

Category		Title
NFR:	2.C.5	Lead production
SNAP:	040309b	Lead production
ISIC:	2720	Manufacture of basic precious and non-ferrous metals
Version	Guidebook 2013	

Coordinator

Jeroen Kuenen

Contributing authors (including to earlier versions of this chapter)

Jan Berdowski, Pieter van der Most, Chris Veldt, Jan Pieter Bloos, Jozef M. Pacyna, Otto Rentz, Dagmar Oertel, Ute Karl, Tinus Pulles and Wilfred Appelman

Contents

1	Overview	3
2	Description of sources.....	3
2.1	Process description	3
2.2	Techniques	5
2.3	Emissions	5
2.4	Controls	7
3	Methods.....	9
3.1	Choice of method	9
3.2	Tier 1 default approach.....	10
3.3	Tier 2 technology-specific approach	12
3.4	Tier 3 emission modelling and use of facility data.....	19
4	Data quality	21
4.1	Completeness	21
4.2	Avoiding double counting with other sectors.....	21
4.3	Verification.....	21
4.4	Developing a consistent time series and recalculation	21
4.5	Uncertainty assessment	22
4.6	Inventory quality assurance/quality control (QA/QC)	22
4.7	Gridding	22
4.8	Reporting and documentation	22
5	Glossary	22
6	References.....	23
7	Point of enquiry.....	24

1 Overview

This chapter presents information on atmospheric emissions during primary and secondary lead production.

The main air pollutants emitted during the production of lead are sulphur dioxide (SO₂), nitrogen oxides (NO_x), carbon monoxide (CO) and carbon dioxide (CO₂). Since these are assumed to originate mainly from combustion activities, emissions of these pollutants are addressed in chapter 1.A.2.b. The most important process emissions are heavy metals (particularly lead) and dust.

2 Description of sources

2.1 Process description

2.1.1 Primary lead production

There are two pyrometallurgical processes available for the production of lead from lead sulphide or mixed lead and zinc sulphide concentrates:

- sintering/smelting in the blast furnace or Imperial Smelting Furnace (ISF);
- direct smelting.

In the sintering process fine particles of metal ores are agglomerated into nodules, briquettes, sinter, or pellets. The sintering process is more extensively discussed in chapter 2.C.1 (Iron and Steel Production). Also a roasting process is involved in which lead sulphide is converted into lead oxide. This is performed either in a blast furnace or ISF. Dust emissions result from handling and stockpiling of raw materials or intermediate products. Abatement methods are the use of bag filters, wet scrubbers or electrofilters.

Direct smelting can be carried out in the following furnaces: Ausmelt/ISA Smelt (bath furnace, top-submerged lancing furnace) -sometimes in combination with blast furnaces, Kaldo (TBRC) and the QSL (bath furnace) integrated processes, and Electric furnace. The Kivcet integrated process is also used and is a flash smelting process. Dust abatement can be provided by bag filters or electrofilters. Improved abatement is encapsulation or evacuation of the process.

The refining process is mainly directed at the removal of copper, silver, bismuth, antimony, arsenic, tin, and other impurities. There are two methods of refining crude lead: electrolytic refining and pyrometallurgical refining. Electrolytic refining uses anodes of decopperised lead bullion and starter cathodes of pure lead. Pyrometallurgical refinery consists of a series of kettles, which are indirectly heated by oil or gas. Dust emissions mainly occur at the treatment of the different by-product streams.

Several improved processes are either in the pilot stage or being used at a single plant. However, no general applicable information is available yet.

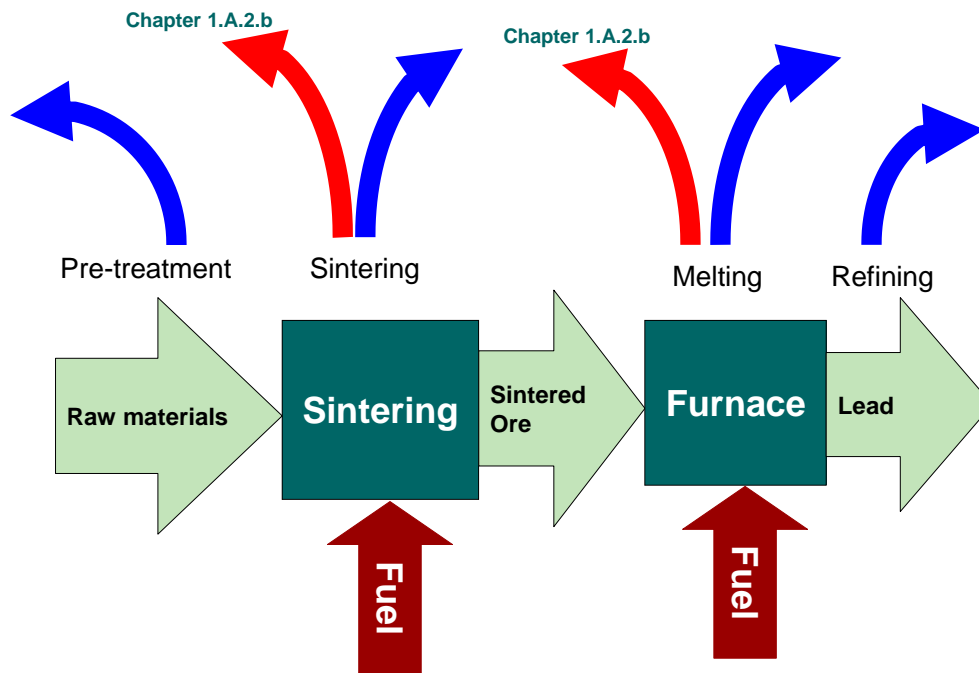


Figure 2.1 Process scheme for lead production (primary process only).

2.1.2 Secondary lead production

A secondary lead smelter is defined as any plant or factory, in which lead-bearing scrap or lead-bearing materials, other than lead-bearing concentrates (ores) derived from a mining operation, is processed by metallurgical or chemical methods into refined lead, lead alloys or lead oxide. The high proportion of scrap acid batteries that is reprocessed provides feed for the alloy lead market (Barbour *et al.*, 1978).

Secondary lead can be produced using pyrometallurgical or hydrometallurgical processes. Up to now hydrometallurgical processes have only been used at a preliminary stage. The pyrometallurgical processes are subdivided as follows (Rentz *et al.*, 1996a):

- battery breaking and processing (scrap preparation);
- smelting of battery scrap materials;
- refining.

In contrast to secondary zinc and copper production, which use a great variety of secondary materials, the recycling of secondary lead materials is concentrated on the processing of scrap batteries, which accounts for about 80 % of secondary lead recycling globally. Metal sheets, pipe scraps, sludge, dross and dusts play only a minor role as secondary raw materials. The reason for this is that most of the lead is used for manufacturing batteries.

Secondary lead is sometimes combined with primary material for refining. Various pyrometallurgical refining technologies can be applied, depending on the feed material and product specification.

