

# **ANNEX 5**

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## **MAPPING TABLES**

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## Annex 5. Relating 2019 Refinement to the 2006 Guidelines

This annex provides a road map for relating sections, equations, tables, figures and boxes in the 2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

Type of Refinement: U – Update, NG – New Guidance, NR – No Refinement.

### CHAPTER 3

#### Sections

- The section, 3.3.2.2, is an update of section 3.3.2.2 Chapter 3 Volume 3 of *2006 IPCC Guidelines* and should be used instead of the section 3.3.2.2 Chapter 3 Volume 3 of *2006 IPCC Guidelines*.
- The section, 3.10.1.2, is an update of section 3.10.1.2 Chapter 3 Volume 3 of *2006 IPCC Guidelines* and should be used instead of the section 3.10.1.2 Chapter 3 Volume 3 of the *2006 IPCC Guidelines*. To remain consistent with the updated terminology in section 3.10.2, the terminology used for the Tier 3 method in this section has been updated to refer to the development and use of an “emission factor method” rather than a “proxy method.” In addition, the lower bound emission factor presented for optimised plants has been updated to reflect the value that in the Annex 3A.1.
- The section, 3.10.1.3, is an update of section 3.10.1.3 Chapter 3 Volume 3 of *2006 IPCC Guidelines* and should be used instead of the section 3.10.1.3 Chapter 3 Volume 3 of *2006 IPCC Guidelines*. This section has been updated to refer to the “emission factor method” rather than the “proxy method.”
- The section, 3.10.2.1, is an update of section 3.10.2.1 Chapter 3 Volume 3 of *2006 IPCC Guidelines* and should be used instead of the section 3.10.1.2 Chapter 3 Volume 3 of *2006 IPCC Guidelines*. This section has been updated to clarify the full range of emissions and their sources at fluorochemical production plants.
- The section, 3.10.2.2, is an update of section 3.10.2.2 Chapter 3 Volume 3 of *2006 IPCC Guidelines* and should be used instead of the section 3.10.2.2 Chapter 3 Volume 3 of *2006 IPCC Guidelines*. The section has been updated with guidance for the Tier 3 method that now includes a method to estimate emissions from equipment leaks and more detail to the method for estimating emissions from process vents. New default emission factors are presented for the Tier 1 method.
- This section, 3.10.2.3, is an update of section 3.10.2.3 Chapter 3 Volume 3 of the *2006 IPCC Guidelines* and should be used instead of the section 3.10.2.3 Chapter 3 Volume 3 of the *2006 IPCC Guidelines*.
- The section, 3.11, is a new section in the Chapter 3 Volume 3 of the 2019 Refinement. It should be placed after section 3.10 Chapter 3 Volume 3 of the *2006 IPCC Guidelines*.
- New Annex was introduced - Annex 3A.1 “Default emission factor for section 3.10.2 Emissions from production of fluorinated compounds (other than HFC-23 emissions from HCFC-22 production)”. This annex provides background information for the Tier 1 default emission factors for fluorinated greenhouse gases (GHG) from fluorochemical production, that are provided in section 3.10.2 in the *2019 Refinement* to the *2006 IPCC Guidelines*. The first section discusses the default emission factors for SF<sub>6</sub> and NF<sub>3</sub> production based on literature search, and the second section discusses the default emission factor estimated from the data reported to the U.S. Greenhouse Gas Reporting Program.

Section Title	Type of Refinement	2006 IPCC Guidelines Section Number	2019 Refinement Section Number
<b>Sub-Chapter 3.3</b>			
Choice of emission factors	U	3.3.2.2	3.3.2.2
<b>Sub-Chapter 3.10</b>			
Introduction	NR	3.10.1.1	3.10.1.1
Methodological issues	U	3.10.1.2	3.10.1.2
Uncertainty assessment	U	3.10.1.3	3.10.1.3
Quality assurance/quality control (QA/QC), reporting and documentation	NR	3.10.1.4	3.10.1.4
Introduction	U	3.10.2.1	3.10.2.1
Methodological issues	U	3.10.2.2	3.10.2.2
Uncertainty assessment	U	3.10.2.3	3.10.2.3
Quality assurance/quality Control (QA/QC), reporting and documentation	NR	3.10.2.4	3.10.2.4
<b>Sub-Chapter 3.11</b>			
Hydrogen Production	NG	-	3.11
<b>Annex 3A.1</b>			
Default emission factor for section 3.10.2 Emissions from production of fluorinated compounds (other than HFC-23 emissions from HCFC-22 production)".	NG	-	Annex 3A.1

## Equations

Equation Title	Type of Refinement	2006 Guidelines Equation Number	2019 Refinement Equation Number
<b>Sub-Chapter 3.3</b>			
No refinements	NR	-	-
<b>Sub-Chapter 3.10</b>			
Tier 1 calculation of HFC-23 from HCFC-22 (produced) using default factor	NR	3.30	3.30
Tier 2 calculation of HFC-23 from HCFC-22 (produced) using factor(s) calculated from process efficiencies	NR	3.31	3.31
Calculation of HFC-23 emission factor from carbon balance efficiency	NR	3.32	3.32
Calculation of HFC-23 emission factor from fluorine balance efficiency	NR	3.33	3.33
Tier 3a calculation of HFC-23 emissions from individual process streams (direct method)	NR	3.34	3.34
Tier 3b calculation of HFC-23 emissions from individual process streams using a Site- Or Process-Specific Emission Factor	U	3.35	3.35
Tier 3c calculation of HFC-23 emissions from individual process streams (by monitoring reactor product)	NR	3.36	3.36
Tier 3a calculation of 'instantaneous' HFC-23 emissions in an individual process stream (direct method)	NR	3.37	3.37

