Lead Product Carbon Footprint

Technical Guidance on Product Carbon Footprint Calculation for Primary and Secondary Lead Production

Version 1.0
By Sphera Solutions GmbH for the International Lead Association
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Contents

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Glossary

CF
Carbon Footprint: sum of GHG emissions and GHG removals in a product system, expressed as CO_2 eq and based on a life cycle assessment using the single impact category of climate change.

CFP
Carbon Footprint of a product

CFR
Carbon Footprint reporting

CO_2
Carbon dioxide

CO_2 eq
Carbon Dioxide equivalents

EPD
Environmental Product Declaration

GHG
Greenhouse gas emissions

GWP
Global Warming Potential

ICMM
International Council on Mining and Metals

IPCC
Intergovernmental Panel on Climate Change

ISO
International Standardization Organization

LCA
Life Cycle Assessment

LCI
Life Cycle Inventory

PCR
Product Category Rules

PEF
Product Environmental Footprint

PM
Precious Metals

PR
Product Rules

Terminology

Primary lead
Refined lead produced mainly from lead concentrate.

Secondary lead
Refined lead produced only from end-of-life lead streams and lead streams from other processes as well as different lead scrap.

Co-products
Products occurring together with the main product. Products that are not the main purpose of the production process.

Characterization factors
Quantitative representation of the relative importance of a specific intervention. Here: GWP of climate relevant gases.

Emission factor
Factor of CO_2-eq per unit of fuels consumed, such as e.g., oil, gas, coal.

Precious metals
Gold, Silver, Platinum, Palladium, Rhodium, Osmium, Iridium, Ruthenium and Rhenium.

Primary data
Life cycle data based on input and output data of a specific company.

Secondary data
Aggregated life cycle data averaged over several producers, as found in public and commercial databases.

1 Executive Summary

The Product Carbon Footprint (PCF) has become an instrument for regulators limiting and reversing climate change effects. Increasingly investors base decisions on PCFs. Designers decide on materials no longer based on costs alone but also on PCF information while downstream users and end consumers demand transparent and credible information on greenhouse gas emissions associated with a product.

Existing methodologies for calculating the PCF for metals such as ISO 14040 / 14044 and 14067 still bear room for interpretation when applied to primary and secondary refined lead production resulting in loss of transparency and credibility. The International Council on Mining and Metals (ICMM) developed, together with Prof. Markus Berger, “A Harmonised Approach to Product Carbon Footprint and Life Cycle Assessment of Non-Ferrous Metals” which is also used as reference for this document.

This document provides practical guidance on calculating the PCF for refined lead production (primary and secondary). The guidance was developed by Sphera Solution GmbH with support from an Industry expert panel and follows ISO 14040/14044, 14067 as well as Product Life Cycle Accounting and Reporting Standards the Greenhouse Gas Protocol and Product Environmental Footprint (PEF) methods.

This guidance is designed for producers of lead metal and associated lead processing companies for calculating and reporting a PCF of refined lead e.g., when reporting to stakeholder’s including customers.

2 Introduction

Climate change and its numerous effects on the environment and subsequently on people and societies has become a global concern. Increasingly, political leaders and regulators include goals and targets for Green House Gas (GHG) emission reductions in national regulations. End users increasingly push for decarbonization while the financial sector has introduced GHG emission-based rating systems. Investments are regularly linked to a company's GHG intensity and reduction strategies. Consequently, societal expectations and the need to limit the impact of climate change increase the push for decarbonization in all economic sectors, including the mining and metals sector.

Any reduction strategy begins with a quantitative baseline. Therefore, quantitative information on GHG emissions is required at various levels. Countries, industry sectors, and companies are expected to report on their Carbon Footprint (CF) and associated CF reduction strategy.

While for Corporate Carbon Footprint (CCF) reporting, the Corporate Accounting and Reporting Standard by Greenhouse Gas Protocol [1] is the widely accepted methodology, the PCF is based on the ISO Standards for Life Cycle Assessment 14040 [2], 14044 [3] and 14067 [4]. These international standards specify principles and requirements for studies to quantify the PCF or a full Life Cycle Assessment (LCA). If the product is an intermediate product such as refined lead, the ISO Standard allows for a cradle-to-gate approach which does include all necessary process steps and upstream information up to the product at the gate of a company.

The ISO Standard is of generic nature and therefore covers metal production in general but not in a specific way for refined lead production to be able to compare published results. This PCF guidance describes the specific approach to be taken to produce refined lead with a lead content of >99.97 % being produced from lead ore and secondary / end of life materials.

The application of this guidance allows lead metal producers and lead processing companies, as well as their customers and other stakeholders involved, to calculate the PCF as kg CO_2 equivalent per kg of lead in a consistent, transparent, and harmonized way.

