



## Short-Term Energy Outlook

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### Forecast highlights

- This edition of the *Short-Term Energy Outlook* (STEO) is the first to include forecasts for 2023.
- The STEO continues to reflect heightened levels of uncertainty as a result of the ongoing COVID-19 pandemic. Notably, the [Omicron variant of COVID-19](#) raises questions about global energy consumption. U.S. real GDP declined by 3.4% in 2020 from 2019 levels. Based on forecasts that use the IHS Markit macroeconomic model, we estimate U.S. GDP increased 5.7% in 2021 and that it will rise by 4.3% in 2022 and by 2.8% in 2023. In addition to macroeconomic uncertainties, uncertainty about winter weather and consumer energy demand also present a wide range of potential outcomes for energy consumption. Supply uncertainty in the forecast stems from uncertainty about OPEC+ production decisions and the rate at which U.S. oil and natural gas producers will increase drilling.
- Brent crude oil spot prices averaged \$71 per barrel (b) in 2021, and we forecast Brent prices will average \$75/b in 2022 and \$68/b in 2023.
- We estimate global liquid fuels inventories fell by an average of 1.4 million barrels per day (b/d) in 2021 compared with inventory growth of 2.1 million b/d in 2020. Global oil inventories rise in the forecast, increasing at a rate of 0.5 million b/d in 2022 and 0.6 million b/d in 2023.
- Global consumption of petroleum and liquid fuels averaged 96.9 million b/d in 2021, up by 5.0 million b/d from 2020, when consumption fell significantly because of the pandemic. We expect global liquid fuels consumption will grow by 3.6 million b/d in 2022 and 1.8 million b/d in 2023.
- Crude oil production from OPEC member countries averaged 26.3 million b/d in 2021, up from 25.6 million b/d in 2020. We forecast that average OPEC crude oil production will rise by 2.5 million b/d to average 28.8 million b/d in 2022 and average 28.9 in 2023.
- U.S. crude oil production averaged 11.2 million b/d in 2021. We expect production to average 11.8 million b/d in 2022 and to rise to 12.4 million b/d in 2023, which would be the highest annual average U.S. crude oil production on record. The current record is 12.3 million b/d, set in 2019.

- U.S. regular gasoline retail prices averaged \$3.02 per gallon (gal) in 2021, compared with an average of \$2.18/gal in 2020. We forecast gasoline prices will average \$3.06/gal in 2022 and \$2.81/gal in 2023. U.S. diesel fuel prices averaged \$3.29/gal in 2021, compared with \$2.56/gal in 2020, and we forecast diesel prices will average \$3.33/gal in 2022 and \$3.27/gal in 2023.
- The natural gas spot price at Henry Hub averaged \$3.91 per million British thermal units (MMBtu) in 2021. Monthly average prices reached \$5.51/MMBtu in October, but they declined in November and December as mild weather prevailed across much of the country, resulting in less natural gas used for space heating. We expect Henry Hub spot prices will average \$3.82/MMBtu in the first quarter of 2022 and average \$3.79/MMBtu for all of 2022 and \$3.63/MMBtu in 2023.
- We estimate that U.S. liquefied natural gas (LNG) exports averaged 9.8 billion cubic feet per day (Bcf/d) in 2021, compared with 6.5 Bcf/d in 2020. We expect [U.S. LNG export capacity increases](#) will contribute to LNG exports averaging 11.5 Bcf/d in 2022 and 12.1 Bcf/d in 2023.
- U.S. dry natural gas production averaged 93.5 Bcf/d in 2021, up 2.0 Bcf/d from 2020. Natural gas production in the forecast averages 96.0 Bcf/d for all of 2022 and then rises to 97.6 Bcf/d in 2023.
- U.S. natural gas inventories ended December 2021 at 3.2 trillion cubic feet (Tcf), 3% more than the 2016–20 average. We forecast inventories will end March 2022 at 1.8 Tcf, which would be 8% more than the 2017–21 average for the end of March.
- U.S. coal production totaled 579 million short tons (MMst) in 2021, up 8% from 2020. We expect coal production will increase by 6% in 2022 and then rise 1% to a total of 619 MMst in 2023.
- U.S. coal consumption was 545 MMst in 2021, a 14% increase from 2020. The increase reflected more use of coal-fired electricity generation amid high natural gas prices. We expect coal consumption will fall by 2% in 2022 and then be relatively unchanged in 2023 at a total of 532 MMst in 2023.
- Total U.S. retail sales of electricity remain relatively unchanged in our forecast for 2022 after increasing by 2.2% in 2021. Forecast increases in sales to the commercial and industrial sectors in 2022 offset lower sales to the residential sector. We forecast total U.S. retail sales of electricity across all sectors will grow by 1.4% in 2023.
- The share of U.S. electric power generation produced by natural gas averaged 37% in 2021, and we expect it will average 35% in 2022 and 34% in 2023. Our forecast for the natural gas share as a generation fuel declines primarily as a result of increased generation from new renewable energy generating capacity. Coal's average generation

share rose to 23% in 2021 as a result of higher natural gas prices, but we expect it to decline slightly over the next two years, averaging near 22% in 2022 and 2023. We expect the nuclear share of generation will remain near 20% over the next two years.

- We expect electricity-generating capacity from renewable energy sources to continue to grow in 2022 and 2023. Our forecast includes both wind and solar capacity growth, with solar capacity growing at a faster rate. The extreme drought conditions in the West may moderate somewhat in the next year, and we forecast that the share of U.S. generation from hydropower will rise from 6% in 2021 to 7% in 2022 and 2023.
- The U.S. retail electricity price for the residential sector in our forecast averages 14.2 cents per kilowatthour in 2022, which is 4% higher than the average retail price in 2021. Forecast residential prices remain relatively the same in 2023.
- Total energy-related carbon dioxide (CO<sub>2</sub>) emissions increased by 6.2% in 2021 as the U.S. economy started to recover from the impacts of the COVID-19 pandemic. We forecast that emissions will rise by 1.8% in 2022 and by 0.5% in 2023. Even with growth over the next two years, forecast CO<sub>2</sub> emissions in 2023 are 3.4% lower than 2019 levels. Energy-related CO<sub>2</sub> emissions are sensitive to changes in weather, economic growth, energy prices, and fuel mix.

## Global liquid fuels

The COVID-19 pandemic continued to affect global oil markets in 2021. Oil consumption and oil production fell sharply in early 2020 in response to the pandemic. During the second half of 2020 (2H20), however, rising economic activity and the easing of pandemic-related restrictions on other activities caused oil consumption to increase. This trend continued into 2021 with rollouts of COVID-19 vaccinations. In much of the world, vaccines contributed to increased personal travel and business activity, resulting in global oil consumption rising by 5.5% in 2021 from 2020. However, global consumption in 2021 remained 3% below 2019 levels.

For more than a year now, oil consumption has outpaced oil production. Production has remained restrained as a result of crude oil production curtailments by OPEC+ members, investment restraint from U.S. oil producers, and other supply disruptions. Oil consumption outpacing oil production has led to persistent withdrawals from global oil inventories and significant increases in oil prices. We estimate that global oil inventories have fallen for six consecutive quarters going back to the third quarter of 2020 (3Q20), declining at an average rate of 2.1 million barrels per day (b/d) in 2H20 and at an average rate of 1.4 million b/d in 2021. Brent crude oil spot prices increased from an average of \$43 per barrel (b) in 3Q20 to an average of \$79/b in 4Q21.

