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Working Towards High Integrity Carbon Credits from Early Plugging of Marginal Oil and Natural Gas Wells: An Issue Primer

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Executive Summary

Throughout the history of oil and natural gas development, the productive life of a well has followed a predictable pattern: Initial output is high, but production rates decline over time as underground reservoirs are depleted. As production declines, individual wells are eventually classified as “marginal” — meaning they produce only small quantities of oil or natural gas relative to the industry average. The U.S. Environmental Protection Agency (EPA) and the U.S. Department of Energy (DOE) define marginal wells as producing less than 15 barrels of oil equivalent per day and/or 90 thousand cubic feet of natural gas per day over the prior 12-month period.

Marginal wells are typically kept in production until they become economically unviable. Ideally, when decommissioned and abandoned, they are subject to proper plugging and remediation in accordance with environmental regulations. However, although marginal wells account for only about 6% of total U.S. oil and natural gas production, research indicates they are responsible for roughly half of all methane emissions from oil and gas as they typically have higher loss rates.¹ Estimates of the actual volume of emissions from marginal wells vary considerably — between 1 million metric tons (MMT) of methane per year and 4 MMT per year, according to research from the National Energy Technology Laboratory and EDF. Converted to carbon dioxide equivalent (CO₂e) using a 20-year Global Warming Potential (GWP) for methane, this uncertainty produces a range of 81 MMT and 324 MMT of CO₂e per year.

The upper end of this range is comparable to the annual emissions of 76 million passenger cars, 86 coal-fired power plants, the State of California or the nation of Kazakhstan.^{2,3} Using a 100-year GWP, 1-4 MMT per year of methane produces a range of 27.9 MMT to 111.6 MMT of CO₂e per year. The upper end of this range is comparable to the annual emissions of 26 million passenger cars, 30 coal-fired power plants, the State of Kentucky or the nation of Turkmenistan.

The environmental impact of marginal wells extends beyond methane. Other emissions from these wells contribute to ground-level ozone, smog and local air pollution challenges in the communities nearest to production sites. EDF has estimated that nearly 8 million Americans live within half a mile of a production location with marginal oil and gas wells.⁴

The range of existing and proposed options for addressing these challenges include:

- Tighter regulation of emissions, including methane and ozone precursors
- Higher financial assurance requirements for older, less productive wells
- Mature asset strategies that transfer ownership of marginal wells to a new entity that responsibly manages their decommissioning, plugging and abandonment
- Differentiated gas markets, which incentivize producers to replace marginal wells with high methane emissions with new, low-emitting wells
- Direct payments to operators of marginal wells for plugging and abandonment

In addition to these options, the voluntary carbon market has emerged as a potential source of financing for the early plugging of marginal wells, through the issuance of carbon credits for avoided methane emissions. If the environmental benefit of early decommissioning can be accurately quantified, the resulting carbon credits can attract private investment to accelerate emissions reductions.

However, significant uncertainties remain. The number and value of credits that can be issued for a

given marginal well project can vary significantly depending on the methodology applied. A useful benchmark for resolving this uncertainty has been developed by the Integrity Council for the Voluntary Carbon Market (ICVCM) — the Core Carbon Principles (CCP). This paper will discuss how the 10 core principles developed by the ICVCM apply to carbon credits for decommissioning marginal oil and gas wells and identify issues that must be further addressed to develop high integrity carbon credits.

Following publication of both this marginal well primer and the parallel orphan well primer, **targeted technical guidance** on key unresolved questions identified in the work will be developed. To be clear: the identification of issues in this primer does not imply that no solutions exist. Instead, this primer will structure future discussions to identify solutions — some which may already exist — to ensure adherence to the CCPs.

While U.S. marginal wells are the focus of this primer, similar challenges may exist in other countries and concepts developed in a U.S. context may have applicability in other jurisdictions.

II. Introduction

Marginal oil and gas wells are low-producing oil and gas wells with known operators or producers and are typically defined as producing less than or equal to 15 barrels of oil equivalent per day.^{1,4} Marginal wells differ from orphan wells in two distinct ways: they are still in production and they have a known responsible party. However, marginal wells pose significant environmental concerns, especially in regards to their associated methane emissions, and voluntary carbon markets (VCMs) have been proposed as a way to mitigate the environmental impacts of these wells by offering financial incentives for early plugging of marginal wells.

The majority of oil and gas sites within the U.S. can be defined as marginal wells. Over 700,000 oil and gas sites, representing 80% of all oil and gas sites, meet the definition of marginal wells, yet these wells contribute only about 6% of U.S. oil and gas production.^{6,7,8} Marginal wells have an outsized environmental impact relative to their production contribution, with studies suggesting that marginal wells could contribute approximately 50% of all methane emissions associated with oil and gas production in the U.S., or approximately 1-4 MMT of methane per year.^{5,7} Using a 20-year GWP for methane, this results in a range of 81 MMT to 324 MMT of CO₂e per year. To put this volume of greenhouse gas in context, the upper end of this range of emissions from marginal oil and gas wells is roughly equivalent to the annual emissions of:^{2,3, 7}

- 76 million gasoline-powered cars
- 86 coal-fired power plants
- The State of California
- The nation of Kazakhstan, according to data compiled by the European Commission

If a 100-year GWP is used, the range of emissions is 27.9-111.6 MMT of CO₂e. The upper end of this range is roughly equivalent to the annual emissions of 26 million passenger vehicles, 30 coal-fired power plants, the state of Kentucky or the nation of Turkmenistan.

