EI 3589

Good plant design for CO_2 stream impurity measurement

First edition

energy institute

GOOD PLANT DESIGN FOR CO_2 STREAM IMPURITY MEASUREMENT

First edition

May 2025

Published by
Energy Institute, London
The Energy Institute is a professional membership body incorporated by Royal Charter 2003
Registered charity number 1097899

The Energy Institute (EI) is the chartered professional membership body for the energy industry, supporting over 23 000 individuals working in or studying energy and 200 energy companies worldwide. The EI provides learning and networking opportunities to support professional development, as well as professional recognition and technical and scientific knowledge resources on energy in all its forms and applications.

The EI's purpose is to develop and disseminate knowledge, skills and good practice towards a safe, secure and sustainable energy system. In fulfilling this mission, the EI addresses the depth and breadth of the energy sector, from fuels and fuels distribution to health and safety, sustainability and the environment. It also informs policy by providing a platform for debate and scientifically-sound information on energy issues.

The EI is licensed by:

– the Engineering Council to award Chartered, Incorporated and Engineering Technician status, and
– the Society for the Environment to award Chartered Environmentalist status.

It also offers its own Chartered Energy Engineer, Chartered Petroleum Engineer, and Chartered Energy Manager titles.

A registered charity, the EI serves society with independence, professionalism and a wealth of expertise in all energy matters.

This publication has been produced as a result of work carried out within the Technical Team of the EI, funded by the EI's Technical Partners. The EI's Technical Work Programme provides industry with cost-effective, value-adding knowledge on key current and future issues affecting those operating in the energy sector, both in the UK and internationally.

For further information, please visit **http://www.energyinst.org**

The EI gratefully acknowledges the financial contributions towards the scientific and technical programme from the following companies:

ADNOC
Astron Energy
BAPCO Energy
Basra Energy
BP
BP Wind
Chevron
CNOOC
Corio Generation
DCC Energy
Drax Group
EDF Renewables
Equinor
Exolum
ExxonMobil International Ltd
Harbour Energy
Iberdrola
Intertek
Ithaca Energy
Kuwait Petroleum Internation
Marathon Petroleum Corporation
Neste
Ocean Winds
OMV
Ørsted
Phillips 66
Prax
Qatar Energy
Repsol
RWE npower
Saudi Aramco
SGS
Shell U.K. Exploration and Production Ltd
Siemens Gamesa Renewables
Spirit Energy
SSE Renewables
SSE Thermal
TAQA
TotalEnergies
Total Wind
Uniper
Valero
Vattenfall
Vestas
Vitol Energy
Woodside
World Fuel Services

However, it should be noted that the above organisations have not all been directly involved in the development of this publication, nor do they necessarily endorse its content.

ISBN 978 1 78725 479 4

Published by the Energy Institute

Hard copy and electronic access to EI and IP publications is available via our website, **https://publishing.energyinst.org**.
Documents can be purchased online as downloadable pdfs or on an annual subscription for single users and companies.
For more information, contact the EI Publications Team.
e: **pubs@energyinst.org**

CONTENTS

Contents continued

Page

Contents continued

Page

Contents continued

Contents continued

Page

LIST OF FIGURES AND TABLES

Page

Figures

Tables

Contents continued

Page

FOREWORD

In 2006, the then Department of Business, Enterprise and Regulatory Reform[1] asked the UK Health and Safety Executive (HSE) to determine if there were any health and safety concerns relating to the deployment of large-scale carbon capture and storage (CCS) technology in the UK.

The HSE carried out a significant review of all aspects of the carbon capture and storage chain from the various capture technologies through to the injection points on the offshore platforms. Part of this process involved approaching the Energy Institute (EI) and the Carbon Capture and Storage Association (CCSA), who jointly organised several workshops to identify the key areas for development. The workshops specifically identified several areas which it believed merited greater attention.

The concerns were split into two broad subject areas:

– modelling the dispersion of any leak of carbon dioxide appropriately; and,
– ensuring good practice from industrial gases sectors is fed into the UK CCS industry and is adequate and appropriate for this new industry.

Three documents were produced to cover these topics[2,3,4], which proved to be a well-used resource. They were intended for guidance only and to improve the industry's knowledge, to assist developers and operators to carry out hazard analysis and procure and manage their plant safely. It was accepted when producing the documents that it would be necessary, at some point in the future, to review the documents. A decade after their publication, recognising both increased interest in CO_2 capture and storage and the work that has been undertaken in the meantime, the EI organised a series of workshops which identified the need to update the earlier documents.

