BS ISO 19694-7:2024

BSI Standards Publication

Stationary source emissions — Determination of greenhouse gas emissions in energy-intensive industries

Part 7: Semiconductor and display industries

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National foreword

This British Standard is the UK implementation of ISO 19694-7:2024.

The UK participation in its preparation was entrusted to Technical Committee EH/2/1, Stationary source emission.

A list of organizations represented on this committee can be obtained on request to its committee manager.

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Published by BSI Standards Limited 2024

ISBN 978 0 539 11936 7

ICS 13.020.40; 13.040.40

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This British Standard was published under the authority of the Standards Policy and Strategy Committee on 29 February 2024.

Amendments/corrigenda issued since publication

Date	Text affected

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International Standard

ISO 19694-7

First edition
2024-02

Stationary source emissions — Determination of greenhouse gas emissions in energy-intensive industries —

Part 7: Semiconductor and display industries

Émissions de sources fixes — Détermination des émissions de gaz à effet de serre dans les industries énergo-intensives —

Partie 7: Industries des semi-conducteurs et des écrans

Reference number
ISO 19694-7:2024(en)

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Contents

Page

Foreword ... **v**
Introduction ... **vi**
1 Scope ... **1**
2 Normative references ... **1**
3 Terms and definitions ... **2**
4 Abbreviated terms ... **6**
5 Determination of GHG emissions principles ... **7**
5.1 General ... 7
5.2 Major GHG emissions in semiconductor and display ... 7
5.3 Determination based on mass balance ... 7
5.4 Determination based on stack emission measurements ... 8
6 Inventory boundaries ... **8**
6.1 General ... 8
6.2 Organizational boundaries ... 8
6.3 Reporting boundaries ... 9
7 Direct GHG emissions and their determination ... **9**
7.1 General ... 9
7.2 Direct GHG emissions from combustion and transportation ... 10
7.3 Direct GHG emissions from process emissions ... 10
7.3.1 General ... 10
7.3.2 Tier 1 ... 13
7.3.3 Tier 2a ... 14
7.3.4 Tier 2b ... 15
7.3.5 Tier 2c ... 15
7.3.6 Tier 3a — Measured process-specific parameters ... 19
7.3.7 Tier 3b — Stack testing ... 19
7.3.8 Fluorinated liquids ... 22
8 Indirect emissions from imported energy and their determination ... **23**
8.1 General ... 23
8.2 GHG emissions from imported electricity ... 23
8.3 GHG emissions from external fossil and alternative fuels production and processing ... 24
9 General requirements for identifying, calculating and reporting of GHG emissions ... **24**
10 Baselines, acquisitions and disinvestments ... **25**
11 Reporting and performance assessment ... **25**
11.1 General ... 25
11.2 Corporate environmental reporting ... 26
11.3 Reporting periods ... 26
11.4 Performance assessment ... 26
12 Uncertainty of GHG inventories ... **27**
12.1 General ... 27
12.2 Assessment of uncertainty of the mass balance based method ... 28
12.2.1 Major sources of uncertainty ... 28
12.2.2 Uncertainty of activity data ... 28
12.2.3 Aggregated uncertainties of activity data ... 29
12.2.4 Application of default values instead of analytical results ... 30
12.2.5 Evaluation of the overall uncertainty of a GHG inventory ... 30
12.3 Assessment of the uncertainty for the stack-measurement method ... 30
Annex A (informative) **Content of the monitoring plan** ... **31**
Annex B (informative) **Default emission factors** ... **32**

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Document Sharing Hub

Full document details: BS ISO 19694-7:2024

Bibliography **40**

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Foreword

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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 146, *Air quality*, Subcommittee SC 1, *Stationary source emissions*.

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Introduction

0.1 General

This document for the semiconductor and display industry is based on *2019 Refinement to the 2006 IPCC Guideline for National Greenhouse Gas Inventories*.