Uncertainty in global oil markets has increased heading into 2022. The way in which the Omicron variant of COVID-19 will affect economic activity and oil consumption this year is still unknown. In late 2021, some restrictions to mitigate the spread of COVID-19 began to return in

many regions, notably Europe, even before the Omicron variant surfaced. These restrictions, in combination with increased measures to combat the Omicron variant, raised the possibility that global oil consumption could decline in the coming months and added downward pressure to oil prices.

We forecast that global oil production will outpace global oil consumption during both 2022 and 2023, resulting in rising global oil inventories. We expect global oil inventories will rise by an average of 0.5 million b/d in 2022 and by 0.6 million b/d in 2023 and that these inventory builds will generally put downward pressure on crude oil prices. Brent prices average \$75/b in 2022 and \$68/b in 2023 in our forecast. However, oil market balances are subject to significant uncertainties during the forecast period, notably, the way in which the ongoing pandemic affects economic growth, oil demand, and the production decisions of OPEC+ members. These factors, among others, could keep oil prices volatile.

***Global petroleum and other liquid fuels consumption.*** Based on preliminary data and estimates, global consumption of petroleum and other liquid fuels grew by 5.0 million b/d in 2021. This growth followed a decline of 8.4 million b/d in 2020. We forecast global oil consumption will grow by 3.6 million b/d in 2022 and by 1.8 million b/d in 2023, reaching 100.5 million b/d in 2022 and 102.3 million b/d in 2023. If realized, the 2022 global liquid fuels consumption level would surpass the pre-pandemic 2019 level and represent a new record for world liquid fuels consumption.

Slowing growth in global oil demand in our forecast mostly reflects slowing economic growth. Our global economic growth assumptions come from Oxford Economics, which forecasts global GDP will increase by 4.5% in 2022 and by 3.9% in 2023, compared with an increase of 5.8% in 2021. In addition, oil demand in early 2021 was still significantly affected by pandemic-mitigation measures. As business activity and personal mobility increased through much of 2021, air travel remained the most affected segment of liquid fuels demand in 2021. Our forecast assumes air travel will increase throughout 2022 and into 2023, but it will continue to remain below pre-pandemic levels. With air travel and jet fuel consumption below pre-pandemic levels, we expect economic growth will be the main driver of oil consumption growth, as demand increases for fuels such as gasoline, diesel, and hydrocarbon gas liquids (HGLs).

We expect non-OECD countries, where economic growth tends to be more oil-intensive than in OECD countries, to lead the growth in demand for oil in 2022 and 2023. In our forecast, non-OECD oil consumption grows by 2.2 million b/d during 2022 and by 1.4 million b/d in 2023. Oil consumption in [OECD countries](#) grows by 1.4 million b/d in 2022 and by 0.3 million b/d in 2023.

Governments in non-OECD countries in the Asia-Pacific and Latin American regions eased mobility and business activity restrictions during 2021 as an increasing share of the population was vaccinated. However, outbreaks of the Omicron variant in some Asia-Pacific countries have led their governments to delay reopening plans or to extend current restrictions. The Middle East and African regions have been relatively slower to ease mobility restrictions than Europe

and the United States. Outbreaks of COVID-19 infections and renewed restrictions on mobility and business activity still pose a significant downside risk in these regions.

Strict mobility restrictions imposed by many of the European OECD countries in 1Q21 gradually eased in 2Q21 as a result of increasing vaccination levels. As a result, Europe experienced a significant jump in economic activity, as capacity limits and restrictions on mobility and nonessential business activity were either reduced or eliminated. However, the spread of the Omicron variant led to a sharp increase in new infections in 4Q21. Some governments have responded by renewing some measures that limit mobility and business activity. Overall, we expect relatively milder movement and business activity restrictions than in 2020 because significant portions of the populations in European countries are fully vaccinated and because some of the new government restrictions have targeted unvaccinated segments of the population.

If currently available vaccines provide insufficient protection against future variants, countries may decide to increase mobility and activity restrictions. This strategy would lead to a longer, more drawn-out recovery in global oil consumption. In addition, the pace of economic growth will drive oil consumption in 2022 and 2023. However, if supply chain issues or central bank measures to limit inflation contribute to GDP growth rates that are lower than those from Oxford Economics that are assumed in this forecast, oil consumption will likely also be lower than forecast.

***Non-OPEC production of petroleum and other liquid fuels.*** We estimate that in 2021, non-OPEC production increased by 0.7 million b/d compared with 2020. Most of this increase came from the three largest non-OPEC producers: the United States, Russia, and Canada. We expect non-OPEC production to increase by 2.8 million b/d in 2022 and by an additional 1.6 million b/d in 2023. The United States and Russia lead production growth among non-OPEC countries in our forecast during both 2022 and 2023. Brazil, Norway, and Canada also contribute significantly to growth in the forecast.

After the United States, Russia is the world's second-largest producer of liquid fuels. Its liquid fuels production averaged 10.8 million b/d in 2021, 0.3 million b/d more than in 2020. We forecast Russia's liquid fuels production will continue to grow in 2022 and 2023 but at a slower rate. From December 2020 to December 2021, Russia's liquid fuels production grew by 0.9 million b/d. However, most of the growth in 2021 occurred during the second half of the year as OPEC+, in which Russia participates, consistently raised its production targets. This growth used up most of Russia's available spare capacity. We forecast that annual growth in oil production in Russia will average almost 0.8 million b/d during 2022 and 0.3 million b/d in 2023.

Canada's liquid fuels production increased by 0.3 million b/d in 2021 to reach a record high annual average of 5.6 million b/d. Production growth in Canada followed increased refinery demand for crude oil in the United States, the removal of production curtailments set by Alberta's provincial government, and the restart of oil sands expansion projects deferred during

the COVID-19 pandemic. In our forecast, we assume that no new upstream projects come online in Canada during 2022 or 2023. We expect oil sands output will continue to grow at smaller increments. Canada's oil sands producers have adjusted the scale and pace of upstream development and investment. These producers have increasingly moved toward smaller incremental expansions or optimizations of existing projects rather than toward larger expansions or greenfield projects. Some growth will also come from removing the bottlenecks from pipeline capacity.

We forecast Canada's production of petroleum and other liquid fuels will increase by 0.2 million b/d in 2022. Some increase in our forecast of Canada's 2022 production follows the expansion of the Enbridge Line 3 crude oil pipeline (0.37 million b/d), which became operational in October 2021. The TransMountain pipeline expansion project (0.59 million b/d) is slated to enter service at the end of 2022. Additional Enbridge expansions and optimizations to its existing pipeline system, if completed, will add more than 0.4 million b/d of export capacity over the forecast period. With this new pipeline capacity from Enbridge and other expansions, oil export constraints will be eliminated by the end of 2023. In 2023, we expect Canada's production of petroleum and other liquid fuels to grow by less than 0.1 million b/d.

Brazil's production of petroleum and other liquid fuels fell slightly in 2021. This decline reflects pandemic-related supply chain disruptions and difficulties Petrobras experienced last year when it restarted the fields that had undergone heavy maintenance in 4Q20. We expect Brazil's production to increase by 0.3 million b/d in 2022, reaching 4.0 million b/d for the first time as production facilities return to normal operation. Our forecast assumes six new floating production storage and offloading (FPSO) units will ramp up through 2023 and continue to drive growth, notably at the Sepia, Mero, and Buzios fields. Once they reach full capacity, these FPSOs will each produce between 70,000 b/d and 180,000 b/d. We expect Brazil's production of petroleum and other liquid fuels to grow by 0.1 million b/d during 2023.