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64 **Equations (Continued)**

Equation Title	Type of Refinement	2006 Guidelines Equation Number	2019 Refinement Equation Number
Tier 3b calculation of HFC-23 emissions in an individual process stream using a Site- Or Process-Specific Emission Factor	U	3.38	3.38
Tier 3b calculation of standard emission for Emission Factor-based method	U	3.39	3.39
Tier 3c calculation of HFC-23 emissions from an individual facility by in-process measurement	NR	3.40	3.40
Tier 1 calculation of production-related emissions	NR	3.41	3.41
Tier 2 calculation of production-related emissions using a mass balance approach	NG	-	3.41a
Tier 3 summation of production-related emissions from process vents and equipment leaks	NG	-	3.41b
Tier 3 direct calculation of production-related emissions from process vents	U	3.42	3.42
Tier 3 calculation of production-related emissions from process vents using a Site- Or Process-Specific Emission Factor	U	3.43	3.43
Tier 3 calculation of emissions from equipment leaks using a Screening Ranges Approach	NG	-	3.43a
Tier 3 calculation of emissions from equipment leaks using a Correlation Approach	NG	-	3.43b
Tier 3 calculation of a Unit-specific Correlation	NG	-	3.43c
Tier 3 calculation of emissions from equipment leaks using a Unit-specific Correlation Approach	NG	-	3.43d
Tier 3 calculation of production-related emissions from equipment leaks	NG	-	3.43e
<b>Sub-Chapter 3.11</b>			
All equations are new	NG	-	3.44-3.50

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66 **Tables**

Table Title	Type of Refinement	2006 Guidelines Table Number	2019 Refinement Table Number
<b>Sub-Chapter 3.3</b>			
Different plant types for the production of HNO <sub>3</sub>	NG	-	3.3.a
Default factors for nitric acid production	U	3.3	3.3
<b>Sub-Chapter 3.10</b>			
HFC-23 default emission factors	U	3.28	3.28
Tier 1 default emission factor for fluorochemical production	NG	-	3.28a
Representative chemical composition of the emitted mass	NG	-	3.28b
<b>Sub-Chapter 3.11</b>			
All tables are new	NG	-	3.29-3.30

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**Figures**

Figure Title	Type of Refinement	2006 Guidelines Figure Number	2019 Refinement Figure Number
<b>Sub-Chapter 3.3</b>			
No refinements	NR	-	-
<b>Sub-Chapter 3.10</b>			
Decision tree for HFC-23 emissions from HCFC-22 production (or other similar by-product emissions from fluorochemical production)	NR	3.16	3.16
Decision tree for emissions of fluorinated greenhouse gas from fluorochemical production processes, applicable to product, by-product, reactant, and fugitive emissions	U	3.17	3.17
<b>Sub-Chapter 3.11</b>			
All figures are new	NG	-	3.18-3.20

**Boxes**

Box Title	Type of Refinement	2006 Guidelines Box Number	2019 Refinement Box Number
<b>Sub-Chapter 3.10</b>			
Plant measurement frequency	NR	3.14	3.14
<b>Sub-Chapter 3.11</b>			
All boxes are new	NG	-	3.15-3.19

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**CHAPTER 4****Sections**

- The section, 4.2.2, is an update of section 4.2.2 Chapter 4, Volume 3 of the *2006 IPCC Guidelines* and should be used instead of the section 4.2.2 Chapter 4, Volume 3 of the *2006 IPCC Guidelines*.
- The section, 4.2.3, is an update of section 4.2.3 Chapter 4, Volume 3 of the *2006 IPCC Guidelines* and should be used instead of the section 4.2.3 Chapter 4, Volume 3 of the *2006 IPCC Guidelines*.
- The sub-chapter, 4.4, for primary aluminium production is an update of sub-chapter 4.4, Chapter 4, Volume 3 of the *2006 IPCC Guidelines* and should be used instead of sub-chapter 4.4, Chapter 4, Volume 3 of the *2006 IPCC Guidelines*, with only two exceptions: sections 4.4.2.1 and 4.4.2.2 (regarding process CO<sub>2</sub> emissions from primary aluminium production) have no refinements and these sections in the existing *2006 IPCC Guidelines* should be used. Updates and new guidance in the rest of sub-chapter 4.4 include:
  - (i) Section 4.4.1 is an updated introduction to GHG emissions from primary aluminium production, including alumina refining via alternative Bayer-Sinter and Nepheline technologies.
  - (ii) Sections 4.4.2.3 to 4.4.2.7 and sections 4.4.3 to 4.4.4 provide updates and new guidance relating to PFC emissions from primary aluminium production. These include:
    - Updated technology classes for accounting PFC emissions only.
    - Updated guidance (including Tier 1-2 default factors and uncertainties) for PFC emissions from ‘high voltage anode effects’ (HVAE), previously termed ‘anode effects’ in the *2006 IPCC Guidelines*. This includes a new Tier 2b-3b methodology.
    - New guidance on PFC emissions from ‘low voltage anode effects’ (LVAE), using either default (Tier 1) or facility-specific (Tier 3c) emission factors, based on maturity of literature at cut-off date.
    - New guidance on accounting PFC emissions during cell start-up (CSU) periods, if not already accounted for in HVAE and LVAE emissions.
    - New guidance on Total PFC emissions, being the sum of HVAE, LVAE and CSU emissions
    - A new Tier 3e facility-specific methodology for total PFC emissions by gas measurement.
    - Corresponding updates relating to Time-Series Consistency, Uncertainty Assessment and QA/QC Reporting and Documentation sections.
  - (iii) Sections 4.4.5 to 4.4.7 provide new guidance relating to GHG emissions from alumina production via alternative Bayer-Sinter and Nepheline processes. It follows on from section 4.4.4, Chapter 4, Volume 3 of the *2006 IPCC Guidelines*.
- The sub-chapter, 4.8, provides new guidance for primary rare earth (RE) metal production. Since there is no existing guidance in the *2006 IPCC Guidelines*, this is an entirely new sub-chapter 4.8 and follows on from sub-chapter 4.7, Chapter 4, Volume 3 of the *2006 IPCC Guidelines*.

