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U.S. Crude Oil Production to 2025: Updated Projection of Crude Types

May 28, 2015

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Preface

U.S. oil production has grown rapidly in recent years. U.S. Energy Information Administration (EIA) data, which reflect combined production of crude oil and lease condensate, show a rise from 5.6 million barrels per day (bbl/d) in 2011 to 7.5 million bbl/d in 2013, and a record 1.2 million bbl/d increase to 8.7 million bbl/d in 2014. Increasing production of light crude oil in low-permeability or tight resource formations in regions like the Bakken, Permian Basin, and Eagle Ford (often referred to as light tight oil) account for nearly all the net growth in U.S. crude oil production.

EIA's latest *Short-Term Energy Outlook,* issued in May 2015, reflects continued production growth in 2015 and 2016, albeit at a slower pace than in 2013 and 2014, with U.S. crude oil production in 2016 forecast to reach 9.2 million bbl/d. Beyond 2016, the *Annual Energy Outlook 2015* (AEO2015) projects further production growth, although its pace and duration remains highly uncertain.

Recent increases in domestic crude oil production and the prospect of continued supply growth have sparked discussion on the topic of how rising crude volumes might be absorbed. As EIA noted nearly two years ago, relaxation of restrictions on U.S. exports of crude oil is only one among several ways to accommodate growing near-term flows of domestic production (EIA, *This Week in Petroleum*, "Absorbing increases in U.S. crude oil production," May 1, 2013). Recognizing that some options, such as like-for-like replacement of import streams, are inherently limited, the question of how a relaxation in current limitations on crude exports might affect domestic and international markets for both crude oil and products continues to hold great interest for policymakers, industry, and the public. In response to multiple requests, EIA is developing analyses that shed light on this question, including earlier reports on gasoline price determinants (EIA, *What drives gasoline prices?,* October 2014), changes in U.S. crude oil imports to accommodate increased domestic production (*This Week in Petroleum*, "Crude oil imports continue to decline," January 23, 2014), options for refinery capacity expansion (EIA, *Technical Options for Processing Additional Light Tight Oil Volumes within the United States*, March 2015), and refinery responses to higher, but fixed, levels of domestic crude oil production under both current crude oil export restrictions and with unrestricted crude oil exports (*Implications of higher domestic crude oil production for U.S. refining*, May 2015).

This report updates and extends a May 2014 EIA report, *U.S. crude oil production forecast – analysis of crude types.* It provides a projection of domestic crude oil production by crude type through 2025, supplementing the overall production projection provided in the AEO2015. Projections of production by crude type matter for several reasons. First, U.S. crude streams vary widely in quality. Second, the economics surrounding various options for the domestic use of additional domestic oil production are directly dependent on crude quality characteristics. Third, actual or potential export values also vary significantly with quality characteristics.

In conjunction with other reports issued by EIA over the past year, this report provides a foundation for further analysis of the market outlook and the effects of a possible relaxation of existing restrictions on U.S. crude oil exports.

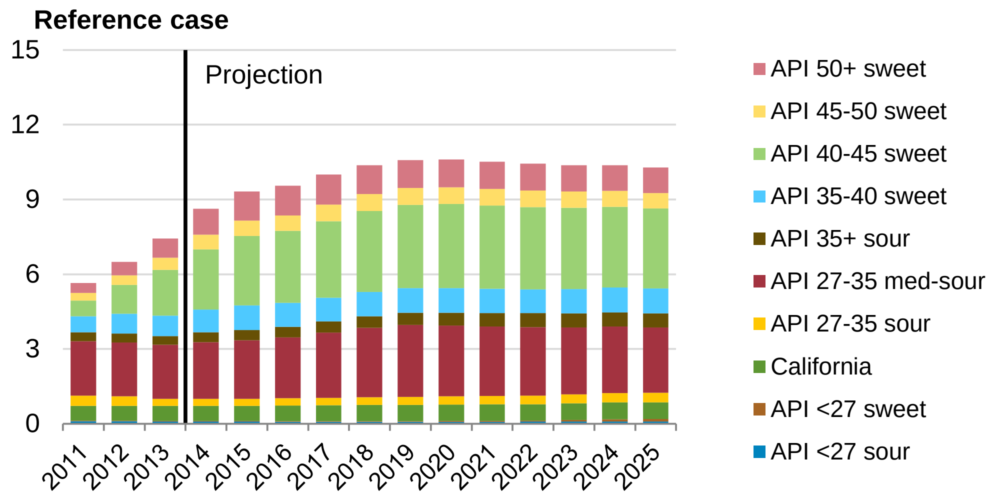
Summary

Recent U.S. crude oil production growth has consisted primarily of light, sweet crude[1] from tight resource formations. Roughly 90% of the nearly 3.0 million barrel per day (bbl/d) growth in production between 2011 and 2014 consists of sweet grades with an API gravity[2] of 40 or above.

In the U.S. Energy Information Administration's (EIA) *Annual Energy Outlook 2015* (AEO2015) this trend is projected to continue. In the AEO2015, U.S. supply of lighter API gravity crude oil continues to outpace that of medium and heavier crudes (Figure 1). Although the rate of growth in light sweet crude slows after 2015 in the Reference case, 65% of EIA's projected production growth between 2013 and 2020 consists of sweet grades with an API gravity of 40 or above. Another 25% of the growth is attributable to an increase in Lower 48 offshore production, which is categorized as medium sour with an API gravity between 27 and 35. After 2020, tight oil production declines, as drilling moves into less productive areas.

Figure 1. U.S. crude oil production by crude type, Reference case

million barrels per day



Source: U.S. Energy Information Administration, *Annual Energy Outlook 2015*.

The pace and duration of projected crude oil production increases are uncertain, and dependent on crude oil prices and the quality and amount of technically recoverable resources. In the AEO2015 High Oil and Gas Resource and High Oil Price cases, the rate of growth in tight oil production is higher than in the Reference case. As a result, sweet grades with an API gravity of 40 or above account for 65% and 68%, respectively, of the total projected increase in U.S. crude oil production between 2013 and 2020

