Version 1.1

BCarbon Methane Capture and Reclamation Protocol

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1. INTRODUCTION

BCarbon is a nonprofit organization creating pathways to net-zero goals that strengthen rural economies and generate ecological co-benefits including soil regeneration, improved water quality and water management, and increased biodiversity. With input from stakeholders including landowners, scientific experts, government officials, environmental organizations, and industry representatives, BCarbon develops standardized protocols to support the issuance and registration of carbon credits associated with carbon sequestration, protection, and permanent greenhouse gas ("GHG") emissions capture.

The BCarbon Methane Capture and Reclamation Protocol ("the Protocol") describes the technical approach required by BCarbon to certify GHG capture and associated land reclamation from the plugging of leaking abandoned oil and gas wells. As administrator of the Protocol, BCarbon's goal is to ensure the complete, consistent, transparent, accurate, and conservative quantification and verification of GHG emission reductions associated with a methane capture and reclamation project ("Project"). The Protocol is designed to operate within a digital measurement, reporting, and verification ("digital MRV" or "d-MRV") framework enabling automated, real-time data onboarding and data processing, quantification, and verifications. The BCarbon d-MRV framework is integrated with a registry that tracks the complete lifecycle of certified projects from project approvals, and issuance, serialization, transferring, and retirement of credits.

The Protocol also introduces important "co-benefits" of Methane Capture & Reclamation (MCR) Projects as described in section 7.0.

1.1. Methane Emissions from Oil and Gas Wells – Time is of the Essence

Methane is responsible for at least 25% of the rise in global temperatures since the start of the industrial revolution.[1] While methane's atmospheric lifetime is around 12 years vs. centuries for CO_2, it absorbs heat 200 times more efficiently than CO_2, making it 84 times as potent a greenhouse gas on a 20-year time scale.[2] In addition to its climate impacts, methane also affects air quality because it contributes to the formation of ground-level (tropospheric) ozone, a dangerous air pollutant.[3] Rapid and sustained reductions in methane emissions are key to limiting near-term warming and improving air quality.

According to the United Nations Environmental Program (UNEP), the oil and gas industry is one of the largest sources of anthropogenic methane emissions and the sector with the greatest potential for emissions reduction.[4] Furthermore, UNEP states that we cannot

[1] "Methane." NASA Climate, last modified 2022, https://climate.nasa.gov/vital-signs/methane/#:~:text=The%20concentration%20of%20methane%20in,(which%20began%20in%201750.

[2] Ruth Dasso Marlaire, "NASA Traces Molecular Characteristics that Heat Earth," NASA, May 5, 2010, https://www.nasa.gov/topics/earth/features/heat-molecules.html#:~:text=Methane%20is%20a%20trace%20gas,short%20lifetime%20of%2012%20years.

[3] "Methane Tracker 2021," IEA, accessed September 20, 2023, https://www.iea.org/reports/methane-tracker-2021.

[4] "IMEO Action," UNEP, accessed September 27, 2023, https://www.unep.org/explore-topics/energy/what-we-do/methane/imeo-action.

meet the Paris Agreement and avoid exceeding 1.5°C without achieving deep reductions in methane emissions from the global oil and gas industry.[5]

Recent numbers released by the U.S. Environmental Protection Agency (EPA) in their Inventory of U.S. Greenhouse Gas Emissions and Sinks report estimate that there are about 3.7 million abandoned oil and gas wells (including orphaned wells and other non-producing wells) within the United States.[6] Plugged wells each emit on average less than 1 kg CH_4 per year, while an unplugged well will emit over 100 kg CH_4 on average in the same year.[7]

Academic field surveys indicate that the majority of active wells emit methane.[8] These emissions are primarily due to maintenance issues.[9] While there is little academic work specifically targeting inactive wells, these are expected to have even more severe maintenance inadequacies, driven primarily by a lack of funding and oversight. As a result, inactive wells are believed to be a significant source of methane emissions.

1.2. Definitions

Term	***Definition***
Abandoned Wells	The term used throughout this Protocol to describe unplugged wells that are not currently in production and which have a known, solvent operator. BCarbon acknowledges that wells in this category may be referred to by other terms in different states or jurisdictions; it is the category, not the specific term, that is relevant for the purposes of eligibility.
Additionality	An evaluation used in carbon markets to demonstrate that the results of a crediting initiative would not have occurred in absence of the incentive of carbon credits. A project is considered “additional” if it would not have happened in a business-as-usual scenario without the crediting project; it is “non-additional” if it would have still occurred.

[5] “Emissions Gap Report 2022,” UNEP, accessed September 21, 2023, https://www.unep.org/resources/emissions-gap-report-2022.
[6] “Inventory of U.S. Greenhouse Gas Emissions and Sinks,” EPA, accessed September 21, 2023, https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks.
[7] EPA, “Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2021" (2023): 3-111.https://www.epa.gov/system/files/documents/2023-04/US-GHG-Inventory-2023-Main-Text.pdf
[8] Mark Omara et al., “Methane Emissions from Low Production Oil and Natural Gas Well Sites,” *Nature Communications* 13, no. 2085 (2022).
[9] J. A. Deighton et al., “Measurements show that marginal wells are a disproportionate source of methane relative to production,” *Journal of the Air & Waste Management Association* 70 (2020): 1030–1042.