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Section Title	Type of Refinement	2006 Guidelines Section Number	2019 Refinement Section Number
<b>Sub-Chapter 4.2</b>			
Introduction	NR	4.2.1	4.2.1
Methodological issues	U	4.2.2	4.2.2
Choice of method: metallurgical coke production	U	4.2.2.1	4.2.2.1
Choice of method: iron and steel production	U	4.2.2.2	4.2.2.2
Choice of emission factors	U	4.2.2.3	4.2.2.3
Choice of activity data	U	4.2.2.4	4.2.2.4
Completeness	U	4.2.2.5	4.2.2.5
Developing a consistent time series	NR	4.2.2.6	4.2.2.6
Uncertainty assessment	U	4.2.3	4.2.3
Quality Assurance/Quality Control (QA/QC), Reporting and Documentation	NR	4.2.4	4.2.4
<b>Sub-Chapter 4.4</b>			
Introduction	U	4.4.1	4.4.1
Choice of method for CO <sub>2</sub> emissions from primary aluminium production	NR	4.4.2.1	4.4.2.1
Choice of emission factors for CO <sub>2</sub> emissions from primary aluminium production	NR	4.4.2.2	4.4.2.2
Choice of method for PFCs	U	4.4.2.3	4.4.2.3
Choice of emission factors for PFCs	U	4.4.2.4	4.4.2.4
Choice of activity data	U	4.4.2.5	4.4.2.5
Completeness	U	4.4.2.6	4.4.2.6
Developing a consistent time series	U	4.4.2.7	4.4.2.7
Uncertainty assessment for primary aluminium production	U	4.4.3	4.4.3
Emission factor uncertainties	U	4.4.3.1	4.4.3.1
Activity data uncertainties	U	4.4.3.2	4.4.3.2
Quality assurance/quality control (QA/QC)	U	4.4.4.1	4.4.4.1
Reporting and documentation	U	4.4.4.2	4.4.4.2
Methodological issues for alumina production	NG	-	4.4.5
Alternative alumina refining processes	NG		4.4.5.1
Choice of method for alumina production	NG	-	4.4.5.2
Choice of emission factors for alumina production	NG	-	4.4.5.3
Choice of activity data	NG	-	4.4.5.4
Completeness	NG	-	4.4.5.5
Developing a consistent time series	NG	-	4.4.5.6
Uncertainty assessment for alumina production	NG	-	4.4.6
Emission factor uncertainties	NG	-	4.4.6.1
Activity data uncertainties	NG	-	4.4.6.2

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**Sections (continued)**

Section Title	Type of Refinement	2006 Guidelines Section Number	2019 Refinement Section Number
Quality assurance/quality control (QA/QC)	NG	-	4.4.7.1
Reporting and documentation	NG	-	4.4.7.2
<b>Sub-Chapter 4.8</b>			
Rare earths production (and all sub-sections included)	NG	-	4.8

**Equations**

Equation Title	Type of Refinement	2006 Guidelines Equation Number	2019 Refinement Equation Number
<b>Sub-Chapter 4.2</b>			
CO <sub>2</sub> emissions from coke production (Tier 1a)	U	4.1	4.1
CH <sub>4</sub> emissions from coke production (Tier 1a)	NG	-	4.1a
CO <sub>2</sub> emissions from metallurgical coke production (Tier 1b)	NG	-	4.1b
CO <sub>2</sub> emissions from metallurgical coke production (Tier 2)	U	4.2	4.2
CO <sub>2</sub> emissions from iron and steel production (Tier 1)	NR	4.4	4.4
CO <sub>2</sub> emissions from production of pig iron not processed into steel (Tier 1)	NR	4.5	4.5
CO <sub>2</sub> emissions from production of direct reduced iron (Tier 1)	NR	4.6	4.6
CO <sub>2</sub> emissions from sinter production (Tier 1)	NR	4.7	4.7
CO <sub>2</sub> emissions from pellet production (Tier 1)	NR	4.8	4.8
CO <sub>2</sub> emissions from flaring (Tier 1)	NG	-	4.8a
CO <sub>2</sub> emissions from iron & steel production (Tier 2)	NR	4.9	4.9
CO <sub>2</sub> emissions from sinter production (Tier 2)	U	4.10	4.10
CO <sub>2</sub> emissions from direct reduced iron production (Tier 2)	NR	4.11	4.11
CH <sub>4</sub> emissions from sinter production (Tier 1)	NR	4.12	4.12
CH <sub>4</sub> emissions from blast furnace production of pig iron (Tier 1)	NR	4.13	4.13
CH <sub>4</sub> emissions from direct reduced iron production (Tier 1)	NR	4.14	4.14
N <sub>2</sub> O emissions from flaring (Tier 1)	NG	-	4.14a
N <sub>2</sub> O emission factors from flaring of blast furnace gas and converter gas	NG	-	4.14b
<b>Sub-Chapter 4.4</b>			
Process CO <sub>2</sub> emissions from anode and/or paste consumption (tier 1 method)	NR	4.20	4.20
CO <sub>2</sub> emissions from prebaked anode consumption (tier 2 and tier 3 methods)	NR	4.21	4.21
CO <sub>2</sub> emissions from pitch volatiles combustion (tier 2 and tier 3 methods)	NR	4.22	4.22

