METHODOLOGY FOR THE QUANTIFICATION, MONITORING, REPORTING AND VERIFICATION OF GREENHOUSE GAS EMISSIONS REDUCTIONS AND REMOVALS FROM

PLUGGING ORPHAN OIL AND GAS WELLS IN THE U.S. AND CANADA

VERSION 1.0

May 2023

ACR
AT WINROCK INTERNATIONAL

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ABOUT ACR^{SM}

ACR is a leading global carbon crediting program operating in regulated and voluntary carbon markets. Founded in 1996 as the first private voluntary greenhouse gas (GHG) registry in the world, ACR creates confidence in the integrity of carbon markets to catalyze transformational climate results. ACR ensures carbon credit quality through the development of environmentally rigorous, science-based standards and methodologies as well as oversight of carbon offset project verification, registration, and credit issuance and retirement reporting through its transparent registry system. ACR is governed by Environmental Resources Trust LLC, a wholly-owned nonprofit subsidiary of Winrock International.

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This methodology was developed by

ACR

McGill University

In collaboration with:

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Well Done
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Acronyms

API	American Petroleum Institute
AOOG	Abandoned and orphan oil or gas well
BLM	Bureau of Land Management
BOEPD	Barrels of oil equivalent per day
CH_4	Methane
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
EIA	Energy Information Agency
GHG	Greenhouse gas
GM	Gas migration
IOGCC	Interstate Oil and Gas Compact Commission
IPCC	Intergovernmental Panel on Climate Change
M	One thousand
MM	One million
Mcf	Volume of 1,000 cubic feet
MMT	Million metric tons
MCFD	One thousand cubic feet per day
MIT	Mechanical integrity test
Mtoe	Million tons of oil equivalent
N_2O	Nitrous oxide

O&G	Oil and gas
OOG	Orphan oil and gas well
OPA	Oil Pollution Act of 1990
ppm	Parts per million
ppmv	Parts per million by volume
P&A	Plug and abandon
SSR	Sources, sinks, and reservoirs
TA	Temporary abandonment
t	Metric ton

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1 Background and Applicability

1.1 Summary Description of the Methodology

This science-based methodology provides the quantification and accounting frameworks, including eligibility and monitoring requirements, for the creation of carbon credits from the reduction in methane emissions by plugging Orphan Oil and Gas (OOG) wells in the U.S. and Canada. Since, methane, although a short-lived pollutant, is a more potent greenhouse gas (GHG) when compared to CO_2 on a Kg-to-Kg basis—and is already responsible for about a third of warming the world has experienced since the industrial revolution—it is imperative to take immediate action to see benefits of mitigating this short-lived climate pollutant to slow down the rate of warming in the near term. This methodology is intended to be used as an incentive to drastically cut emissions by creating carbon credits as a source of funding for the plugging of leaking- sometimes for decades- orphan oil and gas (O&G) wells, and to help operators and jurisdictions prioritize leaking methane as an environmental risk. By following the framework shared in this document, carbon credits may be generated for reduction of emissions after plugging OOG wells that, if unplugged, would continue to emit methane to the atmosphere.

The study of orphaned wells is an active area of research and is often part of the study of abandoned wells as referenced throughout this document, however, at this time the methodology applies only to orphan wells. There are numerous terms that refer to non-producing wells and because the regulation of O&G wells is done predominately on a state or provincial level, and many of those regulations rely upon well status, it is important to identify and consolidate classifications across regulatory boundaries. In this methodology, ACR will use the term abandoned wells to refer to unplugged wells with no recent production which have a known, solvent operator, this classification includes wells in the different states and provinces known as dormant, deserted, inactive, junked, suspended, neglected, shut-in, idle, waiting on completion, and temporary abandoned. The term “Orphan Wells” will refer to wells without a solvent operator, which are not plugged or have been poorly plugged and require additional plugging measures to prevent emissions. These wells may appear on a jurisdiction’s “orphan well list” or they may be unknown orphans that were drilled and poorly plugged or simply abandoned prior to the promulgation of plugging regulation and tracking requirements. Many of the same terms under “abandoned” can also apply to “orphan” wells. The distinction ACR is making is between these two terms is whether the well is associated with an active or solvent operator or has become the responsibility of the state or province.

Different regulatory requirements and responsibilities may apply depending on whether the well is associated with an operator. For example, plugging responsibilities can shift to the state or province when a well is orphaned, and the timing requirements of its plugging responsibility may no longer be present. The study of OOG wells is an active area of research, and this methodology will be updated accordingly as explained in Section 1.4.

The United States Environmental Protection Agency (EPA), in its latest National GHG Inventory,[1] reports 6.6 million metric tons of carbon dioxide equivalent (MMT CO_2e) emissions from abandoned and orphan O&G (AOOG) wells in the United States on an annual basis. However, several studies report that methane emissions from these wells are likely underestimated.[2] The factors contributing to this potential underestimation include the uncertainties associated with the total number of AOOG wells and their emission rates, as well as the limited population of wells studied. Estimates of the onshore AOOG well population in the United States vary from approximately 2.3 million to 3.2 million according to recent studies.[3] Publicly available databases, such as the National Oil and Gas Gateway, or the Bureau of Land Management (BLM) Oil and Gas Statistics, do not provide a complete picture of the AOOG well population and, according to the EPA,[4] private resources (such as Enverus or IHS databases) may underreport the population by over one million wells. One recent study analyzed historical and new field datasets to quantify the number of AOOG wells in Pennsylvania,[5] individual and cumulative methane emissions, and the well attributes that characterize this problem. The study shows that older AOOG wells can still be emitting methane many years after they are drilled, high emitters appear to be unplugged gas wells, and the number of AOOG wells may be as high as 750,000 in Pennsylvania alone.

According to the EPA, less than 1% of documented AOOG wells in Canada and the United States have been measured to estimate emissions.[6] While this presents a challenge in estimating total emissions at a national scale, these existing studies demonstrate that methane is being emitted from AOOG wells across many fields and basins.[7] Ideally, the AOOG well population accounting and emission measurements would need to increase to obtain more accurate national estimates for total emissions. Cumulative emissions from OOG wells are dominated by higher emitters. Inaccurate and incomplete accounting of OOG well count, particularly older wells, and a lack of methane emission information are problems that persist in many major O&G producing regions. Hence, there is a need to design practical solutions and incentives to solve these two challenges. The use of this methodology

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[1] (U.S. EPA, 2019)

[2] (Williams et al., 2021), (Townsend-Small et al., 2016)

[3] (Saint-Vincent et al., 2020)(Kang et al., 2021)

[4] (U.S. EPA, 2018)

[5] (Kang et al., 2016)

[6] (Williams et al., 2021)

[7] (U.S. Department of Energy et al., 2021)

could support the improvement of OOG well inventories, as well as the development of more accurate and representative emission factors for methane emissions in the U.S. and Canada as data from participating projects becomes available. Then, shared data could be analyzed to try to identify patterns behind causes of emissions in OOG wells that would enable plugging funds to be spent to maximize atmospheric benefits.

Stringent regulatory requirements to properly plug and remediate wells were not in place nation-wide until the 1950s (Appendix F); thus, wells plugged before that time may have been inadequately plugged, if at all. Wells that were considered plugged at the time may have degraded further and early plugging records, if any exist, may not be complete and accurate. These inadequately plugged or degraded wells may not be included in a jurisdiction's well records or may be classified as plugged and no longer have an associated operator. Although state and provincial regulatory requirements mandate that operators plug wells at the end of their productive lives,[8] plugging criteria vary in quality and comprehensiveness, and wells are often left without plugging[9] or surface remediation.[10] Even when there is a solvent operator associated with a well, many states and provinces allow operators to categorize wells as "idle"[11] for a certain amount of time or, in some cases, indefinitely. Many wells remain classified as active or producing beyond their economic life to avoid plugging costs and/or maintain producing privileges or mineral leases. These wells have a higher likelihood of becoming orphan, therefore transferring responsibility to the state or province and its taxpayers.

In almost all jurisdictions, financial assurance requirements—a commitment operators make to cover the eventual cost of plugging and remediation[12]—are insufficient to cover the actual costs of proper well plugging and site remediation at the end of a well's productive life. Available bonding data suggest that states on average have secured less than one percent (1%) of the amount needed to plug orphan wells (roughly estimated at up to $280 billion in the U.S.).[13] Exacerbating the funding deficit for plugging orphan wells, new studies suggest that after the 2020 economic downturn, at least 30 O&G exploration and production companies, which operate 116,245 wells in 32 states in United States and four Canadian provinces/territories, have filed for bankruptcy.[14] Canadian observations show that a drop in oil prices leads to an increase in the number of orphan wells in the subsequent three years.[14] Shortfalls in state and provincial plugging funds, and the latent growth of OOG wells population due

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[8] (IOGCC, 2021)

[9] (Kang et al., 2021)

[10] Remediation typically refers to surface restoration and clean up (See Definitions)

[11] ACR uses the term "idle" in this methodology for a non-producing well; note that this term could also be referred to as, for instance, "inactive", "suspended" or "temporarily abandoned", by various states, provinces, or federal governments. Appendix G shows a map of O&G wells categorized with above mentioned statuses in the United States and Canada.

[12] (Lyon & Peltz, 2016)

[13] ("Billion Dollar Orphans," 2020)

[14] (Kang et al., 2021)

to economic downturn and world-wide carbon-neutral transitions, demonstrate that tools such as this methodology can provide a solution to the OOG well plugging crisis.

As the world transitions to a carbon-neutral economy, the number of wells that need to be plugged will likely increase.[14] This science-based methodology provides an incentive to drastically cut emissions from OOG wells using carbon credits as one source of funding. However, the positive impacts extend beyond reducing methane emissions to the atmosphere by addressing the cost to society (taxpayers) of these wells remaining unplugged. Remediation of OOG wells in the near term could result in immediate positive environmental impacts on the quality of water, air, climate, and human ecosystem health with the added societal benefits such as the wellbeing of nearby communities, jobs creation and economic stimulation. Other gases besides methane can be emitted from OOGs.[15] While these gases may not contribute to GHG emissions, the plugging and abandoning of these OOGs will provide quantifiable, local air quality benefits. Finally, data acquisition from participating projects will lead to an increased understanding of the scope of the orphan wells problem, including well emissions and plugging costs, for industry, regulators, and the general population.

