Financial Liabilities and Environmental Implications of Unplugged Wells for Gulf of Mexico and Coastal Waters*

Mark Agerton[†] Siddhartha Narra[‡] Brian Snyder [§]
Gregory B. Upton Jr.[¶]

August 6, 2022

Abstract

In this analysis, we estimate the cost to plug and abandon (P&A) all oil and gas wells in offshore waters, coastal inland waters, and wetlands in the Gulf Coast region of the United States. The estimated cost to P&A over 14,000 wells that are currently not producing is approximately $30 billion. Wells in shallow waters are significantly less expensive to P&A. They make up 90 percent inactive wells, but represent only 25 percent of the total P&A cost. A review of the environmental sciences literature suggests that these shallower wells closer to shore also present larger environmental risks. Thus, focusing P&A efforts on state and shallow federal waters is likely to provide more environmental benefits per dollar of P&A costs compared to deeper wells farther from shore. We assess the historical ownership of unplugged wells in federal waters and show that approximately 88 percent of outstanding federal P&A liability is associated with leases that were at one time owned by a "supermajor" oil and gas company. These historical owners are legally responsible for the eventual P&Aing of these wells should the current owner fail to meet P&A obligations. In state waters, there is no such requirement.

*We thank the Center on Global Energy Policy at the Columbia School of International and Public Affairs for financially supporting this research.

[†]University of California Davis. Department of Agricultural and Resource Economics

[‡]Louisiana State University. Center for Energy Studies.

[§]Louisiana State University. Department of Environmental Sciences.

[¶]Corresponding author. Louisiana State University. Center for Energy Studies. gupton3@lsu.edu

1 Introduction

Over the past century, over 4.5 million oil and gas wells have been drilled in the United States.[1] The U.S. is not only the birthplace of the modern oil and gas industry, but is also the largest current producer of oil and gas globally and has produced more cumulative oil and gas than any other country.[2] The Gulf Coast region of the United States is the epicenter of U.S. offshore and inland water oil and gas operations, and is therefore an ideal area of study. Once a well has reached the end of its useful life, federal and state guidelines require that the well be plugged and abandoned (P&Aed). Although 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.

In this paper, we assess the outstanding financial liability associated with plugging and abandoning (P&Aing) all offshore oil and gas wells in the Gulf of Mexico and inland waters of the Gulf Coast region of the U.S.[3] Understanding the outstanding liability of wells that have not been permanently P&Aed has policy implications both from an environmental standpoint and also in understanding the economics of the decommissioning of long-lived energy infrastructure.

Previous research has assessed the P&A liability of *onshore* oil and gas wells in the U.S.[4] Offshore wells are quite different from onshore wells in terms of the capital and labor resources required, the amount of production from an individual wellbore, decommissioning costs, and the environmental risks presented. Because of these differences, it is important to study offshore wells independently from onshore wells.

For perspective, of the over 4.5 million oil and gas wells drilled in the U.S., about 100,000–less than 2.5 percent–have been *drilled* offshore or in coastal waters. But over the past two decades, approximately 15 percent of U.S. oil and gas *production* has come from federal offshore wells, alone. Thus, although offshore activity is more expensive than onshore oil & gas activity, offshore wells

[1]Estimate based on *Enverus' Drillinginfo*.

[2]Source: BP Statistical Review of World Energy. Accessed July 2022. Includes oil production (thousands of barrels per day) and natural gas production (bcf/d) by country from 1965 through 2021. The United States is both the largest producer of both oil and natural gas in 2021, as well as the largest cumulative producer of both oil and gas summing all years of data.

[3]We include the coastal areas in Louisiana, Texas, Mississippi and Alabama.

[4]See Section 2.4 for a review of this literature.

also produce more on average, and as we will highlight, have much higher P&A costs.

In the following analysis, we review the relevant environmental sciences literature on offshore oil and gas releases, we estimate the cost to P&Aing all unplugged offshore wells, and we provide pragmatic analysis that can guide policy decisions viewed through both an economic and environmental lens. Our analysis leads to several findings.

First, we find that approximately 78 percent of all wells ever drilled in the waters of the Gulf Coast region[5] have been P&Aed. However, of the wells yet to be P&Aed, over 14,000 are not currently producing. We estimate the cost to P&A all of these inactive wells is approximately $30 billion.

Second, we find that wells in shallow waters are significantly less expensive to P&A. We estimate that plugging the approximately 13,000 wells in state waters and shallow federal waters would cost approximately $7.2 billion. Thus, over 90 percent of the inactive wells represent only 25 percent of the total P&A liability. A review of the environmental sciences literature suggest that these shallower wells closer to shore also present larger environmental risks. Focusing P&A efforts on state and shallow federal waters is likely to yield more environmental benefits per dollar than focusing P&A efforts on deeper, more expensive wells farther from shore.

Third, we assess whether inactive wells are likely to produce significant quantities of oil and gas in the future, perhaps warranting the delay of P&Aing. We find that wells that have been inactive for more than 5 years historically, practically speaking, have less than a 4% chance of re-entering production.[6] Thus, there is ample opportunity to P&A inactive wells that are unlikely to reduce U.S. oil and gas production in a meaningful way. This suggests that federal and state orphan well programs and/or stimulus programs aimed at P&Aing idle wells, if managed effectively, are unlikely to have negative impacts on U.S. Gulf of Mexico oil and gas production.

Finally, we assess the historical ownership of unplugged wells in the federal waters of the Gulf of Mexico. Because P&A liability in federal waters reverts to the prior owner should the current owner go bankrupt (30 CFR §556.710 and §556.805), assessment of historical ownership records can provide insights

[5] Inclusive of the federal waters of the Gulf of Mexico and Louisiana, Texas and Alabama coastal waters.

[6] Technically speaking, hazard model results suggest that after 60 months with no production, the well has a 3.3 percent changes of reporting production in the following 15 years.

into the risk of these wells not being P&Aed in the future.[7] Approximately 88 percent of outstanding P&A liability in federal waters ($6.6 billion of $7.6 billion for shallow water, and $30 billion of $34 billion for deep water) is associated with leases that have been owned by a "supermajor."[8] Today, these companies have a combined market capitalization of $1.2 trillion.[9]

Results of this research are of particular interest in light of the global movement to reduce anthropogenic greenhouse gas emissions. Although oil and gas production is expected to continue to rise globally over the coming decades[10], meeting goals of the Paris Agreement almost inevitably will require substituting away from fossil fuels towards other sources of non-carbon emitting energy in the long-run. Our findings can help quantify the potential risks of stranded offshore assets in light of these goals (Caldecott et al., 2016). For instance, at the time of this writing, President Biden has discontinued offshore leasing while simultaneously allocating $4.7 billion to states to "create jobs cleaning up orphaned oil and gas wells across the country."