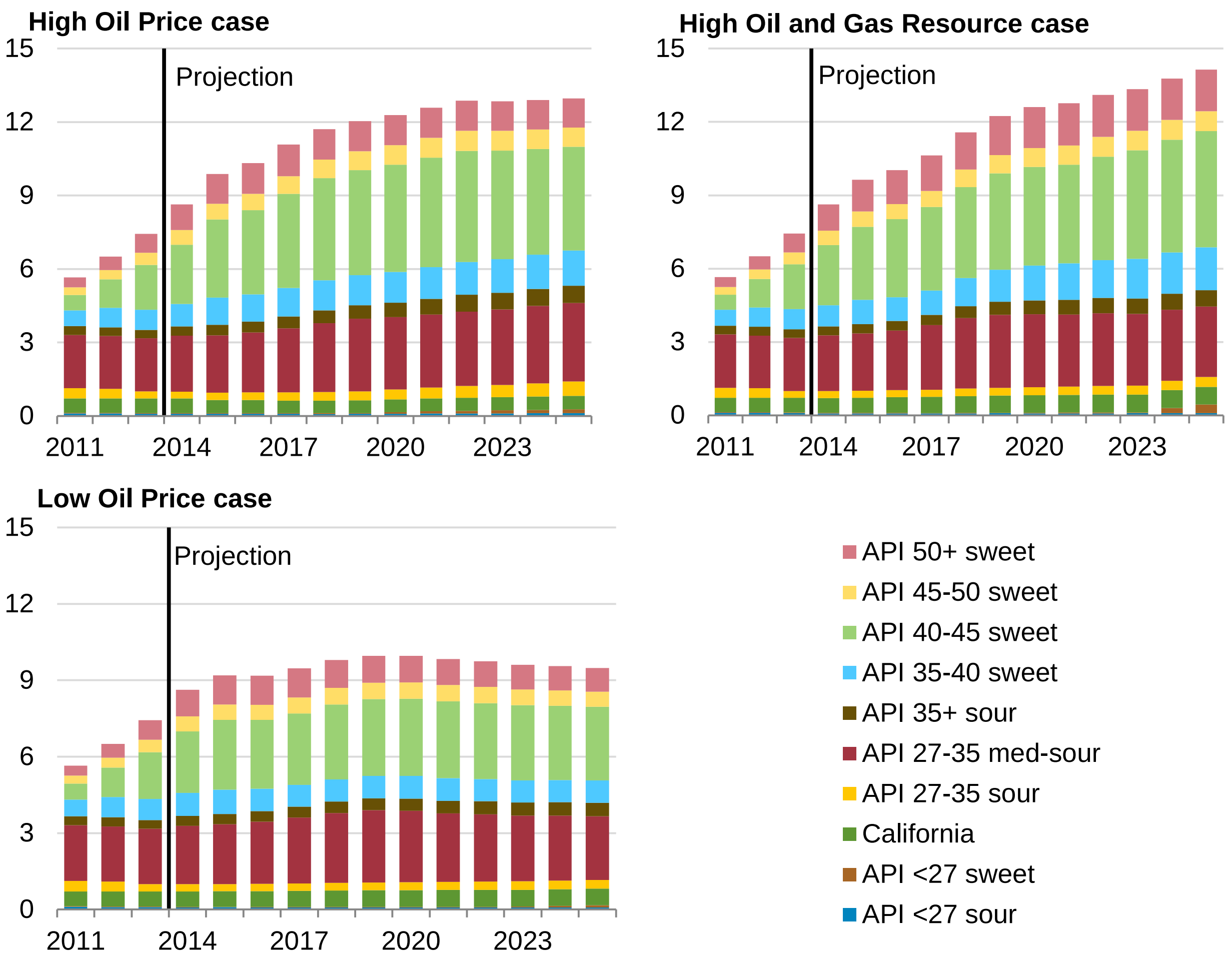
[1] A description of crude quality, as measured by density and sulfur content; light, sweet crude is low density and low sulfur.

[2] American Petroleum Institute measure of specific gravity of crude oil or condensate in degrees, an arbitrary scale expressing the gravity or density of liquid petroleum products. The measuring scale is calibrated in terms of degrees API; it is calculated as follows: Degrees API = (141.5 / specific gravity 60 deg.F/60 deg.F) - 131.5.

(Figure 2). In both cases, the share of U.S. production growth between 2013 and 2020 for Lower 48 offshore drops to about 18%. In 2025, tight oil production is 4% lower than in 2020 in the High Oil Price case and 20% higher than in 2020 in the High Oil and Gas Resource case. U.S. total crude oil production is lowest in the Low Oil Price case. In 2025, projected domestic crude oil production is nearly 800,000 bbl/d lower in the Low Oil Price case than in the Reference case.

Figure 2. U.S. crude oil production by crude type, in three cases

million barrels per day



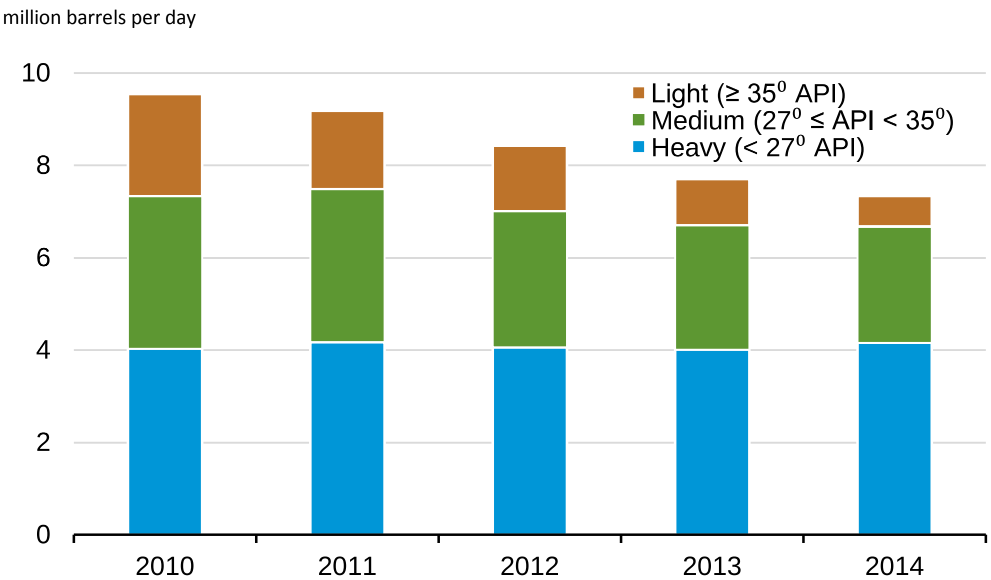
Source: U.S. Energy Information Administration, *Annual Energy Outlook 2015*.

Production of light crude oil with an API gravity of 50 or above is highest in the High Oil and Gas Resource case, reaching 1.7 million bbl/d in 2025 (67% higher than in the Reference case and 42% higher than in the High Oil Price Case). Production of crude oil with an API gravity less than 50 is 9.3 million bbl/d in 2025 in the Reference case compared with 12.4 million bbl/d in the High Oil and Gas Resource case, 11.8 million bbl/d in the High Oil Price case, and 8.5 million bbl/d in the Low Oil Price case.

Given the current restrictions on U.S. crude oil exports[3], information regarding crude supply by type is important. Consistent with recent classification decisions from the U.S. Department of Commerce, Bureau of Industry and Security,[4] minimal processing of crude streams with an API gravity of 50 or above is assumed to result in a petroleum product that may be legally exported without the need for a license.

In the past several years, more than half the additional production of U.S. crude oil has been absorbed by reducing oil imports of similar grades (Figure 3). Of the total 1.8 million bbl/d decline in crude oil imports between 2011 and 2014, roughly 56% was light crude (API 35+). Light crude imports fell from 1.7 million bbl/d in 2011 to 0.7 million bbl/d in 2014, and medium crude imports decreased from 3.3 million bbl/d to 2.5 million bbl/d. Imports of heavy crudes have remained near 4.0 million bbl/d since 2010.

