BS ISO 27919-1:2018

BSI Standards Publication

Carbon dioxide capture

Part 1: Performance evaluation methods for post-combustion CO_2 capture integrated with a power plant

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National foreword

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Carbon dioxide capture —

Part 1: Performance evaluation methods for post-combustion CO_2 capture integrated with a power plant

Captage du dioxyde de carbone —

Partie 1: Méthodes d'évaluation des performances pour le captage du CO_2 post-combustion intégré à une centrale thermique

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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 documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2. www.iso.org/directives

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For an explanation on the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

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

A list of all the parts in the ISO 27919 series can be found on the ISO website.

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.

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Introduction

It is very important to reduce atmospheric carbon dioxide (CO_2) emissions in order to meet climate change mitigation targets. 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 CO_2 from industrial and energy-related sources and stores it underground in geological formations. It can capture emissions from carbonaceous fuel-based combustion processes, including power generation, and is the only technology capable of dealing directly with emissions from several industrial sectors, such as cement manufacture and fertilizer production.

This document is the first in a series of standards for CO_2 capture. It is limited to evaluation of key performance indicators (KPIs) for post-combustion CO_2 capture (PCC) from a power plant using a liquid-based chemical absorption process. New or revised standards focused on other capture technologies and approaches will be developed at a later date.

PCC is applicable to all combustion-based thermal power plants. A simplified block diagram illustrating the PCC is shown in Figure 1.

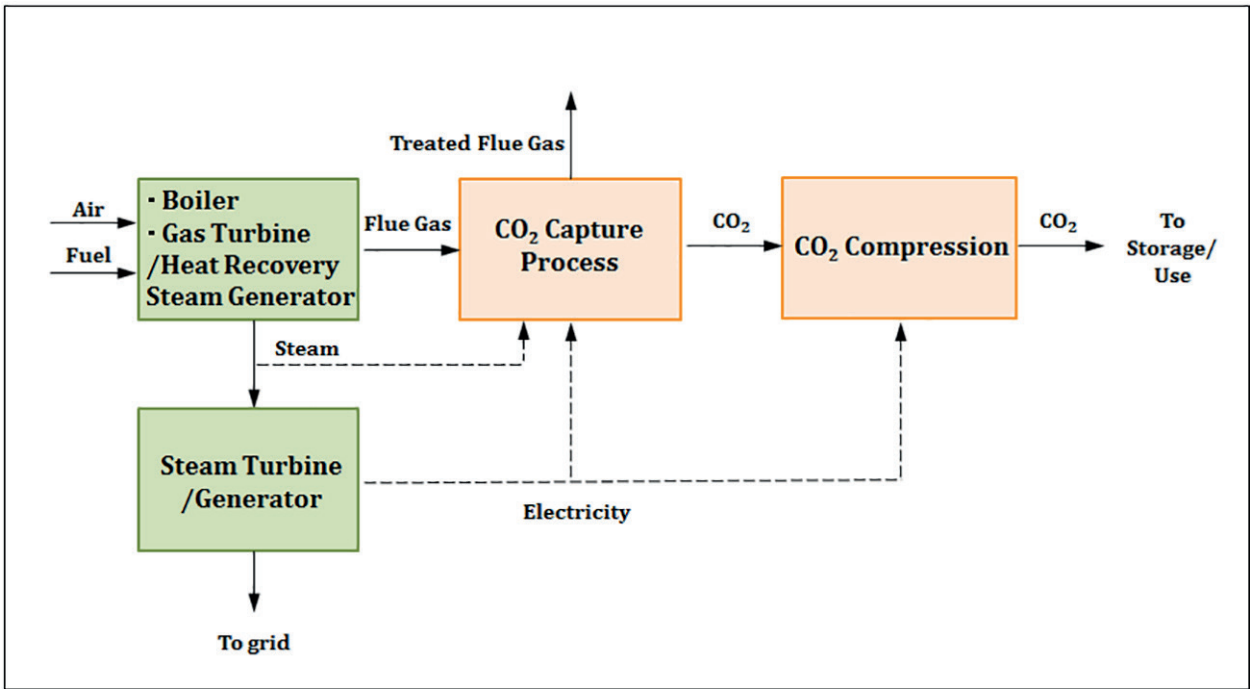

Figure 1 — Simplified block diagram for PCC

In a typical power generation facility, carbonaceous fuel (e.g. coal, oil, gas, biomass) is combusted with air in a boiler to raise steam that drives a turbine/generator to produce power. In a gas turbine combined cycle system, the combustion occurs in the gas turbine to drive power generation, and steam generated through a heat recovery steam generator (HRSG) contributes to additional power generation. Flue gas from the boiler or gas turbine consists mostly of N_2, CO_2, H_2O and O_2 with smaller amounts of other compounds depending on the fuel used. The CO_2 capture process is located downstream of conventional pollutant controls. Chemical absorption-based PCC usually requires the extraction of steam from the power plant's steam cycle or, depending on the absorption liquid/process employed, the use of lower grade heat sources for absorption liquid regeneration.