2.2 Techniques

2.2.1 Primary lead production

Primary lead smelting can be performed in a number of different furnaces, as described in section 2.1.1. Direct smelting can be undertaken using the following furnaces: Ausmelt/ISA, Kaldo (TBRC), QSL (bath furnace) integrated processes, the electric furnace, and the Kivcet integrated process. Sintering/smelting can also be performed in the blast furnace and the ISF. For refining, the main techniques are pyrometallurgical refining and hydrometallurgical refining. Several direct smelting technologies have been under development or are being developed. Information about the emissions of these techniques is not yet available.

2.2.2 Secondary lead production

In general, for the production of secondary lead from battery scrap *two basic process routes* are possible. One route is based on breaking up and dismantling old batteries, and separating the paste, metals and organic substances. Melting and reduction is carried out afterwards in different types of furnaces with an additional refining step. The other route is characterised by the direct treatment of complete and non-dismantled batteries with or without sulphuric acid inside in various smelting furnaces, also with an additional refining step. In detail, in the various stages of pyrometallurgical processing the following technologies are used worldwide (Rentz et al., 1996a):

- **Battery scrap preparation.** For battery scrap preparation various processes are possible, which can be differentiated by the degree of separation of single battery components. On an industrial scale, the MA and CX processes are most common. Generally heavy metal emissions from battery scrap preparation play a minor role compared to the smelting operation. The Varta and the Bergsøe processes are smelting processes carried out without an initial separation, so that the batteries are directly smelted in a furnace.
- **Smelting.** For the industrial production of secondary lead, various kinds of smelting furnaces are employed. The following furnaces are used in secondary lead production:
 - blast furnaces
 - rotary furnaces
 - reverberatory furnaces
 - electric furnaces
- **Refining.** The lead bullion from secondary lead production contains various impurities, such as copper, silver, bismuth, antimony, arsenic, tin, and other impurities. However, in the majority of cases, antimony dominates. As with primary lead, refining can be carried out either electrolytically or pyrometallurgically.

2.3 Emissions

2.3.1 Primary lead production

The main emissions to air from lead and tin production are:

- sulphur dioxide (SO₂), other sulphur compounds and acid mists;
- oxides of nitrogen (NO_x) and other nitrogen compounds;
- metals and their compounds;

- dust;
- sometimes NMVOC and PCDD/F.

Other pollutants are considered to be of negligible importance for the industry, partly because they are not present in the production process and partly because they are immediately neutralised (e.g. chlorine or HCl) or occur in very low concentrations (e.g. CO). Emissions are to a large extent bound to dust (except cadmium, arsenic and mercury that can be present in the vapour phase).

The most relevant step with regard to SO₂ emissions is the sintering process (covered by chapter 2.C.1). However, only about 7 % of the total sulphur in the ore is emitted as SO₂. The remainder is captured by the slag. The concentration of this SO₂ stream can vary from 1.4 to 7.2 g/m³, depending on the amount of dilution air injected to oxidise the carbon monoxide and to cool the stream before baghouse particulate removal (US EPA, 1990).

Nearly 85 % of the sulphur present in the lead ore concentrate is eliminated in the sintering operation (see chapter 2.C.1). In handling process off-gases, either a single weak stream is taken from the machine hood at less than 2 % SO₂, or two streams are taken, a strong stream (5–7 % SO₂) from the feed end of the machine and a weak stream (less than 0.5 % SO₂) from the discharge end. Single stream operation has been used if there is little or no market for recovered sulphur, so that the uncontrolled, weak SO₂ stream is emitted to the atmosphere.

When sulphur removal is required, however, dual stream operation is preferred. The strong stream is sent to a sulphuric acid plant, and the weak stream is vented to the atmosphere after removal of particulate (US EPA, 1990).

Sulphur oxides are also generated in blast furnaces during the smelting process from small quantities of residual lead sulphide and lead sulphates in the sinter feed. The quantity of these emissions is a function not only of the sinter's residual sulphur content, but also of the sulphur captured by copper and other impurities in the slag (US EPA, 1990).

The energy requirement for the different lead and zinc processes varies to a large extent. It depends on the quality of the feed and the products, the use of latent or waste heat and the production of by-products. Refer to the Best Available Techniques Reference (BREF) document for additional information (European Commission, 2001) as well as the draft BREF (European Commission, 2009) with expected adaptation in 2013 ⁽¹⁾.

2.3.2 Secondary lead production

In the secondary lead production process various direct and fugitive heavy metal emission sources are present (Rentz *et al.*, 1996a):

From *battery scrap preparation* only small amounts of particulate heavy metals are emitted as direct emissions if single preparation devices are equipped with a special waste gas cleaning facility.

For the *smelting process*, depending on the type of furnace various kinds of fuels are used. Generally short rotary furnaces and long rotary kilns are equipped with natural gas/air burners or sometimes with oxy-fuel burners, while shaft furnaces use coke as fuel. With the generated waste gas, irrespective of which kind of furnace is used, considerable amounts of heavy metals contained

⁽¹⁾The BREF document for non-ferrous metals industries is presently under review. A finalised version is expected to be adopted in 2013. Information concerning the status of BREF documents is available at <http://eippcb.jrc.es/reference/>.

in the dust are released, as well as certain amounts of gaseous heavy metals, depending on the melting temperature and the vapour pressure.

For *refining and alloying*, several kettles are installed depending on the required lead quality. Because of the reactions in the waste gas from the refining and alloying kettles, various amounts of heavy metals in particulate and gaseous form may be emitted.

Fugitive emissions from secondary lead smelting are released with almost all *stockpiling, transferring, charging, and discharging processes*. The amount and composition greatly depends on the process configuration and operation mode. Values concerning the magnitude of unabated and abated emissions have not been revealed. The smelting furnaces are connected with fugitive emissions during the *charging* of raw materials and the *discharging* of slag and lead bullion. Also the *furnace openings* may be an emission source. Fugitive emissions from refining operations arise mainly during *charging, discharging* and *metal transfer* operations. Refining vessels not covered with primary hoods may be a further emission source.

As in many plants, direct emission sources are preferably equipped with emission reduction measures and fugitive emissions released into ambient air in secondary lead production are generally much higher than direct emissions.

By far the most important SO₂ and NO_x emission source during secondary lead production is smelting furnaces. The amount of SO₂ formed is mainly determined by the amount of sulphur contained in the raw materials and in the fuel used. Although a major part of the sulphur remains in the slag formed during the smelting process, some can be converted to SO₂.

SO₂ concentrations in the off-gas from reverberatory furnaces and blast furnaces are only available on a volume percentage basis. During tests carried out at a reverberatory furnace using natural gas as a fuel, the concentration of SO₂ in the off-gas was measured at about 0.1 % v/v. At a blast furnace using coke as fuel an even smaller off-gas concentration in the range of about 0.03 % v/v was measured (Rentz et al., 1996b).

The formation of polychlorinated dioxins and furans depends on a number of factors such as scrap composition, process type and temperature.

2.4 Controls

2.4.1 Primary lead production

Dust emissions can be abated using fabric filters, wet scrubbers or electro-filters. Improvement can be achieved by using encapsulation or evacuation. New approaches are under development.

