Stayin' Alive:

The Last Days of Stripper Wells in the Ohio River Valley

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Abbreviations

Bbls or Bbls/day: barrels of oil

Bcf: one billion cubic feet of natural gas

BOE: barrel of oil equivalent (one barrel of oil = 6,000 Mcf)

BOED or BOE/day: barrel of oil equivalent per day

Btu: British thermal unit (a heat unit). The heat required to raise the temperature of a one-pound mass of water by one degree Fahrenheit.

CO2e: Carbon dioxide equivalents.

Mbbls: one thousand barrels of oil (1,000 barrels)

MMbbl: one million barrels of oil (1,000,000 barrels)

Mcf: one million cubic feet of natural gas

MCFD or Mcf/day: one million cubic feet of natural gas per day

MCFE or Mcfe: one million cubic feet of natural gas equivalent (one barrel of oil = 6,000 Mcf)

Tcf: one trillion cubic feet of natural gas

Definitions

Marginal well: A well near the end of its economically useful life. Often used interchangeably with the term "stripper well."

Stripper well: An oil or gas well with a maximum daily production is below 15 BOED (15 barrels of oil or 90,000 cubic feet of gas per day) over any consecutive 12-month period. Used interchangeably with the term "marginal well."

Decommissioning: When a well reaches its end of producing life, operators are legally obligated to plug the well, remove surface equipment, and restore the wellsite to its original state. This is commonly referred to as plugging and abandoning a well, or "P&A".

Orphaned Well: An unplugged well where the owner is insolvent or there is no owner of record. Orphaned wells, if they are plugged, are usually plugged by federal and state regulatory agencies.

Overview

In recent years, there has been growing concern over the millions of oil and gas wells that are no longer producing but are threatening the environment and public health and will cost tens of billions of dollars to clean-up. For the first time, Congress has recently taken steps to address some of these non-producing wells: the 2021 Infrastructure Jobs and Investment Act included $4.7 billion to plug more than 81,000 orphaned wells. But a potentially larger crisis is brewing.

While there are already millions of non-producing wells that need to be plugged, this report shows that there could soon be a large wave of even more non-producing wells. There are over 177,000 wells in the Ohio River Valley states of Kentucky, Ohio, Pennsylvania, and West Virginia that are technically producing oil or gas – but only in small amounts. Most of these "stripper wells" are producing less than one barrel of oil or 6,000 cubic feet of gas per day. Many are near the end of their economic life but have been kept alive, sometimes for many years, at very low production levels to avoid clean-up costs. Since 2000, the number of stripper wells – or wells producing less than 15 barrels of oil or 90,000 cubic feet of gas per day – in the region has ballooned by over 40 percent while average stripper well production has declined by nearly one-third.

The growth in stripper wells or “marginal wells”, didn’t happen by accident. It was driven by a combination of policies, including tax subsidies and lax regulation to keep wells unplugged for as long as possible. The Interstate Oil and Gas Compact Commission (IOGCC), which is a quasi-government agency comprised of state governors, industry officials, and other stakeholders – has long championed the preservation of marginal wells, finding that it’s better to leave marginal wells unplugged since all of them could potentially produce oil or gas despite evidence to the contrary.

In October of 2021, *Bloomberg News* published a blockbuster investigative story about Diversified Energy’s “Empire of Dying Wells” in Appalachia, some of which are leaking methane, a powerful greenhouse gas.[1] Diversified Energy is the largest well owner in the United States and Appalachia, with nearly 63,000 low producing wells in the four-state region of the Ohio River Valley alone. As the Bloomberg story highlighted:

> *Diversified hasn’t broken any rules by building an empire of dying wells. Nor has it violated any restrictions on methane emissions, because none apply. Indeed, state and federal policies—from plugging regulations to tax subsidies—encourage companies to do exactly what Diversified is doing: Keep almost dead assets on life support as long as possible, no matter how much they may damage the planet.*

This high concentration of low-producing wells in one company’s portfolio – along with more than 100,000 additional stripper wells in the region - presents a risk that even more wells could become orphaned or wards of the state. If Diversified Energy, or other companies that own stripper wells in the region, were to go out of business, states could be on the hook for billions in clean-up costs since the operators are not required to set aside sufficient clean-up costs upfront.

Compounding these problems are two facts. The first is that the U.S. energy system in the long run is moving away from fossil fuels to cut greenhouse gases that are fueling climate change and because renewable energy sources are often cheaper than fossil fuels in the electricity sector. If the United States moves quickly to lower carbon emissions over the next few decades, gas production will likely decline rapidly along with the solvency of oil and gas operators in Appalachian and throughout the country. This could leave states – especially those in Appalachia – with thousands of additional orphan wells. The second fact is the current, short-term spike in the price of both oil and gas. This increase is an incentive to drill even more wells as soon as possible, diverting capital investment in exactly the wrong direction.

To remedy these problems, states need to act swiftly to require the oil and gas industry to set aside enough money to plug their wells and restore well sites even if their owners are no longer in business. This could be accomplished by placing a small fee on production or with other funding mechanisms. But if states continue with business as usual, it's likely many of these wells will become orphaned, will continue to cause environmental harm, and will be costly wards of the state.

This report unfolds in five parts. First, it looks at the number of stripper wells in the four-state region of Kentucky, Ohio, Pennsylvania, and West Virginia, along with trends in production, productivity, and ownership. Section Two looks at bonding coverage and financial assurance requirements and their relationship to decommissioning costs. The third section explores the various tax preferences for stripper wells in the four states, including the federal marginal well tax credit, while Section Four our examines methane emissions from stripper wells. Section Five explores the number of "uneconomical" stripper wells in the region and in Diversified Energy's portfolio of wells that arguably need to be decommissioned. The report concludes with recommendations to policymakers to ensure companies, not the public, pay for their asset retirement obligations.

Key Findings

- **1 in 5 stripper wells in the United States is found in the Ohio River Valley states.** Approximately 10 out of every 11 producing oil and gas well in the region are low-producing stripper wells at risk of becoming wards of the states. Since 2000, the number of stripper wells in the region has grown by 43 percent and stripper well gas production has declined by nearly one-third. Approximately 72 percent of stripper wells produce less than one barrel of oil equivalent per day (BOED).

- **Most stripper wells are owned by large companies in the Ohio River Valley region**, with 17 companies owning nearly half of all stripper wells. Diversified Energy with over 50,000 stripper wells is the largest owner in the region and is responsible for nearly 43 percent of all stripper well production.

- **Each stripper well represents a substantial liability to the public**: the average stripper well has $214 of bonding coverage while a low-end estimated to plug a well is $30,000, on average. If stripper wells were bonded at full cost ($30,000), stripper well operators would pay an estimated $134 million annually in premiums for this coverage.

- **Decommissioning the estimated 177,000 stripper wells in the region would cost between $5 billion and $16 billion, yet total bonding coverage is less than $40 million.**

- **Stripper wells are largely exempt from state production (severance) taxes**, and the federal government provides hundreds of millions in tax subsidies to stripper well operators. In 2022, the Marginal Well Tax Credit alone is expected to reduce taxes by $320 million for stripper well operators.

- **The 177,000 stripper wells in the four-state region emit at least 199,000 tons of methane annually**, based on regional studies. This is equivalent to the greenhouse gas emissions of 553 million gallons of gasoline.

- **More than 1 in 7 – 31,000 – of the active wells in the four-state region are "uneconomical" and arguably need to be decommission (plugged and abandoned)** . On top of these uneconomical wells, there are additional 192,000 inactive wells that likely need to be decommissioned.

- **A small fee – between 3 to 7 cents per Mcf (thousand cubic feet) of gas produced –deposited into an escrow account over the next 25 years could provide a substantial portion of the funds needed to decommission the 405,000 unplugged active and inactive wells in the four states**, even if the current operators were to walk away and leave their wells orphaned.

Section One:
Stripper Wells in Ohio River Valley States of Appalachia

What are Stripper Wells?

Stripper wells are low-volume producing wells that usually operate on the edge of profitability. There are two commonly used definitions of stripper wells. The Interstate Oil and Gas Compact Commission (IOGCC) defines a stripper well as any well producing less than 10 barrels of oil per day (10 bbl/d) or 60,000 cubic feet (60 Mcf/d) of natural gas during a consecutive 12-month period.[2] The U.S. Energy Information Administration (EIA) and Internal Revenue Service (IRS) define stripper wells as wells with average daily production of less than 15 bbl/d or 90 Mcf/d of natural gas. These wells are called "strippers" because operators theoretically "strip" the last remaining value out of the ground before they are closed down. Some stripper wells are "domestic wells", which are non-commercial wells that produce gas for a property owner and don't feed into the commercial supply system.[3]

Although used interchangeably with stripper wells, "marginal wells" are sometimes defined as a subset of stripper wells that have production costs that exceed what an operator earns from selling the gas or oil from the well. In other words, a 'marginal well' is one that can only turn a profit when the price of oil or gas rises above a critical break-even point. Oil, natural gas, and natural gas liquid production is sometimes aggregated and converted to BOE, or barrels of oil equivalent. One barrel of oil is 42 gallons of oil, which is equivalent to 6 Mcf of natural gas based on heat content (British Thermal Units or BTUs). Gas and oil production is often measured in barrels of oil equivalent per day or BOED. On the flip side, oil and natural gas liquid production, along with dry gas production, is often converted to Mcfe or thousand cubic feet equivalent.

Marginal and Stripper Wells in Ohio River Valley States

There are two publicly available sources for stripper and marginal well counts by state. The IOGCC has published a survey of marginal well counts and production for decades, but its latest report is from 2016. Meanwhile, the US Energy Information Administration (EIA) publishes an annual report on the distribution of U.S. oil and natural gas wells by production rate that can be used to tally the number of stripper wells in each state.[4] The EIA annual reports contain data for active wells in each state, the latest year being 2019. The analysis in this section primarily uses EIA data.

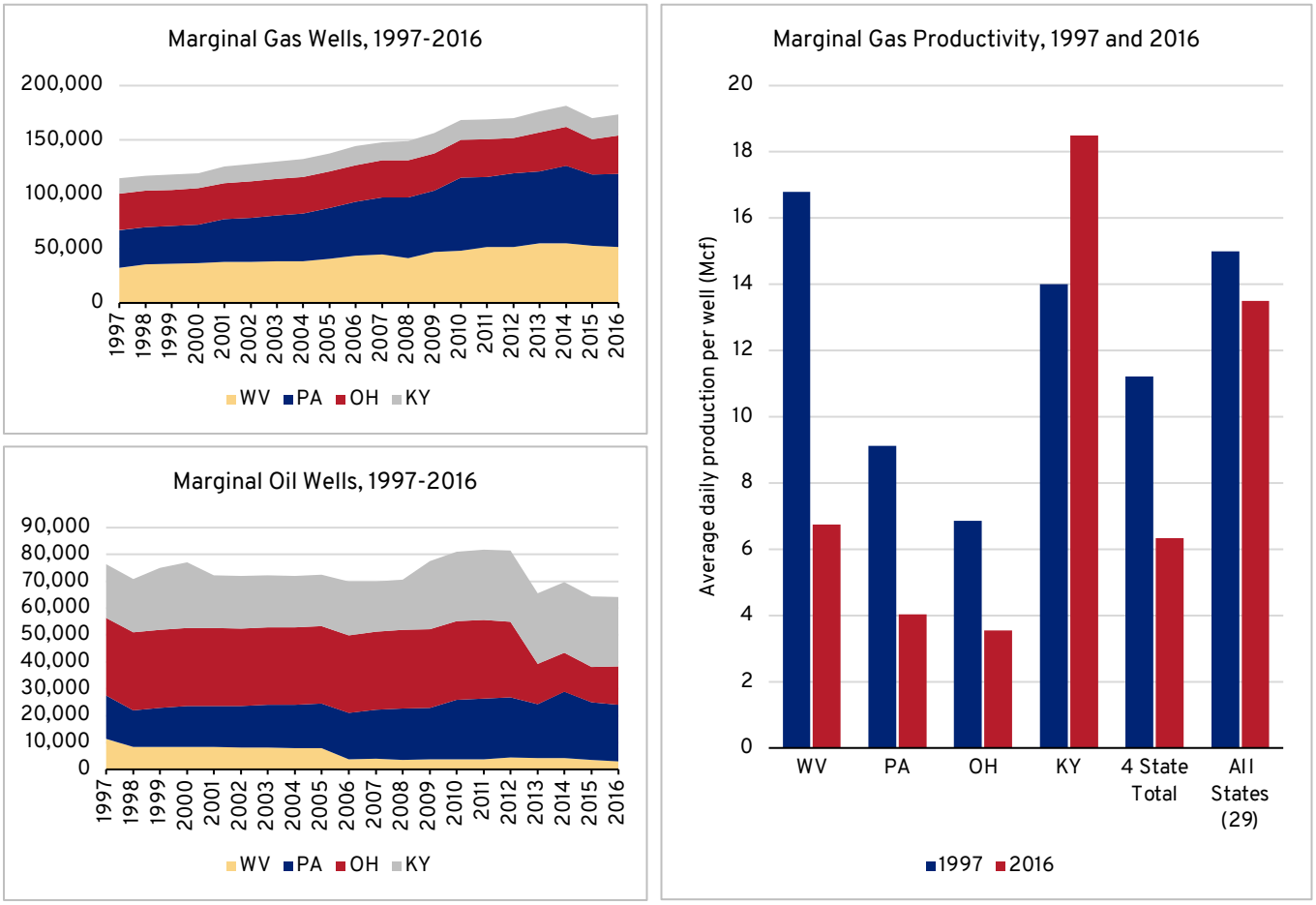
IOGCC Survey of Marginal Wells

In 2016, there were approximately 396,000 marginal oil wells and 381,000 marginal gas wells that produced less than 10 BOED in the 29 states surveyed by the IOGCC. Of that total, the four-states of the Ohio River accounted for 16 percent of marginal oil wells (64,165) and 45.5 percent of marginal gas wells (173,651). In terms of marginal well production, the four-states accounted for just 2.6 percent of oil production and 21.4 percent of gas production in 2016. Pennsylvania had the most marginal gas wells (67,371) in the nation in 2016, while West Virginia ranked third highest (56,412), Ohio fifth (35,377), and Kentucky sixth highest.

The number of marginal wells – including gas and oil marginal wells - has grown by 46,800 over the last 20 years in the four states, according to the IOGCC. This growth is driven entirely by the growth in marginal gas wells. The number of marginal gas wells in the four-states grew from 114,500 to 174,000 from 1997 to 2016, while the number of marginal oil wells declined by about 12,000 or 16 percent.

Marginal oil and gas wells in the four-state region compared to the US are not as productive, and productivity has declined sharply over the last two decades. In 1997, marginal gas wells in the region produced about 11.2 Mcf/d compared to the US average of 15 Mcf/d. Fast forward to 2016, and those numbers had dropped to 6.3 Mcf/d and 13.5 Mcf/d, respectively. While marginal well productivity declined by 10 percent nationally, it declined by 43 percent in the region. However, Kentucky's marginal gas wells did see an increase in productivity over this period. This decline in productivity and growth in marginal wells means that the wells are getting older and declining in production over time. As they continue to age, this means more of these wells will be placed in abandoned or inactive status by states, and eventually will need to be decommissioned.