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2 Institutional and industry context

2.1 Engineering

When oil and gas extraction ceases on a site, industry practice and governmental regulations dictate that the site be decommissioned and returned to its original state. One component of decommissioning involves *plugging and abandoning* (P&Aing) all wellbores on the site. The other component involves decommissioning any platforms or pipelines. In this analysis, we only focus on P&Aing wells, not decommissioning of platforms, pipelines, or other infrastructure.[11]

Proper P&Aing is designed to prevent underground saltwater 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

[7] This is not generally the case in state waters. Historical ownership is well documented in Federal waters, allowing for this analysis.

[8] We define supermajors to include ExxonMobil, Chevron, ConocoPhillips, BP, Shell, Total and Eni.

[9] As of July 1, 2022.

[10] For instance, US EIA (2021) projects global oil demand growth over the next decade in two of its three scenarios, and higher oil demand globally in 2050 in one of its three scenarios.

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

the well adjacent to the freshwater reservoir is also cemented. Typically, the well casing is then cut 6 feet below the surface of the seafloor (or land for onshore wells), and the surface hole is filled with the surrounding sand or dirt. For wells drilled in water, this prevents the well from being a navigational hazard.

As well depth increases, P&A costs increase. Deeper wells require more cement and more time to P&A. Reservoir temperatures and pressures generally rise with well depth, necessitating more powerful equipment 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.

Instead of *permanently* P&Aing a well, companies can also *temporarily* plug a well. When a well is temporarily plugged, it can later 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. There are many offshore wells that have been temporarily plugged or idled for years. Although improvements in market conditions (such as higher oil and gas prices) might prompt some companies to re-start production from some wells, the probability of re-entry likely declines as time progresses. In fact, Muehlenbachs (2015) finds that companies have used temporary abandonment as a tactic to defer higher-cost permanent P&A work on uneconomic wells.

2.2 Environmental risks

A primary rationale for ensuring that wells are properly P&Aed is the environmental risks potentially presented by unplugged idle wells. A number of studies assess the environmental risks of onshore unplugged and orphaned wells (Alboiu and Walker, 2019; Pekney et al., 2018; Ide et al., 2006). Onshore environmental risks, however, are quite different from offshore risks. Moreover, the environmental risk from unplugged offshore wells varies significantly with water depth and distance from shore. The fate of spilled or leaked oil and gas are different in the shallow, nearshore versus deepwater environment, and we discuss them separately. Note that much of our knowledge about these processes was generated in the wake of the Macondo oil spill. Releases from poorly abandoned wells will likely be chronic and small compared to Macondo, but the underlying biochemical and ecological processes that influence the ecological costs have many similarities.

Oil Spills in the Nearshore Versus Offshore GOM Given similar volumes, initial toxicities, and probabilities of oil spills at nearshore and far offshore sites, we would expect the environmental damages of near shore spills to be greater than those farther from shore.[12] This occurs for biochemical and ecological reasons and is largely related to the amount of time the leaked oil is exposed to environmental conditions. As a result, distance to shore, rather than depth itself, is likely to be the most relevant factor in determining environmental risk from oil spills.

Biochemically, a barrel of oil spilled farther from shore has more time to degrade through evaporation, photochemical reactions, and bacterial respiration before it reaches the shore, and it has a greater opportunity to be diluted by ocean currents than a barrel of oil released closer to shore. 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).

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 GOM are especially susceptible (Pezeshki and

[12] We note that the volume of oil spilled may be positively correlated with water depth and distance from shore. For example, wells in shallow water tend to be older and on average have more gas relative to wells in deeper waters. On the other hand, wells further from shore are larger producers on average. We cannot comment on the net implications of such factors as they are likely specific to the oil and gas field.

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%) of the oil stayed in the deepwater environment (Valentine et al., 2014), raining out as marine snow (Passow and Stout, 2020).[13] While this oil has had environmental impacts on deepwater ecosystems (White et al., 2012; Montagna et al., 2013), the sequestration of oil in the deepwater may have also prevented oiling of coastal systems.

Gas Leaks in the Shallow Versus Deepwater GOM 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 deepwater 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. This is likely to be even more true for low-level chronic leaks in which the methanotropic bacterial community has time to respond to methane release. As a result, it is unlikely that methane released from a deepwater wellhead will reach the surface. In contrast, methane leaks from shallow water infrastructure, including from temporarily abandoned platforms, could be a significant emissions source. There is an emerging literature on methane leaks from offshore facilities (Negron et al., 2020; Yacovitch et al., 2020), but to date limited research has compared active to temporarily abandoned facilities.[14] Given that onshore abandoned and orphan wells are

[13] "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.
[14] One notable exception is Böttner et al. (2020).

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 global warming greenhouse gases into the atmosphere. Note leakage would also depend on the method of abandonment as intact conductors might increase the risk of methane escape to the atmosphere.

2.3 P&A regulations

By law, producers must eventually P&A both onshore and offshore wells 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 (30 CFR §250). Thus, in federal waters, companies have two years from when production ceases to complete the cleanup work. State regulations differ somewhat but also place P&A requirements on operators. In Texas, wells become inactive after they have not produced for 12 months, and operators of inactive offshore wells are required to plug them absent an extension from the regulator (16 Tex. Admin Code §3.15). In Louisiana inactive wells are defined as having no reported production or other permitted activity for 6 months and must be plugged within five years of the date of becoming inactive. (Louisiana DNR Rules. Title 43 Part XIX §137)

2.4 Onshore orphaned well studies

A well may become *orphaned* when there is no longer a financially viable company with liability for P&Aing the well. States keep orphaned well lists, and states have different criteria for designating specific wells as orphaned. The immediate cause of orphaning is usually bankruptcy. In such cases, the state takes the financial responsibility for P&Aing the well at the taxpayers' expense.

The Interstate Oil and Gas Compact Commission (IOGCC) tracks onshore and offshore wells designated as orphans by 31 states (IOGCC, 2019, 2020, 2021). In 2020, the Commission identified 92,000 orphan wells (both onshore and offshore) across these states. Of these, we estimate around 15,000 were located within the Gulf Coast states we study (Alabama, Mississippi, Louisiana, and Texas).