The opportunity was taken to restructure the three documents into two. The first[5], which drew on experiences from many countries, provides not only guidance on the various elements that make up a CCS chain (omitting geological storage), but also gives assistance on what is perceived as good practice in design and operation at time of writing. A second document[6] describes all aspects relating to the hazards associated with CO_2, to include approaches to ensuring that hazards are appropriately identified, quantified and mitigated.

During the production of the first of these, several gaps in the scope were noted, which advised a future work programme. This Good Practice Guide addresses one of these, the measurement of

1 Responsibilities now allocated to the Department for Energy Security and Net Zero (DESNZ).

2 Energy Institute. Good plant design and operation for onshore carbon capture installations and onshore pipelines. [Updated to EI 3554]

3 Energy Institute. Technical guidance on hazard analysis for onshore carbon capture installations and onshore pipelines. [Updated to EI 3553]

4 Energy Institute. Hazard analysis for offshore carbon capture platforms and offshore pipelines. [Updated to EI 3553]

5 Energy Institute. EI 3554 Good plant design and operation for onshore and offshore carbon capture installations and pipelines. 2nd edition.

6 Energy Institute. EI 3553 Hazard analysis for onshore and offshore carbon capture installations and pipelines. 2nd edition.

impurities in the captured CO_2 stream, necessary to provide confidence between producers and the transportation and storage entities, and deliver a system which is safe, operable and affordable.

Whilst every reasonable care has been taken to ensure the accuracy and relevance of its contents, the Energy Institute, its sponsoring companies, section writers and the working group members listed in the Acknowledgements who have contributed to its preparation, cannot accept any responsibility for any action taken, or not taken based on this information. The Energy Institute shall not be liable to any person for any loss or damage which may arise from the use of any of the information contained in any of its publications.

This publication will be reviewed in the future, and it would be of considerable assistance for any subsequent revision if users would send comments or suggestions for improvements to:

The Technical Department, Energy Institute
61 New Cavendish Street
London
W1G 7AR
E: technical@energyinst.org.uk

ACKNOWLEDGEMENTS

This project was commissioned by the Energy Institute's Carbon Capture Utilisation and Storage Committee and steered by the EI's CCS2301 'CO_2 impurity measurement Working Group', chaired by Andy Brown of Progressive Energy.

The research and update of the guideline was led by Andy Brown of Progressive Energy as the principal author and coordinated the drafting of other sections by:

Pieter Verloop	Kimman Process Solutions B.V.
Sam Bartlett	National Gas
Nitya Nagesh	National Physical Laboratory
Manohara Gudiyor Veerabhadrappa	National Physical Laboratory
David Simon	Wood

Members of the EI CCS2301 Working Group included:

Eryk Remiezowicz	Air Products
Prakash Patel	Marsh
Georgie Roberjot	Department for Energy Security & Net Zero
Richard Holden	EET Hydrogen
Trupti Patinge	EET Hydrogen
Ben Rowton	National Physical Laboratory
Andrew Clissold	Shimadzu Corporation
Gabriele Chinello	TÜV SÜD
Hooman Haghighi	Wood

The support from a number of equipment manufacturers has been essential to this work and contributions from the following deserve recognition and acknowledgement:

Karl Rogers	ABB
Daniel Currie	Panametrics, a Baker Hughes Business
Dante Grassi	Beamonics
Michael Potts	Emerson
Jeff Hand	Emerson
Paul Keeling	Enviro Technology Services Ltd
Pieter Verloop	Kimman Process Solutions B.V.
Godert de Keijzer	Kimman Process Solutions B.V.
Mike Shepherd	nZero Group
Andrew Clissold	Shimadzu Corporation
Trevor Tilmann	Thermo Fisher Scientific
Paul Le Marquand	Thermo Fisher Scientific
Antti Heikkilä	Vaisala

A draft version was distributed to industry stakeholders for technical review. The following generously gave of their time to provide feedback, which is greatly appreciated:

Sam Bartlett	National Gas
Nitya Nagesh	National Physical Laboratory

Project coordination was carried out by Eva Leinwather and Sreeja Roy (Energy Institute).