Figure 1: Marginal Gas Wells Getting Older, Declining in Production in Ohio River Valley States



Source: Interstate Oil and Gas Compact Commission (IOGCC), Marginal Wells: Fuel for Economic Growth, 2000-2016

EIA Estimates of Stripper Wells

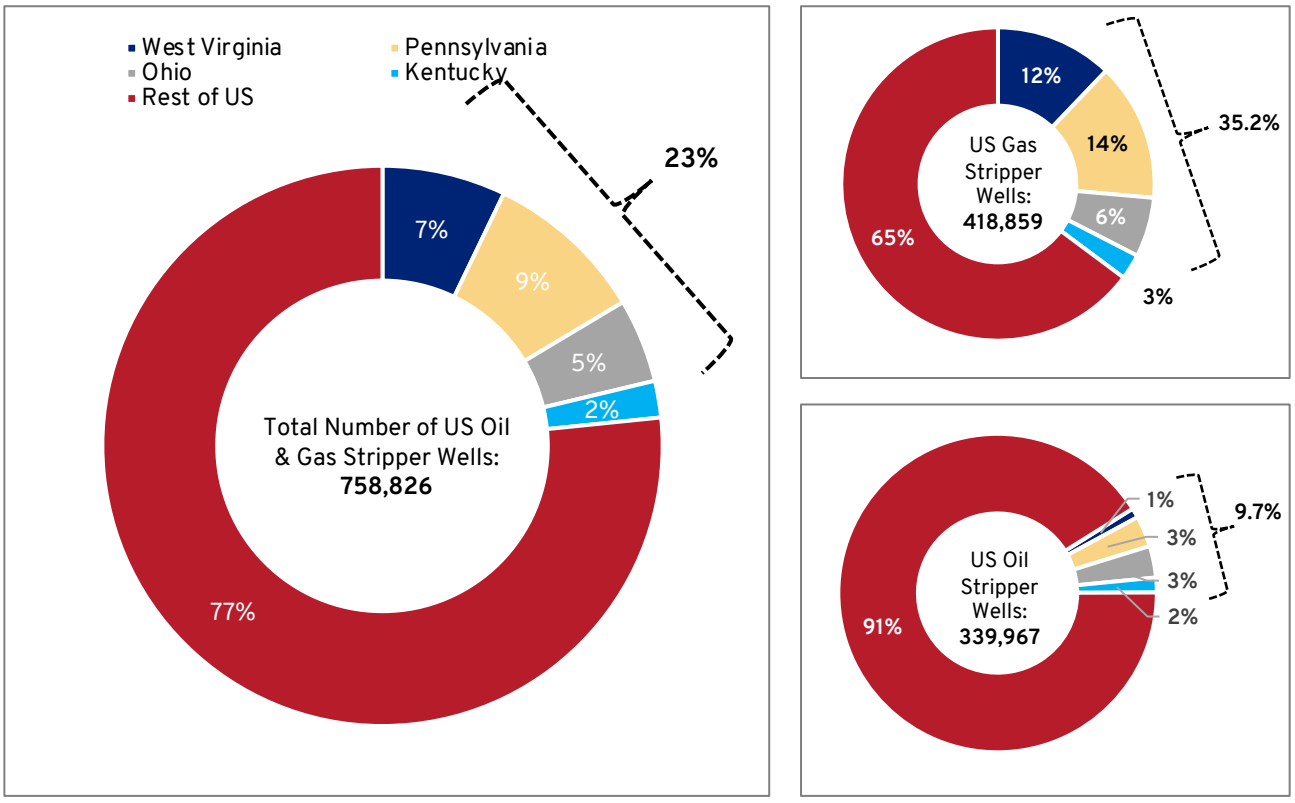
The US Energy Information Administration's annual report, "The Distribution of U.S Oil and Natural Gas Wells by Production Rate," provides data on the number of active oil and gas wells by production rate by state.[5] The report classifies each well as either an oil or gas well by how much oil or gas it produces. If a well produces mostly oil but some gas, it is classified as an oil well and vice-versa.

Stripper Wells in the US and Ohio River Valley Region

Data from the 2019 report shows that most of the active oil and gas wells in the United States are stripper wells or wells that produce less than 15 BOED (15 barrels of oil or 90,000 cubic feet of natural gas per day) According to EIA, 758,826 of the 969,136 active oil and gas wells in the US were stripper wells in 2019 or 78.3 percent. Despite making up more than three-quarters of the nation's wells, stripper wells provided just 6.8 percent of total US oil and gas production in 2019.

The four-states in the Ohio Valley region – Pennsylvania, Ohio, West Virginia, and Kentucky – are host to 177,424 or 23.4 percent of the nation's total stripper wells. While these four states host 35.2 percent of the nation's stripper gas wells, they host just 9.7 percent of US stripper oil wells. This is because most oil is produced in western states, such as Texas and North Dakota.

Figure 2: Nearly 1 in 5 Stripper Wells in the United States Is Found in Ohio River Valley States in 2019



Source: U.S. Energy Information Administration, The Distribution of U.S. Oil and Natural Gas Wells by Production Rate, December 2020.
Note: *Stripper wells produce less than 15 barrels of oil or 90,000 cubic feet of natural gas per day over a 12-month period (BOED)*

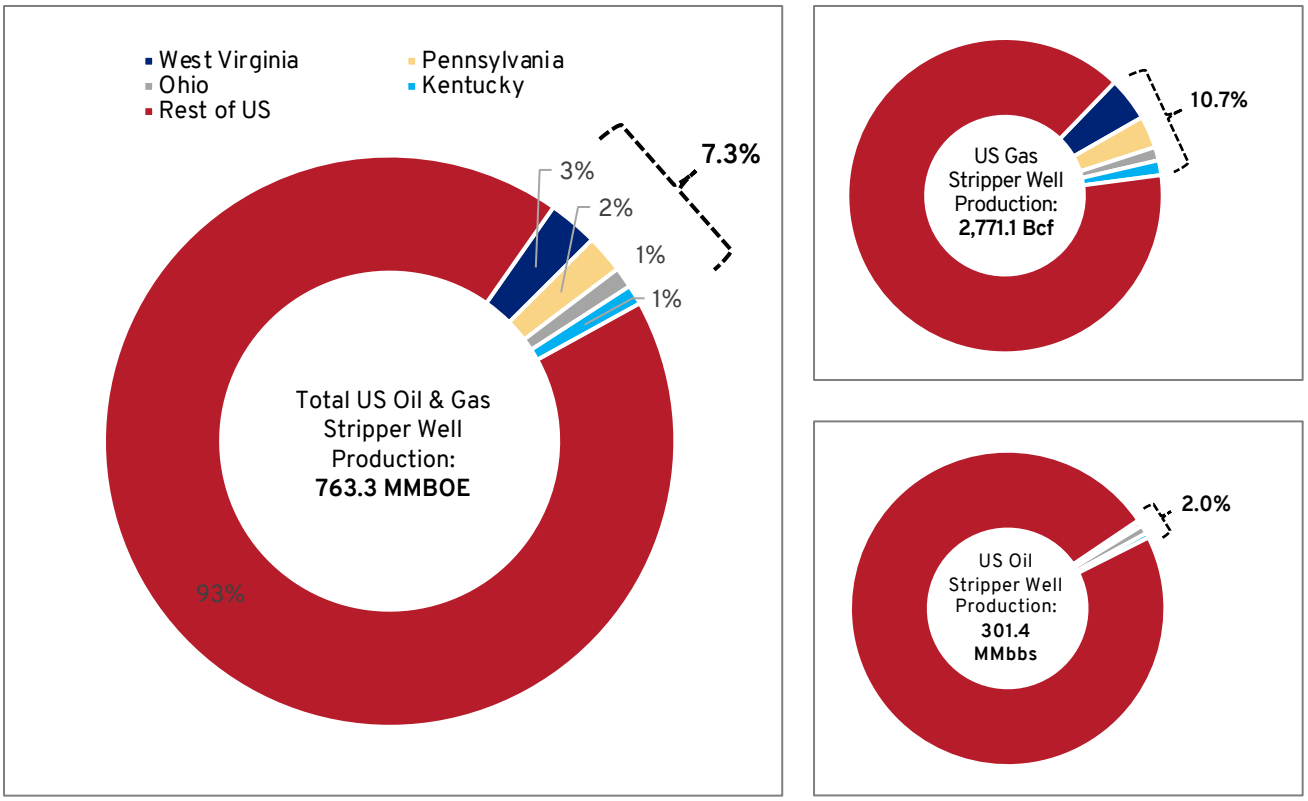
The Ohio River Valley states have a higher concentration of stripper wells than the national average. In 2019, over 92 percent of all active oil and gas wells in the region were stripper wells compared to about 78 percent nationally. This is especially true of oil stripper wells in the region. Almost all (99.4%) oil wells in the four-state region are stripper wells, compared to 79 percent for all states. About 91 percent of all active natural gas wells in the region are stripper wells compared to about 78 percent nationally. In Kentucky, 99.6 percent of active gas wells were stripper wells while 86 percent of Pennsylvania's gas wells were stripper wells.

Stripper Well Production in the US and Ohio River Valley Region

Stripper wells make up a smaller share of oil and gas production compared to their share of wells. While stripper wells account for roughly 78 percent of active oil and gas wells, they make up just 6.8 percent of total oil and gas production in the United States. This includes gas production from both oil and gas wells, and oil production from both oil and gas wells. In 2019, a total of 11,218 MMBOE (million barrels of oil equivalent) was produced, of which, 763 million MMBOEs were from stripper wells and 10,519 MMBOEs from nonstripper wells. In 2019, 6.8 percent of total gas production (38 trillion cubic feet) was from stripper wells while 6.7 percent of total oil production was from stripper wells.

While the four-state Ohio River Valley region hosts a disproportionate share (23%) of stripper wells, production from oil and gas stripper wells in the region only makes up 7 percent of total US stripper well production. This is mostly because the region accounts for just 2 percent of US stripper oil production, while stripper well gas production in the region comprises about 11 percent of total US gas production.

Figure 3: Ohio River Valley States Comprise 7 Percent of US Oil and Gas Stripper Well Production in 2019

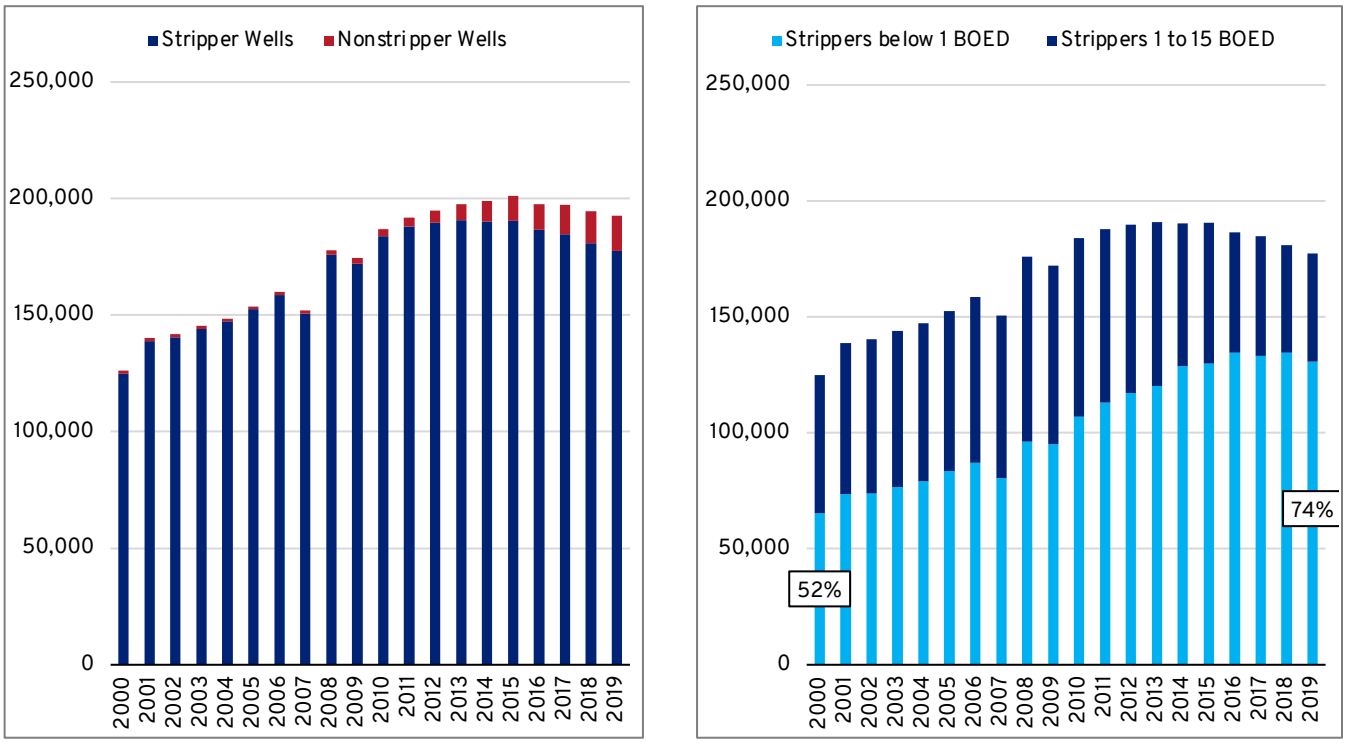


Source: U.S. Energy Information Administration, The Distribution of U.S. Oil and Natural Gas Wells by Production Rate, December 2020.
Note: *Stripper wells produce less than 15 barrels of oil or 90,000 cubic feet of natural gas per day over a 12-month period (BOED)*

Most of the oil production in the four-state region comes from nonstripper gas wells, presumably from unconventional or high-volume shale "fracking" wells. Of the 53 million barrels of oil produced in the four states in 2019, about 89 percent was from nonstripper wells and just 11.4 percent from stripper wells. Approximately 99.5 percent of all gas production came from gas wells in the region. Stripper wells made up just 2.5 percent of all gas production in 2019 in the four states.

Between 2000 and 2019, the number of stripper wells in the region grew from 124,884 to 177,424 or by 42 percent. Most of the growth in stripper wells in the region was from oil and gas wells that produce less than one BOE per day (<6Mcfe). In 2000, there were 65,447 wells producing less than one BOE per day compared to 130,798 in 2019. These ultra-low producing stripper wells made up 52 percent of all stripper wells in 2000 compared to 74 percent in 2019. Comparatively, stripper wells that produce between one and 15 BOE per day have declined from 59,437 to 46,626 wells from 2000 to 2019. The four-state region has seen its share of ultra-low producing stripper wells (less than one BOE per day) in the US grow from 14.3 percent in 2000 to 19.6 percent in 2019.

Figure 3: Number of Ultra-low Producing Stripper Wells Growing in Ohio River Valley States

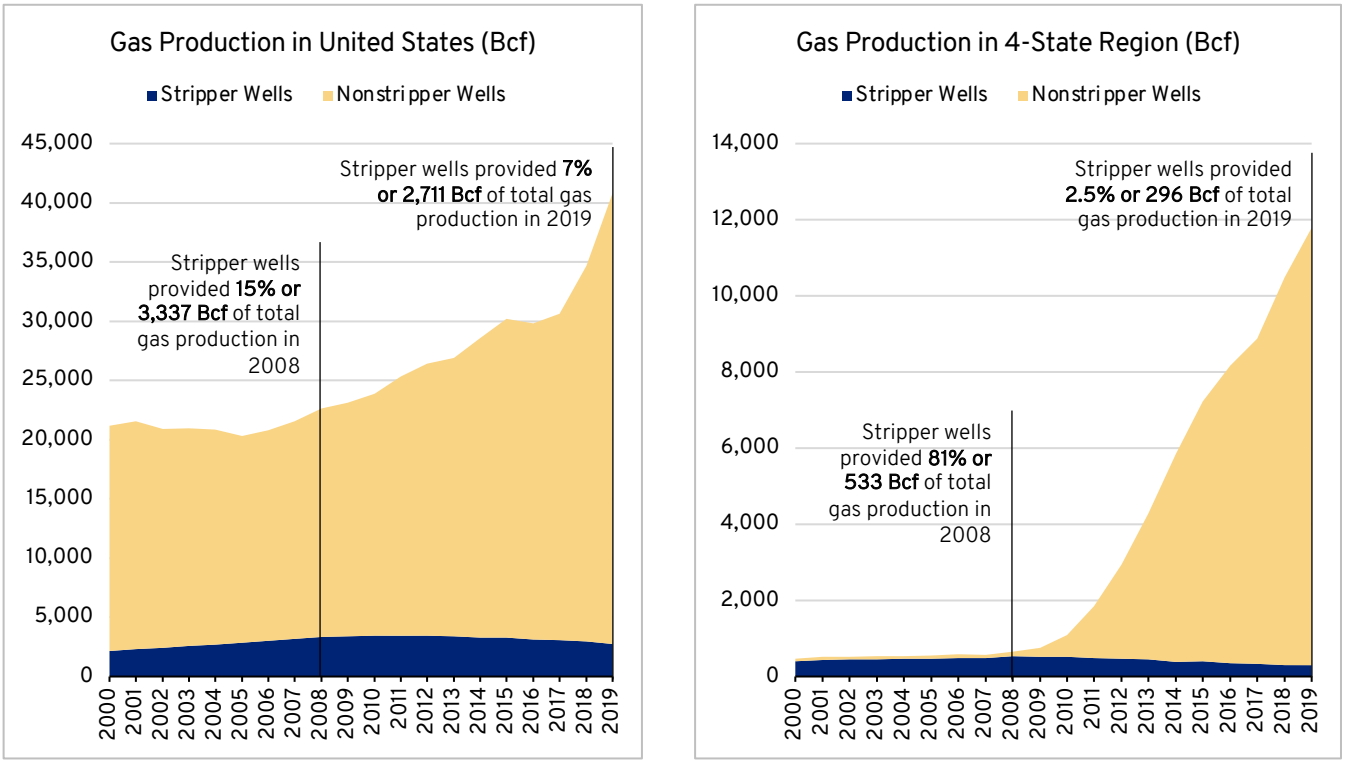


Source: U.S. Energy Information Administration, The Distribution of U.S. Oil and Natural Gas Wells by Production Rate, December 2020.
Note: *Stripper wells produce less than 15 barrels of oil or 90,000 cubic feet of natural gas per day over a 12-month period (BOED)*

While the number of stripper wells, especially ultra-low producing stripper wells, make up a larger share of total oil and gas wells in the region, they are providing a much smaller share of oil and gas production. In 2008, before the shale boom in drilling, stripper wells made up 81 percent of total gas production and 84 percent of total oil production in the region. In 2019, stripper wells made up just 2.5 percent of total regional gas production and just 11 percent of oil production.