Norway's production of petroleum and other liquid fuels grew by less than 0.1 million b/d in 2021, and we expect output to grow by 0.1 million b/d in 2022 and by 0.2 million b/d in 2023. Most of the growth in 2022 comes from the ramp-up in production at the Martin Linge field, which came online in July 2021. The Johan Sverdrup field, which was the main driver of growth in 2021, again is the main source of our forecast growth in 2023. Production from Phase 1 of the project averaged over 0.5 million b/d in 2021, almost 0.1 million b/d more than the peak production of 0.44 million b/d originally expected by the project developers. Phase 2 of the project, with an expected peak production of 0.22 million b/d, will start in 4Q22.

Some of the largest production declines in our forecast occur in Mexico. Mexico's crude oil and other liquid fuels production averaged 1.9 million b/d in 2021, almost unchanged from 2020 and 2019. Last year, the ramp-up of output from the Ixachi, Pokoch, and Hokchi fields stemmed Mexico's long-term production declines. Production in Mexico of petroleum and other liquids falls slightly in 2022 in our forecast. We expect Mexico's oil production to fall faster in 2023, with a decline of 0.1 million b/d. These decreases reflect financial constraints at Mexico's

national oil company, PEMEX, and continued large declines in mature fields. New growth in foreign-operated fields in 2021 and beyond will not offset declines from PEMEX's older fields, in particular the Maloob field.

We forecast that output across a number of other non-OPEC producers will decline in 2022 and 2023, notably in Indonesia and Colombia.

***OPEC production of petroleum and other liquid fuels.*** At the [January 2022 OPEC+ meeting](#), participants reaffirmed their decision to continue to increase production by 0.4 million b/d monthly, with future adjustments possible depending on market conditions. Our forecast assumes that OPEC member countries will not fully increase production in accordance with their targets in 2022. Some countries will be unable to meet their new targets because of wide-ranging challenges to bring idled capacity back online, and other countries will limit increases to avoid large global imbalances between oil production and oil demand.

OPEC crude oil production averaged 26.3 million b/d in 2021, up 0.7 million b/d from 2020. We forecast that average OPEC crude oil production will increase by an additional 2.5 million b/d to average 28.8 million b/d in 2022 and then average 28.9 million b/d in 2023. Our OPEC crude oil production forecast is subject to considerable uncertainty, driven both by country compliance with existing production targets and uncertain future global demand growth.

OPEC+ has instituted monthly meetings to assess global oil market conditions, and the group's production targets are subject to regular adjustments. OPEC+ has indicated that it will adjust production targets in response to changes in global oil demand, but the path of global oil demand in the coming months remains uncertain.

Even with increased OPEC crude oil production, remaining surplus production capacity will be more than sufficient to meet additional demand even if consumption exceeds our expectations. We expect that OPEC surplus crude oil production capacity will decline from 6.0 million b/d in 2021 to average 3.9 million b/d in both 2022 and 2023, compared with an average surplus capacity of 2.2 million b/d from 2010–19. These estimates do not include additional capacity in Iran that is offline because of U.S. sanctions.

Among the OPEC countries, Iran, Libya, and Venezuela are not subject to production targets in the OPEC+ agreement. The STEO forecast assumes current U.S. sanctions remain in place for Iran and Venezuela for the entire forecast period. We also expect that OPEC+ will not implement further production cuts to accommodate any potential increases in oil output from Iran or Venezuela.

After five years of declines, Venezuela's crude oil production rose from 0.5 million b/d in 2020 to almost 0.6 million b/d in 2021, driven by increased service company activity and increased access to condensate and other diluents for blending with Venezuela's heavy crude oil. Despite increases in 2021, we expect Venezuela's crude oil production to decline as a result of ongoing operational difficulties, lack of field and facility maintenance, and continuing sanctions.

Libya's crude oil production rose by 0.8 million b/d to an average of almost 1.2 million b/d in 2021 compared with 2020 after the eastern and western security forces signed a ceasefire agreement in October 2020. The newly formed unified government provided stability among the various factions in Libya in March 2021. Our forecast assumes generally stable production in Libya in 2022 and 2023. However, our forecast of Libya's crude oil production is subject to heightened uncertainty as a result of the tentative political and security situation in Libya and the lack of a budget to support oil and natural gas infrastructure maintenance and repair. Presidential and parliamentary elections set for December 2021 were delayed. Additionally, a blockade at four oil fields disrupted 0.3 million b/d of crude oil production in Libya in late December.

***OPEC non-crude oil liquids.*** OPEC production of non-crude oil liquids increased from 5.1 million b/d on average in 2020 to 5.3 million b/d in 2021. The 2021 production level reflects increases in production of associated liquids as a result of relaxed OPEC production cuts. We expect production of non-crude oil liquids will increase further in 2022 to 5.5 million b/d and stay at that level in 2023.

***Global oil inventories.*** We estimate that global oil inventories decreased by an average of 1.4 million b/d in 2021, after increasing by 2.1 million b/d in 2020. In our forecast, global oil inventories increase by 0.5 million b/d in 2022 and by 0.6 million b/d in 2023. This inventory growth in largely reflects growth in global oil production paired with slowing growth in oil consumption. Global oil supply increases in the forecast, in part, because of easing production cuts from OPEC+ producers and the effects of higher 2021 oil prices on U.S. tight oil production.

Total oil inventories in the OECD fell from 3.0 billion barrels at the end of 2020 to 2.7 billion barrels at the end of 2021. We expect oil inventories in the OECD to rise to 2.8 billion barrels at the end of 2022 and to 2.9 billion barrels at the end of 2021.

***Crude oil prices.*** Oil prices rose during much of 2021, with Brent crude oil spot prices averaging \$71/b for the year compared with \$42/b in 2020. Rising prices reflected growth in global oil demand that outpaced near-term growth in oil production, resulting in falling global oil inventories. During 2021, Brent prices reached their highest monthly average of \$84/b during October. Brent prices fell to an average of \$74/b in December, which largely reflected concerns about how the Omicron variant and potential mitigation efforts may affect near-term oil demand. In addition, increases in crude oil supply from OPEC+ members have likely also contributed to lower oil prices. However, crude oil prices ended December at \$77/b as concerns that Omicron would lead to significant declines in oil consumption eased and as some crude oil production went offline in Libya.

We expect Brent crude oil spot prices will average \$75/b in 2022. Forecast prices remain near current levels in 1Q22, averaging \$79/b for the quarter. Oil markets are generally balanced in 1Q22 in our forecast. After 1Q22, we expect inventory builds through the end of 2022, averaging 0.7 million b/d from 2Q22 through 4Q22. We expect some downward oil price



pressures during this period, with Brent crude oil prices falling to an average of \$71/b by 4Q22. Although inventories build in our forecast, inventory levels are currently lower than in 2019, which may dampen some of the downward price pressures associated with rising inventories. Forecast inventory builds accelerate in 2023, and we expect that Brent crude oil prices will average \$68/b for the year.

Global economic developments and numerous uncertainties surrounding the pandemic in the coming months could push oil prices higher or lower than our current price forecast. Our current price path reflects global oil consumption that increases by 4% from 2021 in 2022 and by an additional 2% in 2023. However, this forecast depends on how any potential new COVID-19 variants develop and how oil consumption behavior changes as the pandemic evolves. Global supply chain disruptions have also likely exacerbated inflationary price effects across all sectors in recent months. How central banks respond to inflation may affect economic growth and oil demand during the forecast period. The duration of, and compliance with, the latest OPEC+ production targets also remains uncertain. Our forecast includes the assumption that OPEC+ will limit production increase to less than the current target of 0.4 million b/d per month. However, this assumption leaves more spare OPEC crude oil production capacity than seen during much of the 2010–19 period. If OPEC countries choose to produce from this capacity rather than hold it as spare, prices would likely be lower than our forecast. In addition, the degree to which the U.S. shale industry responds to the recent relatively high oil prices will affect the oil price path in the coming quarters.