118 **Equations (Continued)**

Equation Title	Type of Refinement	2006 Guidelines Equation Number	2019 Refinement Equation Number
CO <sub>2</sub> emissions from bake furnace packing material (tier 2 and tier 3 methods)	NR	4.23	4.23
CO <sub>2</sub> emissions from paste consumption (tier 2 and tier 3 methods)	NR	4.24	4.24
Total PFC Emissions	NG	-	4.24a
HVAE PFC emissions (Tier 1 method)	U	4.25	4.25
HVAE PFC emissions by Slope method (Tier 2a and Tier 3a methods)	U	4.26	4.26
HVAE PFC emissions by Overvoltage method (Tier 3a method)	U	4.27	4.27
HVAE PFC emissions (Tier 2b and Tier 3b method – (Marks & Nunez 2018a))	NG	-	4.27a
HVAE PFC emissions (Tier 2b and Tier 3b method – (Dion <i>et al.</i> 2018a))	NG	-	4.27b
LVAE PFC emissions (Tier 1 and Tier 3 methods – production-based)	NG	-	4.27c
LVAE PFC emissions (Tier 3 method – as ratio of HVAE emissions)	NG	-	4.27d
Total PFC emissions for start-up of electrolysis cells (Tier 3 <sub>CSU</sub> method)	NG	-	4.27e
Emission rate coefficients for HVAE PFC (Tier 2b method – (Dion <i>et al.</i> 2018a))	NG	-	4.27f
Tier 1: Sintering process emissions based on alumina production data	NG	-	4.27g
Tier 3: Emissions based on carbonate raw material inputs to the sintering kiln	NG	-	4.27h
Emissions captured during carbonization process and contained in produced sodium carbonate	NG	-	4.27i
Emissions from un-calcined SKD not recycled to the kiln	NG	-	4.27j
Weighted average content CO <sub>2</sub> in 'i' Bauxites (Nephelines)	NG	-	4.27k
Emissions from Bauxites (Nephelines) residue	NG	-	4.27l
Emissions from carbon-bearing non-fuel materials	NG	-	4.27m
CO <sub>2</sub> absorption through use of circulating water collected from bauxite/nepheline storage residue area and/or absorption through bauxite residue neutralization	NG	-	4.27n
<b>Sub-Chapter 4.8</b>			
Process CO <sub>2</sub> emissions from anode consumption (Tier 1)	NG	-	4.35
Process CO <sub>2</sub> emissions from anode consumption (Tier 3)	NG	-	4.36
PFC emissions from rare earth metals production (Tier 1 and Tier 3)	NG	-	4.37

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121 **Tables**

Table Title	Type of Refinement	2006 Guidelines Table Number	2019 Refinement Table Number
<b>Sub-Chapter 4.2</b>			
Emission allocations from metallurgical coke production	NG	-	4.1a
Tiers to estimate CO <sub>2</sub> emissions from metallurgical coke production – carbonisation process	NG	-	4.1b
Tier 1 default CO <sub>2</sub> emission factors for coke production	U	4.1	4.1
Tier 1 default CO <sub>2</sub> emission factors for sinter and pellet production	NG	-	4.1a
Tier 1 default CO <sub>2</sub> emission factors for iron and steel production	NG	-	4.1b
Tier 1 default CH <sub>4</sub> emission factors for coke production and iron & steel production	U	4.2	4.2
Tier 1 default N <sub>2</sub> O emission factors for coke production and iron & steel production	NG	-	4.2b
Tier 2 material-specific carbon contents for iron & steel and coke production	U	4.3	4.3
Uncertainty ranges	U	4.4	4.4
<b>Sub-Chapter 4.4</b>			
Tier 1 technology specific emission factors for calculating carbon dioxide emissions from anode or paste consumption	NR	4.10	4.10
Data sources and uncertainties for parameters used in tier 2 or 3 method for CO <sub>2</sub> emissions from prebake cells (CWPB and SWPB) , see equation 4.21	NR	4.11	4.11
Data sources and uncertainties for parameters used in tier 2 or 3 method for CO <sub>2</sub> emissions from pitch volatiles combustion (CWPB and SWPB)	NR	4.12	4.12
Data sources and uncertainties for parameters used in tier 2 or 3 method for CO <sub>2</sub> emissions from bake furnace packing material (CWPB and SWPB)	NR	4.13	4.13
Data sources and uncertainties for parameters used in tier 2 or 3 method for CO <sub>2</sub> emissions from Söderberg cells	NR	4.14	4.14
Summary of accounting methods for PFC emissions	NG	-	4.14a
Technology specific default emission factors for the calculation of HVAE and LVAE emissions from aluminium production (Tier 1 method)	U	4.15	4.15
Technology specific coefficients for the calculation of HVAE PFC emissions from aluminium production using slope methodology (Tier 2a method)	U	4.16	4.16
Specific HVAE-PFC emission rate coefficients based on the anode effect duration as calculated by (Marks & Nunez 2018a) (Tier 2b method)	NG	-	4.16a
Uncertainty range (%) in estimating PFC emissions from individual HVAEs (Tier 2b methods)	NG	-	4.16b
Summary of which guidelines to refer to, for time consistent PFC inventories	NG	-	4.16c
Good practice reporting information for calculating CO <sub>2</sub> and PFC emissions from aluminium production by tier	U	4.17	4.17