Emissions containing SO₂ are often used as input for sulphuric acid plants. Here, emissions from combustion and from other process steps are reconciled. Single stage sulphuric acid plants can attain sulphur oxide levels of 5.7 g/m³, and dual stage plants can attain levels of 1.6 g/m³. Typical efficiencies of dual stage plants in removing sulphur oxides can exceed 99 %. Other technically feasible SO₂ control methods are elemental sulphur recovery plants and dimethylamine and ammonia absorption processes (US EPA, 1990).

Primary measures for the control of SO₂ aim to reduce the sulphur content in the fuel and in the raw materials used. Accordingly lower SO₂ emissions occur when using natural gas instead of heavy fuel oil for short rotary, long rotary and reverberatory furnace firing. Within blast furnace operation, the use of coke with low sulphur content reduces emissions.

For more information consult the Best Available Techniques Reference (BREF) document for additional information (European Commission, 2001).

2.4.2 Secondary lead production

Most secondary lead smelters are equipped with dust removing installations, such as baghouses for the control of direct emissions. The control efficiency of these installations is often very high and can reach 99.9 %. In secondary lead production for most processes it is possible to carry out final dust removal with fabric filters. In this way clean gas dust loads in general below 5 mg/m³ (STP) are achieved. For covering direct emissions from the refining and alloying kettles, primary suction hoods are arranged above the refining and melting kettles. These hoods are also linked to fabric filters. Waste gases from the furnace and the refining kettles may be dusted together in one filter. Electrostatic precipitators or wet scrubbers may be in use for special raw gas conditions. Wet scrubbers are sometimes in place for the control of SO₂. Fugitive particulate emissions can be collected by local systems like hoods and other suction facilities or by partial or complete enclosures (Rentz *et al.*, 1996a).

Oxy-fuel burners have been used in short rotary furnaces resulting in a significant reduction of the fuel input. Accordingly, a smaller pollutant mass flow is observed, although the concentration in the off-gas may be higher than in conventional firing technologies.

Significantly lower emissions occur during secondary lead production if desulphurisation of the lead paste is carried out prior to thermal treating. Within the Engitec-CX process, for example, sulphur is removed from the electrode paste by adding NaOH or Na₂CO₃. According to an operator, a reduction of SO₂ emissions in excess of 90 % can be achieved by this means (Rentz *et al.*, 1996b). For more information consult the Best Available Techniques Reference (BREF) document for additional information (European Commission, 2001).

3 Methods

3.1 Choice of method

Figure 3.1 presents the procedure to select the methods for estimating process emissions from the lead production industry. The basic idea is as follows.

- If detailed information is available: use it.
- If the source category is a key category, a Tier 2 or better method must be applied and detailed input data must be collected. The decision tree in Figure 3.1 directs the user in such cases to the Tier 2 method, since it is expected that it is more easy to obtain the necessary input data for this approach than to collect facility level data needed for a Tier 3 estimate.
- The alternative of applying a Tier 3 method, using detailed process modelling is not explicitly included in this decision tree. However, detailed modelling will always be done at the facility level and results of such modelling could be seen as ‘facility data’ in the decision tree.

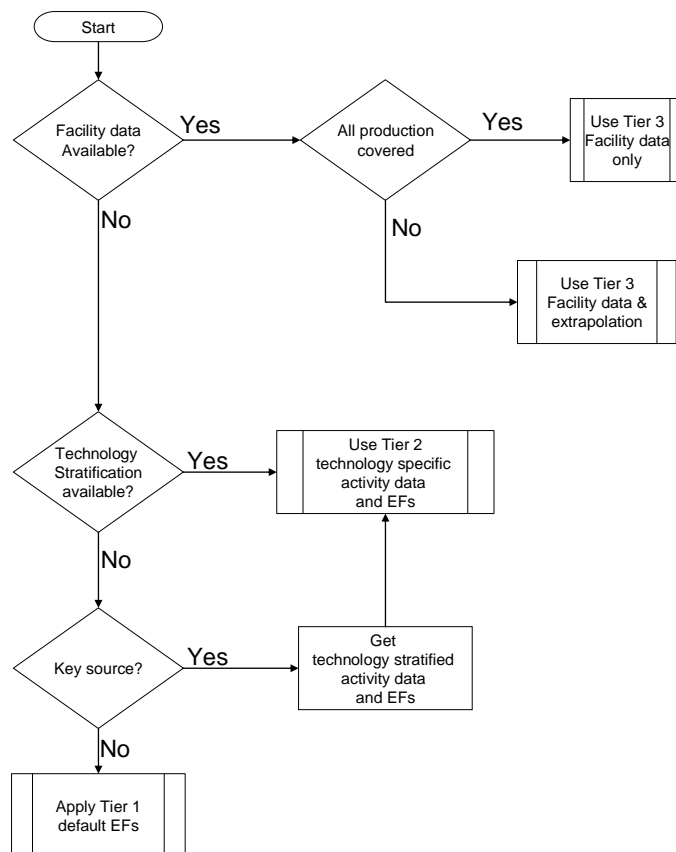


Figure 3.1 Decision tree for source category 2.C.5 Lead production

3.2 Tier 1 default approach

3.2.1 Algorithm

The Tier 1 approach for process emissions from lead production uses the general equation:

$$E_{\text{pollutant}} = AR_{\text{production}} \times EF_{\text{pollutant}} \quad (1)$$

Where:

- $E_{\text{pollutant}}$ = the emission of the specified pollutant
- $AR_{\text{production}}$ = the activity rate for the lead production
- $EF_{\text{pollutant}}$ = the emission factor for this pollutant

This equation is applied at the national level, using annual national total lead production. Information on the production of lead, suitable for estimating emissions using the simpler estimation methodology (Tier 1 and 2), is widely available from United Nations statistical yearbooks or national statistics.

Tier 1 emission factors assume an ‘averaged’ or typical technology and abatement implementation in the country and integrate all sub-processes in lead production from inputting the raw material to the final shipment off the facilities.

In cases where specific abatement options are to be taken into account, a Tier 1 method is not applicable and a Tier 2 or Tier 3 approach must be used.

3.2.2 Default emission factors

The Tier 1 approach needs emission factors for all relevant pollutants, which integrate all sub-processes within the industry from inputting raw materials to the final shipment of the products off site. The default emission factors for primary and secondary lead production are given in Table 3.1 and Table 3.2. The emission factors for heavy metals are primarily obtained from Theloke et al. (2008) (Tier 1 EF). These average emission factors were representative for EU-27, Albania, Belarus, Croatia, Iceland, Former Yugoslav Republic of Macedonia, Moldova, Norway, the European part of Russia, Serbia and Montenegro, Switzerland, and Ukraine. The PM_{10} emission was estimated from the composition of particulate matter emitted from lead smelters given in the SPECIATE database (US EPA, 2011) and the emission of heavy metals given by Theloke et al. (2008). The share of TSP and $PM_{2.5}$ is estimated by using the distribution given in Visschedijk et al. (2004).