This document, which deals with specific requirements for the semiconductor and display industry, has been harmonized with ISO 14064-1 and ISO 19694-1, which deal with broader requirements. ISO 19694-1 and this document provide a harmonized method for:

— measuring, testing and quantifying methods for greenhouse gas (GHG) emissions;

— assessing the level of GHG emissions performance of production processes over time, at production sites; and

— establishing and providing reliable, accurate and quality information for reporting and verification purposes.

0.2 Overview of semiconductor and display manufacturing process

Semiconductor and display manufacture include processes, such as TFD or plasma EWC of silicon-containing materials, that result in significant carbon dioxide emissions. These emissions are the results of the FC gases and nitrous oxide used in the manufacturing process. Other GHG emissions in semiconductor and display industry include the CO_2 and CH_4 from direct emissions of combustion, transportation, manufacturing process or indirect emissions (e.g. room heating, on-site transports, on-site power generation, external power production and external transports).

FC gases are used in two important steps of electronics manufacturing:

a) plasma EWC of silicon-containing materials, and

b) cleaning of the chamber walls of TFD and diffusion tools after processing substrates.

The semiconductor and display industry use N_2O as an input gas in TFD processes, and in other manufacturing processes that use N_2O, such as diffusion and dry removal of photoresist.

The process emission of FC gases and N_2O should be estimated using the *2019 Refinement to the 2006 IPCC Guideline for National Greenhouse Gas Inventories*. In this document, references are made to the relevant parts of *2019 Refinement to the 2006 IPCC Guideline for National Greenhouse Gas Inventories* depending on the element used for appropriate guidance that includes formulae, tables, etc. However, the *2019 Refinement to the 2006 IPCC Guideline for National Greenhouse Gas Inventories* can be corrected if some errors are detected. Therefore, companies are strongly encouraged to keep referring to Reference [4] and to replace the Annex B with the latest corrected version of Chapter 6, Volume 3 of the *2019 Refinement to the 2006 IPCC Guideline for National Greenhouse Gas Inventories* when it is made available.

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Stationary source emissions — Determination of greenhouse gas emissions in energy-intensive industries —

Part 7: Semiconductor and display industries

1 Scope

This document provides a methodology for calculating greenhouse gas (GHG) emissions from the semiconductor and display industry. This document includes the manufacture of semiconductor devices, microelectromechanical systems (MEMS), photovoltaic (PV) devices and displays. This document allows to report GHG emissions for various purposes and on different bases, such as a per-plant basis, per-company basis (by country or by region) or an international group basis. This document addresses all of the following direct and indirect sources of GHG:

— direct GHG emissions [as defined in ISO 14064-1:2018, 5.2.4 a)] from sources that are owned or controlled by the company, such as emissions resulting from the following sources:

  — process: fluorinated compound (FC) gases and nitrous oxide (N_2O) used in etching and wafer cleaning (EWC), remote plasma cleaning (RPC), in situ plasma cleansing (IPC), in situ thermal cleaning (ITC), N_2O thin film deposition (TFD), and other N_2O using process;

  — fuel combustion related to equipment and on-site vehicles, room heating/cooling;

  — fuel combustion of fuels for on-site power generation;

— indirect GHG emissions [as defined in ISO 14064-1:2018, 5.2.4 b)] from the generation of imported electricity, heat or steam consumed by the organization.

Other indirect GHG emissions [as defined in ISO 14064-1:2018, 5.2.4 c) to f)], which are the consequence of an organization's activities, but arise from GHG sources that are owned or controlled by other organizations, are excluded from this document.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO/IEC Guide 98-3:2008, *Uncertainty of measurement — Part 3: Guide to the expression of uncertainty in measurement (GUM:1995)*

ISO 19694-1:2021, *Stationary source emissions — Determination of greenhouse gas emissions in energy-intensive industries — Part 1: General aspects*

ISO 14064-1:2018, *Greenhouse gases — Part 1: Specification with guidance at the organization level for quantification and reporting of greenhouse gas emissions and removals*

