American Carbon Registry
AT WINROCK INTERNATIONAL

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

PLUGGING ABANDONED AND ORPHANED OIL AND GAS WELLS

VERSION 1.0

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ABOUT AMERICAN CARBON REGISTRY® (ACR)

A leading carbon offset program founded in 1996 as the first private voluntary GHG registry in the world, ACR operates in the voluntary and regulated carbon markets. ACR has unparalleled experience in the development of environmentally rigorous, science-based offset methodologies as well as operational experience in the oversight of offset project verification, registration, offset issuance and retirement reporting through its online registry system.

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This methodology was developed by:

The American Carbon Registry

McGill University

In collaboration with:

Fellow Environmental Partners
Oklahoma

Well Done Foundation
Montana

Native State Environmental
Texas

ACRONYMS

ACR	American Carbon Registry
API	American Petroleum Institute
AOOG	Abandoned and Orphan Oil or Gas Well
B	Billion
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
EOR	Enhanced Oil Recovery (Tertiary Recovery)
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
NWoR	Neighboring Well of Review
O&G	Oil and Gas
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 methodology provides the quantification and accounting frameworks, including eligibility and monitoring requirements, for the creation of carbon offset credits from the reduction in methane emissions by plugging abandoned and orphaned oil and gas (AOOG) wells. The study of AOOG wells is an active area of research, and this document will be updated accordingly. This methodology is intended to be used to incentivize the closure – plugging and reclamation - of leaking oil and gas wells that are not in use, sometimes for decades, that would otherwise continue to emit methane to the atmosphere.

For this methodology, ACR will use the term abandoned wells to refer to unplugged wells with no recent production (last 12 consecutive months), which have a known, solvent operator. There are numerous terms that refer to non-producing[1] 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, the term "abandoned" will include wells classified in the different states and provinces as dormant, deserted, inactive, junked, suspended, neglected, shut-in, idle, waiting on completion, and temporary abandoned. The term orphaned wells in this methodology will refer to wells without a solvent operator, and that are not plugged or have been poorly plugged and require additional plugging measures to prevent emissions. Many of the same terms under "abandoned" can also apply to "orphaned" 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 liabilities 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 U.S. Environmental Protection Agency (EPA), in its latest National GHG Inventory[2], reports 6.6 million metric tons of carbon dioxide equivalent (MMT CO_2e) emissions from abandoned and orphaned oil and gas (AOOG) wells in the United States on an annual basis. However, several

[1] Appendix B shows the amount of non-producing - "abandoned" and "orphan" - wells by state according to Enverus database for non-producing wells, and state orphan wells lists.

[2] (US EPA, 2019)

studies report that methane emissions from these wells are likely underestimated[3]. 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 US vary from approximately 2.3 million to 3.2 million according to recent studies[4]. 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[5], private resources (such as Enverus or HSI 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[6], individual and cumulative methane emissions, and the well attributes that characterize this problem. The study shows that methane emissions from AOOG wells persist over multiple years and likely decades, high emitters appear to be unplugged gas wells, and the number of AOOG wells may be as high as 750,000 in Pennsylvania alone[6].

Numerous studies show that methane is being emitted from AOOG wells, but the well population and emission rates need to be better characterized to estimate total emissions and identify high emitters. Currently, less than 1% of AOOG wells in Canada and the U.S. have been measured and documented[7]. Despite questions as to the representativeness of these measurements from this limited number of wells, they are being used to estimate national scale methane emissions. Inaccurate reporting of AOOG well count and emission volumes are a problem that persists in every major oil and gas producing country. Hence, there is a need to design practical solutions and incentives to solve these complex challenges. The use of this methodology will support the improvement of AOOG well inventories, as well as the development of more accurate and representative emission factors for CH_4 emissions in the US and Canada as data from participating projects become available.

Stringent regulatory requirements to properly plug and remediate wells were not in place nationwide until the 1950s; thus, wells plugged before that time are likely to have been improperly plugged, if at all. 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

[3](Williams et al., 2021) (Townsend-Small et al., 2016)
[4] (Saint-Vincent et al., 2020)(Kang et al., 2021)
[5] (U.S. EPA, 2018)
[6] (Kang et al., 2016)
[7] (Williams et al., 2021)
[8] (IOGCC, 2020)
[9] (Kang et al., 2021)
[10] Remediation typically refers to surface restoration and clean up (See Definitions)

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[8]. 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 orphaned, therefore transferring liability to the state or province and its taxpayers.

In almost all jurisdictions, bonding requirements—a financial 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 (estimated at $280 billion in the US).[13] Exacerbating the funding deficit for plugging orphan wells, new studies suggest that after the 2020 economic downturn, at least 30 oil and gas exploration and production companies, which operate 116,245 wells in 32 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 orphaned wells in the subsequent three years[14]. Shortfalls in state and provincial plugging funds, and the latent growth of AOOG wells population due to economic downturn and world-wide carbon-neutral transitions, demonstrate that tools such as this methodology can provide a solution to the AOOG 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 methodology provides the science-based mitigation strategies necessary to drastically cut emissions from AOOG wells using carbon credits as one source of funding. However, the positive impacts extend far beyond reducing CH_4 emissions to the atmosphere by addressing the cost to society (taxpayers) of these wells remaining unplugged. Remediation of AOOG 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 to societal benefits such as the wellbeing of nearby communities, jobs creation and economic stimulation. Additionally, other gases besides methane are often emitted from AOOGs. While these gases may not contribute to GHG emissions, the plugging and abandoning of these AOOGs will provide quantifiable, local air quality benefits. Finally, data acquisition 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.

[11] We use 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.

[12] (Lyon & Peltz, 2016)

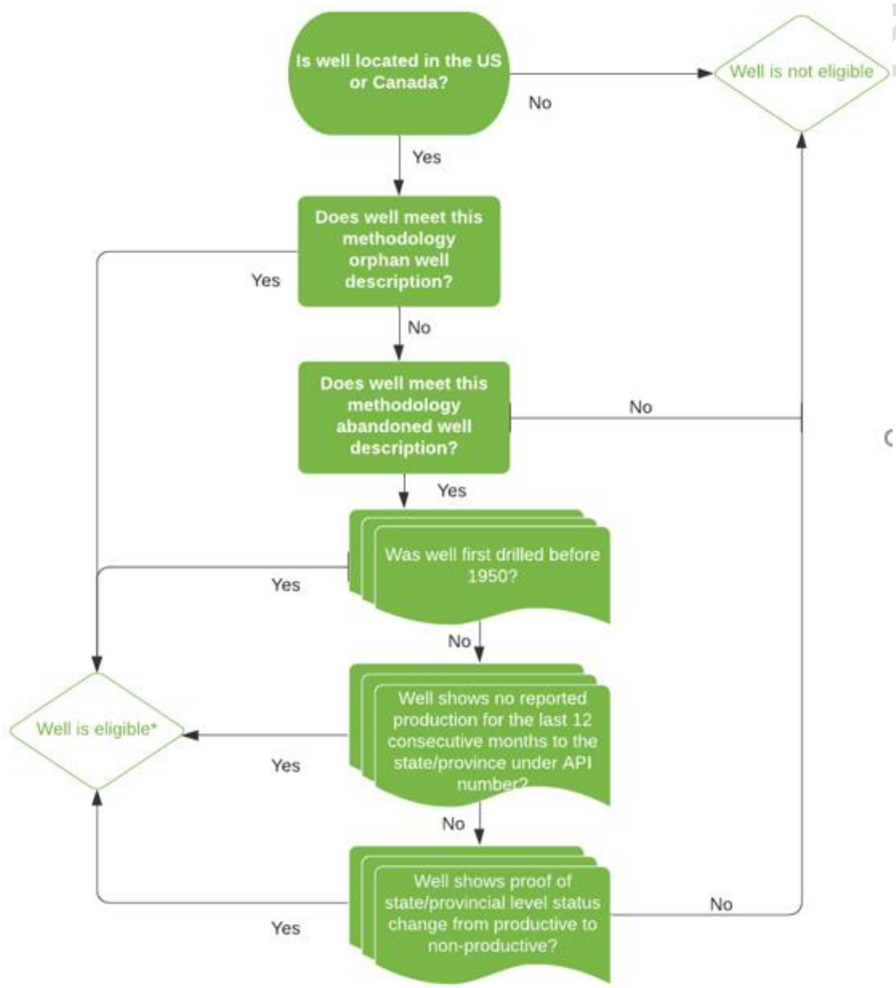
[13] ("Billion Dollar Orphans," 2020)

[14] (Kang et al., 2021)

1.2 APPLICABILITY CONDITIONS

In addition to a project meeting the latest ACR program eligibility requirements as found in the ACR Standard, individual wells must satisfy the eligibility requirements detailed in Figure 1 to be eligible.

Figure 1: Eligibility Decision Tree



1. The project is located in the United States or Canada.
2. The well is emitting CH_4 with no regulatory requirement to prevent the release.
3. The well must meet the definition of **"**orphaned**"** per Appendix A.

Because these wells do not have a solvent operator and are therefore managed by the state or province in which they reside, no regulations are in place to require P&A operations within a mandated timeframe. Under these circumstances, any plugging that occurs is additional to

that which is required by law. Therefore, all orphaned O&G wells are eligible to participate in this methodology.