Emission factors in BREF documents are mostly given in ranges. Where these emission factors are used in the tables below, the range is interpreted at the 95 % confidence interval, while the geometric mean of this range is chosen as the value for the emission factor.

Emissions of NO_x , SO_x and CO are assumed to originate mainly from combustion and are discussed in chapter 1.A.2.b. All other emissions are assumed to originate primarily from the process and are therefore discussed in the present chapter.

Table 3.1 Tier 1 emission factors for source category 2.C.5 Lead production, primary.

Tier 1 default emission factors					
	Code	Name			
NFR source category	2.C.5	Lead production, primary			
Fuel	NA				
Not applicable	HCH				
Not estimated	NO _x , CO, NMVOC, SO _x , NH ₃ , Cr, Cu, Ni, Se, BC, Benzo(a)pyrene, Benzo(a)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene, HCB				
Pollutant	Value	Unit	95 % confidence interval		Reference
			Lower	Upper	
TSP	50	g/Mg lead	25	100	Visschedijk et al. (2004) applied on PM ₁₀
PM ₁₀	40	g/Mg lead	20	80	US EPA (2011, file no. 9000510)
PM _{2.5}	20	g/Mg lead	10	40	Visschedijk et al. (2004) applied on PM ₁₀
Pb	13	g/Mg lead	8.4	17	Theloke et al. (2008)
Cd	0.067	g/Mg lead	0.05	0.1	Theloke et al. (2008)
Hg	0.93	g/Mg lead	0.74	1.1	Theloke et al. (2008)
As	0.015	g/Mg lead	0.01	0.02	Theloke et al. (2008)
Zn	6.5	g/Mg lead	3.3	13	US EPA, no. 9000510 applied on Theloke et al. (2008)
PCB	1.9	g/Mg lead	0.66	5.8	Note 1
PCDD/F	5	µg I-TEQ/Mg lead	0.38	49	UNEP (2005)

Note 1 The EF for PCB may be revised in the future based on new information from UNEP: Toolkit for Identification and Quantification of Releases of Dioxins and Furans and Other Unintentional POPs: <http://chm.pops.int/Implementation/ToolKit/Meetings/7thExpertMeeting2012/tabid/2906/mctl/ViewDetails/EventModID/876/EventID/326/xmid/9376/Default.aspx>.

Table 3.2 Tier 1 emission factors for source category 2.C.5 Lead production, secondary.

Tier 1 default emission factors					
	Code	Name			
NFR source category	2.C.5	Lead production, secondary			
Fuel	NA				
Not applicable	HCH				
Not estimated	NO _x , CO, NMVOC, SO _x , NH ₃ , BC, Hg, Cr, Cu, Ni, Se, Benzo(a)pyrene, Benzo(a)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene, HCB				
Pollutant	Value	Unit	95 % confidence interval		Reference
			Lower	Upper	
TSP	1 625	g/Mg lead	800	3 200	Visschedijk et al. (2004) applied on PM ₁₀
PM ₁₀	1 300	g/Mg lead	650	2 600	US EPA (2011, file no. 2040110)
PM _{2.5}	650	g/Mg lead	325	1 300	Visschedijk et al. (2004) applied on PM ₁₀
Pb	426	g/Mg lead	147	587	Theloke et al. (2008)
Cd	1.1	g/Mg lead	0.50	2.9	Theloke et al. (2008)
As	3.5	g/Mg lead	2.2	5.1	Theloke et al. (2008)
Zn	2.6	g/Mg lead	1.3	5.2	US EPA (2011, file no. 2040110) applied on Theloke et al. (2008)
PCB	3.2	g/Mg lead	1.1	9.6	Note 1
PCDD/F	8	µg I-TEQ/Mg lead	0.5	80	UNEP (2005)

Note 1 The EF for PCB may be revised in the future based on new information from UNEP: Toolkit for Identification and Quantification of Releases of Dioxins and Furans and Other Unintentional POPs: <http://chm.pops.int/Implementation/ToolKit/Meetings/7thExpertMeeting2012/tabid/2906/mctl/ViewDetails/EventModID/876/EventID/326/xmid/9376/Default.aspx>.

3.2.3 Activity data

Information on the production of lead, suitable for estimating emissions using the simpler estimation methodology (Tier 1 and 2), is widely available from United Nations statistical yearbooks or national statistics.

Further guidance is provided in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, volume 3 on Industrial Processes and Product Use (IPPU), chapter 4.6.2.3 'Choice of activity data' (IPCC, 2006).

3.3 Tier 2 technology-specific approach

3.3.1 Algorithm

The Tier 2 approach is similar to the Tier 1 approach. To apply the Tier 2 approach, both the activity data and the emission factors need to be stratified according to the different techniques that may occur in the country.

The Tier 2 approach is as follows:

Stratify the lead production in the country to model the different product and process types occurring in the national lead industry into the inventory by:

- defining the production using each of the separate product and/or process types (together called 'technologies' in the formulae below) separately; and
- applying technology specific emission factors for each process type:

$$E_{\text{pollutant}} = \sum_{\text{technologies}} AR_{\text{production,technology}} \times EF_{\text{technology,pollutant}} \quad (2)$$

where:

$AR_{\text{production,technology}}$ = the production rate within the source category, using this specific technology

$EF_{\text{technology,pollutant}}$ = the emission factor for this technology and this pollutant

A country where only one technology is implemented will result in a penetration factor of 100 % and the algorithm reduces to:

$$E_{\text{pollutant}} = AR_{\text{production}} \times EF_{\text{technology,pollutant}} \quad (3)$$

where:

$E_{\text{pollutant}}$ = the emission of the specified pollutant

$AR_{\text{production}}$ = the activity rate for the lead production

$EF_{\text{pollutant}}$ = the emission factor for this pollutant

The emission factors in this approach will include all sub-processes within the industry from inputting raw materials until the produced lead is shipped to the customers.

3.3.2 Technology-specific emission factors

This subsection provides technology-specific emission factors for primary and secondary lead production. Typical technologies represent typical emission factors for both primary and secondary lead production, while specific technology tables include abatement and regional aspects. Information on abatement of heavy metals is available from Theloke *et al.* (2008). However, no data are available on the abatement of particulates in those particular situations and the typical emission factors for PM are presented in these tables. Since in reality PM and heavy metal emissions will be correlated, inconsistencies between the tables do exist and these emission factors should be handled with care.

Additionally, it must be mentioned that emission factors from various sources have been combined to derive the set of emission factors for each technology and control technology. These data are not always consistent with each other, for instance when the BAT emission factor is higher than an emission factor which is not BAT. This is another reason why the selection of appropriate emission factors from the present subsection must be undertaken with care.

As for the Tier 1 approach, emissions of NO_x, SO_x and CO are assumed to originate mainly from combustion and are discussed in chapter 1.A.2.b. All other emissions are assumed to originate primarily from the process and are therefore discussed in the present chapter.