Figure 3. U.S. crude oil imports by crude oil type



Source: U.S. Energy Information Administration, Form EIA-814, "*Monthly Imports Report*".

Other responses to the increased production of light oil over the past several years have included additional crude exports to Canada and increased refinery runs given the recent cost advantage of U.S. refiners relative to global competitors. For example:

- U.S. exports of crude oil to Canada increased from 46,000 bbl/d in 2011 to 324,000 bbl/d in 2014, and reached 491,000 bbl/d in January 2015.
- Utilization of U.S. refineries increased from 86.2% in 2011 to 90.4% in 2014 and was 88.4% in January 2015. From 2011 to 2014, refinery runs increased by 0.9 million bbl/d.

[3] See Federal Regulations, Title 15: Commerce and Foreign Trade, §754.2: Crude Oil

[4] The U.S. Department of Commerce, Bureau of Industry and Security has determined that condensate which has been processed through a distillate tower can be exported without licensing (FAQs – Crude Oil and Petroleum Products December 30, 2014).

The dwindling amount of light crude imports available to be backed out through further like-for-like substitution, and the limits to increased utilization of existing refinery capacity, could cause absorption of additional increases in domestic production to rely heavily on some combination of the following:

- Continued shifts in the refinery input mix, which can be enabled by investments to relieve constraints associated with running lighter crudes at refineries that were optimized to run heavier ones
- Added splitter or hydroskimmer capacity to convert light crude into a mix of heavier fractions to feed domestic refineries and increase the production of light products available to other markets
- Continued increases in crude oil exports, which will depend in part on the extent of any relaxation of current export restrictions

All of these options have implications for the value of existing refineries and specific refinery units, the mix of products produced by the refining sector, and the market value of each type of crude input and refinery product output. A change in crude production levels, which could be a further market adjustment mechanism, would come into play in the event that the market value of a particular stream reaches a level where production is not economic.

The estimates presented in this paper reflect EIA’s current assessment based on available data. The quality and timeliness of well-level data on production by crude type used to develop the estimates vary widely across states. As part of its continuing effort to improve data on oil and natural gas production, EIA has expanded its collection of monthly natural gas production data from five states and the Gulf of Mexico, and will include both crude oil and natural gas production in 15 states and the Gulf of Mexico. The new data collection, which EIA launched earlier this spring, is expected to provide publishable data on production by state and API gravity over the coming months. Updated estimates of regional production by crude type will be valuable as new plays start commercial development, potentially changing the distribution of production by crude types in the regions where those plays are located.

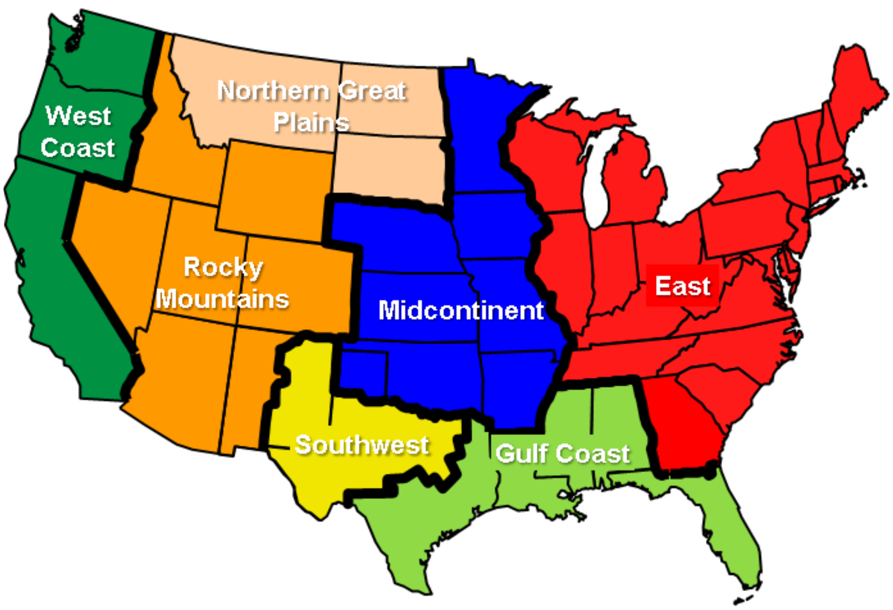
The following two sections of this report expand on the summary information presented above. The first section provides context and background on the EIA assumptions and the second section provides regional crude oil production projections for the AEO2015 Reference, High Oil and Gas Resource, High Oil Price, and Low Oil Price cases.

Context and background

Regions

EIA analyzes U.S. crude oil production according to the regions defined by the map below. Each region contains one or more hydrocarbon-producing geologic basins. In this paper, production is aggregated by crude types to regional totals.

Map 1. U.S. onshore Lower 48 production regions



Source: U.S. Energy Information Administration.

Classification of crude type

There is no single standard classification scheme for grouping the large set of individual crude streams into a manageable number of categories for purposes of analysis. For purposes of this report, domestic production is categorized into ten crude types. As shown in Table 1, the categories are based on API gravity ranges and sulfur content of produced oil. The crude oil produced in California, primarily API gravity less than 27 sour, is categorized separately since it is generally produced and refined in the same geographic region, and is somewhat isolated from the heavy crude market dynamics of the rest of the country.

Table 1. Crude types considered in this analysis

Chart Color	Crude Type	API Gravity	Sulfur Content (%)	a.k.a.
	API 50+ sweet	API>=50	<0.5	Light Sweet
	API 45-50 sweet	45<=API<50	<0.5	
	API 40-45 sweet	40<=API<45	<0.5	
	API 35-40 sweet	35<=API<40	<0.5	
	API 35+ sour	35<=API<40	<0.5	Light Sour
	API 27-35 med-sour	27<=API<35	<1.1	Medium-Medium Sour
	API 27-35 sour	27<=API<35	>=1.1	Medium Sour
	California	API<27	1.1-2.6	
	API<27 sweet	API<27	<1.1	Heavy Sweet
	API<27 sour	API<27	>=1.1	Heavy Sour

Data sources

Although well-level production volumes are published by almost all states, the API gravity and sulfur content of that production are reported by only a few states. The quality and timeliness of well-level data on production by crude type used to develop the estimates vary widely across states. As part of its continuing effort to improve data on oil and natural gas production, EIA has expanded its collection of monthly natural gas production data from five states and the Gulf of Mexico, and now accounts for both oil and natural gas production in 15 states and the Gulf of Mexico.[5] The new data collection, which EIA launched in 2015, will provide information on production by type. In addition to updates reflecting better data, updated estimates of regional production by crude type will likely be valuable as new plays start commercial development. Production from new plays could change the distribution of production by crude types in the regions where those plays are located.

