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GREEN STIMULUS FOR OIL AND GAS WORKERS: CONSIDERING A MAJOR FEDERAL EFFORT TO PLUG ORPHANED AND ABANDONED WELLS

BY DANIEL RAIMI, NEELESH NERURKAR, AND JASON BORDOFF
JULY 2020

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Columbia University CGEP
1255 Amsterdam Ave.
New York, NY 10027
energypolicy.columbia.edu

@ColumbiaUenergy

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ABOUT THE AUTHORS

Daniel Raimi is a senior research associate at Resources for the Future and a lecturer at the Gerald R. Ford School of Public Policy at the University of Michigan. He works on a range of energy policy issues with a focus on oil and gas regulation and taxation and climate change policy. *The Fracking Debate*, his first book, combines stories from his travels to dozens of oil and gas producing regions with a detailed examination of key policy issues, and is published by Columbia University Press as part of the Columbia University Center on Global Energy Policy book series (www.thefrackingdebate.com).

Neelesh Nerurkar is vice president and senior analyst at ClearView Energy Partners, LLC, an independent research firm that examines macro energy issues for institutional investors and corporate strategists. He covers climate and transportation policy issues. Neelesh previously served as a deputy assistant secretary at the US Department of Energy and as an energy advisor to the White House and the US Department of State.

Jason Bordoff is a former senior director on the staff of the National Security Council and special assistant to President Obama. He is now a professor of professional practice in international and public affairs and the founding director of the Center on Global Energy Policy at Columbia University's School of International and Public Affairs.

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EXECUTIVE SUMMARY

The global economic damages wrought by COVID-19 have dramatically magnified the suffering caused by the deadly virus. US lawmakers have already approved $3 trillion in aid to help offset the economic damage, and additional measures are under consideration. At the same time, the need to invest trillions in economic recovery has prompted calls to "build back better" by making the recovery a greener, less carbon-intensive one.

This paper, a joint effort between Resources for the Future and the Center on Global Energy Policy at Columbia University, examines the potential to boost US employment in the oil and gas workforce while also reducing pollution through a federal program to plug orphaned and abandoned oil and gas wells. These wells can leak methane and other pollutants that contribute to climate change, poor air quality, and other health and environmental risks. This research included interviews with key regulatory and industry officials to present the most up-to-date information on this rapidly evolving issue.

While states and the federal government fund well plugging activities through bonding requirements, industry fees, and other sources, these funds have not historically been adequate to reduce the inventory of orphan unplugged wells. Many of these sites date back to the 19th and early 20th centuries, when regulations including bonding requirements were weak or, in many cases, nonexistent. Estimates for the total number of orphaned and abandoned wells range from several hundred thousand to 3 million, depending on the definition of such wells needing attention. At the same time the oil and gas industry, which has seen employment drop to levels not seen since 2006, appears able to scale up to carry out this work. Labor and equipment are readily available due to the low oil price environment created by the collapse in demand from the coronavirus.

The paper finds:

- A significant federal program to plug orphan wells could create tens of thousands of jobs, potentially as many as 120,000 if 500,000 wells were plugged. Addressing 500,000 wells would require state, tribal, and federal agencies to identify and prioritize hundreds of thousands of additional wells, most of which are unaccounted for in current inventories of orphaned wells. These inventories indicate that the largest number of orphaned wells are in Pennsylvania.
- A widespread federal effort to plug orphaned and abandoned oil and gas wells would reduce local air pollution, safety risks, and greenhouse gas emissions at a cost of roughly $67 to $170 per ton of CO_2-equivalent, well within the range of other policy options.
- A significant pool of labor from the oil and gas industry could be deployed toward and benefit from such a program. More than 76,000 direct industry jobs were lost from February to June of 2020, a number that is likely to rise in the months to come. The job losses have been especially acute in rural regions where domestic oil and gas production occurs and where economies are closely tied to industry fortunes, such

as the Permian Basin in West Texas and New Mexico, the Marcellus in Pennsylvania and Ohio, the Bakken in North Dakota, and parts of California, Colorado, Louisiana, Oklahoma, and other states. In these regions, this downturn not only affects workers but also funding for schools, infrastructure, public safety, and more, as a prior collaboration between RFF and CGEP found.

- The costs of plugging and restoring well sites vary widely, and the total outlay of a well plugging program to address the known inventory of 56,600 orphaned wells could plausibly range from $1.4 billion to $2.7 billion. Expanding the program to identify and plug 500,000 wells could plausibly cost between $12 and $24 billion. States have different technical requirements for plugging wells and restoring surface locations, and some wells pose greater risks to groundwater, are harder to access, or are deeper than average. All these factors affect plugging and restoration costs.
- One potential challenge of a very large program (i.e., addressing hundreds of thousands of wells) is that state regulatory offices would likely need to scale up administrative capacity to oversee such programs.
- While states and the federal government require oil and gas companies to post bonds or other forms of financial assurance to pay for well plugging in case firms go bankrupt before plugging wells, these bonds often do not cover the full costs. Federal funding could exacerbate this problem if states and companies see it as alleviating their responsibility to plan for future remediation costs adequately. To avoid this, a federal program could prioritize plugging wells abandoned decades ago that were not subject to modern regulatory frameworks.

INTRODUCTION

Coronavirus cases continue to rise in many parts of the United States, raising fears that economies may be reopening too quickly and further lockdowns may be necessary. Since March, the shutdowns ordered around the nation have taken a devastating economic toll, with 35 million people receiving unemployment insurance or waiting for it. Real-time estimates show that second quarter US GDP could fall by more than 40 percent at an annual rate.[1] Along with sectors such as retail, travel, and dining, the energy industry has been hit very hard, as global orders to shelter in place cratered oil demand and sent prices plummeting.

To date, Congress has approved stimulus aid of about $3 trillion, including $1.7 trillion to a diverse range of affected companies.[2] Lawmakers are currently considering an additional stimulus package of several trillion dollars. More fiscal measures will likely be necessary, particularly if the virus's spread requires new shutdowns or further stymies consumer confidence, discouraging economic activity.

One approach that can deliver stimulative impact by boosting employment quickly in the struggling oil and gas sector while also reducing greenhouse gas (GHG) emissions is a large federal funding program to plug abandoned oil and gas wells. Unplugged abandoned or "orphaned" oil and gas wells—those with unknown or insolvent owners—impose heavy climate costs, risks to local environments, and public safety concerns.[3] These wells can leak liquids such as oil and brine,[4] and emit methane and other air pollutants that damage local air quality and contribute to climate change.[5]

In this paper, the authors estimate that a significant federal effort to plug orphaned and abandoned oil and gas wells has the potential to provide tens of thousands of jobs—potentially up to 119,000 job-years to plug roughly 500,000 wells. These efforts would reduce local air pollution, safety risks and a substantial amount of greenhouse gas emissions at a cost of $67 to $170 per ton of CO_2-equivalent, well within the range of other policy options, while also providing stimulus benefits.