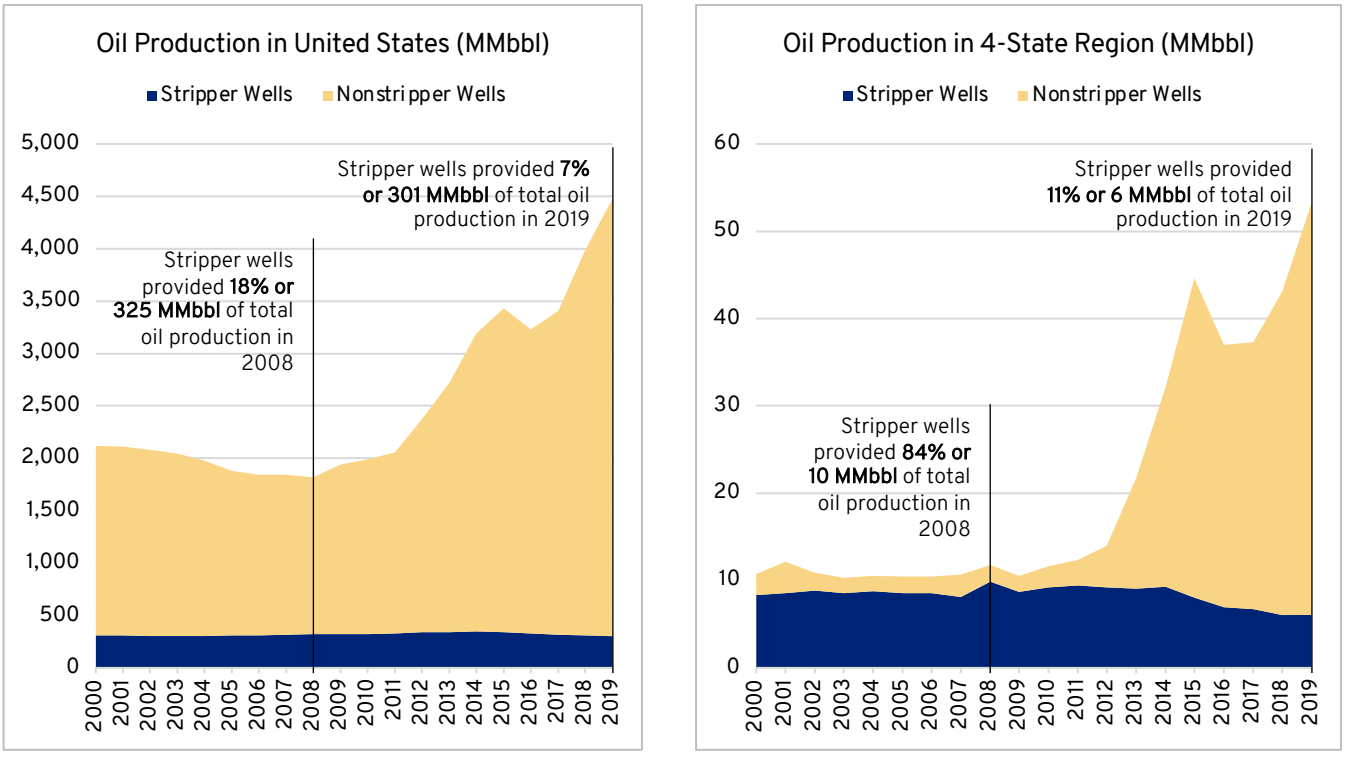
Total stripper well gas production in the region has declined, as well. After peaking in 2008 at 533 billion cubic feet (Bcf), total stripper well gas production in the region was just 296 Bcf in 2019 - the lowest level since at least 2000. Stripper well oil production also declined over this 20-year period. Like stripper well gas production, stripper well oil production peaked in 2008 at 10 million barrels of oil (MMbbl) and declined to just 6 MMbbl of oil in 2019.

Figure 5: The Share of Stripper Well Gas Production is Declining in Ohio River Valley States



Source: U.S. Energy Information Administration, The Distribution of U.S. Oil and Natural Gas Wells by Production Rate, December 2020.
Note: *Stripper wells produce less than 15 barrels of oil or 90,000 cubic feet of natural gas per day over a 12-month period (BOED)*

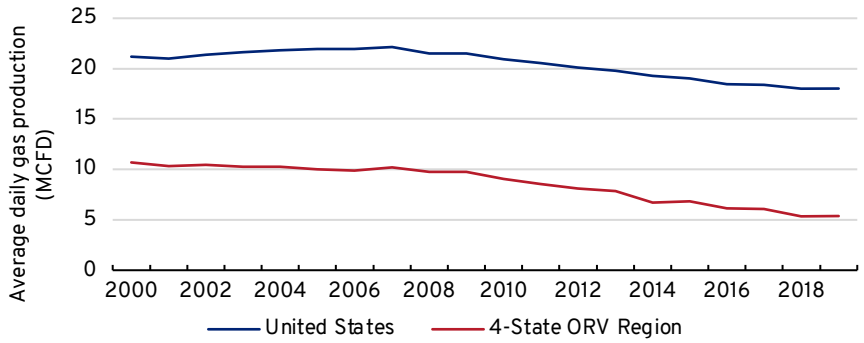
Figure 6: Stripper Well Oil Production and Stripper Well Share of Oil Production is Declining in Ohio River Valley States



Source: U.S. Energy Information Administration, The Distribution of U.S. Oil and Natural Gas Wells by Production Rate, December 2020.
Note: *Stripper wells produce less than 15 barrels of oil or 90,000 cubic feet of natural gas per day over a 12-month period (BOED)*

It is clear most stripper wells in the region are producing less oil and gas and that the number of stripper wells is growing. This is especially true of gas production from stripper gas wells. In 2000, 46 percent of stripper gas wells in the four-state region produced below 6 Mcf per day (1 BOE/day) compared to 71 percent in 2019. The growth in ultra-low stripper wells (those producing less than 6 Mcf/day) has driven down the average daily gas production rate per well.

Figure 7: Stripper Well Gas Productivity is Declining Rapidly in Ohio River Valley States



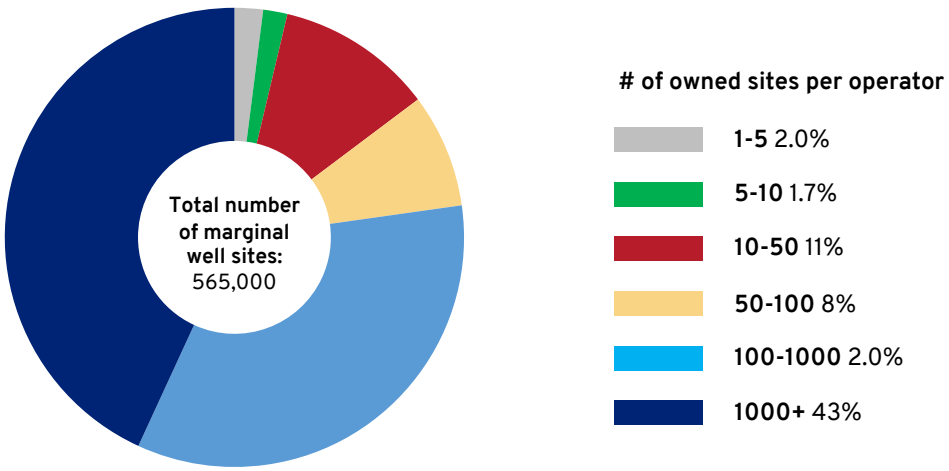
Source: U.S. Energy Information Administration, The Distribution of U.S. Oil and Natural Gas Wells by Production Rate, December 2020.
Note: *Stripper wells produce less than 15 barrels of oil or 90,000 cubic feet of natural gas per day over a 12-month period (BOED)*

As Figure 7 at left shows, the average daily output of gas per well in the four-state region was 10.7 Mcf/day in 2000 compared to 5.4 Mcf/day in 2019 – a decline of about 50 percent. Nationally, gas stripper well productivity declined by just 15 percent between 2000 and 2019. This trend – especially in the four-state region – shows that stripper wells are becoming less productive over time, as more stripper wells become ultra-low stripper wells.

Who Owns Stripper Wells?

While marginal well owners are often portrayed as "mom and pop" operators,[6] a recent analysis by the Environmental Defense Fund (EDF) finds that the vast majority of these wells are owned by large companies.[7] According to EDF, just 93 companies owning more than 1,000 operating wells sites control nearly half of all marginal well sites in the United States. Large companies – those with at least 100 well sites – own more than 75 percent of marginal wells sites. Conversely, small companies - those with fewer than 10 operating sites – control just 4 percent of marginal well sites.

Figure 7: Marginal Well Site Ownership in the United States



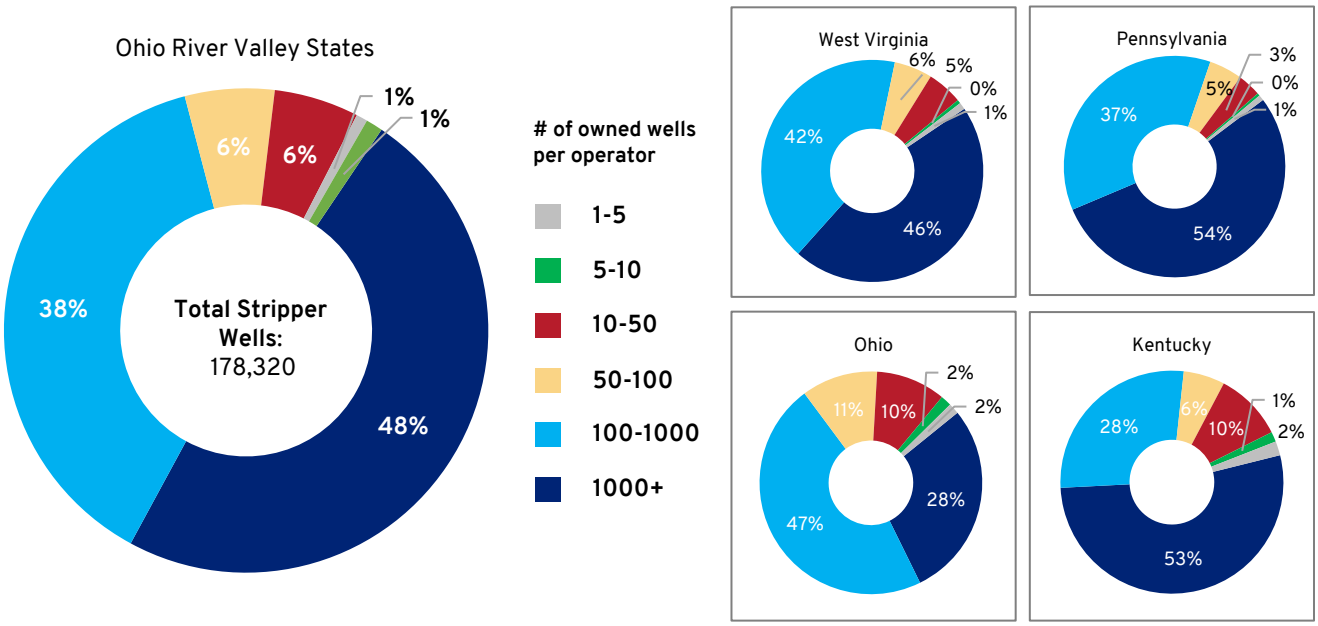
Source: Environmental Defense Fund, Marginal Well Fact Sheet (2021)

To estimate the ownership of stripper wells in the four-state region in the Ohio River Valley, this analysis uses well and production data from The Capitol Forum's Upstream database of oil and natural gas producers in Appalachia.[8] Unlike the EDF analysis above that looks at ownership of well sites, which could include multiple wells, this analysis examines ownership per well based on 2020 and 2019 data.

According to the *TCF Upstream* database, 17 companies in the four-state region own more than 1,000 wells each. These 17 companies own nearly half (48.5%) of all stripper wells in the four-state region that produce less than 90 Mcfe per day (15 BOE/day). Approximately 87 percent of stripper wells in the region are owned by companies with more than 100 active wells. Only 1.9 percent of stripper wells in the region are controlled by companies and individuals that own less than 10 wells.

Pennsylvania had the highest concentration of stripper wells owned by companies with more than 1,000 wells at nearly 91 percent, while Ohio's owners with more than 1,000 wells controlled almost 76 percent. Kentucky has the highest share of small owners – those with fewer than 10 wells – at 3.5 percent while in Pennsylvania smaller owners controlled just 1.2 percent.

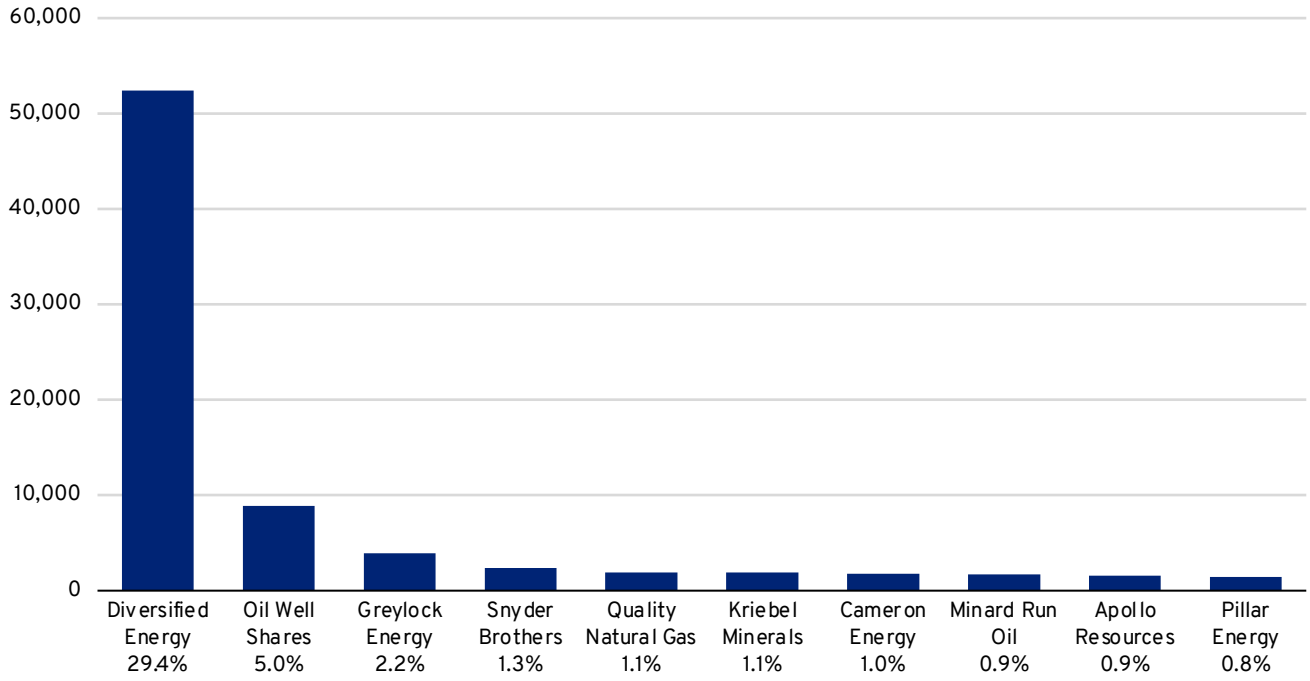
Figure 9: Stripper Well Ownership in Ohio River Valley States



