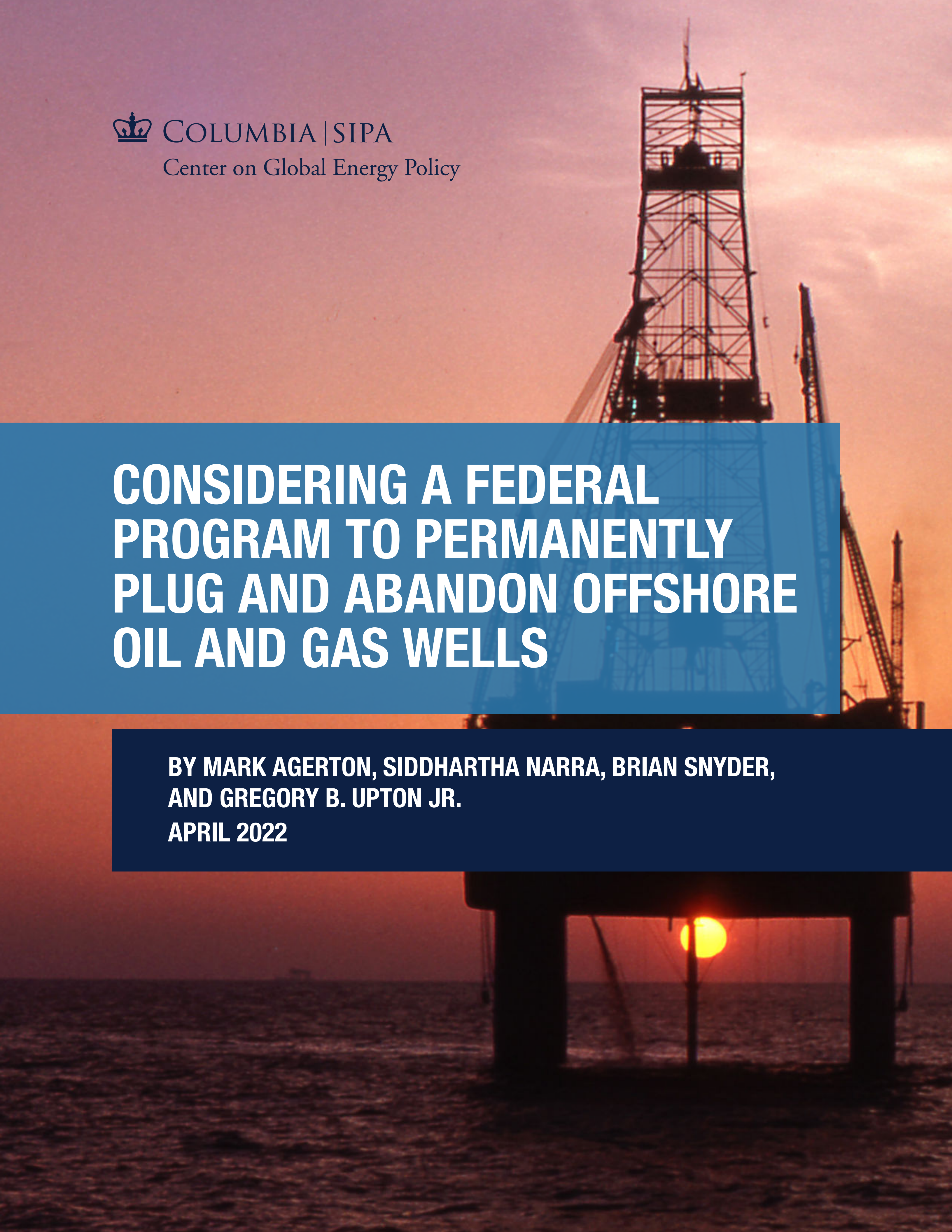

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CONSIDERING A FEDERAL PROGRAM TO PERMANENTLY PLUG AND ABANDON OFFSHORE OIL AND GAS WELLS

BY MARK AGERTON, SIDDHARTHA NARRA, BRIAN SNYDER, AND GREGORY B. UPTON JR.

APRIL 2022

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Cover Source: Photograph from Lynda Miller (MillerLy122), Offshore Oil and Gas History Project, 2001.

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EXECUTIVE SUMMARY

Failure to properly plug and abandon (P&A) oil and gas wells in the United States at the end of their useful life can impose environmental costs and saddle taxpayers with cleanup liabilities. In recent years, US policy makers have expressed increasing concern about P&A issues, especially when it comes to "orphan" wells—oil and natural gas wells, either onshore or in state waters, for which no viable private company with legal responsibility exists. Prior studies of orphan wells have primarily focused on onshore wells, likely because they vastly outnumber offshore wells. But offshore wells have particular features that warrant careful study on their own: they tend to produce more, involve additional environmental and engineering considerations, and cost more to P&A.

This report, part of an oil and gas research initiative at Columbia University's Center on Global Energy Policy, examines offshore P&A liabilities to provide guidance to federal policy makers about the scope of a hypothetical government program to plug and abandon offshore wells. At least three objectives might shape the contours of such a policy: 1) reducing taxpayers' future financial P&A liability for orphan wells, 2) reducing environmental risk, and 3) preserving or increasing employment alongside goals to reduce greenhouse gas emissions globally.

As of the end of 2020, approximately 22,000 offshore oil and gas wells in the United States were not permanently P&Aed. The authors estimate that the cost to P&A all of these wells, including wells that are currently producing, is approximately $47 billion. It should be noted that significant uncertainty remains around aggregate costs, because estimates rely on having accurate information from state and federal well databases as to the number and location of offshore wells as well as average P&A costs per well.

Additional findings from the report include the following:

- Because the literature suggests that leaks from wells at shallower depths and closer to shore present greater environmental risks than releases from more remote wells, and because P&A costs increase dramatically with water depth, the ratio of environmental benefits to financial costs is likely to be more favorable for wells nearer to shore.
- The authors identify a set of inactive wells in shallow waters not likely to re-enter production that could be candidates for a federal P&A program. The P&A costs associated with these wells is estimated at $8.3 billion.
- P&Aing these wells could support approximately 10,500 jobs per year over a 10-year period.
- This P&A activity is unlikely to significantly reduce the supply of oil and gas because these wells are not producing commercial quantities of hydrocarbons.
- Federal stimulus has allocated $4.7 billion to address orphan wells; the majority of this funding will likely be used to P&A wells. Some of the funding could be used by states to update orphan well lists. Identifying such wells and better understanding the financial liability surrounding them could help reduce uncertainty around aggregate P&A costs.

INTRODUCTION

Over the past century and a half, over 4.5 million oil and gas wells have been drilled in the United States.[1] Of these, about 100,000—less than 2.5 percent—have been drilled offshore or in coastal waters.[2] Once a well has reached the end of its life, federal and state guidelines require that the well be plugged and abandoned (P&Aed). Specific requirements vary across jurisdictions and have changed over time. P&Aing a well is intended to permanently ensure that hydrocarbons or other gases and fluids do not escape from the wellbore into the water or atmosphere.[3]

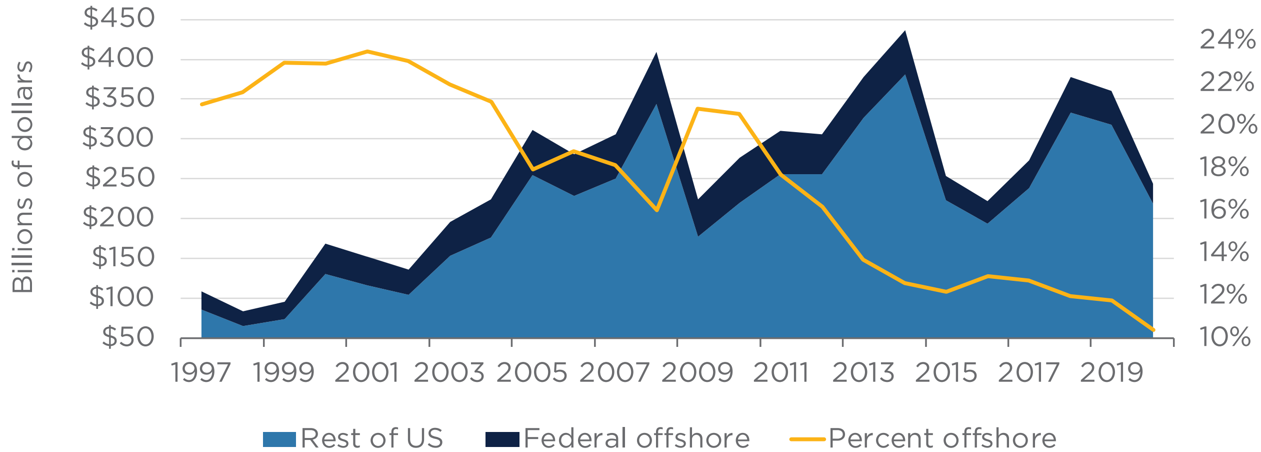
P&Aing orphaned and idle wells may represent an opportunity to reduce greenhouse gas emissions and support jobs for workers in the oil and gas sector without significantly reducing the supply of hydrocarbons. There are at least three objectives that policy makers might try to achieve with such a program: (1) reduce taxpayers' future financial P&A liability for orphaned wells, (2) reduce environmental risk, and (3) preserve or increase employment during the energy transition. The authors aim to provide guidance on how a hypothetical government program to P&A offshore wells might pursue these. Orphaned and inactive wells have become an increasing policy concern in recent years. Orphaned wells are oil and natural gas wells, either onshore or in state waters, for which the state government has officially assumed P&A liability. The government assumes P&A liability for these wells because no financially viable private company with the legal responsibility for these wells exists (Interstate Oil and Gas Compact Commission 2019, 2020, 2021). For instance, if a company goes bankrupt and is unable to fulfill its P&A obligations, the state might then declare the company's wells as orphaned and include them in an official list of documented orphaned wells.[4] When surety bonds are insufficient to cover P&A costs of orphaned wells, taxpayers are likely to end up footing the bill.