Term	*Definition*
American Petroleum Institute (API)	A national trade association that represents the interests of the United States oil and natural gas industry and sets standards for the industry.
Baseline Emissions	Emissions likely to occur if the Project is not implemented.
Carbon Dioxide Equivalent (CO_2e)	A standard unit of measure to express the impact of each different greenhouse gas in terms of the amount of CO_2 that would create the same amount of global warming.
Digital MRV (d-MRV)	An advanced methodology for Monitoring, Reporting, Verification (MRV) that applies digital technologies to streamline data collection, processing, and quality control in the issuance of GHG emission credits.
Environmental Attribute	Greenhouse gas emission reduction recognition in any form, including verified emission reductions, voluntary emission reductions, offsets, allowances, credits, avoided compliance costs, emission rights and authorizations under any law or regulation, or under any emission reduction registry, trading system, or pursuant to any reporting or reduction program for greenhouse gas emissions that is established, certified, maintained, or recognized by any international, governmental, or nongovernmental agency.
Local Regulator	The government entity charged by the relevant state government with the oversight and regulation of oil and gas producing wells within that state. This may include multiple regulatory agencies based on the location of the well. For example, if state, Indian, or federal lands are involved, multiple regulatory agencies may be involved. Furthermore, in some areas, City or County governmental agencies may be involved.
Operator	The entity with authority to conduct oil and gas operations for an oil and gas well. The current or past Operator of a well, or Operator's affiliates, is not eligible to act as Project Developer for such well under this Protocol, with the exception of Project Developers who have legally become Operators for the sole and express purpose of plugging a well.

Term	***Definition***
Orphaned Wells	Wells without a solvent operator that require additional plugging measures to fully decommission the well.
Plug & Abandon (P&A) Activity	Any activity related to the plugging of an oil and gas well. P&A requirements vary by jurisdiction. For all P&A Activity related to a Project, Project Developers must demonstrate Regulatory Compliance.
Pre-Plugging Test	The test performed at each well to confirm the presence of methane in excess of 1,925 parts per billion, which is the globally averaged mean atmospheric methane concentration for December 2022 as reported by NOAA (https://gml.noaa.gov/ccgg/trends_ch4/).
Project Developer	The entity that (i) has a demonstrated contractual right to receive environmental attributes related to the decommissioning of the target wells, and (ii) submits an application for project approval and quantification of emissions reduction with BCarbon per the terms of this Protocol. A well's current or past Operator, or Operator's affiliates, are not eligible to be Project Developer, with the exception of Project Developers who have legally become Operators for the sole and express purpose of plugging a well.
Contractual Right to Environmental Attributes	Legally binding agreement demonstrating (i) the exclusive right to either perform the Project or incentivize the performance of the Project and (ii) the right to receive the Environmental Attributes of the Project.
Regulatory Compliance	The adherence to laws, regulations, and statutes enforced by the governmental or regulatory bodies pertinent to a Project based on the jurisdiction in which it operates.
Roles-Based Access	The assignment of access rights to property for entities based on their role within a program. Such access allows transparency in the carbon credit buying and selling process.

Term	Definition
Total Project Emissions (TPE)	The carbon emissions accounted for during the production activities of a Project, measured in tons of Carbon Dioxide Equivalent *(tCO_2e)*, to be offset against the prevented emissions resulting from Project execution.

1.3. Protocol Purpose and Overview

The purpose of the Protocol is to incentivize the permanent capture of methane present in hydrocarbon reservoirs associated with leaking abandoned oil and gas wells and the reclamation of related surface sites. In addition to significant methane emissions, unplugged wells pose many health, safety, and environmental risks, including toxic water and air hazards (from hydrogen sulfide), flash fires, vapor cloud explosions, and pool fire hazards. Permanently plugging abandoned wells eliminates these hazards as well as the risk of further methane emissions.

This Protocol issues carbon credits for plugging eligible wells using historical production decline curve analysis combined with a leak estimation model. The key underlying observation is that leaking wells eventually completely exhaust the gas that is potentially available over long time-horizons. Field observations of long-inactive wells indicate that the methane is exhausted somewhere within a time horizon of 50-60 years.[10,11] The method of estimating a well's reservoir contents, as well as the method of estimating a well's leaks over time, are described in Section 5 and in Appendices B and C of this Protocol.

Carbon credits issued by BCarbon under this Protocol will be calculated by subtracting a Project's Total Project Emissions (TPE) from its Baseline Emissions.

[10] J.A. Deighton et al., "Measurements show."
[11] A. Townsend-Small et al., "Emissions of coalbed and natural gas methane from abandoned oil and gas wells in the United States," *Geophysical Research Letters* 43, no. 5 (2016): 2283–2290

2. PROJECT ACTIVITIES

Figure 1 below illustrates the steps Project Developers and BCarbon will follow when completing Projects under this Protocol, including the issuance and registration of carbon credits.