3.3.2.1 Primary lead production

Table 3.3 presents emission factors that can be used for primary lead production; unabated. Table 3.4, Table 3.5 and Table 3.6 present emission factors for specific technologies in the primary lead production process. However, data were not available for all pollutants (only for the values referenced in Theloke *et al.*, 2008). The PM₁₀ emission has been estimated from the composition of particulate matter emitted from lead smelters given in the SPECIATE database (US EPA, 2011) and the emission of heavy metals given by Theloke *et al.* (2008). Regarding the EFs concerning abated emissions, the reduction of TSP is assumed to be as efficient as the reduction of heavy metals. The share of PM₁₀ and PM_{2.5} is estimated by using the distribution given in Visschedijk *et al.* (2004).

Table 3.3 Tier 2 emission factors for source category 2.C.5 Lead production, primary lead production, unabated.

Tier 2 default emission factors					
	Code	Name			
NFR source category	2.C.5	Lead production, primary			
Fuel	NA				
SNAP (if applicable)	030304 Primary lead production				
Technologies/Practices	Primary lead production				
Region or regional conditions					
Abatement technologies	Unabated				
Not applicable	HCH				
Not estimated	NO _x , CO, NMVOC, SO _x , NH ₃ , BC, As, Cr, Cu, Ni, Se, Benzo(a)pyrene, Benzo(a)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene, HCB				
Pollutant	Value	Unit	95 % confidence interval		Reference
			Lower	Upper	
TSP	560	g/Mg lead	280	1 120	Visschedijk <i>et al.</i> (2004) applied on PM ₁₀
PM ₁₀	450	g/Mg lead	225	900	US EPA (2011, file no. 9000510)
PM _{2.5}	225	g/Mg lead	110	450	Visschedijk <i>et al.</i> (2004) applied on PM ₁₀

Pb	150	g/Mg lead	100	200	Theloke et al. (2008)
Cd	0.80	g/Mg lead	0.60	1.2	Theloke et al. (2008)
Hg	1.0	g/Mg lead	0.80	1.2	Theloke et al. (2008)
As	0.18	g/Mg lead	0.12	0.24	Theloke et al. (2008)
Zn	75	g/Mg lead	37	150	US EPA, no. 9000510 applied on Theloke et al. (2008)
PCB	1.9	g/Mg lead	0.66	5.8	Note 1
PCDD/F	5	µg I-TEQ/Mg lead	0.38	49	UNEP (2005)

Note 1 The EF for PCB may be revised in the future based on new information from UNEP: Toolkit for Identification and Quantification of Releases of Dioxins and Furans and Other Unintentional POPs: <http://chm.pops.int/Implementation/ToolKit/Meetings/7thExpertMeeting2012/tabid/2906/mctl/ViewDetails/EventModID/876/EventID/326/xmid/9376/Default.aspx>.

BAT production technology

Table 3.4 Tier 2 emission factors for source category 2.C.5 Lead production, primary lead production with BAT technologies.

Tier 2 default emission factors					
	Code	Name			
NFR source category	2.C.5	Lead production, primary			
Fuel	NA				
SNAP (if applicable)	030304 Primary lead production				
Technologies/Practices	Primary lead production				
Region or regional conditions					
Abatement technologies	BAT production technologies				
Not applicable	HCH				
Not estimated	NO _x , CO, NMVOC, SO _x , NH ₃ , BC, As, Cr, Cu, Ni, Se, Benzo(a)pyrene, Benzo(a)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene, HCB				
Pollutant	Value	Unit	95 % confidence interval		Reference
			Lower	Upper	
TSP	500	g/Mg lead	250	1 000	Visschedijk et al. (2004) applied on PM ₁₀
PM ₁₀	400	g/Mg lead	200	800	US EPA (2011, file no. 9000510)
PM _{2.5}	200	g/Mg lead	100	400	Visschedijk et al. (2004) applied on PM ₁₀
Pb	135	g/Mg lead	90	180	Theloke et al. (2008)
Cd	0.72	g/Mg lead	0.54	1.1	Theloke et al. (2008)
Hg	1.0	g/Mg lead	0.80	1.2	Theloke et al. (2008)
As	0.16	g/Mg lead	0.11	0.22	Theloke et al. (2008)
Zn	70	g/Mg lead	35	140	US EPA, no. 9000510 applied on Theloke et al. (2008)
PCB	1.9	g/Mg lead	0.66	5.8	
PCDD/F	5	µg I-TEQ/Mg lead	0.38	49	UNEP (2005)

*Electrostatic precipitator***Table 3.5 Tier 2 emission factors for source category 2.C.5 Lead production, primary lead production with electrostatic precipitator.**

Tier 2 default emission factors					
	Code	Name			
NFR source category	2.C.5	Lead production, primary			
Fuel	NA				
SNAP (if applicable)	030304 Primary lead production				
Technologies/Practices	Primary lead production				
Region or regional conditions					
Abatement technologies	Dry ESP medium effect				
Not applicable	HCH				
Not estimated	NO _x , CO, NMVOC, SO _x , NH ₃ , BC, As, Cr, Cu, Ni, Se, Benzo(a)pyrene, Benzo(a)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene, HCB				
Pollutant	Value	Unit	95 % confidence interval		Reference
			Lower	Upper	
TSP	90	g/Mg lead	45	180	Visschedijk et al. (2004) applied on PM ₁₀
PM ₁₀	70	g/Mg lead	35	140	US EPA (2011, file no. 9000510)
PM _{2.5}	50	g/Mg lead	25	100	Visschedijk et al. (2004) applied on PM ₁₀
Pb	23	g/Mg lead	15	31	Theloke et al. (2008)
Cd	0.12	g/Mg lead	0.09	0.18	Theloke et al. (2008)
Hg	0.95	g/Mg lead	0.76	1.1	Theloke et al. (2008)
As	0.027	g/Mg lead	0.018	0.037	Theloke et al. (2008)
Zn	12	g/Mg lead	6.0	24	US EPA, no. 9000510 applied on Theloke et al. (2008)
PCB	1.9	g/Mg lead	0.66	5.8	
PCDD/F	5	µg I-TEQ/Mg lead	0.38	49	UNEP (2005)

*Virgin activated carbon injection, fabric filters and flue gas desulphurisation***Table 3.6 Tier 2 emission factors for source category 2.C.5 Lead production, primary lead production with abatement.**