This paper estimates oil production by crude type as delivered from well-site or lease storage tanks. Once the oil enters the transportation and distribution systems, it may be commingled with other crude types (e.g., in rail cars or pipelines) or otherwise blended to capture economic opportunities before being delivered to the refinery. A simple example would be to blend relatively lower-value crude oil, with an API gravity less than 27 with an API 50+ oil if the price to sell API 35-40 oil exceeded the cost of buying and blending the inputs. To the extent that such blending occurs, the volume of some crude oil types received by refineries would be different from those estimated from the well-level analysis in this paper.

A final point to consider involves the distinction between very light grades of tight oil, typically produced from the Eagle Ford shale in Texas, which are included in EIA's oil production data, and hydrocarbon gas liquids (HGL), which are produced from the wellhead as gas but are converted to liquids once separated from methane at a natural gas processing plant. These hydrocarbons include ethane, propane, butanes, and hydrocarbons with five or more carbon atoms, referred to as pentanes plus, naphtha or plant

[5] *In addition to the 15 states, Alaska oil and natural gas production data is received directly from state authorities.*

condensate. Plant condensate can also be blended with crude oil, which would change both the distribution and total volume of oil received by refineries.

High Oil and Gas Resource case assumptions

The High Oil and Gas Resource case in AEO2015 was developed using assumptions that result in higher estimates of technically recoverable crude oil and natural gas resources than those in the Reference case. Estimates of technically recoverable tight and 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. The assumptions for the High Oil and Gas Resource case are very optimistic. It is unlikely that improvements of this nature will occur at the same time and pace across the whole country. This case allows for an examination of the potential impacts of higher domestic supply on energy demand, imports, and prices.

The High Oil and Gas Resource case reflects an assumed broad-based future increase in crude oil and natural gas resources, not limited to production of tight and shale oil and natural gas. Optimism about increased supply has been buoyed by recent advances in the production of crude oil and natural gas from tight and shale formations. With the adjusted resource and technology advance assumptions in the High Oil and Gas Resource case, domestic crude oil production continues to increase to more than 12.6 million bbl/d by 2020. Specific assumptions for the High Oil and Gas Resource case, as compared with the Reference Case, include:

- 50% higher estimated ultimate recovery (EUR) levels for tight oil, tight gas, and shale gas wells
- Additional tight oil resources, as well as 50% lower well spacing per acre (i.e., wells are closer together), with a downward limit of 40 acres per well for existing and potential future tight oil resources, to capture the possibility that additional layers or new areas of low-permeability zones will be identified and developed
- Diminishing returns on the EUR when drilling in a county exceeds the number of potential wells assumed in the Reference case, to capture the probability that greater drilling density will cause wells to interfere with each other (i.e., production from one well might reduce production from a nearby well)
- Long-term technology improvements beyond those assumed in the Reference case, represented as a 1% annual increase in the EURs for tight oil, tight gas, and shale gas wells
- 50% higher technically recoverable undiscovered resources for Alaska crude oil and the Lower 48 offshore, reflecting the uncertainty surrounding undeveloped areas where there has been little or no exploration and development activity, and where modern seismic survey data are lacking

The High Oil and Gas Resource case does not include exploration or production activity in the Arctic National Wildlife Refuge or other areas that are currently under drilling moratoria.

High Oil Price case assumptions

In the High Oil Price case, crude oil prices quickly rise to $149/bbl (Brent, 2013 dollars) in 2020 and $169/bbl in 2025 compared with $79/bbl and $91/bbl in the Reference case, respectively. High oil prices result from a combination of higher demand for liquid fuels in non-OECD nations and lower global supply. Additionally, OPEC's market share averages 32% throughout the projection, and non-OPEC petroleum production expands more slowly in the short- to mid-term relative to the Reference case.

Low Oil Price case assumptions

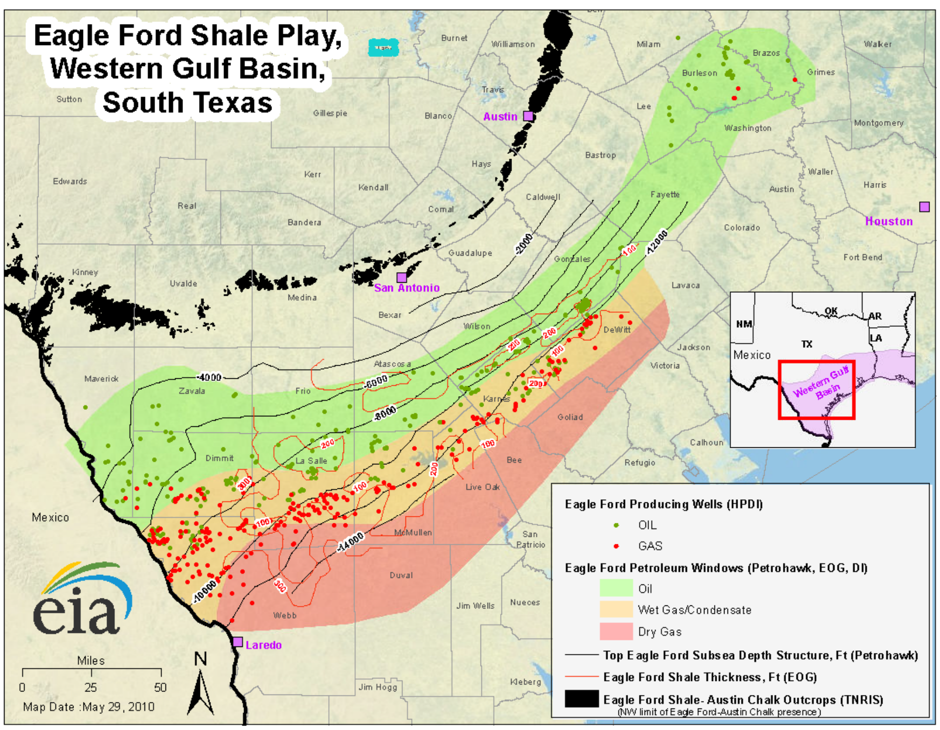
In the Low Oil Price case, the Brent crude oil price drops to $52/bbl in 2015, 7% lower than in the Reference case, and reaches $64/bbl in 2025, 30% lower than in the Reference case, largely as a result of lower non-OECD demand and higher upstream investment by OPEC.

Regional analysis and results

Gulf Coast region

The key producing tight/shale oil play in the Gulf Coast region is the Eagle Ford (located in the Western Gulf Basin). The Eagle Ford play is somewhat unique compared with the other oil producing plays as there are three relatively distinct "windows" of the play (Map 2). The formation becomes deeper moving from northwest to southeast, creating an oil window, a condensate window, and a dry gas window. Since 2010, producers in the Eagle Ford have targeted areas with more liquids, as prices have continued to favor oil over natural gas.