There are several uncertainties to consider, however. First, limited real-world data makes it difficult to estimate the emissions reduction potential precisely. Second, costs could vary considerably based on a range of factors, including the types of wells targeted for plugging, market conditions, and more. Third, there is limited capacity, particularly at the state level, to administer a program on the scale of hundreds of thousands of wells, which could delay implementation, raise costs, or both.

The authors begin by describing the scale of the effort in terms of industry job losses, number of orphaned and abandoned wells, emissions reduction potential, and costs. The discussion then turns to the potential for job creation and the opportunities and challenges associated with scaling the program to hundreds of thousands of wells. Finally, the authors review several issues related to program structure and implementation, including the risk of moral hazard associated with federal intervention to take on private and state liabilities.

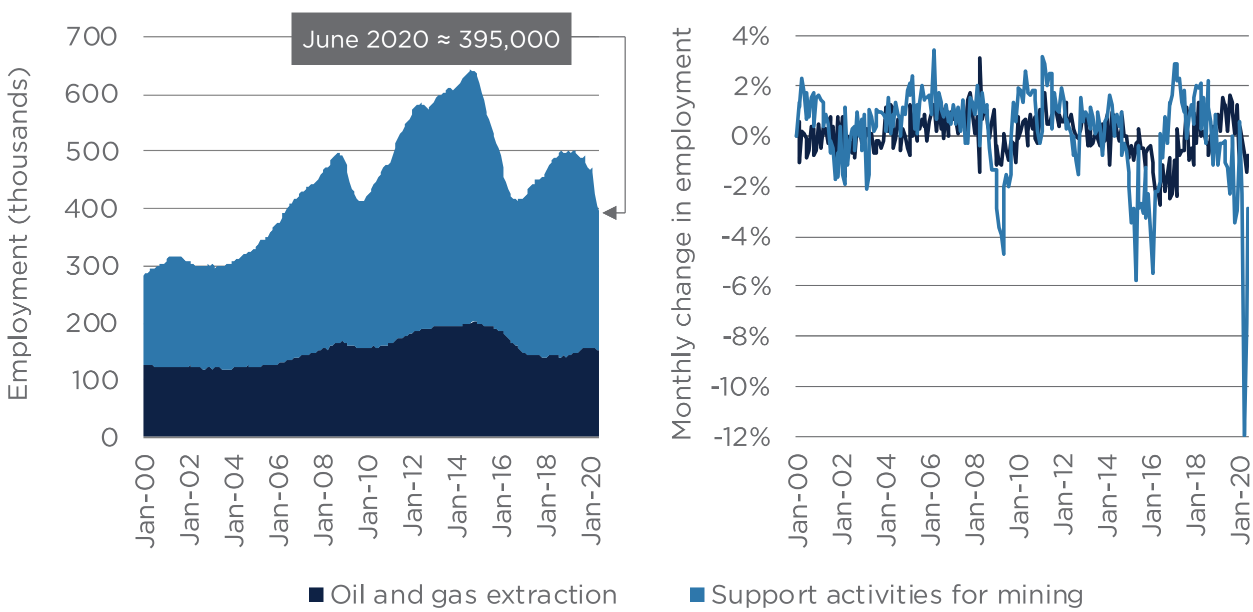
SIZING UP THE CHALLENGE

Energy Industry Job Losses

As in much of the rest of the US economy, job losses in the energy sector due to COVID-19 and the associated recession have been dramatic. Due to the combination of weak demand and robust supply, US benchmark (WTI) oil prices fell from over $60 per barrel (bbl) at the start of the year to less than $20/bbl in April 2020. Prices even went negative for a short time, before rebounding to the low $40s as of this writing. Natural gas prices, which have remained persistently low for over a decade, have fallen farther to below $2 per million British thermal units (MMBtu) through most of this year.

Employment in the oil and gas industry has been affected accordingly, with more than 76,000 direct industry jobs lost from just February to June of 2020, a number that may rise farther in the months to come.[6] And while job growth resumed economy-wide in May, losses continued in the oil and gas sector. In June, industry jobs totaled 394,800, the lowest level since 2006, well before the full onset of the shale revolution (Figure 1).

Figure 1: Employment in the US oil and gas industry



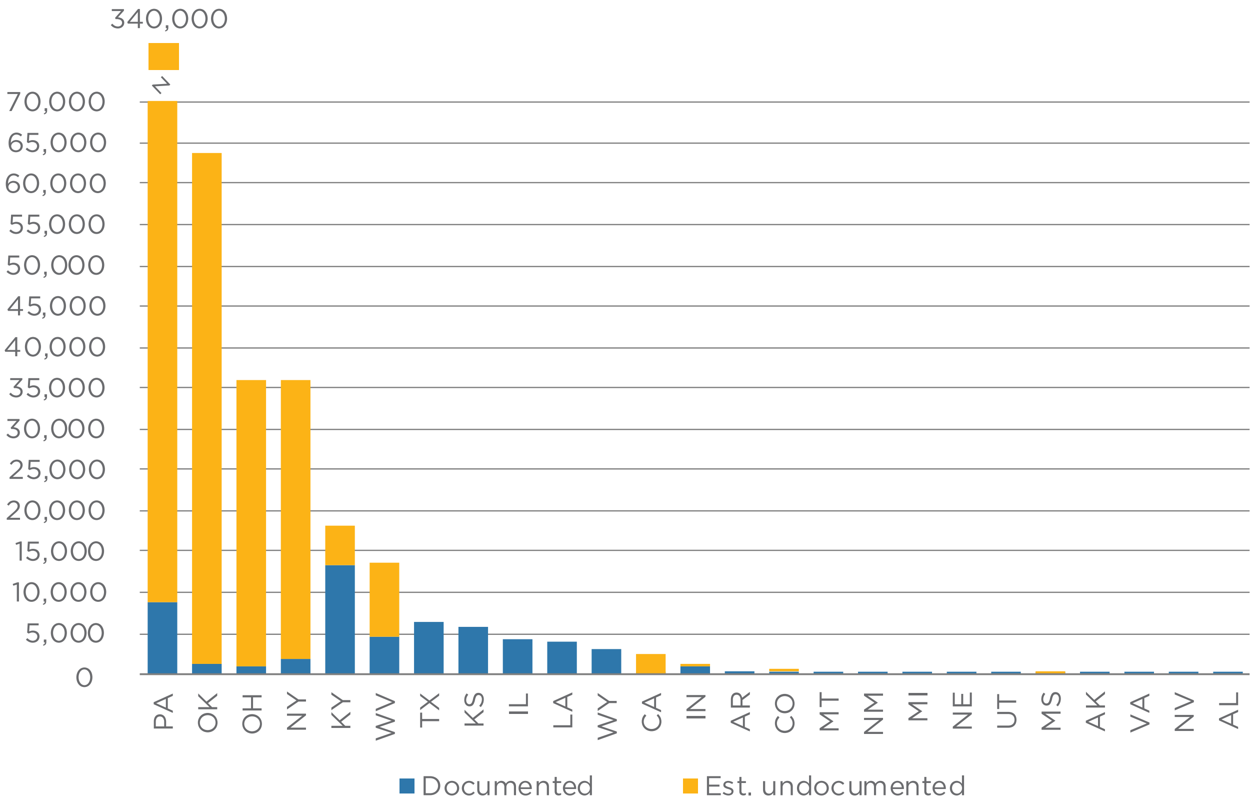
Data source and notes: US Bureau of Labor Statistics.[7] Data consists of NAICS codes 2111 (Oil and gas extraction) and 2131 (Support activities for mining). Data from Jan. 2000 through June 2020.