If an operator takes title of an orphaned well with the intent of performing plugging operations, that well must be plugged within 12 months of transfer of operator in order to be eligible to participate in this methodology.

4. If well does not meet the definition for "orphaned", to be considered **"abandoned",** wells must fall within one or more of the following timeframe buckets:

   a. **Eligibility Bucket #1 – Wells First Drilled Before 1950**

   Although there were different requirements at the state, province, and federal level to ensure that natural resources were protected, it was not until the 1950's when modern regulatory standards in all US jurisdictions required specific provisions for plugging and documenting oil and natural gas wells before they are abandoned. Plugging techniques have since improved and jurisdictions have requirements to ensure environmental protection. Previous, unregulated, abandonment 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. Since many wells were first drilled (or spudded) prior to modern P&A regulations came 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. Therefore, all O&G wells with a spud date prior to December 31st, 1949 are eligible to participate in this methodology.

   b. **Eligibility Bucket # 2 – Oil & Gas Wells with a Designated Operator Drilled in 1950 or Later**

   ONLY in version 1.0 of this methodology, ACR will allow all wells that were first drilled January 1st, 1950 or later, which have a designated operator, which meet the description of this methodology for "abandoned" to be part of offset project only if project proponents:

   1. Show proof of state/provincial level well status change to non-productive status, OR
   2. Show no reported production for the last consecutive 12 months under a corresponding American Petroleum Institute (API) number, UWI, or CWIS.

   Additionally, to prevent gas migration to other formations, groundwater resources, and the atmosphere, this methodology requires that all Neighboring Wells of Review (NWoR) be addressed by the project proponent. This will include a determination of connectivity between wells and may require the proponent to abandon additional leaking wells within the area of review. Additional information on requirements for NWoR is provided in chapter five.

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 offsets against its baseline scenario. AOOG well plugging projects using this methodology will have a crediting period of ten (10) years. Projects involving the same wells will be eligible for a single renewal for an overall possible project life of 20 years. At the end of the first crediting period, wells will need to be screened again for methane emissions and a review of any regulatory updates that require plugging of wells will need to be completed to assure that the project is still additional.

1.4 REPORTING PERIOD

An AOOG well plugging project can only have a single reporting period per crediting period. The reporting period can be defined at the discretion of the project proponent, provided it conforms to the ACR's guidelines on reporting periods.

The project term for an AOGG well plugging project includes the post-plugging monitoring period, as specified in chapter six of this methodology.

1.5 PROJECT START DATE

For this methodology, the start date corresponds to the completion of plugging activities of the first plugged well included in a project.

1.6 PERIODIC REVIEWS AND REVISIONS

ACR might require revisions to this methodology to ensure that monitoring, reporting, and verification systems adequately reflect 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 BOUNDARIES

The physical project boundary demarcates the GHG emission sources included in the project and baseline emissions calculations. An abandoned and orphan well plugging project may include multiple wells- the identified emitter well and the NWoR, wells which may be in hydraulic communication with each other or impacted by plugging operations on any individual well. The physical project boundary encompasses all abandoned and orphaned wells within a hydraulically connected hydrocarbon reservoir or reservoirs. For this methodology, the boundary will be confined to all wells aggregated and to be plugged by a single Project Proponent[15]. The project proponent is responsible for identification of all wells within the surface projection of the project hydrocarbon pool. The proponent must demonstrate to ACR's satisfaction that any wells within the surface projection of the pool are not leaking and in communication with the emitter well(s) and can therefore remain unplugged as part of the project. Tracking and record keeping for wells varies by jurisdiction and the project proponent must check with the applicable authorities.

In large fields with multiple reservoirs or pools, NWoR can be limited to the pools penetrated by the wells to be plugged. Wells that are within the methane drainage pattern of the emitter well and are hydraulically connected will need to be plugged as part of the project. If there are stacked reservoirs, each well within the map projection of the pool will need to be addressed- either by plugging or demonstration that the well is not connected to the project wells. If the NWoR can be shown to not be leaking, they do not need to be plugged. If the project proponent can demonstrate that wells penetrating the reservoir are not hydraulically connected with wells in the reservoir being plugged, those wells do not need to be sampled or plugged. If an emitter well penetrates or is perforated in multiple pools, it must be determined where the methane emissions are originating from and any wells that penetrate or are perforated in those reservoirs must be addressed.

2.2 GHG ASSESSMENT BOUNDARY

Eligible offsets consist of methane that would otherwise be emitted into the atmosphere by AOOG wells within the project.

Physical boundaries are as follows:

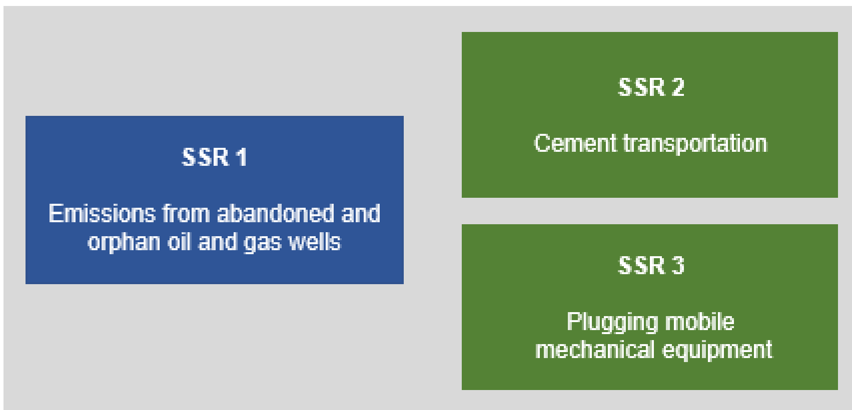
1. Orphan wells identified as emitters and their Neighboring Wells of Review

[15] 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

2. Abandoned wells identified as emitters and their Neighboring Wells of Review

Figure 2: Plugging AOOG Wells Project Boundary Diagram

The project boundary, depicted by the light grey box in Figure 3, is where the plugging of AOOG wells activities happen in the project.



All 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	Abandoned and orphan oil and gas wells that emit methane	Emissions from orphan and abandoned oil and gas wells	CH_4	B	Included
2	Cement transportation	Emissions from the transportation of cement within boundary	CO_2 CH_4 N_2O	P	Included
3		Emissions from mobile mechanical	CO_2 CH_4	P	Included

SSR		DESCRIPTION	GHG	BASELINE (B) PROJECT (P)	INCLUDED OR EXCLUDED
	Plugging Operations (Equipment)	equipment for plugging	N_2O		

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 AOOG well emissions without the project and, therefore, the continual unmitigated release of methane to the atmosphere.

3.2 ADDITIONALITY ASSESSMENT

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

The Regulatory Surplus test requires that AOOG well plugging projects are surplus to regulations, i.e., the emission reductions achieved by plugging these wells are not effectively required by applicable regulation. The Practice-Based Performance Standard ensures that the plugging of these wells reduces the current emissions – considered business as usual - generated by not only high-emitting wells, but all unplugged abandoned and orphan wells within a project.

3.2.1 Regulatory Surplus Test

To pass the regulatory surplus test, the project proponent must demonstrate that there is no existing law, regulation, statute, legal ruling, or other regulatory framework that mandates the project or effectively requires the GHG emission reductions associated with the project activity. In this case, as explained in Appendix A, since regulations are not uniformly enforced in the different states and provinces, wells that fit within the abandoned and orphaned well categories, as described by this methodology, and comply with all eligibility requirements, are considered additional.

3.2.2 Performance Standard

As noted in the analysis presented in Appendix A – The Practice Based Performance Standard, the additionality requirement is met due to inadequate regulation and enforcement at state and provincial levels. For orphaned wells that lack a solvent operator, there is the added challenge of and 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 abandoned and orphan wells, resources for achieving this, including enforcement and bonding, are largely inadequate. All wells that meet this methodology's orphan and abandoned 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.

4 QUANTIFICATION OF GHG EMISSION REDUCTIONS

Quantification of project emission reductions requires calculation of baseline emissions and project emissions.

4.1 BASELINE EMISSIONS

Baseline verification is required to quantify methane emissions from AOOG 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 AOOG wells. Measuring these emissions shall be done using a calibrated methane-specific gas detector and a tested enclosure-based (also referred to as chamber-based) method[16]. Chamber design shall be approved by ACR, or other experts, during project review – project proponents who wish to consult with experts prior to sampling may contact ACR. The enclosed chamber shall encompass the emitting well and 10 cm to 1 m of immediately adjacent soils to also capture any methane emissions that may be migrating up the well annulus. The enclosure-based methods require the measurement of well-mixed gas concentrations inside the chamber using a methane analyzer. The two types of chamber measurements required by this methodology are described below.