There is significant uncertainty about how large total orphaned well liabilities are currently, and perhaps will be in the future. Raimi et al. (2020) focus on onshore orphaned and abandoned wells in the U.S.[15] and estimate 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 $24–48 thousand per well from IOGCC (2019, 2020), the authors calculate that P&A liability for 500,000 wells could plausibly be between $12 and $24 billion. Kang et al. (2021) find at least 116,000 wells across 32 states and four Canadian provinces and territories that are operated by companies which filed for bankruptcy in the first half of 2020. The authors highlight 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) analyzes 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.[16] A number of other studies have focused on P&A risk in specific areas (Dachis et al., 2017; Kang et al., 2016, 2019; Andersen et al., 2009; Cook, 2019; Gardner, 2021).

2.5 Offshore California decomissioning study

CalGEM (2022) is the only study we are aware that focuses specifically on P&Aing offshore wells. The report by the California Geologic Energy Management Division (CalGEM) estimates the P&A and overall decommissioning costs for all offshore wells in California state waters. The report estimates that P&A costs lie in the range of $313–600 million. It compares these estimates to existing bonds, and finds that bonds are insufficient to cover decommissioning. The highest cost estimates are based on the actual decommissioning costs incurred by the California State Lands Commission to decommission Platform Holly and Rincon Island, which were deserted by their former operators. The lowest estimates are provided by the current operators of the remaining platforms.

The CalGEM (2022) report highlights that offshore wells are significantly more expensive to P&A relative to onshore wells. As we show, this qualitative statement holds true for offshore wells in the Gulf of Mexico (GoM). Although comparisons of results from California and the Gulf Coast are instructive, these

[15] 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.

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

two regions are quite different for a number of reasons. First, the California wells are drilled in relatively shallow water—mostly less than 100 feet. In contrast, we classify anything less that 1,000 feet as "shallow" in the GoM. GoM deepwater wells can be in nearly two miles (or approximately 10,000 feet) of water depth. Second, the GoM offshore oil and gas industry and its universe of support services are much larger and more active relative to California. We speculate that this difference in industry structure could help lower costs in the GoM relative to California state and Federal Pacific waters.[17] We view our work as complementary to CalGEM (2022).

2.6 Recent orphan well policy developments

Orphaned wells have become a recent focus of federal and state policy. The November 2021 federal Infrastructure Investment and Jobs Act (HR 3684 §40601) allocated $4.7 billion for cleaning up orphaned wells. Oil and gas producing states have had longstanding programs to P&A orphaned wells. Most idle or orphaned wells in the Gulf of Mexico (GoM) lie in Louisiana or Texas state waters, so these states' orphan P&A programs are the most relevant for Gulf Coast P&A efforts.

Louisiana, the state for which we identify the most offshore P&A candidates, created the Louisiana Oilfield Site Restoration Program in 1993 within the Department of Natural Resources to address orphaned oilfield sites across the state. The program is funded by a fee on oil and gas production and generates approximately $4 million in revenues per year. Despite efforts to plug orphaned wells, the inventory of orphaned wells has increased by over 50 percent since the 2014 oil price crash and currently includes over 4,500 wells. Offshore wells, however, make up a small part of this list: to date, only four have been P&Aed through the orphan well fund.[18]

In Texas, the state for which we identify the second most offshore P&A candidates, the Railroad Commission (RRC) also has a long-running orphaned well plugging program. In FY 2020, the RRC spent approximately $50 million

[17] For a point of comparison, when we used our GoM-based methodology to estimate P&A costs for offshore wells in California state waters in a prior analysis (Agerton et al., 2022), we estimated a P&A cost of around $200 million, compared to the $313–600 million estimate in CalGEM (2022). The difference in our estimates and CalGEM's could be due to a different distribution of costs in California waters versus the GoM. It is also possible that BSEE P&A estimates for the GoM—which we use as a foundation for our estimates—are simply too low relative to actual costs.

[18] Information provided by the Louisiana Department of Natural Resources.

from the Oil and Gas Regulation and Cleanup Fund (OGRC) on oilfield cleanup activities. The OGRC was created in 2011 and is funded through regulatory and permitting fees paid by the oil and gas industry. A search of the RRC's website in November 2021 identified roughly 7,500 orphaned oil and gas wells, more than 1,000 higher than the number in 2018. Very few offshore wells have been P&Aed using this fund.

The federal government does not have an orphaned well list or an orphaned well P&A program. We speculate that the absence of orphaned wells in federal waters stems from two reasons. First, oil and gas activity onshore has been occurring for over a century, while activity in federal waters did not begin in earnest until the 1970s. So, wells in federal waters are on average younger than wells in state waters, and the set of inactive and orphaned wells has had less time to develop. Second, in federal waters the Department of the Interior can require prior owners to P&A wells if the current owner goes bankrupt (30 CFR §556.710 and §556.805). We find that over 85 percent of the estimated outstanding P&A liability is associated with wells that have a "supermajor" as a current or prior owner. This fact has been highlighted in the press due to a 2021 bankruptcy proceeding for Fieldwood Energy.[19]

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3 Identification of offshore wells

The first step in our analysis is to identify the universe of Gulf Coast wells that have yet to be P&Aed. We utilize the term "Gulf Coast" to broadly refer to the Gulf of Mexico (GoM) and coastal waters in Texas, Louisiana, Mississippi and Alabama. We start by compiling a comprehensive dataset of offshore wells in the Federal GoM and the state waters in these four states. Our definition of *state waters* includes inland waters that lie within a state's coastal zone, as well as state waters outside of the officially designated U.S. coastline.[20] 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.

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

[20] In Louisiana, Mississippi and Alabama, the federal/state water boundary is around 5 km (3 miles) from the coastline, while in Texas the boundary is at around 14.5 km (9 miles).

We obtain data on federal offshore wells and their historical production from the Bureau of Safety and and Environmental Enforcement (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 we merge this with historical production data from Enverus (previously DrillingInfo).[21] We use well classifications as reported to state and federal agencies, alongside historical production data to identify the probability that a well will produce in the future after being inactive. In instances where a well status is not listed from the state or federal agency, we also use data from Enverus identify the well's status.

As we discuss in Section 2, the depth of a well is a key determinant of its P&A cost. We face two different challenges in determining the depth of each well. First, public records do not provide a measured depth for a few wells, especially older ones.[22] For these cases, we impute 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 .01 kilometers away. Second, many federal wells have secondary wellbores called *sidetracks*. Sidetracks are additional wellbores that branch off of the initial well, often several thousand feet down. Thus, one *well* can have multiple *wellbores* (also referred to as *boreholes*).[23] 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 P&A costs for wells with multiple wellbores, 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.[24] We find that on average, the incremental distance of a sidetrack

[21] 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.

[22] *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 one percent of wells.