Calvo Buendia, E., Tanabe, K., Kranjc, A., Baasansuren, J., Fukuda, M., Ngarize, S., Osako, A., Pyrozhenko, Y., Shermanau, P. and Federici, S. 2019 Refinement to the 2006 IPCC Guideline for National Greenhouse Gas Inventories *(2019 Refinement*), Volume 3, Chapter 6 Electronics. URL: https://www.ipcc-nggip.iges.or.jp/public/2019rf/index.html

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3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 19694-1 and the following 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
base year
specific, historical period identified for the purpose of comparing *greenhouse gas emissions* (3.14) or *greenhouse gas* (3.13) removals or other greenhouse gas-related information over time

Note 1 to entry: Base year emissions or removals may be quantified based on a specific period (e.g. a year or part of year where seasonality is a feature of the *organization's* (3.27) activity) or averaged from several periods (e.g. several years).

[SOURCE: ISO 19694-1:2021, 3.3, modified — Note 1 to entry has been added.]

3.2
carbon dioxide equivalent
CO_2e
unit for comparing the radiative forcing of a *greenhouse gas* (3.13) to that of carbon dioxide

Note 1 to entry: The carbon dioxide equivalent is calculated using the mass of a given greenhouse gas multiplied by its *global warming potential* (3.15).

[SOURCE: ISO 14064-1:2018, 3.1.13]

3.3
chemical vapour deposition
CVD
process for manufacturing preforms by which vapours and gases react chemically to produce deposits at the surface of a substrate

3.4
equity share
percentage of economic interest in, or benefit derived from, a *facility* (3.7)

Note 1 to entry: Under this approach, an *organization* (3.27) (corporation, group) or a company consolidates its *greenhouse gas emissions* (3.14) according to the (pro rata) equity share it holds in each operation, i.e. according to ownership. As an exception, no emissions are consolidated for so-called fixed asset investments where a company owns only a small part of the total shares of an operation and exerts neither significant influence nor financial control; other possible exceptions relate to the economic substance of a relationship.

3.5
etching
removal of surface material

Note 1 to entry: Etching can be applied with liquids agents (wet chemical etching) or with gases in a recipient (dry etching, plasma etching). The etching agent reacts chemically with the substrate.

[SOURCE: ISO 12679:2011, 3.3]

3.6
etching and wafer cleaning
EWC
removal process of chemical and particle impurities without altering or damaging the wafer surface after *etching* (3.5) the surface material

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3.7
facility
single installation, set of installations or production processes (stationary or mobile), which can be defined within a single geographical boundary, organizational unit or production process

[SOURCE: ISO 14064-1:2018, 3.4.1]

3.8
fixed combustion emission
emission from the fixed combustion, including power generation, heat and electricity generation

3.9
fluorinated compounds and N_2O
FCs and N_2O
types of fluorinated compounds and liquids used to manufacture electrical products

EXAMPLE CF_4, C_2F_6, C_3F_8, c-C_4F_8, C_4F_6, c-C_5F_8, CH_3F, CH_2F_2, CHF_3, C_2HF_5, NF_3, SF_6, COF_2, F_2, C_4F_8O and N_2O.

3.10
fossil fuel
fuels from fossilized materials listed by the Intergovernmental Panel on Climate Change (IPCC)

EXAMPLE Coal, oil, natural gas and peat.

[SOURCE: ISO 19694-3:2023, 3.18]

3.11
fuel combustion
intentional oxidation of materials within an apparatus that is designed to provide heat or mechanical work to a process, or to be used away from the apparatus

3.12
global warming potential
GWP
index, based on radiative properties of *greenhouse gases* (3.13), measuring the radiative forcing following a pulse emission of a unit mass of a given greenhouse gas in the present-day atmosphere integrated over a chosen time horizon (e.g. 100 years), relative to that of carbon dioxide (CO_2)

[SOURCE: ISO 14064-1:2018, 3.1.12, modified — "(e.g. 100 years)" has been added to the definition.]

3.13
greenhouse gas
GHG
gaseous constituent of the atmosphere, both natural and anthropogenic, that absorbs and emits radiation at specific wavelengths within the spectrum of infrared radiation emitted by the Earth's surface, the atmosphere and clouds

Note 1 to entry: For list of greenhouse gases, see latest Intergovernmental Panel on Climate Change (IPCC) Assessment Report.