Source: ORVI analysis of TCF Upstream database.
Note: *Figures use 2020 ownership data for WV, PA, and OH, and 2019 for KY for stripper wells (less than 15 BOED).*

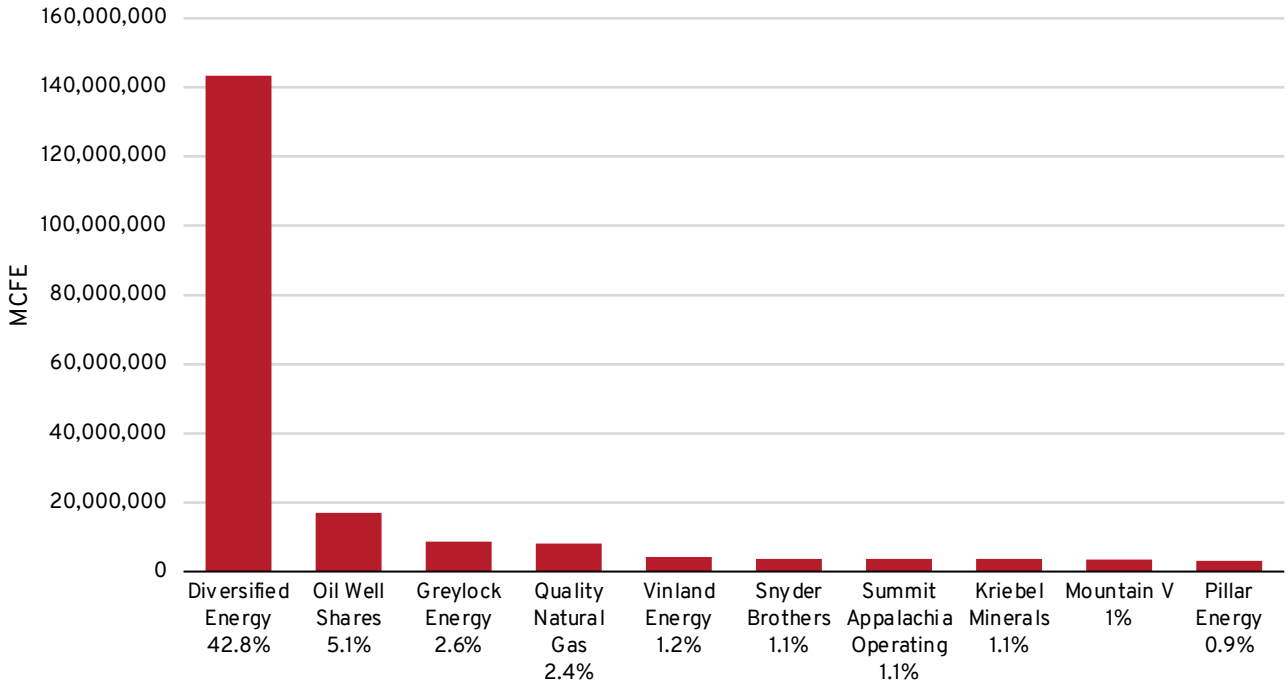
The largest owner of stripper wells in the region and in each state is Diversified Energy, which owns 52,400 wells or 29 percent of the 178,320 stripper wells with ownership information. The next largest owner of stripper wells in the region is Oil Well Shares, which owns 3,600 wells and is the second largest well owner in Ohio and Pennsylvania. Diversified Energy is also the largest stripper well producer in the region, making up nearly 43 percent of all stripper well production.

Figure 10: Top Stripper Well Owners in Ohio River Valley States



Source: ORVI analysis of TCF Upstream database.
Note: *Figures use 2020 ownership data for WV, PA, and OH, and 2019 for KY for stripper wells (less than 15 BOED).*

Figure 11: Top 10 Stripper Well Producers in Ohio River Valley States



Source: ORVI analysis of TCF Upstream database.
Note: *Figures use 2020 ownership data for WV, PA, and OH, and 2019 for KY for stripper wells (less than 15 BOED).*

Section Two: Bonding Coverage and Decommissioning Stripper Wells

Usually before a company can drill an oil or gas well, it must set aside funds to plug and restore a well site after production ceases. These funds – usually cash or bonds (surety or performance bonds) – are a debt like legal obligation that is supposed to provide a financial incentive to drillers to properly decommission their well sites. This financial assurance is also supposed to help ensure where a well is located, such as a state or tribal reservation, can deal with any liabilities associated with the well if the company goes bankrupt or dissolves.

Bonding Coverage of Stripper Wells in Ohio River Valley States

According to the Carbon Tracker Initiative, total bonding coverage – the amount of money oil and gas companies are required to obtain to cover the closing or plugging costs of wells – on unplugged wells is a tiny fraction of what is needed to actually close the wells.[9] Carbon Tracker reports the total value of bonds is $22.4 million in Ohio, $28.7 million in West Virginia, and $47.2 million in Pennsylvania – or about $98 million in total for the three states. Carbon Tracker does not have bonding coverage data for Kentucky. For the three states, this means the bonding coverage is just $232 per well.

Using a decommissioning cost of $30,000 per well, the total cost to decommission the estimated 423,000 documented unplugged wells in these three states is $12.7 billion. This is less than one percent (0.8%) of the $98 million in bonding coverage. Looking at just stripper wells (164,376) compiled by Carbon Tracker in the three states, the decommissioning cost would be $4.9 billion at $30,000 per well. Using a decommissioning cost of around $76,000 per well (Carbon Tracker estimate) to plug all wells in the three states would be $32.3 billion for all wells and $12.3 billion for stripper wells.

The central reason for the large unfunded liabilities in states is the use of "blanket bonds" that inadequately cover the plugging cost of wells. Instead of a single bond per well, a blanket bond provides a fixed amount of coverage to secure decommissioning obligations (plugging a well and restoring the well site) for an unlimited number of wells under a single operator. For operators with many wells, blanket bonds reduce the effective bond coverage per well.

Blanket bond amounts are often unrelated to the actual cost of decommissioning wells. For example, in Pennsylvania, a blanket bond that covers an unlimited number of conventional wells is just $25,000, which is less than it costs to plug just one well. A single well bond is just $2,500 on conventional wells in Pennsylvania. A recent analysis by researchers at the University of Pittsburgh found that bonding "requirements for conventional wells have been–and continue to be–a fraction of reclamation costs as evidenced by our analysis of state well plugging contracts."[10] The researchers found that the bonding requirement on a single shale well - $10,000 – is only 11 percent of the total reclamation costs, including plugging and wellsite restoration for a typical shale the average amount per bond (single and blanket bonds) for Pennsylvania's conventional wells is just $1,600.[11]

Table 1: Carbon Tracker Data on Orphan Liability Risk in West Virginia, Pennsylvania, and Ohio

Carbon Tracker Unplugged Wells (Orphan Liability Risk) in WV, PA, and OH (Excludes 1.2 million undocumented onshore wells in EPA U.S. estimates)										
State	Producing	Stripper	Injection (other)	TA	Zombie	Total Wells	Cost @$30k ($B)	Carbon Tracker Estimate @$76k* ($B)	Carbon Tracker Bonding Estimate ($MM)	Bonding Ratio (%)
WV	3,163	55,823	42,003	951	304	100,444	$3.0	$7.6	$28.7	1%/0.4%
PA	9,971	70,042	49,050	8,422	13,817	151,302	$4.5	$12.2	$47.2	1%/0.4%
OH	2,617	38,511	93,014	8,494	28,766	171,402	$5.1	$12.5	$22.4	0.4%/0.2%
TOTAL	***15,751***	***164,376***	***184,067***	***17,867***	***42,887***	***423,148***	***$12.7 billion***	***$32.3 billion***	***$98.3 million***	***0.8%/0.3%***

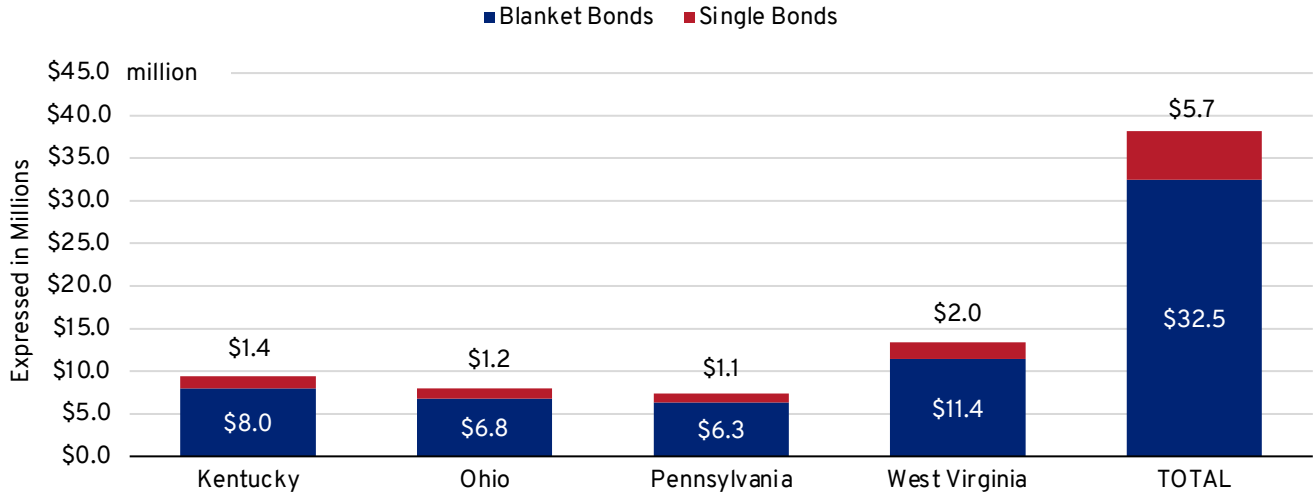
Category	Description
Producing	Unplugged wells with a Last Production (LP) date within the past two years and average daily oil and gas production equal to or greater than 15 barrels of oil or 90 Mcf of natural gas.
Stripper	Unplugged wells with a LP date within the past two years and average daily oil and gas production less than 15 barrels of oil or 90 Mcf of natural gas.
Injection + other	Unplugged injection wells and other unplugged wells with no reported oil and gas production, including wells classified as disposal, dry hole, monitor, observation, other, storage, and water.
TA (LP>24<60)	Unplugged temporarily abandoned (TA) wells with a LP date more than two years but less than 5 years ago.
Zombie (LP>60)	Unplugged wells with a LP date more than five years ago.

Source: Carbon Tracker Asset Retirement Portal.
Note: **The average decommissioning cost provided by CTI averaged $75,629 in the three states for all well types and $75,641 for stripper wells.*

Bonding requirements differ in each of the four Ohio River Valley states based on several characteristics. Each state offers both single well bonding and blanket well bonding. Bonding amounts can differ based on the type of well (shallow, horizontal, vertical or conventional and unconventional) or the number of wells. For example, Kentucky requires individual bonds for shallow wells (set at $2 per drilled foot), vertical deep wells ($25,000), and horizontal deep wells ($40,000). For blanket bonds, Kentucky has tiered amounts for shallow wells starting at $20,000 for one to 25 wells and up to $1.5 million for 4,501 to 5,000 wells. In West Virginia, individual bonds are $5,000 for vertical wells, while in Pennsylvania they are $2,500 and in Ohio it's $5,000. Blanket bonds in West Virginia for vertical wells are $50,000 while all blanket bonds in Pennsylvania are $25,000 and $15,000 in Ohio.

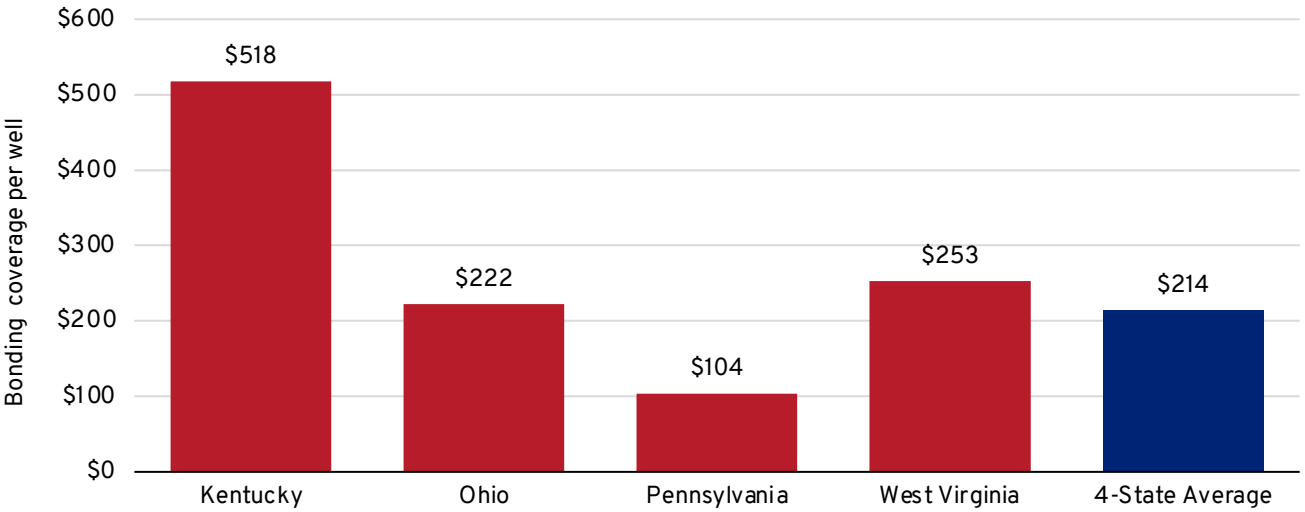
Figure 12 depicts the estimated total bonding coverage for the 178,320 stripper wells in the four-state region that produced less than 15 BOE/day in 2020 or 2019 (Kentucky) using the TCF Upstream database. Total bonding coverage for stripper wells in the region is estimated to be about $38 million. This represents just 0.7 percent of the cost to plug these wells ($5.3 billion) based on a conservative estimate of $30,000 per well. This estimate is very close to the bonding ratio from Carbon Tracker of 0.8 percent, for all unplugged documented wells. The bonding coverage ranged from $104 per stripper well in Pennsylvania to $518 per well in Kentucky. The average across all four states is $214 per well. These estimates assume operators or well owners in each of the four states secured bonding coverage based on the cheapest option available based on the number of wells they own. These bonding coverage estimates are likely more than actual bonding amount since they do not include other inactive and nonstripper wells those operators may own.

Figure 12: Estimated Bonding Coverage for Stripper Wells in Ohio River Valley States



Source: ORVI analysis of The Capitol Forum Upstream database, IOGCC (2021) survey, and Kentucky Energy and Environment Cabinet, Natural Resources (2019 bonding regulations).

Figure 13: Estimated Bonding Coverage Per Well for Stripper Wells in Ohio River Valley States



Source: ORVI analysis of The Capitol Forum Upstream database, IOGCC (2021) survey, and Kentucky Energy and Environment Cabinet, Natural Resources (2019 bonding regulations).