Map 2. Eagle Ford Shale Play

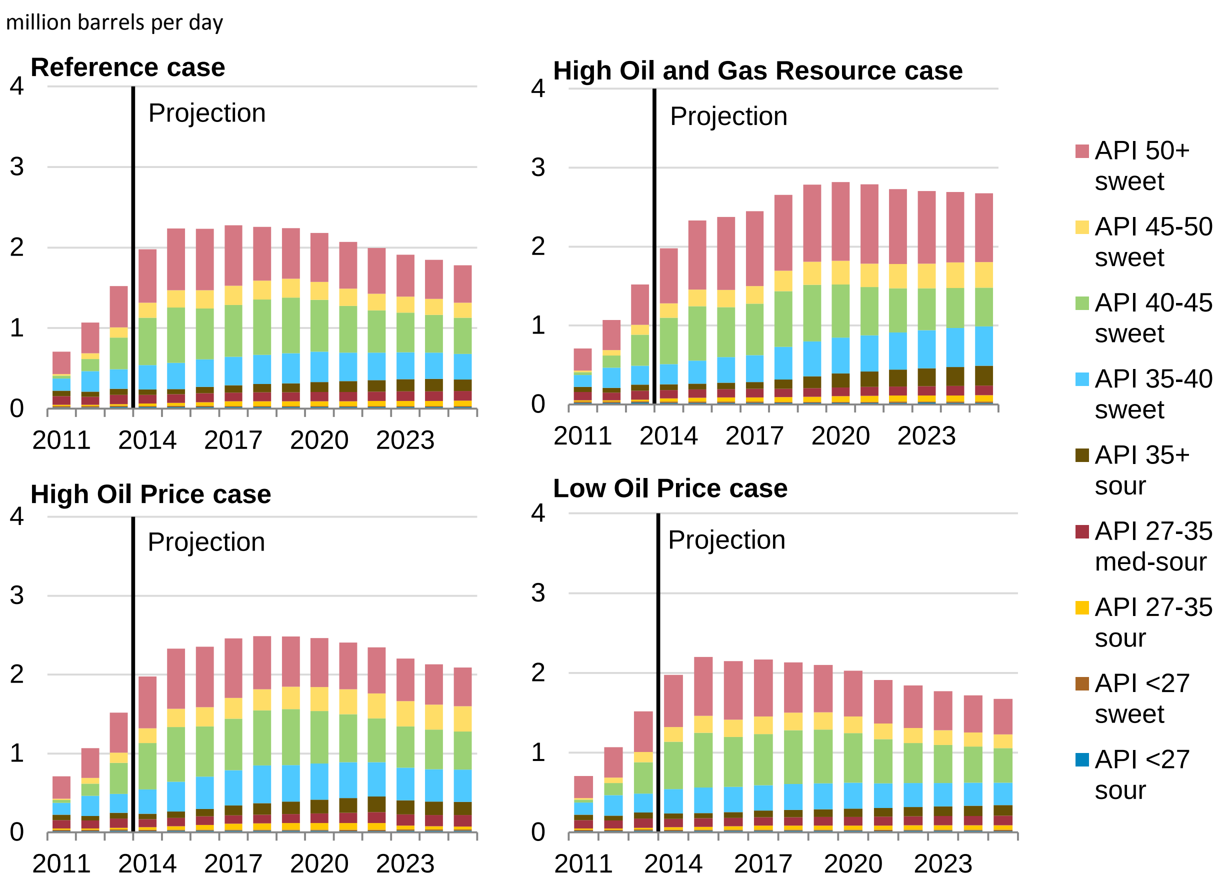


Source: U.S. Energy Information Administration, *http://www.eia.gov/oil_gas/rpd/shaleusa9.pdf.*

This pattern is reflected in the Gulf Coast production outlook, where the production growth since 2011 from wells with reported API gravity between 40 and 50 outpaced the growth in production from wells with an API gravity greater than 50. Since crude oil prices are projected to remain high relative to natural gas prices, this pattern is expected to continue through 2020.

The Gulf Coast production projection is shown in Figure 4. In the Reference, High Oil and Gas Resource, High Oil Price, and Low Oil Price cases, most (67%, 72%, 59% and 73%, respectively) of the growth in Gulf Coast crude oil production between 2013 and 2020 is crudes with an API gravity greater than 40. Light sweet crudes of API 50 or greater average roughly 700,000 bbl/d over the 2014-2020 period in the Reference, High Oil Price, and Low Oil Price cases, compared with over 900,000 bbl/d in the High Oil and Gas Resource case. This light sweet crude category accounts for 37% of the growth in Gulf Coast crude oil production between 2013 and 2020 in the High Oil and Gas Resource case, compared with 15% in the Reference case, 11% in the High Oil Price case and 13% in the Low Oil Price case. In 2025, Gulf Coast crude oil production is lower in all cases than in 2020, as drilling moves to less productive areas but production remains above the 2013 rate of 1.5 million bbl/d.

Figure 4. Gulf Coast crude oil production – by crude type



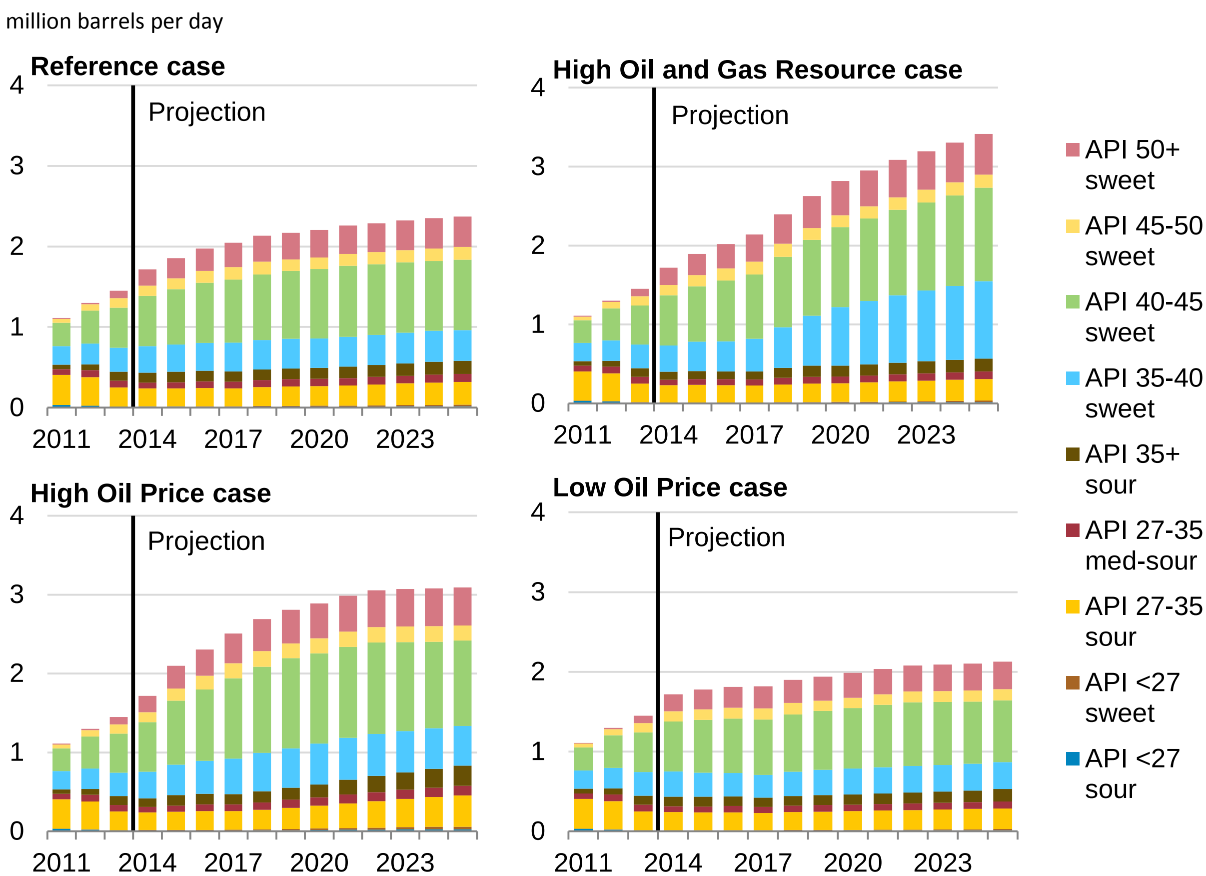
Source: U.S. Energy Information Administration, *Annual Energy Outlook 2015*.

