VERIFICATION STATEMENT

In accordance with ISO 14034:2016
Environmental Technology Verification

Technology & Company Information		
Technology Name	**Company**	**Technology Type & Application**
Thermochemical Methanol Synthesis	Breathe Applied Sciences PVT LTD https://breathesciences.com	Thermochemical conversion of concentrated CO_2 for the production of methanol and CO.

Verification Parameter	Verified Performance
Operational Scale	31.59 ± 0.072 kg CO_2/day
CO_2 Capture in the Product	1.375kg CO_2 / kg methanol
CO_2 Conversion	39.06% ± 5.67%
Methanol Produced	6.46 ± 0.67 kg methanol/day
CO Produced	2.18 ± 0.22 kg CO/day
H_2 Usage	0.67 ± 0.07 kg / kg methanol product
Energy Usage	7.76 ± 1.27 kWh / kg methanol product

Verifier Information			
Verification Body	**Lead Verifier**	**Verification Body Accreditation**	**Verification ID**
350Solutions, Inc. https://350Solutions.com	Kevin McCabe	ANAB Cert. AI-2618 for ISO:IEC 17020-2012/ISO 14034-2016	VS-XP2003

350 VERIFIED ISO 14034

BREATHE

Issue Date: June 22, 2021

ANAB ACCREDITED ISO/IEC 17021 INSPECTION BODY

ENVIRONMENTAL TECHNOLOGY VERIFICATION STATEMENT

BREATHE

Technology Name: Thermochemical Methanol Synthesis

Technology Type: Thermochemical conversion of concentrated CO_2 for the production of methanol and CO (**https://breathesciences.com/#technology**)

Application: Methanol Production

Company: **Breathe Applied Sciences PVT LTD** (**https://breathesciences.com**)

Verification Body: 350Solutions, Inc. - ISO/IEC 17020:2012 and ISO 14034:2016 Environmental Technology Verification, Certificate Number AI-2619

Lead Verifier: Kevin McCabe, 350Solutions, Inc.

TECHNOLOGY DESCRIPTION

Breathe Applied Sciences PVT LTD has developed a thermochemical CO_2 reduction technology which was constructed, commissioned, and operated for the final round of the NRG COSIA Carbon XPRIZE competition. The CO_2 reduction technology demonstrated at the Jawaharlal Nehru Centre for Advanced Scientific Research (JNCASR) utilized CO_2 and H_2 which was purchased in separate bottles and mixed onsite and compressed before being fed to the reactor. Breathe's technology operated at high temperatures (250°C) and pressures (50 bar). For the competition Breathe developed a proprietary catalyst designed specifically to reduce CO_2 to methanol with carbon monoxide (CO) as a by product.

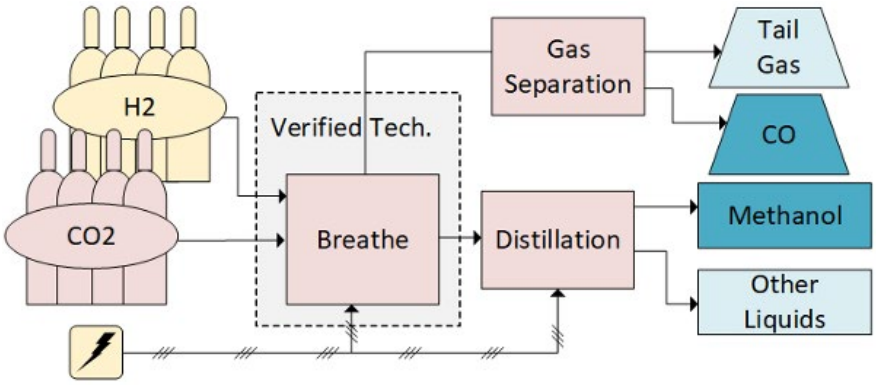

FIGURE 1. Breathe Block Flow Process Summary

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The system demonstrated by Breathe was originally designed to handle a continuous feed of 283 kg/day of CO_2, however, due to safety restrictions related to H_2 storage onsite, the system was demonstrated at 1/10th capacity – with 1/10th of the catalyst loaded into the reactor and 1/10th the input feed rate of gases utilized during operation. The reactor was operated in a single-pass configuration, and no recycle of the tail gas was demonstrated. The liquid products are condensed from the gas phase and would need further refinement to achieve International Methanol Producers and Consumer Association (IMPCA) Quality standards.