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

[24] The kickoff point is the location at a given depth below the surface where the sidetrack is deviated from the original wellbore.

is approximately 39 percent of its full measured depth.[25] In instances where 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 in Section 2.6, state governments have programs that pay to P&A wells that the state determines are orphaned. We obtained records on the actual costs incurred to P&A orphaned wells from the relevant government agencies in Louisiana and Texas. However, very few of the wells that had been P&Aed were offshore. Wells in Louisiana state waters make up the majority of GoM wells in state waters, 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.

We note that our 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. In discussions with oil and gas regulators, industry personnel, and academics, a number of people have expressed concern that such undocumented wells might exist. We also note that records for older wells are more likely to be missing key pieces of information, like measured depth. Given these two caveats, we urge the reader to interpret our statistics as estimates—not a complete census. Nevertheless, we believe that the data we assemble is sufficient for obtaining a reasonable estimate of the aggregate P&A liability.

3.1 Summary statistics

Table 1 presents the number of wellbores and wells that were ever drilled within federal or state waters and that are documented in public databases.[26] Panel A differentiates wells by their location: *federal deepwater* 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 82 thousand wells (99 thousand wellbores), approximately 55 percent of wells (46 percent of wellbores) have been drilled in state

[25] For a given well i, we calculate the average incremental share of a sidetrack as the mean of $share_i \equiv 1 - \frac{kickoff_i}{measureddepth_i}$.

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

Table 1: Number of Wells and Well Bores Ever Drilled in GoM

	(1) Wellbore Count	(2) Well Count
Panel A: Well Location		
State Inland	31,439	31,439
State Offshore	13,601	13,601
Federal Shallow	48,809	34,518
Federal Deep	4,962	2,699
All	98,811	82,257
Panel B: Well Status		
Active	11,086	6,501
P&Aed	74,148	64,373
Temporarily P&Aed	5,605	3,545
Orphaned	752	752
Active Injection	473	473
Idle, Shut in, or inactive	6,747	6,613
All	98,811	82,257

This table includes all documented wells spudded offshore through 2020 in the Federal GoM as well as the state waters of Texas, Louisiana, and Alabama. We include wells which have already been P&Aed, and we exclude wells that are permitted but undrilled as well as wells with suspended drilling operations.

waters, with the remainder in federal waters. Note that no individual wellbores were reported in state waters, so there is only a distinction between wells and wellbores in federal waters. We also highlight that of the wells in state waters, over two-thirds have been drilled in what states designate as inland waters. These inland waters include water bodies such as bays, estuaries as well as marsh and swamp wetlands.

In Panel B of Table 1, we differentiate wellbores and wells by their status.[27] Of the approximately 82 thousand wells ever drilled, about 78 percent have been permanently plugged and abandoned. Only eight percent are either currently listed as active or being used for active injection. Thus, the remaining approximately 14 percent are plausible candidates for P&Aing at this time. We remove wells that have been permanently P&Aed from our sample.

Next, we present summary statistics in Table 2. These summary statistics,

[27] There are many different status designations that vary across state and federal jurisdictions. As discussed in Section 3, we allocate all wells to one of the well statuses listed in Table 1.

and all subsequent analysis, do not include wells that have already been P&Aed (in contrast to Table 1 that includes all wells ever drilled, including wells that are currently P&Aed). Panels A, B and C present estimates for three areas: federal deepwater, 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.

Summary statistics for federal deepwater wells are shown in Panel A of Table 2. 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. 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. Table 2 shows a mean P50 P&A cost per foot of $1,108 and some dispersion for the 778 deep water wells. Although not shown in the table, note that for all 689 with a recorded measured depth (versus imputed measured depth), the cost per foot is exactly the same: $1,156 per foot of measured depth. Thus, this is apparently BSEE's methodology for estimating P&A costs for wells in greater than 1,000 feet of water depth. The P70 and P90 costs are larger and exhibit more variation. BSEE's estimated average cost per wellbore is $24 million. Finally, we note that a large majority of deepwater wells are currently or were at one point owned by a supermajor—84 percent of those with cost estimates and 90 percent of those without.

Panel B displays summary statistics for wellbores in federal shallow waters. BSEE provides estimated cost for just over half of these wells. Shallow water P&A costs per foot are much smaller than deepwater costs: the P50 cost per foot is $60 versus $1,108 for deepwater. 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 one percent) involve subsea completions compared to deepwater wells. Industry managers have told us that costs increase dramatically with a well's measured depth. We note that 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 thousand, compared to $24 million in federal deep waters.[28] As with the deepwater wells, a large majority of federal shallow water wells are currently or at one point owned by a supermajor—88 percent of those with cost estimates and 89 percent of those without.

[28]Compares expected P&A cost in Panel B and Panel A.

Panel C presents summary statistics for wells in state waters. Because these wells are not in federal waters, BSEE does not provide P&A cost estimates for them. We are also unable to collect ownership histories, so we do not indicate whether state wells are or were owned by supermajors. Wells in state waters are in shallower water, closer to shore, and older than those in shallow federal waters. The average depth of wells in state waters is somewhat less than the average depth of wells in federal shallow waters. Notably, water wells in state coastal and offshore areas or located in swamp and marsh areas have a median water depth of zero feet. This reflects the fact that many wells in coastal Louisiana are accessed by dredging canals to the well location. Thus although the well is in water, per se, the water depth in the coastal area is listed as zero feet.

4 Estimating costs

BSEE provides a public database of P&A cost estimates for a subset of federal wells. While there are several steps involved, our empirical strategy is essentially to extrapolate BSEE's P&A costs to wells in federal and state waters without cost estimates, and then sum these costs for subsets of wells. Our analysis relies on two major assumptions. First, we assume that after conditioning on observable well characteristics, the wells BSEE provides a cost estimate for are similar to the wells that it does not. Second, we assume that BSEE's cost estimates are indeed unbiased estimates of the actual P&A cost of the well.

When BSEE provides cost estimates, they are for the P50, P70, and P90 quantiles. We 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 as well as the possibility of cost overruns. To calculate expected P&A costs (versus the P50 cost), we fit a separate log-normal distribution to each set of P50, P70, and P90 cost estimates and calculate the implied expected cost.[29] This assumption of a right tailed distribution of well P&A costs is also consistent with the large costs noted in the CalGEM report (CalGEM, 2022), as well as feedback received from both industry and regulators. Our expected P&A cost that we calculate is approximately 6 percent

[29] 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, and this naturally suggests using a right tailed distribution.