Bankruptcy is a frequent cause of wells becoming orphaned. When oil prices collapsed in late 2014 and again in 2020, many exploration and production (E&P) companies experienced financial distress. Since 2015, an estimated 250 E&P firms have filed for bankruptcy (Haynes Boone 2021). P&A policies and bonding requirements[5] can influence the risk that wells become orphaned when oil and gas companies go bankrupt. For example, Boomhower (2019) examines a policy change in Texas that reduced firms' ability to avoid liability through bankruptcy. He finds that oil and gas production was reallocated to larger firms with better environmental records.

States have tracked orphaned wells for decades. As of December 2020, there were 92,000 documented, officially orphaned wells—both onshore and offshore—that have not been P&Aed (Interstate Oil and Gas Compact Commission 2021). Each year, states designate more wells as orphaned. According to the Interstate Oil and Gas Compact Commission (IOGCC), the number of documented orphan wells has increased in recent years due primarily to the efforts of states to identify and document orphan wells.

Less attention has been paid to P&A liabilities offshore than onshore. While less than 2.5 percent of all wells drilled in the United States have been drilled offshore or in coastal waters, approximately 15 percent of US oil and gas production comes from federal offshore waters alone, with state offshore production adding to that total (see Figure 1).[6]

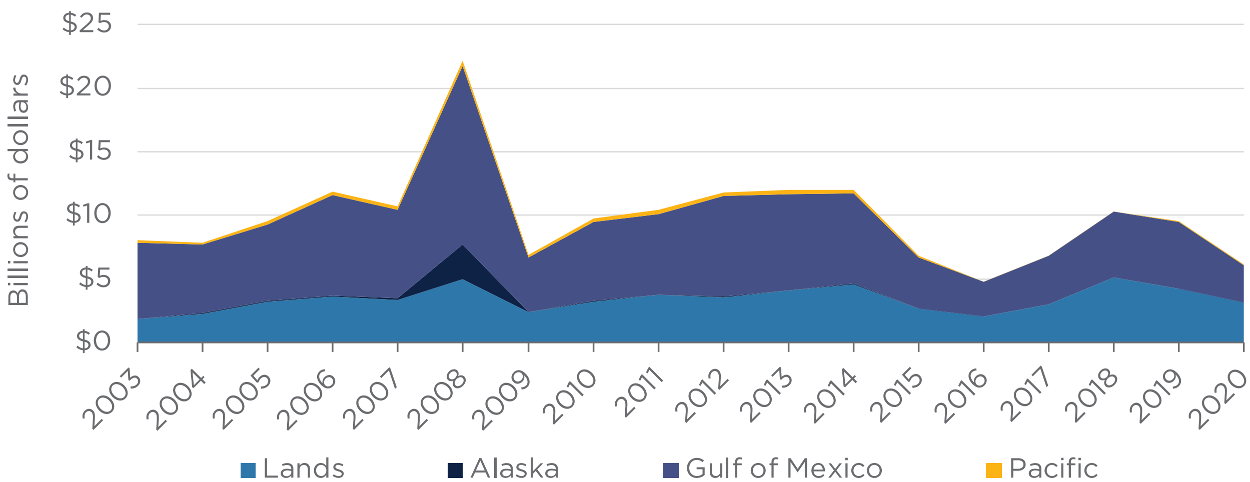
Figure 1: Federal offshore value of production in context



Source: US Energy Information Administration (Natural Gas Withdrawals and Production, Field Production of Crude Oil, WTI Spot Prices, Henry Hub Natural Gas Spot Price); authors' calculations.

Offshore production is a significant contributor to federal revenue. Since 2003 (when the data begins), the federal government has received more than $116 billion in royalty payments from oil and gas produced offshore in federal waters. This represents 65 percent of all federal oil and gas revenues (see Figure 2).[7]

Figure 2: Federal government revenues from oil and gas



Source: US Department of the Interior Natural Resources Revenue Data; authors' calculations.

P&Aing offshore wells is more expensive than P&Aing onshore wells. Based on IOGCC (2019) figures, Raimi et al. (2020) assume that the P&A cost per onshore well is $24,000–$48,000 per well.[8] In contrast, the median Bureau of Safety and Environmental Enforcement (BSEE) P&A cost estimate for deepwater offshore wells is $1,200 per *foot*. Many offshore wells are more than 20,000 feet long, and the costs to P&A a well in deep waters can easily exceed $20 million. Though there are fewer wells offshore than onshore, the offshore P&A liability could still be sizable due to the fact that oil and gas activity offshore is generally more costly than onshore activity.

Current Policy

Current policy discussion around oil and gas extraction is characterized by a tension between at least three objectives: keeping energy costs low, reducing greenhouse gas emissions and the risk of hydrocarbon releases, and preserving or increasing employment. Employment for workers in these sectors during the often referred to "energy transition" is of particular interest as policy makers push for more stringent climate policies. P&Aing orphaned and idle wells may represent an opportunity to reduce greenhouse gas emissions and support jobs for workers in the oil and gas sector without significantly reducing the supply of hydrocarbons.

President Biden's January 2021 "Executive Order on Tackling the Climate Crisis at Home and Abroad"[9] simultaneously called for "plugging leaks in oil and gas wells" and directed the Secretary of the Interior to "pause new oil and natural gas leases on public lands or in offshore waters pending completion of a comprehensive review and reconsideration of federal oil and gas permitting and leasing practices."[10] The pause on federal leasing generated protest from the oil and gas industry and states with significant oil and gas activity on federal lands and waters.[11] In November 2021, a Gulf of Mexico lease sale was conducted. However, in January 2022, a federal judge canceled the leases and argued that the potential climate impacts of the leases were not taken into account. At the time of this writing, the future of offshore leasing is uncertain. If leasing is discontinued, or additional regulatory costs are imposed on oil and gas firms operating in offshore areas, offshore oil and gas employment may decrease. Federal support for offshore P&A activity could be an avenue to support offshore oil and gas workers.

Cleanup of orphaned wells has also been prioritized in the just-passed Infrastructure Investment and Jobs Act. The Act includes $4.7 billion to clean up orphaned oil and gas wells on federal lands.[12] In January 2022, the US Department of the Interior announced $1.15 billion in funding for states from the Act to "create jobs cleaning up orphaned oil and gas wells across the country."[13] The availability of additional funding for P&Aing orphaned wells may prompt states to expand their orphaned well lists.

Oil and gas activity has over a century of history in the United States, and state governments have become increasingly concerned about the financial and environmental liability they may face from orphaned and idle wells. Louisiana, the state for which the authors identify the most offshore P&A candidates, has been grappling with the liability of orphaned wells for many years. The Louisiana Oilfield Site Restoration Program was created in 1993 within the Department of Natural Resources to address orphaned oil field sites across the state. The program is funded by a fee on oil and gas production and generates approximately $4 million in revenue per year. Despite efforts to plug orphaned wells, the inventory of orphaned wells in Louisiana has increased by over 50 percent since the 2014 oil price crash and currently includes more than 4,600 wells. Offshore wells make up a small part of this list, and to date only four have been P&Aed through the orphan well fund.[14] Policy makers have cited the higher cost of offshore P&Aing as the reason for focusing on onshore wells.[15]

In Texas, the state for which the authors identify the second most offshore P&A candidates, the Railroad Commission of Texas (RRC) has a long-running orphaned well plugging program. As of November 2021, the RRC identified roughly 7,500 current orphaned oil and gas wells that have not been permanently P&Aed, more than 1,000 higher than the number in 2018. Of these, approximately 320 Texas orphaned wells are offshore. The Oil and Gas Regulation and Cleanup Fund was created in Texas in 2011 and is funded through regulatory and permitting fees paid by the oil and gas industry. In fiscal year 2020, the RRC spent approximately $50 million from this fund on oil field cleanup activities, which include P&A activity as well as removing tank batteries, flow lines, and other surface equipment from the site. Very few offshore wells have been P&Aed using this fund.

The federal government does not have an orphaned well list in federal waters, nor is there an equivalent program for P&Aing potential orphaned wells. The authors speculate that the absence of orphaned wells in federal waters may stem from the fact that in federal waters, cleanup liability reverts to prior owners if the current owner goes bankrupt.[16]

Industry Background

A review of basic relevant industry terminology may be helpful to readers unfamiliar with the oil and gas industry and P&A work specifically. Discussion is based on Raymond and Leffler (2006) and Hyne (2012), as well as the authors' general knowledge and discussions with industry.

When oil and gas extraction ceases on a site, the site must be decommissioned. One component of decommissioning involves *plugging and abandoning* (P&Aing) all wellbores on the site. The other component involves decommissioning any platforms or pipelines. Decommissioning offshore wells and infrastructure is important for reducing navigation hazards and various environmental and safety risks. In this analysis, the authors focus on only the P&Aing wells, not decommissioning of platforms, pipelines, or other infrastructure.[17]

After a well has produced to the point that it is no longer economical, or damage has occurred to the well such that it is uneconomical to repair, the well should be properly plugged and abandoned. This is required by law, both onshore and offshore, and in state and federal jurisdictions. In federal waters, leases expire one year after production ends, and the operator is required to complete P&A and decommissioning work one year after the lease expires. Thus, in federal waters, companies have two years from when production ceases to complete the cleanup work.

