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Stationary source emissions — Determination of greenhouse gas emissions in energy-intensive industries — Part 7: Semiconductor and display industries

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Contents

Foreword

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This document was prepared by Technical Committee ISO/TC 146, *Air quality*, Subcommittee SC 1, *Stationary source emissions*.

A list of all parts in the ISO 19694 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.

Introduction

0.1 General

This document for the semiconductor and display industry ~~has been~~is based on ~~the Chapter 6, Volume 3, IPCC Methodology Report: "~~*2019 Refinement to the 2006 IPCC Guideline for National Greenhouse Gas Inventories* ~~(*2019 Refinement*)".~~.

This document ~~is harmonized with ISO 14064-1 and 19694-1. As this document,~~ which deals with specific ~~sectors, that is,~~ requirements for the semiconductor and display industry, ~~for~~ has been harmonized with ISO 14064-1 and ISO 19694-1, which deal with broader requirements~~, see also,~~ ISO ~~14064-1 and~~ 19694-1~~. These standards~~ and this document provide a harmonized method for:

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

— assessing the level of GHG emissions performance of production processes over time, at production sites; and ~~the establishment and provision of reliable, accurate and quality information for reporting and verification purposes.~~

~~GHG emissions offset mechanisms, including but not limited to voluntary offset schemes or nationally or internationally recognized offset mechanisms, shall not be used at any point in the GHG assessment according to this document.~~

— 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 ~~thin film deposition (~~TFD~~)~~ or plasma ~~etching and water cleaning (~~EWC~~)~~ of silicon-containing materials, that ~~results~~result in significant carbon dioxide emissions. These emissions are the results of the ~~fluorinated compounds (~~FC~~)~~ gases and nitrous oxide ~~(N_2O)~~ used in the manufacturing process. Other ~~greenhouse gas (~~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: ~~(i)~~

a) plasma ~~etching and wafer cleaning (~~EWC~~)~~ of silicon-containing materials, and ~~(ii)~~

b) cleaning of the chamber walls of ~~thin-film deposition (~~TFD~~)~~ and diffusion tools after processing substrates.

The semiconductor and display industry ~~manufactures~~ use N_2O as an input gas ~~during~~in TFD processes, and ~~for~~in other ~~N_2O using~~ 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 ~~following Chapter 6, Volume 3, IPCC Methodology Report "~~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* ~~(*2019 Refinement*)", which is annexed to this document. In this document, instructions are given as to which part of the *2019 Refinement* should be~~ depending on the element used for ~~each element which companies need to consider so that they can find in the Annex relevant~~ appropriate guidance ~~including equations~~that includes formulae, tables, etc. ~~It should be noted,~~ However, the *2019 Refinement* ~~may be subject~~ *to* ~~correction~~*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 [~~64~~] 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.

~~Other CO_2 sources include direct GHG emissions from fuel combustion (e.g., room heating and cooling, on-site vehicles and on-site power generation), and indirect GHG emissions from imported power consumed by the organization (e.g., external electricity, heat, or steam generation and transported).~~

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. ~~It~~This document includes the manufacture of semiconductor devices, microelectromechanical systems (MEMS), photovoltaic (PV) devices~~,~~ and displays. This document allows ~~for the reporting of~~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 ~~on~~ an international group basis. This document addresses all of the following direct and indirect sources of GHG ~~as defined in ISO 14064-1~~:

— 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 ~~EWC, RPC, IPC, ITC, N_2O TFD,~~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*

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

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

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 19694-1~~:2021~~ 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 ~~*GHG*~~*greenhouse gas emissions* (3.~~18~~14) or *greenhouse gas* (3.13) removals or other ~~GHG~~ 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.~~35~~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 ~~*GHG*~~*greenhouse gas* (3.~~16~~13) to that of carbon dioxide

Note 1 to entry: The carbon dioxide equivalent is calculated using the mass of a given ~~*GHG* (3.16)~~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 ~~(3.39)~~ for manufacturing preforms by which vapours and gases react chemically to produce deposits at the surface of a substrate

3.4
~~**direct greenhouse gas emission**~~
~~**direct GHG emission**~~
~~emission from *greenhouse gas sources* (3.21) owned or controlled by the reporting *organization* (3.35)~~

~~Note 1 to entry: This document uses the concepts of *equity share* (3.6) or *financial control*, (3.10), or operational control to establish *organizational boundaries* (3.36).~~

~~[SOURCE: ISO 19694-1:2021, 3.8]~~

~~3.5~~
~~**emission report**~~
~~stand-alone document intended to communicate an *organization's* (3.35) information related to *GHG* (3.16) and energy, including the results of its performance assessment~~

~~[SOURCE: ISO 19694-1:2021, 3.9]~~

~~3.6~~
equity share
percentage of economic interest in, or benefit derived from, a *facility* (3.~~9~~7)

Note 1 to entry: Under this approach, an *organization* (3.~~35~~27) (corporation, group) or a company consolidates its ~~*GHG*~~*greenhouse gas* *emissions* (3.~~18) in accordance with~~14) according to the (pro rata) equity share it holds in each operation, i.e. ~~in accordance with~~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 ~~(3.10);~~ other possible exceptions relate to the economic substance of a relationship.