4.1.1 Temporal Variation

Emissions measurements, taken over a three-month period, are required for both pre-plugging and post-plugging conditions for every well in the project boundary. Over a period of three months, the following measurements are needed (see Appendix D for timeline):

- Two 24-hour continuous-in-time measurement series for pre-plugging and post-plugging monitoring. For pre-plugging monitoring, sampling begins with the first continous-in-time measurement. The second continous-in-time measurement will be conducted one to two months after the first.
- For post-plugging measurements, the first continuous-in-time measurement shall be conducted at least three days after the plugging date.
- The second post-plugging continous-in-time measurement should be made in the second or third month post-plugging.

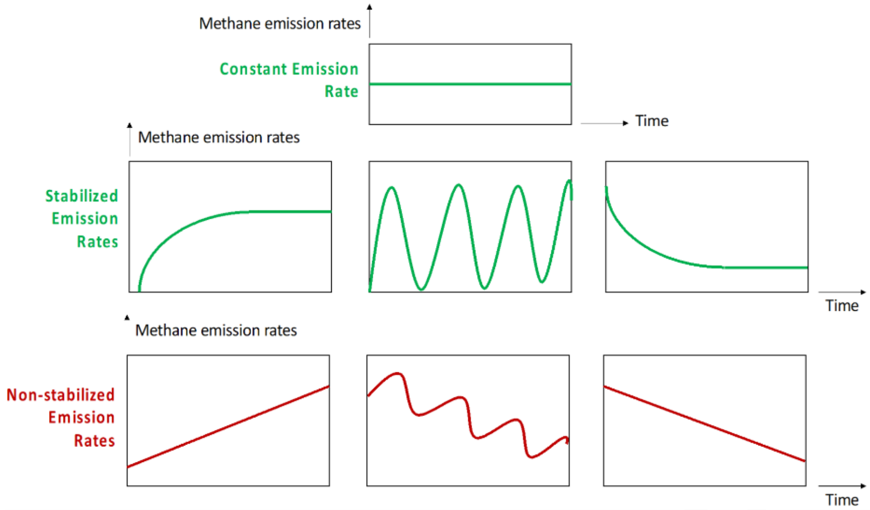
[16] (Livingston & Hutchinson, 1995)

- For both pre- and post-plugging sampling, one point-in-time measurement will be taken at least six days before or after the continuous-in-time measurements- can be taken between the two 24-hour measurement.
- One additional methane assessment is required approximately five years after plugging. This can be done with a handheld sensor or multi-gas sensor with a lower detection limit of 2 ppmv methane. If methane concentrations exceeding 3 ppmv are detected during the test, methane flow rate using a chamber-based method shall be used. This test is to ensure plugged well is not emitting.

Additional sets of measurements are required until methane emission rates are stabilized (Figure 4). All results collected as part of the project sampling must be submitted. Emission rates can be considered stabilized if emission rates vary by a factor of 10 or less - meaning that the ratio of measurement *n* to measurement *n+1* is less than 10 or larger than 0.1. For the continuous-in-time measurements, the chamber must remain on top of the wellhead for a duration of 24 hours. This type of measurement captures the daily variation in the emission rates. For point-in-time or continuous-in-time measurements, non-steady-state or steady-state chambers can be used. If a project developer decides to use the static chamber (non-equilibrium-based) chamber to do the continuous-in-time measurement, then they will need to redeploy the chamber every 30 minutes for a duration of 24 hours. Otherwise, the chamber would reach equilibrium and it will be impossible to capture variations in the emission rates. Fixed-time increments can be 10 to 30 minutes. With each re-deployment, the chamber must be vented using background air such that the methane concentrations in the chamber are equal to background methane concentrations. The sensor shall be used to ensure that the chamber is sufficiently vented. If a regular cyclical pattern is observed (e.g., diurnal variations), the average over each cycle can be used to determine if emission rates have stabilized.

Figure 3: Constant, Stabilized, and Non-Stabilized Emission Rates Example

Emission rates must be stabilized to estimate pre-plugging and post-plugging emission rates. Example methane emission rates over time considered to be stabilized and not stabilized.



4.1.2 Steady-State and Non-Steady-State Chambers

For non-steady-state chambers, the methane emission rate $Q_s \left[\frac{MASS}{TIME}\right]$ is calculated using:

Equation 1: Methane Emission Rate - Non-Steady-State Chambers

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

WHERE

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

The effective chamber volume (V_{eff}) represents the volume that is sampled for methane concentration accumulations in the chamber.

4.1.3 Steady-State Chambers

The methane emission rate, $Q_d \left[\frac{MASS}{TIME}\right]$ is calculated using:

Equation 2: Methane Emission Rate - Steady-State Chambers

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

WHERE

$\mathbf{Q_d}$	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 $\left[\frac{\text{MASS}}{\text{VOLUME}}\right]$

4.1.4 Pre-Plugging and Post-Plugging Emission Calculation

To determine the net GHG reductions for wells, monitoring of methane emissions before and after plugging the well is required.

The baseline (pre-plugging) emissions, BE (t CO_2e/year), and post-plugging emissions, PPE (t CO2e/year) are computed using:

Equation 3: Pre-Plugging and Post-Plugging Emission Calculation

$$\mathbf{BE} = \left(\sum_{1}^{w} Q_{pre-plugging}\right) \times \mathbf{GWP_{100}(CH_4)}$$

$$\mathbf{PPE} = \left(\sum_{1}^{w} Q_{post-plugging}\right) \times \mathbf{GWP_{100}(CH_4)}$$

WHERE

$Q_{pre-plugging}$	Total pre-plugging annual emission rate of all wells to be plugged in the project boundary $\left[\frac{Kg\ CH_4}{Year}\right]$

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

For $Q_{pre\text{-}plugging}$ and $Q_{post\text{-}plugging}$, the first set of methane emission rate measurements (Section 4.1.1) made to determine temporal variation should be analyzed, as follows:

For each continuous-in-time measurement, determine an average emission rate to obtain an equivalent point-in-time emission rate (tCH4/year):

Equation 4: Equivalent point-in-time emission rate

$$\mathbf{Q_1 = \frac{\sum_{j=1}^{N} Q_{i,j}}{N}}$$

WHERE

$\mathbf{N}$	Number of emission rate estimates made for the 24-hour measurement period
$\mathbf{Q_{i,j}}$	$\mathbf{j}^{th}$ emission rate estimate $\left[\frac{t\ CH_4}{Year}\right]$ made on day $\mathbf{i}$. If the variation observed within the 24-hour time-period exceeds a factor of 10, conduct one additional 24-hour continuous-in-time measurement

For each month, average the measured and estimated equivalent point-in-time emission rate(s) to get the average monthly methane flow rate, Q_m, (t CH_4/year):

Equation 5: Monthly Flow Rate

$$\mathbf{Q_m = \frac{\sum_{i}^{C} Q_1 + \sum_{k=1}^{P} Q_k}{C + P}}$$

WHERE

m	Month index
Q_k	$\mathbf{k}^{th}$ measured point-in-time methane emission rate

P	Total number of point-in-time measurements conducted within month m
Q_i	Equivalent point-in-time methane emission rate $\left[\frac{t\,CH_4}{Year}\right]$ based on the i^{th} continuous-in-time measurement
C	Number of continuous-in-time measurements made in month m

If the variation in the measured or equivalent point-in-time methane emission rate does not exceed a factor of 10, average the Q_m values determined for each month of the pre-plugging monitoring period, to get the $Q_{pre\text{-}plugging}$ (t CH_4/year), and average the Q_m values determined for each month of the post-plugging monitoring period, to get the $Q_{post\text{-}plugging}$ (t CH_4/year).

Equation 6: Annual Emission Rate

$$Q_{pre-plugging} = \frac{\sum_{m=1}^{M} Q_m}{M}$$

$$Q_{post-plugging} = \frac{\sum_{m=1}^{M'} Q_m}{M'}$$

WHERE

Q_m	Average monthly methane emission rate $\left[\frac{t\,CH_4}{Year}\right]$
M	Number of months in the pre-plugging monitoring period. The minimum M is 3 and there is no maximum M.
M'	Number of months in the post-plugging monitoring period. The minimum M' is 3 and there is no maximum M'.

M and M' are determined based on the number of months required for emission rates to stabilize (Figure 3).

If emission rates do not stabilize, this methodology cannot be applied.

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, conduct two additional point-in-time measurements made no less than 6 days apart and recompute

equations 5 and 6 using the Q_m for the last month of the first set and the two additional measurements. If emission rates appear to have stabilized (Figure 4), additional measurements are not needed.

4.2 PROJECT EMISSIONS

Depending on project-specific circumstances, certain emissions sources shall be subtracted from total project emission reductions using the equations below. Generally, this includes emissions from plugging activities at the well site and transportation of materials, including cement. Project proponents are responsible for reporting any non-standard emissions or reductions for ACR's consideration.

Equation 7: CO_2 Emissions from Fossil Fuel Combustion for Equipment Used at Plugging Project

$$EQ_{CO_2} = FF_y \times FF_{ef}$$

WHERE

EQ_{CO_2}	CO_2 emissions from fossil fuel used in equipment at plugging project (t CO_2)
FFy	Total quantity of fossil fuel consumed (gallons)
EFef	Fuel specific emission factor for fuel (t CO_2/gallon) — See Appendix F

Equation 8: Cement Transportation Emissions

$$TransC_{CO_2} = FF_y \times FF_{ef}$$

WHERE

$TransC_{CO_2}$	CO_2 emissions from fossil fuel used in equipment at plugging project (t CO_2)
FF_{transC}	Total quantity of fossil fuel consumed (gallons)
EF_{ef}	Fuel specific emission factor for fuel (t CO_2/gallon) — See Appendix F

FF_{transC} can also be calculated based on miles driven and the fuel efficiency of the vehicle used to transport the cement. If cement is mixed onsite, any transportation of other materials or equipment must also be included.