Proper P&Aing is designed to prevent underground salt water from polluting fresh groundwater reservoirs and to prevent leakage of hydrocarbons or other substances from the wellbore over time. When a well is P&Aed, depleted reservoirs are sealed by placing cement plugs in the wellbore. The upper portion of the well adjacent to the freshwater reservoir is also cemented. Typically, the well casing is then cut six feet below the surface of the seafloor (or land for onshore wells), and the surface hole is filled with the surrounding sand or dirt. Offshore, this prevents the well from being a navigation hazard.

As well depth increases, P&A costs increase. Deeper wells require more cement and more time to P&A. Deeper wells are also characterized by higher reservoir temperatures and pressures. These, in turn, mean more powerful equipment is required to pump thicker and more expensive cement that will withstand the additional temperature and pressure. Thus, as with drilling and completion, the P&A cost *per foot* of well depth can increase significantly as the well depth increases. The impact of well depth on P&A costs is accounted for in this analysis.

Instead of permanently P&Aing a well, companies can also temporarily plug a well. When a well is temporarily plugged, it can then be reentered to continue production or used as an injection well. This is often done when new exploratory wells are waiting on appropriate surface and subsea facilities to be installed. The authors show that there are many wells that have been temporarily plugged for years. Although market conditions (such as oil and gas prices) might prompt a company to reenter a well, the probability of reentry likely declines as time progresses.

PRIOR LITERATURE

The Interstate Oil and Gas Compact Commission (IOGCC) tracks onshore and offshore wells designated as orphans by 31 states—the majority if not all states with such wells (Interstate Oil and Gas Compact Commission 2019, 2020, 2021). In 2020, the Commission identified 92,000 orphan wells, both onshore and offshore, across these states. Of these, around 13,500 were located within the coastal states analyzed in this report (Alabama, California, Louisiana, Mississippi, and Texas).

Number and Types of Wells

Studies of P&A liability beyond officially designated orphaned wells have generally focused on onshore wells, identifying a much larger universe of wells that are at risk of becoming taxpayer P&A liabilities in the future. However, there is significant uncertainty about how large this liability will be. Raimi et al. (2020) focus on onshore orphaned and abandoned wells in the US,[18] estimating a wide range for the number of wells at high risk of being orphaned: several hundred thousand to 3 million. Citing a P&A cost of \$24,000–\$48,000 per well from IOGCC (2019, 2020), Raimi et al. calculate that P&A liability for 500,000 wells could plausibly be between \$12 billion and \$24 billion. Kang et al. (2021) find at least 116,000 wells across 32 states and four Canadian provinces/territories that are operated by companies that filed for bankruptcy in the first half of 2020. That study highlights that three in five wells ever drilled in the United States are currently inactive, but only one in three are permanently P&Aed. Boomhower et al. (2018) analyze idle oil and gas wells in California, primarily onshore. Of the 107,000 oil and gas wells in California—both active and idle—they find that 5,540 wells may already have no viable operator or be at high risk of becoming orphaned in the near future. The estimated future financial liability to taxpayers for these 5,540 wells is approximately \$500 million.[19] A number of other studies have focused on P&A liability in specific areas (Dachis et al. 2017; Kang et al. 2016, 2019; Andersen et al. 2009; Cook 2019; Gardner 2021).

None of these studies, however, focuses on offshore wells. This may be because the data sources and cost structure are different for onshore and offshore wells. As the authors show in this paper, offshore P&A liabilities are much larger per well relative to the onshore case and should therefore be estimated separately from onshore wells.

Environmental Costs of Coastal versus Deepwater Oil and Gas Releases

One rationale for ensuring that wells are properly P&Aed is the environmental risks presented by unplugged idle wells. Alboiu and Walker (2019), Pekney et al. (2018), and Ide et al. (2006) study the environmental risks of onshore unplugged and orphaned wells. Onshore environmental risks, however, are different from offshore risks. And while environmental risks presented by offshore wells vary by depth, they also vary across space. The fate of spilled or leaked oil and gas is different in the shallow, nearshore versus deepwater environment.

Oil Spills

Given similar volumes, initial toxicities, and probabilities of oil spills at nearshore and far offshore sites, the environmental damages of nearshore spills are often greater than those farther from shore—for biochemical and ecological reasons—and are largely related to the amount of time the leaked oil is exposed to environmental conditions.

Biochemically, oil spilled farther from shore has more time to degrade through evaporation, photochemical reactions, and bacterial respiration before it reaches the shore (a process called weathering), and it has a greater opportunity to be diluted by ocean currents than oil released closer to shore. Much of the work on this process has been done in the wake of the 2010 Macondo spill that resulted from the Deepwater Horizon blowout in the Gulf of Mexico and created the largest oil spill in history. Finch et al. (2017) studied the toxicity of weathered versus fresh Macondo crude oils on shrimp and fish and found higher toxicity in the fresh oil samples, likely due to higher levels of polycyclic aromatic hydrocarbons (PAHs) in fresh oils. Stefansson et al. (2016) found similar results with echinoderm and bivalve larvae. Faksness et al. (2015) studied weathered and fresh Macondo oil toxicity on algae and copepods and found the fresh oil to be more toxic and to have higher concentrations of aromatics like BTEX (benzene, toluene, ethylbenzene, and xylene) along with PAHs. BTEX and PAHs are known to be mutagenic and cardiotoxic (Martínez-Gómez et al. 2010) and are more soluble in water than other oil compounds (Lin and Mendelssohn 2012). However, PAHs and BTEX are also relatively volatile and evaporate quickly. This evaporation is thought to reduce oil toxicity (Heintz et al. 1999; Esbaugh et al. 2016). In sum, given a choice between oil spilled far from shore and oil spilled near the shore, and assuming all else is equal, oil spilled further from shore would be expected to be less toxic to marine and coastal ecosystems.

From an ecologic perspective, relative to coastal ecosystems the open ocean has low net primary production and biodiversity per unit area; thus, all else equal, a barrel of oil spilled in a coastal system would be expected to have greater ecological impacts than the same barrel spilled some distance from shore. This is especially true for the Northern Gulf Coast, which is dominated by wetlands. Wetland plants are sensitive to toxicity and smothering from crude (Anderson and Hess 2012; Lin and Mendelssohn 2012). Sensitivity to toxicity is determined by the plant species and the toxicity of the crude. Salt marsh plants that form the coast of the Northern Gulf of Mexico are especially susceptible (Pezeshki and Delaune 2015), and Louisiana Light Crude is more toxic than heavier crudes found elsewhere due to the higher proportion of lighter and more soluble and toxic hydrocarbons (Mendelssohn et al. 2012). As a result, allowing oils time to weather before impacting the coast lowers environmental risk.

Smothering by oil is determined by the amount of oil and the number of times an area is oiled during an event. Many wetland plants are perennials and can regrow from roots following oil damage to leaves and shoots, but heavy oiling that impacts soils can lead to longer-term damage (Mendelssohn et al. 2012). This also implies that spills farther offshore generally present lower environmental risk. Spills farther offshore are likely to disperse more, impacting a larger area with lighter and less impactful oiling. A nearshore, coastal spill is more likely to produce a more concentrated oiling in a smaller geographic area. Similarly, in the case of Macondo, a significant fraction (4 to 31 percent) of the oil stayed in the deepwater environment (Valentine et al. 2014), raining out onto the ocean floor (Passow and Stout 2020).[20] While this oil has had environmental impacts on deepwater ecosystems (White et al. 2012; Montagna et al. 2013), the sequestration of oil in the deep water may have also prevented oiling of coastal systems.

Gas Leaks

There are also significant differences between shallow and deepwater releases of methane, ethane, and propane. During the Macondo spill, the majority of methane is thought to have remained in deep water and not reached the surface (Joye et al. 2014). Instead, methane along with ethane and propane were either dissolved and metabolized by bacteria (Crespo-Medina et al. 2014; Valentine et al. 2010; Römer et al. 2019) or stabilized as gas hydrates. In contrast, methane leaks from shallow water infrastructure, including from temporarily abandoned platforms, could be a significant emissions source. There is emerging literature on methane leaks from offshore facilities (Negron et al. 2020; Yacovitch et al. 2020), but to date no study has compared active to temporarily abandoned facilities (see Böttner et al. 2020). Given that onshore abandoned and orphan wells are thought to be important methane sources (Kang et al. 2014; Lebel et al. 2020; Williams et al. 2021), it is plausible that leaks from shallow water wells, but not deepwater wells, would result in the release of greenhouse gases into the atmosphere.

METHODOLOGY

In this analysis, the authors assess a potential policy aimed at stimulating offshore P&A activity focused on wells that are already orphaned or are more likely to become orphaned in the future. While any well—active or not—could potentially become orphaned at some point, wells that are *inactive* may be more likely to become orphaned. Inactive wells (sometimes referred to as *idle* wells) are those that are no longer in use for production of hydrocarbons, injection, or other purposes but have yet to be P&Aed. These wells may be good P&A candidates, as they are less likely to have an economic purpose in the future and more likely to become taxpayer liabilities.

There are at least three objectives that policy makers might try to achieve with such a program: (1) reduce taxpayers' future financial P&A liability for orphaned wells, (2) reduce environmental risk, and (3) preserve or increase employment during the energy transition. The authors aim to provide guidance on how a hypothetical government program to P&A offshore wells might pursue these.

The first empirical goal is to identify the inactive offshore wells that are plausible candidates for P&Aing. We assemble a list of all domestic offshore wells in both federal and state waters for the continental US.[21] Then we identify P&A candidate wells as those that have not produced in five years, are temporarily plugged, or are on inactive federal leases.[22]

The second empirical goal is to estimate the cost of P&Aing these different groups of wells. The Bureau of Safety and Environmental Enforcement (BSEE) provides a public database of P&A cost estimates for a subset of federal offshore wells. We extrapolate these cost estimates to other federal and state wells based on the characteristics of each well.