The intended readership for this document includes power plant owners and operators, project developers, technology developers and vendors, regulators, and other stakeholders. The document will provide several benefits, as outlined in the clauses below. In brief, it provides a common basis to estimate, measure, evaluate and report on the performance of a PCC plant integrated with a power

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plant. It can help various stakeholders to identify potential efficiency improvements among different plant components. It can help to guide the selection of measurement methodologies, and serve as a resource in development of regulations. Finally, it provides the basis for future standards development.

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Carbon dioxide capture —

Part 1:
Performance evaluation methods for post-combustion CO_2 capture integrated with a power plant

1 Scope

This document specifies methods for measuring, evaluating and reporting the performance of post-combustion CO_2 capture (PCC) integrated with a power plant, and which separates CO_2 from the power plant flue gas in preparation for subsequent transportation and geological storage. In particular, it provides a common methodology to calculate specific key performance indicators for the PCC plant, requiring the definition of the boundaries of a typical system and the measurements needed to determine the KPIs.

This document covers thermal power plants burning carbonaceous fuels, such as coal, oil, natural gas and biomass-derived fuels, which are producing CO_2 from boilers or gas turbines, and are integrated with CO_2 capture.

The PCC technologies covered by this document are those based on chemical absorption using reactive liquids, such as aqueous amine solutions, potassium carbonate solutions, and aqueous ammonia. Other PCC concepts based on different principles (e.g. adsorption, membranes, cryogenic) are not covered. The PCC plant can be installed for treatment of the full volume of flue gas from the power plant or a fraction of the total (i.e. a slip stream). Captured CO_2 is processed in a compression or liquefaction step as determined by the conditions for transportation and storage.

The KPIs considered in this document are the following:

a) Specific thermal energy consumption (STEC);

b) Specific electrical energy consumption (SEC);

c) Specific equivalent electrical energy consumption (SEEC);

d) Specific reduction in CO_2 emissions (SRCE);

e) Specific absorbent consumption (SAC) and specific chemical consumption (SCC).

The calculations are based on measurements at the boundaries of the considered system, particularly of energy and utilities consumption. The integrated system includes the definition of interfaces between the PCC plant and the power plant.

This document includes the following items:

— The system boundary which defines the boundaries of the PCC plant and identifies which streams of energy and mass are crossing these boundaries to help power plant operators identify the key streams that are applicable for their particular case.

— Basic PCC plant performance which defines the parameters that describe the basic performance of the PCC plant.

— Definition of utilities and consumption calculation which lists the utility measurements required and provides guidance on how to convert utility measurements into the values required for the KPIs.

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— Guiding principles - Basis for PCC plant performance assessment which describes all guidelines to prepare, set-up and conduct the tests.

— Instruments and measurement methods which lists the standards available for the relevant measurements and considerations to take into account when applying measurement methods to PCC plants.

— Evaluation of key performance indicators which specifies the set of KPIs to be determined and their calculation methods to provide a common way of reporting them.

This document does not provide guidelines for benchmarking, comparing or assessing KPIs of different technologies or different PCC projects.

NOTE For the purposes of this document, thermal energy and electric energy are expressed by the unit of "J" (Joule) and "Wh" (Watt hour) respectively unless otherwise noted, with a prefix of International System of Units (SI) if necessary. (1 J = 1 W·s, 1 Wh = 1 W·h = 3 600 J).

2 Normative references

There are no normative references in this document.

3 Terms, definitions and symbols

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

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

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

3.1 Terms and definitions

3.1.1
absorbent
substance able to absorb liquid or gas

[SOURCE: ISO/TR 27912:2016, definition 3.1]

3.1.2
measurement accuracy
accuracy of measurement
accuracy
closeness of agreement between a measured quantity value and a true quantity value of a measurand

[SOURCE: ISO/IEC Guide 99:2007, definition 2.13]

3.1.3
auxiliary unit
unit providing heat, power and/or other utilities for the PCC plant

3.1.4
boiler feed water
water consisting of the condensate and the make-up water that is sent to the boiler

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3.1.5
carbon dioxide capture and storage
CCS
process consisting of the separation of CO_2 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 CO_2 from industrial emission sources.

Note 2 to entry: The term "sequestration" is also used alternatively to "storage". The term "storage" is preferred since “sequestration” is more generic and can also refer to biological processes (absorption of carbon by living organisms).