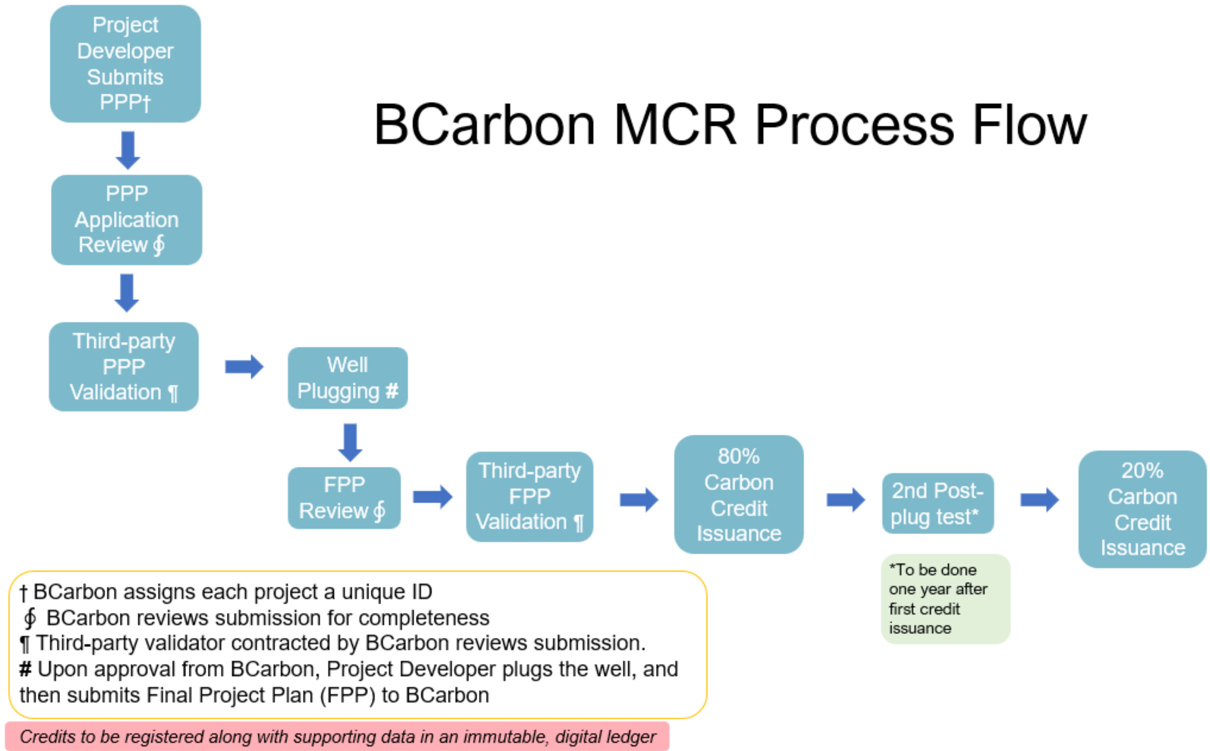

Figure 1. BCarbon Protocol Flowchart

3. APPLICATION OVERVIEW

3.1. Project Submission

Project Developer will submit to BCarbon:

1. A Provisional Project Plan that includes the following :
    a. Project Summary Table that includes summary details for every well included in the Project
    b. Well Details Summary that includes information for each well included in the Project, **<u>including Pre-Plugging Test for each well to confirm the presence of methane</u>**
    c. Well Plugging Plan for each well that includes, at a minimum, all completed forms required by the Local Regulator to maintain Regulatory Compliance through the P&A process
    d. Well Additionality Summary for each well in the Project
    e. Attestation of Contractual Right to Environmental Attributes
    f. Emissions Reduction Report that includes all calculations for estimating Baseline Emissions, Project Emissions, and Post-Project Emissions (assumed to be zero) for each well in the Project
2. Final Project Plan (post-plugging) that includes:
    a. Updates to each section of the Provisional Project Plan, **<u>including the Post-Plugging Test confirming the well has been plugged and is no longer leaking</u>** and acknowledging **<u>a Second Post-Plugging test to be performed on or around the first anniversary of the initial issuance of credits</u>**.
    b. Final GHG Calculations
    c. Demographic Details (see Submittal Guidance document for more information), including but not limited to demographic details listed below:
        i. # of aquifers within 5 miles of the well
        ii. # of water wells within 5 miles of the well
        iii. # of children, women of child-bearing age, and other vulnerable groups within 5 miles of the well
        iv. # of hospitals, nursing/retirement homes, schools, churches, playgrounds, etc.
        v. List of endangered species within 5 miles of the well
        vi. Agricultural land acreage within 5 miles of the well
        vii. Total acreage of land reclamation across all wells
3. Co-Benefits Summary (as applicable)

See associated Guidance for further details on requested format, file type, data source, etc. of each submission.

3.2. BCarbon Review

After the Developer has submitted the Provisional Project Plan, BCarbon will review it and inform the Developer if they have a complete Provisional Project Plan If the

Provisional Project Plan is incomplete, BCarbon will request additional materials from the Project Developer.

After acknowledging the Developer has a complete Provisional Project Plan, BCarbon will conduct a thorough review of the PPP with support from third-party VVBs. Once this process is complete, BCarbon will notify the Developer that they either have 1) an approved project or 2) deficiencies in the Developer's Provisional Project Plan.

Submissions and notifications regarding the Final Project Plan will follow the same order and structure used for the Provisional Project Plan outlined above.

The internal review by BCarbon's team will assess all Project submissions, including GHG calculations, well Additionality, and Regulatory Compliance. This review will also include working with contracted engineers to verify and validate each Provisional and Final Project Plan.

BCarbon agrees to process the Provisional and Final Project Plans as timely as reasonably practicable. Specific timing will vary as BCarbon fine-tunes the application processing procedures and depending on the number of wells in an application.

Process of Validation, Approval, Development, and Issuance of Carbon Credits:

1. Developer submits Provisional Project Plan to BCarbon
2. BCarbon reviews Provisional Project Plan for completeness
3. BCarbon notifies Project Developer of application completeness
4. BCarbon selects and contracts with a third-party validator to review the Provisional Project Plan. Project Developer is responsible for such validation costs and will be notified of the estimated costs of validation prior to an agreement
    a. Validator reviews and returns a sealed Validation Certificate to BCarbon,
5. BCarbon issues carbon credits for Project, subject to final Total Project Emissions figures, such carbon credits to be held on the BCarbon Registry within a Lock-Box Account to be released to the appropriate Project Developer account upon BCarbon receiving the Final Project Plan with final Total Project Emissions figures
6. Project Developer submits Final Project Plan to BCarbon
7. BCarbon receives Final Project Plan and reviews it with a third-party validator, following the same contracting process as outlined for the Provisional Project Plan. Once the Final Project Plan is approved by BCarbon and the validator, BCarbon automatically releases eighty percent (80%) of the carbon credits from the Lock-Box Account to the appropriate Project Developer's account. The remaining twenty percent (20%) of the credits will be released subject to the Second Post-Plugging Test confirming that the well remains plugged and that fugitive methane emissions are not present.

