



BSI Standards Publication

**Carbon dioxide capture, transportation
and storage — Carbon dioxide capture —
Performance evaluation methods for CO₂
capture connected to a CO₂ intensive plant**

National foreword

This British Standard is the UK implementation of ISO 27928:2025.

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**Carbon dioxide capture,
transportation and storage —
Carbon dioxide capture —
Performance evaluation methods
for CO₂ capture connected to a CO₂
intensive plant**

*Capture, transport et stockage du dioxyde de carbone —
Capture du dioxyde de carbone — Méthodes d'évaluation des
performances pour la capture du CO₂ des installations à fortes
émissions de CO₂*

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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This document was prepared by Technical Committee ISO/TC 265, *Carbon dioxide capture, transportation, and storage*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

It is very important to reduce atmospheric carbon dioxide (CO₂) emissions in order to meet climate change mitigation targets. The inclusion of carbon dioxide capture and storage (CCS) among the variety of available emission reduction approaches enhances the probability of meeting these targets at the lowest cost to the global economy. CCS captures CO₂ from industrial and energy-related sources and stores it underground in geological formations. CCS can capture CO₂ emissions from carbonaceous fuel-based combustion processes, including power generation, and is at present the most effective technology capable of dealing directly with emissions from several CO₂ intensive industries, such as steel, cement etc.

As a standard for CO₂ capture, ISO 27919-1 presents an evaluation method of key performance indicators (KPIs) for post-combustion CO₂ capture (PCC) from a power plant. On the other hand, this document covers an evaluation method of KPIs for CO₂ capture from various CO₂ intensive plants. It is noted that ISO 27919-1 and this document are mutually independent; similar terms and symbols used in both the standards are valid only in the respective standards. CO₂ intensive plants suggest industries such as steel, cement, ferro alloys, aluminium and other metals. It is also intended for CCS enabled hydrogen as well as refineries, chemical processing industries such as fertilizer. The CO₂ capture plant takes in the exhaust gas from the CO₂ intensive plant without further integration, i.e. not impacting on the production of the CO₂ intensive plant.

CO₂ intensive industries are characterized by the production of significant volumes of CO₂ as a by-product. In many cases, the CO₂ amounts are comparable or even larger than the amount of the main product. The two largest of such industries, steel and cement manufacture, are responsible for 7 % to 8 % each of global CO₂ production. Typically, the CO₂ intensive industries produce large amounts of CO₂ at each production site, often in the range from some hundred thousand to million tonnes per annum. CO₂ intensive industries, such as steel, cement, etc. are using carbon or carbon-containing raw materials, which often cannot readily be replaced. For example, cement needs limestone and silicon metal needs carbon as the chemical reductant.

In steel production, the dominant CO₂ sources are the iron-making blast furnace and the steel converter, while other production steps (ore sintering, rolling mills, etc.) are producing smaller amounts. A modern, integrated steel plant, making finished steel bars, beams or plates from iron ore emits around two tonnes of CO₂ per tonne of finished product. In contrast, steel produced from scrap in an electric arc furnace emits about 350 kg CO₂ per tonne of steel. However, scrap availability is seriously limited. The exhaust gases from the blast furnace have extra high content of CO₂ (typically 25 % by volume) and high pressure [2 atmospheres (atm) to 4 atm]. The steel converter produces intermittently smaller amounts of flue gas with some lower CO₂ content and at ambient pressure. Other CO₂ producing steps on the way from iron ore to finished products typically produce flue gases with lower CO₂ content (10 % to 15 %), like most fuel combustion and at ambient pressure.

CO₂ capture on the blast furnace exhaust gas can take advantage of the high CO₂ content, pressure and volume of this exhaust gas, typically 75 % of the total CO₂ from the integrated mill. This has been pilot tested with pressure swing adsorption (PSA) on a semi-industrial blast furnace. The adsorbents were zeolites and active carbon. The results showed low energy consumption.