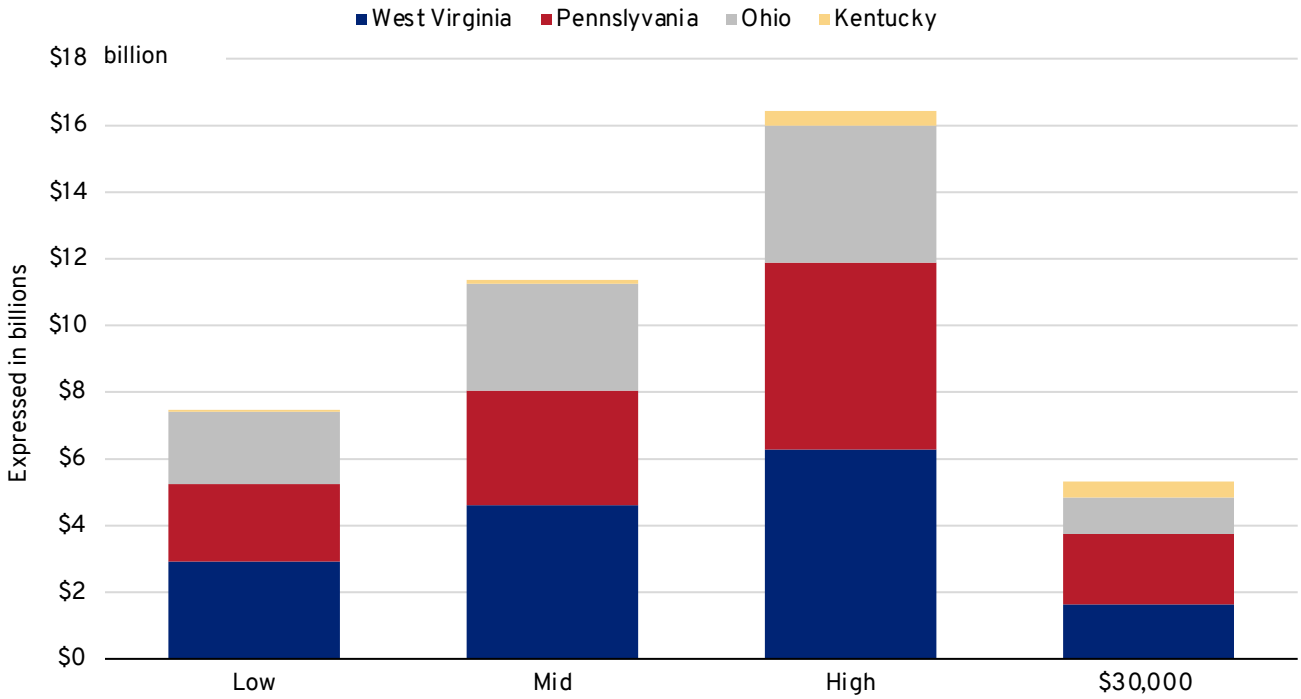
Cost to Clean Up Stripper Wells

A 2021 peer reviewed article by Daniel Raimi (Resources for the Future) and others that examined decommissioning costs of orphan and abandoned oil and gas wells, which includes plugging and site restoration, found that the average cost was $48,703 in Pennsylvania (2019 dollars) at an average depth of 2,056 feet.[12] The study also found that for each additional 1,000 feet of well depth this added 20 percent to decommissioning costs. Overall, the study concluded that the median decommissioning costs was roughly $75,000 per well – which is very close to the $76,000 decommissioning cost per well by Carbon Tracker.

Data from the Pennsylvania Department of Environmental Protection show that the average plugging cost in the state was $33,000 per well over the last decade.[13] The Pennsylvania Independent Petroleum Producers have also said that to plug wells that are old and around 3,000 feet deep costs $33,000 per well, while a report from the Sierra Club in Pennsylvania estimates the cost at $38,000.[14,15] Other companies, such as Seneca Resources Corporation, said the average plugging cost is around $75,000 per well.

In West Virginia, data from the WV Department of Environmental Protection (WV DEP) show that over the last 12 years the average plugging cost was $54,040. Recently, the WV DEP accepted a bid for $85,000 for plugging one well. The largest well-plugging firm in West Virginia – Hydrocarbon Services – advertises on its website that the typical well plugging cost for wells that are about 3,000 feet is between $40,000 and $60,000.[16] In Ohio, the median cost to plug an oil and gas well is $87,508 while the average cost is $111,500. In Kentucky, well plugging can cost anywhere from $3,667 to $28,400, largely depending on the depth and location of the well. The range in estimated plugging cost by state is due to a host of factors, including contract size, location of wells, depth of wells (wells in Kentucky are shallower), the age of the well (older wells cost more to plug), site topography (hilly terrain), type of well (gas wells typically cost more to plug), and surface characteristics (tanks, equipment, well pad). Based on this data, the cost to plug the estimated 177,424 stripper wells in the region ranges from $5.3 billion to over $16 billion based on a cost of $30,000 per well.[17]

Figure 14: Estimated Plugging Cost for Stripper Wells in Ohio River Valley States



Source: EIA (2020) and Ohio River Valley Institute (2021).

Low Bonding Coverage is an Implicit Subsidy

The gap between the total bonding coverage and the cost to plug these stripper wells is roughly $5.3 billion at the low end or about $29,800 per stripper well. The small amount of bonding required is an implicit subsidy provided by the state since it transfers some liability and risks to the public because of inefficient pricing of bond coverage. This funding gap between the cost of the (inadequate) bonding and the cost of decommissioning wells significantly reduces the cost for operators despite their legal obligations to decommission each well.[18] Using a 30-year time horizon for plugging (conventional wells typically produce around 30 years), the annual implicit subsidy provided is around $178 million per year.[19] If the wells are plugged in 20 years, this (implicit) subsidy jumps to $267 million annually. This does not take into account inflation.

Another way to estimate this subsidy is to consider the annual premium that would be paid for "full-cost bonding" of $30,000 per well or $5.3 billion for 177,000 stripper wells. Bonding companies require operators to pay a premium based on the bond amount. The annual premium is usually between 1 to 5 percent of the total bond.[20] If all stripper well operators paid a 2.5 percent annual premium and the total bonded amount was $5.3 billion, premiums would amount to $134 million annually in the aggregate or about $750 per well annually assuming all the stripper well companies could obtain bonding coverage. Today, the total premiums paid in the four-states for bonding coverage likely do not exceed one million dollars. If stripper wells operators in the region had to pay an annual premium of $750 per well, it is likely many of their wells would become uneconomical since many of these wells are barely profitable as it is. Either way it is calculated, it is clear this that insufficient bonding requirements constitute a large subsidy for stripper wells that could likely cost taxpayers in the future.

Section Three:
Tax Subsidies for Stripper Wells

The US has a long history of subsidizing stripper wells through various policies, including tax credits, tax preferences, price controls, and tariffs on oil imports.[21] The threat of low oil and natural gas prices has historically squeezed the profits of marginal well producers. This was especially true in the late 1990s, when oil prices dipped below $14 per barrel and natural gas prices average around $2 per Mcf.[22] In response to these conditions, federal policymakers enacted several tax subsidies in the late 1990s and early 2000s in an effort to keep stripper wells producing, to boost domestic oil and gas production, and to promote "energy independence" and national energy security.[23] Since that time, there has been a boom in high-volume shale hydraulic fracking that has dramatically increased domestic oil and gas production along with reserves. Meanwhile, the share of oil and gas production from stripper wells in the US has declined by half from 2000 to 2019 and the number of stripper wells grew by nearly one-third.[24]

Keeping Stripper Wells Alive

The Interstate Oil and Gas Compact Commission (IOGCC) has "championed the preservation of this country's low-volume, marginally economic wells" for decades alongside industry advocacy groups like the National Stripper Well Association (NSWA) and the Independent Petroleum Association of America (IPAA). These groups have played a vital role along with lawmakers in enacting policies that not only subsidize these low producing wells but that also discourage the decommissioning of marginal wells. Outside of tax policy, the oil and gas industry is subsidized by regulations that allow low-producing wells to stay unplugged after they have become uneconomical. For example, the IOGCC argues that every plugged marginal well represents foregone oil and gas production no matter how little oil or gas it is producing or whether it is economical.

In its 2016 report and survey of marginal wells in the United States, the IOGCC estimates that over 450,000 oil and gas marginal wells have been plugged from 1992 to 2016, resulting in the loss of over $12.5 billion in foregone production along with lost jobs, earnings, and economic output. Surprisingly, the IOGCC marginal well report ignores the fact that marginal wells are typically plugged precisely because they are uneconomical in the first place. Since marginal well producers operate on thin profit margins, the industry has been able to enact tax policies at the public's expense to reduce their cost of doing business. These tax subsidies for stripper and marginal wells have grown over the past few decades and are available at the federal and state level.

Federal Tax Subsidies

According to the Congressional Research Service, there are eight tax preferences or subsidies that reduce the tax liability of the oil and gas sector by $1.5 billion annually.[25] This section explores two tax expenditure applicable to stripper well producers, including percentage depletion and the marginal well tax credit. Stripper well producers also benefit from the exemption from passive loss limitations and the ability to expense intangible drilling costs. On top of these provisions, the oil and gas industry also benefit from many other features of the U.S. tax system, including bonus depreciation and immediate expensing of capital and net operating loss provisions. The federal government has also provided reductions in royalty payments on public land from stripper wells.[26] From 1992 to 2006, the Bureau of Land Management instituted a Stripper Oil Well Property Royalty Rate Reduction Program (RRRP) which lowered the tax responsibilities of stripper well operators.

Percentage Depletion

Perhaps the oldest federal tax subsidy for oil and gas producers and royalty owners is percentage depletion, which has been part of the tax code since 1926.[27] Percentage depletion allows oil and gas companies to recover costs associated with depletion of oil and gas deposits. They are allowed to deduct 15 percent of the gross income from oil and gas produced each year rather than deducting it from the actual depletion of the resource each year. Marginal well producers can deduct more than 15 percent based on a formula linked to the price of oil and gas and can deduct more than their net income from property. The depletion deduction can even be used after marginal well operators have recovered the costs of acquiring and developing the property. This means percentage depletion can result in total deductions exceeding the taxpayer's investment in the well, lowering their tax liability.

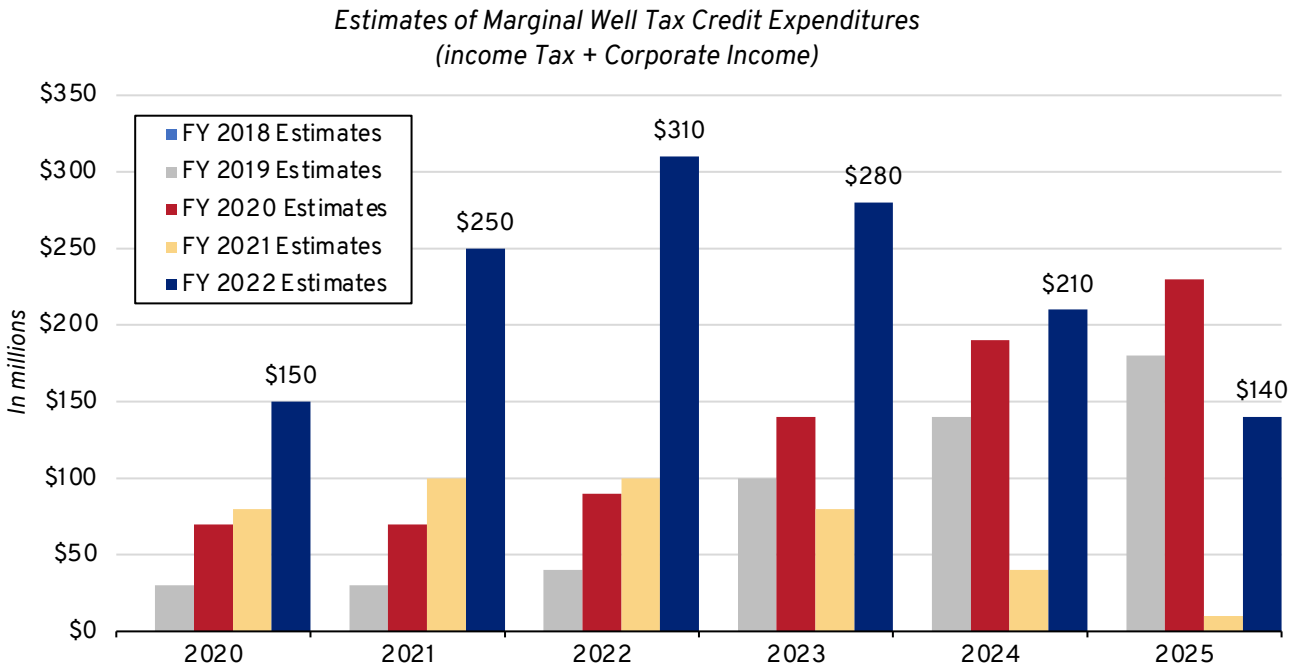
Percentage depletion is limited to a taxpayer's first 1,000 barrels of oil or 6,000 Mcf of natural gas production per day. It is also capped at 65 percent of the taxpayer's taxable income. According to the Joint Committee on Taxation, this subsidy amounted to $600 million in FY 2020 and is projected to cost $2.9 billion from FY 2020 to FY 2024.[28] The National Stripper Well Association (NSWA) maintains that the "loss of the percentage depletion would place marginal well production in jeopardy."[29] In 2005, a NSWA funded study maintained that eliminating the percentage depletion would have lowered the number of producing wells by 4 percent between 2015 and 2025.[30] A 2016 study by the Council on Foreign Relations that looked at the impact of removing the percentage depletion tax preference – along with the intangible drilling costs and manufacturing deduction tax preferences – found that it would not "directly and materially improve U.S. energy security" and that Congress should repeal all three tax preferences.[31]

Marginal Well Tax Credit

In 2004, Congress created the marginal well tax credit as a "safety net" for marginal wells during periods of low oil and gas prices. The marginal well credit was recommended by the National Stripper Well Association (NSWA) in 1999 as a "counter cyclical" measure to boost domestic onshore marginal well production in the lower 48 states as most investment at that time of "U.S. majors" was in developing Alaska and deep-water offshore production.[32] According to the NSWA, low oil prices in the late 1990s caused 136,000 oil and 57,000 gas wells to be shut-in. The marginal well credit was seen as a way to "prevent the abandonment of marginal wells during a temporary price collapse," according to the American Petroleum Institute.[33]

The marginal well credit is $3 per barrel of qualified crude oil and 50 cents per Mcf for qualified natural gas and the credit is adjusted for inflation. In 2019, the credit was $3.90 for oil and 65 cents for gas. To qualify, a marginal well must average daily production of no more than 25 BOE or 150 Mcf/day.[34] The credit starts phasing out based on the inflation-adjusted price of oil and natural gas (set in 2005 of $15 per barrel of oil and $1.67 per Mcf) and fully phases out when prices reach $18 per barrel or $2 per Mcf. In 2019, the phase out period began at $19.52 per barrel and $2.17 per Mcf and was fully phased out if prices exceeded $24.43 per barrel or $2.60 per Mcf. While the credit can be claimed on all wells, it cannot be claimed on more than 1,095 barrels of oil or 6,570 Mcf of gas per well. The credit can be carried back 5 years or forward for 20 years.

Figure 15: Sharp Increase in Marginal Well Tax Credit Expenditures in 2022



Source: U.S. Department of Treasury, Tax Expenditures, FY 2018-2022

While actual tax expenditures or forgone revenue from the marginal well tax credit is not available, the U.S. Department of Treasury publishes ten-year estimates of projected tax expenditures that include the marginal well tax credit.[35] According to the Treasury, those expenditures have grown considerably over the last four years. In June of 2020, they projected that the marginal well tax credit would peak at $100 million. However, the following June the Treasury Department projected the credit would top out at $310 million before falling to $140 million in 2025. This fluctuation is presumably based on several factors, especially the projected price of natural gas and oil.

State Tax Subsidies

Of the four states evaluated in this report, only West Virginia and Kentucky have specific tax subsidies for stripper wells. In Pennsylvania, the state's production impact fee doesn't apply to stripper wells; however, to qualify as a stripper well the well must produce less than 15 BOE for every month of the year, not just a single month.[36] Ohio has a very small severance tax on oil of 10 cents per barrel and 2.5 cents per MCF of natural gas, an effective tax rate of less than 0.4 percent.[37] In Kentucky, the natural gas and oil severance tax is 4.5 percent of gross value. The state allows transportation costs to be deducted from gross value. Also, inactive crude oil and natural gas wells can receive a credit of 4.5 percent for gas or oil produced from 'recovered inactive wells."[38]

In West Virginia, the natural gas and oil severance tax rate is 5 percent of gross value or receipts. Natural gas wells that produce less than 5 Mcf per day and oil wells that produce less than one-half barrel per day are not subject to the state's severance tax.[39] This exclusion applies to most ultra-low producing wells and perhaps half of all active oil and gas wells in the state. The value of this expenditure was $2 million per year in 2020. There is also a reduced severance tax rate of 2.5 percent for vertical conventional wells that produce between 5 Mcf and 60 Mcf per day and for conventional oil wells that produce between one-half barrel per day and 10 barrels per day over a 12-month period. The reduced rate for lower volume vertical oil and gas wells was an estimated $2.2 million per year. All oil and gas operators in the state also receive an annual credit of $500 per taxpayer on the severance tax. In 2021, the state passed legislation recalculating how

natural gas and oil property taxes are valued for tax purposes by allowing more deductions. These changes are expected to lower property taxes by millions per year, but it is unclear if these changes will impact conventional wells.[40]

A 2020 report by the Colorado Office of the State Auditor that evaluated that state's severance tax exemption for stripper wells – those producing less than 15 BOE per day – found that it "may" only help when oil and gas prices are close to the costs of operating a stripper well.[41] The evaluation also found "when prices are low and stripper wells are operating at a loss, the benefit provided by this exemption is unlikely to be significant enough to keep stripper wells open."