Because most domestic oil and gas production occurs in rural regions where local economies are closely tied to industry fortunes, the economic pain for these communities is particularly acute. In regions such as the Permian Basin in West Texas and New Mexico; the Marcellus in Pennsylvania and Ohio; the Bakken in North Dakota; and in parts of California, Colorado, Louisiana, Oklahoma, and other states, this downturn not only affects workers but also funding for schools, infrastructure, public safety, and more.[8]

Scale and Emissions of Abandoned Oil and Gas Wells

In a recent analysis, the Interstate Oil and Gas Compact Commission (IOGCC), an organization of 31 states, reported 56,600 documented unplugged orphaned wells as of 2018.[9] But hundreds of thousands, and perhaps millions, of additional such wells are unaccounted for, often because they predate modern regulation. In the IOGCC report, a dozen states estimated they have an additional 211,000 to 746,000 orphaned wells (and some large oil and gas producing states provided no estimates at all). Regulators in Pennsylvania, where commercial oil drilling began in 1859, reported the largest estimate: between 100,000 to 560,000 undocumented orphaned wells (Figure 2). Some research suggests that even these figures may be a substantial underestimate.[10]

Figure 2: Documented and estimated undocumented orphaned oil and gas wells in the US



Data source and notes: IOGCC (2020). For estimated undocumented wells, some states report a range. For those states, the average of the low and high estimate is used.

In addition to orphaned wells, IOGCC members report 194,400 idle wells as of 2018. Idle wells have not been plugged but are not being used for production or injection, thus posing a risk of becoming orphaned in the near future.[11]

Separately, the EPA estimates that there are 2.1 million unplugged abandoned oil and gas wells nationwide,[12] a far higher number than reported by the IOGCC because the EPA's definition of "unplugged abandoned" wells is more expansive than "orphaned" or "idle" wells. For example, the EPA's definition includes unplugged wells with no recent production that may be classified by states as "inactive," "shut-in," or "dormant."[13] The critical distinction between these wells and orphaned wells is that orphaned wells no longer have an owner who can be held liable for plugging and restoration costs. Wells drilled in modern times may become orphaned if their owner becomes insolvent and does not sell the well. Regulators do not have sufficient capacity to pay for plugging these wells (for details, see the "Well Bonding Requirements and Moral Hazard" section).

Methane, which is emitted at many points in the oil and gas system (including from abandoned and orphaned wells), is a potent but short-lived greenhouse gas. Per ton, methane can have 34 times the global warming potential (GWP) of carbon dioxide over a 100-year period and 86 times the impact over a 20-year period.[14] The EPA estimates that, on average, each unplugged abandoned oil and gas well emits 0.13 metric tons of methane annually. However, this estimate is highly uncertain due to limited real-world data. In recent years, field studies in various US regions have produced estimates ranging from 0.03 to 0.19 tons of methane per well. Using this range and the EPA's estimate of 2.1 million unplugged abandoned wells, the range of potential emissions is roughly 64,000 to 404,000 metric tons of methane per year (Table 1).

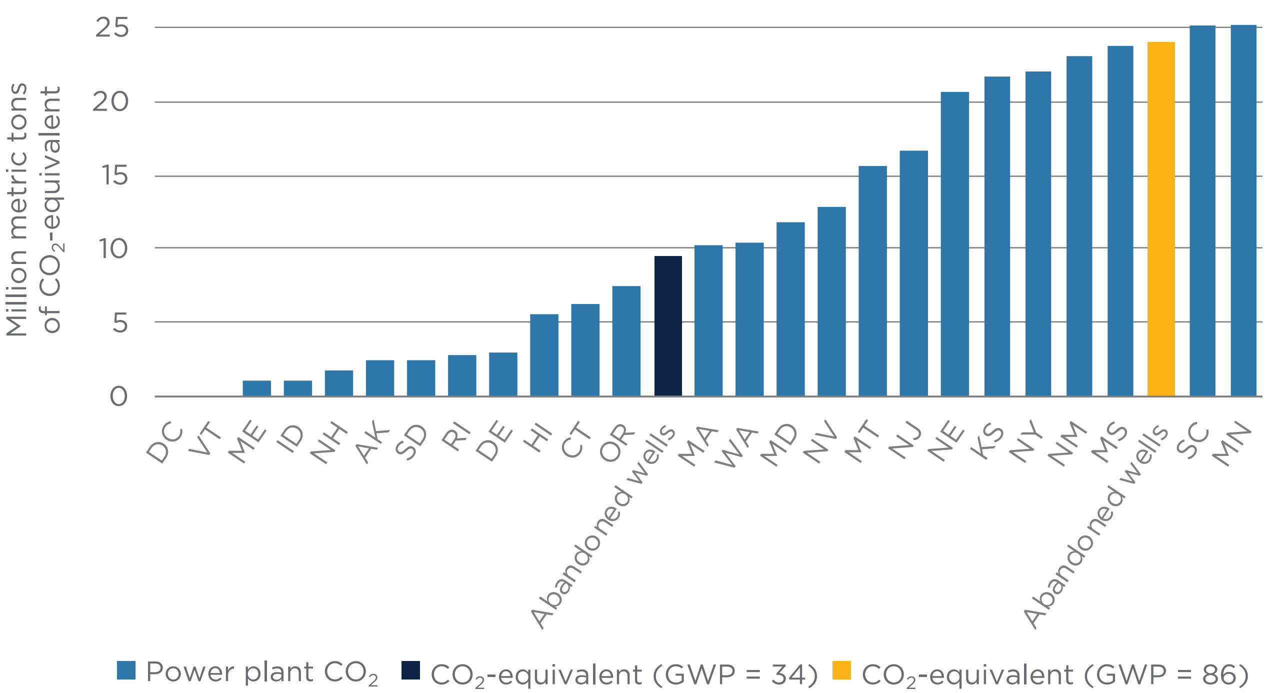
Table 1: Estimates of methane emissions from unplugged abandoned wells (metric tons)

