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Has the Bakken Peaked?

Exhaustion of High-quality Drilling Sites Could Point to Falling Oil Output

Executive Summary

The Bakken oil industry has been on a gut-wrenching roller coaster ride for the last two years, but it may be headed toward a long-term slide. Crude oil production in the region reached an all-time high in late 2019. But in early 2020, the COVID-19 crisis sent oil prices tumbling, sending oil output from the Bakken Shale formation down more than 40 percent to its lowest level since 2013. Crude oil production partially rebounded later in the year but even today remains about one-quarter below its peak. Despite a sharp rise in U.S. oil prices over the past several months, drilling activity in the Bakken remains at less than half its pre-pandemic levels, and the region's recent oil output has faltered.

The Bakken's substantial production decline and the slow recovery of drilling despite rising oil prices raise a critical question: Will Bakken crude oil output ever recover to its previous highs?

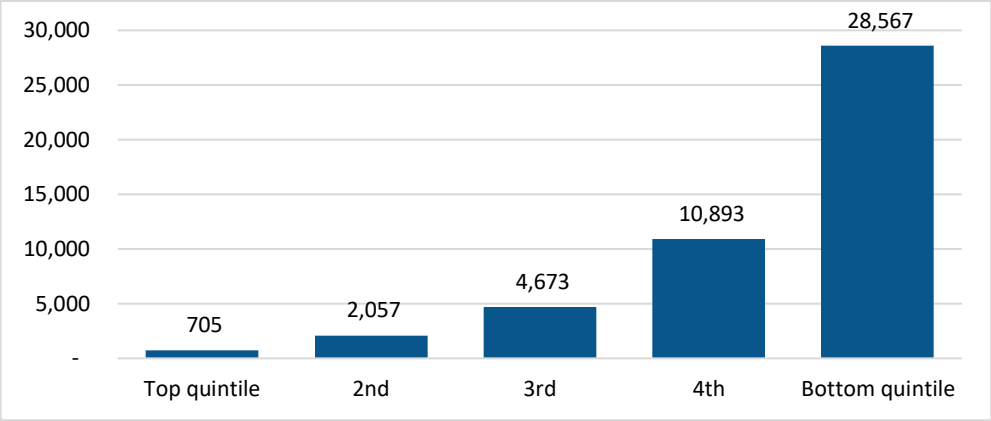
A new IEEFA analysis suggests that **a shortage of high-quality drilling sites poses a long-term risk to Bakken oil production.** This analysis uses data from IHS Markit, one of the world's premiere oil and gas data services, to explore the productivity of wells already drilled in the Bakken and the quality of the remaining acreage left to be drilled in the region.

In the roughly 13 years since the Bakken oil boom began in earnest, the region's oil producers have increasingly concentrated on a few core areas where horizontal wells produce an abundance of oil. But IEEFA's analysis suggests these core areas are almost exhausted, and most of the Bakken's best wells have already been drilled.

Moving forward, oil companies may be able to drill about 700 new top-tier wells—those whose peak oil and gas output would rank among the top 20 percent of wells drilled to date. By comparison, Bakken oil producers brought 600 wells of the same caliber into production in 2019 alone.

If Bakken oil producers resume pre-pandemic rates of drilling, they could easily deplete the remaining inventory of top-quality drilling sites in just over a year.

Figure 1: Number of Remaining Bakken Drilling Sites, Ranked by Peak Monthly Production



Source: IEEFA, estimated from IHS Markit data.

The Bakken has an additional inventory of second-tier drilling locations, ranging in number between 1,500 and 2,100. By comparison, oil companies have brought a total of more than 15,000 wells in the Bakken since 2010. This suggests that the Bakken could run short of both first- and second-tier drilling sites within the next few years.

As the Bakken oil industry depletes its remaining inventory of top-tier wells, it will have no choice but to shift drilling to less-productive areas. The newer wells will produce less oil and gas, and will require steadily higher prices to justify the roughly $7 million price tag to drill and complete a Bakken well. Lower production and weaker profits could force many Bakken oil drillers to curtail output, and aggregate Bakken oil production may fall as the average well productivity declines.

The inexorable decline in the quality of new Bakken oil wells, and the potential decline in total oil production, carries significant fiscal, financial and policy implications. Investors may be forced to lower expectations for profits from oil companies operating in the region. State and local budget planners may need to reduce their expectations for oil and gas revenues. Pipeline regulators may need to reconsider the economic rationale for existing pipelines, particularly the controversial Dakota Access Pipeline (DAPL); even modest declines in production could render DAPL's capacity superfluous.

The inexorable decline in the quality of new Bakken oil wells, and the potential decline in total oil production, carries significant fiscal, financial and policy implications.

At the same time, as North Dakota enters a long-term transition away from the oil and gas sector, new questions will arise about the Bakken oil industry's ability to pay to plug old oil wells and decommission unneeded infrastructure. Investors and policymakers ignore these trends at their peril.