Note 2 to entry: Water vapour and ozone are anthropogenic as well as natural greenhouse gases but are not included as recognized greenhouse gases due to difficulties, in most cases, in isolating the human-induced component of global warming attributable to their presence in the atmosphere.

[SOURCE: ISO 14064-1:2018, 3.1.1]

3.14
greenhouse gas emission
GHG emission
release of a *greenhouse gas* (3.13) into the atmosphere

[SOURCE: ISO 14064-1:2018, 3.1.5]

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3.15
greenhouse gas emission factor
emission factor
coefficient relating *greenhouse gas* (3.13) activity data with the *greenhouse gas emission* (3.14)

[SOURCE: ISO 14064-1:2018, 3.1.7, modified — "GHG" has been removed from the second term and Note 1 to entry has been deleted.]

3.16
greenhouse gas inventory
GHG inventory
list of *greenhouse gas sources* (3.17) and *greenhouse gas* (3.13) sinks, and their quantified *greenhouse gas emissions* (3.14) and greenhouse gas removals

[SOURCE: ISO 14064-1:2018, 3.2.6]

3.17
greenhouse gas source
GHG source
process that releases a *greenhouse gas* (3.16) into the atmosphere

[SOURCE: ISO 14064-1:2018, 3.1.2]

3.18
electricity grid
grid
public electricity network

[SOURCE: ISO 52000-1:2017, 3.4.8]

3.19
indirect greenhouse gas emission
indirect GHG emission
greenhouse gas emission (3.14) that is a consequence of an *organization's* (3.27) operations and activities, but that arise from *greenhouse gas sources* (3.17) that are not owned or controlled by the organization

Note 1 to entry: These emissions occur generally in the upstream and/or downstream chain.

[SOURCE: ISO 14064-1:2018, 3.1.11]

3.20
in situ plasma cleaning
IPC
technique using chemically reactive oxygen plasma to remove hydrocarbon contaminants

3.21
in situ thermal cleaning
ITC
combined process of pyrolysis and oxidation

3.22
lower heat value
LHV
net calorific value
NCV
absolute value of the specific heat (enthalpy) of combustion, for unit mass of the fuel burned in oxygen at constant pressure under such conditions that all the water of the reaction products remains as water vapour (at 0,1 MPa), the other products being as for the gross calorific value, all at the reference temperature

[SOURCE: ISO 1928:2020, 3.1.3, modified — the term "net calorific value at constant volume" has been replaced with "lower heat value", the admitted term "net calorific value" has been added, and "(enthalpy)" has been added to the definition.]

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3.23
micro-electromechanical system
MEMS
DEPRECATED: micro-electromechanical device
system composed of one or more integrated microsized components, such as sensors, actuators, transducers, resonators, oscillators, mechanical components and electric circuits

Note 1 to entry: In the definition, "microsized" is used to mean a size of less than a few millimetres.

Note 2 to entry: Technologies relating MEMS are extremely diverse and include fundamental technologies (such as design, material, processing, functional element, system control, energy supply, bonding and assembly, electric circuit, and evaluation), basic sciences (such as micro-science and engineering) as well as thermodynamics on a micro-scale and microtribology.

Note 3 to entry: The singular and plural forms of the term "MEMS" are identical.

[SOURCE: IEC 62047-1:2016, 2.1.1, modified — the term has been changed to "micro-electromechanical device" and the previous term "micro-electromechanical system" has been listed as a deprecated term; Notes 1 and 2 to entry have been revised.]

3.24
monitoring
continuous or periodic assessment of *greenhouse gas emissions* (3.14) and *greenhouse gas* (3.13) removals or other greenhouse gas-related data

[SOURCE: ISO 14064-1:2018, 3.2.12]

3.25
N_2O other process
semiconductor and display manufacturing process other than *N_2O thin-film deposition* (3.34) using N_2O

EXAMPLE Diffusion and dry removal of photoresist.