Equation 9: Total Project Emissions

$$\mathbf{PROJECT_{total} = EQ_{CO_2} + CM_{CO_2}}$$

WHERE

$PROJECT_{total}$	Project emissions (t CO_2)
EQ_{CO_2}	Plugging Specific Operations Emissions (t CO_2)
CM_{CO_2}	Total Cement Transportation Emissions (t CO_2)

4.3 EMISSIONS REDUCTIONS

Net emissions will include baseline emissions, post-plugging emissions, and project emissions, described in detail in Chapter Seven. All parameters are expressed in t CO_2e/year.

Equation 10: Emission Reductions

$$\mathbf{ER = BE - PPR - PROJECT_{total}}$$

ER	Emissions Reductions (t_{CO_2})
BE	Baseline Emissions (t_{CO_2})
PPR	Post-Plugging Emissions (t_{CO_2})
$\mathbf{PROJECT_{total}}$	Project Emissions (t_{CO_2})

Equation 11: Post-Plugging Emissions

$$\mathbf{PPR = Q_{post-plugging} \times GWP_{100}(CH_4)}$$

WHERE

PPR	Post-Plugging Emissions
$Q_{post-plugging}$	Total post-plugging reduction rate of all wells in the project (t CH_4 /year)

For $Q_{post\text{-}plugging}$, each set of methane emission rate measurements made to determine temporal variation must be analyzed.

For each continuous-in-time measurement, determine an average emission rate to obtain an equivalent point-in-time emission rate (t CH_4/year).

5 PERMANENCE

5.1 PERMANENCE & REVERSAL RISK

Since project proponents must demonstrate that plugging AOOG results in reduced methane emissions, post-plugging monitoring must be conducted. Permanence in this methodology requires demonstration of well and plug integrity, prevention of emission pathways, and confirmation that emissions have not shifted to the NWoR. Project proponents must monitor all wells plugged a **minimum of 3 months** after the completion of plugging. If methane levels of greater than 100 mg/hour/well are detected, no credits associated with that well will be granted.

Previously plugged wells are required to be tested for atmospheric leakage to determine if the well is poorly plugged. The test shall involve a methane detector screening the area within 5 cm of the ground surface for at least 5 minutes. The detector can be a handheld sensor and can be a multi-gas sensor but shall have a lower detection limit of 2 ppmv methane. If methane concentrations exceeding 3 ppmv are detected, methane flow rate using a chamber-based method shall be measured as detailed in the above sampling section. For buried wells, an area of at least 1 m^2 shall be measured. If the measured methane flow rate exceeds 100 mg/hour/well, then the plugged well is considered a poorly plugged well and shall be re-plugged. The plugging status of an AOOG well is determined using government databases. Any well without a government record of plugging completion is considered unplugged.

5.2 NEIGHBORING WELLS OF REVIEW

NWoR includes unplugged and poorly plugged wells in the same oil and gas pool and field/field areas depending on the pool and well locations/depths. A pool is a subsurface hydrocarbon (natural gas and/or oil) accumulation that contains interconnected pore space or other means of hydraulic communication. A field can encompass a single pool or a group of pools, which can be vertically stacked and are within a horizontal areal boundary. A field area is a sub-region within a field, and pools are associated with a field area if field areas exist. This methodology requires that all NWoR that are hydraulically connected to a plugged well and that could provide a methane an alternate emission pathway be plugged. To be eligible, an AOOG well plugging project must plug all these wells within the area of review or demonstrate that wells are not be in communication with the plugged wells (i.e., no credits will be granted to any well plugged as part of a project until all wells with the NWoR are addressed). The project proponent must demonstrate that wells near the plugged well are not a potential pathway for methane from the same reservoir or would otherwise be impacted by the plugging.

There are three approaches to defining the NWoR:

a) For wells in oil and gas fields or field areas with multiple pools, wells within the surface projection of the pool to be plugged must be addressed as part of the review. Wells that can be demonstrated to be in shallower pools will likely not need to be plugged as part of the project. Wells within the same pool as the well to be plugged must also be plugged unless the project proponent can demonstrate a lack of connectivity or influence. Wells in pools deeper than the target pool are included in the NWoR and must be demonstrated to not be connected to the reservoir to be plugged or provide a conduit from the target reservoir to the surface.

b) If the pool and the depth of the pool from which oil and/or gas was produced is uncertain, all wells within a field or field area are included in the NWoR and will need to be plugged unless an operator can demonstrate lack of connectivity.

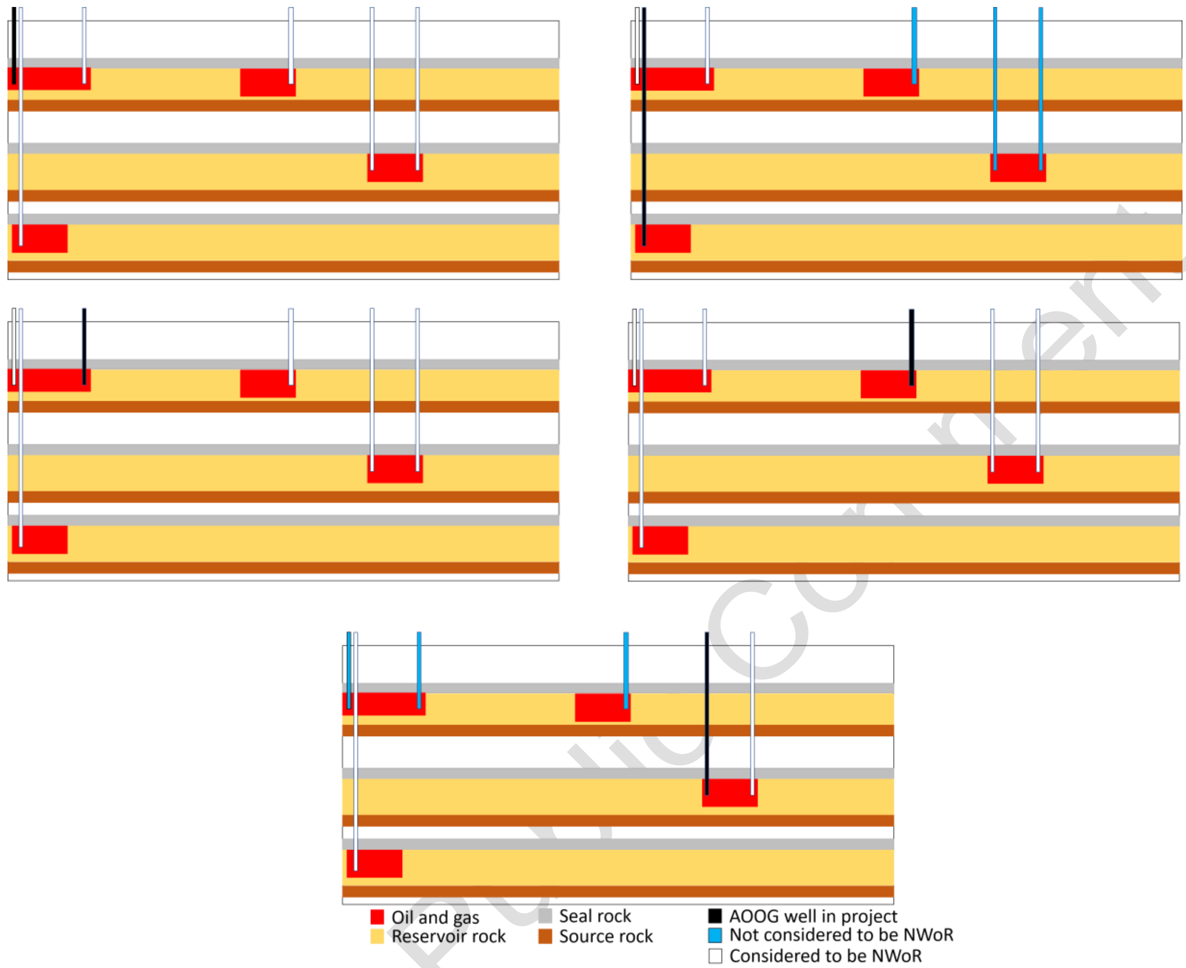
c) If there is uncertainty in the field or field area, the operator must propose an area (subject to ACR approval) and demonstrate the lack of connectivity between wells within the target reservoir.

If an area of review, drainage area, or similar term is defined for the jurisdiction or specific field where a well to be plugged is located, that information shall be detailed in the project proposal.

Figure 5 illustrates several field scenarios and defines the NWoR for each. Wells that penetrate the same reservoir require the proponent to plug or demonstrate that they are not in communication with the well to be plugged. Reservoir geology, structure, and other factors can be used to demonstrate lack of communication. Wells that are shallower than or otherwise do not penetrate the target reservoir will not need to be plugged. Wells that target a deeper reservoir than the target reservoir will need to be shown to not be in communication with the target reservoir through shallower perforations, casing integrity issues, or otherwise.