Table 2: Summary Statistics for Unplugged GoM Wells

	Mean	Median	Std. Dev.	Mean	Median	Std. Dev.
	(1)	(2)	(3)	(4)	(5)	(6)
	BSEE Cost Estimate			No BSEE Cost Estimate		
Panel A: Federal Deepwater (>1,000 feet water depth)						
P50 Cost Per Foot ($/foot)	1,108	1,156	224			
P70 Cost Per Foot ($/foot)	1,341	1,366	258			
P90 Cost Per Foot ($/foot)	1,682	1,675	345			
Expected P&A Cost (million $)	24.14	23.80	7.49			
Water Depth (ft)	4,714	4,428	1,946	3,131	2,945	1,793
Measured Depth (ft)	20,580	19,965	6,170	16,875	16,471	5,824
MD Imputed	11.4%			2.4%		
Measured Depth, orig or imputed (ft)	20,805	20,405	6,098	16,957	16,574	5,842
Spud Year	2011	2012	7	2002	2002	9
Distance to Shore (km)	148	139	80	122	111	77
Subsea Completion	77.8%			34.8%		
Supermajor Ownership	84%			90%		
Wellbore Counts		778			1,678	
Well Counts		444			761	
Panel B: Federal Shallow Water (<1,000 feet water depth)						
P50 Cost Per Foot ($/foot)	60	50	66			
P70 Cost Per Foot ($/foot)	79	70	89			
P90 Cost Per Foot ($/foot)	106	98	123			
Expected P&A Cost (million $)	0.66	0.67	0.78			
Water Depth (ft)	150	140	100	211	177	185
Measured Depth (ft)	10,658	10,476	3,235	10,442	10,388	3,580
MD Imputed	0.1%			0.6%		
Measured Depth, orig or imputed (ft)	10,658	10,477	3,235	10,450	10,411	3,575
Spud Year	1990	1992	15	1988	1989	14
Distance to Shore (km)	57	40	48	57	34	49
Subsea Completion	0.1%			0.4%		
Supermajor Ownership	88%			89%		
Wellbore Counts		6,865			6,176	
Well Counts		3,923			3,590	
Panel C: State Coastal and Offshore						
Water Depth (ft)				2	0	7
Measured Depth (ft)				9,962	9,698	3,557
MD Imputed				10.1%		
Measured Depth, orig or imputed (ft)				9,921	9,700	3,636
Spud Year				1979	1977	21
Distance to Shore (km)				2	0	4
Subsea Completion				0.0%		
Wellbore Counts					9,166	
Well Counts					9,166	

This table includes all documented wells spudded offshore through 2020 in the Federal GoM as well as the state waters of Texas, Louisiana, and Alabama. We exclude wells that have been P&Aed (unlike Table 1), wells that are permitted but undrilled, and wells with suspended drilling operations. We list two sets of statistics for measured depth, one that includes only measured depth information recorded in well databases, and one that also includes imputed measured depth information. Wells in federal waters may have multiple wellbores (boreholes), and we provide counts for both. Wells in state waters only have one wellbore. We also only have information on prior ownership for federal wells, so we indicate ownership by a supermajor for those wells only.

larger than the P50 cost. We normalize expected costs by each well's depth.

Our next step is to use regression analysis to estimate how BSEE cost estimates depend on observable wellbore characteristics. As shown in Table 2, the characteristics and costs of wells in federal deepwater, federal shallow water, and state waters are quite different. Because these populations of wells are different, we estimate separate regression models for all three groups. We then use our estimated regression parameters to predict costs for the wellbores in federal and state waters that lack cost estimates. For federal wells with sidetracks, we also remove the double-counted portion of each sidetrack's measured depth above the kickoff point as discussed in Section 3.

Model 1: Deep Federal Waters Our cost model for federal deepwater wells is simple. For the 689 deepwater wells with a BSEE cost estimate and a recorded measured depth, BSEE estimates that the P50 cost to P&A any federal deepwater well is exactly \$1,156 per foot of measured well depth.[30] Among these 689 wells, there is variation in water depth, distance to shore, and whether the well involved a subsea completion. However, there is no variation in the P50 P&A costs. 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.[31] While there is some variation in the P70 and P90 costs per foot, we were unable to statistically detect systematic relationships between well characteristics available in the public BSEE databases and these costs. The mean of the expected P&A cost for federal deepwater wells with recorded measured depths is \$1,230/ft. To calculate expected P&A costs for wellbores without cost estimates, we simply find the total length of the wellbore (adjusting sidetrack depths to avoid double-counting) and multiply by our average expected cost of \$1,230/ft.

Model 2: Shallow Federal Waters For wells in shallow federal waters, we use equation (1) to estimate the P&A cost. 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 ($subsea_i$):

$$c_i = \alpha + \beta WD_i + \gamma subsea_i + \varepsilon_i. \tag{1}$$

[30] 11.4 percent of federal wells with BSEE cost estimates lacked a recorded measured depth and had to be imputed. See Table 2.

[31] 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.

Model (1) is parsimonious. However, including other well characteristics like 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 that we use.

We estimate the parameters in equation (1) using the expected BSEE P&A cost for all 6,865 wellbores listed in Panel B of Table 2 (including the 0.1 percent for which we had to impute a measured depth). Our estimates imply that the lowest cost per foot is \$18.59 ($\hat{\alpha} = 18.59$) For every 100 feet of water depth, cost per foot rises by \$32 ($\hat{\beta} = .3217$). Wells with subsea completions are significantly more expensive, adding an additional \$870 per foot ($\hat{\gamma} = 869.59$).[32] Using these estimated regression coefficients and data on well characteristics, we predict expected P&A costs for the 6,176 out-of-sample wellbores in federal shallow waters that lack P&A cost estimates.

Model 3: State Waters We 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.

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

The most important difference with the prior (1) is that we estimate the state waters model (2) using only wellbores in federal waters that are less than 15km from shore and do not have subsea completions. Recall that in Louisiana, Mississippi and Alabama, the federal/state water boundary is around 5 km (3 miles), while in Texas the boundary is at around 14.5 km (9 miles). Removing wells greater than 15 km from shore leaves 1,708 wellbores in shallow federal waters with BSEE cost estimates.[33] Effectively, this means we are extrapolating federal shallow water P&A costs into state waters with shallower wells. Ideally, we would estimate P&A costs of wells in state waters using a random sample of wells in state waters that were P&Aed. Unfortunately, and as discussed in Section 2.6, such historical cost data is not available.

Our state waters model (2) also differs from (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, we believe that it is unlikely

[32] All coefficients are statistically different from zero at the $p = .01$ level

[33] Three wells with costs per foot that are clearly outliers are also removed.

that they do. Less than 1 percent of federal shallow water wells have subsea completions.