In cement production, there are two main steps producing CO₂:

- a) Calcination of limestone by heating the main raw material, limestone to 900 °C, after grinding the rock limestone to a fine powder. Heating of the materials occurs in counter current flow with hot exhaust gases from step b). The process equipment can vary from plant to plant.
- b) Clinker burning of a mixture of burnt lime from step a) together with silica containing raw materials occur in a long, rotary kiln. The kiln is normally fired from the material exit end with solid, liquid or gaseous fuel (e.g. coal, oil, gas, biomass and waste). The clinker mix is heated up to 1 450 °C and the clinker is semi-fused to round plum size pellets. A part of the exhaust gases is sent to step a); the rest is sent to the exhaust gas stack. The clinker leaving the rotary kiln passes through a clinker cooler, where combustion air is pre-heated for the kiln.

In lime production, CO₂ generation includes only step a).

After calcination and clinker burning, the clinker is ground together with other mineral raw materials into cement powder, used to make concrete; the biggest volume of construction material globally by far.

The limestone calcination generates 60 % of the total CO₂ produced. The exhaust gas from the rotary kiln combustion carries the remaining 40 %; giving a total of 0,8 to 0,9 tonnes of CO₂ per tonne of clinker. The exhaust gas contains typically 20 % to 22 % of CO₂, moisture and dust. The remaining gas compounds are mostly N₂, O₂ and NO_x with smaller amounts of other compounds depending on the fuel used. The CO₂ capture process is located downstream of conventional contaminant controls of the exhaust gas, and is expected to have minimal, if any, influence on the quality of the cement clinker produced.

Silicon metal (a typical use is in solar panels) is smelted in large bucket shaped furnaces with three large diameter electrodes in through the top. The top of the furnace is semi-closed for operational reasons. Raw materials (typically quartz and carbon) are fed through the top. Extreme high temperatures are generated in the centre of the furnace. This causes the quartz to melt, react with carbon and form a bottom pool of silicon metal, which then is intermittently tapped out. The furnace reactions also generate large volumes of exhaust gases; a mixture of carbon monoxide and silicon monoxide (CO and SiO). As the exhaust gas is cooled down and contacts air at the top of the furnace, these gas components are oxidized into CO₂ and silica dust (SiO₂). The silica particle size typically less than 10 microns in size (particle size as for cigarette smoke) is filtered off and sold as a by-product. The resulting plant exhaust contains varying and low concentrations of CO₂ and air. Recycling off gas back to the furnace top before connecting the exhaust gas to the CO₂ capture plant can result in higher CO₂ concentrations, facilitating the CO₂ capture.

Even if the furnace producing silicon metal is fed exclusively with renewable electricity, the production emits around four tonnes of CO₂ per tonne of silicon metal produced.

Aluminium production is done in long rows of electrolysis cells fed with aluminium oxide (Al₂O₃) powder into a melted fluoride bath. The electricity is fed through bottom (cathode) and top (anode) electrodes. Produced melted aluminium metal gathers in the bottom and is intermittently tapped off. Under the top carbon electrode, CO₂ gas evolves containing over 95 % CO₂; the remainder being fluorides. This cell gas is collected from the long row of cells and then mixed with large volumes of air from building above the cell row (the hall). This gaseous mixture also contains traces of fluorides leaked from the cells. The diluted cell gas is then sent to water washing, to avoid harming the environment. After mixing with the hall air and after water wash, the gas contains 1 % to 2 % CO₂; rest air and moisture.

Aluminium electrolysis produces around 1,5 tonnes of CO₂ per tonne of aluminium product.

To capture CO₂ the cell gas can be diverted to a CO₂ capture unit before mixing it with the hall gas and then sent to washing with water.

CCS enabled hydrogen (commonly referred to as “Blue” hydrogen) is produced by the reforming of short-chain hydrocarbons (typically methane). The product CO₂ from this reaction is captured and exported for permanent storage.

Feedstock gas is purified and mixed with steam, before passing through one or multiple reforming reactor(s), producing a stream consisting primary of hydrogen, CO₂, carbon monoxide (CO) and water. This stream is then passed through a water-gas shift reactor, where residual CO is converted to CO₂ and hydrogen, and then cooled to remove water. The result is a syngas made up almost entirely of CO₂ and hydrogen, at a pressure of approximately 25 bar¹⁾ to 30 bar.