Note 3 to entry: Long term means the minimum period necessary for CO_2 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 could be associated with a beneficial outcome. CCUS is embodied within the definition of CCS to the extent that long term isolation of the CO_2 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 CO_2 from oceans, lakes, potable water supplies and other natural resources.

[SOURCE: ISO 27917:2017, definition 3.1.1]

3.1.6
carbonaceous fuels
any solid, liquid or gaseous fuels containing carbon atoms

3.1.7
capture plant
process and associated equipment that produces a CO_2 stream

3.1.8
chemical absorption
process in which CO_2 is absorbed by chemical reaction

3.1.9
CO_2 capture efficiency
capture efficiency
CO_2 removal efficiency of the capture plant calculated as the amount of CO_2 captured divided by the total amount of CO_2 contained in the flue gas at the inlet of the capture plant

Note 1 to entry: The CO_2 capture efficiency is expressed as a percentage.

3.1.10
CO_2 captured
absolute amount of pure CO_2 captured by the capture plant

3.1.11
CO_2 stream
stream consisting overwhelmingly of carbon dioxide

[SOURCE: ISO 27917:2017, definition 3.1.1, modified — The Note was deleted.]

3.1.12
condensate
water produced by condensation of steam, e.g. a boiler of PCC return to the steam cycle and/or auxiliary boiler

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3.1.13
deep flue gas desulfurization
deep FGD
SO_2 removal unit placed downstream of the main flue gas desulfurization process intended to lower the SO_2 content to the level required by the CO_2 capture plant

Note 1 to entry: Also called a "polishing" FGD.

Note 2 to entry: In the case where no FGD is required by local regulations, and FGD is installed for the purposes of CCS, the new unit will be considered as deep FGD.

3.1.14
dehydrator
moisture removal system and/or equipment

3.1.15
demineralized water
water from which the mineral matter or salts have been removed

[SOURCE: ISO/TR 27912:2016, definition 3.24, modified — The second term "demin water" was removed and in the definition the word "of" was replaced by "from".]

3.1.16
DeNO*x*
process or equipment used to remove NO*x* from the flue gas

3.1.17
effluent
liquid discharged to the environment

3.1.18
fuel specific emission
amount of component generated from complete combustion per unit of heat energy released

3.1.19
host power plant
power plant from which flue gas is sent to the PCC plant

3.1.20
impurities
non-CO_2 substances that are part of the CO_2 stream that may be derived from the source materials or the capture process, or added as a result of commingling for transportation, or released or formed as a result of sub-surface storage and/or leakage of CO_2

[SOURCE: ISO 27917:2017, definition 3.2.12, modified — Notes 1 and 2 were deleted.]

3.1.21
interface
mechanical, thermal, electrical, or operational common boundary between two elements of a system

[SOURCE: ISO 10795:2011, definition 1.120, modified — The abbreviation "I/F" was deleted.]

3.1.22
key performance indicator
measure of performance relevant to the PCC plant integrated with a power plant

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3.1.23
measurement uncertainty
uncertainty of measurement
uncertainty
non-negative parameter characterizing the dispersion of the quantity values being attributed to a measurand, based on the information used

Note 1 to entry: Measurement uncertainty includes components arising from systematic effects, such as components associated with corrections and the assigned quantity values of physical properties, as well as the definitional uncertainty. Sometimes estimated systematic effects are not corrected for; associated measurement uncertainty components are incorporated instead.

Note 2 to entry: The parameter may be, for example, a standard deviation called standard measurement uncertainty (or a specified multiple of it), or the half-width of an interval, having a stated coverage probability.

Note 3 to entry: Measurement uncertainty comprises, in general, many components. Some of these may be evaluated by Type A evaluation of measurement uncertainty from the statistical distribution of the quantity values from a series of measurements and can be characterized by standard deviations. The other components, which may be evaluated by Type B evaluation of measurement uncertainty, can also be characterized by standard deviations, evaluated from probability density functions based on experience or other information.

Note 4 to entry: In general, for a given set of information, it is understood that the measurement uncertainty is associated with a stated quantity value attributed to the measurand. A modification of this value results in a modification of the associated uncertainty.

Note 5 to entry: "Type A evaluation of measurement uncertainty" is defined as an evaluation of a component of measurement uncertainty by a statistical analysis of measured quantity values obtained under defined measurement conditions. "Type B evaluation of measurement uncertainty" is defined as an evaluation of a component of measurement uncertainty determined by means other than a Type A evaluation of measurement uncertainty".

[SOURCE: ISO/IEC Guide 99:2007, definition 2.26, modified — "measurement standards" in Note 1 was changed to "physical properties" and a Note 5 was added.]

