 2021. The 10-year timeline is needed for exploration, appraisal, permitting, and development. The largest fields are brought into production first, with new fields sequentially developed every two years after a prior field begins production if production costs and market conditions support their development. Fields are assumed to take three to four years to reach peak production, maintain peak production for three to four years, and then decline until they are no longer profitable and are abandoned.

Autonomous vehicle cases

In the Reference case, autonomous vehicles are used in shared-use mobility (ride hailing and taxi service) provided by fleet operators, such as transportation network companies (TNCs). The autonomous vehicle cases increase the number of autonomous vehicles used by fleets and also introduce them into households, allowing increased personal mobility through vehicle miles traveled. Transit rail use is reduced by the competition with TNCs while commuter rail use increases because TNC autonomous vehicles provide greater mobility between commuter rail stations and final destinations. Transit bus use declines at first because of competition for passengers, but rebounds once autonomous transit buses become common. Large fleet, long-haul freight trucks start using platooning to improve fuel efficiency, reaching 50% of fleet long-haul freight truck travel by 2050. Reference case autonomous vehicles are conventional internal combustion gasoline engine vehicles. In the Autonomous Battery Electric Vehicle case, battery electric vehicles are an increasing share of new autonomous vehicle sales by 2050, while in the Autonomous Hybrid Electric Vehicle case, gasoline hybrid electric internal combustion engine vehicles are an increasing share of new autonomous vehicle sales by 2050.

Summary of AEO2018 cases

Case name	Scenario name	Datekey
Reference	ref2018	d121317a
Low Economic Growth	lowmacro	d121317a
High Economic Growth	highmacro	d121317a
Low Oil Price	lowprice	d121317a
High Oil Price	highprice	d122017a
Low Oil and Gas Resource and Technology	lowrt	d121317a
High Oil and Gas Resource and Technology	highrt	d121317a
Clean Power Plan	ref_cpp	d121317a
Low Economic Growth with Clean Power Plan	lm_cpp	d121317a
High Economic Growth with Clean Power Plan	hm_cpp	d121317a
Low Oil Price with Clean Power Plan	lp_cpp	d121317a
High Oil Price with Clean Power Plan	hp_cpp	d122017a
Low Oil and Gas Resource and Technology with Clean Power Plan	lr_cpp	d121317a
High Oil and Gas Resource and Technology with Clean Power Plan	hr_cppfc	d121317a
Nuclear Cost +20%, Reference	rfnuc_plus20	d022318a
Nuclear Cost -20%, Reference	rfnuc_less20	d022318a
Nuclear Cost +20%, High Oil and Gas Resource and Technology	hrnuc_plus20	d121517a
Nuclear Cost -20%, High Oil and Gas Resource and Technology	hrnuc_less20	d121517a
Nuclear Cost +20%, Low Oil and Gas Resource and Technology	lrnuc_plus20	d121517a
Nuclear Cost -20%, Low Oil and Gas Resource and Technology	lrnuc_less20	d121517a
$15 Carbon Dioxide Allowance Fee	co2fee15	d022318a
$25 Carbon Dioxide Allowance Fee	co2fee25	d022318a
New Efficiency Requirements	effextendall	d030918a
No New Efficiency Requirements	effrelaxall	d030918a
PTC/ITC Extension	extend50	d032118a
Early PTC/ITC Sunset	sunset	d022318a
Solar PV Tariff	tariff1	d030118a
ANWR, High Resource Base	anwr_rphr	d032818a
ANWR, Mean Resource Base	anwr_rpmr	d032818a
ANWR, Low Resource Base	anwr_rplr	d032818a
Autonomous Battery Electric Vehicle	auto_ev	d033018a
Autonomous Hybrid Electric Vehicle	auto_hev	d033018a