4. PROTOCOL SUMMARY AND PROJECT REQUIREMENTS

This Protocol provides the quantification and accounting frameworks for carbon credits generated from the capture of methane emissions by plugging leaking abandoned and orphaned oil and gas wells and reclamation of the associated surface site. The Protocol provides for the estimation of the remaining methane in the reservoir and allocates credits for preventing the potential release of that gas into the atmosphere.

In this methodology, the term "abandoned wells" will refer to unplugged wells with no recent production which have a known, solvent operator.

4.1. Eligibility

1. Geographic scope:
    a. Projects must be located in the United States or Canada.
2. Accepted well types:
    a. On-land or onshore wells (over freshwater) registered with the appropriate Local Regulator as oil or natural gas producing wells
    b. Only ***compliant*** wells are accepted under this protocol – see section 4.2 for more information.
3. Well with proof that either:
    a. The well has been transitioned to a non-producing status in filings with the Local Regulator or attestation from a certified engineer; or
    b. There has been no net production in the past 3 months
4. Presence of Methane:
    a. A Pre-Plugging Test has confirmed the presence of methane at the wellhead in excess of 1,925 parts per billion, which is the globally averaged mean atmospheric methane concentration for December 2022 as reported by NOAA[12]

4.2. Regulatory Compliance

Wells must be in compliance with the Local Regulator or, in the course of the project, be brought into compliance with the Local Regulator.

At the conclusion of the project, the wells covered must receive approval from the Local Regulator that they have been appropriately plugged and decommissioned, including removal of any equipment and suitable remediation of the site surface soil and vegetation, as required to maintain Regulatory Compliance.

4.3. Earning of Credits

Eighty percent (80%) of total issuable credits will be issued upon completion of BCarbon's review of the Final Project Plan, as described in Section 3. The remaining twenty percent

[12] X. Lan, K.W. Thoning, and E.J. Dlugokencky. "Trends in globally-averaged CH4, N2O, and SF6 determined from NOAA Global Monitoring Laboratory measurements." Version 2023-09

(20%) of total issuable credits will be issued after the second post-plugging test confirms that the well is plugged with no fugitive emissions, to be conducted on or around the first anniversary of the first credit issuance, as illustrated below. If the second post-plugging test confirms the plugging has failed, some or all of the remaining credits to be released may be held by BCarbon at their sole discretion to offset the estimated amount of methane leak.

In the event that the surface owner of the well site refuses to allow testing personnel onto the property for the second post-plugging test, Developer shall submit a statement from the surface owner denying access to the site or affidavit stating that Developer has pursued all due diligence in attempting to access the well site.

Tranche 1: Upon Completion of BCarbon's review of the Final Project Plan	80% of credits
Tranche 2: One year from the date of Tranche 1 issuance, pending Second Post-Plug results	20% of credits

4.4. Project Boundaries

4.4.1 Geographic Boundaries

The geographic boundaries will include the surface wellhead, surface equipment, and surface pad associated with the registered well. Any surface area considered by the Local Regulator to be within scope of their authority by virtue of the presence of the project well will be considered within the geographic boundaries of the project.

4.4.2 GHG Assessment Boundaries

Qualified Projects occur in scenarios where methane would, if not for the enactment of the Project, be released from target wells into the atmosphere. Furthermore, in cases where methane is being released from any surface equipment attached to target wells, such emissions may also be measured and reported for net emission reductions.

4.5 Validation and Verification

BCarbon is committed to certifying quality projects that will result in real climate impacts; each project and application package shall be subject to review, validation, and verification. In particular, BCarbon reserves the right to verify project outcomes throughout and beyond the 2-year period following the P&A of well(s) covered by the Project Developer's application and credits.

5 QUANTIFICATION OF GHG EMISSIONS REDUCTIONS

5.1 Baseline Reference Case

The baseline reference case is a scenario where the methane being emitted from target wells into the atmosphere is not restricted by the Project. The baseline compared against the post-plugging calculation is established by the predicted emissions that would have been released without the Project Developer's implementation of the MCR Project.

Pre-plugging reservoir estimation is required to obtain an estimate of the well's business-as-usual, Baseline Emissions. Pre-plugging reservoir estimates shall approximate current active leaks as well as future potential leaks by estimating how much methane is in the well's reservoir, and how much methane will leak out over time. The method required for estimating reservoir contents is the standard industry decline curve analysis, supplemented with additional gas composition sampling, if needed. The method required for estimating leaks over time is the leak probability model. These methods are detailed in section 5.2 and in Appendices B and C.

For wells without a documented history of natural gas production, BCarbon may entertain alternative methods of estimating reservoir contents and future leak rates. Project Developers with such Projects should present alternative methods to BCarbon for eligibility consideration.

5.2 Production Decline Curve Analysis and Leak Estimation

This method follows the industry standard for estimating the remaining reservoir natural gas, similar to the methods originally outlined by J.J. Arps.[13,14] For each individual well:

1. Estimate the decline rate:
    a. Source at least 42 months of production history for each individual well, sorted by production date.
    b. Drop records with zero producing days and zero monthly production to avoid distorting any indications of production.
    c. Calculate average production per day for each month with non-zero producing days, defining each of these averages as P_i for month i.
    d. Keep the last 36 records (if available) or all production records (if fewer than 36)
    e. For each of the three 12-record periods $\{P_1, \ldots, P_{12}\}$, $\{P_{13}, \ldots, P_{24}\}$, $\{P_{25}, \ldots, P_{36}\}$, calculate the mean (m) and standard deviation (s) of production.
    f. Within each of these three 12-month periods, drop outlying records with production P_i where $ABS(P_i - m) > 2s$, for the m and s of that 12-month period.