3.~~7~~5
etching
~~removing~~removal of surface material

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

[SOURCE: ISO 12679:2011, 3.3]

3.~~8~~6
etching and wafer cleaning
EWC
removal process ~~(3.39)~~ of chemical and particle impurities without altering or damaging the wafer surface after *etching* (3.~~7~~5) the surface material

3.~~9~~7
facility
single installation, set of installations or production processes ~~(3.39)~~ (stationary or mobile), which can be defined within a single geographical boundary, organizational unit or production process ~~(3.39)~~

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

3.~~10~~8
~~**financial control**~~
~~the ability of an *organization* (3.35) to direct the financial and operating policies of an operation with a view to gaining economic benefits from its activities.~~

~~Note 1 to entry: The financial control usually exists if the *organization* (3.35) has the right to the majority benefits of the operation, or if it retains the majority risks and rewards of ownership of the operation's assets. Under this approach, companies consolidate 100 % of the emissions of those operations over which they have financial control; as an exception, consolidation according to *equity share* (3.6) is required for joint ventures where partners have joint financial control.~~

~~[SOURCE: ISO 19694-1:2021, 3.12]~~

~~3.11~~
fixed combustion ~~emissions~~emission

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

3.~~12~~9
fluorinated compounds and N_2O
FCs and N_2O
~~various~~ types of fluorinated compounds and liquids ~~use such as~~ 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 ~~for manufacturing electrical products.~~

3.~~13~~10
fossil ~~carbon~~fuel
~~carbon that is contained in fossilized material~~

~~Note 1 to entry: Examples of fossilized material are~~ fuels from fossilized materials listed by the Intergovernmental Panel on Climate Change (IPCC)

EXAMPLE Coal, oil ~~and,~~ natural gas and peat.

[SOURCE: ISO ~~14067:2018,~~ 19694-3~~:1.7.~~:2023, 3.18]

3.~~14~~11
fuel combustion
intentional oxidation of materials within an apparatus that is designed to provide heat or mechanical work to a process ~~(3.39),~~ or ~~for use~~to be used away from the apparatus~~.~~

3.~~15~~12
global warming potential
GWP
index, based on radiative properties of ~~*GHGs*~~*greenhouse gases* (3.~~16~~13), measuring the radiative forcing following a pulse emission of a unit mass of a given ~~*GHG* (3.16)~~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.~~16~~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 ~~(3.16),~~ 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 ~~(3.16)~~ but are not included as recognized greenhouse gases ~~(3.16)~~ 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.~~17~~14

~~**greenhouse gas activity data**~~
~~**GHG activity data**~~
~~**activity data**~~
~~quantitative measure of activity that results in *greenhouse gas emission* (3.18) or *GHG* (3.16) removal~~

~~[SOURCE: ISO 19694-1:2021, 3.16]~~

~~**3.18**~~
greenhouse gas emission
GHG emission
release of a ~~*GHG*~~*greenhouse gas* (3.~~16) to~~13) into the atmosphere

[SOURCE: ISO 14064-1:2018, 3.1.~~2~~5]

3.~~19~~15
greenhouse gas emission factor
~~GHG~~ emission factor
coefficient relating ~~*GHG*~~*greenhouse gas* (3.13) activity data ~~*(3.17)*~~ with the ~~*GHG*~~*greenhouse gas emission* (3.~~*18*~~14)

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

3.~~20~~16
greenhouse gas inventory
GHG inventory
list of *greenhouse gas sources* (3.~~21), GHG~~17) and *greenhouse gas* (3.13) sinks, and their quantified *greenhouse gas emissions* (3.~~18~~14) and ~~GHG~~greenhouse gas removals

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

3.~~21~~17
greenhouse gas source
GHG source
process ~~(3.39)~~ that releases a ~~*GHG*~~*greenhouse gas* (3.16) into the atmosphere

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

3.~~22~~18
~~grid~~ electricity grid
grid
~~electricity from the grid which is from the~~ public electricity network

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

3.~~23~~19
indirect greenhouse gas ~~emissions~~emission
indirect GHG emission
~~*GHG* *greenhouse gas* *emission* (3.~~18~~14) that is a consequence of an *organization's* (3.~~35~~27) operations and activities, but that arise from *greenhouse gas sources* (3.~~21~~17) that are not owned or controlled by the organization ~~(3.35)~~

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

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

3.~~24~~20
in ~~-~~situ plasma cleaning
IPC
technique using ~~the chemical~~chemically reactive oxygen plasma to remove ~~the~~ hydrocarbon contaminants

3.~~25~~21
in ~~-~~situ thermal cleaning
ITC
~~thermal cleaning is a~~ combined process ~~(3.39) involving~~ of pyrolysis and oxidation

3.~~26~~22
~~**key performance indicator**~~
~~**KPI**~~
~~Type of measure of performance used by industry Note 1 to entry: KPIs are commonly used by an *organization* (3.35) to evaluate its success or the success of an activity in which it is engaged.~~

~~[SOURCE: ISO 19694-1:2021, 3.23]~~

~~**3.27**~~
~~**level of assurance**~~
~~degree of confidence in the *GHG* (3.16) statement~~

~~[SOURCE: ISO 14064-1:2018, 3.4.13]~~

~~**3.28**~~
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

~~Note 1 to entry: Also referred to as "net calorific value" (NCV).~~

[SOURCE: ISO 1928:~~2009~~2020, 3.1.3, modified ~~-~~— the term "net calorific value at constant volume" has been replaced with "lower heat value~~" and Note 1 to entry~~", the admitted term "net calorific value" has been added, and "(enthalpy)" has been added to the definition.]

3.~~29~~23
~~**mass balance**~~
~~relationship between input and output quantity of a specific substance in a defined system, taking into account the formation or decomposition of that substance in the system~~

~~[SOURCE: ISO 19694-1:2021, 3.27]~~

~~**3.30**~~
~~**microelectromechanical systems**~~
micro-electromechanical system
MEMS