3.1.24
PM
particulate matter including $PM_{2,5}$, PM_{10}, and/or total suspended particulate matter

[SOURCE: ISO 25597:2013, definition 3.21]

3.1.25
particulate removal
action to remove particulate matter from the flue gas stream

3.1.26
PCC plant
process and associated equipment that produces a CO_2 stream from combustion gases

3.1.27
permanent plant instrument
instrument installed in the power plant and capture plant for control and monitoring

3.1.28
post-combustion CO_2 capture
capture of carbon dioxide from flue gas stream produced by carbonaceous fuel combustion

[SOURCE: ISO/TR 27912:2016, definition 3.51, modified — In the term, "CO_2" was added and "fuel air combustion" was modified to "carbonaceous fuel combustion" in the definition.]

3.1.29
product CO_2 stream
stream produced by a CO_2 capture and compression/liquefaction process

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3.1.30
reclaiming system
system used to recover CO_2 absorbents for use in the PCC plant to remove the heat stable salts produced by the reaction of organic and inorganic acids with the amine(s) in the absorbents

3.1.31
redundant instrument
duplicate instrument necessary to plant functioning in case of failure of similar instruments for measurement of the same parameters

3.1.32
reference power plant
power plant that is considered to be representative of power generation without CO_2 capture

Note 1 to entry: The power plant is either real or hypothetical.

3.1.33
regeneration
process to regenerate an activity of absorbent after use to its operationally effective state

3.1.34
rejected heat
heat dissipated to the environment by cooling equipment

3.1.35
specific absorbent consumption
amount of CO_2 absorbent consumed to capture and compress/liquefy a tonne of CO_2

3.1.36
specific reduction in CO_2 emissions
calculated net decrease of the CO_2 emissions per unit output of a reference power plant by implementing the PCC process to the host power plant

Note 1 to entry: This measure of emission reduction is normalised with respect to the output of the power plant.

[SOURCE: ISO 27917:2017, definition 3.2.8, modified — "baseline scenario and the CCS project output" has been replaced by "per unit output of a reference power plant by implementing the PCC process to the host power plant".]

3.1.37
specific chemical consumption
amount of chemical consumed to capture and compress/liquefy a tonne of CO_2

3.1.38
specific equivalent electrical energy consumption
overall electrical energy consumption attributed to capture and compression/liquefaction of a tonne of CO_2

3.1.39
specific electrical energy consumption
electrical energy consumed to capture and compress/liquefy a tonne of CO_2

3.1.40
specific thermal energy consumption
thermal energy consumed to capture and compress/liquefy a tonne of CO_2

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3.1.41
reference conditions
conditions for a reference point where results of performance evaluation could be adjusted for the purpose of comparability in the reporting of the results and benchmarking

Note 1 to entry: See Annex E which presents standard reference conditions used as a reference point to adjust the results of performance evaluation.

3.1.42
thermal power plant
power plant that converts heat e.g. released by the combustion of carbonaceous fuels into electricity

3.1.43
tie-in point
point of connection between the utility supply and the PCC plant

Note 1 to entry: This point sits at the PCC plant boundary.

3.1.44
treated flue gas
flue gas of which the CO_2 concentration has been reduced after passing through a PCC plant

3.1.45
utilities
ancillary services needed in the operation of a process, such as steam, electricity, cooling water (CW), demineralised water, compressed air, refrigeration and effluent disposal

3.1.46
vent gases
gases other than flue gases or treated flue gases that are intentionally emitted to the atmosphere

3.1.47
waste heat
heat generated by a process that would normally be dissipated to the environment if special measures for its utilization were not implemented

3.1.48
waste water
excess water allowed to run to waste from the water circuit

[SOURCE: ISO 1213-1:1993, definition 5.1.18]

3.1.49
wet-basis
condition in which a solid, such as a fuel or a gas, such as flue gas, contains moisture

3.2 Abbreviations

CCS	carbon dioxide capture and storage
CW	cooling water
DP	differential pressure
FGD	flue gas desulfurization
FSE	fuel specific emission
GTCC	gas turbine combined cycle
HP	high pressure
HRSG	heat recovery steam generator
IP	intermediate pressure

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KPI	key performance indicator
LHV	lower heating value
LP	low pressure
MP	medium pressure
NO*x*	nitrogen oxides
PCC[a]	post-combustion CO_2 capture
PM	particulate matter
SAC	specific absorbent consumption
SCC	specific chemical consumption
SCWD	specific cooling water duty
SEC	specific electrical energy consumption
SEEC	specific equivalent electrical energy consumption
SO*x*	sulphur oxides, sulfur oxides
SRCE	specific reduction in CO_2 emissions
STEC	specific thermal energy consumption

[a] PCC is often used for pulverized coal combustion. In this document, it refers to post-combustion CO_2 capture.