We forecast West Texas Intermediate (WTI) crude oil prices will average about \$3/b less than Brent prices in the first half of 2022 before widening to a discount of \$4/b less than Brent prices through 2023. This price discount is based on our assumption that the recent discount of WTI to Brent, which averaged less than \$3/b in 2021, reflected low global demand for oil exports and relatively low levels of U.S. crude oil production. As global refinery demand for crude oil and U.S. crude oil supply increases, we expect the WTI discount to return to \$4/b by 2H22. This discount reflects the relative cost of exporting crude oil from the distribution hub in Cushing, Oklahoma, to Asia, compared with the cost of exporting Brent crude oil from the North Sea to Asia.

## U.S. liquid fuels

**U.S. Consumption.** We forecast that petroleum and liquid fuels consumption in the United States will average 20.6 million barrels per day (b/d) in 2022, which would slightly surpass consumption from 2019. In 2023, we forecast that consumption will surpass 2019 levels and reach 20.9 million b/d. The forecast growth in petroleum and liquid fuels consumption is led by increases in gasoline consumption in 2022 and by hydrocarbon gas liquids (HGLs) in 2023.

We forecast that U.S. consumption of HGLs will increase by 0.2 million b/d in 2022 and by 0.1 million b/d in 2023, to reach annual averages of 3.6 million b/d in 2022 and 3.7 million b/d in 2023. We expect all of the HGL consumption growth in 2022 and nearly all of the growth in 2023 to be from increased use of ethane as a petrochemical feedstock. We expect two additional

petrochemical crackers to come online in the United States during the next two years, both of which will exclusively use ethane as a feedstock. As a result, our forecast of ethane consumption rises by 0.3 million b/d in 2022 and by 0.1 million b/d in 2023.

In this STEO, we expect that continuing effects from the COVID-19 pandemic will limit U.S. gasoline consumption and that consumption through 2023 will remain below levels seen before the pandemic in 2019. We forecast that gasoline consumption will increase by almost 0.3 million b/d (3.1%) from 2021 levels to an average approaching 9.1 million b/d in 2022. In 2023, we expect that consumption growth will slow to 0.1 million b/d (1.0%) and that annual consumption will average more than 9.1 million b/d, below the 2019 consumption level of 9.3 million b/d.

Although we expect U.S. gasoline consumption will remain below 2019 levels, we forecast that vehicle miles traveled (VMT) will exceed 2019 levels in 2022 and 2023. In the first half of 2022 (1H22), we expect VMT will be below 1H19 levels. We expect that people's responses to the COVID-19 pandemic will continue to limit driving activity, particularly in 1Q22. We assume the effects of the COVID-19 pandemic on gasoline demand will decrease after 1Q22, and driving activity will increase over the summer season, with personal travel and employment growth bringing VMT above 2019 levels in 2H22. Annual VMT in our forecast for 2022 is about equal to 2019 levels. We expect that VMT growth will continue in 2023 and that VMT will increase by 2.2% compared with 2022.

We expect increasing vehicle fuel efficiency, measured in miles per gallon, to offset some of the increased VMT. In 2022 and 2023, vehicle efficiency will likely increase 1%–2% each year. On December 20, the Biden administration released a [final rule for greenhouse gas emissions from cars and trucks](#) for model years 2023–26. The [final rule increases the stringency of emissions standards](#) by 5%–10% for each model year and replaces the previous standard that increased 1.5% annually. Because the new rule only applies to new cars and because car manufacturers have a great deal of flexibility of when they announce a new model year, we expect that the new rule will have limited effects on fleet-wide vehicle efficiency during 2023.

U.S. distillate consumption increased by almost 0.2 million b/d (4.3%) in 2021. We expect that distillate consumption will increase by more than 0.1 million b/d (3.1%) in 2022 and by less than 0.1 million b/d (1.4%) in 2023, largely because of slowing U.S. GDP growth. Based on forecasts from IHS Markit, annual GDP growth in 2021 averaged 5.7% and is expected to fall to 4.3% in 2022 and 2.8% in 2023. The decreasing rate of GDP growth in our forecast largely slows demand growth for distillate fuel, which includes diesel fuel. Distillate demand, particularly diesel fuel, is closely tied with economic activity and freight movement (such as trucking and rail). We assume that the effects of supply chain bottlenecks on distillate demand will generally decrease compared with 2021, contributing to annual distillate demand growth. If supply chain bottlenecks worsen, however, actual distillate fuel consumption may be less than forecast. Conversely, if supply chain bottlenecks improve, distillate demand could rise above the current forecast.

U.S. jet fuel consumption in the forecast rises from 1.4 million b/d in 2021 to 1.6 million b/d in 2022 and 1.7 million b/d in 2023. We expect responses to the COVID-19 pandemic will have decreasing effects on jet fuel consumption moving further into the forecast period. Jet fuel demand, however, has been the most affected by the pandemic, decreasing from 1.7 million b/d in 2019 to 1.1 million b/d in 2020. Variants of COVID-19 (such as Omicron) could deter people from flying, which may lead to jet fuel consumption being less than forecast.

**U.S. Crude oil supply.** U.S. crude oil production averaged 11.2 million b/d in 2021, down 0.1 million b/d from 2020 as a result of well freeze-offs during extreme cold in February and well shut-ins during Hurricane Ida in late August and early September. Production in 2021 was 1.1 million b/d lower than the annual record of 12.3 million b/d set in 2019. We expect annual average U.S. crude oil production to increase to 11.8 million b/d in 2022 and to 12.4 million b/d in 2023, which would set a new record. Despite our forecast of record annual average crude oil production in 2023, we do not expect production in any month in the forecast will surpass the monthly record of 12.97 million b/d set in November 2019. Production growth reflects oil prices that we expect will be sufficient to lead to continued increases in upstream development activity, which we forecast will proceed at a pace that will more than offset decline rates.

Annual average production numbers can conceal important monthly trends in oil production. For example, in February 2021, monthly average crude oil production from the Lower 48 states (L48) fell by 14% from January, from 8.8 million b/d to 7.6 million b/d, as a result of extreme cold. This event disrupted production operations across the country, particularly in Texas, which experienced widespread well freeze-offs. L48 production increased to 8.9 million b/d in March, as normal operations resumed. Because most L48 production is unconventional tight oil, we expect drilling activity and decline rate dynamics to mainly drive L48 production going forward. Tight oil wells have steep declines in the early years of their production, requiring continuous drilling of new wells to maintain unchanging production rates.

We expect production to increase for most of 2022, as more new wells come online to offset decline rates. For U.S. tight oil production, our models include a four-to-six-month lag between a change in oil price and change in production. We expect that WTI crude oil prices above \$70/b during most of 2H21 and 1H22 increase the number of active drilling rigs and contribute to L48 production growth. We expect annual average L48 production of 9.6 million b/d for 2022.

We expect the WTI crude oil price to average \$71/b in 2022. This price is up \$3/b from the 2021 average and is sufficient for producers to realize positive cash flows in many areas, particularly the more productive areas of the Permian Basin. Producers saw increased cash flow in 2021, having held back on capital investments and cut costs, as crude oil prices rose significantly. Restrained investment led to fewer rig additions than what we have observed at similar crude oil price levels in previous years. With financial conditions among operators improved, we expect development to proceed at a modest pace. We expect average month-over-month L48 production growth to be 50,000 b/d in 2022. Most of L48 growth in the forecast comes from the Permian Basin. We expect L48 production growth to slow to a monthly average of 40,000 b/d in

2023, as a decline in oil prices in our forecast slows rig additions. Annual average L48 crude oil production for 2023 is 10.2 million b/d.