The estimates of emissions from marginal wells continue to improve as more data becomes available through measurement campaigns. These estimates are meant to provide context for the relative size of potential emissions reductions.

Beyond methane, operations associated with marginal wells and the consumption of produced hydrocarbons are also responsible for carbon dioxide (CO₂) and nitrous oxide (N₂O) emissions. The extent of CO₂ and N₂O reductions due to early plugging depends on a series of policy choices and economic assumptions that will be explored later in this primer. Emissions from marginal oil and gas wells are not limited to greenhouse gases (GHGs). Other emissions contribute to local air pollution challenges, including ground-level ozone. EDF estimates that almost 8 million Americans live within half a mile of production locations with marginal oil and gas wells.⁸

Once they become marginal, these wells may continue to operate for decades, because producing from them remains economically viable.¹

There is an argument that early plugging of marginal wells could significantly reduce emissions that would have otherwise continued. VCMs, or private buying and selling of carbon credits based on removals or reductions in GHG emissions, could be a solution for incentivizing early marginal plugging efforts based on avoided emissions. With that said, the VCM is not the only path to reduce emissions from these wells and not all of the solutions rest on decommissioning them. For example, for flowing wells, tighter regulation of such emissions could address leaks while the wells remain operational. And differentiated gas markets, which are intended to create market transparency on emissions from wells, could create incentives for operators to invest in equipment and practices to lower these emissions.

With respect to encouraging plugging of marginal wells, again, the VCM is only one option. Others include direct payments to marginal well operators to plug wells and adequately compensate stakeholders; nurturing the establishment of “mature asset” entities that take possession of marginal wells with the intent to decommission them; or regulatory mechanisms such as enhanced bonding requirements. These other options are outside the scope of this paper.

Trust in VCMs is critical to their effectiveness. Buyers, sellers and external parties must feel confident that the carbon credit value accurately reflects the magnitude of avoided carbon emissions. The ICVCM identifies 10 core principles for high integrity carbon credits, called the CCPs.⁹ The CCPs serve as a global framework to ensure appropriate rigor in VCMs. Through the lens of the CCPs, this paper will identify the main challenges associated with developing high integrity carbon credits for early marginal well plugging. By identifying the key questions that need to be answered in developing high integrity carbon credits, this work will serve as a foundation for future discussions and decision points in issuing carbon credits for early marginal well plugging activities based on avoided GHG emissions. The identification of these issues is not meant to imply that no solutions exist; rather, this primer is meant to serve as a way to structure future discussions to ensure adherence to the CCPs. This issue will focus on marginal wells in the United States, but these concepts could be applied globally.

III. The Core Carbon Principles of high-integrity carbon credits

a. Overview

The ICVCM is an independent non-profit organization that works to establish and ensure integrity in global carbon markets. The ICVCM has established 10 CCPs based on science and fundamentals to ensure that awarded carbon credits have a verifiable climate impact. The ICVCM is widely seen as a leader in the VCM space, and the CCPs are a solid foundation to begin discussion for identifying possible challenges with producing high integrity carbon credits for early plugging of marginal wells. The CCPs have already been used to assess several frameworks spanning a variety of carbon credit categories, including reforestation, carbon dioxide removals and landfill gas capture. There are no current frameworks for early plugging of marginal wells that have been approved by the ICVCM.¹⁰

b. Principles 1-4: Governance and implementation

The first four principles of the CCPs are related to governance and implementation of carbon-crediting programs. These are effective governance; tracking; transparency; and robust independent third-party validation and verification. These are important elements of a carbon credit program, but they largely do not present challenges that are unique to developing high-integrity carbon credits for early plugging of marginal wells. Existing structures and market mechanisms have been developed for other forms of carbon credits and can be utilized for carbon credits from marginal well plugging projects. However, there are a few issues related to governance and implementation that may be unique to marginal wells that we will touch on briefly.

The first is a decision about the legal and ownership implications of marginal well plugging, especially when mineral rights owners and surface landowners are different. The VCM should address potential challenges with differences in ownership, even if that discussion states that these challenges are beyond the scope of the framework. Early plugging of marginal wells must not be in breach of contract with any related parties; necessary legal agreements must be reached before early plugging can occur. Some other issues that may arise are whether a change in mineral rights ownership could lead to new production on a previously plugged marginal well that collected carbon credits (implications for permanence and no double counting), whether awarded carbon credits can be split among mineral rights and surface landowners, and what types of permissions or agreements are needed to ensure integrity (implications for permanence, no double counting and sustainable development).

The second is a decision about third party verification, and clarification on the objective of third-party assessments (i.e. measurements, additionality/eligibility, process audit, checking plugging integrity/permanence, etc.).

Key questions:

- What is the primary objective of third-party verification for marginal wells? What are the qualification requirements for a third-party verifier?
- How will the interests and legal rights of the mineral estate, surface rights, and oil and gas leases be accommodated? Is it within scope of the VCM to clarify these roles?

c. Principle 5: Additionality

Additionality requires that carbon reduction that is awarded carbon credits must be additional, or, in other words, would not have occurred without a VCM. In the context of issuing carbon credits for the early plugging of marginal wells, the additionality requirement necessitates that the well is being plugged earlier than would have been plugged without a VCM, and therefore emissions are prevented.

This primer examines two philosophies concerning additionality and subsequently quantifying carbon credits from the early plugging of marginal oil and gas wells. The first, put forward by the Climate Action Reserve and Open Carbon Protocol, awards carbon credits on the basis of hydrocarbons that are left in the ground that are therefore not produced. Hereafter, this will be referenced as the avoided production (AP) basis.