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[13] J.J. Arps, "Analysis of Decline Curves,*" Transaction: Society of Petroleum Engineers of the American Institute of Mining Metallurgical and Petroleum Engineers Incorporated* 160 (1944): 228-247.
[14] J.J. Arps, "Estimation of Primary Oil Reserves," *Petroleum Transactions, AIME* 207 (1956):182-191.

g. Take the 6-month moving average of the production, denoted as $\{Q_1, \ldots, Q_{36}\}$. This smooths the data.
h. Estimate a regression line described by the natural log (ln) of (Q_i) against time (T) measured in producing days (Equation 1).

Equation 1. This regression estimates parameters A and B in the model. This is fitting an exponential decline curve to the production rates.

$$ln(Q) = A * T + B$$

Where:		UNITS
Q	Smoothed production rate data	MCF/day
A	Decline rate per day	Log(MCF/day)/day
T	Cumulative time of production from the start of the sample	Days
B	Best fit parameter for the level of production in the sample	Log(MCF)

i. The estimated annualized decline rate (EADR) is calculated using Equation 2.

Equation 2. Estimated Annualized Decline Rate.

$$EADR = (1+A)^{365.25}-1$$

Where:		UNITS
EADR	Estimated Annualized Decline Rate	Percent per year
A (from equation 1)	Decline rate per day	Log(MCF/day)/day

To calculate the effective annualized decline rate (ADR), first compare EADR to –3% and take the smaller value. Then, compare that value to –30% and use the greater of those values as your ADR.

Equation 3. Effective Annualized Decline Rate.

$$ADR = max(-30\%, min(-3\%,EADR))$$

Where:		UNITS
ADR	Effective Annualized Decline Rate	Percent per year

EADR	Estimated Annualized Decline Rate	Percent per year

The decline rate is bounded above and below to eliminate results that are inconsistent with industry experience for end-of-life wells.

2. The fitted last production (FLP) is calculated using Equation 4.

Equation 4. Fitted Last Production.

$$FLP = e^{\frac{ZN}{365.25}+B}$$

Where:		UNITS
FLP	Fitted Last Production	MCF/day
Z	Minimum of A *365.25 and -3%	Percent per year
N	Number of producing days between the first and last production records (normally P_0 and P_{36})	Days
B (from equation 1)	Best fit parameter for the level of production in the sample	Log(MCF)

3. The last production estimate (LPE) is determined by Equation 5.

Equation 5. Last Production Estimate.

If EADR < -3%, then LPE = FLP.
If EADR > -3%, then LPE = m for the latest 12-record period.

Where:		UNITS
EADR	Estimated Annualized Decline Rate	Percent per year
LPE	Last Production Estimate	MCF/day
FLP	Fitted Last Production	MCF/day
m	Mean for the latest 12-record period (as calculated in 1.f. above.	MCF/day

4. Estimate the methane fraction of the gas. Project Developers may follow either of two approaches to determine the methane fraction of gas (MFG):

a. Table based on the Gas Research Institute survey "Chemical Composition of Discovered and Undiscovered Natural Gas in the Lower-48 United States; Volume 3: Associated/Dissolved Gas Data" as updated in 1993 and published by the US Department of Commerce:[15] Identify the table associated with the region and the vertical depth for the well. Use the mean value of methane from the table as the MFG.
b. Sample 1 liter of gas from the well and determine the gas composition using a third-party laboratory service using a gas chromatograph. The percentage of methane in the sample can be used as the MFG.

5. Calculate the expected leaks over the target time horizon:
   a. Use the BCarbon Leak Probability Model. This model incorporates the following:
      i. Input characteristics of the well: completion date, shut-in date, sour/non-sour production mix
      ii. Input state of the well (existing leaks, current pressure in the wellbore)
      iii. Fault tree incorporating industry reference estimates of mean service life to determine the probability of the well transitioning into a small leak or large leak state
      iv. Forecast flow rates under multiple leak-states (i.e., large leak, small leak, no leak)
   b. Run the leak model with three standardized parameters:
      i. Flow rate reference for large leaks of 50 years
      ii. Decline time horizon for small leaks of 100 years
      iii. Crediting time horizon of 20 years
   c. will be the total gas leaked, TGL.
6. Methane available to leak (MAvail) will be the probability-weighted sum of the amounts of gas leaked in each state over 20 years.

5.3 Pre-Plugging Emissions Calculations

Baseline Emissions will be set according to the following formula:

1. First, the methane available to leak (MAvail) is determined above in Section 5.2. in units of MCF CH_4 as described above in section 5.2
2. Second, the equivalent amount of atmospheric carbon dioxide (Est_tCO_2e) is calculated using Equation 6.

Equation 6. Equivalent Amount of Atmospheric Carbon Dioxide.

$$Est\_tCO_2e = MAvail * Density * GWP20$$

Where:		UNITS
Est_tCO2e	Equivalent Amount of Atmospheric Carbon Dioxide	tCO2e

[15] R.H. Hugman, P.S. Springer, and E.H. Vidas, *Chemical composition of discovered and undiscovered natural gas in the United States, Volume 3,* 1993.

MAvail	Methane Available to Leak	MCF CH_4
Density	Metric density of methane at STP = 0.0418	lb/cu ft
GWP20*	GWP20 = the 20-year global warming potential for methane as reported in the most recent Intergovernmental Panel on Climate Change (IPCC) Assessment Report (AR.)	tCO2e/tCH4

* Developers shall use the most recent IPCC guidance available at the time of their application submission to BCarbon. As of 25 November 2022, GWP20 is 84, as reported in the IPCC AR5 Working Group 1, Chapter 8, Table 8.7.

3. The project pre-plugging baseline emissions (BE) are calculated using Equation 7.

Equation 7. Project Pre-Plugging Baseline Emissions.

$$BE = min(Est\_tCO_2e, P\_Max)$$

Where:		UNITS
BE	Project Pre-Plugging Baseline Emissions	
Est_tCO_2e	Equivalent Amount of Atmospheric Carbon Dioxide	tCO2e
P_Max	Protocol maximum allowance = 63k tCO2e	tCO2e

BCarbon will consider issuing credits at volumes greater than P_Max (63k tCO_2e) on a case-by-case, per-well basis.

