DATA MANAGEMENT PLAN

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Project full title	Metrology support for carbon capture utilisation and storage
Data management plan	1st ☐ 2nd ☒
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1 Data management plan

1.1 Data summary

Questions	Answers
1 Will you re-use any existing data and what will you re-use them for? State the reasons if re-use of any existing data has been considered but discarded.	This project re-used the following publicly available datasets: 1. WP4: C. W. Scholz and R. Span, Measurement of the (p, ρ, T) Behavior of Liquid MEA and DEA at Temperatures from (293.15 to 423.15) K and Pressures up to 90 MPa, Int. J. Thermophys. 42 (2021). DOI: 10.1007/s10765-021-02808-x.
2 What types and formats of data will the project generate or re-use?	Measured data and associated uncertainties; typically, ASCII (American Standard Code for Information Interchange), MS office format, images in JPEG format, numerical data in CSV format, text description data in Markdown format. Research outputs will include new: software, calibration methods, protocols, materials. Other types and other formats (e.g. TXT, Python, R) may be considered – to be confirmed at a later date. Where possible, data formats are chosen that are supported by Open Source software, or software from different vendors to maximise the update of data sets by other groups.
3 What is the purpose of the data generation or re-use and its relation to the objectives of the project?	Data are generated and used for different purposes. Most of the data generated during the development of novel facilities and measurement standards will be used to demonstrate their capabilities and assess their performance. The project generated 6 datasets. The purpose of the data generation and its relation to the objectives of the project is specified below: Objective1: Validation of the developed primary flow facilities: - https://zenodo.org/records/17734594 Objective 3: Validation of the developed primary reference materials, sampling methods and analysers: - https://zenodo.org/records/17725124 - https://zenodo.org/records/17709032 - https://zenodo.org/records/17241768 Objective 4: An experimental measurements dataset for thermodynamic properties of CO2 and amines mixtures were obtained to support the improvement of available fundamental equation of state and for the development of two new simplified models. - https://zenodo.org/records/17209074 - https://zenodo.org/records/17208811
4 What is the expected size of the data that you intend to generate or re-use?	The overall size of the generated data was approximately 1 MB.
5 What is the origin/provenance of the data, either generated or re-used?	*Data generated in the project* The data/research outputs generated was from measurements, calibrations, testing, comparisons and validations. The project generated 6 datasets. The provenance of the data generated is specified below: 1. Experimental measurements (WP1) 2. Experimental measurements (WP3) 3. Experimental measurements (WP4) *Re-used data* The existing data originated from several sources, which will include participant's pre-existing data, data from the scientific literature, real-world measurement data, and simulation data. The project re-used 1 datasets which originated from the following external sources (from outside of the project): 1. Peer reviewed article
6 To whom might your data be useful ('data utility'), outside your project?	The data might be useful to JCGM, ISO and CEN technical committees, accreditation bodies, research institutes, calibration and testing laboratories, regulators, industry. The data were published on Zenodo to provide the data to end users. The data were provided to: - CEN TC 474 CCUS WG 3 CO_2 metering - ISO TC 265 Carbon dioxide capture, transportation, and geological storage - CEN TC 264 Air Quality - API Manual of petroleum measurement standards chapter 6, metering

	assemblies and chapter 14 natural gas fluids measurements

1.2 Findable, Accessible, Interoperable and Re-usable (FAIR) Data

1.2.1 Making data findable, including provisions for metadata

Questions	Answers
7 Will data be identified by a persistent identifier?	Yes. Published data will have a DOI obtained from an open access repository.
8 Will rich metadata be provided to allow discovery? What metadata will be created? What disciplinary or general standards will be followed? In case metadata standards do not exist in your discipline, please outline what type of metadata will be created and how.	Published data has a DOI obtained from an open access repository. Meta data describes the quantities, units, methods of measurement (if known) and if possible or relevant, the origin of the data. The meta data contains references to the project, and where appropriate, to the owner(s) of the data. The metadata provides information on the following: datasets (description, date of deposit, author(s), venue and embargo); the European Partnership on Metrology funding; grant project name, acronym and number; licensing terms; persistent identifiers, the authors involved. Where applicable, the metadata includes persistent identifiers for related publications and research outputs. The metadata created for all of the project's deposited datasets is open under a Creative Commons Public Domain Dedication (CC 0) or equivalent (to the extent legitimate interests or constraints are safeguarded), in line with the FAIR principles.
9 Will search keywords be provided in the metadata to optimise the possibility for discovery and then potential re-use?	Key words were provided to enhance the discovery of the data by search engines, such as the following: Carbon Capture, Utilisation, Storage, Carbon dioxide, Metrology.
10 Will metadata be offered in such a way that it can be harvested and indexed?	Zenodo complies with FAIR principles (https://about.zenodo.org/principles/). The metadata are indexed in a searchable resource. Metadata are licensed under CC0, except for email addresses. All metadata are exported via Open Archives Initiative Protocol for Metadata Harvesting (OAI-PMH) and can be harvested.