The authors find that while wells in the deep, federal, offshore waters represent the largest total P&A cost, wells in shallower federal waters and state waters are more likely to be inactive. These shallow water wells are also less expensive to P&A compared to the generally deeper wells in federal waters.

Finally, we estimate the economic impacts of completing offshore P&A activity.

Data

The authors compile a comprehensive data set of offshore wells in the federal Gulf of Mexico and federal Pacific Ocean and wells in the state waters of Louisiana, Texas, California, Mississippi, and Alabama.[23] We define *state waters* as inland waters that lie within a state's coastal zone plus state waters outside of the officially designated United States coastline. Our definition of inland waters includes areas in open water but also includes areas such as wetlands. There is little practical difference in P&Aing wells on the margins of inland waters and in state offshore waters, so we group these two categories together for purposes of cost modeling.[24]

We obtain data on federal offshore wells and their historical production from the BSEE. We also obtain data on the historical ownership of all federal offshore leases from BSEE, as well as estimated P&A costs for federal offshore wells. We obtain data on state offshore wells from individual state agencies, and merge this with historical production data from Enverus (previously DrillingInfo).[25] We use well classifications as reported to state and federal agencies, alongside historical production data, to identify inactive wells that may be at higher risk of becoming orphaned. In instances where a well status is not listed from the state or federal agency, data from Enverus is used to inform the decision. We note that older wells are more likely to have incomplete records. Thus, the authors urge the reader to interpret statistics in this report as estimates; the actual well counts and measured depths may differ. Nevertheless, the authors believe that the data assembled is sufficient for obtaining a reasonable estimate of the aggregate P&A liability.

The depth of a well is a key determinant of its P&A cost, but two different challenges arise in determining the depth of certain wells. First, public records do not provide a measured depth for a few wells, especially older ones.[26] For these cases, we input the well's depth with the measured depth of the closest neighbor well. In 95 percent of cases, the neighbor well is less than one kilometer away, and in half of cases, it is less than 0.01 kilometers away. Second, many federal wells have secondary wellbores called *sidetracks*. Sidetracks are additional wellbores that branch off the initial well, often several thousand feet down. Thus, one well can have multiple *wellbores* (also referred to as *boreholes*). There can be multiple boreholes in a single well.[27] In federal waters, measured depth is reported for each sidetrack. Simply summing the measured depth of each sidetrack within a well will double count the common, shallower portion of the well and significantly overestimate the number of feet that must be P&Aed. To avoid double counting, we consider only the incremental length that a sidetrack adds to a well when modeling P&A costs. Specifically, we measure this incremental distance as a sidetrack's measured depth less its kickoff point.[28] The authors find that, on average, the incremental distance of a sidetrack is approximately 39 percent of its full measured depth. For instances in which a sidetrack's kickoff point is not reported, we assume the length of the sidetrack is 39 percent of the listed measured depth.

As discussed, some state governments have programs that pay to P&A wells the state determines are orphaned. The authors obtained records on the actual costs incurred to P&A orphaned wells from the relevant government agencies in Louisiana, Texas, and California. However, very few of the wells that had been P&Aed were offshore. Wells in Louisiana state waters make up the majority of total state water wells, and yet only four offshore wells were P&Aed with the state's orphan well fund. Because so little P&A cost data is available for wells in state waters, we choose to use state orphan well P&A cost records as external validity checks of the reasonableness of our cost estimates rather than using them to estimate P&A costs.

The authors note that their analysis focuses exclusively on *documented* wells that are cataloged in state and federal databases. It is possible that undocumented, unplugged offshore wells exist. These are likely to be older wells.

SUMMARY STATISTICS

Table 1 presents the total number of boreholes and wells drilled within federal or state waters that are documented in public databases.[29] Panel A differentiates wells by their location: *federal deepwater* wells in water depths greater than 1,000 feet; *federal shallow water* wells in water depths less than 1,000 feet; wells in *state offshore areas*; and wells in *state inland waters*.

Of the approximately 86,000 wells (103,000 boreholes), approximately 56 percent (and 46 percent, respectively) have been drilled in state waters, with the remainder in federal waters. Note that no individual boreholes were reported in state waters, so there is only a distinction between wells and boreholes in federal waters. The authors also highlight that of the offshore wells in state waters, over two-thirds have been drilled in what states designate as inland waters.

In panel B of Table 1, we differentiate boreholes and wells by their status.[30] Of the approximately 86,000 wells ever drilled, about 77 percent have been permanently plugged and abandoned. Less than 10 percent are either currently listed as active or being used for active injection. Thus, the remaining approximately 12,000 wells are plausible candidates for P&Aing at this time.

Table 1: Borehole and well counts

	1	2
	Borehole count	**Well count**
Panel A: Well location		
Inland waters	31,980	31,980
State offshore	15,804	15,804
Federal shallow waters	50,235	35,442
Federal deep waters	5,179	2,843
Total	103,198	86,069
Panel B: Well status		
Active	12,645	7,637
Permanent P&A	76,024	66,176
Temporary P&A	5,780	3,644
Orphaned	752	752
Active injection	473	473
Idle, shut in, or inactive	7,524	7,387
Total	103,198	86,069

Note: Borehole counts and well counts only differ in federal waters. This includes wells drilled in California, Texas, Louisiana, Alabama, and federal waters off the coast of these states. We exclude wells that were permitted but never drilled. We also exclude Alaska from our study, as our analysis focuses on the continental US.

Table 2 presents summary statistics (which do not include wells that have already been P&Aed). Panels A, B, and C present estimates for three areas: federal deep water, federal shallow water, and state waters. Columns 1–3 summarize wells with BSEE P&A cost estimates. Columns 4–6 summarize wells without BSEE P&A cost estimates. As a federal agency, BSEE does not provide P&A cost estimates for wells in state waters.

Table 2: Summary statistics

	Mean	Median	Std. Dev.	Mean	Median	Std. Dev.
	1	2	3	4	5	6
	BSEE cost estimate			No BSEE cost estimate		
Panel A: Federal deep water (>1,000 feet water depth)						
P50 cost per foot ($/foot)	$1,156	$1,156	$0	Not Available		
P70 cost per foot ($/foot)	$1,392	$1,375	$90	Not Available		
P90 cost per foot ($/foot)	$1,738	$1,694	$222	Not Available		
Expected P&A cost (million $)	$24.14	$23.80	$7.49	Not Available		
Water depth (feet)	4,675	4,376	1,985	2,957	2,862	1,804
Distance to shore (km)	145.1	135.9	80.5	112.2	104.2	80.1
Measured depth (feet)	20,580	19,965	6,170	16,528	16,000	5,896
Spud year	2010	2012	7.0	2002	2002	9.0
Subsea completion	86.0%	--	--	31.8%	--	--
Wellbore counts	689			1,838		
Well counts	689			853		
Panel B: Federal shallow water (<1,000 feet water depth)						
P50 cost per foot ($/foot)	$59.8	$49.9	$66.3	Not Available		
P70 cost per foot ($/foot)	$78.8	$70.1	$88.6	Not Available		
P90 cost per foot ($/foot)	$106.4	$98.5	$122.7	Not Available		
Expected P&A cost (million $)	$0.66	$0.67	$0.78	Not Available		
Water depth (feet)	150	140	100	230	188	198
Distance to shore (km)	57.4	40.2	48.4	50.1	26.6	48.5
Measured depth (feet)	10,658	10,476	3,235	9,918	9,923	3,823
Spud year	1990	1992	15	1988	1988	13.8
Subsea completion	0.13%	--	--	0.32%	--	--
Wellbore counts	6,858			7,285		
Well counts	6,858			4,288		

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	Mean	Median	Std. Dev.	Mean	Median	Std. Dev.
	1	2	3	4	5	6
	BSEE cost estimate			No BSEE cost estimate		
Panel C: State waters						
Cost per foot ($/foot)	Not Available			Not Available		
Water depth (feet)	Not Available			1.6	0	6.6
Distance to shore (km)	Not Available			1.9	0	3.8
Measured depth (feet)	Not Available			9,433	9,294	3,764
Spud year	Not Available			1979	1977	20.9
Observations	Not Available			10,387		

Federal deepwater wells without estimated P&A costs from BSEE tend to be older: the median spud year is 2002 versus 2012 for wellbores with reported estimated costs.[31] Wellbores without reported estimated costs also tend to be shallower, closer to shore, and in shallower water. They are less likely to involve a subsea completion.[32] For the 689 wellbores that have a P&A cost estimate from BSEE, the P50 P&A cost is the same for each well: $1,156 per foot of measured depth. In other words, BSEE predicts that there is a 50 percent probability that costs will be less than $1,156 per foot. The P70 and P90 costs are larger and vary between wells. The estimated average cost per wellbore is $24 million.

BSEE provides estimated cost for just under half of federal shallow water wells. Shallow water P&A costs per foot are much smaller than deepwater costs: the P50 cost per foot is $59.8 versus $1,156 for deepwater wells. The difference in cost, while large, is not entirely surprising: unlike deepwater wells, shallow water wells tend to be drilled to shallower depths and be closer to shore. Very few (less than 1 percent) involve subsea completions compared to deepwater wells. The average depth of federal deepwater wells is twice that of federal shallow water wells. The average cost to P&A a wellbore in federal shallow waters is listed as $660,000, compared to $24 million in federal deep waters.[33] Given a fixed budget, a federal offshore P&A program would be able to P&A many more shallow water wells than deepwater wells.

BSEE does not provide P&A cost estimates for wells in state waters. Such wells are in shallower water, closer to shore, and older than those in shallow federal waters. The average depth of wells in state waters is similar to the average depth of wells in federal shallow waters.