Figure 4: Wells Considered to be NWoR in the Case of Multiple Pools within a Field

Wells considered to be NWoR in the case of multiple pools within a field. In large fields with multiple field areas, NWoR can be limited to the field area. The figure presents several options but is not comprehensive, each field is unique and must be addressed individually.


Oil and gas
Reservoir rock
Seal rock
Source rock
AOOG well in project
Not considered to be NWoR
Considered to be NWoR

6 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 www.americancarbonregistry.org. Additionally, projects are required to submit a GHG monitoring report for each reporting period. Project Pro-ponents shall use the template for GHG monitoring reports available at http://americancarbon-registry.org/carbon-accounting/tools-templates.

6.1 DESCRIPTION OF THE GHG PLAN

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

The project proponent must prepare a GHG 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. These are expanded upon in the sections below.

6.2 DATA COLLECTION AND PARAMETERS TO BE MONITORED

The project proponent is responsible for monitoring the performance of the offset project and conducting each component of the P&A process in a manner consistent with the methodology. For both pre- and post-plugging measurements, the following data must be collected and reported to ACR :

- Design and approval of the chamber and chamber methodology (steady-state vs. non-steady-state)
- The volume of the chamber along with a photo of the installed chamber.
- Measurements of methane concentrations over time observed in the chamber
- Environmental conditions – precipitation, temperature, humidity

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

- GPS location of the well, photo of the well at ground surface
- Well attributes:
  - **DETAILED:** Well ID, depth, casing details, gas-to-oil ratio, drilled date, completion date, plugged date, operator, production volumes, deviation, oil/gas pool or producing-formation name(s), oil/gas field or field area name, coal area designation, well integrity issues when the well was active. The source of the data and how the data can be obtained shall be described.
  - **ESTIMATED:** Depth, gas-to-oil ratio, oil/gas pool or producing-formation name(s), oil/gas field or field area name. The method used to estimate these attributes must be described.

For wells lacking in detailed or estimated information, the project proponent shall submit what is available. ACR may require additional information about the pool, production history, or other wells within the area for the project to be approved.

6.2.1 Methane Analyzer Specifications

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

- Works in appropriate environmental conditions (e.g., temperature, humidity)
- Provides methane-specific concentrations from 1 ppmv to 100% methane
- Provides a measurement frequency of 1 Hz and a precision of 1 ppmv

Methane analyzers must be calibrated to manufacturer's specifications and calibration logs shall be included in the project plan.

6.2.2 Chamber Specifications

There are two main enclosure-based methods: non-steady-state and steady-state. The steady-state chamber involves continuous flow of a known gas (e.g., air) at a fixed rate using a pump. Non-steady-state chambers do not require a pump. 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. Appendix D contains resources for chambers.

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

The footprint of the enclosure should be sufficiently large to cover the full footprint of the well and a 10 cm to one meter 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 de-gassing or sorption).

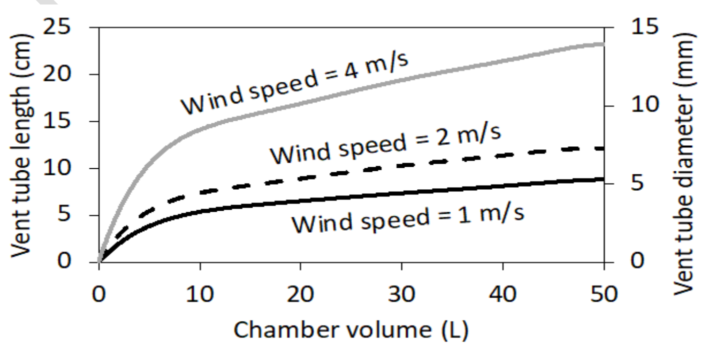
The enclosure shall have a separate detachable base that is inserted 2-6 cm below ground surface and that is open to the atmosphere. This base shall be installed before the rest of the chamber.

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).[17]

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 meter, which should be done per manufacturer's specifications. Calibration logs must be included in the baseline sampling submission.

Figure 5: Vent Tube Length and Diameter for Selected Wind Speeds and Chamber Volumes

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.

6.3 PARAMETERS

UNIT	PARAMETER	POTENTIAL EVIDENCE	SOURCE	BASELINE OR PROJECT?	FREQUENCY OF MONITORING
$(t\ CO_2e/year)$	BE	Enclosure-based measurements	Enclosure-based measurements	B	1/crediting period
$(t\ CO_2e/year)$	PPE	Enclosure-based measurements	Enclosure-based measurements	P	1/crediting period
$\left[\frac{MASS}{TIME}\right]$	Qs	Non-steady-state enclosure-based measurements	Non-equilibrium-based chamber measurement	B and P	1/non-equilibrium-based chamber measurement
[VOLUME]	V_{eff}	Non-steady-state enclosure-based measurements	Non-equilibrium-based chamber measurement	B and P	1/non-equilibrium-based chamber measurement
$\left[\frac{MASS}{VOLUME.TIME}\right.$	$\frac{dC}{dt}$	Non-steady-state enclosure-based	Non-equilibrium-based chamber measurement	B and P	1/non-equilibrium-

UNIT	PARAMETER	POTENTIAL EVIDENCE	SOURCE	BASELINE OR PROJECT?	FREQUENCY OF MONITORING
		measurements			based chamber measurement
$\left[\frac{MASS}{TIME}\right]$	Q_d	Steady-state enclosure-based measurements	Equilibrium-based chamber measurement	B and P	1/equilibrium-based chamber measurement
$\left[\frac{VOLUME}{TIME}\right]$	q	Steady-state enclosure-based measurements	Equilibrium-based chamber measurement	B and P	1/equilibrium-based chamber measurement
$\left[\frac{MASS}{VOLUME}\right]$	C_{eq}	Steady-state enclosure-based measurements	Equilibrium-based chamber measurement	B and P	1/equilibrium-based chamber measurement
$\left[\frac{MASS}{VOLUME}\right]$	C_b	Steady-state enclosure-based measurements	Equilibrium-based chamber measurement	B and P	1/equilibrium-based chamber measurement
$[LENGTH]^2$	Af		Regulatory databases	B and P	1/project
	f and N		Regulatory databases	B and P	1/project
[LENGTH]	r_{state}			B and P	1/project
$[LENGTH]^2$	A_{state}			B and P	1/project

UNIT	PARAMETER	POTENTIAL EVIDENCE	SOURCE	BASELINE OR PROJECT?	FREQUENCY OF MONITORING
$(t\ CH_4/year)$	$Q_{pre\text{-}plugging}$	Enclosure-based measurements	Enclosure-based measurements	B	1/well
$(t\ CH_4/year)$	$Q_{post\text{-}plugging}$	Enclosure-based measurements	Enclosure-based measurements	B	1/well
$Kg\ CO_2/Kg\ CH_4$	$GWP_{100}(CH_4)$		Greenhouse gas inventory reports	B and P	1/project
	w			B and P	1/project
$(t\ CH_4/year)$	$\overline{Q_i}$	Continuous-in-time measurements	Continuous-in-time-measurements	B and P	1/well
$(t\ CH_4/year)$	$\overline{Q_{i,J}}$	Continuous-in-time measurements	Continuous-in-time-measurements	B and P	1/well
	N	Continuous-in-time measurements	Continuous-in-time-measurements	B and P	1/well
	Q_k	Point-in-time measurements	Point-in-time measurements	B and P	Minimum 6/well
	P	Point-in-time measurements	Point-in-time measurements	B and P	Minimum 6/well

UNIT	PARAME-TER	POTENTIAL EVIDENCE	SOURCE	BASELINE OR PROJECT?	FREQUENCY OF MONITORING
°C	Tempera-ture			B and P	

7 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 should be kept for verification, including the method or manufacturer's specification used for calibration.

7.1 OFFSET OWNERSHIP

Since oil and gas 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 verification. The documents shall be retained for a minimum period of three years following the end of the crediting period.

7.2 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. This methodology follows the approach designed for direct measurements of methane emissions from AOOG wells in Pennsylvania[17], one of the states with the greatest number of abandoned and orphan wells in the US. Estimates for errors assumed are +/- 20%, which is the generally accepted random error for static chambers. The value of 20% will then be applied uniformly across all wells in the project.

