

**VERIFICATION ON NEW UPDATED SYSTEM
PROCEDURE AND METHODOLOGY OF CARBON
SPACE TECHNOLOGY VERSION 1.1 AGAINST
CARBON SPACE TECHNOLOGY VERSION 1.0**

Client: CarbonSpace Ltd.

Date of Verification: 6th and 7th May 2024

PART 1: VERIFIED COMPANY DETAILS**1.1 Company Contact Details**

Company Name	CarbonSpace Ltd.
Contact Person	Geza Toth
Business Address	39 Northumberland Road, Ballsbridge, Dublin 4, Ireland, D04 H1F3, Dublin, Ireland
Office Contact Number	-
E-mail	geza@carbonspace.tech
Website	www.carbonspace.tech

1.2 Facilities included in the Scope of the Assessment

Name of Site	Location Address	Visited
Carbon Space Technology (Version 1.1)	39 Northumberland Road, Ballsbridge, Dublin 4, Ireland, D04 H1F3, Dublin, Ireland	Remote Assessment

1.3 Assessment Overview

Assessment Type	Year	Assessment Date
Verification on New Updated System and Methodology of Carbon Space Technology Version 1.1 against Carbon Space System Version 1.0	2024	6 th and 7 th May 2024

1.4 Assessment objective

- This verification report aims to provide a comprehensive overview of the verification process conducted for the updated system of Carbon Space Technology Version 1.1, as compared to the previous Version 1.0. The verification process includes assessing changes made to the documentation and conducting system tests at the project user level through sampling.

1.5 Opening and Closing Meeting**Attendees**

Name	Role
Dr Geza Toth	CEO, Carbon Space
Vitaly Pashkin	Product Market Acceptance Manager, CarbonSpace
Robert Granat	CTO, CarbonSpace

PART 2: INTRODUCTION

- Carbon Space Technology, known as Carbon Space dMRV, is a tool that provides benefits for corporate carbon inventories by offering access to primary carbon data, reducing uncertainties, including carbon stock changes in natural carbon pools, and assessing the impact of sustainable land management. The Carbon Space Technology is developed by Carbon Space Ltd, operating of the Dublin, Ireland.
- Net Ecosystem Exchange (NEE) is the balance of carbon exchange between ecosystems and the atmosphere, accounting for photosynthesis and respiration processes. It represents the total carbon stock change in ecosystem carbon pools, including aboveground biomass, belowground biomass, soil organic matter, and dead organic matter, before any extraction of carbon from these pools. This tool offers data on biogenic land CO₂ removal, supporting multiple carbon accounting frameworks and crediting schemes.
- CarbonSpace's dMRV tool offers a scalable solution for tracking environmental performance across sectors like food supply chains and Nature-based solutions (NBS) projects. It enables users to estimate Net Ecosystem Exchange (NEE), facilitating corporate narrative claims, setting baselines and targets, and carbon accounting reporting toward major standards like ISO14000 and corporate carbon reporting guidelines like GHG Protocol and SBTi, while also supporting life cycle assessments and carbon insetting and offsetting projects.
- The first assessment for the Carbon Space Technology Version 1.0 was conducted on 26th, 29th to 31st May 2023 and 1st & 2nd June 2023. The verification report dated 23rd July 2023 and assurance statement dated 24th August 2023 were submitted to client on 11th August 2023 and 5th September 2023, respectively.
- Carbon Space has made updates to their system and accompanying documents. The latest new upgraded system is known as Carbon Space Technology Version 1.1, and the verification was conducted on 6th & 7th May 2024 in comparing the latest with previous Version 1.0.
- This verification report provides an overview of the verification process and relevant changes of Carbon Space Technology Version 1.1 against the previous system version 1.0. The verification encompasses the update of Carbon Space Technology Version 1.1 at documentation level, including the system test at project user level, by sampling.
- The report delineates the exact objectives and extent of the verification assessment for the Carbon Space Technology, detailing the pivotal stages undertaken, and provides the assurance findings, ultimately leading to a conclusive verification opinion. These elements are further expounded upon in subsequent sections.

PART 3: CONTENT AND ROLES

- CarbonSpace is a digital measurement, reporting, and verification tool that uses direct carbon flux estimates to track carbon performance across supply chains. It disrupts mainstream accounting systems, providing accurate data for nature-based solutions projects. The technology is based on micrometeorology, remote sensing, and machine learning, offering a scalable and accurate approach to carbon monitoring. Use cases include Net ecosystem Exchange (NEE) as an individual metric, corporate carbon inventory, life cycle assessment, carbon insetting and offsetting, ecosystem health and biodiversity assessment, HCV and HCSA assessments, and regional and country-level assessments.