5.4 Post-Plugging Emissions Calculations

Post-plugging emissions are expected to be negligible for a well that has been decommissioned correctly and each site must comply with all local requirements for regulatory recognition that the well has been plugged and abandoned.

5.5 Project Emissions

The following categories of project emissions sources must be assessed and reported:
1. Materials emissions from concrete used for plugging
2. Fuel for equipment and materials transported to project site

3. Fuel for rig operation during plugging activity
4. Methane vented during baseline measurement

Project Developers shall use the current version of the U.S. Environmental Protection Agency's Emission Factors Hub[16] to determine the correct factors to use for their equipment. For diesel fuel, use No. 2 Fuel Oil.

Together, these categories constitute TPE, the total project emissions in terms of tCO_2e. TPE can be accounted for with multiple methods, provided that the Developer clearly outlines their process. See the Guidance Document for further information on specific TPE accounting methods.

After a well is plugged, there may be additional Project Emissions associated with verification (for example, emissions from flyovers). In such cases, the additional Project Emissions will be deducted from the amount of credits allocated to the Project Developer in later tranche(s). BCarbon will communicate with Developers on their options and issue specific requirements in any future verification guidelines.

5.6 Uncertainty Discount

An uncertainty discount will be deducted from granted credits as a buffer against failed plugs from any wells for which credits have been granted in this Protocol. The uncertainty discount for each Project will be 5% of measured gross credits: $D = 5\%$.

5.7 Net Emissions Reductions

The net emissions reduction is calculated using Equation 8.

Equation 8. Net Emissions Reduction.

$$N = (G - TPE) \cdot (1 - D)$$

Where: **UNITS**

N	Net Emissions Reductions	tCO2e
G	Gross Emissions Reductions	tCO2e
TPE	Total Project Emissions	tCO2e
D	Uncertainty Discount (5% of total credits)	tCO2e

[16] Visit the US EPA's GHG Emissions Factors Hub

The number of credits issued will be equal to the net emissions reductions once total project emissions are deducted from gross emissions reductions and reduced by the uncertainty discount.

5.8 Plugging Confirmation

Prior to credits being issued, Project Developers must demonstrate that the well has been designated as "plugged", or equivalent, by the Local Regulator. Also prior to all credits being issued, a post-plugging test and a second post-plugging test are required, confirming that emissions have been reduced to at or below the 1,925 parts per billion threshold.

5.9 Quality Assurance and Control

5.9.1 Credit Ownership

The Project Developer must demonstrate a contractual right to receive environmental attributes related to decommissioning of the target wells from a contractual chain originating with the current operator of the wells.

5.9.2 Plugging and Surface Reclamation Standards

In the absence of plugging requirements set by local and state authorities, Project Developers are required to follow guidelines for design, placement, and verification of cement plugs as set by the American Petroleum Institute (API) Recommended Practice (RP) 65-3 – Wellbore Plugging and Abandonment Standard for US projects, and the Alberta Energy Regulator (AER) Directive 020: Well Abandonment for Canadian projects. Where applicable, plugging, abandonment, and restoration must meet contractual requirements within existing mineral leases should those requirements exceed regulatory minimums. Such requirements are out of the purview of BCarbon and are solely within the Project Developer's responsibility.

5.9.3 Digital MRV Recording

The MCR Project is assigned a Unique ID which allows access to "digital MRV" (d-MRV) and asset data that records:

1. the complete crediting "lifecycle" of the Project including credit issuances, transfers and retirements;
2. relevant information from field monitoring, emission factors, data refinements, verifications, and other relevant inputs;
3. the complete profile of physical and environmental attributes of the Project including the environmental conditions determined from the site analysis

"Roles-based" access to d-MRV asset data is provided through a 3rd party registry that is integrated with BCarbon to participants in the generation and market application of the BCarbon credits including owners of primary data (e.g., landowners, operators, and Project Developers) and secondary data refiners, and 3rd party auditors.

6 DEMONSTRATING ADDITIONALITY

A well is Additional if, at the time of plugging, no person or entity has a firm, non-extendable legal obligation to plug it either (a) by law, regulation, statute, court order or other government requirement, or (b) by private contract (e.g., pursuant to a lease, service, or other agreement with a third party).

No credits will be granted for a well that is included in a project registered under another carbon crediting protocol, whether with BCarbon or another carbon registry.

7 ENVIRONMENTAL AND COMMUNITY CO-BENEFITS

There may be co-benefits associated with Project activities. For example, the reclamation of land surfaces could result in soil-regeneration and increased biodiversity. Reporting Project co-benefits is optional. Potential co-benefits include:

- Soil regeneration
- Increased biodiversity
- Improved water quality
- Removal of potential liabilities for state governments, local communities, and taxpayers
- Improved air quality
- Job creation
- Improved human health conditions

Project Developers should communicate to BCarbon if they wish to combine the MCR Protocol with other BCarbon protocols.

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Appendix A: Engineering Support Letter

RALPH E. DAVIS
AN OPPORTUNE COMPANY

Overview

We (Ralph E. Davis Associates or "RED") have been asked to evaluate the method described in the attached spreadsheet and documentation (the "Proposed Method") devised for estimating the amount of methane gas that can be expected to leak in future years from a portfolio of wells, given certain general premises and well-specific data.

The well-specific data include the last 36 months of historical production volumes, the year the well was shut-in, the presence of an intact surface casing (or "bradenhead") valve, the detection of methane leaking from the well and the presence of sustained casing pressure. The general premises include no change to existing laws and regulations or the way they are enforced, and no change to current operations for each well in the portfolio, including no plugging and abandonment.