In addition to a project meeting ACR program eligibility requirements as found in the most current *ACR Standard*, individual wells must satisfy the following eligibility requirements:

- The well is located in the U.S. or Canada
- The well is emitting methane with no regulatory requirement to prevent the release
- The well is included under any of the following categories
  - Wells with no designated operator
  - Wells considered "plugged" by the operator or regulator (if one was in place) or could have been inadequately or improperly plugged and are still leaking methane.
  - Wells that do not appear on a jurisdiction's orphan well list. These wells do not have a solvent operator and would be classified as "unknown orphans"

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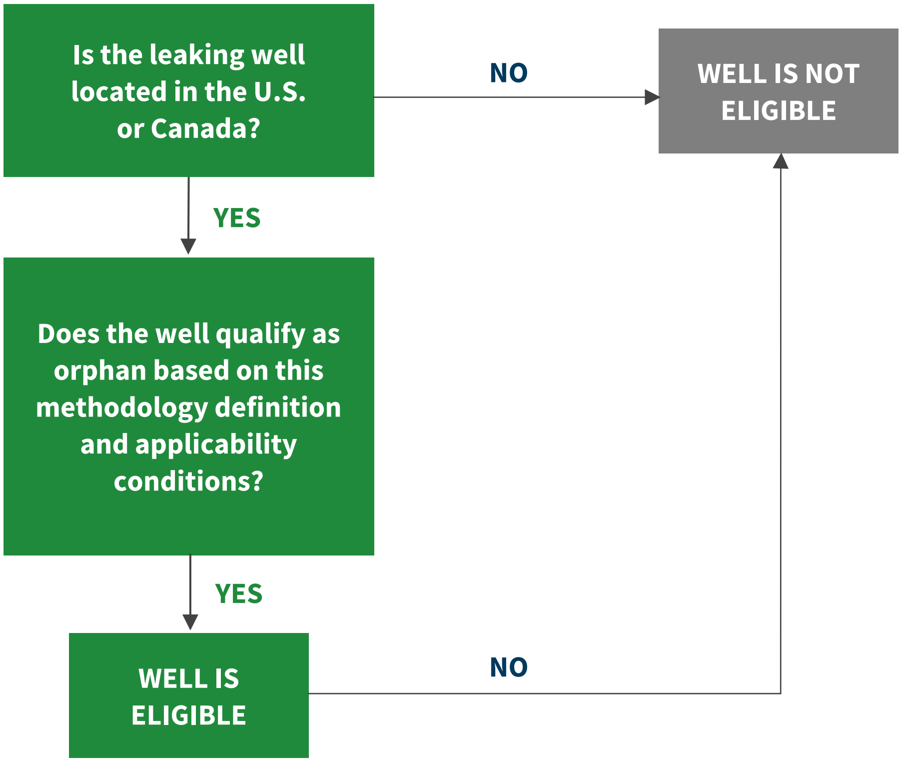
[15] (Raimi et al., 2021), (Townsend-Small & Hoschouer, 2021)

Figure 1: Eligibility Decision Tree



Although there are different requirements at the state, province, and federal level to ensure that natural resources are protected, modern regulatory standards in U.S. jurisdictions began requiring specific provisions for plugging and documenting O&G wells before they are abandoned. Plugging techniques have since improved and jurisdictions have requirements to ensure environmental protection. Appendix F list all states and provinces and the year when they started having regulations in place. Previous unregulated plugging and abandonment (P&A) methods included materials such as wood, rocks, and linen absorbers being used as plugs instead of cement. Currently, regulations prescribe the depth intervals which must be sealed with cement as well as the materials that are allowed in plugging practices. Regulations also prescribe well testing requirements and lengths of time that wells can remain idle or out of production, as seen in Appendix E. Since many wells were plugged prior to modern P&A regulations coming into effect, operators may not have been required to plug or reclaim them. If the proposed project passes the Regulatory Surplus Test, plugging that occurs on these wells is considered additional to that which is commonly required by law.

If an operator takes title of an orphan well with the intent of performing plugging operations, that well is still considered orphan under this methodology. Within 12 months of taking title the operator must demonstrate intent to plug the well by listing the project with ACR.

1.2 Reporting Period

The reporting period begins with the completed plugging of the first well in a project and ends when project proponents confirm that there are no post-plugging emissions in the last well plugged in the same project. Each well within a project will have its own reporting timeline. Validation must be completed within 12 months of the plugging of the last well in the project. The project term for an OOG well plugging project includes the post-plugging monitoring period, as specified in Chapter 5 of this methodology.

1.2.1 START DATE

For this methodology, the start date corresponds to the completion of plugging activities of the first plugged well included in a project after demonstration that there are no emissions from the plugged well—according to Section 5.2. This date will be confirmed by the jurisdiction when the well is reclassified as plugged or decommissioned. All wells in a project must be plugged within 24 months of the project start date.

1.3 Crediting Period

Per the *ACR Standard*, the project crediting period is the length of time for which a GHG Project Plan is valid, and during which a project can generate credits against its baseline scenario. Orphan well plugging activities developed under this methodology will have a single, non-renewable crediting period of twenty years. Credits corresponding to twenty years of quantified avoided methane emissions are eligible for issuance the year that a well is plugged. The 20-year crediting period reflects Enverus oilfield data that demonstrates that the average last production was 17 years ago for wells currently classified as orphan by states, as seen on Appendix C. As additional data becomes available that defines orphan degradation, and potentially high emission rates, and the emission decline curve, ACR will update the methodology.

1.4 Periodic Reviews

Per the *ACR standard*, ACR shall review the validity and underlying assumptions of the performance standard employed in this methodology every 5 years, at minimum. ACR's review will also ensure that monitoring, reporting, and verification systems adequately reflect any changes in the project activities. This methodology may also be periodically updated to reflect regulatory changes, measurement protocol revisions, or expanded applicability criteria. Before beginning a project, the

Project proponent shall ensure that they are using the latest version of the methodology and any relevant Errata and Clarifications.

2 Project Boundaries

2.1 Geographic Boundary

The physical project boundary demarcates the GHG emission sources included in the project and baseline emissions calculations. An orphan well plugging project may include multiple wells. For this methodology, the boundary will be confined to all wells aggregated to be plugged by a single Project Proponent.[16] Wells in a project must follow the latest *ACR Standard* requirements for aggregation. Tracking and record keeping for wells varies by jurisdiction and the project proponent must check with the applicable authorities.

2.2 GHG Assessment Boundary

Eligible emissions include methane that would otherwise be emitted into the atmosphere by OOG wells within the project.

Physical boundaries are orphan wells identified as emitters. Methane that is emitting from surface equipment that is directly connected to leaking wells may also be considered under this methodology. Emissions may be released from the well annulus and near the wellbore. These emissions are eligible if plugging of the well results in their cessation. This does not include residual hydrocarbons in onsite storage tanks, only active emissions directly connected to the well that are confirmed to cease upon plugging. These wells are not productive and will not result in leakage i.e., no new wells will be drilled to replace orphan wells.

The project assessment boundary, depicted by the light grey box in Figure 2 is where the plugging of OOG wells activities happen in the project.

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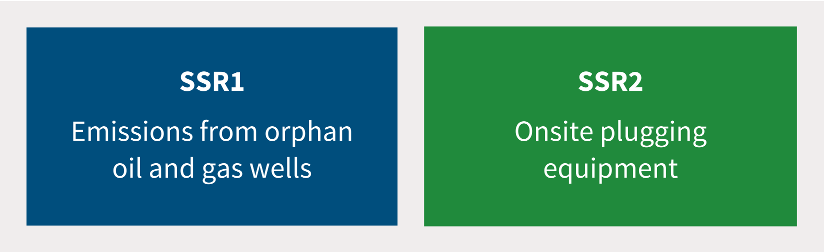
[16] According to the *ACR Standard*, Project proponents wishing to develop a project for registration on ACR shall follow the Standard and must apply an ACR-approved methodology.

Figure 2: Plugging OOG Wells Project Assessment Boundary Diagram



All Sources, Sinks and Reservoirs (SSRs) inside Table 1 are included and must be accounted for under this methodology.

Table 1: Sources, Sinks and Reservoirs

SSR		DESCRIPTION	GHG	BASELINE (B) PROJECT (P)	INCLUDED OR EXCLUDED
1	Orphan O&G wells that emit methane	Emissions from orphan wells	CH_4	B	Included
2	Plugging Operations (Equipment)	Emissions from mobile mechanical equipment for plugging	CO_2 CH_4 N_2O	P	Included

3 Baseline Determination and Additionality

3.1 Baseline Determination

Per the *ACR Standard*, the GHG project baseline is a counterfactual scenario that forecasts the likely stream of emissions or removals to occur if the Project Proponent does not implement the project, i.e., the "business-as-usual" case. In this methodology, the baseline is defined by the OOG well emissions without the project and, therefore, the continual unmitigated release of methane to the atmosphere.

3.2 Additionality Assessment

Emission reductions from OOG well plugging projects must be additional or deemed not to occur in the business-as-usual scenario. The additionality of a project shall be determined based on passing both the Regulatory Surplus Test and the Practice-Based Performance Standard*.*

3.2.1 REGULATORY SURPLUS TEST

The Regulatory Surplus test requires that OOG well plugging projects are surplus to regulations, i.e., the emission reductions achieved by plugging these wells are not required by applicable regulation.

3.2.2 PERFORMANCE STANDARD

The Practice-Based Performance Standard ensures that the plugging of these wells reduces the current emissions—considered business-as-usual—generated by emitting wells. As noted in the analysis presented in Appendix A, the additionality requirement is met due to inadequate regulation at state and provincial levels. For orphan wells that lack a solvent operator, there is the added challenge of not having a responsible party that regulators can hold accountable. Although state and provincial government agencies intend to ensure suitable and timely well plugging for orphan wells, resources for achieving this, including enforcement and financial assurance, are largely inadequate. All wells that meet this methodology’s orphan well description and eligibility section are considered to pass the performance standard.

Please see Appendix A for a complete discussion on the development of the performance standard. In this case, as explained in Appendix A, since regulations are not uniform in the different states and provinces, orphan wells, as described by this methodology that comply with all eligibility requirements are considered additional.

4 Quantification of GHG Emissions Reductions

Quantification of project emission reductions requires calculation of baseline emissions and project emissions. Essential factors to take into consideration before measurements are:

- Methods to measure emissions from leaking wells need to be approved by ACR during GHG Plan preparation
- At least one qualified emissions measurement specialist[17] will be needed to quantify methane prior to plugging and remediating a well. The measurement specialist should not only be proficient at using gas measurement instrumentation, but also able to recognize and avoid/mitigate safety hazards related to the oil and gas well, field conditions, weather variables, etc., to maintain personal safety.
- Ambient emissions measurements taken prior to sampling and after plugging and confirmation sampling post-plugging must be completed with equipment with a detection limit of 1 ppm or less.
- To determine the net GHG reductions for wells, monitoring of methane emissions before and after plugging the well is required. The 100-year global warming potential value used in this chapter is specified in the most recent *ACR Standard*.
- Methane and other air constituents that leak from orphan O&G wells can pose flammability and inhalation threats. Project operator is responsible for undertaking measurements and plugging in a safe and state approved manner.
- It is impossible to predict each field/well/emissions scenario. In the event that the well is high-emitting and sensitive measurement equipment could be damaged due to higher concentrations of methane.

BEFORE PLUGGING

- Ambient methane concentration measurements need to be collected prior sampling
- Methane emissions measurement completed
- Temporal variation of measurements must be followed as explained in Section 4.1.2

AFTER PLUGGING

- Ambient methane concentration measurements need to be collected

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[17] Emissions Measurement Specialist qualifications need to be submitted to ACR for approval before sampling.