PART 4: METHODOLOGY

- Carbon Space has responded to the changing requirements of its users and the progress in carbon accounting methodologies by implementing substantial updates to its system and related documentation. The updated system and documents underwent a verification assessment process to ensure that the changes made to the system and procedures are verified against the previous Version 1.0. The new updated system is known as Carbon Space Technology Version 1.1.
- To ensure the reliability, accuracy, and compatibility of Carbon Space Technology Version 1.1 with existing systems and methodologies, a thorough verification process is conducted to verify the updated procedure documentation and the system implementation at user level. During this verification period, rigorous testing procedures will be employed to assess the performance, functionality, and reliability of the updated system. This includes evaluating the accuracy of carbon data calculations, verifying the effectiveness of new features, and ensuring seamless integration with existing workflows.
- Verification through the documents submitted by Carbon Space MRV integrated into product LCAs provides advantages including the utilization of primary data for monitoring and reporting gross biogenic CO2 removals, decreasing data uncertainties, incorporating changes in land carbon stocks in LCAs, aligning product footprints with supplementary carbon removals in ecosystem carbon pools, and revising emission factors at farm and mill levels.
- The updated documents provided by Carbon Space include annotations indicating the individuals responsible for the updates:

No.	Document	Updated Version
1	White Paper: CarbonSpace’s Technology, Science, and Applications in the Evolving Landscape of Carbon MRV Solutions	February 2024
2	OP_2_002_CarbonSpace Shapefile Guidelines	Carbon Space Technology Version 1.0 Version: 02 Date of issue: 05.05.2023

			<p>Date of last version update: 16.02.2024</p> <p>Added chapters on Land Cover Assurance and Ground Truth of the Land Cover. The update procedure is made by Andrey Dara and approved by Geza Toth.</p>
3	OP_2_001_CarbonSpace Product & Service Delivery		<p>Carbon Space Technology Version 1.1</p> <p>Version: 1.2 Date of issue: 05.05.2023 Date of last version update: 18.01.2024</p> <p>Updated to description of machine learning procedure to latest version using XGBoost, updated description of handling months without satellite data, updated by Robert Granat and approved by Geza Toth.</p>
4	OP_2_003_Validating Customer Input Data		<p>Carbon Space Technology Version 1.1</p> <p>Version: 01 Date of issue: 20.03.2024 Date of last version update: Does not apply</p>
5	OP_2_004_Technical_QA_Procedure		<p>Carbon Space Technology Version 1.1</p> <p>Version: 01 Date of issue: 20.03.2024 Date of last version update: Does not apply</p>
6	TQ_2_001_CarbonSpace Prediction Error Calculation	CO2	<p>Carbon Space Technology Version 1.1</p> <p>Version: 1.2 Date of issue: 05.05.2023 Date of last version update: 18.01.2024</p> <p>Updated error calculations to reflect updates to the core machine learning method and handling of estimates where no satellite data is available, updated by Robert Granat and approved by Geza Toth.</p>
7	TQ_2_002_Validation Description		<p>Carbon Space Technology Version 1.1</p> <p>Version: 1.1 Date of issue: 26.05.2023 Date of last version update: 18.01.2024</p> <p>Added version control table, by Robert Granat and approved by Geza Toth.</p>

- The updated procedure is determined as following a thorough review process involving verification of above documents:

(1) Land Cover Assurance and Ground Truth of the Land Cover:

- CarbonSpace conducts standard quality checks on each asset to verify the accuracy of the land cover data provided by the customer. However, Carbon Space does not assume responsibility for incorrect land cover declarations or correcting them to the accurate classification.
- The update of land cover assurance and ground truth of the land cover emphasizes the importance of integrating current and historical land cover assessments to select accurate models, thereby enhancing the reliability of analyses.

Software like Google Earth Pro is utilized by Carbon Space to access high-resolution historical imagery, enabling the observation of terrain and vegetation cover changes over time, which aids in studying land cover and land use changes.

- Carbon Space acknowledges customers' contractual obligation to provide accurate land cover information but, if necessary, an additional validation will be conducted. Carbon Space accepts the land cover validation following the International Geosphere-Biosphere Programme (IGBP) classification scheme and mandates a specific code for each asset, ensuring accuracy in land cover classification. Emphasizing that land cover assessments should not contain multiple land covers, the procedure in document *CarbonSpace Shapefile Guidelines* stresses the importance of avoiding mixed land covers to prevent inaccuracies that could invalidate results.
- Prior knowledge of crop types and vegetation height significantly influence land cover choices and model selection, directly impacting result accuracy. Carbon Space will request historical records, ground-level photographs, reports on land use, and management documentation to serve as supporting evidence, aiding in accurately delineating land cover.
- The Carbon Space team validates shapefiles and land cover data provided by customers. While customers are responsible for accuracy, Carbon Space acknowledges instances where additional validation may be necessary. Ground truth campaigns are not typically required, but in exceptional cases, such as disputes or when accurate data is unavailable, Carbon Space offers a validation service at an extra cost. This service involves field visits by local partners, following established practices, with campaign scope determined in advance based on plot size and number.
- Carbon Space accepts various forms of ground truth evidence, aligning with provided land cover descriptions, including evidence from HCS/HCV assessments, biodiversity assessments, and field sampling, if they provide relevant information such as GPS coordinates, photographs, tree characteristics, and matching land cover descriptions.