Opinion of the Proposed Method

It is our opinion that the Proposed Method provides a reasonable means of estimating the future methane emissions, its specifications are reasonable, and the methods it employs are consistent with standards and principles generally accepted in the petroleum industry (where such industry standards exist).

The scope of our review and basis for our opinion is shown in Exhibit A.

Disclaimer

Our opinion does not in any way constitute or make a guarantee or prediction of results, and no warranty is implied or expressed that any actual outcome will conform to any outcome based on the Proposed Method.

The opinions expressed herein are subject to and fully qualified by the generally accepted uncertainties associated with the interpretation of geoscience, engineering and production data and do not reflect the totality of circumstances, scenarios and information that could potentially affect actual results and/or decisions made that rely on this report.

There are numerous uncertainties inherent in estimating hydrocarbon resources and in projecting future methane emissions. Oil and gas resources assessments must be recognized as a subjective process of estimating subsurface accumulations of oil and gas that cannot be measured in an exact way.

Projections of methane emissions that are prepared by other parties or measured at the well may differ, perhaps materially, from those estimated by the Proposed Method. Any projection of methane emissions for a given well necessarily involves substantial uncertainty regarding its accuracy. Such uncertainty is based on the availability and quality of the well information, how such information is interpreted and the variability of the population of wells with characteristics similar to the given well.

Statement of Independence

In performing this study, RED is not aware of any conflicts of interest. As an independent consultancy, RED provides impartial technical, commercial, and strategic advice within the energy sector. In the preparation of this document, RED has maintained, and continues to maintain, a strict independent consultant-client relationship with the Client. RED's remuneration was not in any way contingent on the contents of this report.

The management and employees of RED have no interest in any of the methods evaluated or related to the analysis performed, as part of this report. Staff members who prepared this report hold appropriate professional and educational qualifications and have the necessary levels of experience and expertise to perform the work. This report was prepared for public disclosure in its entirety in conjunction with the promulgation of a carbon offset protocol.

Steve Hendrickson, P.E.

President

Ralph E. Davis Associates LLC

Exhibit A

Summary of RED's Review of the Proposed Method

Proposed Method Parameter	How addressed in the Proposed Method	RED's Review
Amount of gas that is available to leak	Best-fit estimate of exponential decline of last 36 months of gas production data (subject to minimum and maximum declines of 3 and 30%) for 30 years	RED back-tested the method against the actual results of approximately 5000 randomly selected producing gas wells in selected basins in the Onshore US, and found that it generated, in the aggregate, estimates of volumes produced over five years that were within approximately 10% of the actual volumes. Individual well results varied, however.
Point in time the well began leaking	Date of last production according to public records	The actual date a well began leaking is typically unknown. This is a conservative assumption that reduces the amount of methane available to be leaked in the future
Gas leak rate	The weighted average between a "large" leak and a "restricted" leak	This is an approach to account for uncertainty in the leak rate
Probability of a "large" leak	10%	Based on "Risk Assessment of Temporarily Abandoned or Shut-in Wells", prepared for the US Department of the Interior, Minerals Management Service, October 2000
"Large" leak rate	50% of the forecasted rate obtained from the exponential decline forecast	This is a specified value in the Protocol.
“Large” leak volume	The volume that would have been produced over 30 years using the extrapolated best-fit exponential decline parameters	The 30-year period is a specified value in the Protocol.
“Large” leak decline rate	Calculated to match the “large” leak volume over a 50- year period, in combination with the “large” leak rate. Minimum value of 0%.	The 50-year period is a specified value in the Protocol.

"Restricted" leak rate	20% of the "large" leak rate, used to match the "large" leak volume, in combination with the "restricted" leak decline rate over the extended time window.	This is a specified value in the Protocol.
"Restricted" leak decline rate	Calculated to match the "large" leak volume over a 100- year period, in combination with the "restricted" leak rate. Minimum value of 0%.	The 100-year period is a specified value in the BCarbon Methane Capture and Reclamation Protocol.

Methane concentration of leaked natural gas	Based on actual gas analysis from the well or within the field; if unavailable, based on published literature	Although a sample from the well (or another well in the field) is the best estimate, there are numerous other sources that can provide reasonable estimates of methane concentration in natural gas. One example is "Chemical Composition of Discovered and Undiscovered Natural Gas in the United States, 1993 Update: Volume 3" prepared for the US Department of Commerce
Methane Greenhouse Gas 20 Year Equivalency (GWP20)	84 tons CO_2 equivalent/tons methane	The Intergovernmental Panel on Climate Change (IPCC) estimates this value to be between 84 and 87

Appendix B: Decline Curve Model

An illustrative example of the decline curve analysis described in Section 5.2 is included in the attached Microsoft Excel spreadsheet “Decline_Curve_Model.xlsx.”

Appendix C: Leak Model

The Leak Model is attached as a Microsoft Excel spreadsheet titled "Leak_Rate_Model.xlsx." This section is a user guide to understanding and applying this model.

Model Inputs

For each well, enter the following well-specific inputs, all on the primary sheet "Leak Rate:"

Input	Cell location	Type	Example
Sour / non-sour?	'Leak Rate'!B4	Binary drop-down	non-sour
Bradenhead valve present?	'Leak Rate'!B5		yes
Sustained casing pressure?	'Leak Rate'!B6	Binary drop-down	yes
Methane detected?	'Leak Rate'!B7	Binary drop-down	yes
Year drilled	'Leak Rate'!B10	Four-digit integer	2006
Year shut-in	'Leak Rate'!B11	Four-digit integer	2010
Plugging year	'Leak Rate'!B12	Four-digit integer	2023
Last rate, mcfpd	'Leak Rate'!B17	Floating point number	8.87
Exponential decline rate, %pa	'Leak Rate'!B18	Floating point number, expressed as a positive percent	3.00%
Methane concentration, %	'Leak Rate'!B21	Floating point number, expressed as a positive percent	75%
"Large" leak decline rate %pa	'Leak Rate'!B26 (see further discussion below)	Floating point number, expressed as a positive percent	0.98%
Restricted rate decline rate %pa	'Leak Rate'!B27 (see further discussion below)	Floating point number, expressed as a positive percent	0.001%