3.3 Symbols

The following mathematical symbols are preparatory for revising variables and formulae in Clause 5, Clause 6 and Clause 9 based on the ISO directives and relevant standards.

$c_{p\,CW}$	Specific heat of CW	[kJ/(kg K)]
ΔE	Fractional increase in plant energy input per unit of product	[-]
FSE	Fuel specific emission	[kg/kJ]
h_{steam}	Specific enthalpy of steam	[kJ/kg]
$h_{condensate}$	Specific enthalpy of condensate	[kJ/kg]
LHV_{fuel}	LHV of a fuel	[kJ/kg]
P_{CW}	Electrical power requirement of CW pump	[MW]
P_{LGP}	Change in gross power output due to the steam extraction from the host power plant steam cycle and/or auxiliary unit	[MW]
P_{PCC}	Electrical power requirement of the PCC plant	[MW]
$P_{NET,ref}$	Net power output of a reference power plant	[MW]
$P_{NET,cap}$	Net power output of a power plant with a PCC plant	[MW]
p_e	Absolute pressure of a gas stream	[kPa]
p_{CWin}	Pressure of CW at the supply side	[kPa]
p_{CWout}	Pressure of CW at the return side	[kPa]
$q_{mCO_2_comp_a}$	Mass flow rate of a product CO_2 stream after compression	[t/h]
$q_{mCO_2_comp_b}$	Mass flow rate of a product CO_2 stream before compression	[t/h]
q_{mCO_2}	Mass flow rate of a product CO_2 stream	[t/h]

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$q_{mCO_2,ref}$	Mass flow rate of CO_2 emission from a reference power plant	[t/h]
$q_{mCO_2e,cap}$	Mass flow rate of CO_2 emission from a power plant with a PCC plant	[t/h]
$q_{m\ stream}$	Mass flow rate of steam to a PCC plant	[kg/h]
$q_{m\ condensate}$	Mass flow rate of condensate from a PCC plant	[kg/h]
$q_{m\ absorbent}$	Consumption rate of absorbent at a PCC plant	[kg/h]
$q_{m\ chemical}$	Consumption rate of a chemical compound at a PCC plant	[kg/h]
q_V	Volume flow rate at a measurement or specific condition	[m^3/h]
q_{Vr}	Volume flow rate at the standard temperature (273,15 K) and pressure (100 kPa) conditions	[m^3/h]
q_{VrCO_2in}	Volume flow rates of CO_2 at a PCC plant inlet on a dry basis at the standard temperature (273,15 K) and pressure (100 kPa) conditions	[m^3/h]
q_{VrCO_2out}	Volume flow rates of CO_2 at a PCC plant outlet (treated flue gas emission side) on a dry basis at the standard temperature (273,15 K) and pressure (100 kPa) conditions	[m^3/h]
$q_{Vr\ flue\ gas\ in}$	Volume flow rate of a flue gas to a PCC plant on a dry basis at the standard temperature (273,15 K) and pressure (100 kPa) conditions	[m^3/h]
$q_{Vr\ flue\ gas\ out}$	Volume flow rate of a flue gas at a PCC plant outlet on a dry basis at the standard temperature (273,15 K) and pressure (100 kPa) conditions	[m^3/h]
$q_{VrCO_2\ comp_a}$	Volume flow rate of a product CO_2 stream after compression on a dry basis at the standard temperature (273,15 K) and pressure (100 kPa) conditions	[m^3/h]
$q_{VrCO_2\ comp_b}$	Volume flow rate of a product CO_2 stream before compression on a dry basis at the standard temperature (273,15 K) and pressure (100 kPa) conditions	[m^3/h]
SAC	Specific absorbent consumption	[kg/t]
SCC	Specific chemical consumption	[kg/t]
SCWD	Specific cooling water duty	[m^3/t]
SEC	Specific electrical energy consumption	[kWh/t]
SEEC	Specific equivalent electrical energy consumption	[kWh/t]
SRCE	Specific reduction in CO_2 emissions	[t/MWh]
STEC	Specific thermal energy consumption	[GJ/t]
T_{CWin}	Temperature of CW at the supply side	[K]
T_{CWout}	Temperature of CW at the return side	[K]
T_S	Average temperature of a gas stream	[K]
w_c	Percentage of carbon by mass in fuel on an as-fired basis	[%]
η_{CO_2}	CO_2 capture efficiency	[%]
η_M	Efficiency of motor	[%]
η_P	Efficiency of CW pump	[%]