The second philosophy awards carbon credits on the basis of methane reductions when high-emitting marginal wells are decommissioned and oil and gas production shifts to newly developed and lower-emitting wells. Hereafter, this will be referenced as the lower emission intensity (LEI) basis.

A high-integrity VCM must first specify the philosophical basis for avoided emissions. This is directly related to robust quantification of avoided emissions (Principle 7) and determining eligibility requirements for additionality (Principle 5), as different underlying philosophies have different quantification approaches. There is an argument to be made that early decommissioning of marginal wells will not occur in the absence of a carbon market, as observed behavior suggests that operators will continue to produce at marginal rates for years or decades, and may subsequently become idle or orphaned. However, issuing carbon credits on the LEI basis of early decommissioning of a marginal well implicitly assumes that emissions avoided by plugging one well are not replaced by emissions elsewhere, or are replaced at a lower rate (leakage). Leakage assumptions will be discussed in more detail, and are directly

tied to the quantification basis.

The AP basis would provide carbon credits for all hydrocarbons left in the ground from the date of the early plugging operation to the date that the well would have been plugged in the absence of a VCM. In some instances, the AP basis changes the scope of the emissions that are included in the carbon credit calculation, as there is an argument to be made that the AP basis avoids not just emissions associated with production, but emissions associated with the entire supply chain and potentially end-use. The AP basis relies on the assumption that hydrocarbons left in the ground due to early plugging will remain in the ground permanently. This assumption is directly related to considerations of physical leakage (i.e. plugging a well increases production of a nearby well due to subsurface connectivity) and market leakage (i.e. oil and gas producers increasing their production in other areas to make up for lost production by early plugging of marginal wells).

The LEI basis assumes that early plugging of marginal wells reduces emissions even if all production is replaced by newer wells because marginal wells have higher methane loss rates than non-marginal wells. Researchers estimate that low-production wells have a production-normalized loss rate of over 10%, compared to the mean methane loss rate of 1.5% for wells in the U.S.⁵ Under this logic, production could remain constant (i.e. market leakage =100%), but emissions could decline if production is shifted from higher-intensity marginal wells to lower-intensity replacement wells. This assumes that the replacement well is in fact less emission-intensive than the marginal well being plugged — a non-trivial assumption worth examining in Principle 7.

The VCM should also specify eligibility requirements to ensure the plugged wells satisfy the additionality requirement, which is dependent on the underlying philosophy. The VCM should define a test that demonstrates the marginal well is being plugged earlier than it would have been without the VCM. One approach is to demonstrate that the well is still economically viable at the time of its plugging, assuming that plugging would not have organically occurred until it became unviable. The Climate Action Reserve *Early Plugging of Marginal Oil and Gas Wells Protocol* public draft as of July 2026 — though it is still under development — requires that the estimated revenue of reservoir reserves is calculated and economic viability proven. An additionality test would also consider other funding or regulations for marginal well plugging. There is state and federal funding available for early plugging of marginal wells. In Colorado for example, the Enterprise Marginal Well Plugging (EMWP) program provides funding to operators to alleviate plugging costs.¹¹ The Methane Emission Reduction Program (MERP) also provides federal funding to measure and reduce methane emissions from marginal wells.¹¹ Other possible financial incentives are plugging to increase real estate value, reducing basin-level emission intensities to meet possible maximum methane emission intensity import requirements for international markets or as part of a new shale development effort.

Key questions:

- How will a project prove that a well is being plugged while still economically viable?
- What is the philosophical basis of avoided emissions? Will it be based on the “avoided production” philosophy, or a “lower emission intensity” philosophy or a hybrid approach?
 - What eligibility requirements are necessary as a result of this basis?
 - Which GHGs and sectors should be included?
- How will issues related to leakage/permanence (i.e. physical leakage, market leakage) be addressed?

d. Principle 6: Permanence

Permanence requires that avoided GHG emissions that are awarded carbon credits remain out of the atmosphere permanently, with measures in place to mitigate the risk of possible failure. ICVCM currently requires 40 years of permanence monitoring, though the Integrity Council is exploring extending this to 100 years in future framework iterations. The question of permanence in the context of marginal wells again depends on the underlying philosophy of the avoided emissions calculations.

Under the AP philosophy, credits equal the production avoided during the period between early plugging and when the well would have been plugged without VCM incentives (typically when it became economically unviable — e.g., 30 years in the future).

A critical permanence requirement: **the well must remain plugged for at least as long as the credited period.** If credits assume 30 years of avoided production, the well must stay sealed for at least 30 years. This requirement should be explicitly defined in VCM protocols.

The larger concern with AP is **market leakage**: if production from the early-plugged marginal well simply shifts to other wells, avoided emissions claims are overstated. AP requires either preventing this production shift or accounting for it in credit calculations.

In the context of the LEI philosophy, the lower emissions must be permanent at least over the appropriate crediting period. For example, assume a marginal well produces 5,800 scf/day of natural gas and leaks about 580 scf CH₄/day (~10% loss rate). Assume this marginal well is plugged approximately four years before it would have become economically unviable but is replaced by a well with a lower loss rate (~0.5%). The avoided emissions relative to 5,800 scf/day of production would be $5,800 \times (0.1 - 0.005) = 551 \text{ scf/day}$. In theory, carbon credits could be awarded on the basis that 551 scf CH₄/day were avoided over a four-year period before the marginal well would have been plugged without a VCM if we consider net avoided emissions under the assumption of lower emission intensity despite 100% production replacement. There is nuance to this calculation, which will be discussed further in Principle 7, but this example illustrates that the permanence of the plugging technology in the context of carbon credit issuance is related to the avoided emission timeframe.