COST MODELING

Estimating the total P&A liability for all offshore wells requires a P&A cost estimate for each well. The authors use regression analysis to estimate how BSEE cost estimates depend on observable wellbore characteristics. Then we use our regression parameters to predict costs for the wellbores in federal and state waters without cost estimates. Finally, for federal deepwater and shallow water sidetracks, we remove the double-counted portion of their measured depth preceding the kickoff point. The result is a cost estimate for each well.

As shown in Table 2, the characteristics and costs of wells in federal deep water, federal shallow water, and state waters are quite different. Because these populations of wells are different, we separately estimate costs for all three groups.

Model 1: Deep Federal Waters

BSEE estimates that the P50 cost to P&A any federal deepwater well is exactly $1,156 per foot of measured well depth. Of the 689 wellbores for which costs estimates are provided, there is variation in water depth, distance to shore, and whether the well was a subsea completion. There is no variation in the P50 P&A cost per foot. Well characteristics are likely to impact the P&A cost per foot but are apparently not taken into account in BSEE's P50 cost estimation methodology.[34]

The authors assume that P&A costs have a right-tailed distribution, so that the expected cost is higher than the median (i.e., P50) cost. This reflects the fact that costs are bounded below by zero and the possibility of cost overruns. To calculate expected P&A costs (versus median), we fit a separate log-normal distribution to each set of P50, P70, and P90 cost estimates and calculate the implied expected cost.[35] The expected P&A cost that we calculate is approximately 6 percent larger than the P50 cost. We normalize expected costs by each well's depth. The authors find that, on average, the expected P&A cost for a deepwater well is $1,230/foot. To calculate expected P&A costs for wellbores without cost estimates, we find the total length of the wellbore (adjusting sidetrack depths to avoid double counting) and multiply by our average expected cost of $1,230/foot.

Model 2: Shallow Federal Waters

The authors use equation 1 to estimate the P&A cost of wells in shallow federal waters. We assume that for well *i*, the cost per measured depth (c_i) depends on the water depth (WD_i) and a binary indicator variable representing whether the well involves a subsea completion (subseai):

$$c_i = \alpha + \beta WD_i + \gamma subsea_i + \varepsilon_i. \qquad (1)$$

Model 1 is parsimonious. However, including other well characteristics such as distance to shore does not improve model fit or make a statistically significant difference in cost estimates. There are certainly many other engineering considerations that affect P&A costs that are left out of equation 1, but these factors do not appear to enter the BSEE P&A cost estimates used.

The authors estimate the parameters in equation 1 using the expected BSEE P&A cost for the 6,858 wellbores listed in panel B of Table 2. Estimates imply that the lowest cost per foot is $18.58 ($\alpha$ = 18.58). For every 100 feet of water depth, cost per foot rises by $32.17 ($\beta$ = 0.3217). Wells with subsea completions are significantly more expensive, adding an additional $870 per foot ($\gamma$ = 870). Using these estimated regression coefficients and data on well characteristics, we predict expected P&A costs for the 7,285 out-of-sample wellbores in federal shallow waters that lack P&A cost estimates.

Model 3: State Waters

The authors assume that P&A costs for wells in state waters are generated by the model in equation 2. The model is very similar to the one used in federal shallow waters. The most important difference is that we estimate the state waters model using only wellbores in federal waters that are less than 15 km from shore. Effectively, this means extrapolating federal shallow water P&A costs into state waters. Ideally, P&A costs of wells in state waters would be estimated using a random sample of wells in state waters that were P&Aed. Unfortunately, this cost data is not available.

$$c_i = \alpha + \beta WD_i + \varepsilon_i. \tag{2}$$

The state waters model 2 also differs from model 1 in that it omits the indicator variable for subsea completions. We do not actually observe whether wells in state waters involve subsea completions; however, the authors believe that it is unlikely that they do based on discussions with industry. There are very few federal shallow water wells with subsea completions within 15 km of shore, and state waters all lie within this distance. In Louisiana and California, the federal/state water boundary is around 5 km (three miles), while in Texas the boundary is at around 14.5 km (nine miles). Removing wells greater than 15 km from shore leaves 1,708 wellbores in shallow federal waters with BSEE cost estimates. We estimate the parameters of model 2 with this sample.

The estimates for equation 2 imply that the P&A cost per foot starts at $25.8 ($\alpha$ = 25.8) and increases by $26.47 for every 100 feet of water depth (β = 0.2647). By comparison, the four orphaned wells that the state of Louisiana paid to P&A cost between $25 per foot to $55 per foot, with an average of $34 per foot.

P&A Candidates

While the authors estimate P&A costs for all offshore wells, three discrete factors suggest a well may be a candidate for a P&A stimulus program. A similar approach has been taken by other studies of orphaned well P&A liability (Boomhower et al. 2018; Kang et al. 2016). These factors include whether 1) the well is listed as idle or has not reported production in five years, 2) the well has been temporarily plugged, and 3) the well is on a federal lease that has expired. These categories are *not* mutually exclusive; individual wells can be included in none, some, or all of the categories. The authors discuss each category separately but hypothesize that wells meeting multiple criteria are unlikely to produce meaningful quantities in the future and are at higher risk of becoming orphaned one day. P&Aing them is unlikely to reduce the future supply of oil and gas.

Wells that are not yet P&Aed but are currently listed as inactive, idle, or shut in, or have not reported production in five years,[36] are not currently being used for an economic purpose (i.e., production or injection).

A well may be temporarily plugged in two common situations. First, firms drill exploratory wells while the economic potential of a location is uncertain. If an exploratory well is successful, the firm is likely to develop the field. The firm may temporarily plug the well while waiting on additional drilling and additional infrastructure to bring hydrocarbons to market. Second, a firm may temporarily P&A instead of permanently P&A wells in order to preserve the option of producing the well again when prices are higher or P&A costs are lower. It is possible that P&A costs per well may be lower if the firm can simultaneously P&A several nearby wells.

Federal leases expire one year after production has been ceased. There can be many wells on one lease, and so if any individual well is still producing, the lease is held by production.[37] The operator is not required to P&A wells or remove unused equipment while the lease is active and held by production. Once the lease is terminated a year after production ceases, the operator has 12 months to decommission platforms and P&A wells. Thus, wells on leases that have not produced for at least two years are also candidates for permanent P&Aing.

RESULTS

Table 3 displays this report's cost estimate to P&A various sets of offshore wells. Column 1 sums over all wells, and columns 2–4 break this total into wells in federal deep waters, federal shallow waters, and state waters. Aggregate costs across all categories are shown in panel A. Total future P&A liabilities for both active and inactive wells are estimated at approximately $47 billion.

Table 3: Aggregated P&A cost estimates (in billion $) by water depth

	1	2	3	4
	Total	Federal deep water	Federal shallow water	State waters
Panel A: Total P&A cost				
Total	$46.97	$36.13	$8.39	$2.45
Well count	*(21,818)*	*(1,703)*	*(9,923)*	*(10,193)*
Panel B: P&A candidate categories				
Inactive wells (A)	$32.49	$24.35	$6.19	$1.94
Well count	*(15,455)*	*(915)*	*(6,710)*	*(7,830)*
Temporary P&A (B)	$9.67	$7.16	$2.44	$0.06
Well count	*(3,759)*	*(272)*	*(3,255)*	*(232)*
Inactive lease (C)	$4.03	$2.80	$1.24	NA
Well count	*(1,288)*	*(134)*	*(1,154)*	*NA*
Active/recently active	$14.05	$11.49	$2.06	$0.50
Well count	*(6,121)*	*(761)*	*(3,007)*	*(2,353)*
Panel C: Wells in multiple categories				
A and B	$9.41	$6.97	$2.37	$0.06
Well count	*(3,603)*	*(252)*	*(3,129)*	*(222)*
A and C	$3.84	$2.67	$1.16	NA
Well count	*(1,169)*	*(123)*	*(1,046)*	*NA*
B and C	$0.96	$0.44	$0.52	NA
Well count	*(669)*	*(19)*	*(650)*	*NA*
A, B, and C	$0.94	$0.43	$0.51	NA
Well count	*(637)*	*(15)*	*(622)*	*NA*
A or B or C	$32.9	$24.6	$6.32	1.95
Well count	*(15,698)*	*(942)*	*(6,916)*	*(7,840)*

Deepwater wells include all wells in water greater than 1,000 feet of water depth. Shallow water wells include wells in water less than 1,000 feet of water depth.

Panel A of Table 3 also highlights that the majority of outstanding P&A liabilities—regardless of well P&A candidate classifications—reside in federal offshore waters, particularly deep waters. Federal deep waters make up approximately 77 percent of the total cost—around $36 billion. About 5 percent of the cost—$2.5 billion—is in state waters. This is not surprising given the complexity, size, and costs of deepwater operations. This is also convenient because it is the wells in state waters close to shore that present higher environmental risks.

Panel B summarizes the total cost to P&A wells meeting at least one of three risk criteria. Note that these criteria are not mutually exclusive, so summing values in panel B will double count wells and costs. Of the $47 billion in future total P&A liability, only $14.1 billion is associated with the 6,121 currently or recently active wells.

Most notably, $32.5 billion (or about 70 percent) of the total P&A liability comes from wells that are currently inactive, $9.7 billion (or about 21 percent) of the liability comes from wells that are currently temporary P&Aed, and $4 billion (or about 9 percent) is located on inactive leases in federal waters. Turning to state waters only, $1.94 billion of the $2.45 billion in future liability (or 79 percent) is associated with inactive wells.

Panel C estimates P&A costs for wells that meet multiple criteria. These wells are plausibly at higher risk of becoming orphaned. Approximately $9.4 billion of estimated P&A costs are associated with wells that are both idle and temporarily P&Aed; $3.8 billion, with wells that are both idle and on inactive leases; and $940 million, with wells that meet all three criteria.