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$\eta_{\text{gas to PCC}}$	Proportion of total flue gas flow to a PCC plant	[%]
η_{ref}	Net power output efficiency of a reference power plant	[%]
η_{PCC}	Net power output efficiency of a power plant with PCC	[%]
ρ_{CW}	Density of CW	[kg/m^3]
Φ_{CW}	Total cooling heat duty at a PCC plant	[kJ/h]
$\varphi_{CO_2\text{in_cap}}$	Volume concentration of CO_2 in the flue gas to a PCC plant on a dry basis	[%]
$\varphi_{CO_2\text{out_cap}}$	Volume concentration of CO_2 in the flue gas at a PCC plant outlet (treated flue gas emission side) on a dry basis	[%]
$\varphi_{CO_2\text{out_comp_a}}$	Volume concentration of CO_2 in the product CO_2 stream after compression on a dry basis	[%]
$\varphi_{CO_2\text{out_comp_b}}$	Volume concentration of CO_2 in the product CO_2 stream before compression on a dry basis	[%]
(Chemical symbols)		
CO_2	Gaseous product by reaction of oxygen in air (combustion) with carbon atom in fuel	

4 Defining the system boundary

4.1 PCC plant integrated with a host power plant

This document is designed to assess the performance of a PCC plant integrated with a carbonaceous fuel-fired thermal power plant, including combined heat and power generation. This document covers the use of all carbonaceous fuel.

A PCC plant integrated with a thermal power plant (also called a host power plant) is characterized as follows:

a) Receives flue gas from one or more host power plants. Flue gas may be pre-conditioned within the host power plant(s), within the PCC plant, or a combination of both;

b) Typically receives utilities and energy from the host power plant or any other auxiliary units, or delivers energy to the host power plant;

c) PCC plant load control is integrated with the host power plant as required by both sides.

Hereafter these applications are called “PCC plant integrated with a host power plant”.

4.2 Boundary of the PCC plant, host power plant and utilities

Figure 2 presents a typical boundary of a PCC plant integrated with a host power plant. Minor variations may result from the specific configuration of a host power plant or a PCC plant. Figure 2 represents a comprehensive configuration that includes a carbonaceous fuel-fired boiler or a natural gas combined cycle, which are prevailing types in this field, and includes multiple items that may not be applicable to all cases. The boundary of any PCC plant may include the following interfaces:

a) Interface with the host power plant: Important elements at this interface include flue gas (downstream of any existing environmental control systems), electricity and heat transfer media, if these are supplied by a host power plant.

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b) Interface with auxiliary units: It includes the auxiliary boiler or auxiliary gas turbine with HRSG that supplies heat transfer media and electrical power to the PCC plant, instead of, or in combination with, a host power plant in case the modification of, or any operational impact on, a host power plant is quite restricted. Only the utility consumption affecting the performance evaluation of the PCC plant should be included in the consumption calculations (see Clause 6).

c) Interface with the environment: The outlet of the PCC plant discharges directly to the atmosphere and waste streams such as waste water, solid waste, and consumables (e.g., filters) should also be included in calculating consumption and utility requirements if present (see Clause 6).

d) Interface with CO_2 transportation infrastructure: It is the first flange at the outlet piping from the CO_2 stream compressor or CO_2 stream pump, if applied.

The performance evaluation boundary of a PCC plant integrated with a host power plant is depicted as a thick dashed line – labelled 100 – in Figure 2. Given the complexity of the system, explanations of the various streams and equipment are provided in Table 1 to Table 5.

