PURO STANDARD OUTPUT AUDIT REPORT

Mammoth

Puro Standard General Rules Version 4 (Issued in Feb 2024)

Facility ID: 417791

Audit Start - End date: 25.3.2025 - 15.4.2025

DNV Project Number: PRJN-868255

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Carbon Removal Method: Geologically Stored Carbon Edition 2024, V2

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Attachments:

ATTACHMENT 1 Final Mammoth Auditors Notes – ADI GSC2024 – Nov 24-Feb 25

Introduction

This report summarises the results and conclusions from the performed facility audit and output audit. The audit is performed as a formal part of the Puro Standard certification process. The key objective is to determine the compliance of the operations with the Puro requirements.

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Production facility standing data

(PURO General rules Version 4.0)

General information

Facility unique identity	417791
CO2 Removal Supplier registering the Production Facility	Climeworks AG.
Name	Mammoth
Location	Suðurvellir 1, 816 Ölfus, Iceland
Date on which the Production Facility became eligible to receive CORCs	17/09/24
Removal Method(s) for which the plant is eligible to receive CORCs	Geologically Stored Carbon Edition 2024, V2
Production Facility has benefited from public support	No
Removal Method specific information as may be specified in the relevant Removal Method specific Methodology	Direct Air Capture and Geologically Stored Carbon
Does the Production Facility Audit documentation fulfil the minimum criteria set in 2.2.4.2 in Puro Standard General Rules Version 4.0?	Yes
Validity of LCA	17.9.2024 – 16.9.2025
Has the CO2 Removal Supplier attested to the accuracy of the information provided by its signature as required in 2.2.4.3 in Puro Standard General Rules Version 4.0?	Yes
Monitoring period for Output Audit	1.11.2024 – 28.2.2025

Base for calculations in Output report

CORC Overall Equation - Aggregated results	
Contributions	**Total over period co2-eq**
C_stored	122.2
E_project	-93.756
E_leakage	0
E_reversal	-0.4
CORCs	28.07
CORC Uncertainty	±11.59%

All reversals were a result of intentional pumping of water from the reservoir monitoring well

Short description of facility and any exclusions from verification scope observed

The Climeworks Mammoth facility is a Direct Air Capture plant in Iceland, where CO_2 is captured from the atmosphere using a sorbent. Captured CO_2 is stored through Climeworks' partner, Carbfix. Here, the CO_2 is dissolved in water and injected into the subsurface to achieve permanent storage of CO_2 through rapid in-situ mineralisation.

Climeworks AG, as the project applicant, has the relevant contractual agreements in place with all parties involved to ensure ownership of produced CORCs.

Statement of confidentiality

The contents of this report, including any notes and checklists completed during the audit will be treated in strictest confidence, and will not be disclosed to any third party without the written consent of the customer, except as required by the appropriate accreditation authorities.

Disclaimer

An audit is based on verification of a sample of available information. Consequently, there is an element of uncertainty reflected in the audit findings. An absence of nonconformities does not mean that they do not exist in audited and/or other areas. Prior to awarding or renewing certification this report is also subject to an independent DNV internal review which may affect the report content and conclusions.

Audit results

Detailed output removal verified

CORC Overall Equation (all values reported as positive numbers)				
Level 1	**Level 2**	**Level 3**	**Level 4***	**Total over period, tonne CO2-eq**
C_stored	C_injected	C_injected_CHI01		127.942
C_stored	C_injected	C_injected_CHI02		0.007
C_stored	C_injected	C_Natural		5.712
C_stored	E_released	E_released_CHI01		0.036
C_stored	E_released	E_released_CHI02		0
E_project	E_capture	Operational emissions	Energy use, material use, waste treatment	93.756
E_project	E_capture	Embodied emissions	Construction, maintenance, disposal	0
E_project	E_transport	Embodied emissions	Construction, maintenance, disposal	0
E_project	E_injection	Embodied emissions	Construction, maintenance, disposal	0
E_leakage	E_ECO			0
E_leakage	E_MA			0
E_reversal	Intentional reversal events (e.g. monitoring)			0.378
E_reversal	Un-intentional reversal events			0
			CORCs	28.067
			CORC factor (net removed / gross stored)	0.219360839
			Gross carbon stored	127.949
			Sum of all deductions from C_stored	5.748

All reversals were a result of intentional pumping of water from the reservoir monitoring well.