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124 **Tables (Continued)**

Table Title	Type of Refinement	2006 Guidelines Table Number	2019 Refinement Table Number
Technology specific default emission factors for the calculation of CO <sub>2</sub> emissions from alternative sintering processes (Tier 1 method)	NG	-	4.17a
Default uncertainty values for Bauxite/nepheline sintering processes	NG	-	4.17b
<b>Sub-Chapter 4.8</b>			
Tier 1 default emission factors for calculating CO <sub>2</sub> emissions from anode consumption	NG	-	4.26
Data sources and uncertainties for parameters used in Tier 3 method for CO <sub>2</sub> emissions from anode consumption	NG	-	4.27
Tier 1 default emission factors and uncertainty ranges for the calculation of PFC emissions from rare earth production	NG	-	4.28
Data sources and uncertainties for parameters used in Tier 3 method for PFC emissions	NG	-	4.29
Good practice reporting information for calculating CO <sub>2</sub> and PFC emissions from rare earth metal production by Tier	NG	-	4.30

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**Figures**

Figure Title	Type of Refinement	2006 Guidelines Figure Number	2019 Refinement Figure Number
<b>Sub-Chapter 4.2</b>			
Illustration of main processes for integrated iron and steel production	NR	4.1	4.1
Estimation of CO <sub>2</sub> emissions from metallurgical coke production	U	4.6	4.6
Decision tree for estimation of CO <sub>2</sub> emissions from iron and steel production	U	4.7	4.7
Decision tree for estimation of CH <sub>4</sub> emissions from coke production	NG	-	4.8a
Decision tree for estimation of CH <sub>4</sub> emissions from iron and steel production	U	4.8	4.8b
Decision tree for estimation of N <sub>2</sub> O emissions from iron and steel production	NG	-	4.8c
Energy or IPPU CO <sub>2</sub> emissions allocation in an integrated iron and steel facility	NG	-	4.8d
<b>Sub-Chapter 4.4</b>			
Decision tree for calculation of CO <sub>2</sub> emissions from primary aluminium production	NR	4.11	4.11
Decision tree for calculation of PFC emissions from primary aluminium production	U	4.12	4.12
Alumina production processes	NG	-	4.12a
Decision tree for estimation of CO <sub>2</sub> emissions from alumina production	NG	-	4.12b
<b>Sub-Chapter 4.8</b>			
Decision tree for calculation of CO <sub>2</sub> emissions from primary rare earth (RE) metal production.	NG	-	4.17
Decision tree for calculation of PFC emissions from primary rare earth (RE) metal production.	NG	-	4.18

**Boxes**

Box Title	Type of Refinement	2006 Guidelines Box Number	2019 Refinement Box Number
<b>Sub-Chapter 4.2</b>			
Flaring activities in metallurgical coke and iron and steel production	NG	-	4.0
<b>Sub-Chapter 4.4</b>			
Fully automated anode effect intervention strategies for PFC emissions	NG	-	4.1a
High and low voltage anode effect description	U	4.2	4.2
PFC emissions during start-up of electrolysis cells	NG	-	4.3
<b>Sub-Chapter 4.8</b>			
Anode effect description (for rare earth metal production by fluoride electrolysis)	NG	-	4.4

## CHAPTER 6

### Sections

This Chapter 6 Volume 3 of the *2019 Refinement* is a complete update of Chapter 6 Volume 3 of the *2006 IPCC Guidelines* and should be used instead of Chapter 6 Volume 3 of the *2006 IPCC Guidelines*.

The *2019 Refinement* of Volume 3 Chapter 6 was designed to maintain the scientific validity of GHG emissions estimates from the electronics industry. Compared to the *2006 IPCC Guidelines*, the *2019 Refinement* takes into account the changes in manufacturing processes and equipment that have occurred in the electronics industry during the thirteen-year interim period and reflect the much larger set of experimental data available (as of 2018 compared to 2006) to calculate default emissions factors for the sector. Also, several methodological refinements are introduced in an attempt to increase accuracy and flexibility, depending on how reporting facilities track gas usage and implement emissions control technologies. The *2019 Refinement* includes six revised methods (Tier 1, 2a, 2b, 2c, 3a, and 3b), compared to four for the *2006 IPCC Guidelines*. The substantial refinements of this Chapter include:

- An expanded basket of gaseous fluorinated compounds (FCs) and fluorinated liquids used or produced as by-products during the manufacture of electronic devices, also including the use and emissions of nitrous oxide (N<sub>2</sub>O);
- Revised Tier 1 method with updated emissions factors for the semiconductor, display, microelectromechanical systems (MEMS), and photovoltaic (PV) sub-sectors;
- Guidance on tracking gas consumption and apportioning use to different process types;
- Updated Tier 2 methods with refined approaches to account for emissions control technologies and emissions control technology uptime;
- An update to the Tier 2a method for the semiconductor sub-sector to account for the size of manufactured wafers and the input gas rather than the process type and input gas;
- An update to the Tier 2b method for the semiconductor sub-sector to account for the size of manufactured wafers and the input gas rather than the process type and input gas;
- A new Tier 2c method for semiconductor and display sub-sectors that accounts for the size of manufactured wafers in addition to the process type and input gas;
- A new section on adapting Tier 2 methods to account for technological changes, including guidance on when facility-specific measurements should be considered, and providing guidance for the use of hybrid methodologies (e.g. by combining the Tier 2c and Tier 3a methods);
- An update to the Tier 3 method (now labelled Tier 3a) to provide guidance on selecting processes for emissions characterizations (including a discussion of “similarity” among recipes);
- A new Tier 3b method that relies on the measurement of emission at the stack level rather than the process level;
- Updated Tier 1 emission factors for heat transfer fluids;
- Updates to the emission factors for Tier 1 and Tier 2 methods, including an expanded list of input gases and by-products; and
- Corresponding updates to the Completeness; Time Series Consistency; Uncertainty; and QA/QC, Reporting and Documentation sections.