1.2.2 Making data accessible

Questions	Answers
Repository:	
11 Will the data be deposited in a trusted repository?	The data were made accessible by deposition in an open access repository. The project's 6 datasets and associated metadata, documentation and code were deposited in Zenodo (https://zenodo.org).
12 Have you explored appropriate arrangements with the identified repository where your data will be deposited?	No, the data were uploaded via a standard procedure and required no special arrangements.
13 Does the repository ensure that the data are assigned an identifier? Will the repository resolve the identifier to a digital object?	Yes, Zenodo assigned an identifier (DOI) to each of the project's deposited datasets. The repository resolves the identifier to a digital object.
Data:	
14 Will all data be made openly available? If certain datasets cannot be shared (or need to be shared under restricted access conditions), explain why, clearly separating legal and contractual reasons from intentional restrictions. Note that in multi-beneficiary projects it is also possible for specific beneficiaries to keep their data closed if opening their data goes against their legitimate interests or other constraints as per the Grant Agreement.	All of the data that were needed to validate the results presented in scientific publications were made openly available as the default.
15 If an embargo is applied to give time to publish or seek protection of the intellectual property (e.g.	Data were made publicly accessible before, at, or shortly after the time of publication as appropriate. Data associated with other project outputs (e.g., reports, journal papers, conference contributions) were released for publication

Questions	Answers
patents), specify why and how long this will apply, bearing in mind that research data should be made available as soon as possible.	in the same effort, so that the data set can be referenced in the project output and vice versa. The project has deposited 6 datasets in Zenodo.
16 Will the data be accessible through a free and standardised access protocol?	Yes. Zenodo provides well described conditions for free and standardised access (see http://about.zenodo.org/policies/). All data associated with the project activities will be made available, with the possible exceptions of data obtained from organisations external to the project consortium. Where possible, permission to release the data will be obtained. Examples containing data sets may be reviewed by reviewers carefully selected by participants and coordinator. Some data sets will be released for general access, for example, to end-users of guides and standards, as soon as the data sets are complete, and quality is assured. Other data will more appropriately be made generally available at the time articles reporting on them are accepted for publication.
17 If there are restrictions on use, how will access be provided to the data, both during and after the end of the project?	No restrictions on the use of the published data are envisaged. Access will simply require a standard user's registration.
18 How will the identity of the person accessing the data be ascertained?	Registered users of the research data repository.
19 Is there a need for a data access committee (e.g. to evaluate/approve access requests to personal/sensitive data)?	No, the appointed corresponding author, with responsibility for the data, decided alone about grating access to the data.
Metadata:	
20 Will metadata be made openly available and licensed under a public domain dedication CC0, as per the Grant Agreement? If not, please clarify why. Will metadata contain information to enable the user to access the data?	In Zenodo, metadata are licensed under CC0, except for email addresses. All metadata are exported via OAI-PMH and can be harvested.
21 How long will the data remain available and findable? Will metadata be guaranteed to remain available after data are no longer available?	The data will remain available and findable for the lifetime of the Zenodo repository, which is expected to be a minimum of 20 years. If data are withdrawn from Zenodo, the DOI and the URL of the original object are retained. In case of closure of the Zenodo repository, best efforts will be made by Zenodo to integrate all content into suitable alternative institutional and/or subject based repositories.
22 Will documentation or reference about any software be needed to access or read the data and will this be included? Will it be possible to include the relevant software (e.g. in open source code)?	Data can be read: 1. By using openly available formats (ODT, PDF, MS Office, JPEG). 2. By sharing software to read the data. 3. By using specialised software: Matlab and Mathematica, Origin. Standard publicly available software was used where possible. Where specialist software tools were developed within Matlab, a short README file was provided with the data file to explain the software required. The majority of the software programmes are available as commercial products or as freeware. For the software developed in the project, the open source code was deposited in the repository (e.g. Zenodo). The project's 6 datasets which have been deposited in Zenodo i) are accessible using the following software tools, ii) require the following documentation about the software, and iii) require the following software: 1. MS Office (WP1 and WP3) 2. An opensource software library implementing two simplified equations of state accessible in text mode and Fortran code (WP4).