A potential source of uncertainty that has been discussed through the course of the development of this methodology is that plugging of a single well within an interconnected pool may not,

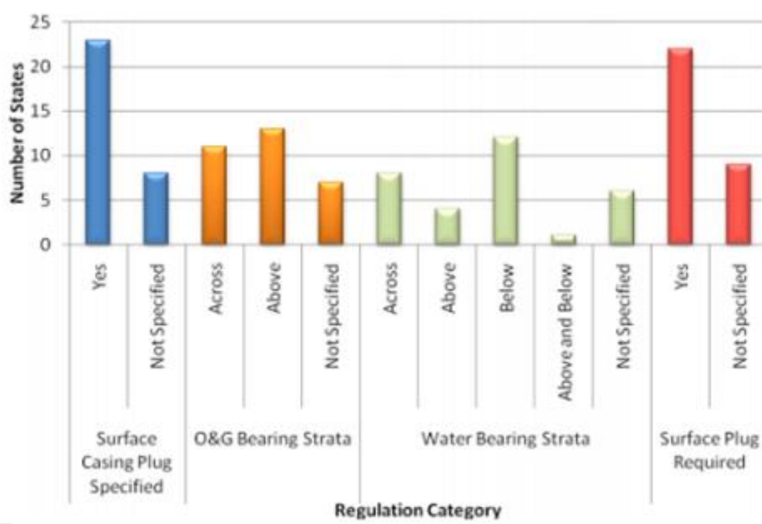
[17] (Kang et al., 2014)

over time, result in reduced methane emissions. To mitigate this uncertainty, this methodology approach has been to plug the Neighboring Wells of Review that are hydraulically connected and within the methane drainage radius. Project proponents must demonstrate that their plugging activities will not exacerbate emissions and that plugging will result in no post-plugging emissions from an individual pool.

7.3 PLUGGING STANDARDS

As detailed in Appendix A, regulation for Plugging and Abandoning oil and gas wells differ in timelines, requirements, and requisites. Figure 8 provides a comparison of the plugging requirements in different states with focus on key elements of plugging perforations in the oil and gas strata, cementing across the freshwater zone, and surface casing plugging. To assure plugging integrity, this methodology will incorporate the American Petroleum Institute (API) Recommended Practice (RP) 65-3 – Wellbore Plugging and Abandonment Standard, as well as states plugging requirements that go beyond the API standard.

Figure 6: Elements of State Well-Plugging Regulations



Source: State Oil and Gas Regulatory Exchange, and Groundwater Protection Council, 2009

DEFINITIONS

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

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
High emitter	A well that shows detected methane levels of greater than 100 mg/hour/well
Inactive well	An oil or gas well that is no longer producing but has not yet been permanently sealed off — a process with a terribly confusing name: abandoning.
Oil and Gas Commission/ Regulator	Every state and province have a division, board, or commission responsible for overseeing the oil and gas industry. These entities issue permits, collect information used to assess fees and taxes, and hire inspectors to ensure compliance with environmental and safety regulations.
Neighboring Well of Review (NWoR)	A well that is within close proximity to a well of interest. As part of this methodology, a project proponent must determine whether the NWoR is in hydraulic communication with a studied well and if the P&A operations on that well will impact, or be impacted by, the NWoR. It is possible for wells to be hydraulically connected without any adverse impacts to the wells or project.
Orphan well	A well without a solvent operator and for which no records exist concerning drilling, plugging, or abandonment.
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.
Project Proponent	An individual or entity that undertakes, develops, and/or owns a project. This may include the project investor, designer, and/or owner of the lands/facilities on which project activities are conducted. The Project Proponent and landowner/facility owner may be different entities. The Project Proponent is the ACR account holder.
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.

APPENDIX A: DEVELOPMENT OF PERFORMANCE STANDARD

During the spring of 2020, amid the COVID-19 pandemic and worldwide economic slowdown, global oil markets were subject to arguably the greatest volatility seen in the last 30 years (for example, in April 2020, U.S. benchmark oil prices dropped below zero for the first time in history). As oil and gas price volatility is likely to continue, oil and gas wells are at a greater risk to move from producing to abandoned to orphaned statuses without adequate bonding and without addressing currently orphaned wells.

According to the Director of North Dakota's Department of Mineral Resources, from March to April of 2020, North Dakota added 360 new orphaned wells. Indeed, the United States Environmental Protection Agency (EPA) states that since 1990, the reported population of abandoned wells has increased by 27%, and that in the US there are approximately 3.2 million abandoned wells. The Government of Alberta has estimated that there are currently 97,000 inactive wells in Alberta that have not been decommissioned and the British Columbia Oil and Gas Commission reports 8,500 dormant wells, or wells that have been largely inactive for 5 years, from which more than a quarter are leaking. Still, many AOOG wells are unaccounted for, and every year more orphaned and abandoned wells are discovered and reported. In Pennsylvania alone, there are between 470,000 and 750,000 such wells, with estimated state-wide emissions of 0.04–0.07 Mt methane (CH_4) per year.

Unfortunately, the lexicon regarding AOOG wells is not uniform across all states and the federal government. For instance, the EPA refers to the term abandoned wells as follows:

- Wells with no recent production and that are not plugged. Common terms (such as those used in state databases) might include inactive, temporarily abandoned, shut-in, dormant, and idle.
- Wells with no recent production and no responsible operator. Common terms might include orphaned, deserted, long-term idle, and abandoned.
- Wells that have been plugged to prevent migration of gas or fluids .

In Canada, the same problem of regionally specific terminology persists. For example, the Alberta and Saskatchewan regulators deem the type of well described above as orphaned, where in British Columbia, these wells fall under the dormant site category. The major oil and gas producing provinces – Alberta, British Columbia, Northwest Territories, Ontario, Saskatchewan, and Yukon - have varying systems for managing wells for which no producer accepts the environmental liability. Provincial rules around "abandoned" wells include:

In contrast with some terminology used in the US, wells are considered “abandoned” in Alberta if they have been properly decommissioned according to the requirements of the Alberta Energy Regulator (AER). An “abandoned” well in Alberta is the equivalent of a “plugged” well in the US.

In Alberta, wells, facilities, or pipelines are considered orphaned when the licensee has become insolvent, and the Orphan Well Association (OWA) 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 Oil and Gas Commission.

In Saskatchewan, orphaned sites can mean 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 “abandoned wells” as those wells with no recent production (i.e., within the preceding consecutive12 months), a known, solvent operator, and that are not plugged or properly plugged. We refer to the term “orphaned wells” as those wells with no responsible operator and that are not plugged or properly plugged. For orphaned wells, the dis-tinction ACR is making is whether the well is associated with insolvent operator or not. This dis-tinction is important in that different regulatory requirements may apply depending on whether the well is associated with an operator. As appendix C shows in detail, the IOGCC reports 56,000 documented orphaned wells in the US, highlighting that this amount is underestimated.

A.1 FINANCIAL ASSURANCE FOR OIL AND GAS WELLS

At the time a well is drilled, an operator is often required to post a bond (for an individual well), or a blanket bond (for multiple wells located within a state or a province) that may be returned to the operator only after the well is plugged. Bonds are designed to help prevent or reduce taxpayer losses in every state because the bond money may be used to reclaim wells when operators or other liable parties do not reclaim the wells due to insolvency or cessation of business activities. In these situations, the wells are considered to be orphaned and become a state liability for remediation as there is no other responsible party. Ideally, these bonds would be high enough and would require oil and gas 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 remediation of all the U.S. and Canada’s AOOG wells would be an extremely large financial burden. A report from the Interstate Oil & Gas Compact Commission (IOGCC, a multi-state government entity that collects data on abandoned and orphaned oil and gas wells across

the U.S. and Canada) 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 were sufficient to cover less than 5% of the average cost of plugging a well. 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 OIL AND GAS WELL REMEDIATION

State and provincial regulations to require financial assurance, through bonding, for plugging wells were first introduced in 1941 in North Dakota (however, in the case of Mississippi, financial assurance through bonding requirements was not introduced until 1992). 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 a well can take in different jurisdictions including temporarily abandoned (TA) and long-term idle prior to being permanently plugged[18,19]. 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 60 months. However, many states allow the TA[20]. To avoid abuse of the TA[21]. 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.

Oil and gas industry has not been held accountable by regulators for the proper remediation of orphaned and abandoned oil and gas wells and this is demonstrated by many studies[22, 23] and

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[18] Meaning that operator has fulfilled all requirements for Temporarily Abandonment status

[19] 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”. Regardless of the specific term or status used to define these wells, the important factor is the length of time elapsed since the well was producing oil or gas. For purposes of this methodology, a well categorized as “temporarily abandoned” is considered to be “abandoned” to determine whether it is eligible under the performance standard.

[20] (Muehlenbachs, 2015)

[21] (IOGCC, 2019)

[22] (Ho et al., 2018a)

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

different organizations[24]. The overall weakness in the regulatory environment to properly govern oil and gas well remediation has been studied extensively[25, 26]. 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 are in place to limit potential negative environmental and public health impacts associated with orphaned and abandoned oil and gas wells. According to IOGCC[8], the State Oil and Gas Regulatory Exchange and the Groundwater Protection Council[27] 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[19], regulations are not enforced by state and provincial oil and gas 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 allowable 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 Oil and Gas 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[23]). Therefore, it can be concluded that plugging wells at the end of their productive life, although required by law, is not uniformly enforced, and is not the observed trend.

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

A.3 U.S. STATE WELL PLUGGING FUNDS

All available analyses on state/provincial wells plugging funds have concluded that increased amounts of money are needed to remediate AOOG wells. Accordingly, the U.S. Government Accountability Office estimates that remediating an orphaned or abandoned well runs from $20,000 to $145,000 or more, putting the price tag for remediating America's orphaned 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 no or insufficient financial assurance is available are properly plugged and abandoned. These plugging funds are financed differently by state but are typically

[24] (Bloom, n.d.)