Table 4 shows results in federal waters for the Gulf of Mexico (GOM) and Pacific Ocean separately. Approximately 94 percent of P&A liability is in the federal GOM, with the remaining 6 percent in the Pacific. Panels B and C break down these costs by risk category, as Table 3 does.

Table 4: Aggregated P&A cost estimates (in billion $) in federal waters by region

	1	2	4
	Total	Gulf of Mexico (GOM)	Pacific Ocean
Panel A: Total P&A cost			
Total	$44.52	$41.96	$2.56
Well count	*(11,626)*	*(10,746)*	*(880)*
Panel B: P&A candidate categories			
Inactive wells (A)	$30.54	$28.13	$2.40
Well count	*(7,625)*	*(7,055)*	*(570)*
Temporary P&A (B)	$9.60	$9.47	$0.14
Well count	*(3,527)*	*(3,428)*	*(99)*
Inactive lease (C)	$4.03	$1.83	$2.21
Well count	*(1,288)*	*(1,035)*	*(253)*
Active/recently active	$13.56	$13.43	$0.13
Well count	*(3,768)*	*(3,481)*	*(287)*
Panel C: Wells in multiple categories			
A and B	$9.34	$9.21	$0.14
Well count	*(3,381)*	*(3,282)*	*(99)*
A and C	$3.84	$1.66	$2.17
Well count	*(1,169)*	*(939)*	*(230)*
B and C	$0.96	$0.87	$0.10
Well count	*(669)*	*(620)*	*(49)*
A, B, and C	$0.94	$0.84	$0.10
Well count	*(637)*	*(588)*	*(49)*
A or B or C	$30.97	$28.53	$2.43
Well count	*(7,858)*	*(7,265)*	*(593)*

Table 5 breaks down results by the four states with significant offshore oil and gas activity: Louisiana, Texas, California, and Alabama. Louisiana has more than 7,500 wells associated with approximately $2 billion in P&A liability. Eighty-four percent of this liability is in wells that are inactive. Thus, Louisiana state waters would likely receive the most from a federal stimulus program to P&A offshore wells.

Texas and California are a distant second and third place, respectively, behind Louisiana, with $236 million and $202 million in outstanding P&A liability. Alabama has approximately $16 million in liability. Of this, approximately 70 percent is associated with active wells.

Table 5: Aggregated P&A cost estimates (in million $) in state waters

	1	2
	Cost	Well count
Panel A: Louisiana		
Inactive (A)	$1,666	(6,330)
Temporary P&A (B)	*$59*	*(223)*
Active/recently active	*$325*	*(1,245)*
A and B	*$56*	*(213)*
Total	*$1,994*	*(7,585)*
Panel B: Texas		
Inactive (A)	$177	(668)
Temporary P&A (B)	*<$1*	*(3)*
Active/recently active	*$59*	*(280)*
A and B	*<$1*	*(3)*
Total	*$236*	*(948)*
Panel C: California		
Inactive (A)	$102	(824)
Temporary P&A (B)	*<$1*	*(1)*
Active/recently active	*$100*	*(809)*
A and B	*<$1*	*(1)*
Total	*$202*	*(1,633)*
Panel D: Alabama		
Inactive (A)	$5	(8)
Temporary P&A (B)	*$3*	*(5)*
Active/recently active	*$11*	*(19)*
A and B	*$3*	*(5)*
Total	*$16*	*(27)*

Includes only state waters. Does not include federal waters off the shore of respective states.

Benefit-Cost Ratio

The authors do not conduct a formal benefit-cost analysis, but two findings allow a qualitative statement about where the ratio of environmental benefits to P&A costs is greatest. First, the estimated cost of P&A activity increases dramatically in deeper waters far from shore. Second, the environmental benefits of P&Aing wells are likely to be greater in shallow, coastal waters. These two findings imply that, in general, the ratio of environmental benefits to P&A costs is likely to be greatest for the less costly, shallow, coastal wells.

ECONOMIC IMPACTS OF P&A ACTIVITY

According to estimates in Table 3, $8.3 billion would be sufficient to P&A all wells that are inactive, temporarily P&Aed, or on inactive leases in federal shallow waters or state waters. To estimate the economic impacts of an $8.3 billion offshore P&A stimulus program spread over 10 years, the authors use the Regional Input-Output Modeling System (RIMS II). RIMS II was created and is maintained by the Bureau of Economic Analysis, part of the US Department of Commerce. RIMS II is an input-output model that is based on a detailed set of industry accounts that measure the goods and services produced by each industry. Large underlying data sets trace the flow of goods and services throughout the economy to final users. RIMS II is considered a backward linkages model, in that an increase in demand for an output results in an increase in demand in inputs needed to create those outputs.

RIMS II multipliers can be used to estimate the amount of labor inputs needed to complete $8.3 billion of P&A work. Offshore P&A activities fall into the sector "support activities for mining," and so the multipliers for this sector are the relevant ones for calculating the economic impact of P&A activities.[38] We assume that domestic firms and workers perform all P&A activities.[39]

The authors estimate economic impacts using both the "Type I" and "Type II" multipliers provided by RIMS II. Type II multipliers account for both the interindustry and household spending of a final demand change. Type I multipliers account for only the interindustry effect. Thus, Type II multipliers by definition are larger than Type I. We examine impacts on employment, earnings, and value added. Employment includes counts of workers at establishments that employ workers in relevant sectors. Earnings (synonymous with "labor income") include wages and salaries, proprietors' income, plus employer contributions to insurance, pensions, and social insurance. Value added represents the contribution to gross domestic product (GDP). Earnings is one component of value added. Horowitz and Planting (2009) provide more detailed information on RIMS II and interpretation of the multipliers.

Table 6 displays the annual economic activity (employment, earnings, and value added) associated with $830 million of annual P&A work. The authors estimate that based on Type I multipliers, this amount of P&A expenditure would require 5,265 jobs per year to complete this work, including direct workers, contractors, and suppliers. After taking into account household spending in the economy, this P&A expenditure would be associated with more than 10,500 jobs per year, economy-wide. The authors further estimate that this P&A expenditure would generate $402 million in Type I earnings and $632 million in Type II earnings. The average earnings per worker would be around $76,300 (referencing Type I). Finally, the P&A work would contribute about $1.2 billion to US GDP per year (i.e., value added).

Table 6: Estimated annual economic impacts of P&A activity

	1	2
	Type 1	Type 2
Employment (jobs)	5,265	10,520
Earnings (millions $)	*$402*	*$632*
Value added (millions $)	*$750*	*$1,185*

RIMS II 2019. Includes $830 million in P&A activity per year.

Interpretation of Economic Impacts

It is important to note that we can only estimate the economic activity associated with P&A efforts. This is different from the *additional, new* activity induced by a federal stimulus program relative to a counterfactual without a stimulus program. For example, firms are already required to P&A wells under state and federal guidelines, and if federal P&A spending were to subsidize this activity, there would be some wells that would have been P&Aed regardless of whether the stimulus program is in place. Of course, there would also likely be some wells that would not have been P&Aed absent a stimulus. The amount of new economic activity generated by a federal offshore P&A stimulus program depends critically on the specifics of the program and the degree to which the program leads to additional P&A activity beyond what would otherwise occur.

The specific mix of incentives in a P&A policy that induce companies to clean up their wells matters a great deal to the overall efficiency of such a program and the degree to which it stimulates additional P&A activity. Given the large numbers of inactive, unplugged wells in state and federal waters, and that the Government Accountability Office has called for updating federal offshore decommissioning requirements (Government Accountability Office 2015, 2021), it may be prudent to consider how a P&A stimulus might best be combined with other P&A policy changes such as modification of upfront bonding requirements.

Broadly speaking, the incentives to P&A wells can be thought of as "carrots" that make it more economic for a firm to P&A wells earlier rather than later (and perhaps reduce the probability that the well is never properly P&Aed) and "sticks" that make it more expensive ***not*** to P&A wells. On the carrots side, policy makers could provide subsidies for firms to P&A their own wells or purchase inactive wells from companies and then P&A those wells, both at the taxpayer's expense. On the sticks side, policy makers could increase the opportunity cost of holding inactive, unplugged wells by increasing bonding requirements or requiring additional rental payments on inactive leases. In designing these policies, it is important to consider how these incentives not only change firms' decision to P&A wells but also their decision to drill them in the first place. For example, a poorly designed P&A subsidy could reduce the lifetime investment cost of extracting hydrocarbons and might induce firms to drill additional unproductive wells. It could also create a moral hazard (hidden action) problem—

for example, firms might make engineering decisions that are not observable to the regulator but that lead to higher future P&A costs that can be passed on to the taxpayer. Finally, there may be ways for policy makers to encourage neighboring firms to coordinate P&A activity in order to achieve economies of scale and lower average costs per well. The exact mix of P&A incentives is an important question, though beyond the scope of this study.

CONCLUSION

Any program to encourage P&A activities will need to balance multiple objectives. One objective might be minimizing environmental risks from unplugged wells. Another might be minimizing future financial risks of orphan wells for either states or the federal government. Finally, policy makers might be interested in stimulating job growth in particular states.[40] Three findings from this report may help inform policy decisions based on the relative importance assigned to each of these objectives.

First, the ratio of environmental benefits to P&A costs is generally higher for wells nearer to shore. As shown in Table 2, BSEE estimates that deepwater wells have a median cost per foot that is almost 20 times higher than for shallow water federal wells. Thus, policy makers concerned with environmental effects may wish to prioritize wells in state waters and shallow federal waters.