Source	Riddick et al. (2019)	Townsend-Small et al. (2016)	EPA (2020)	Kang et al. (2016)
Emissions per well	0.03	0.09	0.13	0.19
Total emissions for 2.1 million wells	63,801	191,404	276,472	404,075

Source: US EPA.[15] Other estimates are drawn from a summary in Kang et al.[16]

For simplicity, we use the EPA's estimate of roughly 280,000 metric tons of methane each year for the remainder of this analysis. This level of emissions is equivalent to roughly 9.5 million metric tons of carbon dioxide per year when using a 100-year time frame. For context, that is about as much CO_2 as 2.1 million passenger vehicles emit annually,[17] or slightly less than all the CO_2 emitted by all of the power plants in Massachusetts in 2017.[18] If we instead use a 20-year global warming potential of 86, the CO_2 equivalent is roughly 24 million metric tons per year—more than all the CO_2 from power plants in New York State in 2017 (Figure 3).[19]

Figure 3: Greenhouse gas emissions from US unplugged abandoned wells in context



Data source and notes: CO_2-equivalents are authors' calculations based on US EPA[20] methane emissions estimates from unplugged abandoned oil and gas wells for year 2018. Power plant CO_2 emissions are from the US EIA for year 2017.[21]

Costs of Plugging Wells

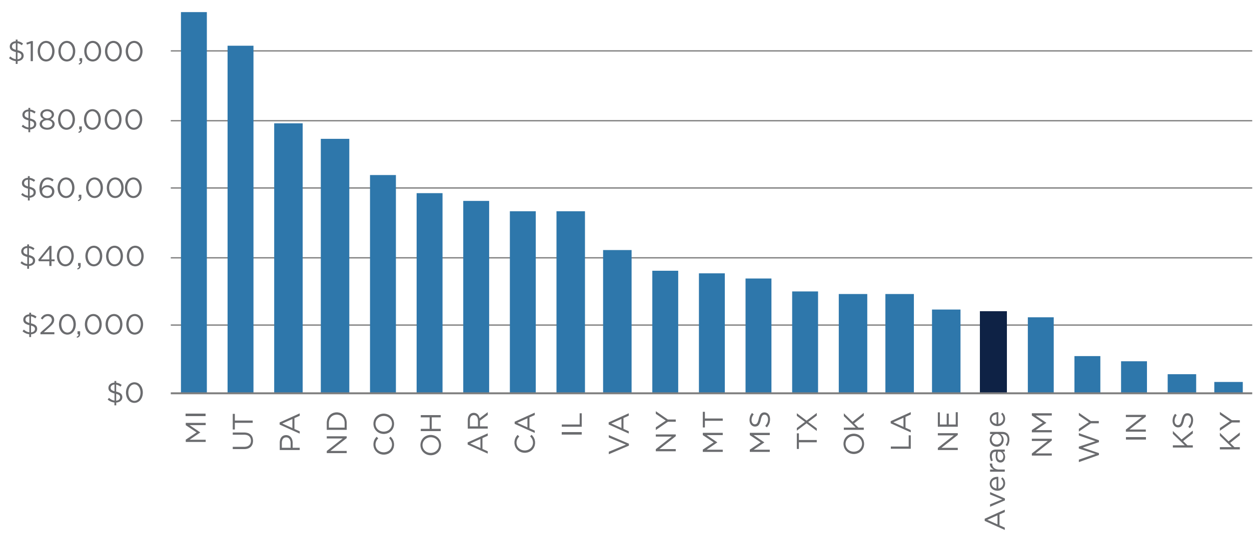
The costs of plugging and restoring well sites vary widely. Some wells pose greater risks to groundwater, meaning that plugging operations are more complex. Some are easily accessible, while others are in hard-to-reach or more sensitive locations, such as on a steep hill surrounded by forest or in a highly developed area. In addition, deeper wells are typically more expensive than shallow wells to plug, as they require additional time and resources such as cement.

IOGCC member states reported average costs ranging from less than $4,000 per well in Kentucky to over $100,000 per well in Utah and Michigan. This wide range reflects some of the differences noted earlier, along with other factors. One reason for the variation is that states have different technical requirements for plugging wells and restoring surface locations, with stricter requirements generally resulting in higher costs.

Another difference is that some states only plug the most hazardous wells, such as those with surface leaks that could cause contamination or other characteristics that make them more costly than an "average" orphaned well. For example, the high costs seen in Michigan and

Utah are based on a small number of wells (six in Michigan and one in Utah). This suggests that Michigan and Utah have only plugged their most problematic wells, which would be more costly than the "average" well. Across reporting states, the average cost is roughly $24,000 per well, including the costs of plugging and surface restoration (Figure 4).[22]

Figure 4: Average plugging and restoration costs per well



Data source and notes: IOGCC[23]. Where states reported average surface remediation costs separately, we have included them here. The average is a weighted average and is relatively low because the largest number of wells have been plugged in lower-cost states such as Texas, Louisiana, Wyoming, and Kansas.

Whether future plugging costs would be similar to historical costs is uncertain. In some locations, such as North Dakota, regulators have estimated that plugging and surface restoration for newly orphaned modern wells would cost upward of $150,000 per well.[24] These wells are typically deeper than "conventional" oil and gas wells and include horizontal lengths stretching for over 1 mile, requiring significantly more material to plug than most older wells. Deeper wells create additional technical challenges, such as greater subsurface pressures.

Because many of the 56,600 wells reported to the IOGCC are decades or generations old and thus predate modern regulation, it is plausible that future costs for plugging these wells could be in the range of $24,000 each. However, if plugging efforts instead focus on newly orphaned wells, costs could be considerably higher. In the case of North Dakota, the cost of $150,000 per modern well is roughly double the historical figure the state reported to the IOGCC.

Because of the considerable uncertainty involved, we estimate a "low" and "high" cost figure for future efforts, with a low of $24,000 per well and a high of $48,000 per well (reflecting the doubling of cost estimates from North Dakota). Multiplying by 56,600 wells, total costs could plausibly range from $1.4 billion to $2.7 billion. If the program were to be scaled up to address 500,000 wells (discussed in detail below), costs could plausibly range from $12 billion to $24 billion.

Plugging costs could also change over time due to market conditions and other factors. For example, a return to higher oil and gas prices could lead to more drilling, which could induce additional demand for labor and services from oilfield workers and service providers. With higher demand for these inputs, workers and service providers could demand higher wages and service fees, increasing plugging and restoration costs. Conversely, companies plugging and restoring large numbers of wells could become more efficient over time, leading to lower future costs.