Introduction: Bakken Oil Output Has Already Declined

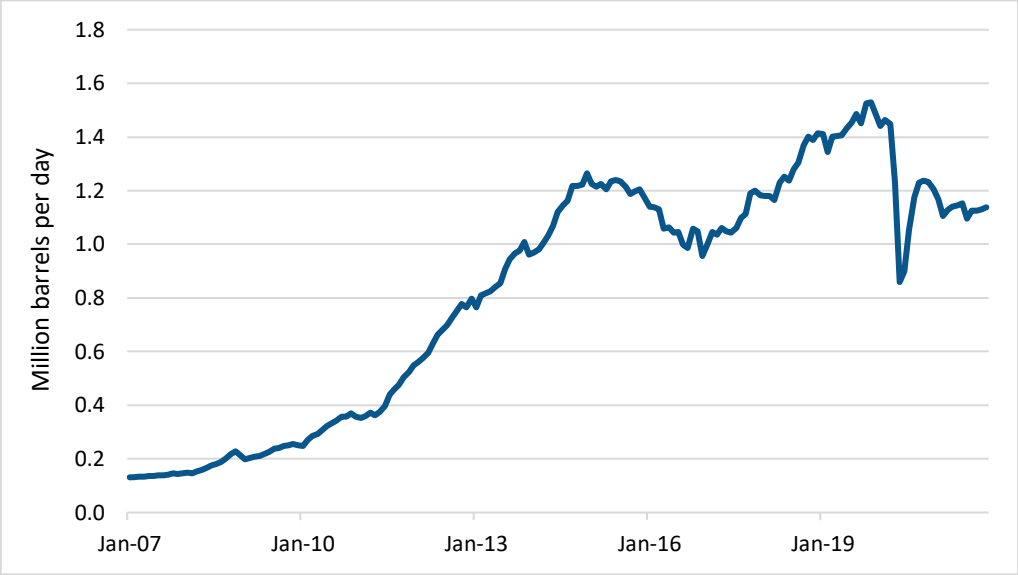
During the early stages of the fracking boom, the Bakken Shale—a region spanning western North Dakota and eastern Montana—became a U.S. oil industry powerhouse. Starting in 2008, drilling of horizontal wells in the region skyrocketed, with the Bakken representing an outsized share of all new hydraulically fractured oil wells in the United States.[1] As oil companies expanded their Bakken operations, the region's crude output rose from fewer than 200,000 barrels per day (bpd) in 2007 to more than 1.2 million bpd in 2014. (See Figure 2.) A decline in oil prices from 2014 through 2016 led to production declines, but as oil prices recovered in 2016, Bakken oil output rose again, surpassing 1.5 million barrels per day in late 2019.[2] North Dakota officials projected that the Bakken oil boom would continue, with output hitting 2 million barrels per day by 2030.[3]

Yet by late 2019, Bakken oil production had already started to falter. The global COVID-19 crisis dramatically accelerated the decline. As oil price collapsed and surpluses mounted, many Bakken oil companies shut in their wells,[4] and drilling in the region fell to its lowest level since the dawn of the fracking boom. In February 2020, immediately before the oil price collapse, 53 drilling rigs operated in the Bakken. During the second half of 2020, the Bakken averaged just 11 rigs.[5]

Market chaos led to gyrations in Bakken oil output: First, a collapse as oil wells were taken offline, then a rebound as many of those wells were restarted, then a softer decline as drilling rates fell and output from existing wells fell. Bakken oil output now stands at roughly 1.14 million barrels per day, down from an all-time high of 1.53 million bpd in November 2019—meaning that Bakken crude oil output has fallen about 25 percent from its peak, and currently remains below its early 2014 levels.[6] Market conditions became so dire that two of the region's top producers, Whiting Petroleum and Oasis Petroleum, filed for bankruptcy protection in 2020. Both companies had racked up a troubling decade-long record of negative free cash flows,[7] and the market turmoil of 2020 tipped both companies into insolvency.

[1] U.S. Energy Information Administration. Drilling Productivity Report. October 18, 2021.
[2] Energy Information Administration. Drilling Productivity Report. September 2021.
[3] Dickinson Press. Bigger than some of OPEC: North Dakota on track to reach 2 million barrels of oil per day by 2030. May 4, 2019.
[4] BIC Magazine. GlobalData: Bakken producers desperate to shut in wells until crude oil price recovers. June 10, 2020.
[5] Baker Hughes. North America Rig Count. September 17, 2021.
[6] U.S. Energy Information Administration, *op. cit.*
[7] IEEFA. In a Tumultuous 2020, Shale Firms Slashed Capex to Generate Cash. March 2021.

Figure 2: Bakken Oil Production, 2007-2021



Source: Energy Information Administration, Drilling Productivity Report, October 2021.

Bakken production appears unlikely to stage a strong rebound soon. Only 23 oil rigs operate in the region, down almost 90% from the region's 2012 high of 224 active rigs.[8] Continental Resources, Hess Corporation, Whiting Petroleum and Oasis Petroleum—the top four Bakken drillers, which accounted for 31% of Bakken oil production in 2020—plan to boost capital expenditures by less than 10% from their level last year, leaving their 2021 capital expenditures 45% below 2019 levels.[9] North Dakota government officials, once bullish on the Bakken's prospects, recently predicted that oil production in North Dakota will remain flat through the first half of 2022.[10]