(2) Description of machine learning procedure to latest version using XGBoost and description of handling months without satellite data:

- The update to the latest version of the CarbonSpace machine learning procedure involves two main changes: one of it is using XGBoost as the machine learning algorithm for training the regression model and replacing "gap-fill" with a machine learning-based regression model trained on meteorological data. These changes aim to estimate carbon fluxes (y) based on satellite and meteorological observations by modelling the function F

such that $y = F(x)$, where x is a feature vector composed of meteorological and satellite observations.

- The handling of months without satellite data has been updated in the Carbon Space methodology to include a machine learning-based regression model trained on meteorological data. The updated approach involves gap-filling using a reanalysis of meteorological data, specifically utilizing agrometeorological data from the Copernicus Climate Data Store to estimate missing monthly values. This gap-filling step integrates climate data with NEE time series from Fluxnet stations and NEE time series calculated by Carbon Space to estimate missing values, enhancing the accuracy of the dataset provided to customers.
 - The overall approach of machine learning model training at Carbon Space is detailed in a peer-reviewed publication and implemented in their cloud-native software platform. The training updates are done on a point release basis considering new eddy covariance datasets, updated satellite and meteorological data, and identifying more effective machine learning approaches.
 - The update on procedure of document *CarbonSpace Product and Services Delivery Procedure*, has made revision to the latest version of the machine learning procedure at CarbonSpace involves transitioning to XGBoost as the machine learning algorithm for training the regression model and enhancing the regression model training process with meteorological data to estimate carbon fluxes based on satellite and meteorological observations.
- (3) Updated error calculations to reflect updates to the core machine learning method and handling of estimates where no satellite data is available:
- When satellite data is not available, the error estimate is determined by conducting experiments using models trained on both satellite and meteorological data as well as on meteorological data only. By performing K-fold cross validation experiments, the root mean squared error (RMSE) values for each land cover are calculated to estimate the error expected when predicting daily flux for a given land cover.
 - Additionally, confidence intervals for NEE estimates can be calculated based on the RMSE of the predictions, assuming unbiased model predictions following a normal distribution with the same variance σ . The confidence interval can be expressed in terms of the student's t -distribution, providing a range for the estimated error.
 - The updated error calculations now reflect changes to the core machine learning method and the handling of estimates in situations where no satellite data is available. These updates have been made to enhance the accuracy and robustness of the prediction model used in estimating carbon fluxes based on satellite and meteorological observations.
 - Verified from the procedure document of *CarbonSpace CO2 Prediction Error Calculation*, the key points regarding the updated error calculations include:
 - Incorporating adjustments to the core machine learning algorithm to improve prediction accuracy.
 - Implementing new strategies for handling situations where satellite data is unavailable, ensuring reliable estimates even in such scenarios.

- These modifications aim to enhance the overall performance and reliability of the prediction model in estimating carbon fluxes by leveraging both satellite and meteorological data effectively.
- Each updated system procedure document undergoes a meticulous review process led by Andrey Dara to ensure accuracy and compliance with existing system procedure and methodology. Following this review, final approval is granted by CEO of Carbon Space before the implementation of the updated system procedures.

PART 4: VERIFICATION AND VALIDITY PROCEDURE

The verification process encompassed several essential Carbon Space Technology Version 1.1's system procedures and methodology documents, comprising:

- A comprehensive desk review of the updated system procedures and methodology documents of Carbon Space Technology Version 1.1 against the previous system of Version 1.0.
- Detailed verification of the document's changes, review and approval of the changes and how the changes track is been monitored at Carbon Space management level.
- A desk evaluation of the NEE system's compliance and quality management systems to ensure accurate application at user level. This assessment of new system application at user level is conducted at separate verification report.

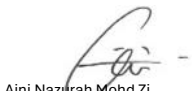


PART 5: ASSURANCE FINDINGS

- Carbon Space's approach utilizes verifiable data to reduce uncertainty and risk, offering full pool accounting at lower monitoring costs compared to other solutions. The use of direct carbon flux measurements sets Carbon Space apart, backed by established science in micrometeorology, remote sensing, and machine learning.
- After independently verifying the updated system procedure and thoroughly examining the methodologies provided by Carbon Space Technology Version 1.1, Control Union moderately assures that the verification of updated system of Carbon Space Technology Version 1.1 is substantively accurate and consistently aligns with the previous system of Version 1.0.

PART 6: VERIFICATION OPINION

- In accordance with the defined scope, objectives, and assessment criteria, the verification of updated system procedure of Carbon Space Technology Version 1.1 has been thoroughly evaluated against the previous system of Version 1.0. Verification of the submitted updated system procedure and methodology documents by Carbon Space, along with the application of the new system at the user level, has achieved a moderate level of assurance upon analysis.
- The practical application of the new system at the user level was closely verified and assessed at separate verification assessment. This involved observing how users interacted with the system, identifying any potential issues or challenges, and assessing the overall usability and effectiveness of the system in real-world scenarios.

PART 7: VALIDATION AND ACKNOWLEDGE

Verification by		
Name	Aini Nazurah Mohd Zi	 Aini Nazurah Mohd Zi 07/05/2024
Role	Assessor	
Date	07/05/2024	
Acknowledged by		
Name	Supun Nigamuni	 Supun Nigamuni 
Role	Managing Director	
Date	20/05/2024	