Regardless of philosophy, the VCM must also ensure that plugging technologies last for as long as intended given the crediting period of the protocol. Well plugging is intended to be permanent but plug failures do occur, which is defined in this paper as premature failure of plugging technologies. There is limited data on the frequency of such events, though anecdotal accounts and a limited number of scientific studies show that emissions after plugging can occur and should be considered in a high-integrity carbon credit framework. There are some drivers of failure that may not be preventable, even with modern equipment and materials. Older wells may have been drilled with non-standardized equipment. They may also have been shot (a method for removing obstructions by initiating explosions in the subsurface) or treated with acid to increase rock permeability.¹² These activities can lead to well holes with non-uniform diameters or pockets of rock that are difficult to properly plug. The presence of hydrogen sulfide can also corrode equipment and cement, as well as posing serious safety concerns that should be addressed prior to plugging.¹² Subsurface conditions can also lead to plugging failures, especially if there is connectivity between plugged wells and producing wells. Plugging failure can occur if there is fluids pressure buildup, injection from nearby wells or stress changes in the reservoir.^{13,14}

The environmental impacts of plugged well failures can vary significantly. In extreme cases in the Permian Basin, geysers of toxic wastewater have been observed coming out of plugged wells.¹⁵ Other studies have found leaks from plugged wells in several other U.S. basins, though there is variability in the magnitude difference between methane emissions from plugged and

unplugged wells in different studies.^{16,17,18} Plugged wells in coal areas can have similar emission rates to unplugged wells, while plugged wells in non-coal areas may leak at a significantly lower rate.^{16,17,18}

The literature suggests that proper plugging techniques can reduce the risk of plugging failure but cannot eliminate it entirely. Further, even properly plugged wells may fail after a long time. A high-integrity carbon credit framework must recognize the risk of failure, identify actions to mitigate the risk of failure, and develop an action plan to quantify and, if appropriate, retroactively adjust carbon credit issuance if well plugging failure occurs and the permanence requirement is not met. The framework will also need to decide how to assess permanence, such as periodic checking of emissions or third-party verification, and determine how long a properly plugged well will last.

Key questions:

- What does permanence mean in the context of early plugging of marginal wells?
- What mineral rights and surface rights ownership concerns need to be addressed to ensure permanence? What procedures need to be in place to ensure avoided emissions are lasting over the expected timeframe?

e. Principle 7: Robust quantification of emissions reductions

Before developing a VCM framework that supports robust quantification of emission reductions, we must first achieve alignment on three key questions:

- What do we want to quantify?
- What are our priorities for quantification?
- What are the decisions that will need to be made in regard to quantifying net avoided emissions in terms of CO₂e?

These questions do not address the technical challenges associated with quantification of emissions but are an important first step that will inform the approach of subsequent technical decisions.

i. What do we want to quantify?

The decision on what to quantify hinges on the underlying philosophy of the avoided emissions. In the AP approach, the main quantification objective is the volume of hydrocarbons left in the ground that would have otherwise been produced had carbon credits not been awarded. The AP approach also brings into question the scope of emissions that are to be considered. Carbon credits can either be awarded on the basis of emissions (loss) that would have been put into the atmosphere during production or can include emissions associated with the entire supply chain of those hydrocarbons, from production to end-use, as is in the Climate Action Reserve draft protocol.¹⁹ The AP approach could also be expanded to GHGs beyond methane, as there are CO₂ emissions and other possible GHGs associated with avoided production. The Climate Action Reserve draft protocol also considers CO₂ emissions when determining CO₂e. However, this relies on the underlying market leakage assumption, since if production of oil and gas remains stable due to development in another region, net CO₂ emissions would remain unchanged. One of the largest sources of uncertainty in the AP approach is the assumption of physical and market leakage, which will be discussed in more detail in Section 3.iii.

In the LEI approach, the main quantification objective is to calculate the avoided emissions by replacing high emission intensity marginal well production with low intensity production. This would require measurement or accurate estimates of emissions from the old well and theoretical new well. The first quantification task at hand would be calculating the methane emissions and methane emission intensity associated with the to-be-plugged marginal well. Understanding the differential between the emissions from a marginal well and a theoretical “new well” that replaces or exceeds the previous production is not a trivial task. A new well will not be drilled in direct replacement of a previously plugged well. Rather, a production company will likely continue to drill to meet production demands and growth strategy goals. A LEI-based method will need to determine how to estimate an emission intensity from a newer well, such as using a basin-specific average, specify which checks or measurements, if any, are required to prove this assumption, and decide what to do in the case that total emissions increase even if emission intensity is lower. Each of these philosophical approaches will be accompanied by further technical investigation, but alignment must first be reached on the main quantification objective. Each approach will also need to determine a time varying function of the emissions, whether it be a constant rate, based on a decline curve, or another approach, from the time of plugging until the end of the crediting period. Credits are typically determined up front (i.e. immediately after the plugging operation) and must make an assumption about how the well will behave, or would have behaved, over a period of years.

The VCM should also specify the scale at which carbon credits will be awarded, which has direct implications for the market mechanism of carbon credit issuance. For example, a mechanism that awards carbon credits by project may require quantification at each well level. The existing frameworks take this approach. However, other approaches, such as a jurisdictional approach, would award carbon credits based on avoided emissions across an entire region. The market approach may dictate the quantification scale.

ii. What are our priorities for quantification?