The Bakken Has More Oil Takeaway Capacity Than It Needs

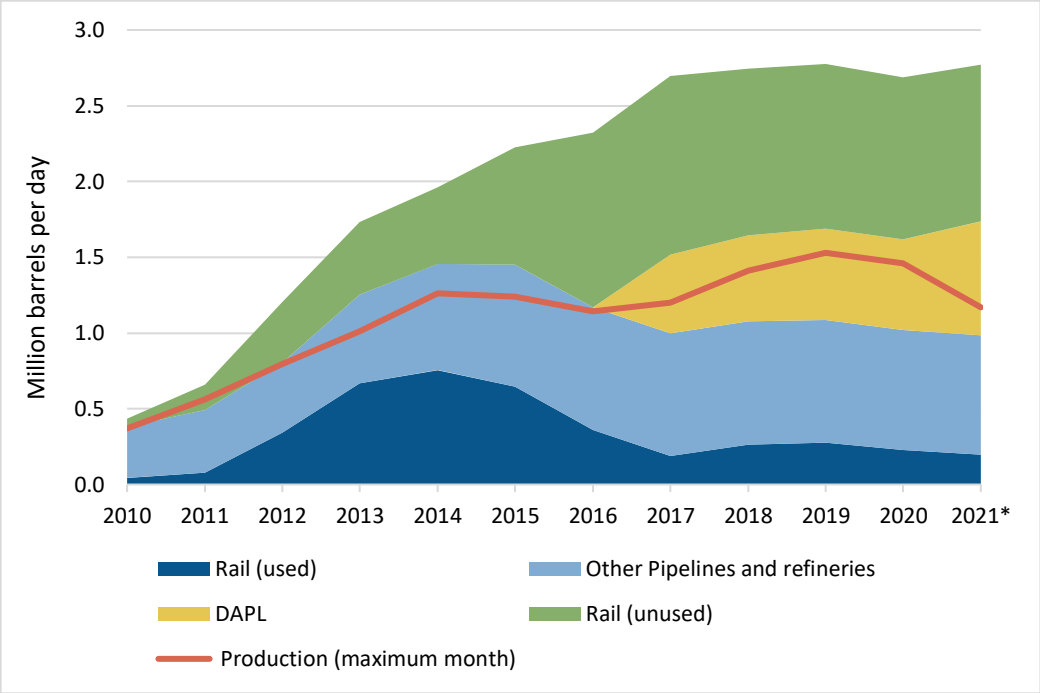
During the Bakken oil sector's growth phase, pipeline and midstream companies quickly constructed a massive pipeline and oil-by-rail infrastructure to ship crude oil out of the Bakken into Midwestern and coastal crude markets. This pipeline buildout continues today. In early August, Energy Transfer LP announced that it had completed an "optimization project" on the controversial Dakota Access Pipeline (DAPL) that increased maximum throughput to 750,000 barrels of oil per day (bpd), up from the pipeline's previous capacity of 570,000 bpd.[11]

[8] Baker Hughes. North America Rig Count. September 17, 2021.
[9] SEC filings for Continental Resources, Hess Corporation, Whiting Petroleum, and Oasis Petroleum. See also *Appendix 2: Citations and estimates for major Bakken oil producer capital expenditures.*
[10] Bloomberg. North Dakota Sees Its One-Time Oil Gushers Stalled Until 2022. December 14, 2020.
[11] The Motley Fool. Energy Transfer LP (ET) Q2 2021 Earnings Call Transcript. August 3, 2021.

All told, the Bakken has total crude oil takeaway capacity of almost 2.8 million barrels per day—well over twice as much capacity as the region currently requires. (See Figure 3.) Oil pipelines account for 1.47 million bpd of total Bakken takeaway capacity. A local refinery adds an additional 68,000 bpd.[12]

Pipeline capacity may grow yet again if the proposed Bridger Expansion crude pipeline is brought into service,[13] which would boost total Bakken crude pipeline capacity to 1.62 million bpd, lifting total oil takeaway capacity to more than 2.9 million bpd. It would grow even larger if Energy Transfer goes through with its proposal to boost DAPL's total capacity to 1.1 million bpd.[14] A proposed new refinery could add another 49,500 bpd.[15]

Figure 3: Bakken Oil Takeaway Capacity vs. Production, 2010-2021



Source: North Dakota Pipeline Authority, US Energy Information Administration, IEEFA estimates.
**2021 estimated from partial-year data.*

The Bakken also has roughly 1.2 million barrels per day of oil-by-rail loading capacity, the vast majority of which sits idle most of time. Crude oil shipments from the Bakken peaked in 2014, but some crude oil is still transported by rail out of the Bakken, particularly to refineries in Washington State and the Northeast U.S. that lack pipeline access from North Dakota. In 2019, Bakken oil-by-rail shipments stood

[12] North Dakota Pipeline Authority. Oil Transportation Table. September 19, 2021.
[13] Bridger Pipeline Company. Bridger Pipeline LLC, Belle Fourche Pipeline Company, and Butte Pipe Line Company Announce Commencement of Binding Open Season. January 29, 2021.
[14] Bismarck Tribune. Dakota Access Pipeline operator plans large capacity expansion. June 19, 2019.
[15] Grand Forks Herald. Construction of oil refinery to start in 2022 near North Dakota's only national park, CEO says. September 14, 2021.

at roughly 275,000 bpd, averaged over the year, though rail shipments likely approached 300,000 bpd in the peak month of that year. In the first seven months of 2021, Bakken rail export volumes averaged roughly 195,000 bpd.[16]