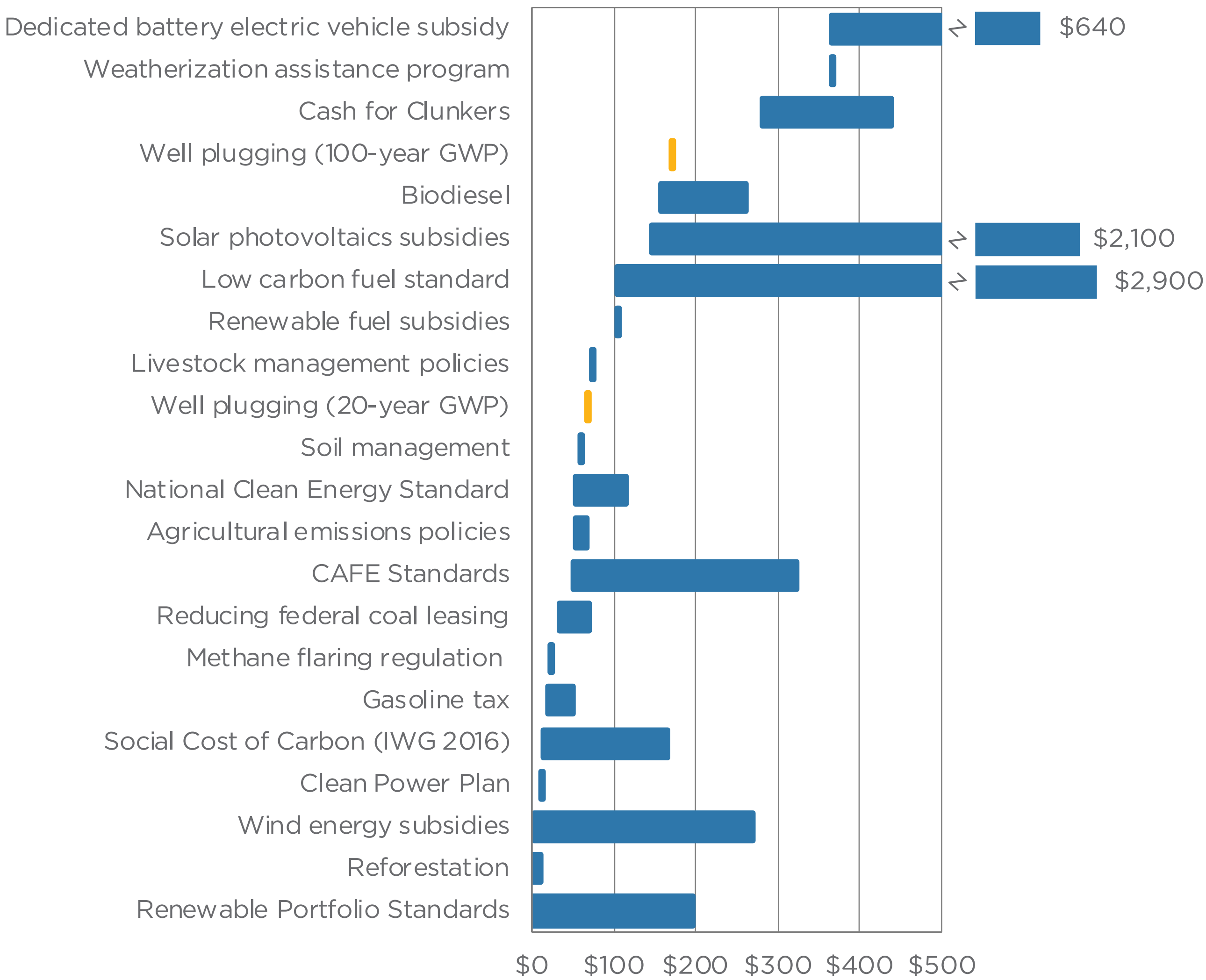
Mitigation Costs in Context

Plugging orphaned and abandoned oil and gas wells can reduce a considerable amount of methane emissions.[25]

As discussed earlier, the EPA estimates that unplugged abandoned wells emit, on average, 0.13 metric tons of methane per year, and plugging 56,600 wells could plausibly cost $1.4 billion at the low end. Based on these figures, we estimate abatement costs are roughly $5,700 per metric ton of methane. Using the 2016 estimates for the social cost of methane from the Interagency Working Group on Social Cost of Greenhouse Gases,[26] this would equate to roughly $170 per metric ton of CO_2-equivalent (CO_2e). This calculation assumes it takes three years to plug all wells and that plugs last for at least 100 years, and uses a 100-year GWP of 34. Using the 20-year GWP of 86, which emphasizes the short-term benefits of methane mitigation, we estimate mitigation costs of around $67 per ton of CO_2e. (For details on our methodology for estimating these costs, please see the appendix.)

Such abatement costs are on the high end of the US government's 2016 estimate for the social cost of carbon, which put the social costs of CO_2 in 2020 at between $15 and $152 per ton, with a central value of $50 (adjusted to 2019 dollars).[27] However, they are on the lower end of other recent estimates of the social cost of carbon appearing in the peer-reviewed literature.[28] In addition, our estimated abatement costs are similar to, and in some cases lower than, static costs of other federal and state climate policies (Figure 5).[29] What's more, the cost per ton does not include the safety and local environmental benefits of well plugging. Most importantly in the current context, the program must be evaluated on its ability to deliver economic stimulus in the form of short-term job creation in addition to cost-effective abatement.

Figure 5: Range of static GHG abatement costs by policy (2019 \$/ton CO_2-equivalent)



Data sources and notes: Estimates compiled in Gillingham and Stock.[30] Authors have inflated to 2019 dollars. Social Cost of Carbon estimate from US Interagency Working Group.[31]

Of course, this estimate is subject to considerable uncertainty for several reasons. First, lower or higher plugging costs would enhance or reduce the cost effectiveness of the effort. At the same time, if methane emissions from unplugged abandoned wells are higher than estimated by the EPA, the effort would be more cost effective (and vice versa if methane emissions were lower than EPA's estimates).

Our estimate also assumes that abandoned wells emit a constant rate of methane over decades. However, time-series data on methane emissions from such wells are not available, making this an uncertain prospect. It is plausible that emission rates would decrease over time as the release of methane from underlying rock formations reduces subsurface pressures. However, it is also plausible that as wells age and become more degraded, new migration pathways for methane could emerge, potentially increasing emissions over time. Additional data on methane emissions over time would help refine our estimates.