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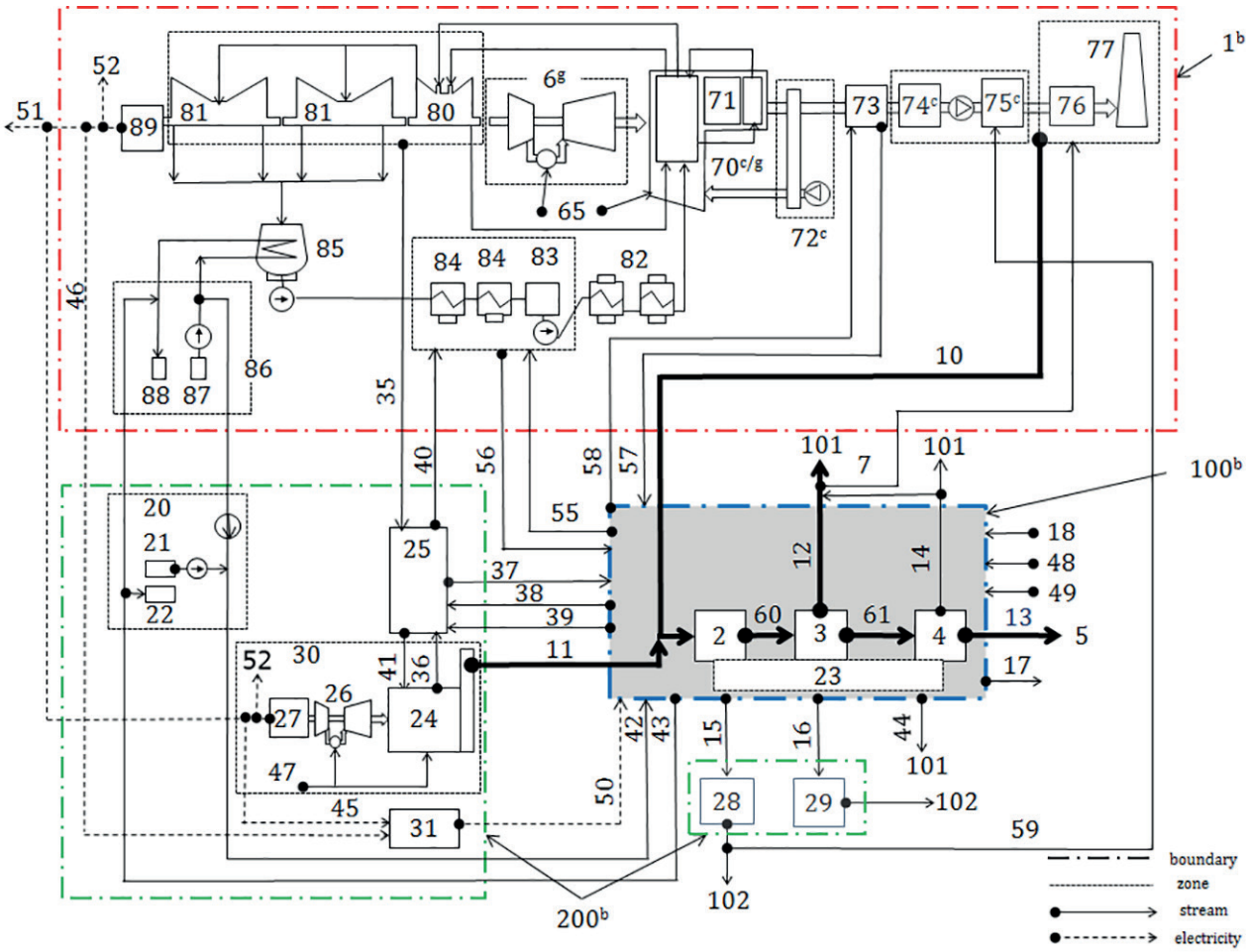

Key

1 host power plant boundary – this block flow configuration is typical for a coal fired boiler and a GTCC plant

2 pre-treatment (quencher, deep-FGD, flue gas fan) – conditioning of the flue gas in preparation for separation of CO_2. This can include removal of contaminants that could damage the absorbent, temperature control to optimize absorber efficiency, etc.

3 CO_2 capture section

4 CO_2 compression/liquefaction section (including CO_2 purification)

5 CO_2 transportation system

6 gas turbine in a GTCC - the item designated as a boiler (70) would be a HRSG and the air preheater and forced draft fan (72), particulate removal system (74), and FGD (75) would be removed

7 ducting to a stack if required (this stream, if it exists, might contain residual CO_2)

10 flue gas from host power plant

11 flue gas from auxiliary unit (auxiliary steam and power generation system, #30)

45 electricity from an auxiliary power generation system

46 electricity from the host power plant to the PCC plant

47 fuel to the auxiliary steam and power generation system

48 chemicals

49 demineralized water, industrial water

50 electricity diverted to power equipment and systems associated with the PCC plant, including fans, pumps, and the compression system

51 net power export

52 electricity diverted from the host power plant or the auxiliary power generation system to power other equipment within the same plant or system

55 medium transferring waste heat from the PCC plant to the host power plant – (e.g. boiler feed water for pre-heating)