Section Four:
Methane Emissions and Stripper Wells

Stripper wells are a significant source of methane (CH_4) emissions in the United States. Methane, the primary component of natural gas (90%), is a powerful greenhouse gas that has 86 times the warming power of carbon dioxide over a 20-year time span, and it accounts for roughly 10 percent of all greenhouse gas emissions from human activities. According to the EPA, natural gas and oil production accounted for about 20 percent of all methane emissions in 2019. Recent studies suggest that the methane emissions from oil and gas production may be twice as high as EPA estimates.[42]

A June 2021 report from the Clean Air Taskforce and Ceres found that total company-reported methane emissions from hydrocarbon production in Appalachia was 183,860 metric tons, the equivalent of 9.2 million tons of carbon dioxide. Diversified Energy, which primarily operates stripper wells, was the largest source of methane emissions from the oil and gas industry in the Appalachian basin. In 2019, Diversified Energy emitted a reported 29,694 metric tons of methane or 15.9 percent of total methane emissions from reported gas production in the Appalachian region. Meanwhile, EQT, the largest gas producer in the region, which produced more than nine times as much gas as Diversified Energy did in 2019, reported emitting 34 percent less methane (19,336 MT) than Diversified Energy.

Estimating Methane Emissions from Stripper Wells in Appalachia

Several studies have examined methane emissions from conventional oil and gas wells and low-producing stripper wells, showing that some stripper wells emit as much gas directly into the atmosphere as they reported producing for fuel. A 2016 study by Mark Omara and others that looked at methane emissions from conventional oil and gas wells (and tanks) in West Virginia and Pennsylvania found that the average well emitted about 7.5 metric tons of methane annually.[43] Omara and others found that, as proportion of total production volumes, stripper wells can emit as much as 10 times more methane as a fraction of gas production than high volume wells, mostly because of aging equipment.

Another study of methane emissions from ultra-low producing stripper wells (less than one BOE per day) in Ohio by Amy Townsend-Small and others found that average annual methane emissions were 1.1 metric tons per well.[44] A 2019 study by Stuart Riddick and others found similar results: that the emission rate for conventional oil and gas wells in West Virginia was approximately 1.2 metric tons of methane per well annually.[45] Riddick also found that wellhead methane emissions from stripper wells were 7.5 times larger than estimates from the EPA, with average methane loss rate of nearly 9 percent of production leaked per wellhead.

The average methane emission factor for marginal wells of 1.1 metric tons annually per well from the Townsend-Small study indicates that stripper wells in the four-state region of the Ohio River Valley (177,424) emit around 199,000 tons of methane annually. This is equivalent to the greenhouse gas emissions of 553 million gallons of gasoline consumed over one million gasoline powered passenger vehicles annually, according to the EPA's Greenhouse Gas Equivalences Calculator.[46] Applying this methane emission factor to the number of stripper wells in each states shows that Pennsylvania is emitting about 79,000 metric tons of methane annually, along with 61,000 tons in West Virginia, 41,000 tons in Ohio, and 18,000 tons in Kentucky. On top of methane emissions, stripper wells are also emitting volatile organic compounds (VOCs) such as benzene that are linked to some chronic diseases such as cancer.

Recent Federal Efforts to Curb Methane Emissions

There have been efforts at the federal level to impose a small fee on methane released by oil and gas wells.[47] The Build Back Better Act, which passed the U.S. House in November of 2021 (H.R. 5376), included a $900 to $1,500 per ton fee on methane emitted from natural gas and petroleum systems, including methane leakage in excess of 0.2 percent from oil and gas production.[48] An analysis by Energy Innovation Policy & Technology found that the proposed methane fee would significantly reduce industrial greenhouse gas emissions from 2023 to 2050.[49] By 2050, the fee would "avoid 172 million metric tons (MMT) of carbon dioxide equivalent (CO2e) annually, equal to the annual emission from more than 36 million gasoline-powered passenger vehicles." This represents about 11 percent of U.S. greenhouse gas emissions from the industrial sector in 2019.[50]

The U.S. Environmental Protection Agency is also proposing stricter rules for monitoring methane from new wells and especially older stripper wells.[51] EPA's proposed rule includes a comprehensive monitoring system for well sites and compressor station, the use of advanced technology to find major leaks, a zero-emissions standard for new and existing pneumatic controllers and standards to eliminate venting of gas and require its capture and sale. According to Platt Analytics, the cost of compliance to bring over 750,000 stripper wells into compliance would be $1.2 billion per year or 34 cents per BOE. EPA estimates that the new rule would reduce methane emissions by 41 million tons (920 million tons CO2e) from 2023 to 2035 and results in a cumulative net climate benefit of $48 billion during this period. By 2030, EPA projects that the rule would lower methane emissions by 74 percent from 2005 levels.[52]

Section Five:
Uneconomical Wells in the Ohio River Valley Region

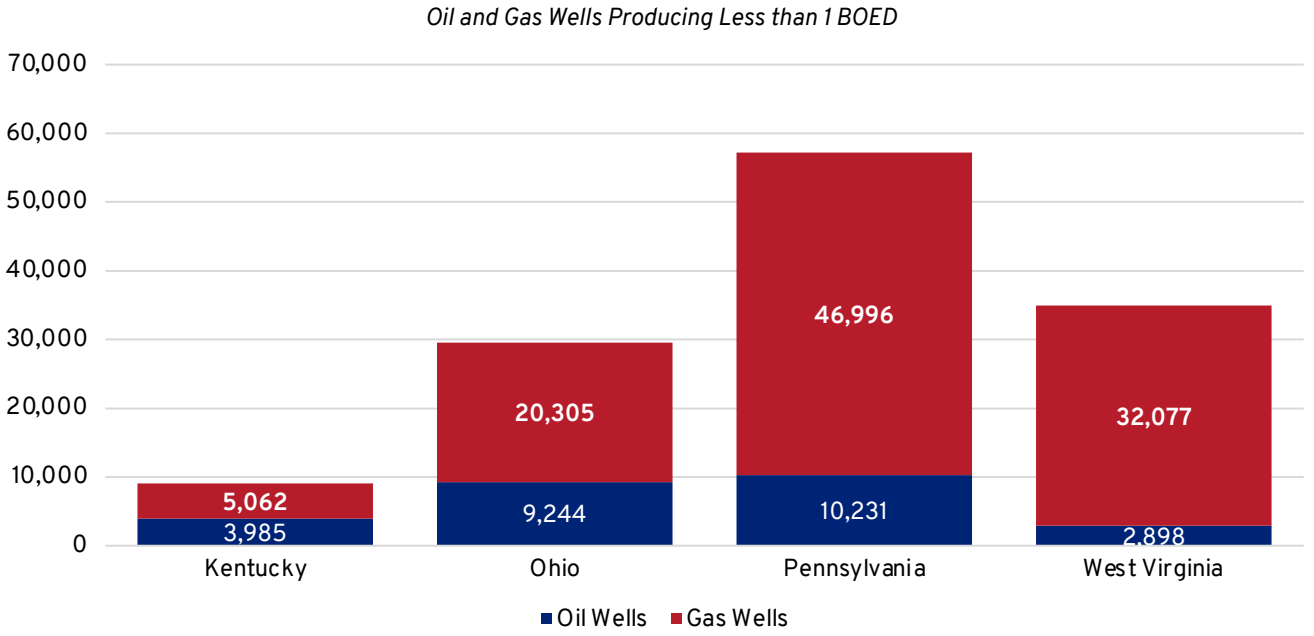
It can be difficult to determine when a stripper well has reached the end of its life. This is because the economic viability of a stripper well hinges on several factors. These factors include oil and gas prices, decommissioning costs, production levels, and operating expenses. According to the National Stripper Well Association, when oil prices fall below $30 per barrel stripper wells become unprofitable.[53] Some oil analysts have estimated that half of all stripper production in the United States would stop if oil prices dipped below $40 per barrel, while others estimate the breakeven price for existing non-shale oil well operators is about $34 per barrel.[54] According to S&P Global, the breakeven price for natural gas in Appalachia was estimated to be $1.86 per Mcf in 2020.[55] However, others, have found that the break-even price for dry gas production from the Marcellus play, the predominate shale basin in Appalachia, is closer to $2.5/Mcf while the breakeven price can be as low as $1.50/Mcf in Ohio (focused on the Utica shale formation).[56]

In many instances, it may be cheaper to put off decommissioning a well even if it is losing money or has a negative cash flow for years. For example, a stripper oil well in Pennsylvania can cost $2,000 a month or $24,000 a year to operate, according to some estimates, and the typical plugging cost in Pennsylvania is estimated at $33,000 per well.[57] If the price of oil is $30 per barrel, and the stripper well produces just 2 barrels of oil per day (730 barrels annually), it would earn just $21,900, for an annual loss of $2,100. Therefore, the operator could produce at this price for around 15 years before the loss would be higher than the plugging cost. Not paying for decommissioning an uneconomical well allows operators to use those funds in other places that can make them money, such as drilling another well.

The point at which a stripper well becomes “uneconomical” or no longer viable and needs to be decommissioned is largely determined when the value of production is below operating costs – the breakeven point - for the foreseeable future. In some jurisdictions in order to maintain a mineral lease production must be in “paying quantities”.[58] For example, in developing its definition of an “inactive well”, the Colorado Oil and Gas Conservation Commission (COGCC) determined that wells producing less than one barrel of oil equivalent per day (BOED) is “well below the threshold at which a well can continue to operate profitably” based on “the Commission’s experience and current and long-term oil prices.”[59]

There are approximately 130,800 oil and gas wells in the four-state region that produced less than 1 BOED in 2019. Wells producing less than 1 BOED made up approximately 74 percent of all stripper wells (177,424 produced less than 15 BOED) in the region and 68 percent of all active oil and gas wells (192,723) in 2019. The vast majority (104,440 or 80%) of stripper wells producing less than 1 BOED are gas wells while 20 percent (26,358) are oil wells. These ultra-low stripper wells made up just 0.7 percent of total gas production (53.3 Bcf) and 4.9 percent of total oil production in the four-state region in 2019.

Figure 16: Ultralow Producing Stripper Wells Comprise 130,000 (68%) of Producing Oil and Gas Wells in Ohio River Valley States



Source: U.S. Energy Information Administration, The Distribution of U.S. Oil and Natural Gas Wells by Production Rate, December 2020.
Note: *One barrel of oil (BOE) is equivalent to 6,000 cubic feet of natural gas per day over a 12-month period (BOED)*

A 2021 study by scholars at the University of Pittsburgh found that conventional natural gas wells producing less than 0.5 Mcf (500 cubic feet) per day are "highly likely to be uneconomical even if gas prices rise considerably" and should "arguably be decommissioned."[60] The study estimated that one-third of conventional gas wells that reported production in Pennsylvania between 1980 and 1999 were under this threshold and "very likely uneconomical."

To determine the minimum production threshold for a gas well to be economical, the study used an annual operating expense of $886 per well and a price of $3.94 per Mcf. To break even or cover operating expenses, the well would have to produce 0.6 Mcf per day (0.6 Mcf x 365 days = 225 Mcf; 225 Mcf x $3.94 per Mcf = $886). Rounding to the nearest half Mcf, the study used a production threshold of 0.5 Mcf per day (182.5 Mcf annually) as the threshold for "uneconomical wells".

As noted in the study, the minimum production threshold of 0.5 Mcf per day is likely to be conservative, for several reasons. First, the estimate of per well operating expense of $886 only includes base operating or lease operating expenses. Lease operating expenses are "expenses to maintain producing oil and gas leases including labor, equipment repair, maintenance, utilities, insurance and overhead." However, it does not include expenses such as transportation, taxes, general and administrative expenses (G&A), storage, marketing, processing, and other expenses. Also not included is the initial cost to purchase and install the equipment as part of the producing property.[61]

Second, the study uses the highest forecasted Henry Hub spot price of gas from the Energy Information Administration (EIA) over the next five years ($3.94 per Mcf). In general, Henry Hub spot prices – which is for a natural gas distribution network in Louisiana – are historically higher than gas prices in Appalachia and Pennsylvania because of pipeline constraints.[62] According to EIA's 2021 Annual Energy Outlook, projected natural gas prices for the eastern United States aren't expected to rise above $3 per Mcf over the next 30 years.[63]

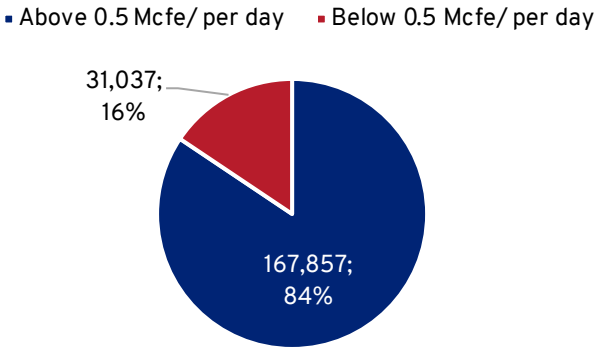
Lastly, the per well base operating expense is derived from Diversified Energy, which is the largest well owner in Pennsylvania, Appalachia, and the nation, and because of its economies of scale they likely have lower per

well base operating costs than most operators. Moreover, the per well base operating expense for all of Diversified Energy's wells is likely higher than $886 which is based only on Pennsylvania wells. Using a similar method as the University of Pittsburgh study for all of Diversified Energy's wells yields a per well base operating cost closer to $1,300 per well, which would increase the number of uneconomical wells.[64]

Estimating Uneconomical Wells in Ohio River Valley States

To estimate the number of wells in the four-state region that fall below the minimum production threshold of viability, this analysis will use well and production data from The Capitol Forum's Upstream database of Appalachia oil and natural gas producers.[65] The *TCF Upstream* database contains real-time production, well reporting, and operator ownership data of over 915,00 wells in Kentucky, New York, Ohio, Pennsylvania, Tennessee, Virginia, and West Virginia. TCF Upstream also provides information by state on historical production (1980-present), well operational status, well type, configuration, location, and production status.

Figure 17: More than 1 in 7 Producing Oil and Gas Wells is "Uneconomical"



Source: The Capitol Forum Upstream Database.
Note: *Mcfe = million cubic feet equivalent. This figure includes oil and gas wells. Figures use 2020 production data for WV, PA, and OH, and 2019 production data for Kentucky.*

According to the *TCF Upstream* database, there are an estimated 199,000 active oil and gas wells in West Virginia, Ohio, Pennsylvania, and Kentucky. Of this number, approximately 31,000 wells – more than 1 in 7 producing oil and gas wells - produced less than 0.5 Mcfe per day in 2020 or 2019 and could very likely be "uneconomical" and need to be plugged or decommissioned.

Among the top 10 operators of "uneconomical" stripper wells in the four-state region, Diversified Energy owned the most wells at 3,788, representing nearly 12.2 percent of the region's wells producing less than 0.5 Mcfe per day. Diversified Energy operates more than six times as many uneconomical wells as Am-Tek Oil in Ohio, which ranks second in the region with an estimated 493 uneconomical wells.