The Dakota Access Pipeline (DAPL), a 1,172-mile pipeline designed to carry oil from the Bakken region of western North Dakota to an oil transportation hub in Patoka, Ill., has been the subject of ongoing controversy. First proposed in 2014 and placed into service in 2017, its construction raised issues of tribal sovereignty and threats to drinking water at the pipeline's Missouri River crossing.[17] Legal challenges to the pipeline have continued since the pipeline was put into service. In March 2020, a district court judge found that the U.S. Army Corps of Engineers had improperly granted the pipeline an easement to cross Lake Oahe without an appropriate environmental review. The Army Corps is in the process of drafting an environmental impact statement, a process which is expected to take until March 2022. The pipeline continues to operate while the environmental review is drafted.[18]

Over the past several years, these legal controversies have created a risk that federal regulators could shut down DAPL if environmental requirements are not met. But a continuation of recent production declines could, as a matter of practicality, render the pipeline's capacity superfluous. Assuming a 90% capacity utilization for the Bakken region's lone oil refinery, 95% utilization of pipelines other than DAPL, and a return to 2019's level of oil-by-rail shipments, IEEFA estimates that Bakken's other oil pipelines and refineries and oil-by-rail shipments could handle just over 1 million bpd of oil production.[19] Given the significant surplus of pipeline capacity in the Bakken, even modest declines in oil production from current levels could allow the region to handle its crude production without DAPL's capacity, while keeping oil-by-rail volumes at levels experienced within the last several years.

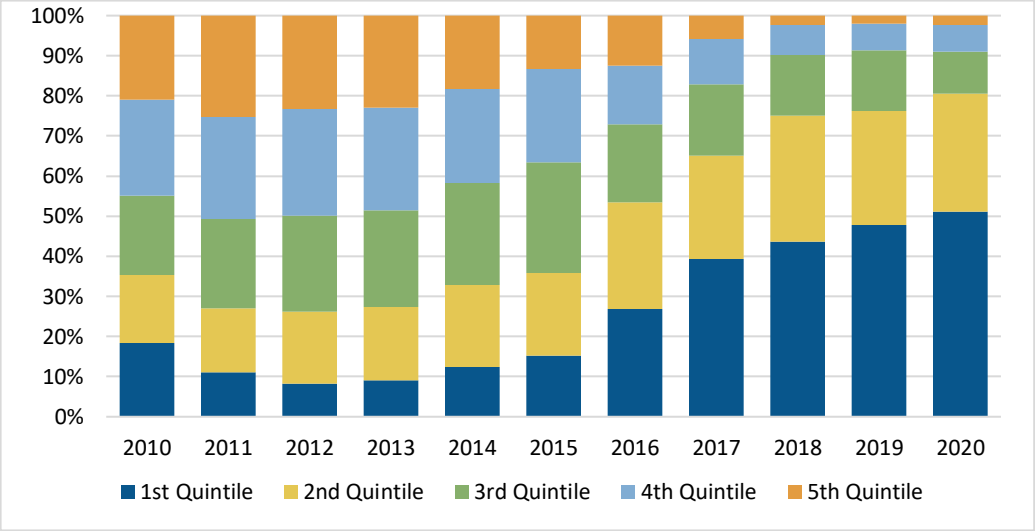
[16] North Dakota Pipeline Authority. NDPA Website Data. September 17, 2021. Also see: Washington Department of Ecology. Crude Oil Movement Quarterly Reports. September 17, 2021.
[17] University of Denver Water Law Review. Water, Oil, and Tribal Sovereignty: The Fight for the Dakota Access Pipeline. November 15, 2016.
[18] Grand Forks Herald. Judge dismisses tribe's case against DAPL, closing the books for now. June 22, 2021.
[19] IEEFA estimate, based on North Dakota Pipeline Authority. Oil Transportation Table. September 30, 2021.

The Bakken Is Running Short of High-Quality Drilling Sites

IEEFA used data from IHS Markit, one of the world's premiere oil and gas data services, to explore the productivity of wells already drilled in the Bakken, and the quality of the remaining acreage left to be drilled in the region. IEEFA supplemented IHS Markit data with information from other publicly available data sources, including the North Dakota Pipeline Authority and the U.S. Energy Information Administration.

IEEFA's analysis of historic Bakken drilling trends shows that drillers have steadily migrated into the region's most productive subregions—the so-called sweet spots—over the last decade. In both 2019 and 2020, almost 80 percent of all horizontal wells drilled were among the top two quintiles of wells drilled in the Bakken since 2001, as measured by the peak output per 1,000 horizontal feet drilled. (See Figure 4.) These high-quality wells were concentrated in specific subregions of the Bakken that have proven to have high levels of oil, gas and other hydrocarbons that can be extracted from underground shale formations.

Figure 4: Bakken Well Quality, by Year (1st quintile = most productive)



Source: IEEFA analysis of IHS Markit data.

The Bakken oil industry is quickly exhausting the region's sweet spots and depleting its remaining inventory of top-quality drilling sites. IEEFA's analysis of IHS data suggest that between 564 and 705 top-tier drilling sites remain in the Bakken. (See Table 1.) In comparison, Bakken oil drillers completed more than 600 top-quintile sites in 2019 alone. Similarly, at 2019's pace of drilling for second-tier wells, there is only a five- to six-year inventory of second-quintile drilling sites remaining in the Bakken.