LABOR CAPACITY AND JOB CREATION

Oil and gas workers carry out a wide range of tasks, and many jobs are highly specialized. In many cases, recently unemployed energy workers possess the skills required to plug wells and restore surface sites. For example, plugging requires workers to characterize a well's interior using wirelines or other logging equipment, use perforating guns to create a connection between the wellbore and the surrounding rock, cement portions (or the full length) of the well, test the integrity of that cement, haul equipment and materials, and more.

Based on these duties, along with multiple conversations with industry experts,[32] it appears that there is a clear match between the skills of unemployed oil and gas workers and the requirements needed to plug orphaned and other abandoned wells properly.

How many jobs could an extensive plugging program create? Regulators in Colorado, Pennsylvania, and Alberta, Canada, provided the authors with estimates of labor requirements for recent well plugging and remediation operations.[33] Announcements from regulators in North Dakota also estimate labor requirements for future plugging and site restoration. These estimates range considerably due to the factors described in the previous section.

On average, these estimates indicate that plugging ten wells requires 2.4 person-years of work. If this number were to stay constant over time (an uncertain prospect), plugging 56,600 wells would create roughly 13,500 jobs for one year. As noted earlier, the potential costs for plugging and restoring 56,600 wells could plausibly range from $1.4 to $2.7 billion. Using our central estimate of 13,445 jobs, the average cost per job-year would be roughly $101,100 to $202,200, with a wider range based on state estimates (Table 2). For reference, one recent analysis of the effects of federal infrastructure spending under the American Recovery and Reinvestment Act (ARRA) estimates that the average cost per job-year was about $170,000 for the years 2009 through 2013.[34] Across all ARRA spending, the CBO estimates that costs per job-year were between roughly $170,000 and $870,000 in 2010.[35]

Table 2: Estimated job-years and costs for plugging 56,600 wells

State	Alberta	Colorado*	North Dakota	Pennsylvania	Average
Job-years	5,602	12,408	24,164	11,604	**13,445**
Cost per job-year (low)	$242,650	$109,556	$56,258	$117,150	**$101,112**
Cost per job-year (high)	$485,301	$219,112	$112,517	$234,301	**$202,224**

Data sources for jobs estimates: Internal communications with oil and gas regulators in Alberta, Colorado, and Pennsylvania citing historical data. North Dakota estimate comes from recent reporting,[36] quoting Lynn Helms (director of the ND Department of Mineral Resources).
**Colorado estimates include departmental staff time and contractor time; all other estimates include contractor time only.*

Scaling Up

It may be possible to scale a plugging program well beyond just the 56,600 catalogued orphaned wells in the US. For example, if the average job creation estimates from Table 2 and methane emissions estimates from Table 1 are used, a hypothetical program to plug 500,000 wells could lead to 119,000 job-years and reduce 65,000 metric tons of methane, equivalent to 2.2 million metric tons (MMT) of CO_2 over a 100-year time frame (5.6 MMT CO_2e over 20 years).

Given the 76,000 recently unemployed oil and gas workers, and the equipment and material that they had been using until recently, there would most likely be sufficient capacity to scale well beyond 56,600 wells. Indeed, oil and gas employment peaked at 643,000 in September 2014, nearly 250,000 higher than the June 2020 level,[37] reinforcing the notion that there is no shortage of skilled labor. In recent conversations with the authors, experts from multiple large oilfield service firms have expressed confidence that they could scale to plug hundreds of thousands of wells over several years.

However, from an economic perspective, some questions arise. As the program scale expands, the marginal cost of plugging each well may increase if demand for well plugging services leads to higher labor and equipment costs. On the other hand, companies carrying out the work could become more efficient over time, which could lead to lower marginal costs. At this time, we are unable to estimate these effects due to lack of data.

In addition, more extensive plugging programs would require regulatory bodies to scale up accordingly. State offices that manage well plugging are not currently staffed to administer programs on the order of tens or hundreds of thousands of wells per year. Carrying out the contracting process, monitoring operations, and enforcing regulations requires trained professionals. For example, in Texas, each well plugging operation is overseen on-site by a staff member of the state Railroad Commission, the relevant regulatory body.[38] Without additional resources, a program to plug hundreds of thousands of wells would likely strain states' administrative capacity.

Finally, a larger plugging program would likely require more time to execute. If energy prices were to rebound in that time frame, oil and gas producers might bid up the price of oil field services, again raising the total outlay of a plugging program.

One approach to limiting the risk of rising costs would be to contract with service providers now to plug a large number of wells at a fixed price over several years. Such an approach would provide certainty to contractors and their workers and limit project cost inflation risks.

PROGRAM STRUCTURE

Federal support could take the form of a grant program to the appropriate regulatory bodies at the state, tribal, and federal levels. This would not be the first such program created by lawmakers. The Energy Policy Act of 2005 authorized the Department of Energy to provide technical and financial assistance to help states "remedy environmental problems" caused by orphan wells on private, state, tribal, and federal lands.[39] DOE provided some technical assistance, but Congress never appropriated funds for financial assistance, according to North Dakota Mineral Resources Director Lynn Helms.[40]

Adequacy of Existing State Funds

States fund well plugging activities through bonding requirements, industry fees and taxes, penalties, legislative appropriations, and salvage value from on-site equipment. IOGCC's count of documented orphaned wells has remained roughly flat near 60,000 through five assessments since 1992,[41] which suggests that current funding sources have been insufficient to reduce the inventory.

Future plugging funds are likely to face cyclical challenges, as the number of orphan wells will tend to increase as oil and gas companies face bankruptcies due to low prices. This challenge could be exacerbated as fee revenues fall with decreased drilling and production. At the same time, state budgets are under strain as the recession reduces general revenues, while pandemic response creates new spending needs in sectors such as health care and education.

The combination of these factors suggests that the number of orphaned wells is likely to increase, perhaps dramatically, while states will face greater challenges financing their existing plugging programs.

Well Bonding Requirements and Moral Hazard

As noted earlier, states and the federal government require oil and gas companies to post bonds or other forms of financial assurance to cover the cost of well plugging and site restoration should a company not be able to do so due to bankruptcy. However, multiple studies have indicated that these bonds are often insufficient to cover the full costs of plugging and restoration.[42]

For example, regulators offer "blanket" bonds, which allow operators to issue a single form of financial assurance to cover every well in a state or on certain federal lands. Blanket bond amounts vary across jurisdictions, with some as low as $25,000 (Pennsylvania) or $100,000 (North Dakota and Wyoming), with Texas's maximum blanket bond amount at $250,000.[43] In North Dakota and Pennsylvania, for example, the average cost of plugging per well is more than $70,000. On federal lands, blanket bonds are offered at $150,000, a level that was set in 1951 and has not been adjusted for inflation.[44] The Moving Forward Act, which passed the House of Representatives on July 1, included provisions to increase federal lands bonding requirements, including raising blanket bonds to $1 million, and adjusting for inflation going forward.[45] The bill would also authorize a federal program to plug orphan wells for $2 billion over five years.