CO₂ is then captured from this syngas stream and exported for storage. Depending on the plant's configuration and reformer design, CO₂ can also be captured from plant's fired heater and reformer flue gases. Hydrogen is typically purified using a pressure swing adsorption (PSA) unit, from which the rejected “tail gas” is combusted to produce process heat or steam.

Modern CCS enabled hydrogen flowsheets are capable of capturing in excess of 95 % of all carbon within the feedstock hydrocarbon gas.

For other CO₂ intensive industries, beyond steel, cement, silicon, aluminium and CCS enabled hydrogen, see relevant textbooks. The intended user of this document includes CO₂ intensive plant owners and operators,

1) 1 bar = 0,1 MPa = 10⁵ Pa; 1 MPa = 1 N/mm².

project developers, technology developers and vendors, regulators, and other stakeholders. This document provides a common basis for estimating, measuring and evaluating the performance of a CO₂ capture plant connected to a CO₂ intensive plant.

Carbon dioxide capture, transportation and storage — Carbon dioxide capture — Performance evaluation methods for CO₂ capture connected to a CO₂ intensive plant

1 Scope

1.1 This document specifies methods for measuring and evaluating the performance of CO₂ capture connected to a CO₂ intensive plant, and which separates CO₂ from the CO₂ intensive plant exhaust gas in preparation for subsequent transportation and geological storage. In particular, this document provides a common methodology to calculate key performance indicators (KPI) for the CO₂ capture plant. To determine the KPIs, the boundaries of the CO₂ capture plant need to be defined and the necessary parameters need to be measured.

1.2 This document covers the CO₂ capture plant capturing CO₂ from CO₂ containing exhaust gas connected to CO₂ intensive plants. The connection of a CO₂ capture plant to a CO₂ intensive plant is anticipated to have negligible impact on the product quality or the quantities produced by the CO₂ intensive plant. This is in contrast with the integration of CO₂ capture plants with power plants which usually results in a reduction of the power plant output. For the CO₂ intensive industry, it is important that product quality remains the same after connection of the CO₂ capture plant, in order for the industry to continue to meet customer requirements.

The CO₂ capture technologies covered by this document are able to operate without interfering with the operations of the CO₂ intensive plant. Frequently used CO₂ capture technologies are chemical absorption (e.g. liquid amine) and solid adsorption [e.g. pressure swing adsorption (PSA), temperature swing adsorption (TSA)]. Other CO₂ capture concepts are membranes, cryogenic and other capture technologies. The CO₂ capture plant can be installed for treatment of the full volume of exhaust gas from the CO₂ intensive plant or a fraction of the total (i.e. a slipstream). Captured CO₂ is then conditioned, e.g. dried and compressed or liquefied, as determined by the conditions needed for transportation and storage. The transportation can be either through a pipeline or through an intermediate storage facility waiting for shipment; either by tanker car, train or ship.

The system includes interfaces between the CO₂ capture plant and the CO₂ intensive plant as well as the CO₂ transportation and storage system.

1.3 This document is intended to describe the following KPIs:

- a) CO₂ capture rate;
- b) specific electrical energy consumption (SEC);
- c) specific thermal energy consumption (STEC);
- d) specific material consumption (e.g. absorbent or adsorbent) (SMC).

The calculations are based on measurements at the boundary of the CO₂ capture plant, particularly of energy and other utilities consumption.

1.4 This document includes:

- a) the CO₂ capture plant boundary (see [Clause 4](#)), which defines the boundaries of the CO₂ capture plant and identifies which streams of energy and mass are crossing these boundaries to identify the key streams that are applicable for their particular case;

- b) the basic performance of CO₂ capture plant (see [Clause 5](#)), which defines the parameters that describe the basic performance of the CO₂ capture plant;
- c) the utilities and consumption calculation (see [Clause 6](#)), which lists the utility measurements required and provides guidance on how to convert utility measurements into the values required for the KPIs;
- d) the guiding principles (see [Clause 7](#)), the basis for CO₂ capture plant performance assessment, which describes all guidelines to prepare, set-up and conduct the tests;
- e) the instruments and measurement methods (see [Clause 8](#)), which lists the standards available for the relevant measurements issues and considerations to take into account when applying measurement methods to CO₂ capture plants;
- f) the evaluation of key performance indicators (see [Clause 9](#)), which specifies the set of KPIs to be determined and their calculation methods.