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

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

[27] (State Oil and Gas Regulatory Exchange & Groundwater Protection Council, 2009)

funded via fees, fines, public revenue, and taxes[28]. 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 "Orphaned Well" as "…any well abandoned prior to July 1, 1950, or for which no records exist concerning its drilling, plugging or abandonment".[29] 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. Another case is Texas, where there were 440,000 producing oil and gas wells and 130,000 wells that were not producing[30]. Although the State has given funds to the Texas Railroad Commission (organization which regulates the industry in Texas) to plug wells, in a two-year period, the State only plugged an equal number of wells as the number of wells that were abandoned during that two-year period[29]. The available funding to remediate wells is simply insufficient to address the issue.

A.4 CANADIAN WELL DECOMMISSIONING FUNDING

In April 2020, Canada announced a $1.7B CAD fund to clean up orphaned and inactive wells. The $1.7B CAD is structured as a jobs program, helping energy sector workers keep their jobs and fails to meet the magnitude of funds needed to remediate orphaned wells across Alberta alone, which has been estimated to cost $100B CAD[31]. Finance Canada reports approximately 5,560 orphaned wells, with an additional 139,000 inactive wells across Alberta, BC, and Saskatchewan[32]. The average cost to plug a well in the Canadian provinces has been calculated at $61,477 (CAD)[33].

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 op-

[28] These include fees: annual, idle well, permits, civil penalties and settlements, fines: appropriations, and State Oil and Gas Agency operating budgets, forfeited bonds, and salvage

[29] (Buchele, 2019)

[30] (Texas Senate, 2019)

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

[32] (Harris, 2020)

[33] (IOGCC, 2019)

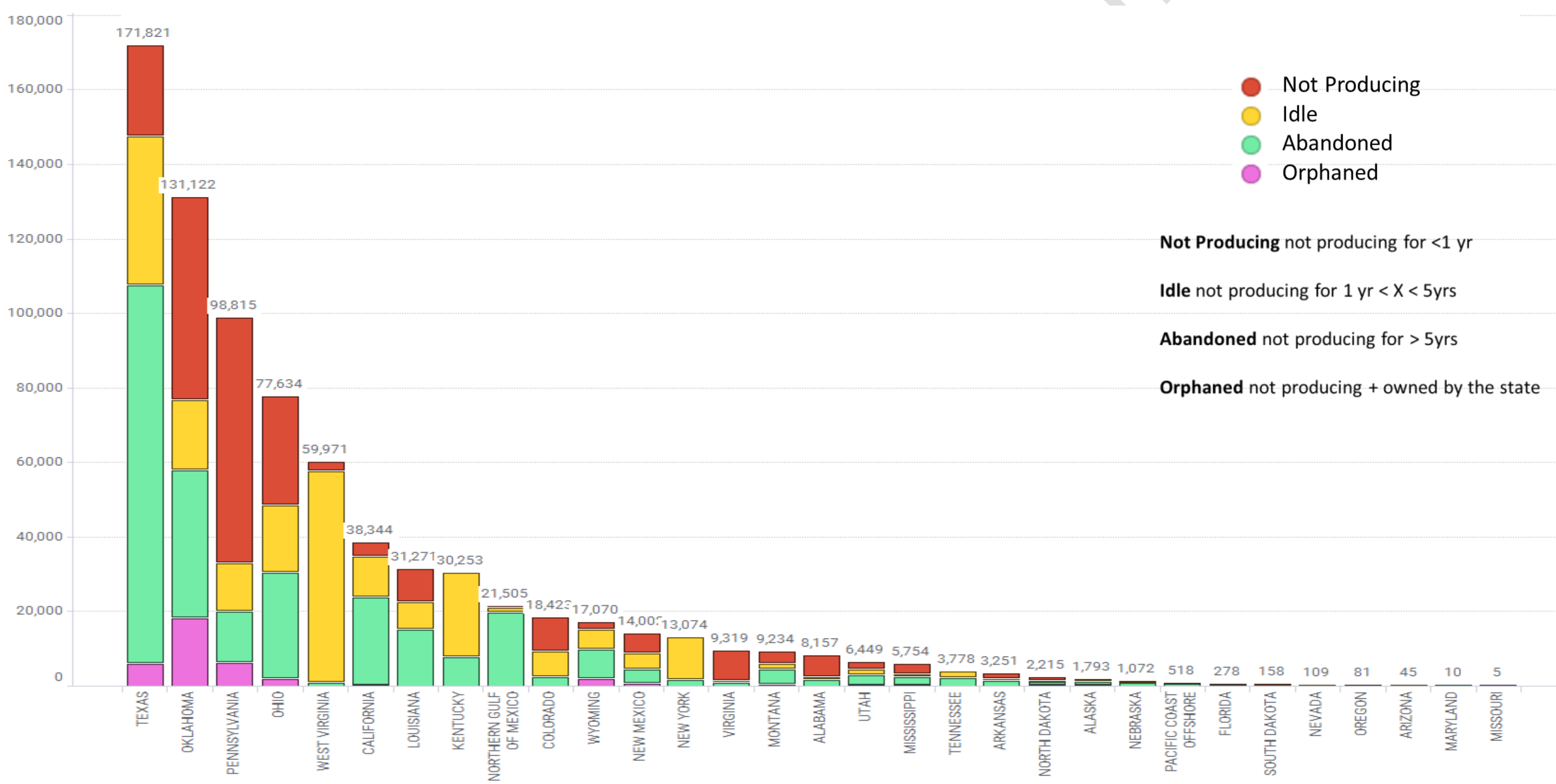
erations or other preventative measures (i.e., Mechanical Integrity Test). Loopholes to this requirement have emerged over time which has contributed to an increase in the abandoned well population as described in this methodology. Per ACR observations on *Enverus Drilling Info* database searches, as 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 10-year CH_4 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 orphaned 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[34] to have 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, certain AOGG wells detailed in Chapter 1 are considered to pass the performance standard test for additionality. Orphaned wells are a state liability, while many abandoned wells are at risk of becoming orphaned 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 AOOG 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

[34] (Kang et al., 2019)

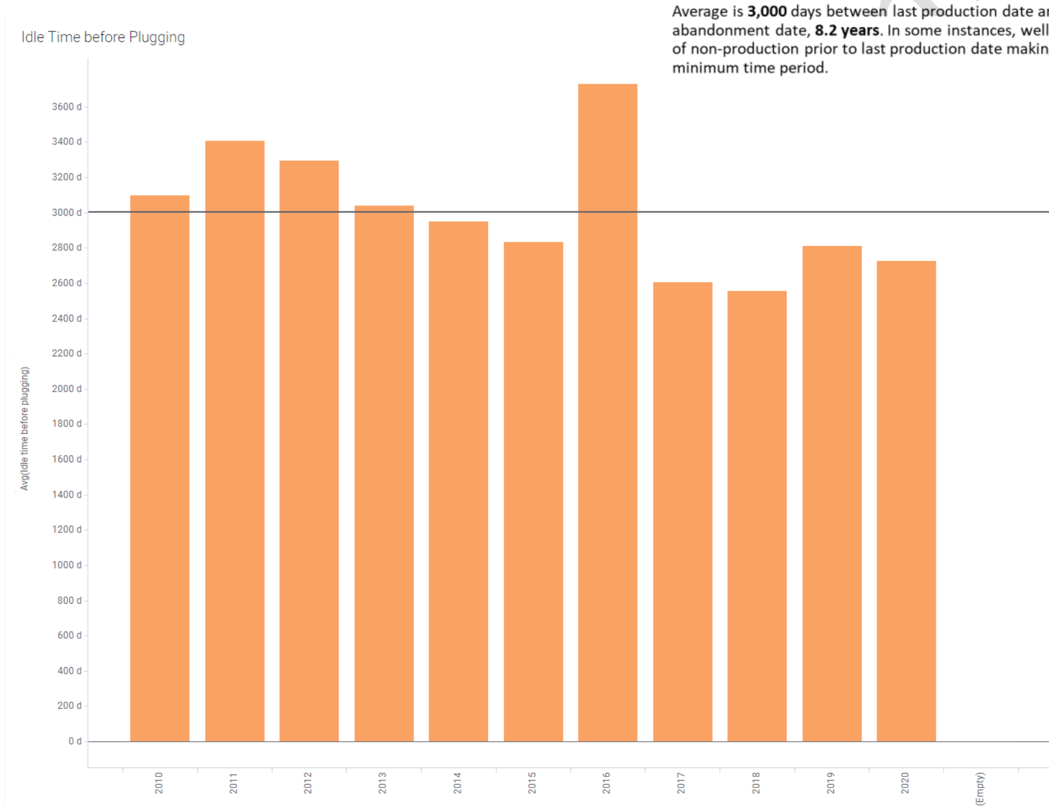
APPENDIX B: NON-PRODUCING WELLS BY STATE