From 2020 to 2021, annual average production in the U.S. Federal Gulf of Mexico (GOM) increased from 1.6 million b/d to 1.7 million b/d. This increase occurred despite Hurricane Ida, which affected the GOM in late August 2021, causing monthly average crude oil production from the region to decline from 1.9 million b/d in July 2021 to 1.1 million b/d in September 2021. At the peak of the hurricane-related disruptions, 96% of GOM crude oil production was shut in, according to estimates by the U.S. Department of Interior's Bureau of Safety and Environmental Enforcement. We expect annual average GOM production of 1.8 million b/d in 2022 and remain near that level in 2023, still below the record 1.9 million b/d of 2019.

Alaska's crude oil production in the forecast stays near the 2021 level of 0.4 million b/d in both 2022 and 2023.

**Hydrocarbon gas liquids supply.** We forecast U.S. production of hydrocarbon gas liquids (HGLs) to increase by 0.5 million b/d in 2022 to an average of 5.9 million b/d and then increase to an average of 6.1 million b/d in 2023. HGL production will increase as a result of rising production of natural gas in 2022 and 2023, higher rates of natural gas processing plant utilization, and continuing efficiency improvements in the U.S. natural gas processing plant fleet. Ethane production will rise to meet growing demand from the domestic industry and global importers for ethane as a petrochemical feedstock. We expect U.S. ethane production to increase by 0.3 million b/d and by 0.2 million b/d in 2022 and 2023, respectively, reaching an average of 2.6 million b/d in 2023. We expect net ethane exports to grow by 40,000 b/d in 2022 and by 20,000 b/d in 2023 as a result of rising global petrochemical demand and additional capacity to ship U.S. ethane overseas. We forecast propane production will rise by almost 0.1 million b/d in both 2022 and 2023.

**Liquid biofuels.** After COVID-19-related responses reduced demand for transportation fuels in 2020, U.S. biofuels consumption returned near to pre-pandemic levels in 2021. We forecast biofuels consumption will increase further in 2022, based on our expectation of increased demand for transportation fuels and the current targets in the Renewable Fuel Standard (RFS) program. Based on the current RFS targets, we forecast increases in biomass-based diesel production, consumption, and net imports.

U.S. biodiesel production increases in 2022 and 2023 in our forecast. U.S. biodiesel production decreased by 10% from 2020 to 2021, averaging an estimated 107,000 b/d in 2021. We expect biodiesel production will increase by 7% to average 114,000 b/d in 2022 and increase to 115,000 b/d in 2023. These production increases follow our expectation of growing U.S. diesel consumption, along with higher RFS targets and the continuation of the \$1/gal biodiesel and renewable diesel tax credit through December 2022.

Net U.S. imports of biomass-based diesel increased by 31% to 28,000 b/d in 2021, and we expect net imports to increase to an average of 46,000 b/d in both 2022 and 2023. Increased net imports of biomass-based diesel primarily reflect increased volumes of renewable diesel imported to meet both California Low Carbon Fuel Standard requirements and the federal RFS targets.

U.S. ethanol production increased in 2021 from 2020 but remained lower than 2019 levels. U.S. ethanol production in 2021 averaged 980,000 b/d, an increase of 8% from 2020. Ethanol production in our forecast rises to an average of 1.02 million b/d in both 2022 and 2023.

U.S. ethanol consumption averaged 910,000 b/d in 2021, an increase of 10% from 2020. We forecast ethanol consumption will average 930,000 b/d in 2022 and almost 950,000 b/d in 2023. The increase in ethanol consumption reflects our expectation of increasing gasoline demand. At the forecast levels for 2022 and 2023, the ethanol share of gasoline consumption would be near 2020 and 2021 levels of 10.3%.

**Product prices.** Reduced demand for liquid fuels in the United States during 2020 led to low prices for gasoline and diesel fuel during the same period. In 2021, increases in economic activity and personal mobility contributed to increasing prices for crude oil, gasoline, and diesel fuel compared with 2020. U.S. retail prices for regular-grade gasoline averaged \$3.02/gal during 2021, and retail diesel prices averaged \$3.29/gal, up 84 cents/gal and 73 cents/gal, respectively, from their 2020 averages.

Higher retail prices for gasoline and diesel in the United States reflect an increase in demand for petroleum fuels as well as increasing crude oil prices. After decreasing significantly in 2020, refinery margins (the difference between the wholesale price of gasoline and the price of Brent crude oil) reached their highest levels since 2014 for both gasoline and diesel in 2021. Refinery margins increased significantly beyond their recent five-year averages, driven primarily by rising fuel demand amid still restrained refinery production. [Significant increases in renewable identification number \(RIN\) prices](#), which are embedded in wholesale product prices, also raised refinery margins.

Supply disruptions also contributed to increased refinery margins for those facilities that continued operations during several instances in 2021. In February, a severe [cold weather system](#) in Texas resulted in a reduction in refinery operations along the U.S. Gulf Coast. In May, a [cyberattack](#) on the Colonial Pipeline put upward pressure on retail fuel prices because of related logistical constraints. In August, [hurricanes](#) along the U.S. Gulf Coast (particularly in Louisiana) caused flooding and temporary refinery shutdowns, which also contributed to lower refinery production at that time.

Wholesale U.S. refinery gasoline margins started 2021 at a monthly average of 27 cents/gal in January, before increasing to 62 cents/gal in August. We estimate margins averaged 49 cents/gal in December, resulting in an average of 48 cents/gal for 2021, up from 31 cents/gal in

2020 and 32 cents/gal in 2019. As forecast refinery runs continue to increase and inventories grow, we estimate gasoline refinery margins will decrease over the forecast period, averaging 42 cents/gal in 2022 and 38 cents/gal in 2023.

Ongoing uncertainty and volatility related to the COVID-19 pandemic, the Omicron variant, and potential future variants all present additional downside risks for refinery margins and wholesale product prices. However, potential short-term disruptions related to inclement weather, like those that took place in February and August 2021, present upside risks for product prices throughout the forecast.

We expect U.S. regular retail gasoline prices will average \$3.20/gal in 1Q22, 64 cents/gal higher than at the same time last year, but down 13 cents/gal compared with 4Q21. We expect the U.S. regular retail gasoline price will average \$3.28/gal in January 2022 before decreasing through the year as crude oil prices and refinery margins fall, eventually averaging \$2.77/gal in December 2022. We forecast the U.S. regular gasoline retail price, which averaged \$3.02/gal in 2021, will average \$3.06/gal in 2022 and \$2.81/gal in 2023.

Regional annual average forecast prices for 2022 range from a low of \$2.71/gal in the Gulf Coast region (PADD 3) to a high of \$3.86/gal in the West Coast region (PADD 5). Reduced refinery capacity on the West Coast compared with 2019 pre-pandemic levels is likely to contribute to higher refinery margins, wholesale prices, and resale margins in that region in the future.

The retail price of diesel fuel in the United States averaged \$3.29/gal in 2021, which was 73 cents/gal higher than in 2020. We forecast the diesel price will average \$3.33/gal in 2022 and \$3.27/gal in 2023. We expect that global economic activity returning to pre-pandemic levels will help drive diesel refinery margins higher than their multiyear lows in 2020 during the forecast period. Diesel refinery margins averaged 42 cents/gal in 2021, which was 4 cent/gal higher than the 2016–20 average and 12 cents/gal higher than levels seen in 2020. We forecast that diesel refinery margins will average 47 cents/gal in 2022 and 45 cents/gal in 2023.