- Temporal variation of measurements must be followed as explained in Section 4.1.2

4.1 Methane Measurement Methods

As of the publishing date of this methodology, satellite mounted sensors nor aerial technologies have demonstrated an appropriate sensitivity. The ACR approved method to measure methane fugitive emissions from OOG well heads consist of using bottom-up, local point, ground-based, enclosure techniques done by a trained methane emissions measurement specialist to assure measurement integrity.

Methane emissions measurement methods must be able to demonstrate that all emissions are being captured and measured by their equipment. At the time of publication, the Hi-Flow sampler and the chamber-based methods are approved by ACR when applied correctly in the field. Other techniques and types of equipment may develop, and Project Proponents may reach out to ACR to seek approval for other methods that achieve similar results.

Project proponents shall consult with ACR during GHG Plan preparation, prior to measurement collection to confirm there is sufficient information about the selected methods and that their equipment, sampling protocol and chosen qualified measurement specialist[18] meet the below ACR requirements:

- The direct sampling approach yields a value with at least 95% confidence.
- There can be confirmation of proper operation in accordance with manufacturer's specifications—ensuring data is accurately aggregated over the correct amount of time.
- Date, time, and location of methane measurement will be documented—video, photo, print out, report, etc.—so measured data can be verified
- A qualified measurement specialist' shall have training and field experience with the specific equipment and methods that have been proposed and approved by ACR for use at the targeted well sites. Ideally the measurement specialist will have 20+ hours of training and experience with the specific equipment type and/or methods.

Among potential methods to be approved, ACR is anticipating:

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[18] A measurement specialist refers to the contractor, partner, or agency employee who will be conducting methane measurements at the site for methane. A 'qualified measurement specialist' will have training and field experience with the specific equipment and methods that have been proposed and approved by ACR for use at the targeted well sites. Ideally the measurement specialist will have 20+ hours of training and experience with the specific equipment type and/or methods.

- **BINARY TYPES OF INSTRUMENTATION.** Detect/non detect sniffers, trace gas analyzers (TGA), gas rovers, or Ring Down Laser Absorption Spectrometer (RDLAS), or the less sensitive optical gas imaging (OGI) which help to visualize plume location at the well site. Once leak is detected by one of the binary instruments, a methane quantification method can be used.
- **THE WIDELY ACCEPTED HI-FLOW SAMPLER AND/OR FLUX CHAMBERS.** Static and dynamic, are direct emission measurements techniques. Most importantly, these techniques have a high sensitivity of detecting methane emissions rates of 1 gram per hour or lower, making them appropriate for orphan well plugging projects.

4.1.1 METHANE ANALYZER SPECIFICATIONS

The methane analyzer must be able to quantify methane-specific concentrations. Combustible gas or multi-gas species analyzers that measure a range of gases including methane shall not be used. Moreover, the analyzer shall meet or exceed the following specifications:

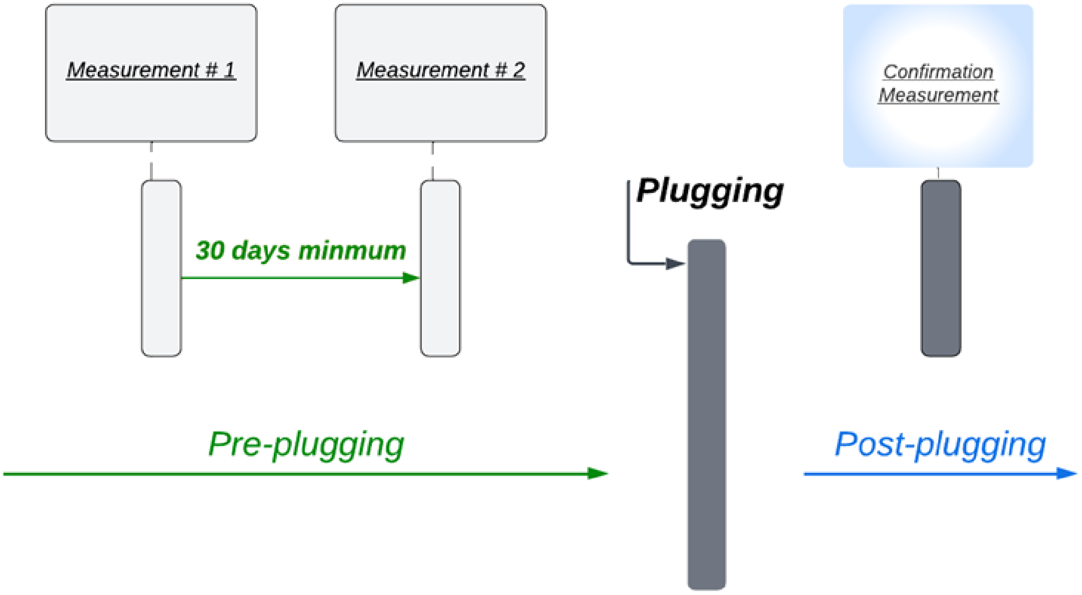
- Working range of environmental conditions (e.g., temperature, humidity)
- Methane-specific detection must demonstrate that concentrations detected are within the factory specified range of detection equipment
- Manufacturer's specifications for calibration and calibration logs.
- Equipment model number, serial number, calibration procedures, calibration records, corrective measures taken if instrument does not meet performance specifications.

4.1.2 TEMPORAL VARIATION

Emissions measurements, taken over a minimum 30-day period, are required to determine pre-plugging conditions for every well in the project boundary.

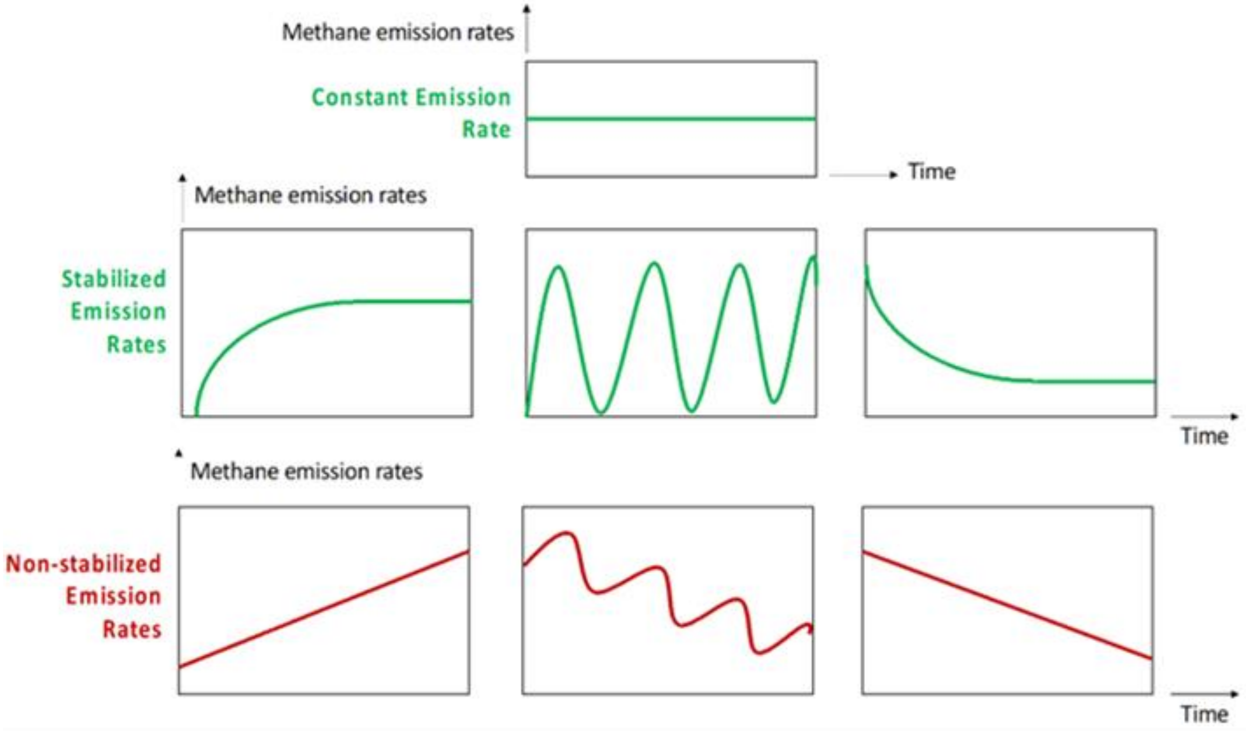
Two flow rate measurement series are required for pre-plugging monitoring at each well, as demonstrated in Figure 3. Sampling begins with the first measurement. The second measurement will be conducted at least 30 days after the first. Regardless of method, measured emission rates must stabilize for a minimum of two hours. See Figure 4 for guidance of what "stabilized" emission rate means in this context.

Figure 3: Temporal Variation



Example methane emission rates over time considered to be stabilized and not stabilized. Emission rates must show no decline over the sampling period which can be demonstrated by graphing the results, fitting a line to the data to show a resulting slope of less than 1%.

Figure 4: Constant, Stabilized, and Non-Stabilized Emission Rates Example



4.1.3 CHAMBER METHOD

The enclosure-based methods require the measurement of well-mixed gas concentrations inside the chamber using a methane analyzer. Sampling can be conducted for longer than the 2-hour minimum to reach stable emission rates (Figure 4). The chamber must remain on top of the wellhead for a minimum duration of two hours.

Additional resources for this method can be found in Appendix D.

4.1.4 OTHER ACR APPROVED NON-CHAMBER METHODS

Methane emission rates can be considered stabilized for non-chamber methods if emission rates over a 2-hour period vary by a factor of 10 or less—meaning that the ratio of measurement n to the mean emission rate of at least two hours of sampling is less than 10 or larger than 0.1.

This can be done by collecting flow rates at a maximum of 10-minute intervals over a 2-hour period. If emissions rates are collected at intervals less than 10 minutes, the measured rates shall be averaged over a 10-minute period and the average rates must stabilize over a 2-hour period. The Mean of two hours of sampling will be considered the emission rate. If the observed change in emission rates during initial testing exceeds a factor of 10, meaning that the ratio of measurement n to measurement n+1 is less than 10 or larger than 0.1, additional measurements may be collected. If the variation in the measured methane emission rates does not exceed a factor of 10, the $Q_{pre\text{-}plugging}$ (t CH_4/year) rate is considered stable. The second sampling period must stabilize within 10% of the first measurement. The Mean of these two measurements will give the emission rate for well.

All results collected as part of the project sampling must be submitted as supplemental data for verification, including records for background levels of methane upwind of the well to be plugged, all methane emission measurements time and day of measurement, graphs that show stabilization, and consequent calculations. If emission rates do not stabilize, the well is not eligible for crediting.

4.2 Baseline Emissions

Baseline verification is required to quantify methane emissions from OOG wells in the business-as-usual scenario, where the well is unplugged, and no mitigation activities have been conducted. Baseline emissions are determined by direct measurement of emissions rates from OOG wells. Measuring these emissions must be done using a calibrated methane-specific gas detector and/or a tested enclosure-based (also referred to as chamber-based or static chamber) method.[19] Measurement methods design shall be approved by ACR during GHG Plan preparation—project proponents who wish to consult with experts prior to sampling may contact ACR.