Given these issues related to bonding, one of the main concerns with any large-scale federal plugging program involves the concept of moral hazard, which arises when an individual or business is insulated from bearing the full cost of a risky activity.

In this context, federal funding could exacerbate the tendency for some oil and gas operators to inadequately provide for future plugging and remediation costs, as they may anticipate that taxpayers or other companies (where fees pay for plugging funds) will foot the bill. Perhaps more importantly, states and the federal government could continue charging insufficient bond amounts to cover the costs of eventual cleanup if they anticipate future federal funding to plug wells.

To avoid this moral hazard risk, the program could be set up to prioritize the plugging and restoration of older well sites. Many of these sites date back to the 19th and early 20th centuries, when regulations including bonding requirements were weak or, in many cases, nonexistent. Plugging these long-abandoned wells that owners passed on decades ago does not raise the same moral hazard concerns as plugging wells that were drilled recently by companies operating under modern regulatory frameworks.

Some have proposed tying federal aid to requirements that states update their well bonding requirements to more accurately reflect real-world plugging and restoration costs.[46] Although the notion of states updating their policies to reflect these costs may be appealing in principle, such a proposal would very likely cause delays in deploying stimulus funds to put people back to work.

One approach that may thread the needle on these constraints would be setting conditions that take effect in the future. For example, federal lawmakers could require recipient states to publish estimates for the level of fees/bonding that would cover future orphan well costs and commit to a roadmap for how they plan to cover them in the future.

CONCLUSION

A large federal effort to plug orphaned and abandoned oil and gas wells has the potential to provide tens of thousands of jobs—potentially up to 120,000. These efforts would reduce local air pollution, safety risks, and greenhouse gas emissions at a cost of $67 to $170 per ton of CO_2-equivalent, well within the range of other policy options. These costs are somewhat uncertain due to limited data on methane emissions from abandoned wells and potential changes to the future costs of carrying out such a program.

Practically speaking, the industry appears ready to scale up in order to carry out this work, as labor and equipment are readily available in today's low oil price environment. One potential challenge is that scaling to plug hundreds of thousands of wells would likely require states to expand their regulatory capacity, potentially slowing the speed of plugging operations. Another concern related to moral hazard (where federal plugging efforts disincentivize companies and states from adequately saving for future needs) could be addressed by focusing on plugging and restoring the sites of older wells, which often predate modern regulation.

APPENDIX: MITIGATION COST METHODOLOGY

We estimate the cost of mitigation based on spending an average of $24,018 per well to plug 56,600 orphan wells over three years (25 percent of wells in the first year, 50 percent in the second, and the rest in the third). The average well cost and the total number of wells are based on IOGCC data discussed in the paper. We assume the work is done over three years because it takes time to administer and ramp up plugging activity, though we do not have data for exactly how long this would take. For context, costs approach $180/$CO_2$e if we assume the work is done evenly over six years.

We assume annual emissions per well of 0.13 metric tons of methane based on the EPA's Greenhouse Gas Inventory estimates, which we convert to CO_2e based on the social cost of methane (SCM) and social cost of carbon (SCC) at a 3 percent discount rate as estimated by the Interagency Working Group on Social Cost of Greenhouse Gases (IWG). The SCM and SCC, respectively, rise from $1,457 and $51 in 2020 to $3,036 and $83 in 2050 (in 2019 dollars), producing a conversion factor that increases from 29 in 2020 to 36 in 2050. Because the IWG's estimates for the SCM and SCC stop in 2050, we hold these values constant at these levels for years beyond 2050.

We divide the total program costs of about $1.4 billion by the present value of 100 years of emissions reductions from these wells, which we estimate at roughly 7.9 million metric tons of CO_2e (at a 3 percent discount rate), producing a figure of $172 per ton of CO_2e avoided. If average emissions per well are 25 percent higher, the cost of mitigation would fall to around $140/$CO_2$e. If they were 25 percent lower, the cost of mitigation would increase to $230/$CO_2$e.

NOTES

1. Federal Reserve Bank of Atlanta, "GDPNow." Estimate retrieved on June 25, 2020. Real-time estimates and historical estimates available at: https://www.frbatlanta.org/cqer/research/gdpnow.

2. Board of Governors of the Federal Reserve System, "Monetary Policy Report," June 12, 2020, https://www.federalreserve.gov/monetarypolicy/files/20200612_mprfullreport.pdf. This includes the Congressional Budget Office (CBO) estimate for $2.4 billion in spending in four stimulus bills as well as $454 billion for the Department of the Treasury to fund lending facilities established by the Federal Reserve and $46 billion to provide loans to the airline industry (CBO assumes these loans are paid back and does not count them as an expenditure).

3. Definitions vary, but typically, abandoned wells are those that have been taken out of production, and orphaned wells are a subset of abandoned wells for which no owner can be determined.

4. See, for example, Groundwater Protection Council, "State Oil and Gas Agency Groundwater Investigations and Their Role in Advancing Regulatory Reforms: A Two-State Review: Ohio and Texas," 2011, http://www.gwpc.org/sites/default/files/State%20Oil%20%26%20Gas%20Agency%20Groundwater%20Investigations.pdf.

5. For an analysis and review of methane emissions from abandoned wells, see Mary Kang, 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 (September 2019): 594–601, https://doi.org/10.1016/j.enpol.2019.05.045.

6. US Bureau of Labor Statistics, BLS Data finder 1.1, "Current employment statistics survey," seasonally adjusted data. Accessed on June 14, 2020, via https://beta.bls.gov/dataQuery/search. This includes the sectors "Oil and gas extraction" and "Support activities for mining," which includes oil and gas service companies. BLS data from the "Quarterly Census of Employment and Wages," which is only available through December, indicates that around 96 percent of employment categorized as "Support activities for mining" (NAICS code 2131) is jobs drilling oil and gas wells (213111) or support activities for oil and gas operations (213112).

7. Ibid.

8. See, for example, Daniel Raimi, Ronald Minsk, Jake Higdon, and Alan Krupnick, "Economic Volatility in Oil Producing Regions: Impacts and Federal Policy Options," Columbia University Center on Global Energy Policy and Resources for the Future, 2019, https://www.rff.org/publications/reports/economic-volatility-oil-producing-regions-impacts-and-federal-policy-options/; and Richard Newell and Daniel Raimi, "The fiscal impacts of increased U.S. oil and gas development on local governments," *Energy Policy* 117 (2018):

14–24, DOI: 10.1016/j.enpol.2018.02.042.