## Natural gas

**Natural gas consumption.** Consumption of natural gas in the United States averaged 83.0 billion cubic feet per day (Bcf/d) in 2021, almost unchanged from 2020. We expect U.S. natural gas consumption will remain at nearly the same level in both 2022 and 2023.

The largest natural gas-consuming sector in the United States is the electric power sector. We forecast that the electric power sector will consume an average 28.8 Bcf/d in 2022, which is 6% less than in 2021. This decline is a result of rising electricity-generating capacity from renewable energy. We expect that the consumption of natural gas by the electric power sector will decline by 0.5 Bcf/d (2%) in 2023.

Industrial sector consumption of natural gas in our forecast increases by 3% during 2022, averaging 23.2 Bcf/d, and grows to 23.5 Bcf/d in 2023, as demand for industrial goods and economic activity increases.

We expect combined U.S. residential and commercial natural gas consumption will average 22.6 Bcf/d in 2022, up 4% from 2021. Based on National Oceanic and Atmospheric Administration forecasts, this STEO assumes colder temperatures this year, with 6% more heating degree days (HDDs) across the United States in 2022 compared with 2021. We expect natural gas consumption in the U.S. residential and commercial sectors to increase by 1% to 22.8 Bcf/d in 2023, driven by the assumption of slightly colder weather than 2022.

**Natural gas production.** U.S. production of dry natural gas averaged an estimated 93.5 Bcf/d in 2021, up 2.0 Bcf/d (2%) from 2020. Natural gas production fell in 2020 as a result of low natural gas and oil prices that reduced drilling activity. Production grew in 2021 as drilling activity came back online, especially in the Permian Basin, where associated gas production in that region contributed to the overall growth in natural gas production. We forecast dry natural gas production will increase by 2.5 Bcf/d (3%) in 2022. Recent increases in oil and domestic natural gas prices contribute to an overall increase in drilling activity in 2022 that will lead to production growth from 2Q22 onward. Growth in dry natural gas production in 2022 is led by the Haynesville region, where production tends to be sensitive to change in U.S. benchmark Henry Hub natural gas prices, and by the Permian Basin, where production tends to be more sensitive to oil prices. In 2023, we expect dry natural gas production to increase by 1.5 Bcf/d (2%) to reach 97.6 Bcf/d.

**Natural gas trade.** We forecast natural gas exports will reach record highs in 2022 and continue to grow in 2023. Net natural gas exports averaged 10.7 Bcf/d in 2021 and we forecast that they will increase to 13.4 Bcf/d in 2022 and 14.3 Bcf/d in 2023. A combination of both rising liquefied natural gas (LNG) exports and increases in pipeline exports to Mexico will drive this increase.

The United States exported an estimated 11.2 Bcf/d of LNG in December 2021, an increase of 0.7 Bcf/d over the previous record set in November. LNG export growth in 2021 was driven by rising natural gas demand and high LNG prices in Europe and Asia, reductions in global supply because of several unplanned outages at LNG export facilities worldwide, and cold weather in key LNG consumption markets, particularly in Asia.

Rising demand for LNG imports in Europe and Asia and the completion of planned projects that will bring new U.S. LNG export capacity online in 2022 supports growth in LNG exports in the forecast. We forecast that U.S. LNG exports will average 11.5 Bcf/d in 2022, up from 9.8 Bcf/d in 2021. In 2023, we forecast that U.S. LNG exports will average 12.1 Bcf/d. The completion of Train 6 at Sabine Pass, the optimization of operations at Sabine Pass and Corpus Christi LNG terminals, and the completion of a new LNG export facility—Calcasieu Pass LNG—are all expected

in 2022; these expansions will [increase total U.S. LNG export capacity in 2022 to become the world's largest](#).

As of December 2021, existing U.S. LNG baseload liquefaction capacity was 10.1 Bcf/d, and peak capacity was 12.2 Bcf/d (including uprates to LNG production capacity at Sabine Pass and Corpus Christi). By the end of 2022, U.S. baseload capacity will increase to 11.4 Bcf/d, and peak capacity will increase to 13.8 Bcf/d, across seven LNG export facilities and 44 liquefaction trains, including 16 full-scale, 18 mid-scale, and 10 small-scale trains at Sabine Pass, Cove Point, Corpus Christi, Cameron, Elba Island, Freeport, and Calcasieu Pass.

Pipeline exports of U.S. natural gas have also increased as more [infrastructure](#) has been built to transport natural gas both to and within Mexico and as more natural gas-fired power plants come online in Mexico. Gross U.S. pipeline exports to Mexico and Canada in the forecast average 8.9 Bcf/d in 2022, up 0.4 Bcf/d (5.0%) from 2021, and 9.2 Bcf/d in 2023.

U.S. natural gas pipeline imports, almost all of which come from Canada, increased by 0.7 Bcf/d in 2021. We forecast natural gas pipeline imports to decrease 0.7 Bcf/d in 2022 because the United States will import less natural gas in response to increases in domestic production. Pipeline imports in the forecast remain relatively unchanged in 2023.

**Natural gas inventories.** U.S. working natural gas inventories ended December at 3,221 Bcf, 4% less than one year ago, but 3% more than the five-year (2016–20) average. We forecast close-to-average storage withdrawals in 1Q22, resulting in inventories that total 1,822 Bcf at the end of March, which would be 8% more than the five-year (2017–21) average for that time of year. For the 2022 April–October storage injection season, injections in our forecast do not keep pace with the five-year average rate. The lower-than-average injections reflect demand growth in the industrial sector and rising demand for U.S. exports. We expect that inventories will reach 3,668 Bcf at the end of October 2022, which would be within 1% of the five-year average for the end of October and nearly identical to inventory at the end of October 2021.

**Natural gas prices.** Henry Hub spot prices averaged \$3.91/MMBtu in 2021. Natural gas prices were volatile throughout 2021. Early in 2021, volatility resulted from [near record-high spot prices](#) during the [extreme winter weather](#) in February. During the rest of the year, Henry Hub prices rose from \$2.62/MMBtu in March to \$5.51/MMBtu in October, before falling back to \$3.76/MMBtu in December, amid a warmer-than-normal start to the heating season across most of the country.

We forecast the Henry Hub spot price will average \$3.79/MMBtu in 2022. In 1Q22, we forecast the average Henry Hub spot price of natural gas will be \$3.82/MMBtu. We expect prices will stay near current levels as natural gas inventory levels remain near the five-year average levels. Prices average \$3.78/MMBtu for the remaining three quarters of 2022. We expect the Henry Hub spot price of natural gas to average \$3.63/MMBtu in 2023.



Although we expect natural prices to decline in 2022 and 2023 compared with 2021, prices in the forecast stay relatively high compared with recent years. This dynamic is partly the result of reductions in coal-fired electricity-generating capacity and ongoing constraints in the coal market, which make increases in coal generation (and associated decreases in natural gas generation) less sensitive to rising natural gas prices than they have been in recent years. In addition, natural gas price volatility could result from weather-related increases or decreases in demand and uncertainties about the way in which rising levels of natural gas exports could affect the U.S. market.

## Coal

**Coal production.** U.S. coal production totaled 579 million short tons (MMst) in 2021, up 44 MMst (8%) from 2020. The 2021 increase primarily reflected more consumption of coal in the electric power sector amid an increase in natural gas spot prices, which made coal more economically competitive relative to natural gas for electricity generation dispatch.