Positive indications

- Climeworks have successfully managed to scale up their processes taking along learnings from the successful operations at Orca. They have detailed processes related to monitoring and data collection that allow for easily verifiable outputs when they will generate CORCs.

Recommendations for improvement

- With regards to criteria 3.6.2, it is acknowledged that there has been an evaluation conducted on nationally determined contributions and that there remains a lack of clarity from the host country on this matter. Climeworks are continuing to engage on this matter to update their initial evaluation.

Audit findings

Detailed findings requiring corrective actions:

The uncertainty propagation approach taken by Climeworks is applied with a slight inaccuracy, wherein the Root Sum of the Squares method is applied using the absolute uncertainties in tonnes of CO2eq. The method should be applied using the relative uncertainty (percent values). This has resulted in an overstatement to the uncertainty for this monitoring period. The value for uncertainty should be reported as 28.07 tCO2eq **±11.59%**, as opposed to the 13.14 tCO2eq (approximately 46%) quoted by Climeworks. It is noted that at this stage, the uncertainty has no impact on the amount of CORCs issued during a monitoring period.

Conclusion

Conclusion	
The company is found compliant towards CORC requirements set in Puro Standard General Rules Version 4.0 and the Geologically Stored Carbon methodology, and CORCs can be issued to the Output during the Monitoring period	Yes
The company is found NOT to be fully compliant towards CORC requirements set in Puro Standard General Rules Version 4.0 and the Geologically Stored Carbon methodology, and corrective actions are needed before CORCs can be issued to the Output during the Monitoring period	

Audit type	Module	Evidence piece	Description	Associated requirements	Evidence used to verify	Auditor's verification remarks	Compliance (Yes, No, Partial)	Corrective Action or recommendation
Output Audit	**01. CORC Report**	CORC Report Summary	Summary of CORCs reported by the supplier over the monitoring period, following a template provided by Puro. Any supporting data referenced in the document shall be provided separately. Supporting data are necessary for auditor to conduct verifications of the calculations. In the context of the CORC Report Summary, supporting data can refer to various types of operational records, evidencing carbon stored, reversal quantification, leakage mitigation.	['2.2.2', '2.3.1', '3.2.2', '3.2.5', '3.3.6', '4.2.1', '4.2.2', '4.2.4', '4.2.5', '4.3.1', '4.4.1', '4.4.4', '4.4.5', '4.4.6', '4.5.3', '4.6.1', '4.6.2', '4.7.1', '4.7.2', '4.7.3', '4.8.1', '4.8.2', '4.8.3', '4.8.4', '4.8.5', '5.2.7', '5.3.1', '5.3.2', '6.2.2', '6.2.3', '6.2.4', '6.2.5', '6.2.6', '6.2.7', '6.3.1', '6.3.2', '6.3.3', '6.3.4', '6.3.5', '7.4.3', '8.5.3']	Puro CORC Report Mammoth_V1.1	CORC output report is submitted in the template provided by Puro. Supporting LCA is provided along with other supporting operational documentation, suppliers invoices and uncertainty calculations.	Yes	
		Life cycle assessment for Output Audit	Updated LCA calculation file(s) with activity data corresponding to the audited period. Any supporting data referenced in the document shall be provided separately. Supporting data are necessary for auditor to conduct verifications of the calculations. In the context of the LCA, supporting data can refer to various types of operational records, such as energy metering, transportation distances, materials consumed, waste generated.	['3.3.6', '4.5.3', '5.2.7', '5.3.1', '5.3.2']	Mammoth LCA Model	LCA is updated with data corresponding to the audited monitoring period. Calculations match supporting information.	Yes	
	02. Updated facility documents	Updated monitoring plan	An annual update to the Monitoring plan. Remark: not necessary in case of a combined Facility and Output Audit.	['7.2.5', '7.2.6', '7.2.7', '7.3.3', '7.3.4', '7.3.5', '7.4.1', '7.4.2', '7.4.3', '7.4.4', '7.6.2', '7.6.3', '8.5.4']	Monitoring Plan V1	Monitoring plan is provided, this period saw some issues with one of the analysers, backup analyser was used for calculation of mCO2,captured. This remains in line with the GSC methodology.	Yes	
		Updated risk assessment of the removal activity	An annual update to the Risk assessment of the removal activity. Remark: not necessary in case of a combined Facility and Output Audit.	['8.5.1', '8.5.2', '8.5.3', '8.5.4']	Mammoth Risk Register	Updated risk register is provided.	Yes	
		Updated storage site monitoring plan	An annual update to the Storage site monitoring plan. Remark: not necessary in case of a combined Facility and Output Audit.	['7.2.5', '7.2.6', '7.2.7', '7.3.1', '7.3.2', '7.3.3', '7.3.4', '7.3.5', '7.5.3', '7.6.1', '7.6.2', '7.6.3', '7.7.1', '7.7.2', '7.7.3', '7.7.5', '8.5.4']	Monitoring Plan V1	Monitoring plan for the storage site is provided	Yes	
		Updated leakage determination form	An annual update to the Leakage determination form. Remark: not necessary in case of a combined Facility and Output Audit.	['4.6.1', '4.6.2', '4.8.1', '4.8.2', '4.8.4', '6.1.1', '6.1.2', '6.1.3', '6.1.4', '6.1.5', '6.2.1', '6.2.2', '6.2.3', '6.2.4', '6.2.5', '6.2.7', '6.3.1', '6.3.2', '6.3.3', '6.3.4', '6.3.5']	Leakage Determination	As for the leakage assessment for the facility audit, CW have assessed the potential for ecological leakage through both Direct and Indirect land use change. No significant sources of land use changes, given construction on an existing industrial site. CW assessed market leakage from two view points, the first being electricity use and the second being heat use. With regards to electricity usage, an analysis of the electricity grid has shown a average value of 90% of electricity in Iceland generated through renewable sources (Geothermal and Hydropower). Hence leakage value set to zero. For thermal power, again leakage is assessed as zero. 97% of iceland is connected to district heating schemes, CW also recycles thermal energy back to the geothermal plant (connected to district heating network). **There has been no need to update for this output audit.**	N/A	