Although the system was operating at 10% catalyst and throughput capacity, system design did not enable a linear reduction in energy consumption at reduced scale. Preliminary data (unverified) was provided at higher throughputs and catalyst loading and indicates that energy consumption per kg CO_2 input is reduced as CO_2 throughput increases. However, due to limited data availability at the time of verification, energy consumption rates at full capacity and the impact of increased throughput on other parameters was not evaluated nor verified.

VERIFICATION DESCRIPTION

The primary objective of this assessment was to verify the performance claims made by Breathe with respect to their thermochemical methanol synthesis technology. Verification parameters were assessed quantitatively using data generated from analysis of tail gas samples taken after condensible liquids were removed as well as analysis of the collected liquids. Verifiers used data generated during the verification process to determine whether the data met the objectives of the verification process. The results of the verification represent a confirmation of the performance of the technology achieved under the same conditions, constraints, and limitations as those specified for the generation of the data used for verification. Breathe's performance claims specified in the application for verification include:

Performance Claim 1 – Operational Size: Operational size is defined as the average daily rate of CO_2 fed into the conversion system during operations and represents the operational scale during the verification demonstration. Performance results are verified within the range of relevant operating conditions summarized in ***Table 2*** that were evident during this demonstration.

Performance Claim 2 – CO_2 Embodied in Product: CO_2 embodied in the product is defined as the ratio of CO_2 that was converted into the primary product (methanol) on mass basis during the verification demonstration. Performance results are verified within the range of relevant operating conditions summarized in ***Table 2*** that were evident during this demonstration.

Performance Claim 3 – Conversion of CO_2: Defined as the fraction of CO_2 converted as the mass ratio of CO_2 input and CO_2 output embodied in the methanol and carbon monoxide, expressed as a percentage. The performance claim is presented as the daily average conversion efficiency during the verification demonstration within the operational conditions defined during the period.

Performance Claim 4 – Methanol Production: The average daily rate of methanol produced (as measured in the collected liquid product) during the demonstration period and within the range of operating conditions. Liquid composition was verified by gas chromatography.

Performance Claim 5 – CO Production: The average daily rate of CO produced as measured in the tail gas during the demonstration period and within the range of operating conditions. Gas composition was verified by gas chromatography, but purified CO was not actually separated from other gasses.

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Performance Claim 6 and 7 – Hydrogen and Energy Usage per tonne CO_2 in Product: For every tonne of CO_2 that was converted into methanol, the conversion system required hydrogen and electricity to complete the conversion process. These inputs were normalized to methanol output and verified.

After initial reviews of the technology and following the Verification Plan, performance verification was specified using independent performance data generated during the verification at the JNCASR in the Fall of 2020 during the XPRIZE competition. Using data that was determined to be relevant to the performance claims and of sufficient quality to support verification, 350Solutions assessed the verifiability of the claims. The verification also statistically examined variability and confidence intervals in the supporting data used to verify performance claims including comparative sample analytical results and analytical variability.

VERIFICATION OF PERFORMANCE

The verification demonstrates that all seven of the technology performance claim criteria were met. For all results, 31 days of data collected between December 4, 2020 and January 3, 2021 were used. The summary in ***Table 1*** presents the in-field verified values and associated uncertainties for each Verification Parameter. Uncertainties here are presented as the combined Type A (statistical) and Type B (measurement) uncertainties of the parameters.