Different priorities for the quantification objective will also influence protocol recommendations. Some possible objectives are listed as follows:

- Scientific accuracy of quantified avoided emissions
- Broad applicability of quantification approaches
- Transparency and consistency in methods
- Flexibility in methods

Some of these objectives are in tension with one another. For example, prescriptive measurement protocol that specifies measurement technologies, measurement count, etc., may be limited in its applicability if the measurement techniques are prohibitively expensive, requires specialized training or the well is located in a difficult or dangerous-to-access location. The VCM could offer alternative quantification approaches in these cases, such as allowing modeling approaches or national averages instead of measurement, but flexibility in allowable methods could potentially compromise the consistency or accuracy of quantified carbon credits. There may also be a tradeoff in scientific accuracy vs. feasibility. Tolerances for compromise in each of these objectives should be discussed ahead of building out a high-integrity VCM framework.

iii. What are the decisions that will need to be made to quantify net avoided emissions in terms of CO₂e?

a. Relevant GHGs

The VCM must first decide the scope of relevant emissions, and the GHGs that will be included in the CO₂e calculations, which is the metric upon which carbon credits are usually awarded. The VCM must specify the relevant sectors for quantifying the associated emissions. Specifically, the VCM should state whether just emissions associated with production are to be included in the carbon credit calculations, or whether emissions associated with other operations (gathering and boosting, processing, transportation, end-use) are also relevant.

Lastly, the VCM should also specify the GHG species that are to be included in the carbon credit calculation. Most literature around marginal wells focuses on their methane emissions, but CO₂ and N₂O are also recognized by the EPA as being significant to oil and gas systems' environmental impact.²⁰ This decision is also related to the decision of the basis for carbon credit issuance (AP vs. LEI) as some emissions, such as CO₂ from end-use combustion, is not relevant in the LEI framework.

b. Crediting period selection

The crediting period refers to the duration over which carbon credits will be calculated. The crediting period is difficult to determine. There is a lack of long-term measurements associated with emissions from plugged wells. Carbon credits awarded on the basis of early plugging suggests that the appropriate crediting period would be from the date of early plugging to the date when the well would have become economically unviable based on decline curve analysis. The Climate Action Reserve draft protocol assumes an initial crediting period of 10 years, which can be extended if deemed eligible to up to 20 years, or the specific well's economic limit.¹⁹ The Open Carbon Protocol method by ClimateWells has a crediting period of 10 years.²¹ A high-integrity VCM will need to clearly define how to determine appropriate crediting period.

c. GWP

The volume of avoided GHGs is typically then converted into CO₂e, which is used as a common basis for awarding carbon credits based on the avoidance of different GHGs. The philosophy behind GWP is that different GHGs have different radiative efficiencies and lifetimes, which leads to different warming potentials. In basic terms, GWP is a way to compare how the warming impact of 1kg of a non-CO₂ GHG would compare to the warming potential of 1kg of CO₂. However, the GWP value can change depending on which time horizon is used. Methane has a GWP₂₀ of 81 based on the IPCC's 6th assessment report (AR6), meaning that over a 20-year horizon, the global warming potential of 1kg of methane is 81x higher than 1kg of CO₂.²² The GWP₁₀₀ of methane is 27.9.^{22,23} The selected GWP (i.e. either GWP₂₀ or GWP₁₀₀) significantly impacts the resulting CO₂e value. The U.S. EPA and the Intergovernmental Panel on Climate Change use GWP₁₀₀ as their baseline.^{23,24} GWP has received criticism due to its dependence on time frame selection, and some research recommends using different climate metrics or combinations of climate metrics to more accurately reflect climate impact.^{25,26} A carbon crediting framework will need to decide on the climate impact metric that will be used for awarding carbon credits, whether it be GWP on a specific time horizon or an alternative.

d. Considerations for net emissions reductions

Another important decision in quantifying the avoided volume of emissions is determining if and how to account for other associated emissions. Leakage, both physical and market, remains a concern when determining the net avoided emissions associated with early plugging of marginal wells. Physical leakage refers to increased emissions or production at a nearby well due to the plugging of another well. The Open Carbon Protocol recommends either a 5% or 20% emission deduction to account for physical leakage (i.e. the fraction of hydrocarbons they estimate to be recoverable by nearby wells).²¹ The deduction depends on geological characteristics indicating the degree of reservoir communication:

- **Low risk (5% deduction):** Limited historical signs of interference between wells; depleted reservoir; high water mobility; offset well far from project well or lower on structure
- **Medium risk (20% deduction):** Moderate signs of interference; active reservoir drive mechanism; moderate water mobility; offset well close to project well or at similar structural position

The physical leakage problem is also present when issuing carbon credits for orphan wells. It is still uncertain how impactful physical leakage will be to a project's net avoided emissions. The Open Carbon Protocol notes that in some cases the physical leakage will not impact the projects credits, whereas in other cases it may render the project ineligible for credits.²¹

The Climate Action Reserve draft protocol uses pre- and post-plugging production rates to determine physical leakage (if pre- and post-plugging production in the region remains constant, no adjustment for physical leakage is required).¹⁹

Market leakage refers to increased production in another region to offset the loss of production due to well plugging. Both the Open Carbon Protocol and Climate Action Reserve draft protocol reference a 56%-57% market leakage rate based on a study by the Resources for the Future and the Rocky Mountain Institute.^{27,21} Market and physical leakage estimates are deducted from the initial avoided emissions quantity. Both have potentially significant implications in determining total net emissions. Market leakage rates especially are highly uncertain and can significantly impact the climate benefit of the early plugging operation. The integrity of the carbon credits could be degraded if the market leakage is higher than estimated, especially for the AP basis, as a market leakage of near 100% would mean that no production was avoided. The other consideration is whether to deduct project emissions, or emissions associated with plugging of the well itself. The Climate Action Reserve draft protocol deducts project emissions from their net avoided emissions calculations whereas the Open Carbon Protocol by ClimateWells assumes project emissions are zero because the plugging would have eventually occurred anyway.^{19,21}

Key questions:

- What volume do we want to quantify as the baseline emissions?
- What are our priorities for the quantification protocol?