	Updated uncertainty quantification approach	An annual update to the Uncertainty quantification approach. Remark: not necessary in case of a combined Facility and Output Audit.	['4.8.1', '4.8.2', '4.8.3', '4.8.4', '4.8.5', '5.3.2']	Uncertainty calculation	Uncertainty quantification has been updated in line with the current monitoring period.	Partial	Minor Non-Compliance: The uncertainty propagation approach taken by Climeworks is applied with a slight inaccuracy, wherein the Root Sum of the Squares method is applied using the absolute uncertainties in tonnes of CO2eq. The method should be applied using the relative uncertainty (percent values). This has resulted in an overstatement to the uncertainty for this monitoring period. The value for uncertainty should be reported as 28.07tCO2eq +/-11.59%, as opposed to the 13.14tCO2eq quoted by Climeworks. It is noted that at this stage, the uncertainty has no impact on the amount of CORCs issued during a monitoring period. Climeworks to update for next output audit.
	Updated biomass sourcing form	An annual update to the Biomass sourcing form. Remark: not necessary in case of a combined Facility and Output Audit.	['3.2.4', '3.7.1', '3.7.2', '3.7.3', '6.2.2', '6.3.5']	N/A	N/A	N/A	
	Storage site closure report	Only if the storage site was closed during the current verification period. A site closure report detailing relevant information for future use.	['7.7.4', '7.7.6']	N/A	Storage site is not being closed	N/A	
03. Operational records	Operational records used in CORC calculations	A collection of operational records, from capture to storage, that support the CORC Report Summary and the LCA, also referred to as supporting data.	['2.2.2', '2.3.1', '3.2.2', '3.2.5', '3.3.6', '4.2.1', '4.2.2', '4.2.3', '4.2.4', '4.2.5', '4.3.1', '4.4.1', '4.4.2', '4.4.3', '4.4.4', '4.4.5', '4.4.6', '4.5.3', '5.2.7', '5.3.1', '5.3.2', '7.4.3']		Supporting data is present and is used as basis for calculations in the CORC report summary and within the LCA	Yes	
	Records of biomass used	Records of biomass feedstock used and having resulted in the CORCs reported during the current monitoring period. The records shall be possible to link to the evidence submitted separately demonstrating the biomass eligibility (see Biomass evidence).	['3.2.4', '3.7.1', '3.7.2', '3.7.3', '4.4.5', '6.2.2', '6.3.5']	N/A	Direct Air Capture is used for Mammoth	N/A	
	Biomass evidence	Evidence required as per the Puro Biomass Sourcing Criteria to demonstrate the eligibility of the biomass feedstock used and having resulted in the CORCs reported during the current monitoring period, covering type, origin and sustainability criteria.	['3.2.4', '3.7.1', '3.7.2', '3.7.3', '6.2.2', '6.3.5']	N/A	Direct Air Capture is used for Mammoth	N/A	
	Leakage evidence	Evidence required to demonstrate mitigation of leakage, as applicable, in relation to the Leakage determination form (provided in Facility Audit, or its last update). As part of the Output Audit, the evidence expected here is evidence that must be updated or provided at each verification, such as proof of purchase of renewable energy certificates in sufficient amounts and types (if this mitigation option is used by the supplier).	['4.6.1', '4.6.2', '6.2.3', '6.2.4', '6.2.5', '6.2.6', '6.2.7', '6.3.1', '6.3.2', '6.3.3', '6.3.4']	Leakage Determination	As for the leakage assessment for the facility audit, CW have assessed the potential for ecological leakage through both Direct and Indirect land use change. No significant sources of land use changes, given construction on an existing industrial site. CW assessed market leakage from two view points, the first being electricity use and the second being heat use. With regards to electricity usage, an analysis of the electricity grid has shown a average value of 90% of electricity in Iceland generated through renewable sources (Geothermal and Hydropower). Hence leakage value set to zero. For thermal power, again leakage is assessed as zero. 97% of iceland is connected to district heating schemes, CW also recycles thermal energy back to the geothermal plant (connected to district heating network). **There has been no need to update for this output audit.**	N/A	
	Carbon dioxide balance checks	A carbon dioxide balance demonstrating that the amount of eligible carbon dioxide injected and attributed to a given Production Facility does not exceed the amount of eligible carbon dioxide captured and sent for permanent storage by this Production Facility. This piece of evidence is important in the context of shared infrastructure for carbon dioxide transport and injection, where mixing of carbon dioxide streams from multiple stakeholders and facilities is possible along the supply-chain, as well as in the context of a carbon dioxide stream split for several end-uses (permanent storage and non-storage applications).	['3.2.5', '3.2.13', '4.2.6', '4.4.6']	Mammoth CDR Production Report	Mammoth remains in the ramp up phase, with only 12 capture units (12 of 72) and one LPU (1 of 6) in operation. Mammoth Production report outlines the production 'waterfall' in which the captured CO2 based on the nameplate capacity is the start point, and CDR generated factors in the losses throughout the entire process. Captured value is not above nameplate capacity for plant.	Yes	