In 2022, we expect U.S. coal production to increase by 33 MMst (6%) to 612 MMst. Our forecast coal production increases by 27 MMst (8%) in the Western Region, 3 MMst (3%) in the Interior Region, and 2 MMst (2%) in Appalachia.

In 2023, we expect coal production to increase by 8 MMst (1%) to 619 MMst. Coal production rises by 8 MMst (2%) in the Western Region and by 3 MMst (3%) in the Interior Region. Forecast production declines by 2 MMst (1%) in Appalachia.

Despite less demand from the electric power sector, we expect coal production will grow in 2022 and 2023. The expected increased production reflects demand to replenish [depleted coal stocks](#). Electric power sector inventories saw significant draws in 2021, and we expect stocks to increase by the end of 2023. In our forecast, inventories reach 85 MMst at the end of 2022 and 91 MMst at the end of 2023. In addition, we expect rising demand for coking coal—used for steelmaking—both domestically and for export.

Much of the [decrease in coal mine capacity](#) that occurred in 2020 appears to be permanent. Coal producers have experienced labor and capital shortages, which we expect will continue to limit supply in the forecast. Despite these limitations, we forecast more coal production in 2022 and 2023 than in 2021 as utilization at existing mines rises.

**Coal consumption.** In this forecast, we expect the retirement of approximately 19 gigawatts (GW) of coal-fired power plant capacity through 2023, a decline of 9%. As a result, we forecast electric power sector demand for coal will decrease by 14 MMst in 2022 and by 2 MMst in 2023. Rising natural gas prices led to increased demand for coal-fired power generation in 2021. We expect that natural gas prices will remain relatively high compared with past years, keeping coal consumption in the electric power sector above 2020 levels but below 2021 levels. The expected decline in electric power sector consumption leads to a decline in overall coal consumption in

our forecast. We forecast total U.S. coal consumption for all sectors to decrease by 11 MMst (2%) in 2022 to 534 MMst and by a further 3 MMst (<1%) in 2023 to 532 MMst.

Coal is an essential component of the steel-making process. Demand for coal to make steel increases by 16% in 2022 and by 3% in 2023, particularly for infrastructure-related materials. As a result, we expect demand for coking coal to rise by more than 3 MMst from 2021 to 2023, offsetting some of the decline in electric power sector coal consumption.

**Coal trade.** Annual U.S. coal exports increased by an estimated 26% in 2021 to reach 87 MMst. Metallurgical coal exports were 47 MMst in 2021, 12% more than the previous year, and steam coal exports were 40 MMst, 47% more than in 2020.

A majority of the 25 leading U.S. coal export destinations increased their imports of U.S. coal in 2021 through October, which is our most recent data. The ongoing trade dispute between Australia and China has continued to increase opportunities for swing coal suppliers, such as the United States, to gain market share and increase overall exports of coal. Between January and October 2021, China imported almost 11 MMst of U.S. coal, more than in the previous four years combined. Metallurgical coal accounts for a large share of China's imports, representing about 90% of China's imports of U.S. coal in 2021.

We expect U.S. coal exports will rise by 1 MMst in 2022 and by 3 MMst in 2023. The increase reflects our assumption that the seaborne coal market in 2022 and 2023 will experience slightly higher demand for U.S. coal. Metallurgical coal will drive the increase in coal exports. We assume global steel production, which increased moderately 2021, will grow further during the forecast period and increase U.S. metallurgical coal exports to 50 MMst in 2022 and 55 MMst in 2023. Forecast U.S. steam coal exports total 38 MMst in 2022 and 37 MMst in 2023, largely unchanged from 2021.

**Coal prices.** The delivered coal price to U.S. electricity generators averaged an estimated \$1.98/MMBtu in 2021. Coal prices increased throughout the year as a result of coal market constraints, averaging \$1.92/MMBtu in 1H21 and \$2.03/MMBtu in 2H21. We forecast that coal prices will fall to \$1.94/MMBtu in 2022 and to \$1.81/MMBtu in 2023.

## Electricity

**Electricity consumption.** We forecast that consumption of electricity in the United States, including retail sales and direct use of electricity, will increase by 0.6% in 2022 and 1.4% in 2023. Preliminary data indicate that electricity consumption grew by 2.0% in 2021, and year-over-year growth was fastest in the first half of last year when the economy began to return to pre-pandemic patterns.

Year-to-year changes in residential electricity consumption are most related to changes in temperature, often measured using [heating degree days](#) (HDDs) and [cooling degree days](#) (CDDs). In 2021, retail sales of electricity to the residential sector grew by 1.2%. Most of this

growth last year occurred in 1Q21 when residential electricity consumption grew by 11% from the same quarter in 2020 in response to colder weather. Part of this increased residential consumption during the first quarter may also have reflected changing patterns of electricity use as more people work from home compared with the months in 1Q20 before the pandemic. Residential electricity sales during the last three quarters of 2021 averaged about 1.8% less than the same period in 2020.

In 2022, our forecast include 6.5% more HDDs for the United States than last year, with most of that increase occurring in 4Q22 compared to a mild start to this winter. The increase is less in the southern area of the country where heating with electricity is more prevalent. Cooler temperatures during the summer months of 2022 throughout most of the country (6.4% fewer CDDs) than in 2021 would lead to less use of air-conditioning. The effect of cooler forecast summer temperatures offsets the effect of a colder forecasted 4Q22, leading to an overall 2.2% decline in annual residential retail sales of electricity in our forecast during 2022. We expect residential electricity sales to grow by 2.1% in 2023.

The colder winter weather early in 2021 led to more electricity consumption in the commercial sector, but economic activity and growth in private-sector jobs were still limited at that time. The number of people employed during 1Q21 was 5.6% lower than during the same period in 2020; however, employment during the last three quarters of 2021 returned to an average of 5.8% year-over-year growth. As a result, retail sales of electricity to the commercial sector grew by an estimated 2.7% in 2021. For 2022, we forecast commercial sector electricity use to grow by 1.7%, reflecting the effect of continued economic growth offset somewhat by expected milder summer temperatures this year. We expect commercial sector electricity consumption to grow by 0.4% in 2023.

The U.S. industrial production index for electricity-intensive industries increased by 5.9% in 2021 after declining by 6.4% in 2020. This increase helped to raise U.S. retail electricity sales to the industrial sector by an estimated 2.9% last year. We expect the electricity-weighted industrial production index to grow by 4.1% and 2.5% in 2022 and 2023, respectively, leading to forecast growth in U.S. industrial sector electricity use of 2.8% in 2022 and 1.7% in 2023.

***Electricity generation.*** Electricity generation by the U.S. electric power sector grew by an estimated 2.9% in 2021 after having fallen 2.9% in 2020, which was the largest decline in generation since 2009. We expect the U.S. electric power sector will generate about the same amount of electricity in 2022 as in 2021. Total electric power sector generation in the forecast grows by 1.3% in 2023.

Up until 2021, U.S. coal-fired electricity generation [had fallen every year since 2014](#). However, we estimate that coal generation in 2021 grew by 17%. Some of this increase was a result of the overall increase in U.S. electricity demand last year after the pandemic-related decline in 2020, but most of the increase in coal generation last year was in response to natural gas prices that have been much higher than in past years. We estimate that the cost of natural gas delivered to

U.S. electric generators in 2021 averaged \$4.88/MMBtu, twice the average cost in 2020. Higher fuel costs also contributed to an estimated 3% decline in U.S. natural gas generation in 2021.