Southwest region

Virtually all oil production in the Southwest region comes from the Permian basin. Permian oil production averaged 1.3 million bbl/d in 2013, compared with 100,000 bbl/d from the rest of the Southwest region. Production by crude type has changed rapidly, as new drilling in the Southwest region increasingly targets the various stacked tight oil formations, rather than the conventional oil formations which have been developed for decades.

EIA expects this trend to continue through 2025, as Southwest crude oil production is projected to increase from an annual average of 1.4 million bbl/d in 2013 to 2.4 million bbl/d in the Reference case and 2.1 million bbl/d in the Low Oil Price case in 2025 (Figure 5). In the High Oil and Gas Resource and High Oil Price cases, the projected growth in Southwest production is roughly double that of the Reference case, with production reaching over 3.0 million bbl/d in 2025. Production of sweet crude oil with an API gravity between 40 and 45 maintains it share of close to 35% of total Southwest crude oil production in all four cases through 2025.

Figure 5. Southwest crude oil production – by crude type



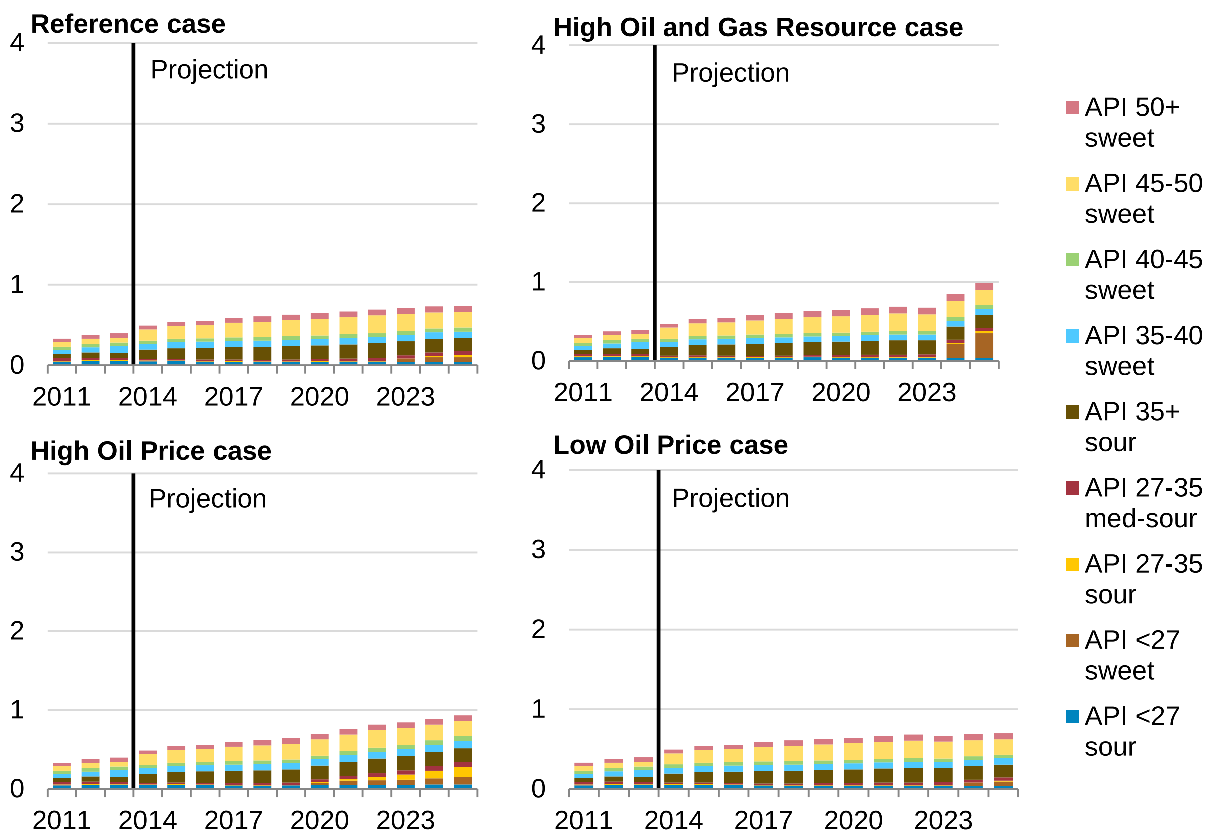
Source: U.S. Energy Information Administration, *Annual Energy Outlook 2015*.

Rocky Mountains region

The Rocky Mountains region is a significant producer of natural gas, although natural gas production has been declining in recent years as high oil prices and recent drilling success in the Niobrara formation have steered producers towards oil production. The distribution of Rocky Mountains crude oil production reflects this, showing a relatively stable percentage of API 50+ production, where API 50+ production is commonly produced from wells targeting natural gas. By 2020, production of crude oil with an API gravity between 35 and 50 expands to more than 72% of total oil production. Rocky Mountains oil production surpasses an average of 640,000 bbl/d in 2020 in all cases, reaching 700,000 bbl/d in the High Oil Price case (Figure 6). After 2020, production of crude oil with API gravity less than 27 increases as the economics of the Fractured Interbed play in the Paradox Basin become more favorable. Given the adjusted resource and technology advance assumptions in the High Oil and Gas Resource, the startup of this play is more dramatic in this case than in the other cases. In 2025, crude oil with API gravity less than 27 accounts for 36% of total Rocky Mountains production in the High Oil and Gas Resource case compared with less than 17% in the Reference, High Oil Price and Low Oil Price cases.

Figure 6. Rocky Mountains crude oil production – by crude type

million barrels per day



Source: U.S. Energy Information Administration, *Annual Energy Outlook 2015*.