APPENDIX C: AVERAGE TIME BETWEEN LAST PRODUCTION AND PLUGGING OF A WELL IN THE LAST DECADE

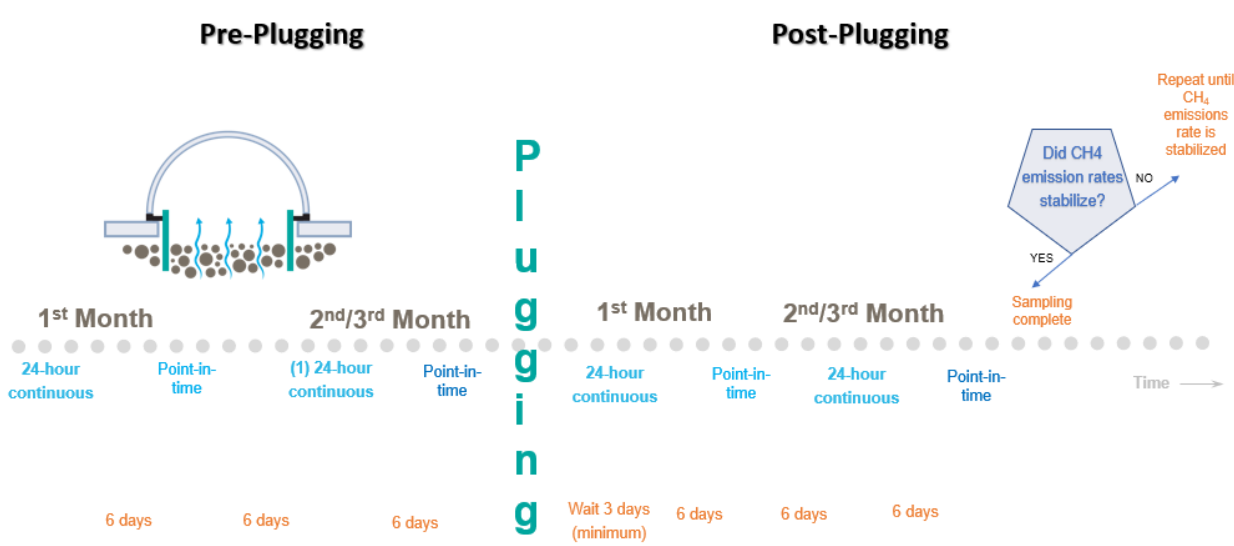
Source: Enverus

Average is **3,000** days between last production date and abandonment date, **8.2 years**. In some instances, wells had months of non-production prior to last production date making this a minimum time period.



APPENDIX D: TEMPORAL VARIATION & CHAMBER METHOD REFERENCES

Temporal Variation



References for Chamber Method Guidance

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APPENDIX E: TIME ALLOWED FOR WELLS TO BE NON-PRODUCING BEFORE P&A

AMOUNT OF TIME ALLOWED FOR EACH STEP IN THE P&A PROCESS				
US States/ CA Province	Max Well Idle time (months)	Extra months allowed	Temporary Abandonment Allowed	Possibility of Renewal
UNITED STATES				
AL	6	1	12	
AK			60	yes
AZ	1		60	
AR	24	12	36	
CA	24	36		
CO			36	
ID	24		36	yes
IL	24	60	24	
IN	2		60	yes
KS	3	12	12	yes
KY	0		24	yes
LA	6		60	
MI	12		60	
MS	12	12	Indefinite	
MT	12		Not specified	

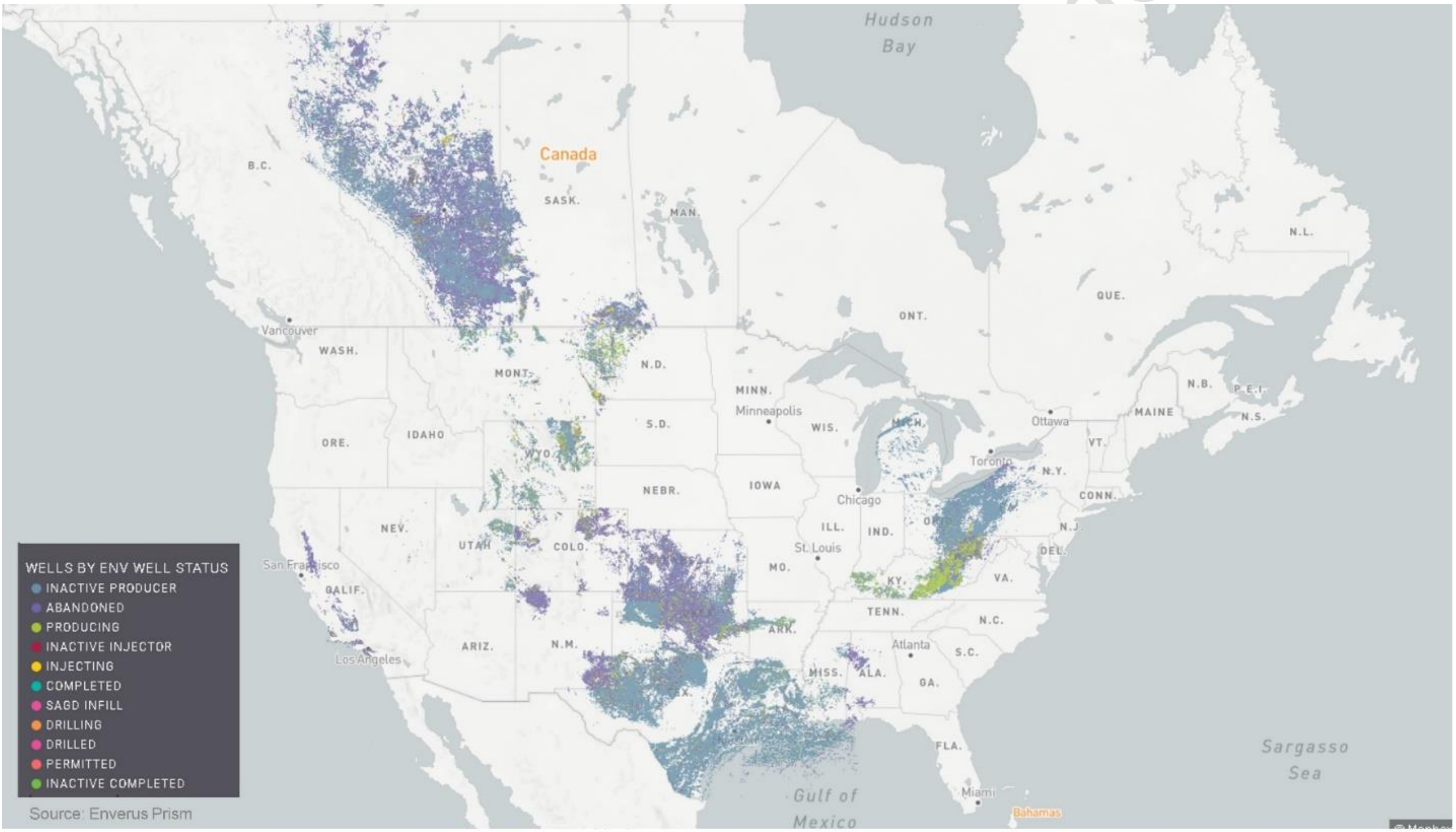
AMOUNT OF TIME ALLOWED FOR EACH STEP IN THE P&A PROCESS				
NE	12		12	
NV	12		12	
NM	15	12	60	
NY	12	3	15	
ND	12		12	yes
OH	24		12	
OK	12		Indefinite	
PA	12		60	yes
SD	12		60	yes
TX	12		Indefinite	yes
UT	12		60	yes
VA	36		Indefinite	yes
WV	12		60	yes
WY	24		Indefinite	yes
CANADA				
Alberta	18/24		Perpetuity	

APPENDIX F: EMISSION FACTORS

Project proponents shall use the current version of the U.S. Environmental Protection Agency's Power Profiler (http://oaspub.epa.gov/powpro/ept_pack.charts) to determine what regional emission factor should be used in accordance with the Emissions & Generation Resource Integrated Database (eGRID) for EFEL. eGRID emission factors are available at http://www.epa.gov/energy/egrid. To calculate emissions, project proponents shall use the below emission factors for fossil fuels which will be revised periodically based on updated information.

FOSSIL FUEL TYPE	POUNDS (LBS.) CO_2	PER UNIT	KILOGRAMS (KG) CO_2	PER UNIT	LBS. CO_2/ MMBTU	KG CO_2/ MMBTU
GASES						
Propane	12.70	Gallon	5.76	Gallon	139.05	63.07
Butane	14.80	Gallon	6.71	Gallon	143.20	64.95
Butane/ Propane Mix	13.70	Gallon	6.21	Gallon	141.12	64.01
Natural Gas	117.10	Thousand cubic feet	53.12	Thousand cubic feet	117.00	53.07
Gasoline	19.60	Gallon	8.89	Gallon	157.20	71.30
Flared natural gas	120.70	Thousand cubic feet	54.75	Thousand cubic feet	120.60	54.70
Petroleum coke	32.40	Gallon	14.70	Gallon	225.10	102.10
Other petroleum & miscellaneous	22.09	Gallon	10.02	Gallon	160.10	72.62

APPENDIX G: O&G WELLS IN THE USA AND CANADA



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