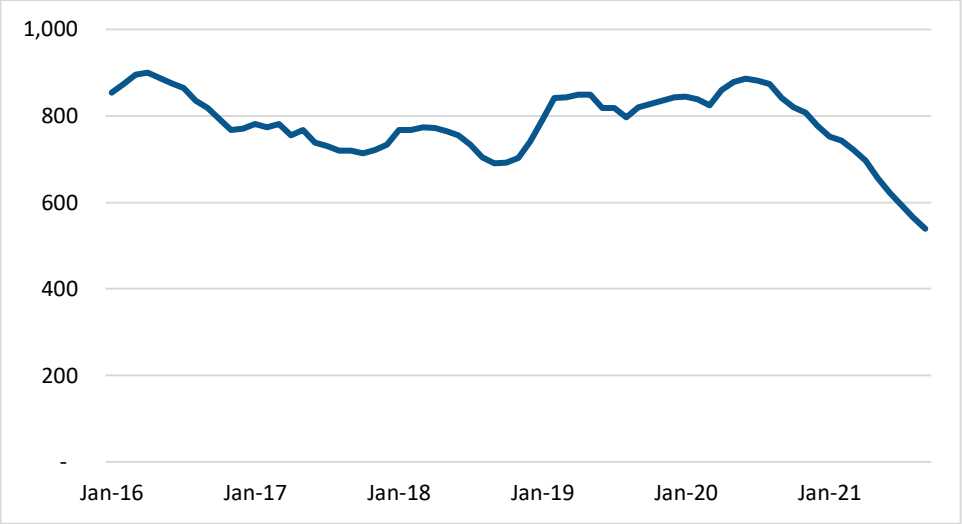
Table 1: Remaining Bakken Drilling Sites and Wells Drilled

	1st Quintile	2nd Quintile	3rd Quintile	4th Quintile	5th Quintile
Drilling sites remaining (low)	564	1,645	3,738	8,715	22,854
Drilling sites remaining (high)	705	2,057	4,673	10,893	28,567
Wells drilled in 2019	609	364	195	85	25
Total wells drilled, 2016-2021*	2,091	1,440	815	455	234

Source: IEEFA, estimated from IHS Markit data.
Note: Well quintiles are ranked by peak oil and gas production for horizontal wells brought into production in the Bakken from 2001 through 2021. Drilling sites are ranked based on how likely future oil and gas output compares with historic quintiles. Gas volumes are converted to oil at market equivalents (20:1) rather than energy equivalents (6:1).

In addition to new drilling sites, the industry also has a supply of drilled-but-uncompleted wells (DUCs). As with high-quality drilling sites, the supply of top-tier DUCs is also declining. Between June 2020 and September 2020, the Bakken oil industry drilled about 395 new horizontal oil wells but completed (fracked) 725 new wells. By completing more wells than it drilled, the industry has depleted its inventory of DUCs by about 40 percent since June 2020. (See Figure 5.) Based on data from the North Dakota Pipeline Authority and the U.S. Energy Information Administration, IEEFA estimates that as of October 2021, the Bakken has an inventory of roughly 350 higher-quality DUCs that could be brought into production over the coming two years.[20] The remaining DUCs represent lower-quality wells that may never be completed.

Figure 5: Bakken Drilled-but-Uncompleted (DUC) Wells



Source: Energy Information Administration, Drilling Productivity Report, October 2021.

[20] IEEFA analysis, based on: U.S. Energy Information Administration. Drilling Productivity Report. October 18, 2021.
North Dakota Pipeline Authority. North Dakota Oil & Gas Research Program. December 16, 2020.

In 2019, the Bakken oil industry brought roughly 1,250 new oil wells into production. If the Bakken oil industry were to resume that pace, it would quickly boost Bakken oil production—yet it could also potentially deplete its entire inventory of top-quintile drilling sites and high-quality DUCs within a single year.

Declining Well Quality Will Lead to Lower Production per Well and Worse Economics

As the Bakken oil industry exhausts its remaining inventory of top-tier drilling sites and DUCs, it will be forced to concentrate its efforts on lower-quality drilling sites. These wells will cost roughly the same to drill and complete as higher-caliber prospects, but will produce less oil and gas. As a result, the exhaustion of top-tier drilling sites will result in less oil and gas production per well, higher breakeven prices and lower profitability for the Bakken oil industry.

Historically, higher-tier Bakken wells tend to be far more profitable than lower-tier wells. IEEFA's analysis of IHS Markit data finds that the average top-quintile Bakken well drilled in 2019 and 2020 can break even financially when long-term oil prices reach or exceed about $41 per barrel. But lower-tier wells produce less oil and gas and have higher breakeven prices. Wells in the middle quintile, for example, break even when U.S. oil prices are at $53 per barrel, or roughly $12 more than a top-tier well.[21] Bottom-quintile wells break even at roughly $64 per barrel, or $23 more than a bottom-tier well. Looking more broadly at wells drilled from 2010 through 2021, bottom-quintile wells would break even only if long-term prices rose above $88 per barrel.