9. IOGCC, "Idle and Orphan Oil and Gas Wells," March 2020 update, http://iogcc.ok.gov/iogcc-issues-report-on-idle-and-orphan-oil-and-gas-wells. In a May update, IOGCC included a revision for New Mexico's documented unplugged orphan well count, raising the 2018 total to around 56,900. That update also included 2019 figures for some states. California's count increased from 16 to around 4,900. Other reported changes were much smaller.

10. Mary Kang et al., "Identification and Characterization of High Methane-Emitting Abandoned Oil and Gas Wells," *Proceedings of the National Academy of Sciences* 113, no. 48 (2016): 13636–41, https://doi.org/10.1073/pnas.1605913113.

11. States define the requisite period of nonproduction/use to qualify as "idle" differently.

12. EPA, "Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2018," Washington, D.C., 2020, https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks.

13. Ibid., 3–101.

14. IPCC, *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change* (Cambridge, UK, and New York, NY: Cambridge University Press, 2013), http://www.climatechange2013.org/report/. See Chapter 8, Table 8.7.

    We use the IPCC global warming potentials (GWP) for methane of 34 for a 100-year time frame and 86 for a 20-year time frame, which include climate-carbon feedbacks. The EPA uses a 100-year methane GWP of 25 in its annual Greenhouse Gas Inventory, following UN guidance that requires the use of GWPs from the IPCC's Fourth Assessment, Chapter 2, Table 2.14 (2007).

15. EPA, "Inventory."

16. Kang et al., "Reducing Methane Emissions." For this analysis, we assume that all unplugged abandoned wells emit methane at the same rate. This simplifying assumption differs from the more detailed estimates from the EPA and Kang et al., who estimate regional and nationwide emissions based on region-specific emissions factors.

17. The EPA reports that a passenger vehicle emits on average 4.6 Mt/Y, https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P100U8YT.pdf.

18. US Energy Information Administration, "Table 4: 2017 State Energy-Related Carbon Dioxide Emissions by Sector," 2020, https://www.eia.gov/environment/emissions/state/.

19. Ibid.

20. EPA, "Inventory."

21. US Energy Information Administration, "Table 4."

22. IOGCC, "Idle and Orphan."

23. Ibid.

24. James MacPherson, "North Dakota aims to use COVID-19 aid to plug oil wells," AP News, May 14, 2020, https://apnews.com/0c7ed45aca2daa707d7fcea8fbefb737.

25. Notably, plugged abandoned wells can also emit methane. However, because the EPA estimates in its 2020 Inventory that emissions from unplugged abandoned wells are far greater than plugged wells, we focus exclusively on unplugged abandoned wells here.

26. IWG, "Addendum to Technical Support Document on Social Cost of Carbon for Regulatory Impact Analysis under Executive Order 12866: Application of the Methodology to Estimate the Social Cost of Methane and the Social Cost of Nitrous Oxide," August 2016, https://19january2017snapshot.epa.gov/sites/production/files/2016-12/documents/addendum_to_sc-ghg_tsd_august_2016.pdf.

27. IWG, "Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866," August 2016, https://19january2017snapshot.epa.gov/sites/production/files/2016-12/documents/sc_co2_tsd_august_2016.pdf.

28. See, for example, Katharine Ricke, Laurent Drouet, Ken Caldeira, and Massimo Tavoni, "Country-level social cost of carbon," *Nature Climate Change* 8 (2018), DOI: 10.1038/s41558-018-0282-y; and Kent D. Daniel, Robert B. Litterman, and Gernot Wagner, "Declining CO_2 price paths," *Proceedings of the National Academy of Sciences* 116, no. 42 (2019), DOI: 10.1073/pnas.1817444116.

29. Notably, the cost estimates we present from Gillingham and Stock (see next note) are static cost estimates. That is, they do not take into account spillovers. In particular, static cost estimates do not account for how costs may change over time.

30. Kenneth Gillingham and James H. Stock, "The Cost of Reducing Greenhouse Gas Emissions," *Journal of Public Economics* 32, no. 4 (2018): 53–72, DOI: 10.1257/jep.32.4.53.

31. IWG, "Addendum."

32. This statement is based on conversations with numerous experts from multiple state regulatory bodies, oilfield service companies, and oil and gas operators.

33. We also gathered estimates from two large independent oil and gas operators, which were similar in magnitude to our average.

34. Based on estimates from: Andrew Garin, "Putting America to work, where? Evidence on the effectiveness of infrastructure construction as a locally targeted employment policy," *Journal of Urban Economics* 111 (2019), DOI: 10.1016/j.jue.2019.04.003.

35. Congressional Budget Office, "Estimated Impact of the American Recovery and Reinvestment Act on Employment and Economic Output in 2014," 2015, https://www.cbo.gov/sites/default/files/114th-congress-2015-2016/reports/49958-ARRA.pdf. Notes: Job-

year estimates are those of the authors based on data provided in Table 2 of the CBO report, which reports that full-time equivalent employment due to ARRA spending in 2010 was between 900,000 and 4.7 million. Note that the CBO estimated that this was the peak year of ARRA-related employment.

36. MacPherson, "North Dakota."

37. US Bureau of Labor Statistics, 2020. See note 6.

38. Conversation on June 19 with Keith May, Field Operations, Oil & Gas Division, Railroad Commission of Texas.

39. Energy Policy Act of 2005. 109th US Congress, First Session. https://www.govinfo.gov/content/pkg/BILLS-109hr6enr/pdf/BILLS-109hr6enr.pdf.

40. Comments made during a forum hosted by the US Natural Resources Committee, Subcommittee on Energy and Mineral Resources, June 1, 2020, https://naturalresources.house.gov/hearings/reclaiming-orphaned-oil-and-gas-wells_creating-jobs-and-protecting-the-environment-by-cleaning-up-and-plugging-wells.

41. These publications are available at: http://iogcc.ok.gov/publications.

42. For an analysis of federal lands, see GAO, "Oil and Gas: Bureau of Land Management Should Address Risks from Insufficient Bonds to Reclaim Wells," 2019, https://www.gao.gov/products/gao-19-615. For an analysis of private and state lands, see Jacqueline S. Ho et al., "Managing Environmental Liability: An Evaluation of Bonding Requirements for Oil and Gas Wells in the United States," Environmental Science and Technology 52, no. 7 (2018): 3908–3916, DOI: 10.1021/acs.est.7b06609.

43. IOGCC, "Idle and Orphan."

44. GAO, "Oil and Gas."

45. Moving Forward Act, House Resolution 2, 116th US Congress.

46. See, for example, Kate Kelly and Jenny Rowland-Shae, "How Congress Can Help Energy States Weather the Oil Bust During the Coronavirus Pandemic," Center for American Progress, April 29, 2020, https://www.americanprogress.org/issues/green/reports/2020/04/29/484158/congress-can-help-energy-states-weather-oil-bust-coronavirus-pandemic/.

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