Our estimates for equation (2) imply that the P&A cost per foot starts at \$25.8/foot ($\hat{\alpha} = 25.8$) and increases by \$26.47 for every 100 feet of water depth ($\hat{\beta} = .2647$).[34] 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. The fact that these costs incurred by the state of Louisiana to P&A specific orphaned wells are in the range of our estimates is reassuring. main.tex

5 Identifying P&A priorities

For policy purposes, the relevant quantities of interest are less likely to be the parameters of a cost model or the cost of an individual well, but the aggregate cost for sets of wells with particular characteristics that make them relevant to the public. We identify two such sets of wells—first, wells that are not producing and are unlikely to produce in the future, and second, federal wells that were ever owned by a "supermajor" oil and gas company that could serve as a backstop for P&A liability.

5.1 Non-producing wells

The first group of wells likely to be of interest to policymakers is the set of non-producing wells that are unlikely to begin production again. A key opportunity cost of P&Aing a non-producing well (besides the expense of doing so) is the loss of a real option to restart production from that well in the future (Muehlenbachs, 2015). The value of this option is smallest for wells that are not very profitable and, therefore, highly unlikely to re-enter production. Some of these wells, in fact, may have negative values to the company and represent future financial liabilities without revenue. P&Aing these wells is unlikely to reduce the supply of oil and gas since they are not currently producing.

We identify three factors that suggest a non-producing well is unlikely to resume production in the future: (A) the well is listed as idle or has not reported production in five years, (B) the well has been temporarily plugged, and (C) the well is on a federal lease that has expired. These factors are *not* mutually exclusive: individual wells can be included in none, some, or all of them. We discuss

[34] Coefficients are statistically different from zero at the $p = 0.01$ level.

each factor separately, but we hypothesize that wells with multiple factors are unlikely to produce meaningful quantities in the future.

Inactive wells First, we identify 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.[35] "Inactive", "idle", and "shut-in" are status codes identified in federal and state well databases. Restarting production involves a one-time cost in addition to the ongoing cost to maintain a producing well. Profitable wells sometimes temporarily shut-in for operational or safety reasons (such as a hurricane) but restart quickly once the event subsides because production revenue is larger than the cost to restart. Other wells will not be restarted if the company decides that the costs associated with restarting are higher than the projected revenues.

To quantitatively identify inactive wells, we estimate the probability that an non-producing well restarts production as a function of the time it has not produced. Economic theory suggests that the more time a well does not produce, the more likely it is that the well is unprofitable, and the lower the probability it will restart in the future. Using data on all Federal GoM production from 1947 to Nov 2021, we statistically estimate the probability that a well restarts production in s months or less after stopping production.[36] Figure 1 plots the Kaplan-Meier estimator of this probability. The estimate shows that most wells which restart production do so within the first couple of years. After three years of no reported production, a well has a 5.8 percent chance of reporting production in the following seventeen years. Similarly, after five years of no reported production, a well has a 3.3 percent chance of reporting production in the following seventeen years. Of course, in theory wells could re-enter production at some point in the future, for which we cannot observe at this point in time. But practically speaking, these results suggest that after five years of no reported

[35] 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.

[36] We aggregate production data to the API 10 level. We then identify all production gaps in which a well produces nothing for at least one month. Each observation is then an s-month gap in production. For example, if a well produces in Jan 1996 ($t = -1$), does not produce Feb–Mar 1996 ($t = 0, 1$), and produces again starting in Apr 1996 ($t = 2$), we record a 2-month production gap. Some wells stop producing and never produce again. We retain these observations, assuming that the well remains at risk of restarting production, and define Nov 2021 as a censoring date. Using these data, we estimate Pr(restart by $t - s$|produced in $t - 1$ but not t) with a Kaplan-Meier estimator.

production, a well has less than a 4 percent chance of producing oil and/or gas in the future.

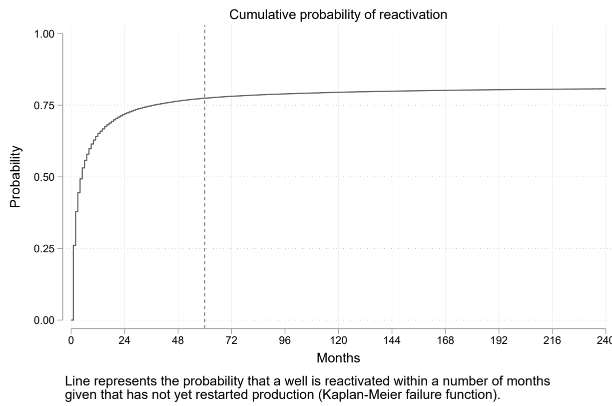

Figure 1: Cumulative probability of production restart within s months

Temporarily plugged Second, we identify wells that have been temporarily plugged. There are two common situations where a well may be temporarily plugged. 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.

Expired federal leases Third, we identify wells in federal waters that are on inactive leases. Federal leases expire one year after production has been ceased. Thus, we consider a lease expired once a year passes with no reported oil and gas production. There can be many wells on one lease, and so if any individual well is still producing, the lease is held by production. The federal government does not require that the operator P&A wells or remove unused equipment as long as the lease is held by production. One year after the last well on a lease halts production, the lease is terminated, and the operator is obligated to decommission platforms and P&A wells within twelve months. Thus, wells that have not been P&Aed within one year after a lease becomes inactive leases are not in compliance with BSEE regulations.

5.2 Supermajor ownership

The second set of wells that are of policy interest consists of those in federal waters that were ever owned by one of the "supermajor" oil and gas companies, or one of the firms they purchased.[37] The Department of the Interior can hold prior owners liable for P&Aing old wells in federal waters if the current owner goes bankrupt (30 CFR §556.710 and §556.80). State governments generally cannot do this. As of July 1, 2022, the supermajor oil and gas companies have a combined market capitalization of $1.2 trillion. Wells that have been owned by a supermajor are plausibly at lower risk of not being properly P&Aed because these large corporations serve as backstops for this liability. The 2021 bankruptcy proceeding for Fieldwood Energy underscores how prior owners of federal offshore wells may end up footing large P&A liabilities.[38]

6 Results

Table 3 displays aggregate P&A cost estimates. 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. We estimate that total future P&A liabilities for both active and inactive are approximately $44 billion.

Main results Panel A in Table 3 highlights that the majority of outstanding P&A liabilities—regardless of well P&A candidate classifications—reside in federal offshore waters, particularly deep waters. Specifically, $42 of $44 billion of the total P&A liability is associated with federal wells. Deepwater wells are especially expensive to P&A due to their complexity, size, and depth, plus the costs of deepwater operations. Only 1,617 deepwater wells represent $34.5 billion in P&A costs, while 9,166 wells in federal shallow waters only represent around $7.6 billion in P&A costs. State wells represent a much smaller share of

[37]We define the set of supermajors as Chevron, Shell, Exxon, Mobil, Conoco, BP, Texaco, Total, Union Oil Company, Atlantic Richfield, XTO, and Eni.