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12	treated flue gas (mostly nitrogen, but might contain residual CO_2) to be vented or sent to a stack
13	product CO_2 stream, sent for transport
14	CO_2 vent stream to the atmosphere required for start-up, shut-down, emergency and during significant operational disturbances
15	waste water sent for treatment
16	waste sent to a waste handling system
17	by-product
18	fresh absorbent
20	CW generation system – the cooling system can include cooling towers, a once-through CW system, or air fin coolers
21	CW intake - A CW intake can be common to the host power plant or the PCC plant
22	CW outfall - A CW outfall can be common to the host power plant or the PCC plant
23	air fin cooler integrated into PCC plant
24	auxiliary steam generation system - e.g. HRSG on auxiliary gas turbine or auxiliary boiler
25	steam distribution system
26	auxiliary gas turbine
27	auxiliary generator
28	waste water treatment system
29	waste handling system
30	auxiliary steam and power generation system
31	power distribution system – controls the amount of power diverted to the PCC plant to operate fans, pumps, blowers, and the compression system
35	steam from a host power plant – although labelled as steam here, this can also be a different thermal energy transfer medium (e.g. hot oil)
36	steam from an auxiliary steam generation system – although labelled as steam here, this can also be a different thermal energy transfer medium (e.g. hot oil)
56	host power plant waste heat used in the PCC plant or return of PCC plant waste heat used in the host power plant – this stream can represent host power plant waste heat that is used in the absorbent regeneration process in the PCC plant or the return of waste heat that was generated in the PCC plant and used in the host power plant (e.g. boiler feed water preheating)
57	medium transferring waste heat from the host power plant to the PCC plant. A common source of waste heat in a host power plant is the heat contained in the flue gas. This stream integrates the heat supplied to the PCC plant by stream 37
58	power plant waste heat return from PCC plant – this stream represents the return of waste heat from stream 57 to the host power plant
59	use of PCC plant effluent in FGD – waste water from the PCC plant can potentially be used as make-up water in the FGD system
60	flue gas after pre-treatment – this stream is the flue gas stream after contaminants have been removed and temperature adjustments have been made in preparation for entering the absorber (from item 2 to 3)
61	product CO_2 stream leaving the CO_2-capture section prior to entry into the compression system (from item 3 to 4)
65	fuel to host power plant
70	boiler – or HRSG in GTCC case
71	NO_x removal system
72	air preheater and forced draft fan (not applicable in GTCC case)
73	flue gas heat recovery system
74	particulate removal system (not applicable in GTCC case)
75	FGD (not applicable in GTCC case)
76	flue gas heater, if necessary
77	stack and treated flue gas duct
80	high pressure (HP) – intermediate pressure (IP) turbine
81	low pressure (LP) turbine
82	HP heaters
83	deaerators
84	LP heaters
85	steam condenser

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37	steam supplied from the host power plant to PCC plant to drive absorbent regeneration and other processes -– although labelled as steam here, this can also be a different thermal energy transfer medium (e.g. hot oil)	86	power plant CW supply system
38	exhaust steam from the PCC to the host power plant – if steam is the heat transfer medium used in the PCC, any exhaust steam can be returned to the host power plant	87	power plant CW intake
39	steam condensate from the PCC to the host power plant – if steam is used and condensed in the PCC, this stream returns the condensate to the host power plant	88	power plant CW outfall
40	steam condensate return to the host power plant	89	power plant generator
41	steam condensate return to the auxiliary steam generation system	100	Line representing the PCC plant boundary
42	CW feed – if the CW system for the host power plant and/or auxiliary unit is used to supply CW to the PCC plant, it is accounted for in this stream	101	atmosphere
43	CW return – CW returned from the PCC to the host power plant and/or to the auxiliary unit	102	landfill and/or hydrosphere
44	rejected heat from the process cooler integrated into the PCC plant (# 23)	200	auxiliary unit boundary

NOTE All different streams and equipment for this figure are summarized in ascending order in Annex A. Only three superscripts are used. These superscripts indicate either different options related to the type of power system (c for coal, g for a gas) or to demark a system boundary.

b Boundary.

c Only in the case of coal fired boiler.

g Only in the case of GTCC.

Figure 2 — PCC plant boundary

Several of the items numbered in Figure 2 have a direct bearing on the KPIs defined in Clause 1. Items related to specific reduction in CO_2 emissions are included in Table 1. These include flue gas streams entering the PCC plant from the host power plant and any auxiliary units as well as streams leaving the PCC plant following CO_2 separation. Note the flue gas streams entering the PCC plant do not necessarily represent all of the CO_2-containing flue gas generated by the host power plant or auxiliary units. The PCC plant may be designed for partial capture, with a certain percentage of the flue gas routed to the PCC plant for treatment while the remaining flue gas and its associated CO_2 simply vented to the atmosphere. This possibility is discussed further in Clause 5.

It should also be noted that the KPIs related to the equivalent electrical energy consumption, i.e. SEEC and SRCE, can be applied to a case with an auxiliary unit defined in 4.2 b). The auxiliary unit can be included with a host power plant when calculating the KPI as explained in 9.4 and 9.5, if the electricity generated in the auxiliary unit is used to power equipment in the PCC plant and their application is agreed among the related parties due to its specification depending on each project. In this case the interpretation of the above KPI is influenced by both the fuel specific emissions [kg/kJ] explained in D.2 and the heat rate of the auxiliary unit. If these are different from a host power plant, then the main parameters used for each calculation should be listed with the KPI for mutual understanding among the related parties.

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