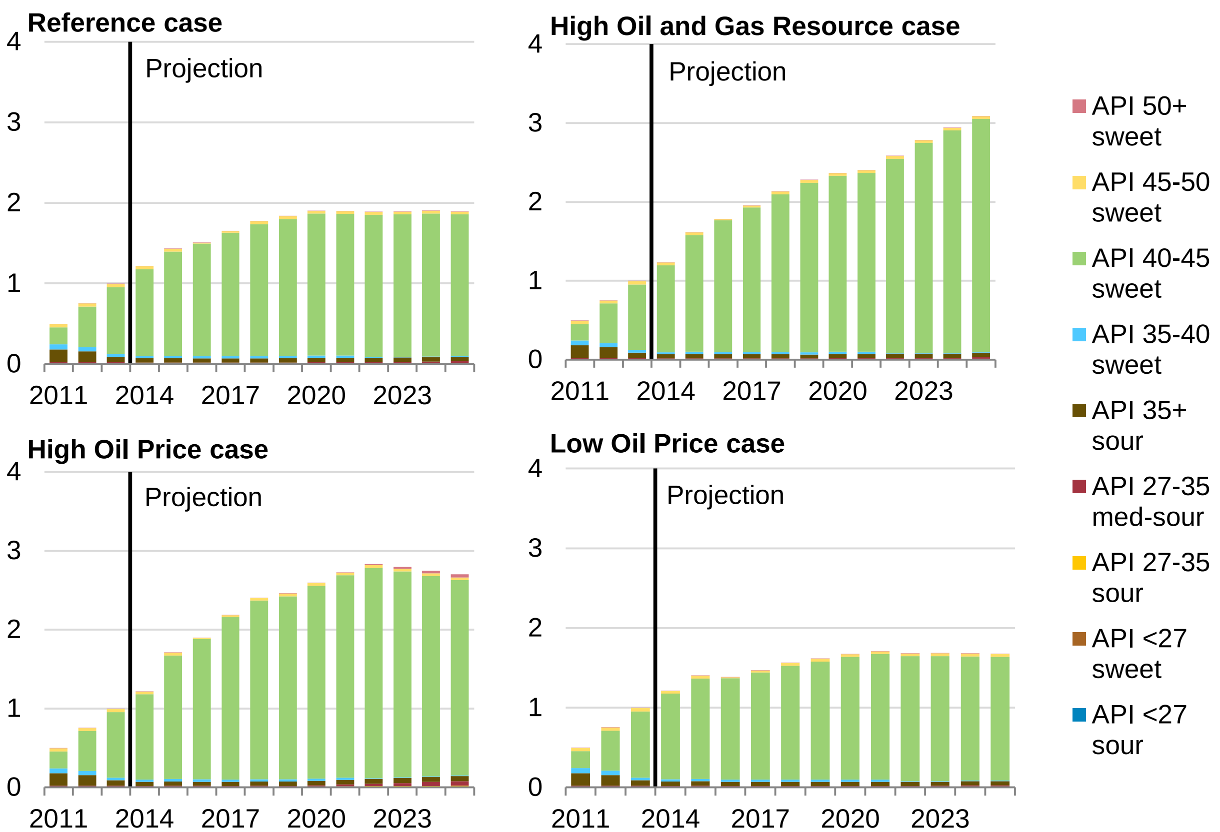
Northern Great Plains region

The largest regional crude oil production growth is expected to come from tight oil production in the Northern Great Plains, primarily from the Bakken formation (including the Three Forks). While additional API gravity data was not available from the North Dakota Industrial Commission, industry reports indicate that Bakken crude oil consistently measures between API 40 and 45. The share of crude oil production in the API 40-45 sweet category increased from 43% in 2011 to 83% in 2013.

Between 2011 and 2013, crude oil production in the Northern Great Plains more than doubled, increasing from 495,000 bbl/d in 2011 to over 995,000 bbl/d in 2013. Northern Great Plains crude oil production in 2025 is projected to average 1.9 million bbl/d in the Reference case and 1,7 million bbl/d in the Low Oil Price case, over 90% of which has an API gravity between 40 and 45 (Figure 7). With greater potential resources assumed in the High Oil and Gas Resource case and higher oil prices in the High Oil Price case, crude oil production in this region is projected to increase even more than in the Reference case, averaging nearly 3.1 million bbl/d and 2.7 million bbl/d in 2025, respectively.

Figure 7. Northern Great Plains crude oil production – by crude type

million barrels per day



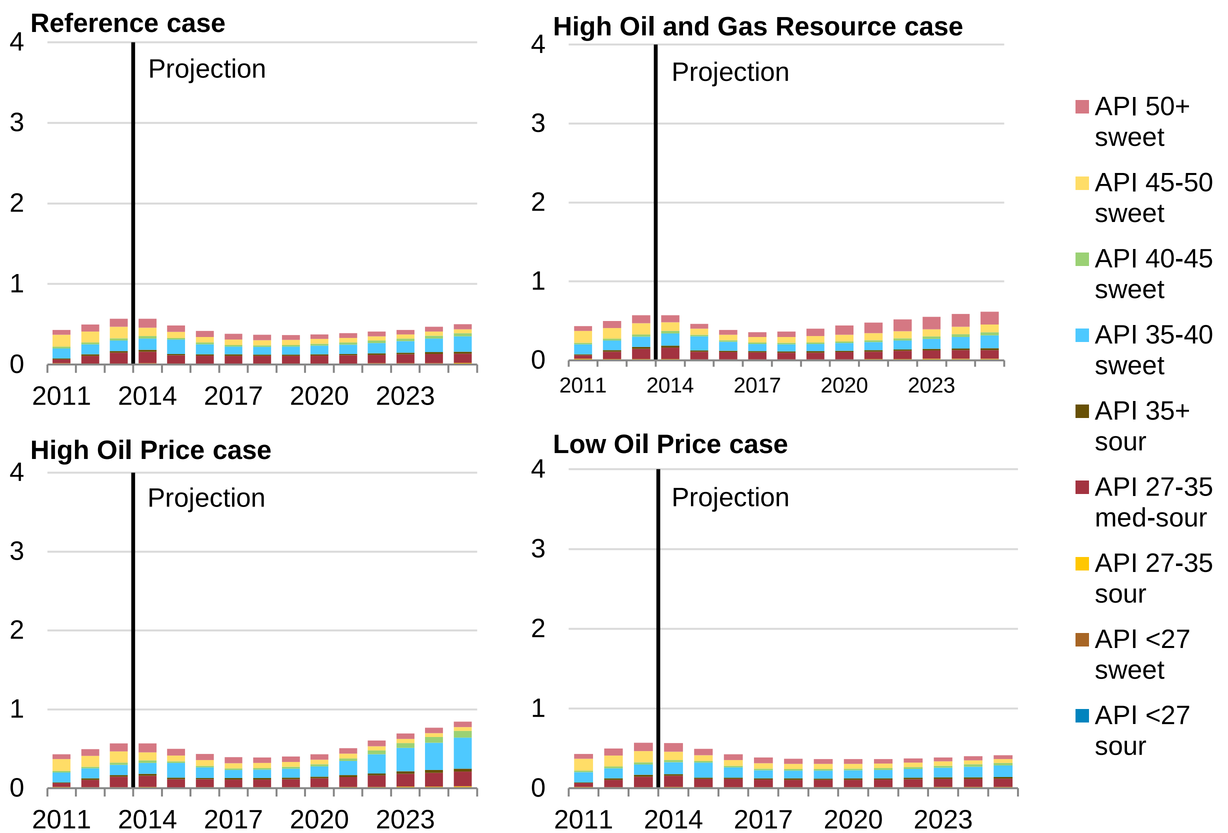
Source: U.S. Energy Information Administration, *Annual Energy Outlook 2015.*