Baseline emissions will be calculated according to the following steps:

- Prior to sampling, background levels of methane must be recorded upwind of the well to be plugged. This measurement may be taken with the same sampling device as the well measurements and must be collected prior to each sampling event.
- The sampling method shall encompass the emitting well and at least 10 cm of immediately adjacent soils to also capture any methane emissions that may be migrating up the well annulus.
    - The chamber method is used in this methodology to illustrate measurement and calculation requirements—see Appendix D. Other quantification methods may be used provided that they can demonstrate that concentrations detected are within the factory specified range of detection equipment.

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[19] (Livingston & Hutchinson, 1995)

- Existing onsite equipment will also vary for each project. Some wells may have nothing above grade while others may have extensive casings and surface equipment exposed with multiple leak points. A leak point may even be located at a distance from the well itself, depending on the surface equipment. Project proponent may measure each leak separately or in aggregate (if possible) and must confirm during post-plugging confirmation sampling that each leak location has no remaining emissions.

4.2.1 PRE-PLUGGING CALCULATION

Project developers are responsible for using appropriate equipment for measuring flow and existing infrastructure, which may vary widely across wells and fields.

The baseline (pre-plugging) emissions, BE (t CO_2e/year), are computed using:

Equation 1: Pre-Plugging Calculation

$$\mathbf{BE} = \frac{\left(\sum_{n}^{w} \mathbf{Q_{pre-plugging}}\right) \times \mathbf{GWP_{100}(CH_4)}}{\mathbf{1000}}$$

WHERE

$\mathbf{BE}$	MT CO_2e per year
$\mathbf{Q_{pre-plugging}}$	Total pre-plugging annual emission rate of all wells to be plugged in the project boundary $\left[\frac{\mathrm{Kg\ CH_4}}{\mathrm{Year}}\right]$
$\mathbf{w}$	Total number of wells to be plugged in a project
Kg to MT	1000
$\mathbf{GWP_{100}(CH_4)}$	100-year global warming potential for methane (CH_4)

4.3 Emission Reductions from Plugging

For post-plugging verification, it is considered sufficient to verify that there are no methane enhancements above background. If emissions are detected, the well must be remediated until there are no emissions.

Equation 2: Emission Reductions from Plugging in Crediting Period

$$ER = (BE - PP) \times 20$$

WHERE

ER	Emission Reductions from plugging t(CO_2e)
BE	MT CO_2e per year (Equation 1)
PP	MT CO_2e per year (Equation 3)
20	Years in crediting period

4.4 Project Emissions

Depending on project-specific circumstances, certain emissions sources shall be subtracted from total project emission reductions using the equation below, which includes emissions from plugging activities at the well site. A project can constitute plugging one well or several, project emissions encompass all emissions for plugging all wells.

Equation 3: CO_2 Emissions from Fossil Fuel Combustion for Equipment Used at Plugging Project

$$PE = \sum_{n}^{y} \frac{FF_{q,j} \times FF_{ef,j}}{1000}$$

WHERE

PE	CO_2e emissions from fossil fuel used in equipment at plugging project (t CO_2e)
FFq,j	Total quantity of fossil fuel j consumed (gallons)[20] in all plugging jobs required for project completion

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[20] Plugging records that show diesel/gasoline used during plugging event need to be shared with ACR for verification.

FFef,j	Fuel specific emission factor for fuel j 10.19 Kg CO_{2e} per gallon diesel, and 8.78 Kg CO_{2e} per gallon of gasoline[21]
y	Total number of fossil fuels used at plugging project
Kg to MT	1000

4.5 Leakage

Leakage is a term that refers to secondary effects where the GHG emission reductions of a project may be negated by shifts in market activity or shifts in materials, infrastructure, or physical assets associated with the project. The emissions from orphan wells generally result from inadequate plugging or failed equipment. Once a well is plugged and confirmed to no longer be emitting, there is no response within the O&G industry that would result in additional emissions. Based on that sequence of events, plugging of orphan wells should not increase the total number of orphan wells, and consequently result in the increase of fugitive methane going to the atmosphere. Therefore, for this Methodology, “leakage” is considered zero.

4.6 Uncertainty

Equation 4: Uncertainty Calculation

The following equation is mandatory for all projects.

$$\mathrm{UNC} = \sqrt{\mathrm{UNC_{BSL}}^2 + \mathrm{UNC_{WP}}^2}$$

WHERE

UNC	Total Project Uncertainty, in %
UNC_{BSL}	Baseline uncertainty, in %
UNC_{WP}	With-project uncertainty, in %

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[21] https://www.eia.gov/environment/emissions/co2_vol_mass.php

Per the *ACR Standard*, UNC may be set to zero if the project achieves ACR's sampling precision requirement of within 10% of the mean with 90% confidence. Projects must meet the 10% precision requirement in order to be eligible. However, given ongoing research and data collection needs regarding migration of reservoir methane to neighboring wells and long-term integrity of well plugs, ACR conservatively requires all projects to apply a 5% uncertainty deduction from quantified emission reductions as detailed in Section 4.9 and Section 6.2. This deduction will be revisited as more research is completed and information becomes available.

4.7 Permanence and Reversal Risk

Since project proponents must demonstrate that plugging OOG results in avoided methane emissions, post-plugging monitoring must be conducted. Permanence in this methodology requires demonstration of well and plug integrity and prevention of emission pathways from the reservoir.

Plugged wells are required to be tested for atmospheric leakage to determine if the well is properly plugged. The test shall involve a methane detector screening the area within 5 cm of the ground surface for at least 5 minutes. If any portion of the plugged well casing remains above grade after plugging, it shall also be screened for emissions. The detector can be a handheld methane sensor and shall have a lower detection limit of 1 ppm methane. If methane concentrations exceeding 2 ppm above background are detected, methane flow rate shall be quantified as detailed in the above sampling section.

For buried wells, an area of at least above the wellhead 1 m^2 shall be measured. If the measured methane flow rate exceeds 1.0 g/hour, then the plugged well is considered a poorly plugged well and shall be re-plugged prior to credits associated with that well are granted. Prior to credits being issued, Project Proponents must demonstrate that the well has been designated as "plugged", or equivalent, by the appropriate jurisdiction.

4.8 Total Emission Reductions

Equation 5: Total Emission Reductions in Reporting Period

$$\mathrm{ER} = (\mathrm{BE} - \mathrm{PE})$$

WHERE

ER	Total Emissions Reductions (t_{CO_2e}) Equation 3

PE	CO_2e emissions from fossil fuel used in equipment at plugging project ($\mathbf{t_{CO_2e}}$) Equation 4
ER	Emission Reductions from plugging t(CO_2 e)

4.9 Net GHG Reductions

Provide a quantification method to account for the difference in GHG emissions between the baseline and with-project scenarios. The Net GHG Emissions equation utilizes a 5% uncertainty deduction for all projects under this methodology.

Equation 6: Net GHG Reductions

$$\mathbf{NetGHG\ Reductions = ER \times (1 - UNC)}$$

WHERE

NetGHG	Net GHG Emissions ($\mathbf{t_{CO_2e}}$)
TER	Project Emissions ($\mathbf{t_{CO_2e}}$)
UNC	5%

5 Monitoring and Data Collection

Each project shall include a GHG monitoring plan sufficient to meet the requirements of the *ACR Standard*. The plan shall collect all data required to be monitored and in a manner that meets the requirements for accuracy and precision of this Methodology. Project proponents shall use the template for GHG project plans available at acrcarbon.org/program_resources/. Project proponents must coordinate with ACR and verification body to determine if equipment and documentation, in conjunction with appropriate communication, can substitute for field visits during project activities.

5.1 Description of the Monitoring Plan

The project proponent must prepare a monitoring plan describing (for each separately) the following: a) project implementation; b) technical description of the monitoring task; c) data to be monitored and collected; d) overview of data collection procedures; e) frequency of the monitoring; f) quality control and quality assurance procedures; g) data archiving; and h) organization and responsibilities of the parties involved in all the above.

The monitoring of project implementation is required to document all project activities that could cause an increase in GHG emissions compared to the baseline scenario.

These are expanded upon in the sections below.

5.2 Data Collection and Parameters to be Monitored

The project proponent is responsible for monitoring the performance of the carbon project and conducting each component of the plugging process in a manner consistent with the methodology. The following data must be collected and reported to ACR:

- Design, specification, and approval of the chamber and chamber methodology or other approved measurement equipment
- Photographs of the deployed measurement system

- All data inputs for the calculation of the project baseline emissions and project emissions reductions including:
    - Measurements of methane concentrations over reported sampling interval– including time-stamped, georeferenced videos, pictures or reports.
    - Dated logs with diesel/gasoline used in plug jobs for each well in each project
- Emission reductions calculations
- Method for measurement information including
    - Model number, serial number, manufacturer calibration procedures
    - Calibration results documentation
    - Methane analyzer information
    - Maintenance records for equipment—when necessary
- Documented date, time and location for ambient methane concentration readings
- Environmental conditions: precipitation (onsite reporting required), temperature, humidity, wind speed (onsite measurement required)

In addition, the following information about the well shall be provided:

- Well identifier: API, UWI, or CWIS
- Surface location of the well
- Photo(s) of the well at ground surface
- Documentation that the well is in regulatory compliance (owned wells only) from appropriate jurisdiction
- Documentation that the sampler and plugger have rights to access and plug well
- Methane measurement specialist credentials
- Copy of license of pipe pulling and well plugging company approved by the appropriate state agency
    - Company name
    - Company address
    - Expert experience
    - Counties were company can operate within the state
- Copy of timely Intend to Plug notification to all applicable agencies prior cementing operations so that Field Inspectors may have the opportunity to witness plugging procedures Copy of plugging record given by the appropriate regulatory agency

5.2.1 PARAMETERS

UNIT	PARA-METER	POTENTIAL EVIDENCE	SOURCE	BASELINE OR PROJECT	FREQUENCY OF MONITORING
$(\text{t CO}_2\text{e/year})$	BE	Enclosure-based measurements	Enclosure-based measurements	B	Two 2-hour monitoring events and one confirmation sample/ crediting period
$(\text{t CO}_2\text{e/year})$	PP	Quantification measurements	Quantification measurements	P	Two 2-hour monitoring events and one confirmation sample/ crediting period
$\left[\frac{\text{MASS}}{\text{TIME}}\right]$	Q_s	Non-steady-state enclosure-based measurements	Non-equilibrium-based chamber measurement	B and P	Two 2-hour /non-equilibrium-based chamber measurement
$[\text{VOLUME}]$	V_{eff}	Non-steady-state enclosure-based measurements	Non-equilibrium-based chamber measurement	B and P	Two 2-hour /non-equilibrium-based chamber measurement
$\left[\frac{\text{MASS}}{\text{VOLUME} \times \text{TIME}}\right]$		Non-steady-state enclosure-based measurements	Non-equilibrium-based chamber measurement	B and P	Two 2-hour /non-equilibrium-based chamber measurement
$\left[\frac{\text{MASS}}{\text{TIME}}\right]$	Q_d	Steady-state enclosure-based measurements	Equilibrium-based chamber measurement	B and P	Two 2-hour /equilibrium-based chamber measurement