Based on data from IHS Markit and public data sources, including the Energy Information Administration and the North Dakota Pipeline Authority, IEEFA developed a Bakken oil production model that estimates the number of new wells that are needed to maintain production at a given production target. (For an explanation of this model, see *Appendix 1: Bakken Oil Production Model, Data and Methods*.) Initially, the model assumes that the quality of new wells will be similar to the quality of wells completed recently, with 50% of new wells in the first quintile measured by peak productivity, 30% in the second quintile, 11% in the third, 6% in the fourth, and 3% in the fifth. Over time, as the supply of higher-tier drilling sites is exhausted, the model shifts new drilling toward the remaining lower-tier sites. For

[21] Source: IEEFA analysis of IHS data. IHS calculates a breakeven price for each well, defined as the price that results in a $0 net present value, based on the estimated capital and operating costs of the well, historical and projected production of both oil and gas, and a 10 percent discount rate. Note that IHS estimates of breakeven prices exclude certain corporate costs, such as land purchase, mineral rights acquisition, and interest on loans. As a result, a company that drills only wells that "break even" at a given price may still be unprofitable at a corporate level, even if oil prices are at or above "breakeven" levels. Also note that companies that drill "breakeven" wells may produce negative long-term free cash flows for years, since it can take many years for revenues from oil and gas production to offset the capital costs of drilling. As a result, IEEFA does not endorse the use of an individual oil well's estimated breakeven pricing for assessing the financial quality of the well or the financial health of the well's operator.

each month, the model calculates the average breakeven price for the mix of wells drilled each year.[22]

Based on this model, IEEFA developed three potential scenarios for breakeven pricing for future Bakken oil production, using the following assumptions:

- **Low Case**: **Steady production, zero inflation:** The industry maintains total Bakken oil production at roughly 1 million barrels per day through 2031. Drilling costs do not rise from today's levels. Oil companies can consistently drill 10 wells per square mile section.
- **Medium Case**: **Rebounding production, 1% inflation:** The industry boosts total Bakken oil production to 1.5 million barrels per day through 2031—roughly matching the region's previous peak production. Drilling costs rise at 1% per year. Oil companies can consistently drill 9 wells per square mile section.
- **High Case: Surging production, 2% inflation**: The industry ramps up Bakken oil production to 2.0 million barrels per day—the 2030 production volume suggested by a North Dakota Pipeline Authority 2019 forecast.[23] Drilling costs rise at 2% per year. Oil companies can consistently drill 8 wells per square mile section.

In all three cases, as the Bakken oil industry depletes its remaining stock of high-quality DUCs and drilling sites, the breakeven price for new oil wells rises substantially. (See Figure 6.) This rise is due largely to lower productivity and higher breakeven prices for lower-quality wells.

IEEFA's model suggests that faster short-term production gains lead to faster depletion of the best drilling prospects, and an accelerated deterioration of average well quality. Yet even in the "low case" scenario, top-quintile Bakken drilling sites are largely gone by the end of 2024. The gradual decrease in the productivity of newer Bakken wells would also require oil producers to drill and complete more wells simply to keep production flat, boosting capital spending and crimping short-term cash flows for the industry.

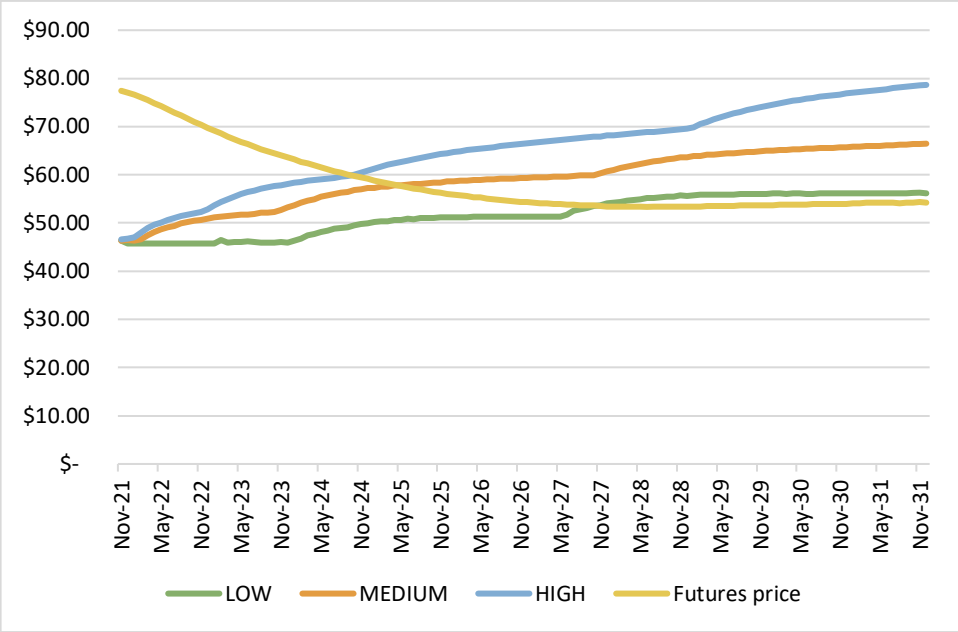
Even in the "low case" scenario, top-quintile Bakken drilling sites are largely gone by the end of 2024.