Model outputs

The model produces both intermediate and final outputs. The key intermediate outputs are the forecast of flows under the three states over the forecasting time horizon (located in 'Leak Rate'!F:M.) The final outputs are:

Output	Cell location	Type	Example
CH_4 Volume leaked pre-plugging	'Leak Rate'!B44	Floating point number, expressed as MCF	3,997
CH_4 Volume leaked post plugging in the crediting window	'Leak Rate'!B45	Floating point number, expressed as MCF	6,332
CO_2 Mass leaked pre-plugging	'Leak Rate'!D44	Floating point number, expressed as tCO_2e	6,368
CO_2 Mass leaked post plugging in the crediting window	'Leak Rate'!D45	Floating point number, expressed as tCO_2e	10,087

Model overview

The model forecasts expected leaks based on a three-state model:

1) No leak
2) "Large" leak
3) "Restricted" leak

The model uses the most recent flow and the estimated production decline rate to extrapolate a counterfactual "as-if producing" gas flow vector. For this extrapolation, the flow starts at a daily rate equal to the Last Production Estimate (LPE.) For each future year, this rate declines exponentially following the decline rate estimated from the historical production data (see section 5.2.). The sum of the values from the years from the shut-in date until the end of the "Volume Window" (from cell 'Leak Rate'!B19) in that vector is the reference potential volume of gas, This appears, in cumulative form, as DCA Forecast in column 'Leak Rate'!P.

For each of the two leak states, the model forecasts a potential flow rate over time that is similar to the DCA forecast, but with adjustments for the starting value, the number of years in the time window, and the decline rate. In each case, the associated decline rate is estimated to produce a total volume of gas equal to the reference potential volume from the DCA Forecast. This is described in more detail below.

For the "large" leak state, the starting daily rate is equal to the Last Production Estimate (LPE) multiplied by the "Large" leak factor. From that starting year, the forecast leak flow rate decays exponentially at the calculated implied rate in cell 'Leak Rate'!B26.

The forecast flows in the "Restricted" leak state are similar, though there is an additional adjustment to the starting flow rate and the associated decay rate. The starting rate is the "large" leak starting rate multiplied by the "Restricted" leak factor in cell 'Leak Rate'!B31. The decay rate for the restricted state is the calculated implied rate in cell 'Leak Rate'!B33.

From the year in which the well was shut-in, the model estimates a probability that the well is in each of the three leak states. These probabilities are used to calculate a weighted sum of the expected volume of leaked gas in that year. This weighted sum is then added for the years in the crediting window to arrive at an expected volume of leaked gas. This is then adjusted to account for the methane fraction and then converted to an equivalent mass of CO_2 under standard conditions set at 60°F and 14.5 PSIA.

Leak Decline Rates

The leaks from the well are expected to flow at a slower rate than in the counterfactual producing state used to estimate the DCA Forecast. The key underlying observation is that leaking wells eventually completely exhaust the gas that is potentially available over long time-horizons. Field observations of long inactive wells indicate that the methane is exhausted somewhere within a time horizon of 50-60 years.[17,18] Based on this observation, the two leak sub-models are calibrated to emit the same volume of gas as the DCA Forecasts, but at slower initial rates, with a longer time horizon, and a slower flow decay rate.

Leak sub-model parameters

For generating potential flows in the restricted leak state, the key parameters are:

Parameter	Value or Calculation Method	Notes
Initial "Large" leak rate	50% of the “large” leak rate	This is a specified value in the Proposed Method
“Large” leak time window	50 years	Set conservatively to fully cover the window from field observations.
“Large” leak decline rate	A positive value calculated to reproduce the DCA Forecast volume over the “Large” leak time window (for example, using excel solver or goalseek so that cell ‘Leak Rate’!B29 is as close to 0 as possible.) In cases where no positive value will produce a match with the DCA forecast volume, use 0.001% as a default value.	Implied by the assumption that the total volume of leaks will eventually match the DCA Forecast volume.
Initial "Restricted" leak rate	20% of the “large” leak rate	This is a specified value in the Proposed Method

[17] J.A. Deighton et al., “Measurements show.”
[18] A. Townsend-Small et al., “Emissions of coalbed and natural gas methane.”

"Restricted" leak time window	100 years	Set conservatively to fully cover the window from field observations.
"Restricted" leak decline rate	A positive value calculated to reproduce the DCA Forecast volume over the "Restricted" leak time window (for example, using excel solver or goal-seek so that cell 'Leak Rate'!B36 is as close to 0 as possible.) In cases where no positive value will produce a match with the DCA forecast volume, use 0.001% as a default value.	Implied by the assumption that the total volume of restricted leaks will eventually match the large leak volume

Example Calculation

For illustrative purposes, consider a well with the following characteristics:

Input	**Value**
Sour/non-sour?	non-sour
Bradenhead valve present?	yes
Sustained casing pressure?	yes
Methane detected?	yes
Year drilled	2006
Year shut-in	2010
Plugging Year	2023
Last rate, mcfpd	8.87
Exponential decline rate, %pa	3.00%

Based on these input values, the DCA forecast estimates a total volume of emissions of 64,042 MCF. To match that volume with the standard leak state parameters, the implied decline rate for the large leak is 0.98%pa and, for the restricted leak flows, the implied decline rate is 0.001%pa (the default value, as no positive value will allow a match with the DCA forecast volume.).

For this example well, the model forecasts a total volume of methane leaked in the crediting window of 6,332 MCF and a CO_2 equivalent mass of 10,087 tCO_2e.