Tier 2 default emission factors					
	Code	Name			
NFR source category	2.C.5	Lead production, primary			
Fuel	NA				
SNAP (if applicable)	030304 Primary lead production				
Technologies/Practices	Primary lead production				
Region or regional conditions					
Abatement technologies	Virgin activated carbon injection (SIC)+FF+FGD				
Not applicable	HCH				
Not estimated	NO _x , CO, NMVOC, SO _x , NH ₃ , BC, As, Cr, Cu, Ni, Se, Benzo(a)pyrene, Benzo(a)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene, HCB				
Pollutant	Value	Unit	95 % confidence interval		Reference
			Lower	Upper	
TSP	0.30	g/Mg lead	0.15	0.60	Visschedijk et al. (2004) applied on PM ₁₀
PM ₁₀	0.25	g/Mg lead	0.12	0.50	US EPA (2011, file no. 9000510)
PM _{2.5}	0.20	g/Mg lead	0.10	0.40	Visschedijk et al. (2004) applied on PM ₁₀
Pb	0.015	g/Mg lead	0.010	0.020	Theloke et al. (2008)
Cd	0.00008	g/Mg lead	0.00006	0.00012	Theloke et al. (2008)
Hg	0.10	g/Mg lead	0.080	0.12	Theloke et al. (2008)
As	0.000018	g/Mg lead	0.000012	0.000024	Theloke et al. (2008)
Zn	0.0075	g/Mg lead	0.0037	0.015	US EPA, no. 9000510 applied on Theloke et al. (2008)
PCB	1.9	g/Mg lead	0.66	5.8	
PCDD/F	5	µg I-TEQ/Mg lead	0.38	49	UNEP (2005)

3.3.2.2 Secondary lead production

Table 3.7 presents a set of emission factors that can be used for secondary lead production; unabated. Table 3.8, Table 3.9 and Table 3.10 present emission factors for specific technologies within secondary lead production. However, data were not available for all pollutants (only for the values referenced in Theloke *et al.*, 2008). The PM₁₀ emission has been estimated from the composition of particulate matter emitted from lead smelters given in the SPECIATE database (US EPA, 2011) and the emission of heavy metals given by Theloke *et al.* (2008). Regarding the EFs concerning abated emissions, the reduction of TSP is assumed to be as efficient as the reduction of heavy metals. The share of TSP and PM_{2.5} is estimated by using the distribution given in Visschedijk *et al.* (2004). Separate abatement efficiencies supplied for particulates are presented below.

Table 3.7 Tier 2 emission factors for source category 2.C.5 Lead production, secondary lead production; unabated.

Tier 2 default emission factors					
	Code	Name			
NFR source category	2.C.5	Lead production, secondary			
Fuel	NA				
SNAP (if applicable)	030307 Secondary lead production				
Technologies/Practices	Secondary lead production				
Region or regional conditions					
Abatement technologies	Unabated				
Not applicable	HCH				
Not estimated	NO _x , CO, NMVOC, SO _x , NH ₃ , BC, Hg, As, Cr, Cu, Ni, Se, Benzo(a)pyrene, Benzo(a)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene, HCB				
Pollutant	Value	Unit	95 % confidence interval		Reference
			Lower	Upper	
TSP	14 800	g/Mg lead	7 400	29 600	Visschedijk <i>et al.</i> (2004) applied on PM ₁₀
PM ₁₀	11 800	g/Mg lead	5 900	23 600	US EPA (2011, file no. 2040110)
PM _{2.5}	8 800	g/Mg lead	4 400	17 600	Visschedijk <i>et al.</i> (2004) applied on PM ₁₀
Pb	5 800	g/Mg lead	2 000	8 000	Theloke <i>et al.</i> (2008)
Cd	15	g/Mg lead	20	40	Theloke <i>et al.</i> (2008)
As	47	g/Mg lead	30	70	Theloke <i>et al.</i> (2008)
Zn	35	g/Mg lead	17	70	US EPA (2011, file no. 2040110) applied on Theloke <i>et al.</i> (2008)
PCB	3.2	g/Mg lead	1.1	9.6	Note 1
PCDD/F	8	µg I-TEQ/Mg lead	0.5	80	UNEP (2005)

Note The EF for PCB may be revised in the future based on new information from UNEP: Toolkit for Identification and Quantification of Releases of Dioxins and Furans and Other Unintentional POPs: <http://chm.pops.int/Implementation/ToolKit/Meetings/7thExpertMeeting2012/tabid/2906/mctl/ViewDetails/EventModID/876/EventID/326/xmid/9376/Default.aspx>.

BAT production technology**Table 3.8 Tier 2 emission factors for source category 2.C.5 Lead production, secondary lead production with BAT technologies.**

Tier 2 default emission factors					
	Code	Name			
NFR source category	2.C.5	Lead production, secondary			
Fuel	NA				
SNAP (if applicable)	030307 Secondary lead production				
Technologies/Practices	Secondary lead production				
Region or regional conditions					
Abatement technologies	BAT production technologies				
Not applicable	HCH				
Not estimated	NO _x , CO, NMVOC, SO _x , NH ₃ , BC, Hg, As, Cr, Cu, Ni, Se, Benzo(a)pyrene, Benzo(a)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene, HCB				
Pollutant	Value	Unit	95 % confidence interval		Reference
			Lower	Upper	
TSP	13 300	g/Mg lead	6 700	26 600	Visschedijk et al. (2004) applied on PM ₁₀
PM ₁₀	10 600	g/Mg lead	5 300	21 200	US EPA (2011, file no. 2040110)
PM _{2.5}	7 900	g/Mg lead	3 900	15 800	Visschedijk et al. (2004) applied on PM ₁₀
Pb	5 220	g/Mg lead	1 800	7 200	Theloke et al. (2008)
Cd	14	g/Mg lead	9.0	36	Theloke et al. (2008)
As	42	g/Mg lead	27	63	Theloke et al. (2008)
Zn	31	g/Mg lead	15	62	US EPA (2011, file no. 2040110) applied on Theloke et al. (2008)
PCB	3.2	g/Mg lead	1.1	9.6	
PCDD/F	8	µg I-TEQ/Mg lead	0.5	80	UNEP (2005)

Electrostatic precipitator**Table 3.9 Tier 2 emission factors for source category 2.C.5 Lead production, secondary lead production with electrostatic precipitators.**

Tier 2 default emission factors					
	Code	Name			
NFR source category	2.C.5	Lead production, secondary			
Fuel	NA				
SNAP (if applicable)	030307 Secondary lead production				
Technologies/Practices	Secondary lead production				
Region or regional conditions					
Abatement technologies	Dry ESP medium effect				
Not applicable	HCH				
Not estimated	NO _x , CO, NMVOC, SO _x , NH ₃ , BC, Hg, As, Cr, Cu, Ni, Se, Benzo(a)pyrene, Benzo(a)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene, HCB				
Pollutant	Value	Unit	95 % confidence interval		Reference
			Lower	Upper	
TSP	2 250	g/Mg lead	1 100	4 500	Visschedijk et al. (2004) applied on PM ₁₀
PM ₁₀	1 800	g/Mg lead	900	3 600	US EPA (2011, file no. 2040110)
PM _{2.5}	1 350	g/Mg lead	670	2700	Visschedijk et al. (2004) applied on PM ₁₀
Pb	885	g/Mg lead	340	1 362	Theloke et al. (2008)
Cd	2.3	g/Mg lead	1.5	6.1	Theloke et al. (2008)
As	7.2	g/Mg lead	4.6	9.3	Theloke et al. (2008)
Zn	5.3	g/Mg lead	2.6	11	US EPA (2011, file no. 2040110) applied on Theloke et al. (2008)
PCB	3.2	g/Mg lead	1.1	9.6	
PCDD/F	8	µg I-TEQ/Mg lead	0.5	80	UNEP (2005)