- Are there tradeoffs between scientific accuracy and feasibility?
- What are the decisions that will need to be made in regard to quantifying net avoided emissions in terms of CO₂ equivalence? With what guiding principles do we want to inform these decisions?
 - GWP, relevant GHGs, crediting period, scope of avoided emissions, deductions for market leakage, physical leakage/subsurface connectivity, project emissions and uncertainty
- Is there enough information for a defensible quantification approach for either of these philosophies?
 - Do we have a method to reliably estimate market leakage and physical leakage?
 - Do we have a method to reliably estimate emissions on an LEI basis if that is the selected philosophy?

f. Principle 8: No double counting

High-integrity carbon credits also require that GHG removals or reductions only be credited once. In the context of early plugging of marginal wells, this means that carbon credits can only be issued once per plugged well. The no double counting requirement can be achieved so long as there is transparency and tracking in well plugging activity.

One consideration is whether credit stacking is allowable, or if mixing of funding sources is allowable, and if so, under which circumstances. Credit stacking can refer to either combining multiple carbon reduction and removal projects, or receiving other types of credits, such as water credits, for co-benefits associated with the activity.

Key questions:

- Are there situations where credit stacking is allowable? Can funding sources be mixed (i.e. federal funding and carbon credits)?

g. Principle 9: Sustainable development benefits and safeguards

High-integrity carbon credits must also have clear procedures to ensure that mitigation activities meet current industry standards. Well plugging efforts have occurred for a long time, and best practices and standards for well plugging are well documented.^{28,29,30} A new report by the National Academies was published on technologies and practices for orphan well plugging and remediation.³¹ Proper well plugging is critical to developing high-integrity carbon credits, as improper well plugging can affect the permanence of the avoided emissions, and lead to other harmful outcomes such as the continued leaking of methane and contamination of underground sources of drinking water (USDWs). A high-integrity carbon crediting framework will need to identify acceptable methods and safety precautions for well plugging and site remediation, and develop a process that ensures awarded carbon credits were achieved in a way that aligns with best practices.

Key questions:

- Are there any additional concerns with sustainable development benefits and safeguards? How will compliance with these safeguards be assessed?

h. Principle 10: Contributions to the net zero transition

Under this principle, action taken to mitigate GHG emissions must not lock in carbon-intensive practices or contribute to a goal that is contradictory to the net zero transition. Early plugging of marginal wells helps contribute to reducing the carbon intensity of the current energy system by avoiding future emissions. Plugging a marginal well also results in the end-of-life for an oil and gas well. There is the possibility that plugging old marginal wells results in the drilling of new wells, but it may be argued these new wells would likely have been drilled anyway, and modern practices and newer wells ultimately reduce the overall environmental impact of the sector.

IV. Other challenges with early plugging of marginal wells

One challenge to be aware of when developing a VCM for early plugging of marginal wells is the potential for legal restrictions on early well plugging. Energy companies often do not own the land or mineral rights from which they produce, and often lease and pay royalties to mineral rights owners. Marginal wells are still in production, and early plugging of these wells could be in violation of the lease agreement or contract depending on the specific details. Surface and mineral rights owners can also change if they are bought or sold, which could have implications for the permanence of the early plugging projects if a new owner decides to continue hydrocarbon production.

Key question:

- Are legal concerns related to surface and mineral rights in-scope for the VCM protocol? If so, how should these be addressed?

V. Co-benefits of early plugging of marginal wells

In most carbon crediting frameworks, avoided GHG emissions are the sole basis for awarding carbon credits. However, other environmental and social benefits are acknowledged and characterized as co-benefits. In the case of early plugging of marginal wells, other air pollutants are avoided that are hazardous to human health, such as benzene, a known carcinogen, hydrogen sulfide, toluene, ethylbenzene, xylenes and other volatile organic compounds (VOCs).^{32,33,34} There is a lack of literature that looks specifically at the health impacts of marginal wells, but given that 80% of wells in the U.S. are low producing and 8 million Americans live within a half mile of a marginal well, it is likely that these concerns are highly relevant to the marginal well population.⁸ Other co-benefits may include beneficial land use, such as using the sites for renewable energy, avoiding ground and surface water contamination, and restoring wildlife and ecological habitat.

Key questions:

- Should the VCM explicitly account for co-benefits when quantifying carbon credits?