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

Table 3: Aggregated GoM P&A Cost Estimates (billion $) and Well Counts by Jurisdiction

	Total	Federal Deep	Federal Shallow	State
Panel A: Total P&A Cost				
All	$44.33	$34.48	$7.61	$2.25
	(19,341)	*(1,617)*	*(9,166)*	*(8,558)*
Panel B: P&A Candidate Categories				
Inactive Wells (A)	$30.11	$22.69	$5.57	$1.85
	(14,099)	*(829)*	*(6,263)*	*(7,007)*
Temporary P&A (B)	$9.52	$7.14	$2.32	$0.06
	(3,673)	*(272)*	*(3,170)*	*(231)*
Inactive Lease (C)	$1.83	$1.03	$0.80	
	(1,038)	*(45)*	*(993)*	
A or B or C	$30.51	$22.98	$5.67	$1.85
	(14,318)	*(856)*	*(6,446)*	*(7,016)*
Active / Recently Active	$13.82	$11.49	$1.94	$0.39
	(5,023)	*(761)*	*(2,720)*	*(1,542)*
Panel C: Wells in Multiple Categories				
A&B	$9.26	$6.96	$2.25	$0.06
	(3,518)	*(252)*	*(3,044)*	*(222)*
A&C	$1.66	$0.91	$0.75	
	(942)	*(34)*	*(908)*	
B&C	$0.87	$0.44	$0.43	
	(622)	*(19)*	*(603)*	
A&B&C	$0.84	$0.43	$0.42	
	(590)	*(15)*	*(575)*	

Well counts are listed in parentheses and italics below P&A cost (billion $). This table aggregates up to the level of the well for Federal waters, not the wellbore. In state waters, there is one wellbore per well. Deepwater includes all wells in water greater than 1,000 feet of water depth. Shallow water wells includes wells in water less than 1,000 feet of water depth. State waters do not have inactive federal leases (category "C"), so these spots are left blank in the table.

P&A costs—8,558 of them cost around $2.3 billion to P&A, about 5 percent of outstanding offshore GoM P&A liability.

Panel B in Table 3 further shows that the majority of P&A costs are also associated with wells that meet one of our three criteria for potential P&A candidates: Inactive Wells (A), Temporarily P&Aed wells (B), or Inactive Federal Leases (C) defined in Section 5.1. Overall, only 31 percent of P&A liability—$13.8 of $44.3 billion—is associated with active wells. Specifically, for federal deepwater, 33 percent of P&A liability is associated with active wells. This share drops to 25 percent in federal shallow water and to just 17 percent in state water. The fact that a larger share of P&A liability in state waters is associated with inactive wells could reflect differences in regulation between state and federal wells and the fact that wells in state waters tend to be older than wells in federal waters (see Table 2).

Panel C in Table 3 shows P&A costs and well counts for wells that meet multiple criteria. These wells are perhaps the most likely to be orphaned at some point. The majority of wells that are classified as inactive (A) do not fall into multiple categories. This can be seen by comparing category A in Panel B to the A&B and A&C categories in Panel C. Of the Temporarily P&Aed wells (B), 96 percent of are also Inactive (A).

Supermajors While 95 percent of oustanding P&A liabilities in the GoM are associated with federal waters, the fact that P&A liability in federal waters reverts to prior owners may limit federal taxpayers' orphan well risk. Table 4 splits P&A liability and well counts in federal deep and shallow waters by whether the well was ever owned by a supermajor.[39] Summing across the supermajor-associated P&A costs and well counts, we can see that 87 percent of wells (9,381 wells) and 88 percent of P&A liability ($36.9 billion) in the Federal GoM is associated with a supermajor.[40] Even though Panel B shows that around two thirds of the total outstanding P&A liability in the Federal GoM is associated with inactive wells (category A), most of these P&A liabilities are backstopped by the largest public oil and gas companies in the world.

[39]See Section 5.2 for our definition of a supermajor.

[40]Recall that some wellbores (i.e. API-10) have multiple sidetracks (i.e. API-12). In some cases, for a well with multiple sidetracks some sidetracks were drilled after ownership was transferred from a supermajor to a smaller company. In these instances, some share of the P&A cost is allocated to prior supermajor ownership, while the residual is not. The share is calculated based on the share of measured depth from the wellbore beyond the sidetrack's kickoff point. In these instances, the API-10 for tabulating well counts is included in both categories.

Table 4: Aggregated Federal GoM P&A Cost Estimates (billion $) and Well Counts by Supermajor Ownership

		Deepwater		Shallow Waters	
	Total	Supermaj.	Non-sup.	Supermaj.	Non-sup.
Panel A: Total P&A Cost					
All	$42.08	$30.29	$4.19	$6.57	$0.99
	(10,783)	*(1,405)*	*(212)*	*(7,976)*	*(1,066)*
Panel B: P&A Candidate Categories					
Inactive Wells (A)	$28.26	$20.03	$2.66	$4.88	$0.64
	(7,092)	*(724)*	*(105)*	*(5,520)*	*(631)*
Temporary P&A (B)	$9.46	$5.83	$1.31	$2.06	$0.25
	(3,442)	*(226)*	*(46)*	*(2,838)*	*(313)*
Inactive Lease (C)	$1.83	$1.02	$0.02	$0.61	$0.16
	(1,038)	*(43)*	*(2)*	*(776)*	*(176)*
Active / Recently Active	$13.43	$9.99	$1.50	$1.61	$0.32
	(3,481)	*(657)*	*(104)*	*(2,318)*	*(392)*

Well counts are listed in parentheses and italics below P&A cost (billion $). Deepwater includes all wells in water greater than 1,000 feet of water depth. Shallow water wells includes wells in water less than 1,000 feet of water depth. We identify a well as being owned by a supermajor if the following regular expression returns a match for any year for a given well's owner `(chevron|shell|exxon|mobil|conoco|bp|texaco|total|union oil|atlantic richfield|xto|^eni)` and the firm's name is not "RBP Offshore," "TBP Offshore Co.," or "Mobile Mineral Corporation."