*Fabric filters***Table 3.10 Tier 2 emission factors for source category 2.C.5 Lead production, secondary lead production with state of the art fabric filters.**

Tier 2 default emission factors					
	Code	Name			
NFR source category	2.C.5	Lead production, secondary			
Fuel	NA				
SNAP (if applicable)	030307 Secondary lead production				
Technologies/Practices	Secondary lead production				
Region or regional conditions					
Abatement technologies	FF state-of-the-art				
Not applicable	HCH				
Not estimated	NOx, CO, NMVOC, SOx, NH3, BC, Hg, As, Cr, Cu, Ni, Se, Benzo(a)pyrene, Benzo(a)fluoranthene, Benzo(k)fluoranthene, Indeno(1,2,3-cd)pyrene, HCB				
Pollutant	Value	Unit	95 % confidence interval		Reference
			Lower	Upper	
TSP	1.5	g/Mg lead	0.75	3.0	Visschedijk et al. (2004) applied on PM ₁₀
PM ₁₀	1.2	g/Mg lead	0.60	2.4	US EPA (2011, file no. 2040110)
PM _{2.5}	0.90	g/Mg lead	0.45	1.8	Visschedijk et al. (2004) applied on PM ₁₀
Pb	0.58	g/Mg lead	0.20	0.80	Theloke et al. (2008)
Cd	0.0015	g/Mg lead	0.0010	0.0040	Theloke et al. (2008)
As	0.0047	g/Mg lead	0.0030	0.0070	Theloke et al. (2008)
Zn	0.0035	g/Mg lead	0.0017	0.0070	US EPA (2011, file no. 2040110) applied on Theloke et al. (2008)
PCB	3.2	g/Mg lead	1.1	9.6	
PCDD/F	8	µg I-TEQ/Mg lead	0.5	80	UNEP (2005)

3.3.3 Abatement

A number of add-on technologies exist that are aimed at reducing the emissions of specific pollutants. The resulting emission can be calculated by replacing the technology specific emission factor with an abated emission factor as given in the formula:

$$EF_{technology,abated} = \eta_{abatement} \times EF_{technology,unabated} \quad (4)$$

where:

- $EF_{technology, abated}$ = the emission factor after implementation of the abatement
 $\eta_{abatement}$ = the abatement efficiency
 $EF_{technology, unabated}$ = the emission factor before implementation of the abatement

This subsection presents default abatement efficiencies for particulates. Abatement efficiencies for particulates are presented in Table 3.11. These efficiencies are related to the older plant technology, using the CEPMEIP emission factors (Visschedijk *et al.*, 2004). These abatement efficiencies are used to estimate the particulate emission factors in the Tier 2 tables above.

Table 3.11 Abatement efficiencies ($\eta_{\text{abatement}}$) for source category 2.C.5 Lead production for particulate matter.

Tier 2 Abatement efficiencies					
	Code	Name			
NFR Source Category	2.C.5	Lead production			
Fuel	NA	not applicable			
SNAP (if applicable)	040309b	Lead production			
Abatement technology	Particle size	Efficiency	95% confidence interval		Reference
		Default Value	Lower	Upper	
Modern plant (BAT): fabric filters for most emission sources	particle > 10 μm	98.8%	96.4%	99.6%	Visschedijk et al. (2004)
	10 μm > particle > 2.5 μm	96.2%	88.6%	98.7%	Visschedijk et al. (2004)
	2.5 μm > particle	90.0%	70.0%	96.7%	Visschedijk et al. (2004)
Conventional installation: ESP, settlers, scrubbers; moderate control of fugive sources	particle > 10 μm	95.0%	80.0%	98.8%	Visschedijk et al. (2004)
	10 μm > particle > 2.5 μm	86.7%	46.7%	96.7%	Visschedijk et al. (2004)
	2.5 μm > particle	66.7%	0.0%	91.7%	Visschedijk et al. (2004)

3.3.4 Activity data

Information on the production of lead, suitable for estimating emissions using the simpler estimation methodology (Tier 1 and 2), is widely available from United Nations statistical yearbooks or national statistics. This information is satisfactory to estimate emissions with the use of the simpler estimation methodology.

For a Tier 2 approach these data need to be stratified according to technologies applied. Typical sources for this data might be industrial branch organisations within the country or specific questionnaires submitted to the individual lead works.

Further guidance is provided in the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, volume 3 on Industrial Processes and Product Use (IPPU), chapter 4.6.2.3 'Choice of activity statistics' (IPCC, 2006).

3.4 Tier 3 emission modelling and use of facility data

3.4.1 Algorithm

There are two different emission estimation methods that go beyond the technology-specific approach described above:

- detailed modelling of the lead production process;
- facility-level emission reports.

3.4.1.1 Detailed process modelling

A Tier 3 emission estimate, using process details will make separate estimates for the consecutive steps in the production process of lead.

3.4.1.2 Facility-level data

Where facility-level emission data of sufficient quality (see the guidance chapter on QA/QC in Part A of the Guidebook) are available, it is good practice to use these data. There are two possibilities:

- facility reports cover all lead production in the country;
- facility-level emission reports are not available for all lead plants in the country.

If facility level data are covering all lead production in the country, it is good practice to compare the implied emission factors (reported emissions divided by national lead production) with the default emission factor values or technology-specific emission factors. If the implied emission factors are outside the 95 % confidence intervals for the values given below, it is good practice to explain the reasons for this in the inventory report

If the total annual lead production in the country is not included in the total of the facility reports, it is good practice to estimate the missing part of the national total emissions from the source category, using extrapolation by applying:

$$E_{Total,pollutant} = \sum_{Facilities} E_{Facility,pollutant} + \left(National\ Production - \sum_{Facilities} Production_{Facility} \right) \times EF \quad (5)$$

where:

$E_{total,pollutant}$	=	the total emission of a pollutant for all facilities within the source category
$E_{facility,pollutant}$	=	the emission of the pollutant as reported by a facility
$Production_{total}$	=	the production rate in the source category
$Production_{facility}$	=	the production rate in a facility
$EF_{pollutant}$	=	the emission factor for the pollutant

Depending on the specific national circumstances and the coverage of the facility-level reports as compared to the total national lead production, it is good practice to choose the emission factor (EF) in this equation from the following possibilities, in decreasing order of preference:

- technology-specific emission factors, based on knowledge of the types of technologies implemented at the facilities where facility level emission reports are not available;
- the implied emission factor derived from the available emission reports:

$$EF = \frac{\sum_{Facilities} E_{Facility,pollutant}}{\sum_{Facilities} Production_{Facility}} \quad (6)$$

- the default Tier 1 emission factor. This option should only be chosen if the facility-level emission reports cover more than 90 % of the total national production.

3.4.2 Tier 3 emission modelling and use of facility data

Lead production plants are major industrial facilities and emissions data for individual plants might be available through a pollutant release and transfer registry (PRTR) or another emission reporting scheme. When the quality of such data is assured by a well developed QA/QC system and the emission reports have been verified by an independent auditing scheme, it is good practice to use such data. If extrapolation is needed to cover all lead production in the country, either the implied emission factors for the facilities that did report or the emission factors as provided above could be used.