$\left[\frac{\mathrm{VOLUME}}{\mathrm{TIME}}\right]$	q	Steady-state enclosure-based measurements	Equilibrium-based chamber measurement	B and P	Two 2-hour /equilibrium-based chamber measurement
$\left[\frac{\mathrm{MASS}}{\mathrm{VOLUME}}\right]$	C_{eq}	Steady-state enclosure-based measurements	Equilibrium-based chamber measurement	B and P	Two 2-hour /equilibrium-based chamber measurement
$\left[\frac{\mathrm{MASS}}{\mathrm{VOLUME}}\right]$	C_b	Steady-state enclosure-based measurements	Equilibrium-based chamber measurement	B and P	Two 2-hour /equilibrium-based chamber measurement
($t\ CH_4$/year)	$Q_{pre\text{-}plugging}$	Enclosure-based measurements	Enclosure-based measurements	B	1/well
Kg CO_2/Kg CH_4	GWP_{100} (CH_4)		Most current version of *ACR Standard*	B and P	1/project
	w	Documentation for site verification can include time-stamped, georeferenced data, videos, or pictures		B and P	1/project
($t\ CH_4$/year)		Flow rate measurements	Flow rate measurements	B and P	1/well
($t\ CH_4$/year)		Flow rate measurements	Flow rate measurements	B and P	1/well
	N	Flow rate measurements	Flow rate measurements	B and P	1/well

°C	Temperature			B and P	
t CO_2e	EQ_{CO2e}	Fuel consumed	Fuel measurements	P	1/project
Vol	FFy	Fuel consumed	Fuel measurements	P	1/project
t CO_2e/vol	EFef	Emissions Factor	EPA Emission Factor Hub	P	1/project

6 Quality Assurance and Control

QA/QC procedures shall be implemented during all phases of the project to assure data quality and completeness. This methodology incorporates the calibration requirements contained in the EPA Mandatory Greenhouse Gas Reporting requirements for facilities that emit GHG. Calibration procedures specified by the equipment (gas analyzers) manufacturers must be used, and calibration records for all monitoring equipment must be kept for verification, including the method or manufacturer's specification used for calibration.

6.1 Credit Ownership

Since O&G well plugging projects involve complex interest management frameworks, the ownership to the title of CO_2-equivalent credits associated with the project's emission reductions must be clearly defined. This can be done through contracts amongst the parties in which one of the companies has clear ownership of the credits. Alternatively, through contract, title to the credits can be transferred to an outside third party, who will be the responsible party to ACR.

Owners of CO_2 credits shall provide assurances that they have the legal right to fulfill project commitments. The documentation associated with ownership and legal rights shall be maintained by the Project Proponent and provided during validation and verification. The documents shall be retained for a minimum period of three years following the end of the crediting period.

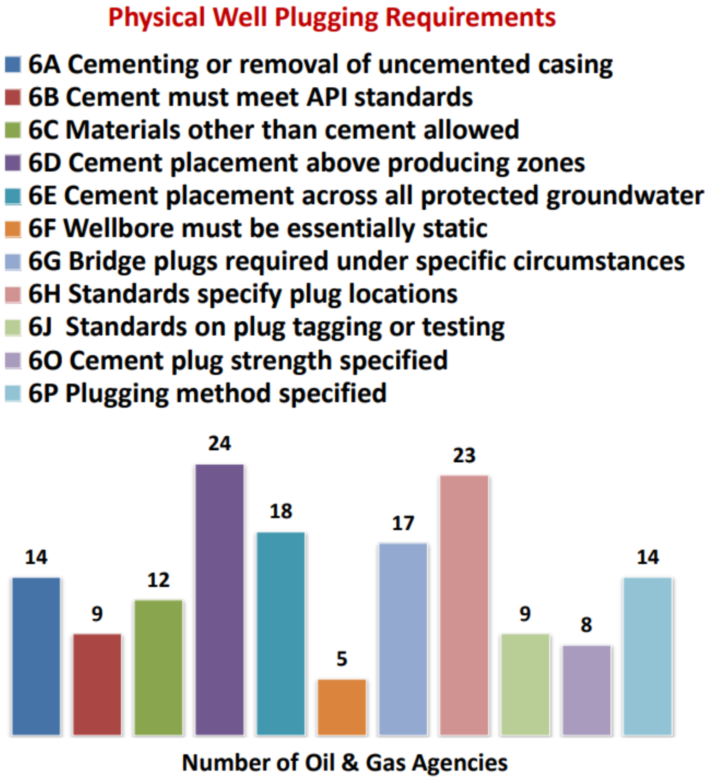
6.2 Conservative Approach and Uncertainty

The emission reduction calculations in this methodology are designed to minimize the possibility of overestimation and over-crediting of GHG emission reductions due to uncertainties. A potential source of uncertainty that has been identified is whether the plugging of a single well within an interconnected pool may not, over time, result in additional methane emissions in neighboring wells. There is no research on the topic and through many ACR discussions with experienced geoscientists and reservoir engineers, it has been determined that this risk is extremely and acceptably low. However, to conservatively mitigate this uncertainty, this methodology applies a 5% deduction to all projects, as specified in Section 4. This deduction will be revisited as more research is done and information becomes available.

6.3 Plugging Standards

As detailed in Appendix A, regulations for Plugging and Abandoning O&G wells differ in timelines, requirements, and requisites. Figure 5 provides a comparison of the plugging requirements in different states with focus on key elements of plugging perforations in the O&G strata, cementing across the freshwater zone, and surface casing plugging. To assure plugging integrity, this methodology incorporates the American Petroleum Institute (API) Recommended Practice (RP) 65-3 – Wellbore Plugging and Abandonment Standard, as well as local, state, and provincial responsible agency's plugging requirements that go beyond the API standard. If there is conflict between different jurisdictional requirements ACR will review and approve plugging methods.

Figure 5: Elements of State Well-Plugging Regulations



SOURCE: Groundwater Protection Council, State Oil and Natural Gas Regulations Designed to Protect Water Resources, Third Edition, November 2017

Definitions

If not otherwise defined here, the current definitions in the latest version of the American Carbon Registry Standard apply.

Abandoned wells	Wells with no recent production, and without a responsible operator.
Cement	Any material or combination of materials fluidized and pumped into the well to provide a seal.
Field	Group of pools, which can be vertically stacked and are within a horizontal areal boundary.
Inactive well	An inactive well is any oil or gas well that is no longer producing but has not yet been permanently sealed off through the process of Plug and Abandon as defined below.
Legacy well	Wells that were drilled before well-permitting and well- plugging regulations were established.
Marginal well	A producing well that requires a higher price per Mcf or per barrel of oil to be worth producing, due to low production rates and/ or high production costs from its location (e.g., far from good roads for oil pickup and no pipeline) and/or its high co-production of substances that must be separated out and disposed of (e.g., saline water, non-burnable gasses mixed with the natural gas).
Oil and Gas Commission/ Regulator	Each state and province has a division, board, or commission responsible for overseeing the Oil and Gas (O&G) industry. These entities issue permits, collect information used to assess fees and taxes, and hire inspectors to ensure compliance with environmental and safety regulations.
Orphan well	A well without a solvent operator.
Parts per Million	A unit of concentration frequently abbreviated to ppm. For gases, ppm refers to volume (or mole) units.
Plug	A verifiable barrier located within the wellbore that may be mechanical or cement.

Plug and Abandon (P&A)	To permanently seal and retire a wellbore, usually after either it is determined there is insufficient hydrocarbon potential to complete the well, or the well has reached its economic limit. Different regulatory bodies have their own requirements for plugging operations. Most require that cement plugs be placed and tested across any open hydrocarbon-bearing formations, across all casing shoes, across freshwater aquifers, and perhaps several other areas near the surface, including the top 20 to 50 ft (6 to 15 m) of the wellbore.
Plugging	A well is plugged by setting mechanical or cement plugs in the wellbore at specific intervals to prevent fluid flow. The plugging process usually requires a workover rig and cement pumped into the wellbore. This methodology follows the American Petroleum Institute Wellbore Plugging and Abandonment Recommended Practice 65-3 of June 2021.
Pool	A subsurface hydrocarbon (natural gas and/or oil) accumulation.
Poorly plugged	A plugged well in which the flow rate exceeds 1.0 g/hour.
Severance tax	Severance tax is a state tax imposed on the extraction of non-renewable natural resources that are intended for consumption in other states.
Site remediation	Remediation of a well site, including clean-up of spills and remediation of conditions endangering public health or safety, causing contamination of water or the surface, or creating a fire hazard.
Spud	To commence drilling operations.
Surety Bond	In most states and provinces, oil and gas well operators that are involved in exploring, drilling, and plugging of wells are required to secure a surety bond to guarantee the compliance of statutes and regulations set forth by each state for the issuance of a license or permit.
Temporary Abandonment Status	State of a well currently not producing oil and/or gas but that may return to production. Can also be a specific regulatory term in certain states or provinces as shown in Appendix E.
Qualified methane emissions	A measurement specialist refers to the contractor, partner, or agency employee who will be conducting methane measurements at the site for methane. A 'qualified measurement specialist' will have training and field experience with the specific

measurement specialist	equipment and methods that have been proposed and approved by ACR for use at the targeted well sites. Ideally the measurement specialist will have 20+ hours of training and experience with the specific equipment type and/or methods.

Appendix A: Development of Performance Standard

The performance standard approach developed for this methodology was based on evaluating the adoption rates or penetration levels of plugging OOG wells. Currently, the regulatory framework in the U.S. provides voluntary incentives to encourage the plugging and remediation of orphan wells. Section 40601 of Title VI (Methane Reduction Infrastructure) of the 2021 Bipartisan Infrastructure Law (BIL) requires the establishment of a program for 24 eligible states to apply for initial, formula, and performance grants to plug, remediate, and reclaim over 10,000 high-priority orphan wells located on state-owned or privately owned lands. Before plugging and remediating orphan wells, participating states will need to identify and characterize their inventory of orphan wells and prioritize wells based on the following criteria: 1) public health and safety, 2) potential environmental harm, and 3) other subsurface impacts or land use priorities. The prioritization does not require that states consider fugitive methane emissions as the top priority for plugging. Therefore, orphan wells, which have been prioritized due to being high emitters of methane and are plugged represent an additional benefit to the atmosphere. Using this methodology, carbon credits could be generated by projects that yield surplus GHG reductions that exceed any GHG reductions otherwise required by law or regulation or any GHG reduction that would otherwise occur in a conservative business-as-usual scenario.