VI. Existing frameworks for carbon credits from early plugging of marginal wells

There are three planned or existing frameworks for issuing carbon credits from early plugging of marginal wells. They have significant overlap in authorship but are not identical. The first, active as of April 1, 2024, is published by Open Carbon Protocol and was authored by ClimateWells.²¹ This protocol is still under development according to the Carbon Registry, but is available online.³⁵ The second is written by the Climate Action Reserve, also in collaboration with ClimateWells, and is available in draft form as of July 2026.¹⁹ The third is not yet publicly available, but is expected to be released in mid-2026 by The Gold Standard and is also being authored by ClimateWells.³⁶

Methodology	Open Carbon Protocol by ClimateWells	Climate Action Reserve
Countries	U.S.	U.S.
Maximum Crediting Period (yrs)	10 yr	Maximum of two 10-yr credits (20 years total). Economic lifetime used if <10 yr, <20 yr
Crediting Principle	Emissions based on left-in-ground principles. Quantifies all emissions that would have occurred in upstream, midstream and downstream processes using Oil-Climate Index	Emissions based on left-in-ground principles. Quantifies all emissions that would have occurred in manufacturing/extraction, processing/refining, transportation and end-use combustion
Well eligibility requirements	Well is in good standing, has economically recoverable reserves, and passes Technical Permanence Review and Quantitative Permanence Review	Must demonstrate economic viability of the well to satisfy additionality requirement and demonstrate that no federal, state or local regulation would require early plugging
Avoided emission quantification approach	Baseline emissions calculated using adjusted economic lifetime x oil climate field index coefficient (tCO ₂ e/BOE) with 1% or 5% deduction for uncertainty, 5% or 20% deduction for physical leakage and a 57% recommended market leakage deduction	Baseline emissions calculated using adjusted economic lifetime x oil climate field index coefficient (tCO ₂ e/BOE) with uncertainty discount, 5%-20% deduction for physical leakage, project emissions deduction and market leakage deduction that project developers determine
GHGs	Oil climate index (OCI) offers information on both methane and carbon dioxide	Oil climate index (OCI) offers information on both methane and carbon dioxide; methodology specifies using both
GWP	Oil climate index (OCI) offers information on both GWP20 and GWP100; methodology specifies using GWP20	Oil climate index (OCI) offers information on both GWP20 and GWP100; methodology specifies using GWP100

Sector/scope of emissions?	Upstream, midstream and downstream, and consumer end-use	Upstream, midstream and downstream, and consumer end-use
Project emissions deducted?	No	Yes
Buffer for market leakage or physical leakage?	Yes	Yes

References

1. U.S. Environmental Protection Agency. (2025). *Marginal conventional wells*. <https://www.epa.gov/natural-gas-star-program/marginal-conventional-wells>
2. Crippa, M., Guizzardi, D., Pagani, F., Banja, M., Muntean et al. GHG emissions of all world countries - 2025 Report, Publications Office of the European Union, Luxembourg, 2025, doi:10.2760/9816914, JRC143227.
3. U.S. Energy Information Administration. (2025). *State carbon dioxide emissions data*. <https://www.eia.gov/environment/emissions/state/>
4. Environmental Defense Fund. (July 18, 2022). *U.S. low-producing oil and gas wells and the people affected by their pollution*. <https://www.edf.org/low-producing-wells-map>
5. Environmental Defense Fund. (2021). *Marginal oil and gas wells: By the numbers*. https://www.edf.org/sites/default/files/documents/MarginalWellFactsheet2021_o.pdf
6. Omara, M., Zavala-Araiza, D., Lyon, D. R., Hmiel, B., Roberts, K. A. and S. P. Hamburg (2022). Methane emissions from US low production oil and natural gas well sites. *Nature Communications*, 13, Article 2085. <https://doi.org/10.1038/s41467-022-29709-3>
7. GSI Environmental Inc. (2022, April 28). *Quantification of methane emissions from marginal (low production rate) oil and natural gas wells: Final project report* (DOE Award No. DE-FE0031702). U.S. Department of Energy, National Energy Technology Laboratory. <https://www.osti.gov/servlets/purl/1865859/>
8. United States Environmental Protection Agency. (2024). *Greenhouse gas equivalencies calculator*. EPA. <https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator>
9. Integrity Council for the Voluntary Carbon Market. (n.d.). The Core Carbon Principles. <https://icvcm.org/core-carbon-principles/>
10. Integrity Council for the Voluntary Carbon Market. Accessed March 2026. *Assessment status*. <https://icvcm.org/assessment-status/>
11. Colorado Energy & Carbon Management Commission. (n.d.). *Marginal well plugging*. Accessed March 2026. <https://ecmc.colorado.gov/regulation/marginal-wells>
12. Heagle, D. J. and R. Sealey (2023). The implications of Ontario's historical oil and gas drilling and abandonment practices for abandoning orphan and legacy wells. *Geoscience Canada*, 50(4), 277–294. <https://doi.org/10.12789/geocanj.2023.50.203>
13. Babaleye, A. O., Kurt, R. E. and F. Khan (2019). Safety analysis of plugging and abandonment of oil and gas wells in uncertain conditions with limited data. *Reliability Engineering & System Safety*, 188, 133–141. <https://doi.org/10.1016/j.ress.2019.03.027>
14. Mainguy, M., Longuemare, P., Audibert, A. and E. Lécolier (2007). Analyzing the risk of well plug failure after abandonment. *Oil & Gas Science and Technology – Revue d'IFP Energies nouvelles*, 62(3), 311–324. <https://doi.org/10.2516/ogst:2007026>
15. Friedman, L. (2025, March 3). Texas oil boom threatened by toxic water, leaking wells. *Bloomberg*. <https://www.bloomberg.com/graphics/2025-permian-basin-geyser/>
16. Kang, M., Mauzerall, D. L., Ma, D. Z. and M. A. Celia (2019). Reducing methane emissions from abandoned oil and gas wells: Strategies and costs. *Energy Policy*, 132, 594–601. <https://doi.org/10.1016/j.enpol.2019.05.045>
17. Kang, M., Christian, S., Celia, M. A., Mauzerall, D. L., Bill, M., Miller, A. R., Chen, Y., Conrad, M. E., Darrah, T. H. and R. B. Jackson (2016). Identification and characterization of high methane-emitting abandoned oil and gas wells. *Proceedings of the National Academy of Sciences*, 113(48), 13636–13641. <https://doi.org/10.1073/pnas.1605913113>