TABLE 1 - BREATHE VERIFIED PERFORMANCE

Verification Parameters	Verified Performance
Operational Scale *(kg CO_2/day)*	31.59 ± 0.072 kg CO_2/day
CO_2 Utilization *(kg CO_2 / kg methanol)*	1.375 kg CO_2/kg methanol
CO_2 Conversion Results	39.06% ± 5.67%
Methanol Production *(kg methanol/day)* *(kg methanol/ kg CO_2 input)*	6.46 ± 0.67 kg methanol/day 0.205 ± 0.021 kg methanol/kg CO_2 input
CO Production *(kg CO/day)* *(kg CO/ kg CO2 input)*	2.18 ± 0.22 kg CO/day 0.269 ± 0.028 kg CO/kg CO_2 input
H_2 Usage *(kg/day)* *(kg/kg methanol/product)*	4.34 ± 0.0067 kg/day 0.67 ± 0.07 kg/kg methanol product
Energy Usage *(kWh/day)* *(kWh/kg methanol/product)*	50.16 ± 6.24 kWh/day 7.76 ± 1.27 kWh/kg methanol product

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Table 2 presents the operating conditions under which the Verification Parameters were observed during the demonstration period. These operating conditions have direct correlation to system performance and should be considered in conjunction with the verified performance.

TABLE 2- BREATHE OPERATING CONDITIONS

Verification Parameters	Observed Average Value	Observed Range
Acceptable CO_2 Input Flow Rate*	31.59 kg/day	31.53-31.61 kg/day
Hydrogen to CO_2 ratio	3.02	2.94-3.12
Reactor Temperature	243°C	148-274°C

*283 kg/day nameplate capacity

The basis for the verification was an operational period of 31 days during which data was collected on process operations using on-site data-logging and PLC systems. Total system operations and operating characteristics for which data was reviewed and verified are summarized in ***Table 3***.

TABLE 3- OPERATIONAL PERIOD

Verification Period Characteristic	Observed Value	Observed Range
Total Hours Operated	605 hrs.	5-24 hrs./day
System Availability	81.3%	

DATA QUALITY

350Solutions, an ANAB accredited ISO/IEC 17020:2012 inspection body for ISO 14034:2016 Environmental Technology Verification, was contracted by XPRIZE to provide independent verification of the Breathe Thermochemical Methanol Synthesis technology. The verification process applied was based on 350Solutions' Standard Operating Procedure QSP-350-223-01: "ISO 14034 Environmental Technology Verification", the ISO Technical Committee 207 draft guidance document *"Environmental technology verification — E.T.V — Guidance to Implement ISO 14034"*, and a technology specific Verification Plan. The objectives and approaches used for this verification were designed to apply these principles and processes to Breathe's application for verification and performance claims. Following ISO 14034 guidance, the data quality assessment included:

- Data quality assessment for the specified performance claims;
- Assessment of ancillary data quality (operations, relevance, and representativeness);
- Performer competence (testing and analytical providers);
- Sampling and analytical procedures (repeatability, accuracy, measurement equipment calibration and quality checks); and
- Data management and processing.

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Assessment of the quality of data used to verify technology performance was based on three primary components:

- Conformance with the requirements of ISO Standards 14034 and 17025.
- Assessment of the scientific approaches and statistical analyses – specifically, evaluation of measurement uncertainty in laboratory and field demonstration test results, and the statistical analyses of measurement uncertainty.
- The quality of reference laboratory procedures and results.

In broad terms, the existing data provided by Breathe to verify performance with respect to the performance claims were found to be acceptable for verification. The laboratory conducting reference sample analyses was verified as impartial with respect to technology development, and in conformance with the requirements of ISO Standard 17025. Sound scientific approaches and statistical analyses are detailed in the Verification Report and demonstrate that the quality of data and data analyses support verification of the performance claims. Assessment of data quality for the reference laboratory results was verified acceptable based on verification of the following data quality assessments:

- Review and verification of acceptable laboratory SOPs and methods,
- Satisfactory verifier observation of laboratory facilities, equipment, and operations,
- Review and observation of performer competence (qualifications and training policies),
- Sampling and analytical procedures (repeatability, accuracy, measurement equipment calibration and quality checks), and
- Satisfactory data management and processing.

All of the findings of the data quality review support verification of the performance claims and conform to the requirements of the standards.

Detailed results of the verification are presented in the Final Report titled *Environmental Technology Verification Report – Breathe,* (350Solutions 2021). The report can be made available to the interested parties upon request to Breathe.

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