Note: Because this chapter completely replaces the corresponding chapter in the *2006 IPCC Guidelines*, the equations, tables, figures, and boxes here have all been renumbered in simple sequential order, without reference to the corresponding equations, tables, figures, or boxes in the *2006 IPCC Guidelines* (where those exist).

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Section Title	Type of Refinement	2006 IPCC Guidelines Section Number	2019 Refinement Section Number
Introduction	U, NG	6.1	6.1
Etching and TFD cleaning for semiconductors, liquid crystal displays, and photovoltaics	U, NG	6.2.1.1	6.2.1.1
Fluorinated Liquids	U, NG	6.2.1.2	6.2.1.2
Choice of emission factors	U, NG	6.2.2	6.2.2
Etching and TFD cleaning for semiconductors, liquid crystal displays, and photovoltaics	U	6.2.2.1	6.2.2.1
Fluorinated Liquids	U	6.2.2.2	6.2.2.2
Choice of activity data	U	6.2.3	6.2.3
Completeness	U	6.2.4	6.2.4
Developing a consistent time series	U	6.2.5	6.2.5
Uncertainty Assessment	U	6.3	6.3
Emission factor uncertainties	U	6.3.1	6.3.1
Activity data uncertainty	U	6.3.2	6.3.2
Quality Assurance/Quality Control (QA/QC), Reporting, and Documentation	U	6.4	6.4

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178 **Equations**

Equation Title	Type of Refinement	2006 Guidelines Equation Number	2019 Refinement Equation Number
Tier 1 Method for estimation of the set of GHG emissions	U	6.1	6.1
Consumption of input gas i	NG	-	6.2
Transfers of Input Gas i	NG	-	6.3
Apportioning of C to Process Types/Sub-types	NG	-	6.4
Emissions of input gas i	E	6.2	6.5
By-product emissions	E	6.3-6.6	6.6
By-product emissions from hydrocarbon fuelled combustion emissions control systems	NG	-	6.7
Emissions reduction impact of emissions control technology for gas i	NG	-	6.8
Emissions reduction impact of emissions control technology for by-product k	NG	-	6.9
Estimate of the mass fraction of gas i emitted from process tools equipped with emission control technologies	NG	-	6.10
Estimate of the mass fraction of by-product k emitted from process tools equipped with emissions control technologies	NG	-	6.11
Uptime of emissions control systems	NG	-	6.12

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Equation Title	Type of Refinement	2006 Guidelines Equation Number	2019 Refinement Equation Number
Emission of input gas i	E	6.7	6.13
By-product Emissions from input gas i	E	6.8-6.11	6.14
By-product emissions from combustion emissions control equipment	NG	-	6.15
Emissions reduction impact of emissions control equipment on input gas i	NG	-	6.16
Emissions reduction impact of emissions control equipment on by-product k	NG	-	6.17
Estimate of the fraction of mass of gas i emitted from process p from tools equipped with emissions control equipment	NG	-	6.18
Estimate of the fraction of mass of by-product k emitted from process p from tools equipped with emissions control equipment	NG	-	6.19
Uptime of emissions control systems	NG	-	6.20
Preliminary estimate of stack process gas emissions	NG	-	6.21
Preliminary estimate of by-product emissions from stacks	NG	-	6.22
Uptime of emissions control systems	NG	-	6.23
Total fluorinated GHG input gas emitted from stack system during sampling period	NG	-	6.24
Total fluorinated GHG By-product gas emitted from stack system during sampling period	NG	-	6.25
Gas specific emission factor	NG	-	6.26
By-product specific emissions factor	NG	-	6.27
Annual emissions of gas i	NG	-	6.28
Annual emissions of by-product k	NG	-	6.29
Average emission control system uptime	NG	-	6.30
Tier 1 Method for estimation of total FC emissions from fluorinated liquids	E	6.12	6.31
Tier 2 Method for estimation of FC emissions from fluorinated liquids	U	6.13	6.32

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186 **Tables**

Table Title	Type of Refinement	2006 Guidelines Table Number	2019 Refinement Table Number
Information sources necessary for completing the tiered emission estimating methods for electronics manufacturing	U	6.1	6.1
Tier1 Gas-specific emission factors for process GHG emissions from electronics manufacturing	U	6.2	6.2
Tier 2a method – default emission factors for GHG emissions from Semiconductor manufacturing	U	6.3	6.3
Tier 2a & 2b methods – default factors for $\gamma_I$ and $\gamma_K$ for semiconductor manufacturing	NG	-	6.4
Tier 2b method – default emission factors for GHG emissions from Semiconductor manufacturing	NG	-	6.5
Tier 2c method ( $\leq 200\text{mm}$ ) – default emission factors for GHG emissions from semiconductor manufacturing	NG	-	6.6
Tier 2c method (300mm) – default emission factors for GHG emissions from semiconductor manufacturing	NG	-	6.7
Tier 2c method – default emission factors for GHG emissions from Display manufacturing	U	6.4	6.8
Methods and procedures for conducting emissions tests for Stack Systems	NG	-	6.9
Maximum field detection limits (FDL) applicable to fluorinated compounds (FC) concentration measurements for Stack Systems	NG	-	6.10
Emissions Control Equipment suitability table for Destruction Removal Efficiency (DRE) of Process GHG Emissions	NG	-	6.11
Tier 2 default DRE parameters for electronics industry process gas emissions reduction technologies	U	6.6	6.12
Tier 1 Default Emission Factors for fluorinated liquids	NG	-	6.13
Estimates of relative uncertainties (%) of Tier 2b emission factors for semiconductor manufacturing, 95 percent confidence intervals	U	6.9	6.14
Estimates of relative uncertainties (%) of Tier 2c emission factors for semiconductor manufacturing ( $\leq 200\text{ mm}$ ), 95 percent confidence intervals	U	6.9	6.15
Tier 2a & 2b methods – estimates of relative uncertainties (%) for $\gamma_I$ and $\gamma_K$ (SEMICONDUCTOR), 95 percent confidence intervals	NG	-	6.16
Information necessary for full transparency of estimates of emissions from electronics manufacturing	U	6.11	6.17