Midcontinent region

The Midcontinent region is not expected to be a major source of domestic crude oil production. Midcontinent crude oil production averaged 432,000 bbl/d in 2011, increasing to over 570,000 bbl/d in 2013. In 2014, crude oil production fell slightly under 570,000 bbl/d and is projected to continue to decrease through 2017, dropping below 400,000 bbl/d with light crude oil (API 35 and above) making up more than 70% of the total region's production (Figure 8). After 2017, Midcontinent crude oil production increases in all cases, averaging roughly 500,000 bbl/d in the Reference case, 615,000 bbl/d in the High Oil and Gas Resource, 846,000 bbl/d in the High Oil Price case, and 417,000 bbl/d in the Low Oil Price case in 2025.

Figure 8. Midcontinent crude oil production – by crude type

million barrels per day



Source: U.S. Energy Information Administration, *Annual Energy Outlook 2015.*

Alaska, Lower 48 Offshore, East, and West Coast regions

In the AEO2015, all Alaska and Gulf of Mexico oil production is assumed to be API 27-35, medium sour. Over 85% of crude oil production in the East region is projected to be light sweet crude with an API gravity greater than 35. West Coast region production, coming from California, is primarily API gravity less than 27 sweet. Per the "Defining crude types" discussion above, California production is categorized by its own crude type.

Based on projections of annual average production projections for 2013 to 2020 in the AEO2015 Reference case (Figure 9):

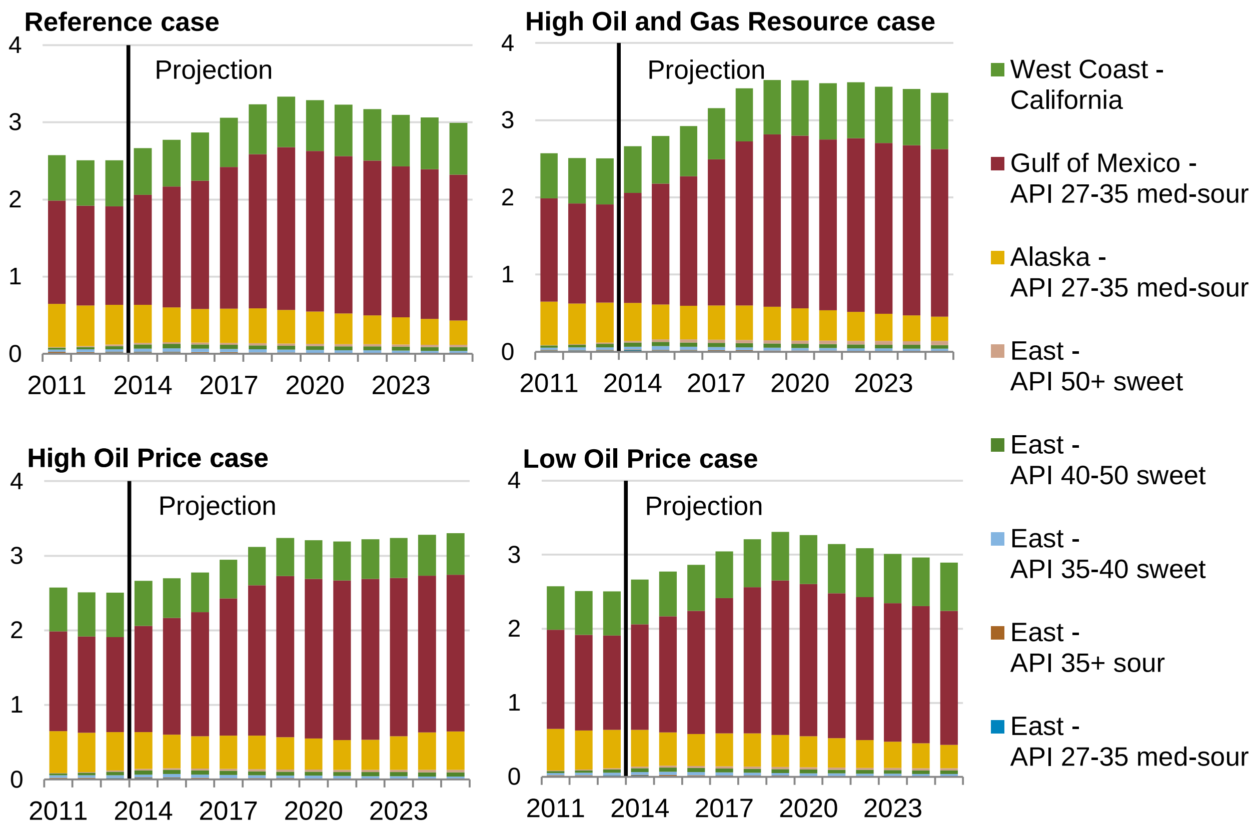
- Alaska production declines from 515,000 bbl/d to 418,000 bbl/d
- Gulf of Mexico production increases from 1.3 million bbl/d to 2.1 million bbl/d
- East production increases slightly from 120,000 bbl/d to 131,000 bbl/d
- West Coast (onshore and offshore) production increases from 595,000 bbl/d to 660,000 bbl/d

Crude oil production from these four regions is very similar across the Reference, High Oil and Gas Resource, High Oil Price, and Low Oil Price cases with a couple of notes. In the High Oil and Gas Resource case, Gulf of Mexiso production pushes the total production rate in these regions to over 3.5 million bbl/d by 2019. In the High Oil Price case, drilling shifts out of the West Coast to more economic tight oil formations in other regions. In 2019, West Coast crude oil production decreases to 513,000 bbl/d in the High Oil Price case.

After 2020, crude oil production in these four regions declines in the Reference, High Oil and Gas Resource, and Low Oil Price cases, lead by declines in Alaska and Gulf of Mexico production. In 2025, total crude oil production in these four regions averages 3.0 million bbl/d in the Reference case, 3.4 million bbl/d in the High Oil and Gas Resource case, and 2.9 million bbl/d in the Low Oil Price case, still higher than the production rate of 2.5 million bbl/d in 2013. In the High Oil Price case, crude oil production in all four regions remains relatively stable between 2020 and 2025, averaging 3.2 million bbl/d.

Figure 9. Alaska, Lower 48 Offshore, East, and West Coast crude oil production – by crude type

million barrels per day



Source: U.S. Energy Information Administration, *Annual Energy Outlook 2015*.