Drilling cost inflation, while historically volatile and unpredictable, could play a role in rising Bakken breakeven prices. After hitting the lowest level on record in 2020, producer prices for the oil and gas extraction industry have rebounded sharply this

[22] IHS calculations of breakeven prices take into account the price differential between Bakken crude and WTI crude.
[23] Dickinson Press. Bigger than some of OPEC: North Dakota on track to reach 2 million barrels of oil per day by 2030. May 4, 2019.

year, reaching their highest level since 2014 and potentially presaging rapid increases in drilling costs over the coming year.[24]

Figure 6: Breakeven Prices Under Three Different Bakken Production Scenarios



Source: IEEFA and CME Group.

Although today's oil prices are more than sufficient to incentivize today's level of drilling, the oil futures market projects that today's high prices will gradually ease.[25] Even in IEEFA's "low case" scenario, projected breakeven prices rise above today's futures prices by 2028. If this pricing scenario were to play out, then even Bakken production of 1 million barrels per day could be impossible to sustain economically for more than six years.

Conclusion

The Bakken oil industry faces profound uncertainty. Although today's oil prices are as high as they've been since 2014, the past 15 years have encompassed tremendous volatility, with oil prices reaching as high as $158 per barrel and as low as negative $40 per barrel during the worst months of the COVID crisis. Meanwhile, global oil demand has grown more uncertain, as electric car sales have surged in China and Europe and the global imperative to slash carbon emissions picks up steam.

Yet one thing is all but certain for the industry: Over the coming years, the Bakken will progressively exhaust its best remaining drilling sites. As that happens, the

[24] Federal Reserve Bank of St. Louis. Producer Price Index by Industry: Oil and Gas Extraction. October 19, 2021.
[25] CME Group. Crude oil futures - Settlements. October 10, 2021.

average quality and productivity of new wells will decline, and the economics of Bakken oil production will face new and growing challenges.

The inexorable decline in the quality of new Bakken oil wells and the potential decline in total oil production that could result carries significant fiscal, financial and policy implications. Investors may be forced to lower expectations for profits from oil companies operating in the region. State and local budget planners may need to reduce their expectations for oil and gas revenues. At the same time, as North Dakota enters a long-term transition away from the oil and gas sector, new questions will arise about the Bakken oil industry's ability to pay to plug old wells and decommission unneeded oil infrastructure. Investors and policymakers ignore these trends at their peril.

As the Bakken oil industry depletes its remaining inventory of top-tier wells, it will face a stark choice.

On one hand, it can shift to less-productive areas to maintain output. The newer wells will produce less oil and gas, so the industry will have to ramp up drilling steadily just to keep production flat. This path has the potential to keep the industry on the cash-draining treadmill that has already driven top Bakken drillers, including Whiting Petroleum and Oasis Petroleum, into insolvency.

On the other hand, oil companies can choose to curtail drilling, allowing production to gradually fall as a result. That would render much of the industry's investments in pipeline capacity as stranded assets. And as oil production falls, state and federal regulators may need to reconsider the economic rationale for existing pipelines, particularly the controversial Dakota Access Pipeline (DAPL). Even modest declines in production from today's levels could render DAPL's capacity superfluous.

While future oil prices, demand, and oil industry production strategies remain uncertain, there is no turning back from geological reality. According to North Dakota Mineral Resources Director Lynn Helms, "the end of (core area-drilling) is on the horizon."[26] Or, as an analyst for IHS Markit stated: "We're starting the long, long goodbye" for Bakken oil production.[27]

[26] OK Energy Today. Bakken production to peak in 5 years? February 12, 2020.
[27] Wall Street Journal. Behind the Energy Crisis: Fossil Fuel Investment Drops, and Renewables Aren't Ready. October 17, 2021.

Appendix 1: Bakken Oil Production Model, Data and Methods

Number of wells drilled, by quintile. Within each oil and gas play, the IHS Markit Dynamic North America (IHS-DNA) data system categorizes each horizontal well drilled since 2001 into one of five quintiles, based on how the well's peak production of oil and gas per 1,000 lateral feet compares with all other horizontal wells drilled over the period. IHS-DNA classifies all Bakken Shale wells as part of a single play. To better capture the economics of gas production, IEEFA converted gas production into oil equivalents based on estimated market price equivalency (20 MMBtu per barrel of oil) rather than energy equivalency.

Quality of undrilled acreage in the Bakken, by well quality. IHS-DNA estimates the quality of undrilled acreage in each oil and gas play, based on forecasted peak-month production of oil and gas from a well that might be drilled on that acreage. For all undrilled acreage, IHS-DNA estimates future peak production of a potential well based on the production history of nearby wells, weighting closer wells more heavily than wells that are farther away, and more recent wells more heavily than older wells. IHS-DNA's methods assign potential drilling sites into one of five quality categories. Top-tier wells are expected to produce volumes of oil and gas that would fall within the top quintile of wells drilled from 2001 to the present, as ranked by peak-month production of oil equivalents, with gas converted to oil at market price equivalency. Similarly, wells drilled in bottom-tier acreage would have peak oil and gas production that would fall within the bottom quintile of wells drilled over the period.

Number of potential future wells in the Bakken. For the future drilling scenarios presented in this report, IEEFA assumed that oil companies would elect to drill between 8 and 10 new wells per square-mile section, numbers that are consistent with drilling spacing in the Bakken Shale since 2011.