**Figures**

Figure Title	Type of Refinement	2006 Guidelines Figure Number	2019 Refinement Figure Number
Decision tree for estimation of GHG emissions from electronics manufacturing	U	6.1	6.1
Decision tree to determine need for measured emission factors	NG	-	6.2
Decision tree for estimation of emissions from fluorinated liquids loss from electronics manufacturing	U	6.2	6.3
Decision Tree for Process GHG Emission Control System Default Emission Factors	NG	-	6.4

**Boxes**

Box Title	Type of Refinement	2006 Guidelines Box Number	2019 Refinement Box Number
Fluorinated greenhouse gas by-products	NG	-	6.1
Site specific apportioning model verification example	NG	-	6.2
Why default gamma values in the Tier 2a and 2b methods may not be accurate in certain situations, and why the Tier 2c, 3a or 3b methods are strongly encouraged.	NG	-	6.3

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**CHAPTER 7****Sections**

- Section 7.1.1 “Chemicals and relevant application areas covered” in the *2006 IPCC Guidelines*: The text about HFCs and Montreal Protocol has been updated. Text and references from the *2006 IPCC Guidelines* are to a large extent retained.
- Section 7.1.2.2 “Choice of method” in the *2006 IPCC Guidelines*: Text updated in order to briefly describe the four new tables with consumption figures for 2015.
- Section 7.5.2.1 “Choice of method” in the *2006 IPCC Guidelines*: New guidance on how to build a refrigeration and air conditioning inventory (Tier 1 and tier 2 emission factor approaches) appears in Boxes 7.2a-c.
- Section 7.5.2.2 “Choice of emission factors” in the *2006 IPCC Guidelines*: Text is updated to describe new information from studies of emission factors. New guidance in terms of examples of national studies on emission rates for stationary refrigeration and air-conditioning systems are found in Annex 7A.1.
- New spreadsheet “Calculation Example for 2F1 (Tier 2)” (MS Excel) was introduced

Section Title	Type of Refinement	2006 Guidelines Section Number	2019 Refinement Section Number
Chemicals and relevant application areas covered	U	7.1.1	7.1.1
Overview of ODS substitute issues	NR	7.1.2.1	7.1.2.1
Choice of method	U	7.1.2.2	7.1.2.2
Choice of emission factors	NR	7.1.2.3	7.1.2.3
Choice of activity data	NR	7.1.2.4	7.1.2.4
Completeness	NR	7.1.2.5	7.1.2.5
Developing a consistent time series	NR	7.1.2.6	7.1.2.6
Uncertainty Assessment	NR	7.1.3	7.1.3
Quality Assurance/Quality Control (QA/QC), Reporting, and Documentation for all ODS substitutes applications	NR	7.1.4	7.1.4
Choice of method	U	7.5.2.1	7.5.2.1
Choice of emission factors	U,	7.5.2.2	7.5.2.2
Choice of activity data	U	7.5.2.3	7.5.2.3
Applying Tier 2 methods – the example of mobile air conditioning (MAC)	U	7.5.2.4	7.5.2.4
Completeness	NR	7.5.2.5	7.5.2.5
Developing a consistent time series	NR	7.5.2.6	7.5.2.6
Uncertainty Assessment	NR	7.5.3	7.5.3
Quality Assurance/Quality Control (QA/QC), Reporting, and Documentation	NR	7.5.4	7.5.4
Annex 7A.1 to Chapter 7. Examples of national studies on emission rates for stationary refrigeration and air-conditioning systems	NG	-	Annex 7A.1 to Chapter 7
Spreadsheet “Calculation Example for 2F1 (Tier 2)” (MS Excel)	NG	-	Spreadsheet to Chapter 7

## Tables

- Tables Table 7.1: Footnote 2 is elaborated, specifying that methodology for estimating emissions for plasma etching is not included in chapter 7. This issue was not in the mandate/TOC.
- Three new tables with consumption figures to address the issue of adding data on the distribution of ODS-substitutes by application, e.g. broadening the set of countries to include developing as well as developed countries. This issue was suggested placed under 7.5.2.3 in the TOC (mandate), but we argue that 7.1.2.2 is the relevant section because it an elaboration related to table 7.3 which is located in section 7.1.2.2.
  - New table 7.3a: Provides information similar to table 7.3 in 2006 Guidelines (distribution of HFC use by application area), but for 2015.
  - New table 7.3b: Provides information for 2015 on use of HFCs in RAC by substance and sub-application area in Article 5 Parties.
  - New table 7.3c: Provides information for 2015 on use of HFCs in RAC by substance and sub-application area in non-Article 5 Parties.
  - New table 7.3d: Provides information for 2015 on the share of HFCs used for manufacturing and servicing in RAC.
- Table 7.9: Specifications are made for charge and operating emission factors maritime, railway, busses in sub-application mobile air conditioning to address the issue of updating emission factors by further segregating equipment types.
- Three new tables with emission factors for commercial and industrial refrigeration to address the issue of updating emission factors by further segregating equipment types, regions, and time periods, are presented in Annex 7A.1.