An orphan well is an O&G well that is inactive, unplugged, and has no solvent owner. At the end of an O&G well's productive life, they must be properly plugged to prevent air, water pollution and high-priority methane emissions, as well as to keep surrounding communities free of health and safety risks.[22] However, in the United States alone, there are over 117,672 documented unplugged orphan wells within 27 states,[23] and likely over a million of undocumented ones, with additional wells discovered every year. According to the United States Department of Energy and Geological Survey, in 2020, there were between 310,000 and 800,000 of orphan undocumented wells reported by 15 different states. The 2021 IOGCCC report states that the amount of undocumented wells is underestimated, and studies report that in Pennsylvania alone—one of the states that first started oil exploration- there are between 470,000 and 750,000 such wells.[24]

In Canada, the major O&G producing provinces are Alberta, British Columbia, Northwest Territories, Ontario, Saskatchewan, and Yukon—have differing systems for managing wells for which no producer accepts the environmental liability. Most of Canadian onshore O&G wells—approximately 600,000—

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[22] EDF, n.d.

[23] Merrill et al., 2023

[24] Kang et al., 2016

are mainly located in Alberta and Saskatchewan provinces. In 2020, these two provinces reported an approximate total of 10,000 documented orphan wells and the estimate excludes the roughly 7,400 wells that at the time did not have a solvent owner and require clean-up in the form of either plugging and/or reclamation, but had not yet officially transition to orphan status.[25]

The total number for orphan wells -documented and undocumented- is unknown. Well status in the U.S. includes active, inactive, completed, shut-in, drilled, abandoned, temporary abandoned (TA), drilled but uncompleted (DUC), plugged and abandoned (P&A), orphan, and other codes. Well status in one location can mean something different in another. In Canada, the same problem of regionally specific terminology persists for well categorization. For example, the Alberta and Saskatchewan regulators deem the type of well described above as orphan—a well is an O&G well that is inactive, unplugged, and has no solvent owner, where in British Columbia, these wells fall under the “dormant” categorization. In Alberta, wells, facilities, or pipelines are considered orphan when the licensee has become insolvent, and the Orphan Well Association (OWA)[26] has undertaken the responsibility of abandonment and reclamation of wells for which the licensee is insolvent. In British Columbia, orphan wells are those where the producer has declared bankruptcy or cannot be located and designated as such by the BC O&G Commission.[27] In Saskatchewan, orphan can describe a well, facility or associated flowline, or their respective sites, if the entity responsible for the site does not exist, cannot be located, or does not have the financial means to contribute to the costs of remediation. For this methodology, ACR will refer to the term “orphan wells” as those wells with no responsible operator and that are not plugged or properly plugged.

Based on the above discussion, at the time or publication, OOG wells described in Chapter 1, which pass the eligibility requirements of Chapter 2, are considered to pass the performance standard test for additionality. Orphan wells are a state or provincial responsibility, and as discussed above, are highly unlikely to be remediated in the near term. To demonstrate eligibility in this methodology, the title/ownership of an OOG well must rest with or be transferred to an entity that will plug and monitor the well or the project proponent must demonstrate to ACR’s satisfaction that they are eligible to plug a well, monitor for emissions, and receive credits. It must be demonstrated that the project developer has uncontested rights to the emissions and plugging of the well.

A.1 Financial Assurance for O&G Wells

At the time a well is drilled, an operator is often required to post a bond in the U.S. or a refundable security deposit in Canada for an individual well, a blanket bond for multiple wells located within a

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[25] (Office of the Parliamentary Budget Officer, 2021)

[26] (Alberta Energy Regulator, 2021)

[27] (Menon, 2022)

state or a province which shall be returned to the operator only after the well is plugged. In some jurisdictions, other methods of financial assurance are considered besides bonding. Bonds and refundable security deposits are designed to help prevent or reduce taxpayer liability in the states or provinces because the bond money may be used to reclaim wells when operators or other responsible parties do not reclaim the wells due to insolvency or cessation of business activities. In these situations, the wells are considered to be orphan and become the state or province's responsibility for remediation. Ideally, these bonds would be high enough and would require O&G producers to account for the potential external environmental costs of their operations. However, in practice, bond funds are very often insufficient to cover proper plugging and reclamation expenses.

Proper plugging and remediation of all the U.S. and Canada's OOG wells is an extremely large financial burden. A report from the IOGCC analyzed the ratio between the minimum bond requirement for an individual well based on state requirements and the actual average plugging cost per well. Per ACR analysis of the IOGCC data, bonds were insufficient to cover remediation costs in the United States and Canada. Further, this analysis found that in states such as Utah, Pennsylvania, Illinois, and Montana, bond requirements would cover less than 5% of the average cost of plugging a well- not including any additional site remediation or removal of surface facilities. In South Dakota, one operator orphaned numerous natural gas wells that will cost almost $1 million to plug while the state only required $10,000 in bond money from the operator. These analyses and examples demonstrate that the financial assurance mechanisms designed to ensure proper well remediation are woefully inadequate.

A.2 Regulatory Considerations for O&G Well Remediation

State and provincial regulations to require financial assurance, often through bonding, for plugging wells were first introduced in 1941 in North Dakota and as late as 1992 in Mississippi. Before a well is plugged and abandoned, wells are often idled for a certain amount of time, the maximum length of time that a well can be idled varies from state to state as shown in Appendix B. There are different regulatory paths an operator can take in different jurisdictions including classifying wells as Temporarily Abandoned (TA) and long-term idle prior to being permanently plugged.[28, 29] In many jurisdictions it is possible to file for extension or temporarily return the well to production to restart the process. The initial term of the TA stage varies from as little as 12 months in certain states to up to

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[28] Meaning that operator has fulfilled all requirements for Temporary Abandonment status

[29] Note that ACR refers to this stage as "temporarily abandoned" but, depending on state regulations, this stage could be referred to, inter alia, as "idle", "long term idle", "inactive", or "dormant".

60 months.[30, 31] Ultimately, the TA extension process allows wells that, in many cases, will never be produced to remain inactive and for the operators of these wells to avoid proper remediation. This allows methane to continue to emit and the risk of groundwater contamination to persist long past the point that these wells should have been plugged/remediated.

Historically, the O&G industry has not been held accountable by regulators for the proper remediation of orphan O&G wells and this is demonstrated by many studies[32, 33] and research conducted by numerous organizations.[34] The overall lack of enforcement in the regulatory environment to properly govern O&G well remediation has been studied extensively.[35, 36] These studies typically conclude that bonding reform is needed to increase funding to guarantee proper remediation, and that sectoral regulatory reform is necessary to ensure that proper remediation and abandonment procedures and enforcement are in place to limit potential negative environmental and public health impacts associated with orphan and abandoned O&G wells. According to IOGCC,[37] the State O&G Regulatory Exchange and the Groundwater Protection Council[38] regulatory provisions exist to provide exemptions and/or permit renewals at the state/provincial commission level that allow well operators to extend the time for temporary abandonment and even perpetuate it. TA status extensions leave a growing number of wells unplugged every year. According to the Natural Resources Defense Council and FracTracker Alliance,[39] regulations are not enforced by state and provincial O&G commissions, and other enforcement organizations (i.e. BLM), due to several factors including under-staffing, lack of transparency, inconsistent data recording by different organizations with different objectives within states, lack of enforcement infrastructure, and a lack of clarity around violations (for instance, in Colorado, even though some inspections are “unsatisfactory,” violations may not be recorded, in Wyoming, the O&G Conservation Commission has not tracked inspections or noncompliance issues for years, and, in the State of Utah, no fines have been levied for lack of appropriate remediation in two decades at least[40]). Therefore, it can be concluded that plugging wells at the end of their productive life, although required by law, is not uniformly enforced.

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[30] (Muehlenbachs, 2015)

[31] (IOGCC, 2021)

[32] (Ho et al, 2018a)

[33] (J. Ho et al., 2016)

[34] (Bloom, n.d.)

[35] (U.S. Government Accountability, 2019)

[36] (J.Ho et al, 2016)

[37] (IOGCC, 2021)

[38] (Ground Water Protection Council, 2017)

[39] These include fees: annual, idle well, permits, civil penalties and settlements, fines: appropriations, and State O&G Agency operating budgets, forfeited bonds, and salvage

[40] (IOGCC, 2021)

Projects that meet a practice-based performance standard can be considered additional. Those wells that fall within eligibility categories identified in chapter two are considered to meet performance standards.

A.3 United States Well Plugging Funds

All available analyses on state/provincial wells plugging funds have concluded that increased funds are necessary to properly remediate OOG wells. The states, federal agencies, and Native American tribes responsible for their plugging and remediation often do not have the funding needed to safely and effectively clean orphan wells.[41] So, for generations, huge numbers of these wells have been left to pollute communities. Accordingly, the United States Government Accountability Office (GAO) estimates that remediating an individual orphan or abandoned well runs from $20,000 to $145,000, and in some cases as high as $1,000,000,[42] putting the price tag for remediating America's orphan and abandoned wells somewhere between $60 billion to $435 billion.

Some states have established plugging, emergency remediation, and site restoration funds to ensure that wells for which insufficient financial assurance is available are properly plugged. These plugging funds are financed differently by state but are typically funded via fees, fines, public revenue, and taxes.[43] Nevertheless, although these funds exist in some states, the conditions under which the funds can be used often make the goal of plugging wells difficult to achieve. For example, the state of Virginia has a fund to reclaim abandoned wells, but The Virginia Gas and Oil Act defines "Orphan Well" as "…any well abandoned prior to July 1, 1950, or for which no records exist concerning its drilling, plugging or abandonment".[44] Therefore, any well abandoned after July 1, 1950, or for which records do not exist is not a candidate for reclamation using state reclamation funds.[45] The available funding to remediate wells is simply insufficient to address the issue.

A.4 Canadian Well Decommissioning Funding

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[41] (Peltz, n.d.)

[42] (Raimi et al., 2021)

[43] These include fees: annual, idle well, permits, civil penalties and settlements, fines: appropriations, and State O&G Agency operating budgets, forfeited bonds, and salvage

[44] (Buchele, 2019)

[45] (IOGCC, 2021)

In April 2020, Canada announced a $1.7B CAD fund to clean up orphan and inactive wells. The $1.7B CAD is structured as a jobs program, helping energy sector workers transition their jobs. The funds for the program fail to meet the minimum needed to remediate orphan wells across the provinces of Alberta, British Columbia, Ontario, and Saskatchewan where the majority of the wells are located. Alberta alone, the current inventory of orphan wells has been estimated at $100B CAD.[46] Finance Canada reports that there are approximately 5,560 orphan wells with an additional 139,000 inactive wells across Alberta, British Columbia, and Saskatchewan.[47] The average cost to plug a well in the Canadian provinces has been calculated at $61,477 (CAD).[48]

A.5 Timing Requirements for Abandoned Wells

Efforts have been made to normalize state and provincial regulations, specifically regarding timing requirements to plug a well. As explained in depth in this Practice-Based Performance Standard and shown in the graphic in Appendix C in the average well case, an operator has approximately five years of inactivity before the average regulatory body begins to require P&A operations or other preventative measures (i.e., Mechanical Integrity Test). Loopholes to this requirement have emerged over time which has contributed to an increase in the abandoned well population as described in this methodology. Per ACR findings on Enverus Drilling Info database searches, as well as in IOGCC reports, historically abandoned non-productive time before plugging averages between 5 and 10 years, therefore requiring P&A operations before that timeframe would not be considered common practice, which creates additionality within projects.