		Records of reversal events	Records of reversal events having taken place during the current monitoring period.	['4.7.1', '4.7.2', '4.7.3']	Mammoth CDR Production Report	Records are made of reversal events, these are intentional related to the production of water from the monitoring well, required for monitoring purposes. These are accounted for as a loss.	Yes	
		Records of calibration events	Records of calibration events of any monitoring equipment used for CORC quantification	['4.2.7', '7.2.8', '7.2.9']	Calibration Reports	Calibration has occurred on some key meters during the monitoring period, recorded within documentation.	Yes	
		Records of incidents and risk realisation	Records of incidents having taken place during the monitoring period, covering both social and environmental safeguards, as well as the materialization of potential risks that were identified for the Production Facility (cf. Risk Assessment).	['3.8.4', '8.5.5']	Mammoth CDR Production Report	No recorded incidents have taken place during the monitoring period. As discussed above, records are made of reversal events, these are intentional related to the production of water from the monitoring well, required for monitoring purposes. These are accounted for as a loss.	Yes	
	04. Positive impacts on SDGs	SDG Report and associated evidence	A summary of positive impacts to the sustainable development goals (SDGs) that the CO2 Removal Supplier is achieving with the operations of its Production Facility, alongside associated evidence to demonstrate the SDG impacts (whenever available) as per the requirements defined for each SDG indicator, in the Puro SDG Assessment Requirements (available in the document library). Note that this document will be publicly available in Puro's Registry once certified. Parts of the underlying evidence for each SDG claim may also be made public, as described in the SDG Assessment Requirements.	['3.9']	N/A	No documents provided as no additional claim is made.	N/A	