Second, unplugged wells in state waters may be at higher risk of becoming orphaned relative to wells in federal waters. Over 80 percent of potential P&A costs in state waters are from wells that are currently inactive. Further, P&A liability for wells in state waters (unlike those in federal waters) does not revert to the prior lessee if the lease is assigned to a new company. That means that should the current lessee declare bankruptcy and walk away from its P&A obligations, state bankruptcy courts cannot generally require the prior lessee to foot the P&A costs.[41] The fact that prior owners retain liability for decommissioning assets in federal waters, even after those assets are sold, has been highlighted in the recent bankruptcy proceeding for Fieldwood Energy, in which Fieldwood filed for Chapter 11 protection under the US bankruptcy code with regard to assets in the federal Gulf of Mexico.[42]

Third, because the majority of offshore P&A liabilities are in the state and federal waters of the Gulf of Mexico, federal stimulus funds are likely to benefit Louisiana and Texas the most.

REFERENCES

Agerton, Mark, Ben Gilbert, and Gregory Upton. "The Economics of Natural Gas Venting, Flaring and Leaking in U.S. Shale: An Agenda for Research and Policy." USAEE Working Paper 20-460, 2021.

Alboiu, Vanessa, and Tony R. Walker. "Pollution, Management, and Mitigation of Idle and Orphaned Oil and Gas Wells in Alberta, Canada." *Environmental Monitoring and Assessment* 191 (2019): 611.

Andersen, Matt, Roger Coupal, and Bridgette White. "Reclamation Costs and Regulation of Oil and Gas Development with Application to Wyoming." *Western Economics Forum* 8 (2009): 1–9.

Anderson, Christopher J., and Thomas A. Hess. "The Effects of Oil Exposure and Weathering on Black-Needle Rush (Juncus roemerianus) Marshes along the Gulf of Mexico." *Marine Pollution Bulletin* 64 (2012): 2749–55.

Boomhower, Judson. "Drilling Like There's No Tomorrow: Bankruptcy, Insurance, and Environmental Risk." *American Economic Review* 109, no. 2 (2019): 391–426.

Boomhower, Judson, Mikel Shybut, and M. Daniel DeCillis. "Orphan Wells in California: An Initial Assessment of the State's Potential Liabilities to Plug and Decommission Orphan Oil and Gas Wells." Technical Report. California Council on Science & Technology, 2018.

Böttner, Christoph, Matthias Haeckel, Mark Schmidt, Christian Berndt, et al. "Greenhouse Gas Emissions from Marine Decommissioned Hydrocarbon Wells: Leakage Detection, Monitoring and Mitigation Strategies." *International Journal of Greenhouse Gas Control* 100, 103119 (2020): 1–16.

Cook, Kristin Alexandra. "An 'Inescapable Obligation'—The Treatment of Well Decommissioning Liability in Recent Oil and Gas Bankruptcies." Master's thesis. The University of Texas at Austin, 2019.

Crespo-Medina, M., C. D. Meile, K. S. Hunter, A.-R. Diercks, et al. "The Rise and Fall of Methanotrophy following a Deepwater Oil-Well Blowout." *Nature Geoscience* 7 (2014): 423–7.

Dachis, Benjamin, Blake Shaffer, and Vincent Thivierge. "All's Well That Ends Well: Addressing End-of-Life Liabilities for Oil and Gas Wells." Technical Report 492. C. D. Howe Institute, 2017.

Esbaugh, Andrew J., Edward M. Mager, John D. Stieglitz, Ronald Hoenig, et al. "The Effects of Weathering and Chemical Dispersion on Deepwater Horizon Crude Oil Toxicity to Mahi-Mahi (Coryphaena hippurus) Early Life Stages." *Science of the Total Environment* 543 (2016): 644–51.

Faksness, Liv-Guri, Dag Altin, Trond Nordtug, Per S. Daling, et al. "Chemical Comparison and Acute Toxicity of Water Accommodated Fraction (WAF) of Source and Field Collected Macondo Oils from the Deepwater Horizon Spill." *Marine Pollution Bulletin* 91 (2015): 222–9.

Finch, Bryson E., Solmaz Marzooghi, Dominic M. Di Toro, and William A. Stubblefield. “Phototoxic Potential of Undispersed and Dispersed Fresh and Weathered Macondo Crude Oils to Gulf of Mexico Marine Organisms.” *Environmental Toxicology and Chemistry* 36 (2017): 2640–50.

Government Accountability Office. “Actions Needed to Better Protect Against Billions of Dollars in Federal Exposure to Decommissioning Liabilities.” Technical Report 16-40. US Government Accountability Office, 2015.

Government Accountability Office. “Updated Regulations Needed to Improve Pipeline Oversight and Decommissioning.” Technical Report 21-293. US Government Accountability Office, 2021.

Gardner, Grant. “Inactive Oil and Gas Wells on Federal Lands and Minerals: Potential Costs and Conflicts.” Technical Report. The National Wildlife Federation and Public Land Solutions, 2021.

Haynes Boone. “Oil Patch Bankruptcy Monitor.” Technical Report. Haynes and Boone, LLP, 2021.

Heintz, Ron A., Jeffrey W. Short, and Stanley D. Rice. “Sensitivity of Fish Embryos to Weathered Crude Oil: Part II. Increased Mortality of Pink Salmon (Oncorhynchus gorbuscha) Embryos Incubating Downstream from Weathered Exxon Valdez Crude Oil.” *Environmental Toxicology and Chemistry* 18, no. 3 (1999): 494–503.

Horowitz, Karen J., and Mark A. Planting. “Concepts and Methods of the Input-Output Accounts.” Technical Report. Bureau of Economic Analysis. US Department of Commerce, 2009.

Hyne, N. J. *Nontechnical Guide to Petroleum Geology, Exploration, Drilling and Production*. 3rd ed. Tulsa, Oklahoma: PennWell, 2012.

Ide, S. Taku, S. Julio Friedmann, and Howard J. Herzog. “CO2 Leakage through Existing Wells: Current Technology and Regulations.” 8th International Conference on Greenhouse Gas Control Technologies, June 2006, 19–22.

Interstate Oil and Gas Compact Commission. “Idle and Orphan Oil and Gas Wells: State and Provincial Strategies.” Technical Report. Interstate Oil & Gas Compact Commission, 2019.

Interstate Oil and Gas Compact Commission. “Idle and Orphan Oil and Gas Wells: State and Provincial Strategies Supplemental Information.” Technical Report. Interstate Oil & Gas Compact Commission, 2020.

Interstate Oil and Gas Compact Commission. “Idle and Orphan Oil and Gas Wells: State and Provincial Strategies 2021.” Technical Report. Interstate Oil & Gas Compact Commission, 2021.

Joye, Samantha B., Andreas P. Teske, and Joel E. Kostka. “Microbial Dynamics following the Macondo Oil Well Blowout across Gulf of Mexico Environments.” *Bioscience* 64, no. 9 (2014): 766–77.

Kaiser, Mark J., and Allan G. Pulsipher. “Idle Iron in the Gulf of Mexico.” Technical Report 2007-031. US Department of the Interior. Mineral Management Service, 2007.

Kang, Mary, Adam R. Brandt, Zhong Zheng, Jade Boutot, et al. "Orphaned Oil and Gas Well Stimulus—Maximizing Economic and Environmental Benefits." *Elementa: Science of the Anthropocene* 9, no. 1 (2021): 1–13.

Kang, Mary, Shanna Christian, Michael A. Celia, Denise L. Mauzerall, et al. "Identification and Characterization of High Methane-Emitting Abandoned Oil and Gas Wells." *Proceedings of the National Academy of Sciences of the United States of America* 113, no. 48 (2016): 13636–41.

Kang, Mary, Cynthia M. Kanno, Matthew C. Reid, Xin Zhang, et al. "Direct Measurements of Methane Emissions from Abandoned Oil and Gas Wells in Pennsylvania." *Proceedings of the National Academy of Sciences* 111, no. 51 (2014): 18173–7.

Kang, Mary, Denise L. Mauzerall, Daniel Z. Ma, and Michael A. Celia. "Reducing Methane Emissions from Abandoned Oil and Gas Wells: Strategies and Costs." *Energy Policy* 132 (2019): 594–601.

Lebel, Eric D., Harmony S. Lu, Lisa Vielstädte, Mary Kang, et al. "Methane Emissions from Abandoned Oil and Gas Wells in California." *Environmental Science & Technology* 54, no. 22 (2020): 14617–26.

Lin, Qianxin, and Irving A. Mendelssohn. "Impacts and Recovery of the Deepwater Horizon Oil Spill on Vegetation Structure and Function of Coastal Salt Marshes in the Northern Gulf of Mexico." *Environmental Science & Technology* 46, no. 7 (2012): 3737–43.

Martínez-Gómez, C., A. D. Vethaak, K. Hylland, T. Burgeot, et al. "A Guide to Toxicity Assessment and Monitoring Effects at Lower Levels of Biological Organization following Marine Oil Spills in European Waters." *ICES Journal of Marine Science* 67, no. 6 (2010): 1105–18.

Mendelssohn, Irving A., Gary L. Andersen, Donald M. Baltz, Rex H. Caffey, et al. "Oil Impacts on Coastal Wetlands: Implications for the Mississippi River Delta Ecosystem after the Deepwater Horizon Oil Spill." *BioScience* 62, no. 6 (2012): 562–74.

Montagna, Paul A., Jeffrey G. Baguley, Cynthia Cooksey, Ian Hartwell, et al. "Deep-Sea Benthic Footprint of the Deepwater Horizon Blowout." *PLOS One* 8, no. 8 (2013): e70540.

Negron, Alan M. Gorchov, Eric A. Kort, Stephen A. Conley, and Mackenzie L. Smith. "Airborne Assessment of Methane Emissions from Offshore Platforms in the U.S. Gulf of Mexico." *Environmental Science & Technology* 54 (2020): 5112–20.