3.26
N_2O thin film deposition
N_2O TFD
thin-film deposition using N_2O as an input gas

3.27
organization
person or group of people that has its own functions with responsibilities, authorities and relationships to achieve its objectives

Note 1 to entry: The concept of organization includes, but is not limited to, sole-trader, company, corporation, firm, enterprise, authority, partnership, association, charity or institution, or part or combination thereof, whether incorporated or not, public or private.

[SOURCE: ISO 14064-1:2018, 3.4.2]

3.28
organizational boundary
grouping of activities or *facilities* (3.9) in which an *organization* (3.27) exercises operational or financial control or has an *equity share* (3.4)

[SOURCE: ISO 14064-1:2018, 3.4.7]

3.29
photovoltaic device
PV device
device which produces an electric potential difference between two points in a material by the absorption of photons

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3.30
process emission
emission from industrial processes involving chemical transformation other than combustion

[SOURCE: ISO 19694-1:2021, 3.36, modified — "including chemical and mineralogical transformations" has been changed to "involving chemical transformation".]

3.31
remote plasma cleaning
RPC
plasma processing method in which the plasma and material interaction occurs at a location remote from the plasma

3.32
reporting boundary
grouping of *greenhouse gas emissions* (3.14) or greenhouse gas removals reported from within the *organizational boundary* (3.28) as well as those significant *indirect greenhouse gas emissions* (3.19) that are a consequence of the *organization's* (3.27) operations and activities

[SOURCE: ISO 14064-1:2018, 3.4.8]

3.33
source stream
specific fuel type, raw material or product that

a) creates emissions of relevant *greenhouse gases* (3.13) at one or more emission sources as a result of its consumption or production;

b) contains carbon and is included in the calculation of *greenhouse gas emissions* (3.14) using a mass balance methodology

3.34
thin film deposition
TFD
process of producing thin films by physical vapour deposition or *chemical vapour deposition* (3.3) as well as other techniques

3.35
transport combustion emission
combustion emission from transportation activities

3.36
uncertainty
parameter associated with the result of quantification which characterizes the dispersion of the values that can be reasonably attributed to the quantified amount

Note 1 to entry: Uncertainty information typically specifies quantitative estimates of the likely dispersion of values and a qualitative description of the likely causes of the dispersion.

[SOURCE: ISO 14064-1:2018, 3.2.13]

3.37
verification
process for evaluating a statement of historical data and information to determine if the statement is materially correct and conforms to criteria

[SOURCE: ISO 14064-1:2018, 3.4.9]

4 Abbreviated terms

For the purposes of this document, the following abbreviated terms apply.

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CVD	chemical vapour deposition
DRE	destruction removal efficiency
EF	emission factor
EWC	etching and wafer cleaning
FC	fluorinated compound
GHG	greenhouse gas
GWP	global warming potential
IPC	in situ plasma cleansing
IPCC	intergovernmental panel on climate change
ITC	in situ thermal cleaning
KPI	key performance indicator
LHV	lower heat value
MEMS	microelectromechanical systems
NER	normalized emission rate
OEM	original equipment manufacturer
PI	performance indicator
PV	photovoltaic
TFD	thin film deposition
RPC	remote plasma cleaning
WSC	World Semiconductor Council

5 Determination of GHG emissions principles

5.1 General

The determination of GHG emissions can in principle be done through a mass balance method or through stack emission measurement or a combination of these two approaches. The choice of appropriate methodology should depend on the obtention of accurate results with acceptable measurement uncertainties at reasonable costs.

5.2 Major GHG emissions in semiconductor and display

GHG emissions in semiconductor and display industry include the family of FCs, N_2O and CH_4, which are from direct emissions of combustion, transportation and manufacturing processes, or from indirect emissions.

5.3 Determination based on mass balance

The GHG emissions of an installation may be determined based on mass balance. Emissions from source streams are calculated from input or production data, obtained by means of measurement systems, and additional parameters from laboratory and analysis [including the reduction of mass of gas i (D_i), the use

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