Table Title	Type of Refinement	2006 Guidelines Table Number	2019 Refinement Table Number
Main application areas for HFCs and PFCs as ODS substitutes	U	7.1	7.1
Distribution of HFC use by application area for 2015	U	7.3	7.3
HFC consumption for RAC in article 5 parties. Per cent of total by substance and sub-application area for 2015	NG	-	7.3a
HFC consumption for RAC in non-article 5 parties. Per cent of total by substance and sub-application area for 2015	NG	-	7.3b
HFC consumption for RAC in article 5 parties and non-article 5 parties. Per cent of total by manufacturing and servicing for 2015	NG	-	7.3c
Default estimates for charge, lifetime and emission factors for refrigeration and air-conditioning systems	U	7.9	7.9
California study for 2008: Emission factors for refrigeration and air conditioning systems	NG	-	7A.1
Japan study for 2008: Emission factors for refrigeration and air conditioning systems	NG	-	7A.2
German study for 2009-2013: Emission factors for refrigeration and air conditioning systems	NG	-	7A.3

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**Figures**

Figure Title	Type of Refinement	2006 Guidelines Figure Number	2019 Refinement Figure Number
Decision tree for actual emissions from the refrigeration and air conditioning (RAC) application	NR	7.6	7.6
Example of spreadsheet calculation for Tier 1a/b assessments	NR	7.7	7.7

**Equations**

Equation Title	Type of Refinement	2006 Guidelines Equation Number	2019 Refinement Equation Number
Calculation of net consumption of a chemical in a specific application	NR	7.1	7.1
Calculation of emissions of a chemical from a specific application	NR	7.2A	7.2A
Calculation of emissions of a chemical from an application with banks	NR	7.2B	7.2B
General mass balance equation for Tier 1b	NR	7.3	7.3
Summary emissions equation based on phases of the lifecycle	NR	7.4	7.4
Determination of refrigerant emissions by mass balance	NR	7.9	7.9
Summary of sources of emissions	NR	7.10	7.10
Sources of emissions from management of containers	NR	7.11	7.11
Sources of emissions when charging new equipment	NR	7.12	7.12
Sources of emissions during equipment lifetime	NR	7.13	7.13
Emissions at system end-of-life	NR	7.14	7.14

**Boxes**

- Three new boxes to address the issue of increased user-friendliness and suggestion of box with “recipe”-style guidance on how to launch the HFC inventory. Location according to suggestion in TOC (mandate):
  - New box 7.2a: Intended to simplify the process of starting an inventory on HFCs, focusing on the larger areas of use and the tier 1 and 2 EF approach.
  - New box 7.2b: Aims at giving an overview of the annual emission estimation process, focusing on the bank of HFCs in equipment in use.
  - New box 7.2c: Provides information on two ways to establish the existing bank of HFCs.
- One new box to address the issue of increased user-friendliness, suggestion of examples regarding the collection of activity data, and the suggestion to further emphasizing the data and literature associated with the Montreal protocol. Location according to suggestion in TOC (mandate):
  - New box 7.3a: List of data sources commonly used for collecting data on HFCS, with a short description of each.
- Box 7.4 in the *2006 IPCC Guidelines* contains misleading information in terms of the emission factors used for MAC. They are outside the default ranges presented in Table 7.9 in 2006 GL due to assumptions on frequent A/C service with high leakage rate. We suggest to reduce the figure to be inside the default ranges provided in the *2006 IPCC Guidelines* Table 7.9 to consistent with the methodologies described.

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<b>Box Title</b>	<b>Type of Refinement</b>	<b>2006 Guidelines Box Number</b>	<b>2019 Refinement Box Number</b>
How to build a R/AC inventory in a few simple steps – Tier 1 and 2 emission factor approaches	NG	-	Box 7.2a
The basic elements of an emission inventory for R/AC	NG	-	Box 7.2b
How to build the bank of HFC	NG	-	Box 7.2c
Accounting for imports and exports of refrigerant and equipment	NR	7.3	7.3
Common data sources for the HFC inventory	NG	-	Box 7.3a
Example of the application of a Tier 2a calculation for mobile air conditioning	U	Box 7.4	Box 7.4

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**CHAPTER 8 AND APPENDIX 1****Sections**

- New guidance for waterproofing of electronic circuits has been added to the Section 8.3 “Use of SF<sub>6</sub> and PFCs in other products”.
- New guidance for Textile, carpet, leather and paper fluorinated treatment emissions has been added to the Section 8.3 “Use of SF<sub>6</sub> and PFCs in other products”.
- New Appendix 1 for “Possible Approaches for Estimating FC Emissions from Textile, Carpet, Leather and Paper Industries: Basis for Future Methodological Development” was introduced

Section Title	Type of Refinement	2006 Guidelines Section Number	2019 Refinement Section Number
<b>Chapter 8</b>			
Introduction	U	8.3.1	8.3.1
Methodological Issues	U	8.3.2	8.3.2
<b>Appendix 1</b>			
Possible Approaches for Estimating Fluorinated Compounds Emissions from Textile, Carpet, Leather and Paper Industries: Basis for Future Methodological Development	NG	-	Appendix 1

**Equations**

Equation Title	Type of Refinement	2006 Guidelines Equation Number	2019 Refinement Equation Number
<b>Chapter 8</b>			
Waterproofing of electric circuits	NG	-	8.22a
<b>Appendix 1</b>			
All equations are new	NG	-	1.a1-1.a.18

**Tables**

Table Title	Type of Refinement	2006 Guidelines Table Number	2019 Refinement Table Number
<b>Chapter 8</b>			
Emission Factor for Waterproofing of Electronic Circuits	NG	-	8.11
<b>Appendix 1</b>			
All tables are new	NG	-	1a.1-1a.4

**Boxes**

There are no boxes in Chapter 8 of the *2006 IPCC Guidelines* and in Chapter 8 of the *2019 Refinement*

Box Title	Type of Refinement	2006 Guidelines Box Number	2019 Refinement Box Number
<b>Appendix 1</b>			
All boxes are new	NG	-	Box 1A.1-1A.2