Passow, Uta, and Scott A. Stout. "Character and Sedimentation of 'Lingering' Macondo Oil to the Deep-Sea after the Deepwater Horizon Oil Spill." *Marine Chemistry* 218, no. 103733 (2020): 1–14.

Pekney, Natalie J., J. Rodney Diehl, David Ruehl, James Sams, et al. "Measurement of Methane Emissions from Abandoned Oil and Gas Wells in Hillman State Park, Pennsylvania." *Carbon Management* 9, no. 2 (2018): 165–75.

Pezeshki, S. Reza, and Ronald D. Delaune. "United States Gulf of Mexico Coastal Marsh Vegetation Responses and Sensitivities to Oil Spill: A Review." *Environments* 2, no. 4 (2015): 586–607.

Raimi, Daniel, Alan J. Krupnick, Jhih-Shyang Shah, and Alexandra Thompson. "Decommissioning Orphaned and Abandoned Oil and Gas Wells: New Estimates and Cost Drivers." *Environmental Science & Technology* 55, no. 15 (August 2021): 10224–30.

Raimi, Daniel, Neelesh Nerurkar, and Jason Bordoff. "Green Stimulus for Oil and Gas Workers: Considering a Major Federal Effort to Plug Orphaned and Abandoned Wells." Technical Report. Resources for the Future and Center for Energy Policy at Columbia University, 2020.

Raymond, Martin S., and William L. Leffler. *Oil and Gas Production in Nontechnical Language*. Tulsa, Oklahoma: PennWell, 2006.

Römer, Miriam, Chieh-Wei Hsu, Markus Loher, Ian R. MacDonald, et al. "Amount and Fate of Gas and Oil Discharged at 3400 m Water Depth from a Natural Seep Site in the Southern Gulf of Mexico." *Frontiers in Marine Science* 6, no. 700 (2019): 1–18.

Stefansson, Emily S., Chris J. Langdon, Suzanne M. Pargee, Susanna M. Blunt, et al. "Acute Effects of Non-Weathered and Weathered Crude Oil and Dispersant Associated with the Deepwater Horizon Incident on the Development of Marine Bivalve and Echinoderm Larvae." *Environmental Toxicology and Chemistry* 35, no. 8 (2016): 2016–28.

Valentine, David L., G. Burch Fisher, Sarah C. Bagby, Robert K. Nelson, et al. "Fallout Plume of Submerged Oil from Deepwater Horizon." *Proceedings of the National Academy of Sciences* 111, no. 45 (2014): 15906–11.

Valentine, David L., John D. Kessler, Molly C. Redmond, Stephanie D. Mendes, et al. "Propane Respiration Jump-Starts Microbial Response to a Deep Oil Spill." *Science* 330, no. 6001 (2010): 208–11.

White, Helen K., Pen-Yuan Hsing, Walter Cho, Timothy M. Shank, et al. "Impact of the Deepwater Horizon Oil Spill on a Deep-Water Coral Community in the Gulf of Mexico." *Proceedings of the National Academy of Sciences* 109, no. 50 (2012): 20303–8.

Williams, James P., Amara Regehr, and Mary Kang. "Methane Emissions from Abandoned Oil and Gas Wells in Canada and the United States." *Environmental Science & Technology* 55, no. 1 (2021): 563–70.

Yacovitch, Tara I., Conner Daube, and Scott C. Herndon. "Methane Emissions from Offshore Oil and Gas Platforms in the Gulf of Mexico." *Environmental Science & Technology* 54, no. 6 (2020): 3530–8.

NOTES

1. From the Enverus (formerly DrillingInfo) database, which is based on state and federal records. Because not all wells were recorded in these databases, the actual number is likely higher.

2. The count of offshore wells varies based on how offshore wells are defined. For example, a well drilled in a bay might be categorized as either being in “inland waters” or being “offshore.” In addition to wells offshore of the coastline, we include all wells drilled in water or wetlands in the coastal zone.

3. Although beyond the scope of this analysis, behind CO_2, methane is the largest source of greenhouse gas globally, and the oil and gas industry is the second largest source of anthropogenic methane, behind agriculture. For a review of methane emissions in the upstream oil and gas sector, see Agerton et al. (2021).

4. We use the term “orphaned well” only to refer to wells that a state has officially documented as being orphaned. We do not use the term to refer to undocumented wells or wells owned by bankrupt companies. The criteria for wells to be designated as orphaned differ across states.

5. Although specifics of requirements differ across jurisdictions, oil and gas companies are typically required to put up some kind of bond to reduce risk of the company not properly P&Aing the well at the end of its useful life.

6. Figure based on 2020 numbers. Source: EIA, Petroleum & Other Liquids, Crude Oil Production.

7. This includes federal waters in Alaska, the Atlantic Ocean, Gulf of Mexico, and Pacific Ocean. However, the vast majority ($110 billion) comes from the Gulf of Mexico. This number includes rental payments, bonus payments, and royalties. According to the US Department of the Interior, from 2003 to 2020, the federal government received $177.6 billion in bonuses, rental payments, and royalties from oil and gas activity, and $116.2 billion was from offshore activity including the Gulf of Mexico, Pacific Ocean, and Alaska.

8. In a follow-up peer-reviewed paper, Raimi et al. (2021) found that the median decommisioning costs are roughly $20,000 for plugging only and $76,000 for plugging and surface.

9. January 27, 2021, Sec. 208.

10. “Executive Order on Tackling the Climate Crisis at Home and Abroad,” January 27, 2021, Sec. 208.

11. For example, Texas: “Executive Order by the Governor of the State of Texas,” Executive Order GA-33, January 28, 2021; Louisiana: House Committee on Natural Resources and

Environment and Senate Committee on Natural Resources, February 10, 2021, Louisiana State Legislature.

12. H.R. 3684, 117th Cong, §40601.

13. US Department of the Interior, "Biden Administration Announces $1.15 Billion for States to Create Jobs Cleaning Up Orphaned Oil and Gas Wells," Press Releases, January 31, 2022.

14. Information provided by the Louisiana Department of Natural Resources.

15. Based on personal conversations with members of the Louisiana Oilfield Site Restoration Program and the Louisiana Department of Revenue.

16. For more information, see prior-mentioned Fieldwood Energy bankruptcy proceeding.

17. See Kaiser and Pulsipher (2007) for more information on abandonment of offshore platforms.

18. The report does not explicitly state that offshore wells are not included, but the cost data used to produce estimates is clearly in the range of reasonable costs for onshore wells.

19. The study notes that this estimate ignores environmental or health damages that could be caused by orphaned wells.

20. "Marine snow" is a term used to describe dead and decaying small organic matter falling like "snowflakes," sometimes coating the bottom of the ocean floor.

21. This includes wells in federal Gulf of Mexico and federal Pacific waters, as well as wells in waters of Texas, Louisiana, California, Mississippi, and Alabama.

22. Although not shown here, analysis of the data reveals that wells are unlikely to reenter production after five years of being inactive.

23. These locations include pretty much all of the offshore wells in the continental US.

24. In some instances, wells will be drilled into the same reservoir and tied to the same platform, yet some are technically in federal waters and others in state waters.

25. Production data is available from individual state databases, and Enverus uses this to populate their databases. However, each state has different reporting requirements, and matching raw state agency data to individual wells can be difficult. Enverus does this matching in a careful way.

26. *Measured depth* is the total distance from the top of the wellbore to the end of the bottom hole. Measured depth is missing in less than 1 percent of wells.

27. Specifically, a well is identified by a 10-digit API number, while a borehole is identified by a 12-digit API number. Note that in state waters, data is only available at a 10-digit API number level (i.e., for each well). Thus, the distinction between wells and boreholes is only in federal waters. API numbers are unique numbers assigned to every oil and gas well in the United States.

28. The kickoff point is the location of a wellbore for which a sidetrack begins.

29. This includes wells drilled in California, Texas, Louisiana, Alabama, and federal waters off the coast of these states. We exclude wells that were permitted but never drilled. We also exclude Alaska from our study.

30. Note that there are many different status designations that vary across state and federal jurisdictions. As discussed in section 5, all wells are allocated to one of the well statuses listed in Table 1.

31. The spud date is the day that the drill bit begins drilling into the ground.

32. In these subsea wells, the wellhead and production equipment are located on the bottom of the ocean, typically accessed by a remotely operated vehicle.

33. Comparing expected P&A cost in panel B and panel A.

34. While BSEE provides P50 cost estimates at the wellbore level (for an API 12), only one wellbore per well (API 10) has a cost estimate.

35. Specifically, we find the location and scale parameters that minimize the Euclidean distance between the P50, P70, and P90 costs and the corresponding quantiles of the log-normal distribution. Note that given the distribution is truncated at zero (i.e., a well cannot have negative costs to P&A), this natural suggests using a right-tailed distribution.

36. We note that well status codes differ across states. Harmonizing these across jurisdictions was a key task. We also note that in federal waters, some wellbores (i.e., API 12) are listed as inactive, but another wellbore within that well (i.e., API 10) is listed as either P&Aed or currently producing oil and gas. If an individual wellbore is listed as active or P&Aed within a well, we apply that status to all wellbores in the well.

37. A lease with any reported production is "held by production," meaning that the lease owner continues to have the opportunity to drill new wells and reenter nonproducing wells (of course, this is subject to obtaining appropriate permits for activity).

38. Specifically, we utilize Type I and Type II multipliers from Summary Table 2.5 for the entire United States (2012, 2019).

39. If non-US companies and workers are hired to complete some portion of this work, economic impacts would be lower.

40. For example, this was the stated goal of a Canadian $1.7 billion program to clean up orphan wells in mid-2020.

41. The authors note that they are not attorneys, but have generally been told this to be the case.

42. United States Bankruptcy Court for the Southern District of Texas Houston Division, Case No. 20-33948 (MI).

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