1.2.3 Making data interoperable

Questions	Answers
23 What data and metadata vocabularies, standards, formats or methodologies will you follow to	Meta data will be provided in accordance with the stipulations of the Grant Agreement. Furthermore, in the meta data the quantities and units will be provided as well as relevant key words.

make your data interoperable to allow data exchange and re-use within and across disciplines? Will you follow community-endorsed interoperability best practices? Which ones?	The datasets will use the trusted repository's basic metadata schema for administrative data, which is compliant with the recommended standards used by DataCite (https://search.datacite.org/) and OpenAIRE (https://www.basesearch.net/). For individual datasets, the following discipline-specific vocabularies, standards, formats, and methodologies will be used: e.g. GUM, OBO foundry, DICOM, NetCDF, HDF5, CityGML, INSPEC, ISO 9001.
24 In case it is unavoidable that you use uncommon or generate project specific ontologies or vocabularies, will you provide mappings to more commonly used ontologies? Will you openly publish the generated ontologies or vocabularies to allow their re-use, refinement or extension?	No mappings were necessary, as the datasets were described using standard terminologies and/or terminology used was chosen to be compatible with the existing literature.
25 Will your data include qualified references[1] to other data (e.g. other data from your project, or datasets from previous research)?	No, the project's datasets do not include any references to other data.

1.2.4 Increase data re-use

Questions	Answers
26 How will you provide documentation needed to validate data analysis and facilitate data re-use (e.g. readme files with information on methodology, codebooks, data cleaning, analyses, variable definitions, units of measurement, etc.)?	A short README file (e.g. Markdown) was provided together with the data, in order to enable data analysis and to facilitate data re-use
27 Will your data be made freely available in the public domain to permit the widest re-use possible? Will your data be licensed using standard re-use licenses, in line with the obligations set out in the Grant Agreement?	The data were licensed under the latest available version of the Creative Commons Public Domain Dedication License (CC 0) or a license with equivalent rights as set out in the Grant Agreement. Users will be required to acknowledge the consortium and the source of the data in any resulting publications. The project's 6 datasets which have been deposited in Zenodo include the following licenses (where necessary): 1. Creative commons Attribution 4.0 International (WP1 and WP3). 2. MIT with commercial limitations (WP4).
28 Will the data produced in the project be useable by third parties, in particular after the end of the project?	The data published in open-access journals are usable by third parties as the datasets have been deposited in Zenodo. The data that do not relate to peer-reviewed publications were not made available. 2 of the project's datasets are subject to restrictions on re-use: 1. Two simplified equations of state for designing CO2 transport and capture processes 2. Density and speed of sound measurements in MEA + CO2 and DEA + CO2
29 Will the provenance of the data be thoroughly documented using the appropriate standards?	Yes, the provenance and context of the data was thoroughly documented to meet relevant standards using the Provenance and Context Content Standard (PCCS) Matrix. Data were accompanied by information on how they were captured, processed, analysed, and validated. Other information was also provided.
30 Describe all relevant data quality assurance processes.	Data quality was assured through repeated and comparison measurements, adherence to standards for data recording, the use of controlled vocabularies and standard terminology, through the metrological characterisation of the measurement set-ups and through the validation of the data collected. Other

[1] A qualified reference is a cross-reference that explains its intent. For example, X is regulator of Y is a much more qualified reference than X is associated with Y, or X see also Y. The goal therefore is to create as many meaningful links as possible between (meta)data resources to enrich the contextual knowledge about the data. (Source: https://www.go-fair.org/fair-principles/i3-metadata-include-qualified-references-metadata/)

Questions	Answers
	quality assurance processes included the provision of test results along with the data and the peer-review of publications based on the data.
31 Further to the FAIR principles, DMPs should also address research outputs other than data, and should carefully consider aspects related to the allocation of resources, data security and ethical aspects.	*Allocation of resources* The costs for making other research outputs FAIR are included in the project's budget and were claimed if compliant with the Grant Agreement's conditions. Where feasible, long-term preservation was ensured by depositing the other research outputs in repositories. The coordinator will decide on a case-by-case basis on which other research outputs will be deposited and for how long. *Security of other research outputs* The participants stored other research outputs on their organizations' networks, which are protected by firewall, backups etc. Other research outputs were stored in the project's SharePoint environment, with password-protected login. Deposition in public repositories provide additional security as they have multiple replicas in a distributed file system which is backed up on a nightly basis. This project did not generate sensitive other research outputs. The other research outputs were safely stored in open access repositories. *Ethical aspects* There are issues that could impact on the sharing of other research outputs. • Information relating to other research outputs acquired from third parties, e.g. manufacturers, was not shared without their explicit consent. • Information relating to other research outputs collected by the consortium at commercial sites was not shared without the site owner's explicit consent. The project did not share other research outputs with identifiable personal information. Sensitive information relating to the other research outputs was collected, separated as soon as possible and kept secure.