1.5 This document does not provide guidance for benchmarking, comparing or assessing KPIs of different technologies or different CO₂ capture projects. Health, safety and environment (HSE) is not included.

2 Normative references

There are no normative references in this document.

3 Terms, definitions, abbreviated terms and symbols

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <https://www.electropedia.org/>

3.1 Terms and definitions

3.1.1

absorbent

substance able to selectively absorb liquid or gas components in its bulk phase

3.1.2

accuracy

measurement accuracy

closeness of agreement between a measured quantity value and a true quantity value of a measured entity

[SOURCE: ISO/IEC Guide 99:2007, 2.13, modified — the admitted term "accuracy of measurement" has been deleted, "measurand" has been replaced with "measured entity" in the definition and Notes 1, 2 and 3 to entry have been deleted.]

3.1.3

adsorbent

substance able to selectively adsorb liquid or gas components on its surface

3.1.4

auxiliary unit

unit providing electricity or thermal (heating or cooling) or other utilities for the CO₂ capture plant

3.1.5**carbon dioxide capture and storage****CCS**

process consisting of the separation of CO₂ from industrial and energy-related sources, transportation and injection into a geological formation, resulting in long term isolation from the atmosphere

Note 1 to entry: CCS is often referred to as carbon capture and storage. This terminology is not encouraged because it is inaccurate: the objective is the capture of carbon dioxide and not the capture of carbon. Tree plantation is another form of carbon capture that does not describe precisely the physical process of removing CO₂ from industrial emission sources.

Note 2 to entry: The term “sequestration” is also used alternatively to “storage”. The term “storage” is preferred.

Note 3 to entry: Long term means the minimum period necessary for CO₂ geological storage to be considered an effective and environmentally safe climate change mitigation option.

Note 4 to entry: The term carbon dioxide capture, utilization (or use) and storage (CCUS) includes the concept that isolation from the atmosphere can be associated with a beneficial outcome. CCUS is embodied within the definition of CCS to the extent that long term isolation of the CO₂ occurs through storage within geological formations. CCU is carbon capture and utilization (or use) without storage within geological formations.

Note 5 to entry: CCS should also ensure long term isolation of CO₂ from oceans, lakes, potable water supplies and other natural resources.

[SOURCE: ISO 27917:2017, 3.1.1, modified — Note 2 to entry has been modified.]

3.1.6**chemical absorption**

process in which CO₂ is absorbed by chemical reaction

3.1.7**CO₂ capture**

separation of CO₂ in such a manner as to produce a concentrated stream of CO₂ that can readily be transported for storage

3.1.8**CO₂ captured**

CO₂ in the *product CO₂ stream* ([3.1.31](#)) produced by a CO₂ capture plant that produces a *CO₂ stream* ([3.1.14](#)) from exhaust gases

3.1.9**CO₂ capture plant boundary**

boundary

performance evaluation boundary of a CO₂ capture plant

3.1.10**CO₂ capture rate**

CO₂ removal efficiency of the CO₂ capture plant calculated as the quotient of the CO₂ volume flow rate in the *product CO₂ stream* ([3.1.14](#)) divided by the CO₂ volume flow rate in the inlet gas stream

Note 1 to entry: CO₂ capture rate is expressed as a percentage.

3.1.11**CO₂ conditioning**

processes needed before transportation to make the *CO₂ stream* ([3.1.14](#)) leaving the capture plant meeting downstream specifications, e.g. drying (dehydration) purification, compression, liquefaction and dehydration

3.1.12**CO₂ intensive industry**

industry producing significant volumes of CO₂ as a by-product