Table 5: Aggregated P&A Cost Estimates (million $) and Well Counts in State Waters

		Alabama	Louisiana		Texas	
	Total	Offshore	Inl. Wtr.	Offshore	Inl. Wtr.	Offshore
Panel A: Total P&A Cost						
All	$2,245	$16	$1,297	$697	$119	$117
	(8,557)	*(27)*	*(4,970)*	*(2,612)*	*(552)*	*(396)*
Panel B: P&A Candidate Categories						
Inactive Wells (A)	$1,848	$5	$1,077	$589	$85	$92
	(7,006)	*(8)*	*(4,131)*	*(2,199)*	*(368)*	*(300)*
Temporary P&A (B)	$62	$3	$17	$41	$0	$0
	(230)	*(5)*	*(56)*	*(166)*	*(2)*	*(1)*
Active / Recently Active	$395	$11	$219	$105	$34	$25
	(1,543)	*(19)*	*(839)*	*(405)*	*(184)*	*(96)*
A or B	$1,851	$5	$1,077	$592	$85	$92
	(7,014)	*(8)*	*(4,131)*	*(2,207)*	*(368)*	*(300)*
Panel C: Wells in Multiple Categories						
A&B	$60	$3	$17	$39	$0	$0
	(222)	*(5)*	*(56)*	*(158)*	*(2)*	*(1)*

Well counts are listed in parentheses and italics below P&A cost (million $). Table includes wells offshore state waters, as well as inland waters. Inland waters are defined as water bodies that are inland from the state shoreline as well as wetlands in the state coastal zone. State offshore is defined as state waters between the state coastline and the federal–state boundary.

State waters Table 5 breaks down results by the three Gulf Coast states with significant offshore oil and gas activity: Louisiana, Texas, and Alabama, as well as whether the wells are located in Inland Waters or Offshore.[41] Our definition of inland waters includes areas in open water, but also includes areas such as wetlands.

Panel A shows that the majority of P&A liability and wells are in Louisiana: around $2 billion in P&A liability from about 7,500 wells. P&A liability in Texas is an order of magnitude smaller at around $240 million associated with 1,000 wells. Alabama is yet another order of magnitude smaller: 27 wells implying around $16 million in P&A liability. In Louisiana and Texas, only 16 and 25 percent of outstanding P&A liability is associated with active wells, while in

[41] We define inland waters as those which lie within a state's coastal zone, while we define offshore as state waters outside of the officially designated United States coastline but before the federal/state water boundary. In Louisiana and Alabama, the federal/state water boundary is around 5 km (3 miles) from the coastline, while in Texas the boundary is at around 14.5 km (9 miles).

Alabama active wells contribute around 70 percent of P&A liability. Panel A also shows that in Louisiana and Texas, around two thirds and one half of wells and P&A liability are concentrated in inland waters inside the official U.S. coastline versus offshore, outside of the coastline. As discussed in Section 2.2, environmental damages of near shore spills are likely to be greater than those farther from shore, all else equal.

Panel B shows that much of the outstanding P&A liability is associated with non-producing wells (category A): 84 percent in Louisiana and 75 percent in Texas. In all three states and especially Texas and Louisiana, the number of temporarily P&Aed wells (category B) and their associated costs are one and even two orders of magnitude smaller than the figure for inactive, non producing wells (category A). Further comparing these two categories with their intersection (A&B in Panel C) demonstrates that almost all temporarily P&Aed wells are inactive, but very few inactive wells are temporarily abandoned.

7 Conclusion

In this paper, we assess the outstanding financial liability associated with plugging and abandoning (P&Aing) all offshore oil and gas wells in the Gulf of Mexico and inland waters of the Gulf Coast region of the U.S. Understanding the outstanding liability of wells that have not been permanently P&Aed has policy implications both from an environmental standpoint but also in understanding the economics more broadly of the decommissioning of infrastructure at the end of its life. Our results highlight a number of broad trends in the offshore oil and gas industry and geared towards policymakers interested in potential future liability for future generations.

First, although approximately 78 percent of all wells ever drilled in our sample have been P&Aed, there are currently over 14,000 non-producing wells that have also not been permanently P&Aed. In fact, there are more *inactive, non-producing* wells that have not been P&Aed than currently active wells. This is particularly true for Louisiana and Texas, where only 17 and 25 percent of P&A liability is associated with active wells. Our hazard analysis revels that after five years of no reported production, these inactive wells have less than a 4 percent chance or re-entering production into the future. Thus, there is a concern that many of these wells in state waters might be at risk of being orphaned in the future. A review of the environmental sciences literature also reveals that the environmental damages of near shore spills is likely greater than those farther from shore.

We also show that wells in shallow waters are significantly less expensive to P&A. Specifically, plugging the approximately 13,000 inactive wells in state waters and shallow federal waters (of the approximately 14,000 total wells) would cost approximately \$7.2 billion (of approximately \$30 billion in total). Thus, over 90 percent of the inactive wells can be plugged for about 25 percent of the total cost. Because these shallower wells closer to shore also present larger environmental risks, P&Aing wells in state and shallow federal waters is likely to provide more environmental benefits per dollar of P&A spending relative to P&Aing a more expensive, deepwater well.

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A Supplemental Figures

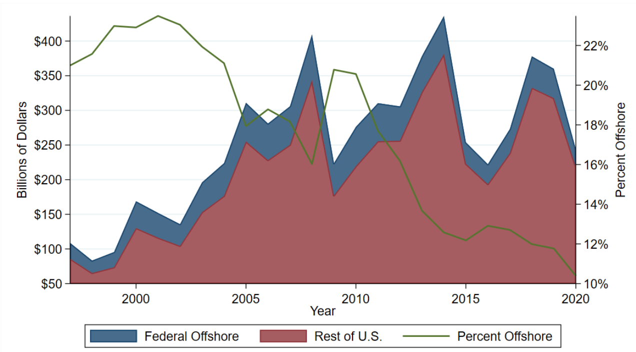

Figure 2: Federal Offshore Value of Production in Context

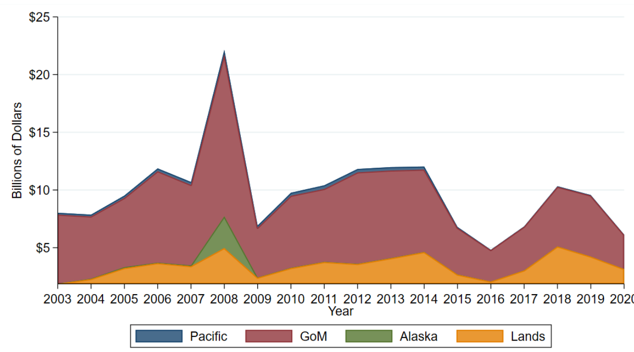

Figure 3: Federal Government Revenues from Oil & Gas