We expect the delivered cost of natural gas for electricity generation will fall to an average of \$4.10/MMBtu in 2022. However, that price remains higher than the average price in recent years. Despite a forecast of lower fuel costs, U.S. natural gas generation is likely to decline in 2022 as rapidly growing renewable energy sources produce more generation. We forecast the share of total U.S. generation from natural gas will average 35% in 2022, down from 37% in 2021. The decline in natural gas generation is especially pronounced in Texas, where a large amount of solar and wind capacity is scheduled to come online.

Lower natural gas prices also tend to discourage generation from coal, and we forecast the U.S. coal generation share to average 22% in 2022, which is slightly below last year. This forecast decline in coal generation is largest in the Northeast and western areas of the country.

We expect the share of generation from renewable sources will increase from 20% in 2021 to 23% in 2022 and to 24% in 2023. We expect most of the increase in renewables generation will come from new solar and wind capacity expansions in the electric power sector. We forecast that hydropower will fuel about 7% of generation in both 2022 and 2023. In 2021, the [drought affecting the West restrained electricity generation by hydropower](#). U.S. hydropower generation contributed about 6% of the total in 2021, which is the lowest share since 2015. In the forecast, the share of total generation for renewables other than hydropower, which was 13% in 2021, rises to 16% in 2022 and to 17% in 2023.

In April 2021, New York's [Indian Point](#) nuclear power plant retired. This retirement contributed to the reduction in the nuclear share of U.S. total generation from 21% in 2020 to 20% last year. The Palisades nuclear power plant in Michigan is scheduled to retire in the summer of 2022. However, we expect the amount of U.S. nuclear generation will remain relatively steady in the forecast as two reactors at the Vogtle plant in Georgia are scheduled to come online in 2022 and 2023.

Over the next two years, our forecast of the U.S. electricity generating capacity from renewable sources continues to grow. Growth in wind capacity begins to moderate, but growth in solar capacity remains strong. Since 2019, more non-hydropower renewables capacity has been added to the U.S. generation fleet [than natural gas capacity](#). This trend continues during the forecast period; operators report 29 gigawatts (GW) of planned utility-scale solar and wind capacity additions in 2022 and 28 GW in 2023. Preliminary data indicate that operators plan to add 5 GW of battery storage capacity in 2022 and 5 GW in 2023, annual increases of 84% in 2022 and 47% in 2023. Most planned [battery storage additions will be paired with solar capacity](#).

We forecast that in 2022 additions of utility-scale solar capacity in GW will exceed wind additions for the first time. We expect that 21 GW of solar photovoltaic (PV) capacity will be

added by the electric power sector in 2022. We forecast an additional 25 GW for 2023. We forecast small-scale solar PV capacity will increase by about 5 GW in 2022 and by a similar amount in 2023. Residential PV accounts for 70% of this additional small-scale solar PV capacity for 2022 and 64% for 2023.

Preliminary data indicate that solar PV capacity additions continued in 2021 despite tariff and [supply chain issues](#). Forecast solar capacity growth reflects various state and federal policies to support renewable energy. We expect growth to continue over the forecast period, supported by the [solar investment tax credit](#) (ITC) under the Consolidated Appropriations Act. Under the ITC, projects that start in 2022 are eligible for a 26% tax credit. The credit drops to 22% for projects that start in 2023. States such as Texas and Florida are set to add significant solar PV in the next two years.

Wind capacity in the electric power sector grows by 7 GW in 2022 in our forecast and by an additional 4 GW in 2023. This growth in forecast wind capacity for 2022 and 2023 marks a decline from the record of 17 GW added in 2021, which surpassed the previous [record of 14 GW set in 2020](#). This slowing growth in wind can be partly attributed to the phasedown of the production tax credit (PTC) and supply chain issues. The PTC, which at the end of 2020 was [extended through the 2021 calendar year](#), provides a 2.5 cents per kilowatthour (kWh) benefit for facilities entering service or securing 5% safe harboring (spending at least 5% of total estimated project cost). Producers of safe harbored projects are able to claim the PTC four years after they qualify.

Because [wind capacity is often added at the end of the calendar year](#), increases in generation frequently lag behind increases in capacity for the year they occur in, and they are reflected in the generation for the next year.

***Electricity prices.*** Wholesale electricity prices throughout the country trended higher in 2021, reflecting the increasing cost of natural gas for power generation. Last year, average annual wholesale prices ranged from \$38 per megawatthour (MWh) in Florida to \$190/MWh in Texas, though the Texas average would be \$43/MWh excluding February when [severely cold temperatures](#) caused hourly prices to surge in excess of \$6,000/MWh. We expect 2022 average wholesale electricity prices at trading hubs in the eastern part of the country will generally be higher than in 2021, with the exception of PJM, where we expect prices will be mostly unchanged. In the central and western areas, we expect wholesale prices will be lower at most hubs in 2021, with the exception of California where we expect slightly higher prices.

We forecast the U.S. retail electricity price for the residential sector will average 14.2 cents/kWh in 2022, which is 3.8% higher than the average retail price in 2021. Forecast residential prices remain relatively constant in 2023.

## U.S. economic assumptions and energy-related carbon dioxide emissions

**U.S. economy.** We incorporate IHS Markit’s macroeconomic forecast model for the United States with our own energy price forecasts to create STEO forecasts.

Based on this model, we estimate that U.S. real GDP grew by 5.7% in 2021. In 2022, U.S. real GDP will grow by 4.3% and by 2.8% in 2023. In comparison, real U.S. GDP fell by 3.4% in 2020. Total industrial production mirrors this pattern. Following a decline of 7.2% in 2020, we estimate it grew by 5.6% in 2021 and will increase by 4.6% in 2022 and 2.8% in 2023. The unemployment rate fell to an estimated 4.2% in December 2021 and our forecast assumes it will fall to an average 3.6% in 2022 and to 3.4% in 2023. This follows an unemployment rate of 8.1% in 2020. Nonfarm payroll employment increased by a total of 3.9 million persons in 2021 (2.7%), and our forecast assumes it will rise by 5.6 million in 2022 (3.8%) and 2.4 million in 2023 (1.6%). Price levels were notably elevated in 2021 when the Consumer Price Index (CPI) rose 4.6%. However, CPI growth in our forecast slows to 3.4% in 2022 and to 2.1% in 2023.

**Energy-related carbon dioxide emissions.** Energy-related carbon dioxide (CO<sub>2</sub>) emissions rose by 6.2% in 2021 relative to 2020, and we estimate that they will rise by 1.8% in 2022 and by 0.5% in 2023. Energy-related CO<sub>2</sub> emissions are sensitive to changes in weather, economic growth, energy prices, and fuel mix. Forecast petroleum-related CO<sub>2</sub> emissions increase by 4.8% in 2022 and by 1.1% in 2023 as economic and mobility activity return to pre-pandemic patterns. We forecast a decrease in coal CO<sub>2</sub> emissions and a modest increase in natural gas CO<sub>2</sub> emissions over the next two years. We forecast CO<sub>2</sub> emissions from coal to fall by 3.0% in 2022 and by 0.3% in 2023 as coal-fired electricity generation is displaced, primarily by renewable sources. We expect CO<sub>2</sub> emissions from natural gas to rise by 0.7% in 2022 and by 0.1% in 2023 as demand for space heating rises.

### Notable forecast changes

- For more information, see the [detailed table of forecast changes](#).

This report was prepared by the U.S. Energy Information Administration (EIA), the statistical and analytical agency within the U.S. Department of Energy. By law, EIA's data, analyses, and forecasts are independent of approval by any other officer or employee of the U.S. Government. The views in this report therefore should not be construed as representing those of the U.S. Department of Energy or other federal agencies.