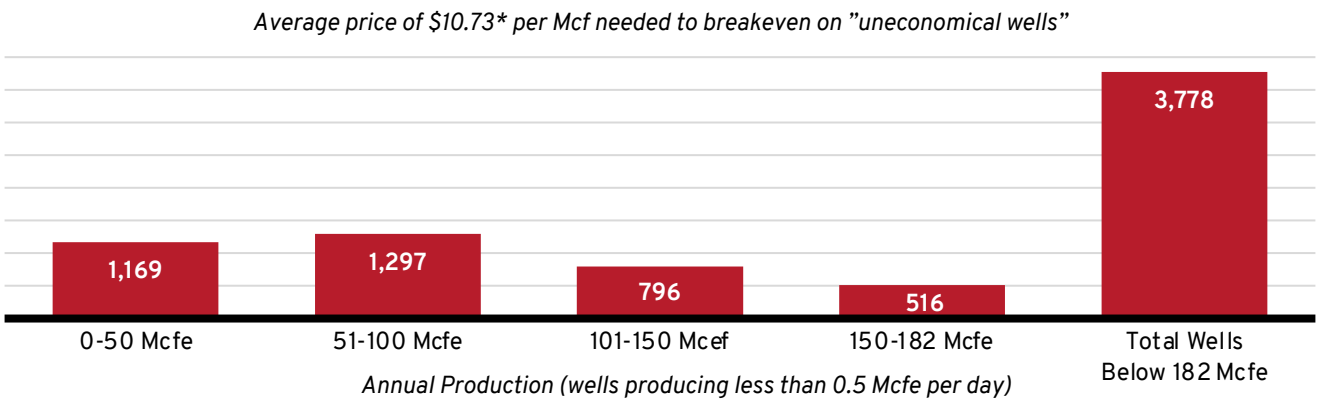
Table 2: Top Ten Operators of "Uneconomical" Producing Wells in Ohio River Valley States

Operators	Number of wells	Share of wells	Location of Wells
Diversified Energy Co.	3,788	12.2%	KY, WV, OH, PA
AM-Tek Oil Inc.	493	1.6%	OH
Gas & Oil Management Associates Inc.	450	1.4%	PA
KCS Energy Inc.	407	1.3%	PA
Apollo Resources LLC	380	1.2%	PA
Allshouse Terrence L Jr	358	1.2%	PA
R Oil & Gas Ent Inc.	323	1.0%	PA (all oil wells)
Creston Oil Corporation	303	1.0%	WV
Kylander Oil Inc.	308	1.0%	PA
Ross and Wharton Gas Co Inc.	306	1.0%	WV

Source: The Capitol Forum Upstream Database.
Note: *Table includes oil and gas wells. Figures use 2020 production data for WV, PA, and OH, and 2019 production data for Kentucky.*

Two-thirds of Diversified Energy's uneconomical wells - those producing less than 0.5 Mcfe per day –produce less than 100 Mcfe per year or less. The average annual well production among the 3,788 uneconomical wells is just 80 Mcfe per year or 0.22 Mcfe per day. Because most of these wells are producing such small quantities of gas and oil, it means prices would have to reach enormous heights for them to breakeven. For example, for all 3,788 of these wells to cover the estimated base operating expense of $886 per well, gas prices would have to reach $10.73 per Mcf, on average.

Figure 18: Production Distribution of Wells for Diversified Energy Under 500 Mcfe per Day



Source: The Capitol Forum Upstream Database.
Note: *Mcfe = million cubic feet equivalent. Figures use 2020 production data for WV, PA, and OH, and 2019 production data for KY. *The 3,778 wells produced 311,968 Mcfe. At an average price of $10.73 Mcf, that is $3.3 million or the total operating costs at $886 per well.*

Unplugged Inactive Wells Ripe for Decommissioning

In addition to the ultra-low producing wells that are likely uneconomical, there are over 230,000 unplugged inactive wells that will eventually need to be decommissioned. For purposes of this report, an "inactive well" is a nonproducing and unplugged well that is either shut-in (capped in place), abandoned (no production for at least one year), temporally abandoned or inactive (usually status granted by states upon application), and orphaned (no current operator). At what point inactive wells will need to be decommissioned varies, but most research and experience suggests that once a well has become inactive – either shut-in, abandoned, idled, or orphaned – it is rarely reactivated. As Rystad Energy recently pointed out in an analysis of stripper and marginal wells:

> *Historically, we have observed that when these operators shut down their marginal wells, it's usually for good, with no plans to reactivate them when the oil price improves due to the high alternative costs and potential pressure loss impact from shutting and restarting these wells.*[66]

A 2020 joint analysis by the Center for Public Integrity and the *L.A. Times* analyzed 40 years of state well data in California and found that "once a well has been dormant for just 10 months, there's a 50-50 chance it will never produce again."[67] Moreover, the analysis found that after five years of inactivity "the chance that a well is ever active again falls to 1 in 4." A 2017 study of inactive wells in Alberta, Canada found that a 200 percent increase in oil prices would only cause 12 percent of oil wells and 7 percent of gas wells to be reactivated.[68]

In 2021, the Pennsylvania Department of Environmental Protection fined Range Resources $294,000 for misclassifying over 40 conventional gas wells as temporarily inactive (viable for future use) when the wells "did not have future utility or significant reserves remaining in place."[69] According to a recent report in Colorado, some operators in Western states avoid inactive status for wells by "selling past production from

leasehold tank inventory or by 'swabbing' the well to extract and sell a small amount of fluid product each year."[70] Some operators let a well produce for an hour or a day once a year to avoid inactive status.

States have different policies governing on how long a well can be idle, inactive or "temporarily abandoned." In West Virginia and Pennsylvania, wells are not permitted to remain idle for more than one year, while in Ohio wells can remain idle for two. In Kentucky, wells are generally permitted to be idle for only 3 months. When a well stops producing at economic rates, operators can apply for inactive or temporary abandoned (TA) status upon meeting various requirements. In West Virginia, for example, operators must demonstrate "bona fide future use."[71] Other non-production requirements for TA status include demonstrating that the well is not a threat to the environment.

In Pennsylvania, temporary inactive well status can last for at least five years and can be renewed each year. In Ohio, it is two years while in West Virginia it is up to five years if the well demonstrates a "bona fide future use." In Kentucky, an inactive well can apply for a temporary abandonment permit for two years and it can be renewed indefinitely.[72] A recent report from Resources for the Future finds that the "easier it is for operators to idle and to apply and re-apply for temporary abandonment status for their wells, the more likely it is that wells will be left in an idle or temporarily abandoned status indefinitely and therefore avoid proper decommissioning.[73]

Table 3: Idle Wells and Temporary Abandonment Rules

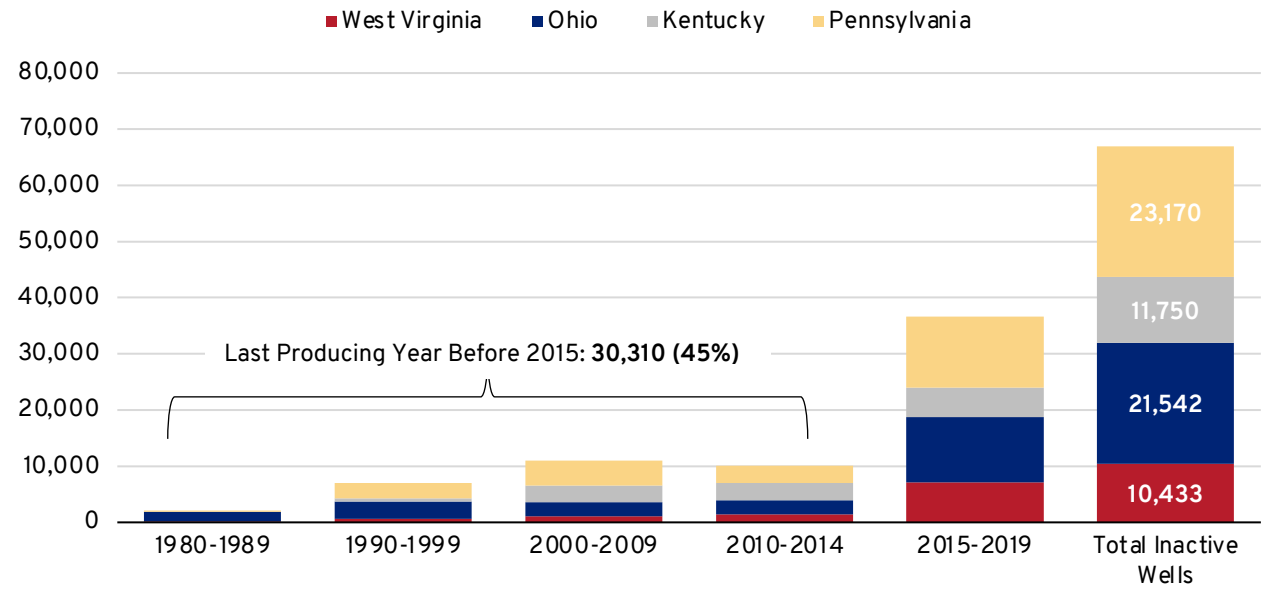
State	Max. Well Idle Time	Duration of Temporary Abandonment (TA)	Extensions for TA Status
Kentucky	3 months	2 years	Limited
Ohio	1 to 2 years	1 year	Limited
Pennsylvania	1 year	5 years	Unlimited
West Virginia	1 year	5 years	Unlimited

Source: Resources for the Future, Plugging Gaps in Inactive Well Policy (2016).

According to the TCF Upstream database, there are 230,700 unplugged non-producing oil and gas wells in the four-state region that are either inactive, abandoned, shut-in, or orphaned. Of this amount, only 29 percent or 67,000 wells had any gas or oil production from 1980 to 2020 that was reported to state agencies. This means approximately 71 percent or 164,000 of the inactive wells did not have any gas or oil production that was reported to state oil and gas databases. Of the approximately 164,000 inactive wells with no reported production, about 14,000 had a production report filed, which contained no positive quantities of gas and oil production, while about 150,000 had no production report at all. The lack of reporting suggests either that the well is defunct or is not producing and should be plugged according to state regulations, or that some of the inactive wells are in production and the operator is not taking the time to file a report.

Of the 67,000 wells with a production report, approximately 45 percent, or 30,300 have not produced any oil or gas since 2014 while 55 percent, or about 36,600, reported production between the years 2015 and 2019. Among with wells with reported production from 2015 to 2019, 14,575 reported oil or gas production in 2019 while 22,010 reported production between 2015 and 2018. Inactive wells that have not produced oil or gas for more than 5 years are sometimes referred to as "zombie wells" and are at high-risk of being orphaned.[74]

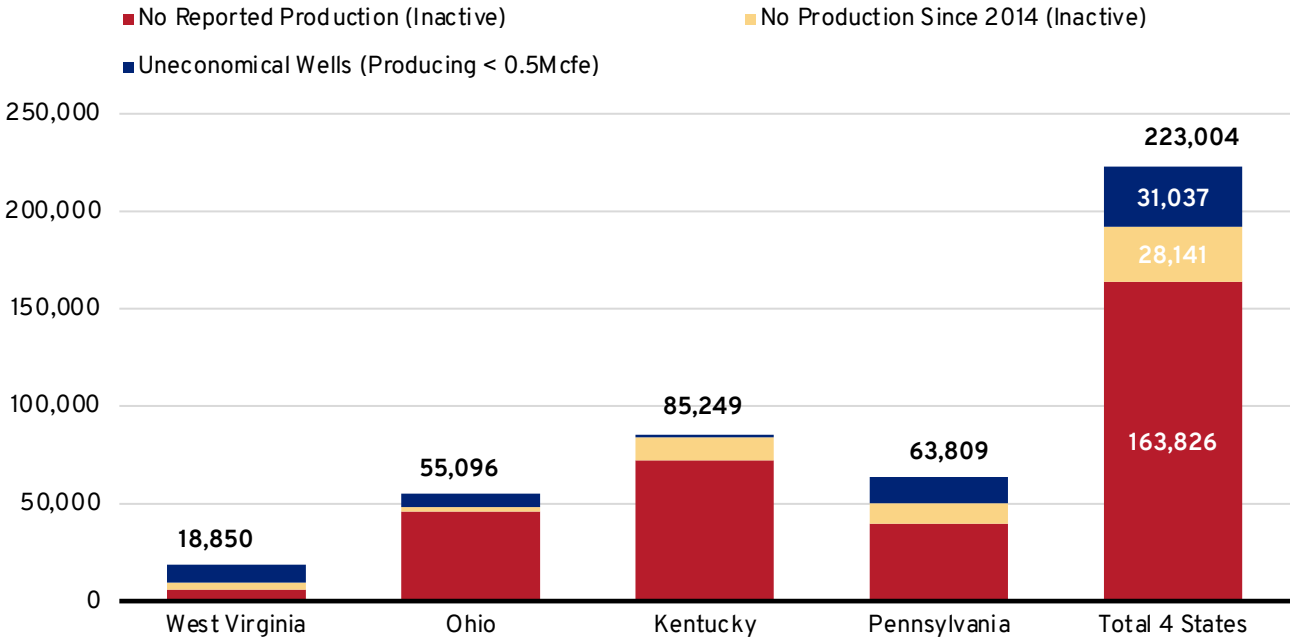
Figure 19: Historical Production Periods for Inactive Wells with Reported Production in Ohio River Valley States



Source: The Capitol Forum Upstream Database.
Note: *Inactive wells includes in-active, shut-in, abandoned, and orphaned wells*

Including the 30,300 inactive oil and gas wells with no production over the last five years along with the 164,000 inactive wells that had no reported production, approximately 194,000 wells in the four-state region are presumably uneconomical and should be decommissioned. An additional 31,000 ultra-low and uneconomical producing oil and gas stripper wells identified previously - those with a production threshold of less than 0.5 Mcfe per day – increases this amount to just above 223,000 wells.

Figure 20: Nearly a Quarter of a Million Wells in Ohio River Valley States Could Be Uneconomical



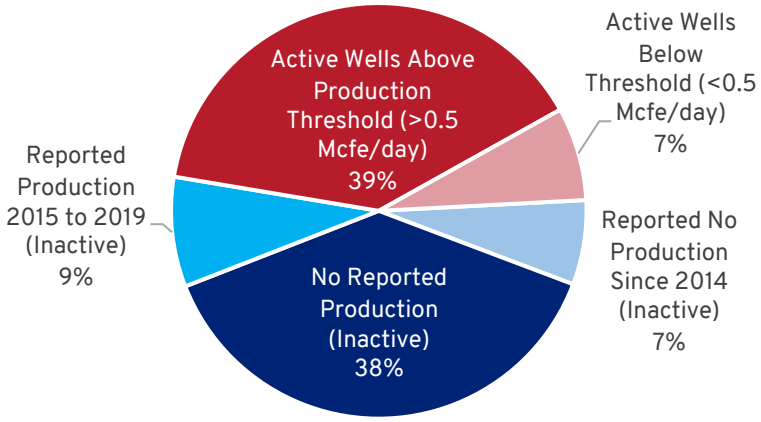
Source: The Capitol Forum Upstream Database.
Note: *Inactive wells includes in-active, shut-in, abandoned, and orphaned wells*

Figure 20 depicts the status of over 427,000 inactive and active wells in the four-state region. This includes approximately 198,000 active producing wells, including those producing above and below the "uneconomical" production threshold, and the 230,000 unplugged oil and gas wells that are inactive. Altogether, over 60 percent of these wells probably need to be decommissioned. If it is assumed that the wells with inactive status that produced oil and/or gas over the last five years (36,585) can be brought back into economical production, then more than half or 52 percent of these wells (223,000) probably need to be decommissioned.

Of wells owned by Diversified Energy, approximately 7,700 are inactive (abandoned, shut-in, inactive or orphan), and, of 53,000 active wells, about 3,800 are uneconomical or producing less than 0.5 Mcfe per day. Among the inactive wells with reported production (7,200), about 76 percent (5,450) produced oil or gas over the last five years while about 1,750 have not produced any oil or gas for more than five years. At a minimum, these 1,750 wells should be decommissioned, and arguably another 10,000 should be as well, if inactive and uneconomical wells are included.

These estimates do not include the hundreds of thousands of undocumented unplugged legacy wells in the region. According to a 2021 analysis by Mary Kang at McGill University and others, there could be an estimated 4 million abandoned oil and gas wells in the United States, including 410,000 in West Virginia, 610,000 in Pennsylvania, 183,000 in Ohio, and 115 000 in Kentucky.[75]

Figure 21: Less Than 40 Percent of Oil and Gas Wells in Ohio River Valley States are Economical



Source: The Capitol Forum Upstream Database.
Note: *Inactive wells includes in-active, shut-in, abandoned, and orphaned wells. Does not include permitted, not drilled, cancelled, plugged, or unidentified wells.*

Most of these abandoned wells are unplugged or improperly plugged legacy wells from the Appalachian oil boom in the late 1800s.

Operators of inactive or uneconomical producing wells have strong incentives to delay decommissioning their wells since it requires spending and generates no revenue. And because the bonding for these wells is just a tiny fraction of the cost to decommission them operators will sit on them for as long as possible. This is especially true since state policies implicitly treat inactive wells as though they all have future production potential and allow operators to indefinitely suspend operations.