1 INTRODUCTION

The introduction of new technologies is usually accompanied by new challenges, and transitioning the carbon-based energy economy that has served humankind since the dawn of creation to something more sustainable is no exception. Carbon (dioxide) capture and storage (CCS) is expected to make a significant contribution towards managing down the atmospheric CO_2 inventory, and projects to deliver its long-term removal are currently being developed in many nations across the globe. These CCS projects, planned around tens of million tonnes annually, are being developed commercially, initially incentivised by Government support, with the awareness that the technology cannot yet be described as fully mature, and is therefore not without some degree of risk. These risks are typically managed by several actors, including conservative design and operational controls.

One of the operational controls is, having set a purity specification for the captured CO_2 stream[7], providing confidence that the impurities are within the limits agreed between the producer and the transportation and/or storage operator. The limits are set to avoid unwanted chemical consequences (e.g. corrosion), thermodynamic effects (e.g. sudden phase changes) and reduction in downhole capacity (e.g. promotion of sulphate reducing bacteria). Such confidence is gained by measurement of the levels of impurity at the custody transfer point(s): out-of-specification CO_2 streams may be rejected (usually vented to atmosphere).

Any financial incentive between the parties is a function of the direct measurement of the CO_2 content of the stream. Knowledge of the impurity content of a CO_2 stream allows calculation of the CO_2 content, which could be used as a check. There is therefore a fiscal motivation to provide accurate measurement of the CO_2 content itself and of the impurities. A requirement to do this is therefore included in the commercial and regulatory codes that can govern a CCS network.

Accurate measurement of the impurity content of the CO_2 stream is one of the challenges facing this relatively new industry. This Good Practice Guide is intended to provide guidance to developers in the existence of, and selection of suitable equipment, to enable them to deliver a safe and operable CCS system. It is noted that off-line and on-line measurements have different challenges and therefore need slightly different approaches for impurity measurements. In this context, 'off-line' refers to sample collection followed by laboratory analyses) and 'on-line' refers to continuous measurement as close as practicable to 'real time', with the latter being preferable for reasons which are described herein.

This relatively new industry therefore needs analysers, validated methods, and calibration gases. Whilst existing commercial systems may be offered for the measurement of impurities in CCS applications, it is not always the case following testing that they have demonstrated the capability to identify specific analytes.

Section 2 describes the scope of this guide – what is included and what has been excluded. Section 3 describes the impurities to be measured and some of the factors that will need to be considered, including functions unique to the measurement of impurities in CO_2 streams in a CCS context. Section 4 illustrates the ranges over which the measurement equipment might expect to be calibrated and offers comment on the potential value of beyond-calibration capacity. Sections 8 and 9 describe, for each of the impurities listed, what measurement techniques are available at the time of writing, and provide a high-level summary of key

7 A CO_2 stream is defined as 'a stream consisting overwhelmingly of carbon dioxide, usually greater than 95 mol% carbon dioxide' as per ISO 27913:2024, section 3.4.

issues that can influence the designer's choice. These sections are for 'on-line' (samples being automatically taken at defined intervals whenever the plant is operational), and 'manual' which refers to the less frequent measurement, often by a plant operator, respectively.

Much of the focus in earlier sections is on hardware, sections 7 and 10.6 address the important issues of standards against which the equipment will be calibrated, and how such calibration would be supported by Primary Reference Materials.

A summary of the 'state of the art' is provided in section 10, and seeks to identify what measurement equipment is available now, what could reasonably be made available within about one year, what might become available within a two/three-year horizon and what requires more fundamental development and is beyond currently available technology.

Throughout the document certain gaps will have been identified, both in the suitability of hardware on an appropriate timescale, in the availability of recognised standards, and how calibration is to be confirmed. Section 12 lists these and, based on a subjective assessment by the Working Group, assigns priorities to support existing and planned CCS projects, together with an idealised timescale to development, assuming that the work was adequately resourced.

A substantial appendix (15.2) provides the reader with a very brief description of each of the measurement techniques referred to in the preceding sections, particularly in sections 8 and 9.

This publication has been produced as a result of work carried out within the Technical Team of the Energy Institute (EI), funded by the EI's Technical Partners and other stakeholders. The EI's Technical & Innovation Programme provides industry with cost effective, value adding knowledge on key current and future issues affecting those operating in the energy sector, both in the UK and beyond.

Energy Institute
61 New Cavendish Street
London W1G 7AR, UK

t: +44 (0) 20 7467 7100
f: +44 (0) 20 7255 1472
e: pubs@energyinst.org
www.energyinst.org

9781787254794

ISBN 978 1 78725 479 4
Registered Charity Number: 1097899