Estimated future breakeven prices. IEEFA developed a model of Bakken oil production that estimated future breakeven prices for all new wells drilled in the play, assuming that the Bakken oil industry targeted oil production at a specified level. Key elements of this model include:

- **Historic Bakken Shale oil production,** taken from the U.S. Energy Information Administration, the North Dakota Department of Natural Resources, and IHS-DNA.
- **Oil production from existing, already-drilled wells,** taken from IHS-DNA forecasts.
- **Future oil production from the inventory of Bakken Shale drilled-but-uncompleted (DUC) wells,** based on data from the North Dakota Pipeline Authority and IHS-DNA, and IEEFA estimates.
- **Production from future wells, by well quintile,** based on IEEFA estimates derived from IHS-DNA data.

- **Number of drilling sites, by well quintile,** based on IEEFA estimates derived from IHS-DNA data.

- **Breakeven prices for futures wells, by well quintile,** based on IEEFA's analysis of IHS-DNA data for wells drilled in 2019 and 2020.

- **Target share of wells drilled, by well quintile,** based on recent percentages of wells drilled, by quintile, as estimated by IEEFA from IHS data.

IEEFA's model assumes that the Bakken oil industry targets sustained oil production at a particular level. If oil production in any month falls below that level, IEEFA's model increases the number of wells drilled in the subsequent month, with assumed limits on the pace of increase corresponding to the historic month-to-month increases in drilling activity. Similarly, if oil production in a given month lands above the target, then the model decreases drilling rates in the following month. IEEFA's model initially targets the quality of future wells to approximate the number of wells drilled in each quintile in 2019. As high-quality drilling sites grow scarce, the model progressively shifts drilling activity to lower-quality acreage. For each month in the future, IEEFA estimates breakeven prices for all new Bakken Shale wells based on a quintile-weighted average of breakeven prices, based on quintile-specific breakeven prices from 2019 and 2020.

As a more detailed explanation of this model:

- IEEFA initially assumes that the Bakken Shale contains a fixed number of remaining drilling sites in each of five quintiles, based on IEEFA's interpretation of IHS-DNA estimates of remaining undrilled acreage and its likely productivity, and a specified number of wells per section.

- The model also assumes a fixed number of remaining DUCs that can be completed, along with future production from those DUCs, based on IEEFA's interpretation of data from the North Dakota Pipeline Authority and IHS-DNA data.

- The model initially assumes that oil production volumes from existing wells will decline according to IHS-DNA forecasts.

- If production in any month falls below the assumed target level, IEEFA's model assumes that more DUCs and new wells will be completed in the following month. Conversely, if production exceeds the target, fewer wells will be completed in the following month; however, monthly drilling activity never drops below a specified level. In this way, the model assumes oil production volumes that move steadily towards target levels of production, and then maintains production at that roughly that level over time.

- The model assumes that the Bakken oil industry will continue to target higher-quality drilling sites first, in proportion with recent observed trends.

- Over time, as the inventory of higher-tier drilling sites is depleted, the model assumes that the Bakken oil industry progressively shifts towards lower-tier drilling sites.

- For each month, the model estimates the average breakeven price across all wells, based on a quality-weighted average of all new wells drilled during that month and recent breakeven prices, inflated at a specified producer price inflation rate.

As oil production from existing wells declines, the model assumes that the oil industry will drill new wells, targeting higher-caliber DUCs and drilling sites first. As the industry depletes its inventory of high-quality wells, it shifts new drilling activity towards lower-quality drilling sites with higher breakeven prices. As this process advances, the quality and productivity of new wells decreases and breakeven prices rise.

Appendix 2. Citations and Estimates for Major Bakken Oil Producer Capital Expenditures

Continental Resources: 2019 10-K, $2,661.8M in non-acquisition capex. 2020 10-K, $1,159M in non-acquisition capex. Press Release, Feb. 16, 2021, $1.4 B in 2021 capex excluding mineral acquisition. Press Release, Aug. 2, 2021, reconfirms $1.4 B in 2021 capex.

Hess Corporation: 2020 10-K, $2,743M in E&P Capital and Exploratory Expenditures in 2019, $1,786M in 2020, $1.9B guidance for 2021.

Oasis Petroleum: 2020 10-K. $225M in predecessor 2020 capex, $18 in successor 2020 capex, $843M in 2019 capex. August 3, 2021 8-K, $96M in 1H2021 capex, $115-135 guidance for 2H2021 capex.

Whiting Petroleum Corporation: 2020 10-K. Exploration and development expenditures of $778M in 2019 and $209 in 2020. Press Release, August 4, 2021, $240-$252 updated guidance for 2021 capex.

Table: Cap Expenditures for Top 4 Bakken Drillers

	2019	2020	2021
Continental Resources	2,662	1,159	1,400
Hess Corporation	2,743	1,786	1,900
Oasis Petroleum Inc.	822	243	221
Whiting Petroleum Corporation	778	209	246

About IEEFA

The Institute for Energy Economics and Financial Analysis (IEEFA) examines issues related to energy markets, trends and policies. The Institute's mission is to accelerate the transition to a diverse, sustainable and profitable energy economy. www.ieefa.org

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