If state regulators and stripper well operators are mistaken in their assumption that these wells will be restarted in the future, these policies are masking billions in potential liabilities as many operators could go bankrupt or go out of business. The result could be the creation of thousands of orphan wells, for which the state and taxpayers would have to absorb decommissioning costs. As a 2019 report from the US Government Accountability Office (GAO) notes, operator bankruptcies due to low oil and gas prices can lead to additional orphaned wells when defaulted bonds are inadequate to cover decommissioning costs.[76] For example, when Colorado-based PetroShare Corp. went out of businesses in 2020 many of its inactive wells were orphaned in the process.[i] While the state of Colorado seized $325,000 in bonds for the 53 orphaned wells and 58 orphan well sites, this only amounted to about $6,100 for each well, leaving the state to pay the rest. (The state estimates that the average plugging and clean-up cost to decommission a well to be about $93,000.) Another example is when Weatherly Oil and Gas, a Texas-based oil company, which filed for bankruptcy in 2019 left the state with 173 orphan wells, having only paid for a third of the cost to plug and clean up the sites.[77]

Section Six:
Conclusion and Recommendations

While all states require oil and gas operators to plug their wells, this often does not happen and enforcement – especially around idle wells that haven't produced for years – is poor. As the previous section showed, thousands of wells have not produced in years or have failed to report at all. On top of this, bonding coverage for oil and gas wells is just a tiny fraction of plugging costs. At the same time, stripper wells, – which account for over 90 percent of active wells in the four-state region – are producing 50 percent less gas than they did two decades ago, and many are likely to be uneconomical. The large growth in stripper wells in the region – over 40 percent – has been encouraged by tax subsides at the federal and state levels, which were mostly enacted when stripper wells commanded a larger share of domestic oil and gas production. In sum, this large growth in stripper wells, coupled with declining stripper well production and hundreds of thousands of inactive and uneconomical wells, presents significant risk to states.

Many of these stripper wells – along with nearly all abandoned wells – are at a high risk of becoming orphaned. The four states in the region already have over 28,500 documented orphaned wells – or over two-thirds of the nation's orphaned wells. There could be over one-million unplugged abandoned wells in the region. While the Infrastructure Investment and Jobs Act of 2021 potentially provide over $1 billion in funding for Ohio River Valley states to plug and remediate orphaned wells, it won't directly address the over $12 billion in unfunded liabilities associated with active wells.[78]

In our 2021 report, "Repairing the Damage from Hazardous Abandoned Oil & Gas Wells," we recommended the creation of a federal office similar to the Abandoned Mine Land program to address unplugged abandoned and orphan wells. This would include placing a small fee on oil and gas production to fund a plugging and reclamation program. This federal program would help close the gap between actual bonding coverage and the full costs to decommission the more than 1.2 million estimated unplugged abandoned wells, many of which are orphan wells or abandoned wells in the Ohio River Valley region.

If states don't want to be left "holding the bag," they should take several steps to prevent inactive, stripper, and other active wells from becoming orphaned. They could use federal orphan well funding to verify ownership of wells and create an inventory of wells that are "at risk" of becoming orphaned. But they would still need to enact significant bonding reform or a fee on gas production that would flow into a dedicated fund.

A 2021 report by the Western Organization of Resource Councils (WORC) outlined a comprehensive list of sound state policy recommendations to prevent orphan wells and ensure that companies pay for well and well site clean-up. These recommendations included ways for states to address insufficient bonding coverage, idle wells that are either at risk of being orphaned, orphan well clean-up, well transfers, and accountability and transparency within regulatory divisions. For example, WORC recommended the elimination of blanket bonds and suggested that all bonding amounts should be tied to the projected cost to plug and reclaim an operator's wells and associated sites.

One potential problem with tying bonding amounts or other financial assurances to decommissioning costs (i.e., full cost bonding) is that some operators – especially small ones with low producing wells – may not be able to obtain bonding because they do not have the reserves necessary to pay for plugging and reclamation.[79] For example, if an operator in West Virginia owns 100 gas wells and has a blanket bond of $25,000 but is then forced to obtain $3,000,000 in bonding (@$30,000 per well), they may be unable to secure the bond let alone have funds in reserve. Many operators could also go out of business or file bankruptcy because of full-cost bonding, which could result in an avalanche of wells being orphaned and made wards of the state.

The Orphan Well Prevention Act

Instead of making significant changes to financial assurances regimes, states could require a fee on production that is set aside in an account to pay for plugging and reclaiming well sites. This could also include provisions that require operators to set aside monies before they transfer wells or apply for new well permits. One model for this is the "Orphan Well Prevention Act of 2021," which was introduced in the West Virginia House of Delegates.[80] The legislation requires operators that have wells producing in sufficient quantities (above 60 Mcf/Day) to pay 15 cents per Mcf into an interest-bearing escrow account that would be used to plug wells and reclaim well sites. The set aside plugging funds can be paid to an entity, or to the operator, if the chief of the Office of Oil and Gas certifies that the well has been plugged to state standards.

The bill also requires operators to set aside plugging funds in the escrow account before any new well permit is issued and requires that any operator that has unplugged wells that have not produced for 12 months to set aside money in the escrow account for those unplugged wells. In addition, the bill requires that any wells that are transferred from one operator to another be accompanied by funds for plugging the wells. These funds would be deposited in an escrow account before the wells can be transferred. The bill also requires previous operators of wells that became hazardous (e.g., leaking methane or brine) during the time when they were owners, to plug these wells.

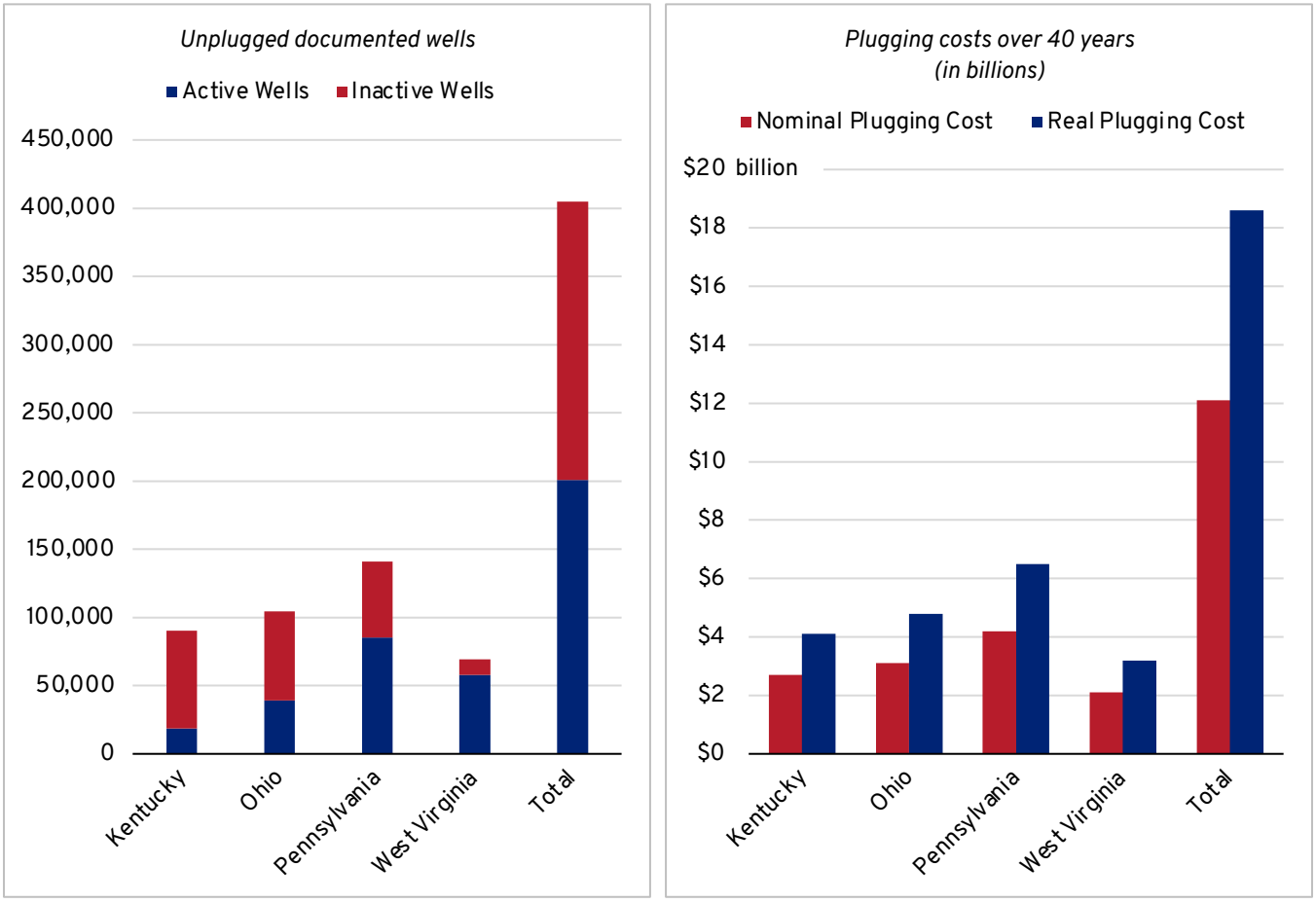
The theory behind the Orphan Well Prevention Act is that the current bonding system and other regulatory requirements has failed, resulting in thousands of orphan wells and thousands of zombie wells that are in a "slow-motion" process of becoming orphaned.[81] And because stripper wells make up a large share of the wells but only a small share of production value, the only way to pay for plugging and reclamation is for nonstripper wells to pay for most of the plugging and reclamation costs. This is similar to the federal Abandoned Mine Land Fund, which assesses a small per ton fee on current coal production to pay for abandoned mines before 1977.

Modeling the Orphan Well Prevention Act in the Four-State Region

Using the Orphan Well Prevention Act as a model, this section sketches out a plan to plug and reclaim the unplugged documented wells on the estimated production fee required for each state to plug these wells. There are an estimated 405,000 unplugged wells in the four states, including 201,000 active wells and 204,000 inactive wells (inactive, abandoned, and shut-in). Using a very conservative average plugging and well reclamation cost of $30,000 per well, it would cost an estimated $12.1 billion to decommission the 405,000 wells without adjusting for inflation.

Figure 22 on the following page develops a time horizon for plugging and reclaiming these well sites over a 40-year period. Assuming 2 percent average annual inflation and that the 405,000 wells would be plugged over a 40-year time horizon, with a five-year scaling up period from 2022 to 2026, the total cost would be about $18.6 billion. This includes a cost of $3.2 billion in West Virginia, $4.1 billion in Kentucky, $4.8 billion in Ohio, and $6.5 billion in Pennsylvania. Developing a large-scale plugging program in these states that includes large contracts and expansion of the industry would potentially lower plugging costs. However, these figures use a very conservative estimate for plugging costs. Horizontal wells, especially deep high-volume shale wells, would cost considerably more – perhaps double the costs of plugging conventional wells.

Figure 22: Unplugged Wells and Estimated Plugging Costs in Ohio River Valley States

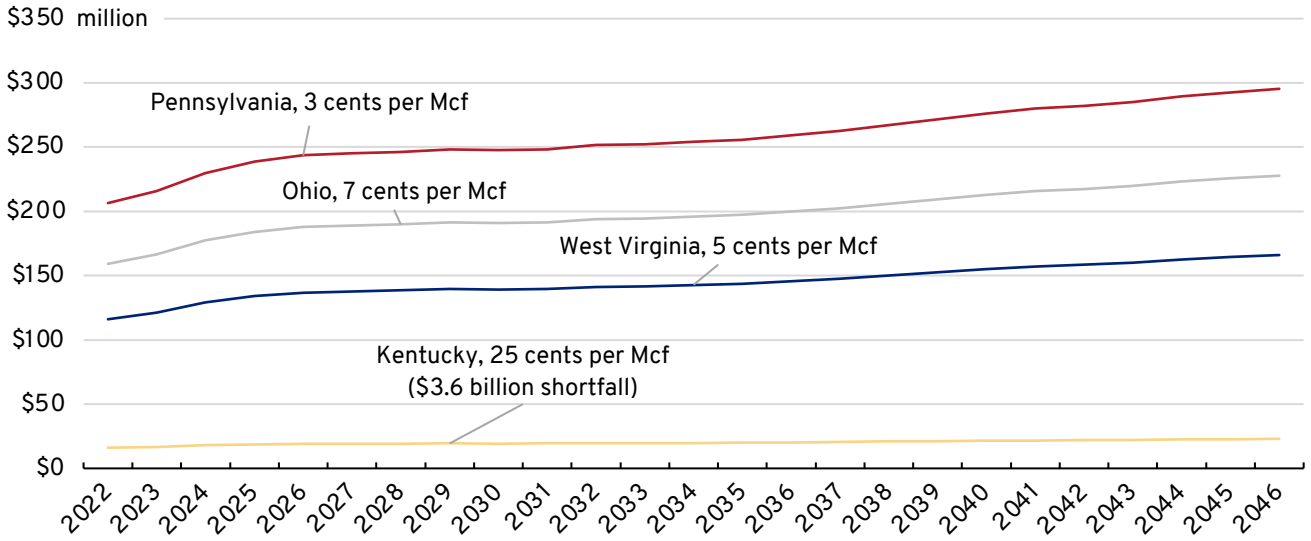


Source: The Capitol Forum Upstream Database.
Note: *Inactive wells includes in-active, shut-in, abandoned, and orphaned wells. Does not include permitted, not drilled, cancelled, plugged or unidentified wells. Well plugging cost is assumed to be $30,000 per well. Expected inflation rate of 2 percent per annum.*

Estimating the requisite Mcf fee for each state requires estimating future natural gas production. According to the U.S. Energy and Information Administration's 2021 Annual Energy Outlook, dry natural gas production in eastern states is expected to grow from 11.7 trillion cubic feet (Tcf) in 2022 to 17.7 Tcf by 2050. In 2020, the four-states in the Ohio River Valley region comprised 98.5 percent of all eastern region gas production. Pennsylvania made up 58.7 percent (7 Tcf), West Virginia 19.8 percent (2.4 Tcf), Ohio 19.4 percent (2.3 Tcf), and Kentucky 0.6 percent (0.7 Tcf). Total dry natural gas production is expected to grow from 11.5 Tcf in 2022 to 17.5 Tcf by 2050 in the four-state region.

Based on these estimates, and assuming revenue collections from a per Mcf fee are carried out over a 25-year period from 2022 to 2046, the required fee per Mcf is 3 cents per Mcf in Pennsylvania, 5 cents per Mcf in West Virginia, and 7 cents per Mcf in Ohio. Kentucky is not included in the analysis because even a sizable per Mcf fee would not close the gap in funds and plugging costs. For example, a 25 cents per Mcf fee in Kentucky would only provide an estimated $500 million over 25 years or just 12 percent of anticipated plugging costs. Kentucky will need to consider using an Mcf fee combined with additional state revenues to meet its plugging obligations.

Figure 22: Estimated Annual Revenue from Mcf Fee for Ohio River Valley States to Meet Plugging Needs



Source: ORVI analysis of US Energy Information Administration data

These estimates do not consider the impact of putting plugging funds in an interest-bearing account. If plugging funds are put into an interest-bearing account, the plugging costs could be considerably lower depending on the timing of revenue and disbursements and the investment rate of return. It is also important to consider that the projected natural gas production from the EIA may be overly optimistic, especially since more utilities are moving toward renewable energy to meet carbon reduction goals.[82] If the United States can achieve net-zero carbon emissions by 2050, some analysis finds that natural gas production will have to decline between 25 and 85 percent over this period.[83] This means that there may be a narrow period available for states to hold the industry accountable for plugging wells. Otherwise, states could have to resort to finding revenue from other sources.

Endnotes

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64. According to the August 2021 Investor Presentation (https://d1io3yog0oux5.cloudfront.net/_8106d09f8f7cc0cf3a77698af30efe95/dgoc/db/562/4513/pdf/DEC+Investor+Presentation+August+2021.pdf), the base lease operating expense was $2.53 per BOE or $0.42 per Mcfe in FY 2020. Total production in FY 2020 was 36,538 Mboe or 219,228,000 Mcfe. According to the August 2021 Asset Retirement Supplement Presentation (https://d1io3yog0oux5.cloudfront.net/_8106d09f8f7cc0cf3a77698af30efe95/dgoc/db/562/4383/pdf/DEC_Asset_Retirement_Supplement.pdf), the company has a total of 69,000 wells. This equates to an average annual production of 3,177 Mcfe per well in 2020. Multiplying annual average production per well (3,177 Mcfe) by the base lease operating expense of $0.42 per Mcfe equals $1,340 in base lease operating expenses per well, $453 higher than the estimate used in the study.

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