To comply with this methodology, 20-year methane emissions reduction credit, wells would need to be plugged approximately that much sooner than they would if this methodology where not in place—approximately 1-5 years after becoming idle. For orphan wells, most jurisdictions lack the means to address the backlog of wells and it is possible that these wells would remain unplugged indefinitely or for long time periods, potentially allowing decades of emissions. It is also true that given the volume of AOOG in existence today, and those same historical plugging trends, it is not likely that the P&A service providers within the Oil Field Service Sector could keep up with the demand for plugging services this methodology may generate, therefore ACR has erred on the side of increased timeframe to allow the market to catch-up (hopefully creating jobs along the way). Generally, oil wells[49] to have

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[46] (De Souza et al., 2018)

[47] (Harris, 2020)

[48] (IOGCC, 2021)

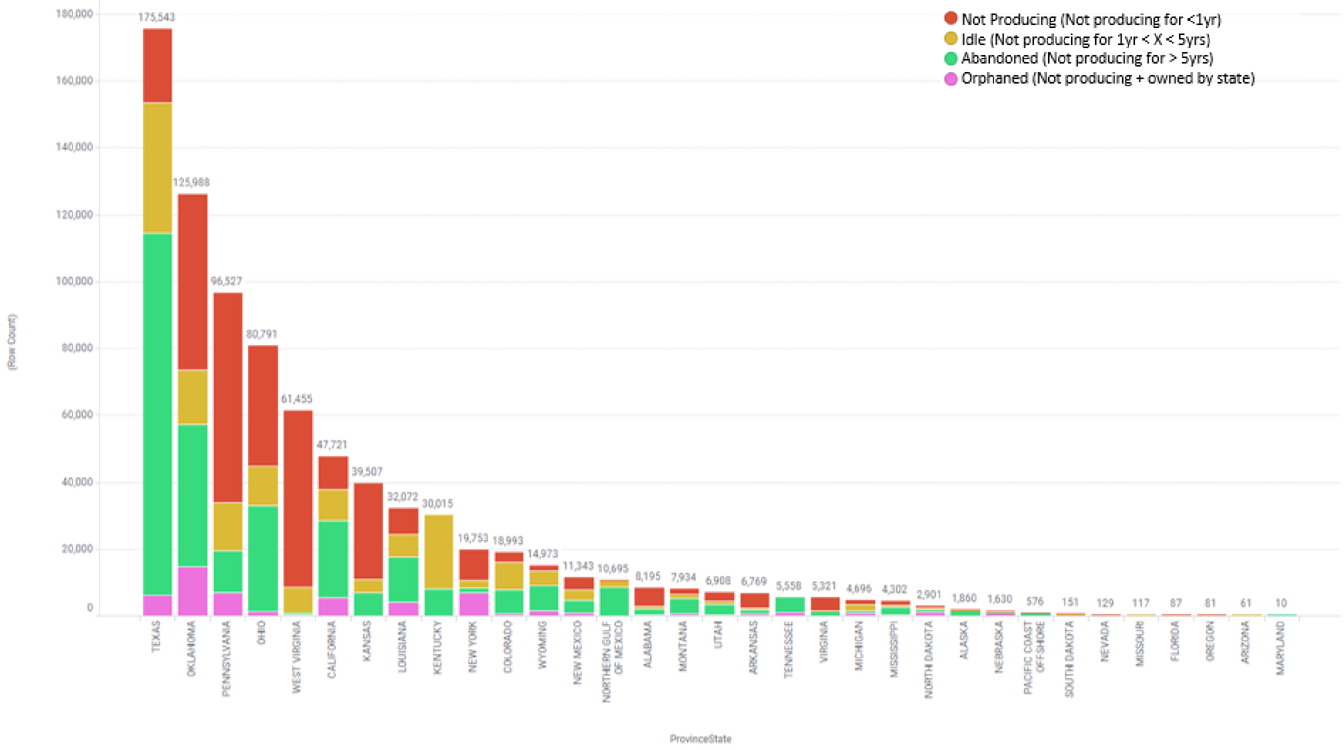
[49] (Kang et al., 2019)

less GHG emissions also allows for the increased timeframe whereas gas wells should be considered priority when plugging.

Based on the above discussion, at this time, OOG wells detailed in Chapter 1 are considered to pass the performance standard test for additionality. Orphan wells are a state responsibility, and, as discussed above, are highly unlikely to be remediated in the near term. To qualify for eligibility in this methodology, the title/ownership of an OOG well must be transferred to an entity that will plug and monitor the well or the project proponent must demonstrate to ACR's satisfaction that they are eligible to plug a well, monitor for emissions, and receive credits.

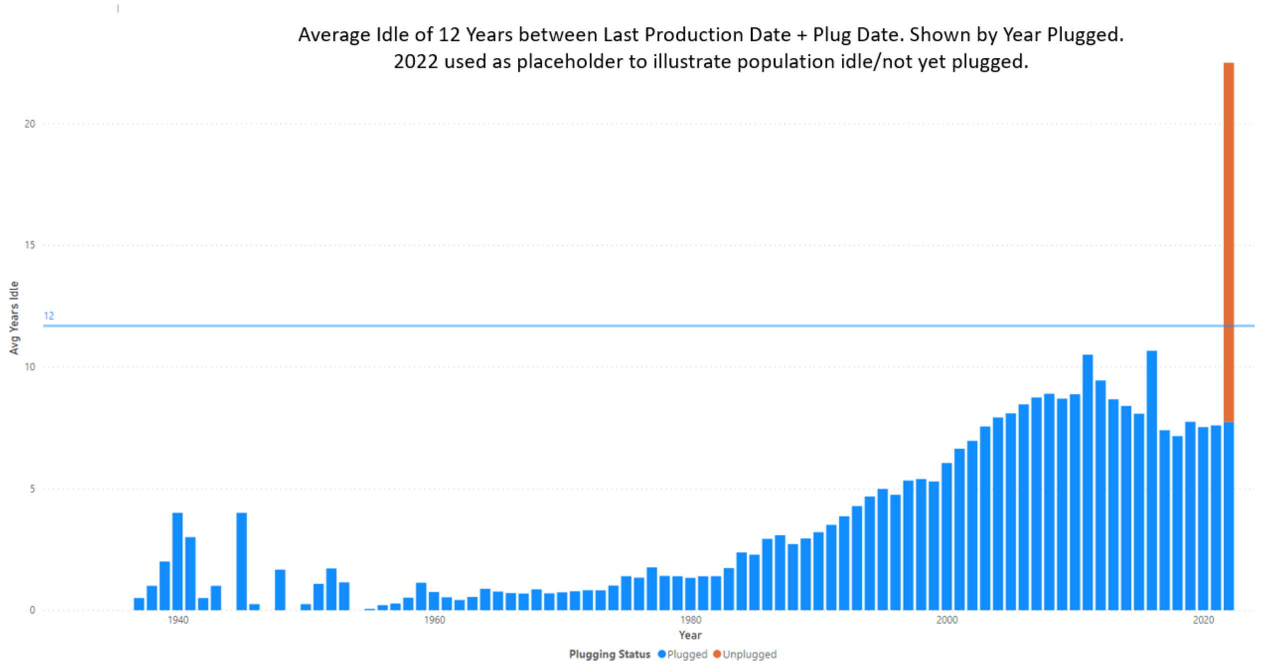
Appendix B: Non-Producing Wells by State

Non-Producing Unplugged Well Counts by State



SOURCE: Well data compiled from Enverus in August 2022.

Appendix C: Average Time Between Last Production and Plugging of a Well



SOURCE: Well data compiled from Enverus in August 2022. Chart shows wells plugged since 1937 (year on x-axis) versus how long that well was not on production (time idle on y-axis). This chart demonstrates that the time spent idle has increased for wells being plugged. There is also a significant backlog of unplugged wells, as demonstrated in orange in 2022.

Appendix D: Chamber Method, Quantification Guidelines and References

D.1 Chamber Specifications

There are two main enclosure-based methods: non-steady-state non-through flow (NSS-NTF), and steady-state through-flow (SS_TF or open dynamic chamber). The steady-state chamber involves continuous flow of a known gas (e.g., air) at a fixed rate using a pump or other source of regulated air flow, such as an air tank. Non-steady-state chamber method, where the emissions point—well head in this case—is temporarily covered with a chamber, and the gas flux across the surface is calculated from the chamber headspace concentration change over time.[50] Data collected from non-steady-state chamber measurements include a time series of methane concentrations in the chamber and the chamber volume. Data collected from steady-state chamber measurements includes equilibrium methane concentrations, air flow through the chamber, methane concentrations in the gas pumped through the chamber, and chamber volume.

For inclusion in the project plan, a chamber design includes:

- Materials used to build the chamber, including name and manufacturer
- Fans: the type, number, orientation and location within the chamber
- Vent tube material, diameter, and length
- Gas analyzer: flow rate, sampling frequency, precision, upper and lower detection limits, schedule for calibration, calibration method
- Dimensions (height, diameter or widths) and corresponding volume
- Shape: cylinder, rectangular prism, or other
- Safety precautions when using a non-steady state chamber, since methane concentrations could build up to explosive levels inside the chamber, which could turn into a potentially hazardous situation.

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[50] (Maier et al., 2022)

The footprint of the enclosure must be sufficiently large to cover the full footprint of the well and a minimum 10 cm buffer around the well. The materials used to build the chambers shall be tested to ensure that it does not affect methane concentrations in the chamber (e.g., via degassing or sorption).

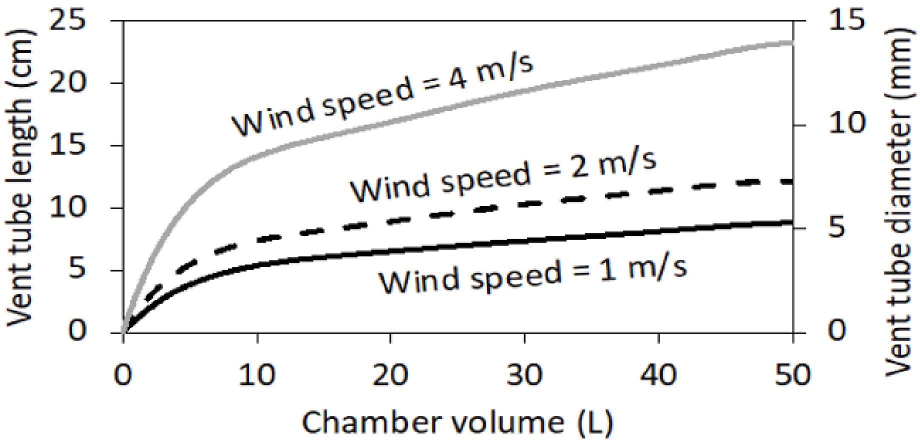
The enclosure shall have a separate detachable base that is inserted 2-6 cm below ground surface and that is open to the atmosphere. This base shall be installed before the rest of the chamber.