1.3 Other research outputs

Questions	Answers
32 In addition to the management of data, beneficiaries should also consider and plan for the management of other research outputs that may be generated or re-used throughout their projects. Such outputs can be either digital (e.g. software, workflows, protocols, models, etc.) or physical (e.g. new materials, antibodies, reagents, samples, etc.).	The following new software was released: 1. Two simplified equations of state for designing CO2 transport and capture processes
33 Beneficiaries should consider which of the questions pertaining to FAIR data above, can apply to the management of other research outputs, and should strive to provide sufficient detail on how their research outputs will be managed and shared, or made available for re-use, in line with the FAIR principles.	As far as possible, the FAIR data approaches specified in questions 7-30 above were applied to the management of this project's other research outputs. This commitment was met by releasing the new software that was developed in the project under license, by placing the new calibration methods, and protocols, in a trusted repository and by patenting the new material that was developed in the project in line with the requirements of the project's consortium agreement.

1.4 Allocation of resources

Questions	Answers
34 What will the costs be for making data or other research outputs FAIR in your project (e.g. direct and indirect costs related to storage, archiving, re-use, security, etc.) ?	The costs for making the data and other research outputs Findable, Accessible, Interoperable and Re-usable (FAIR) were 5 000 € (personnel costs). These costs were kept to a minimum by using a free repository (Zenodo) and by making only relevant data and other outputs FAIR.

35 How will these be covered? Note that costs related to research data/output management are eligible as part of the European partnership on metrology grant (if compliant with the Grant Agreement conditions).	The costs for making the data FAIR were included in the project's budget and will be claimed as they were compliant with the Grant Agreement's conditions.
36 Who will be responsible for data management in your project?	The coordinator, with support from the participants, had overall responsibility for the management of data/research outputs and quality assurance. The coordinator was responsible for coordinating updates to the data management plan and for deciding on a case-by-case basis which data/research outputs will be kept and for how long. The participant(s) that produced the data were responsible for organising backup and storage, archiving, and for depositing the data/research outputs within the chosen repositories.
37 How will long term preservation be ensured? Discuss the necessary resources to accomplish this (costs and potential value, who decides and how, what data will be kept and for how long)?	Long term preservation was ensured by depositing the data within repositories (Zenodo), where they are guaranteed to be stored for at least 10 years. No costs were associated with the long-term preservation of the data in these repositories. The data will increase in value over time because of its fundamental impact in a wide range of applications. It will enable the technologies developed in the project to be taken up by the measurement supply chain and by standards bodies including ISO/TC265 Carbon dioxide capture, transportation, and geological storage, CEN TC 474 CCUS and CEN TC 264 Air Quality. These standards bodies will need access to the data to justify the robustness of future standards. The data will also be of value as it underpins the results of published datasets. The coordinator and participants decided on a case-by-case basis what data will be kept and for how long (at least 10 years)

1.5 Data security

Questions	Answers
38 What provisions are or will be in place for data security (including data recovery as well as secure storage/archiving and transfer of sensitive data)?	*Data recovery and secure storage* Deposition in the Zenodo public repository provides additional security as it has multiple replicas in a distributed file system which is backed up on a nightly basis. Data will also be backed-up on the partner organisations' own servers, to mitigate the (very low) risk of loss of data from the central repository. *Transfer of sensitive data* The project did not generate sensitive data.
39 Will the data be safely stored in trusted repositories for long term preservation and curation?	Yes, the data was safely stored in the Zenodo open access repository.

1.6 Ethics

Questions	Answers
40 Are there, or could there be, any ethics or legal issues that can have an impact on data sharing? These can also be discussed in the context of the ethics review. If relevant, include references to ethics report(s) and the ethics section in the Annex 1.	There were no issues that could impact on data sharing.
41 Will informed consent for data sharing and long-term preservation be included in questionnaires dealing with personal data?	The project did not share data with identifiable personal information.

1.7 Other issues

Questions	Answers
42 Do you, or will you, make use of other national / funder / sectorial /	Data management was compliant with: - The research data policy of the European Partnership on Metrology;

departmental procedures for data management? If yes, which ones (please list and briefly describe them)?	- European laws about data security and the protection of privacy (e.g. GDPR); - Institutional guidelines; - Scientific community guidelines.

2 Open science: research data management

Statement	**Put an X in the box to confirm**	**Or, list any exceptions to this**
All participants have adhered to the requirements of the project's GA and CA with respect to open science: research data management (GA Article 17 and its Annex 5) for this reporting period	☒	