No generally accepted emission models are available for the lead production industry. Such models could be developed, however, and used in national inventories. If this happens, it is good practice to compare the results of the model with a Tier 1 or Tier 2 estimate to assess the credibility of the model. If the model provides implied emission factors that lie outside the 95 % confidence intervals indicated in the tables above, it is good practice to include an explanation for this in the documentation with the inventory and preferably reflected in the Informative Inventory Report.

3.4.3 Activity data

Since PRTRs generally do not report activity data, such data in relation to the reported facility-level emissions are sometimes difficult to find. A possible source of facility level activity might be the registries of emission trading systems.

In many countries national statistics offices collect production data at the facility level but these are in many cases confidential. However, in several countries national statistics offices are part of the national emission inventory systems and the extrapolation, if needed, could be performed at the statistics office, ensuring that confidentiality of production data is maintained.

4 Data quality

4.1 Completeness

Care must be taken to include all emissions, from combustion as well as from processes. It is good practice to check whether the emissions reported as 'included elsewhere' (IE) under source category 2.C.5 are indeed included in the emission reported under combustion in source category 1.A.2.b.

4.2 Avoiding double counting with other sectors

Care must be taken that the emissions are not double counted in processes and combustion. It is good practice to check that the emissions reported under source category 2.C.5 are not included in the emission reported under combustion in source category 1.A.2.b.

4.3 Verification

4.3.1 Best Available Technique emission factors

BAT emission limit values are available from the BREF document for the non-ferrous metal industry (European Commission, 2001).

The BREF document describes the technologies necessary to achieve BAT emission levels. For lead production, no generic emission concentrations are given that may be compared against the Tier 1 estimate. However, some numbers for different techniques and processes are available from the BREF document (European Commission, 2001) and may be used for verification purposes.

4.4 Developing a consistent time series and recalculation

No specific issues.

4.5 Uncertainty assessment

No specific issues.

4.5.1 Emission factor uncertainties

No specific issues. The quality of the emission factors presented is rated as 'B'. The guidance chapter on uncertainties in Part A of the Guidebook gives information on how to interpret this quality rating.

4.5.2 Activity data uncertainties

No specific issues.

4.6 Inventory quality assurance/quality control (QA/QC)

No specific issues.

4.7 Gridding

No specific issues.

4.8 Reporting and documentation

No specific issues.

5 Glossary

$AR_{\text{production, technology}}$	The production rate within the source category, using a specific technology
$AR_{\text{production, technology}}$	The production rate within the source category, using a specific technology
$AR_{\text{production}}$	The activity rate for the lead production
Combustion process with contact	A process in which the hot flue gases from a combustion process are directly injected into the reactor where the chemistry and physics take place converting the raw materials into the product. Examples are: <ul style="list-style-type: none"> • Primary iron and steel • Cement • ...
$E_{\text{facility, pollutant}}$	The emission of the pollutant as reported by a facility
$E_{\text{pollutant}}$	The emission of the specified pollutant
$E_{\text{total, pollutant}}$	The total emission of a pollutant for all facilities within the source category
$EF_{\text{country, pollutant}}$	A country-specific emission factor
$EF_{\text{pollutant}}$	The emission factor for the pollutant
$EF_{\text{technology, abated}}$	The emission factor after implementation of the abatement

EF _{technology, pollutant}	The emission factor for this technology and this pollutant
EF _{technology, unabated}	The emission factor before implementation of the abatement
ESP	Electrostatic precipitator: dust emissions abatement equipment
FF	Fabric filters: dust emissions abatement equipment
Penetration _{technology}	The fraction of production using a specific technology
Production _{facility}	The production rate in a facility
Production _{total}	The production rate in the source category
$\eta_{\text{abatement}}$	The abatement efficiency

6 References

- Barbour, A.K., Castle, J.F. and Woods, S.E., 1978. 'Production of non-ferrous metals'. In: *Industrial Air Pollution Handbook*, A. Parker (ed.). Mc Graw-Hill Book Comp. Ltd., London.
- European Commission, 2001. *Integrated Pollution Prevention and Control (IPPC), Reference Document on Best Available Techniques in the Non-Ferrous Metal Industries*, December 2001.
- European Commission, 2009. *Integrated Pollution Prevention and Control (IPPC). Draft Reference Document on Best Available Techniques for the Non-Ferrous Metals Industries*. Draft July 2009.
- IPCC, 2006. *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Prepared by the National Greenhouse Gas Inventories Programme, Eggleston H.S., Buendia L., Miwa K., Ngara T. and Tanabe K. (eds). IGES, Japan.
- Rentz, O., Sasse, H., Karl, U., Schleef, H.-J. and Dorn, R., 1996a. *Emission Control at Stationary Sources in the Federal Republic of Germany, Volume II, Heavy Metal Emission Control*. Umweltforschungsplan des Bundesministers für Umwelt, Naturschutz und Reaktorsicherheit, Luftreinhaltung, 204 02 360.
- Rentz, O., Schleef, H.-J., Dorn, R., Sasse, H. and Karl, U., 1996b. *Emission Control at Stationary Sources in the Federal Republic of Germany, Volume I, Sulphur Oxide and Nitrogen Oxide Emission Control*. Umweltforschungsplan des Bundesministers für Umwelt, Naturschutz und Reaktorsicherheit, Luftreinhaltung, 204 02 360.
- Theloke, J., Kummer, U., Nitter, S., Gefthler, T. and Friedrich, R., 2008. *Überarbeitung der Schwermetallkapitel im CORINAIR Guidebook zur Verbesserung der Emissionsinventare und der Berichterstattung im Rahmen der Genfer Luftreinhaltkonvention*. Report for Umweltbundesamt, April 2008.
- UNEP, 2005. *PCDD/PCDF Toolkit 2005*. United Nations Environmental Programme, Nairobi.
- US EPA, 1990. *AIR Facility Subsystem*. United States Environment Protection Agency Doc. 450/4-90-003. Research Triangle Park, NC, USA.
- US EPA, 2011. SPECIATE database version 4.3, U.S. Environmental Protection Agency's (EPA). Available at: <http://cfpub.epa.gov/si/speciate/>. (accessed 5 June 2013).

Visschedijk, A.J.H., Pacyna, J., Pulles, T., Zandveld, P. and Denier van der Gon, H., 2004. 'Coordinated European Particulate Matter Emission Inventory Program (CEPMEIP)'. In: Dilara, P. *et. al* (eds), *Proceedings of the PM emission inventories scientific workshop, Lago Maggiore, Italy, 18 October 2004*. EUR 21302 EN, JRC, pp 163–174.

7 Point of enquiry

Enquiries concerning this chapter should be directed to the relevant leader(s) of the Task Force on Emission Inventories and Projection's expert panel on Combustion and Industry. Please refer to the TFEIP website (www.tfeip-secretariat.org) for the contact details of the current expert panel leaders.