The upper portion of the enclosure shall have a vent tube with a diameter and length based on wind speeds and the chamber volume (Figure 6).

Prior to each sampling event, the chamber must be tested to ensure that it is airtight and functioning properly. The project proponent shall monitor and record this testing and include with their baseline sampling submission. This is separate from the calibration of the methane quantification meter, which must be done per manufacturer's specifications. Calibration logs must be included in the baseline sampling submission.

Vent tube length and diameter for selected wind speeds and chamber volumes.

Figure 6: Vent Tube Length and Diameter for Selected Wind Speeds and Chamber Volumes



SOURCE: Livingston and Hutchinson (1995)

To ensure that the gases inside the chamber are well-mixed and that the chamber is sealed appropriately, fans or other devices that provide sufficient circulation without affecting pressures inside the chamber shall be installed. The location and orientation of the fans shall be used to ensure that the effective well-mixed volume in the chamber is equivalent to the volume inside the chamber. The location, number, and types of fans are considered a part of the chamber design.

D.2 Accounting Baseline Emissions from Non-Steady-State Chambers

For non-steady-state chambers, the methane emission rate Qs is calculated using:

METHANE EMISSION RATE – NON-STEADY-STATE CHAMBERS

Equation 7: Accounting Baseline Emissions from Non-Steady-State Chambers

$$Q_s = V_{eff} \times \frac{dC}{dt}$$

WHERE

Q_s	Methane flow rate from the well determined using non-equilibrium-based chamber $\left[\frac{\text{MASS}}{\text{TIME}}\right]$
V_{eff}	Effective chamber volume [Volume]
$\frac{dC}{dt}$	Time rate of change in methane concentrations inside the chamber $\left[\frac{\text{MASS}}{\text{VOLUME}\times\text{TIME}}\right]$

The effective chamber volume (V_{eff}) represents the volume that is sampled for methane concentration accumulations in the chamber. The required time period for this measurement is 10 minutes. If sampling equipment records readings at a higher resolution, rates shall be averaged over 10-minute period.

D.3 Accounting Baseline Emissions from Steady State Chambers

The calculated example methane emission rate, Qd :

METHANE EMISSION RATE – STEADY-STATE CHAMBERS

Equation 8: Methane Emission Rate – Steady State Chambers

$$\mathbf{Q_d = q\,(C_{eq} - C_b)}$$

WHERE

Q_d	The methane emission rate from the well determined using equilibrium-based chamber $\left[\frac{\text{MASS}}{\text{TIME}}\right]$
q	Flow of air flushed through the chamber $\left[\frac{\text{VOLUME}}{\text{TIME}}\right]$
C_{eq}	Methane concentration in the chamber at equilibrium $\left[\frac{\text{MASS}}{\text{VOLUME}}\right]$
C_b	Methane concentration of the air flushed through the chamber $\left[\frac{\text{MASS}}{\text{VOLUME}}\right]$

D.4 Chamber Method References

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Appendix E: Time Allowed for Wells to be Non-Producing Before P&A

Below is a table of various time limits for operators with non-producing wells taken from the 2021 IOGCC report.[51] In some cases, fees may be assessed on wells based on the amount of time wells have been idle or temporarily abandoned.

AMOUNT OF TIME ALLOWED FOR EACH STEP IN THE P&A PROCESS

U.S. STATE/ CA PROVINCE	MAXIMUM WELL IDLE TIME (MONTHS)	EXTRA MONTHS ALLOWED	TEMPORARY ABANDONMENT ALLOWED (MONTHS)	POSSIBILITY OF RENEWAL
UNITED STATES				
Alabama	6	1	12	
Alaska	No Approval Required	No Approval Required	60	Yes
Arizona	2	60	60	
Arkansas	24	36	36	
California	No Approval Required	No Approval Required		
Colorado	No Approval Required	No Approval Required	36	
Idaho	24	36	36	Yes
Illinois	24	24	24	

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[51] (Interstate Oil & Gas Compact Commission, 2021)

AMOUNT OF TIME ALLOWED FOR EACH STEP IN THE P&A PROCESS				
Indiana	2	60	60	Yes
Kansas	3	12	12	Yes
Kentucky	12	24	24	Yes
Louisiana	60	Indefinite	60	
Michigan	12	12-60	60	
Mississippi	12	Indefinite	Indefinite	
Montana	12	Unspecified	Not Specified	
Nebraska	12	12	12	
Nevada	12	12	12	
New Mexico	15	12	60	
New York	12	3	15	
North Dakota	12	84	12	Yes
Ohio	24	12	12	
Oklahoma	12	12-60	Indefinite	
Pennsylvania	12	60	60	Yes
South Dakota	6	60	60	Yes
Tennessee	12	60		
Texas	12	Unspecified	Indefinite	Yes
Utah	12	60	60	Yes
Virginia	36	Unspecified	Indefinite	Yes
West Virginia	12	60	60	Yes
Wyoming	24	Indefinite	Indefinite	Yes

AMOUNT OF TIME ALLOWED FOR EACH STEP IN THE P&A PROCESS

CANADA

Alberta	18/24		Perpetuity	
British Columbia	12	12-180		
Northwest Territories	24	60		
Saskatchewan	When Unused	Unspecified		
Yukon	12	60+		

Appendix F: Year of Introduction of Plugging Legislation by State and Province

Below is a table displaying the year that plugging legislation was first introduced in the United States and Canada (in Canada, plugging is often referred to as "abandonment"). The years for the United States are based on the 1992 IOGCC report, *A Study of Idle Oil and Gas Wells in the United States*[41]. The average and median year of passage of plugging legislation passage in the United States is 1945 and 1948, respectively. The average and median year of passage of plugging (abandonment) legislation in Canada is 1950 and 1958, respectively. The total average and median year of passage of plugging legislation in both the United States and Canada is 1946 and 1948, respectively. For consistency, ACR has only included states and provinces mentioned in the above Appendix E.

U.S. STATE/ CA PROVINCE	YEAR OF PLUGGING LEGISLATION
UNITED STATES[52]	
Alabama	1945
Alaska	1958
Arizona	1959
Arkansas	1939
California	1915
Colorado	1951
Florida	1946

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[52] (IOGCC, 1992)

U.S. STATE/ CA PROVINCE	YEAR OF PLUGGING LEGISLATION
Idaho	1963
Illinois	1939
Indiana	1947
Kansas	1935
Kentucky	1941
Louisiana	1912
Michigan	1927
Mississippi	1948
Missouri	1966
Montana	1953
Nebraska	1959
Nevada	1954
New Mexico	1935
New York	1963
North Dakota	1941
Ohio	1965
Oklahoma	1915
Pennsylvania	1955
South Dakota	1939
Tennessee	1968
Texas	1917

U.S. STATE/ CA PROVINCE	YEAR OF PLUGGING LEGISLATION
Utah	1955
Virginia	1948
West Virginia	1929
Wyoming	1951
CANADA	
Alberta	1938[53]
British Columbia	1958[54]
Northwest Territories	1960[55]
Saskatchewan	1936[56]
Yukon	1960[55]

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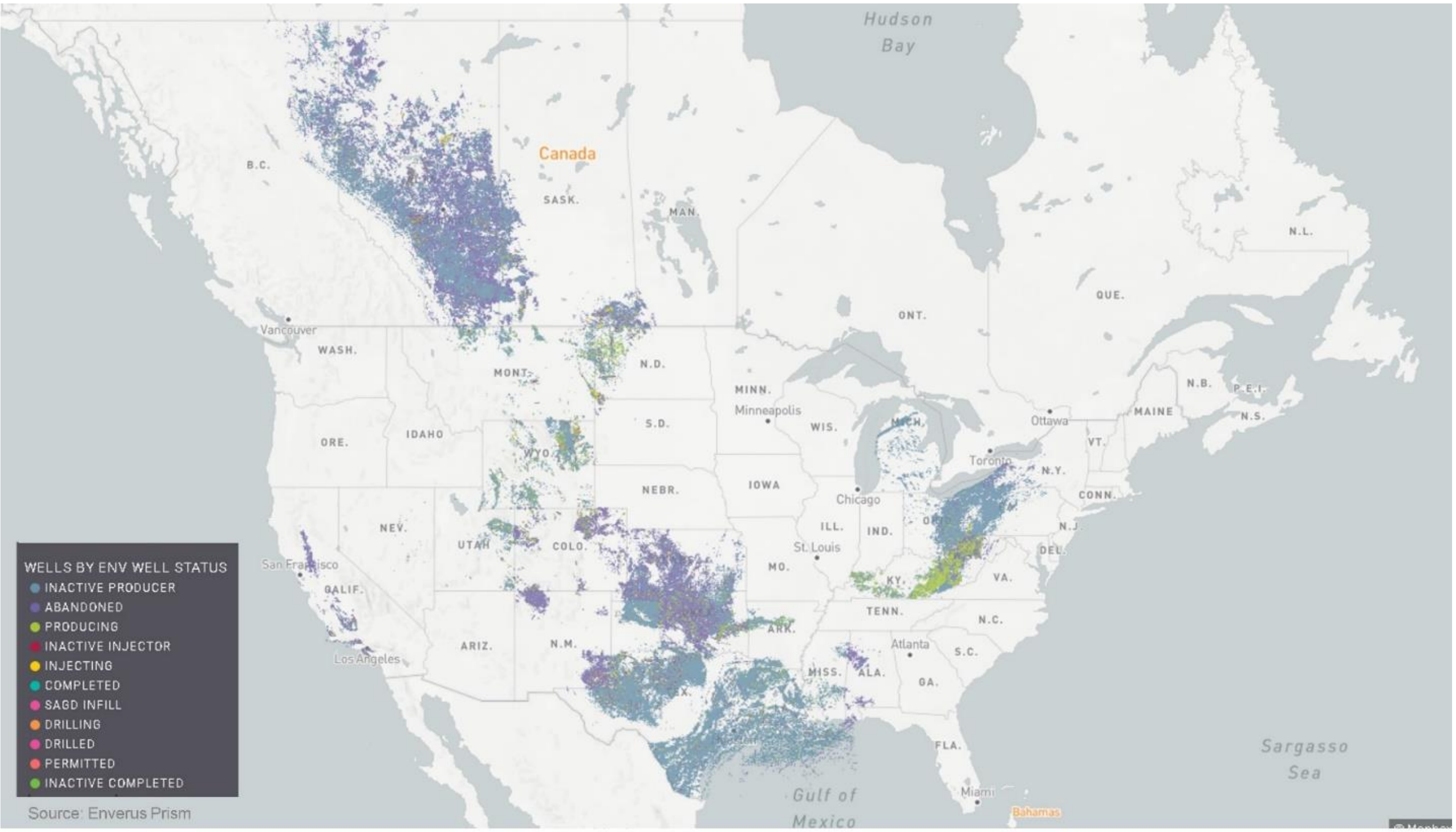
[53] (Alberta Energy Regulator, 2018)

[54] (B.C. Reg. 1958)

[55] (Government of Canada, 1960)

[56] (RSS 1936)

Appendix G: O&G Wells in the U.S. and Canada



Source: Enverus Prism

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