18. Townsend-Small, A., Ferrara, T. W., Lyon, D. R., Fries, A. E. and B. K. Lamb (2016). Emissions of coalbed and natural gas methane from abandoned oil and gas wells in the United States. *Geophysical Research Letters*, 43(5), 2283–2290. <https://doi.org/10.1002/2015GL067623>
19. Climate Action Reserve. (2026). *U.S. early plugging of marginal oil and gas wells: Workgroup draft version 1.0*. <https://climateactionreserve.org/wp-content/uploads/2026/04/US-Marginal-Wells-Workgroup-Draft-Public.pdf>
20. U.S. Environmental Protection Agency. (2024). *Inventory of U.S. greenhouse gas emissions and sinks: 1990–2022* (EPA 430-R-24-004). <https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2022>
21. ClimateWells. (2024). Early decommissioning of marginal oil and gas wells in the United States. Open Carbon Protocol. <https://pilot.ocp.earth/all-methodologies/3?roundId=7>
22. Environmental Defense Fund. (2022). *Emission equivalency tool documentation: Methodology* [PDF]. <https://www.edf.org/sites/default/files/content/emission-equivalency-tool-documentation-meth-odology-23062022.pdf>
23. U.S. Environmental Protection Agency. (2025). Understanding global warming potentials. <https://www.epa.gov/ghgemissions/understanding-global-warming-potentials>
24. Intergovernmental Panel on Climate Change. (2022). Technical summary. In *Climate change 2022: Mitigation of climate change. Contribution of Working Group III to the Sixth Assessment Report of the IPCC*. Cambridge University Press. <https://www.ipcc.ch/report/ar6/wg3/chapter/technical-summary/>
25. Balcombe, P., Speirs, J. F., Brandon, N. P. and A. D. Hawkes (2018). Methane emissions: Choosing the right climate metric and time horizon. *Environmental Science: Processes & Impacts*, 20(10), 1323–1339. <https://doi.org/10.1039/C8EM00414E>
26. Mar, K., Ungar, C., Walderdorff, L. and T. Butler (2022). Beyond CO₂ equivalence: The impacts of methane on climate, ecosystems, and health. *Environmental Science & Policy*, 134, 127–136. <https://doi.org/10.1016/j.envsci.2022.03.027>
27. Prest, B., Fell, H., Gordon, D. and TJ Conway (2024.) Estimating the emissions reductions from supply-side fossil fuel interventions, *Energy Economics*, 136, 107720, <https://doi.org/10.1016/j.eneco.2024.107720>.
28. National Academies of Sciences, Engineering, and Medicine. (2023). Practices and standards for plugging orphaned and abandoned hydrocarbon wells: Proceedings of a workshop. The National Academies Press. <https://www.nationalacademies.org/read/28035/chapter/1>
29. Tinsley, C. (2018). The Underground Injection Control Program and the current framework for injection of carbon dioxide [PDF]. U.S. Environmental Protection Agency. https://www.epa.gov/sites/default/files/2018-06/documents/well_plugging_2018_-_chuck_tinsley.pdf
30. Energy Workforce & Technology Council. (2022). Recommended best practices for orphan well plugging [PDF]. <https://www.energyworkforce.org/wp-content/uploads/2022/04/Recommended-Best-Practices-for-Orphan-Well-Plugging.pdf>
31. National Academies of Sciences, Engineering, and Medicine. (2023). Plugging America's forgotten wells: National Academies study addresses decades-long problem. <https://www.nationalacademies.org/news/plugging-americas-forgotten-wells-national-academies-study-addresses-decades-long-problem>
32. Johnston, J., Lim, E. and H. Roh (2019). Impact of upstream oil extraction and environmental public health: A review of the evidence. *Science of The Total Environment*, 657, 187-199, <https://doi.org/10.1016/j.scitotenv.2018.11.483>

33. Buonocore, J. J., Reka, S., Yang, D., Chang, C., Roy, A., Thompson, T., Lyon, D., McVay, R., Michanowicz, D. and S. Arunachalam (2023). Air pollution and health impacts of oil & gas production in the United States. *Environmental Research: Health*, 1(2).
<https://doi.org/10.1088/2752-5309/acc886>
34. Colborn, T., Kwiatkowski, C., Schultz, K. and M. Bachran (2011). *Natural gas operations from a public health perspective. Human and Ecological Risk Assessment: An International Journal*, 17(5), 1039–1056. <https://doi.org/10.1080/10807039.2011.605662> [Natural Gas Operations from a Public Health Perspective: Human and Ecological Risk Assessment: An International Journal: Vol 17, No 5](#)
35. International Carbon Registry. (n.d.). *M-ICR0006 methodology*.
<https://www.carbonregistry.com/m-icr-0006>
36. Gold Standard for the Global Goals. (n.d.). *Early decommissioning of marginal oil and gas wells*.
<https://globalgoals.goldstandard.org/in-development/early-decommissioning-of-marginal-oil-and-gas-wells/>