3 Purpose of the Guidance

The purpose of this guidance is to provide producers of refined lead and lead processing companies and their stakeholders - end users (customers), legislators, academia, LCA practitioners and non-governmental organisations (NGOs) - with a standardized and transparent approach to calculate and report the climate change impact for all relevant GHG emissions (expressed in CO_2-equivalent) from the primary production of refined lead, including the mining, concentration, smelting, refining and casting of lead ores as well as secondary production of refined lead (from recycling) including, collection, preparation, smelting, refining and casting.

The guidance uses ISO 14040, 14044 and 14067 [2], [3], [4] standards on environmental management as a starting point, but as these standards are generic in nature, the guidance presents specific principles, requirements and methodologies for quantifying GHG emissions from primary and secondary refined lead production processes and the associated cradle-to-gate carbon footprints of the related products. It ensures that carbon footprint data communicated by lead producers are coherent and based on the same assumptions, calculations, methods, and parameters.

The guidance also aligns with the GHG Protocol's Product Life Cycle Accounting and Reporting Standard [5], which builds on the framework and requirements established in the ISO standards (ISO 14040 & ISO 14044). Both the GHG Protocol and the ISO standards allows for the development of Product Rules (PR) or Product Category Rules (PCR) to add sufficient detail for product comparisons in a consistent, transparent and credible manner. The guidance is intended to provide such details while at the same time allowing companies to apply rules from both standards which best fit their processes.

	ISO LCA Standards	GHG Protocol Product Standard	ILA PCF guidance
Environmental Impacts	Environmental impact as • Carbon footprint • Energy consumption • Resource use • Water footprint • Etc.	Climate impact as • Carbon footprint	Climate impact as • Carbon footprint
Unit	Different, according to impact category	Kg CO_2 eq.	Kg CO_2 eq.
Relevant Standards	ISO 14040 (framework) ISO 14044 (LCA guidance) ISO 14067 (carbon footprint of products)	• A Corporate Accounting and Reporting Standard • Product Life Cycle Accounting and Reporting Standard GHG Protocol builds on ISO Standard	Building on ISO standards
Field of application	Applies to all materials for all environmental impact categories	Applies to all materials for carbon footprint only	Applies to primary and secondary refined lead producers and for carbon footprint only

Table 1: The ILA PCF Guidance's relation to other standards

4 System Boundary and Data Collection

A system boundary is the set of criteria that determines which unit processes, inputs, outputs, and impacts are to be considered in building an inventory of GHG emissions associated with a product (either from ore or from scrap where it occurs) up to the gate of the factory which produces it. This type of system boundary is also known as “cradle-to-gate”. A unit process is a discrete step in the production cycle of a product. In the following a generic description of primary and secondary refined lead production and latest statistics are shown.

Lead production from primary lead feedstock

In 2022 between 8% (in the Americas) and 45% (in Asia) of lead was produced from ore obtained from mining. In Europe the share of primary lead was 17%. Globally, the proportion of total output accounted for by secondary production was between 55% and 65% of total refined lead production [20].

Primary lead is typically sourced from lead-bearing ores including copper and zinc ores. Primary lead production relies on pyrometallurgical technologies such as the conventional sinter plant and blast furnace process as well as newer, continuous methods such as the QSL, KIVCET, and Isa/Ausmelt processes, which are more energy-efficient and environmentally friendly. Sintering prepares lead sulfide ores by reducing its sulfur content, while the blast furnace or a continuous smelting furnace reduces the ore to molten lead. Refining further purifies the lead bullion to a high purity lead metal and co-product stream including silver, gold, antimony, etc.

The system boundaries need to include the relevant process steps, for primary lead:

- Mining (open pit and underground)
- Beneficiation (typically selective floatation)
- Smelting
- Refining
- Casting
- Sulfuric acid production

Lead production from secondary lead feedstock

In 2022 between 92% (in the Americas) and 55% (in Asia) of secondary lead was produced from end-of-life lead-based batteries or other lead scrap sources such as lead sheets, leach residues from zinc production, etc. In Europe the share of secondary lead was 83%. [20]

Secondary lead is predominantly sourced from lead-based battery breaking and processing but also from other industry lead scrap followed by pyrometallurgical smelting and refining. Smelting takes place in furnaces such as blast, reverberatory, and rotary furnaces to recover lead from lead-based battery scrap and industrial lead scrap. These processes separate the lead paste and metallics from the polymeric components and acid, melt them to reduce oxides to elemental lead, and then refine the lead into a finished product. Newer technologies such as Isasmelt, TSL, KIVCET and QSL also exist, treating a wider range of materials.

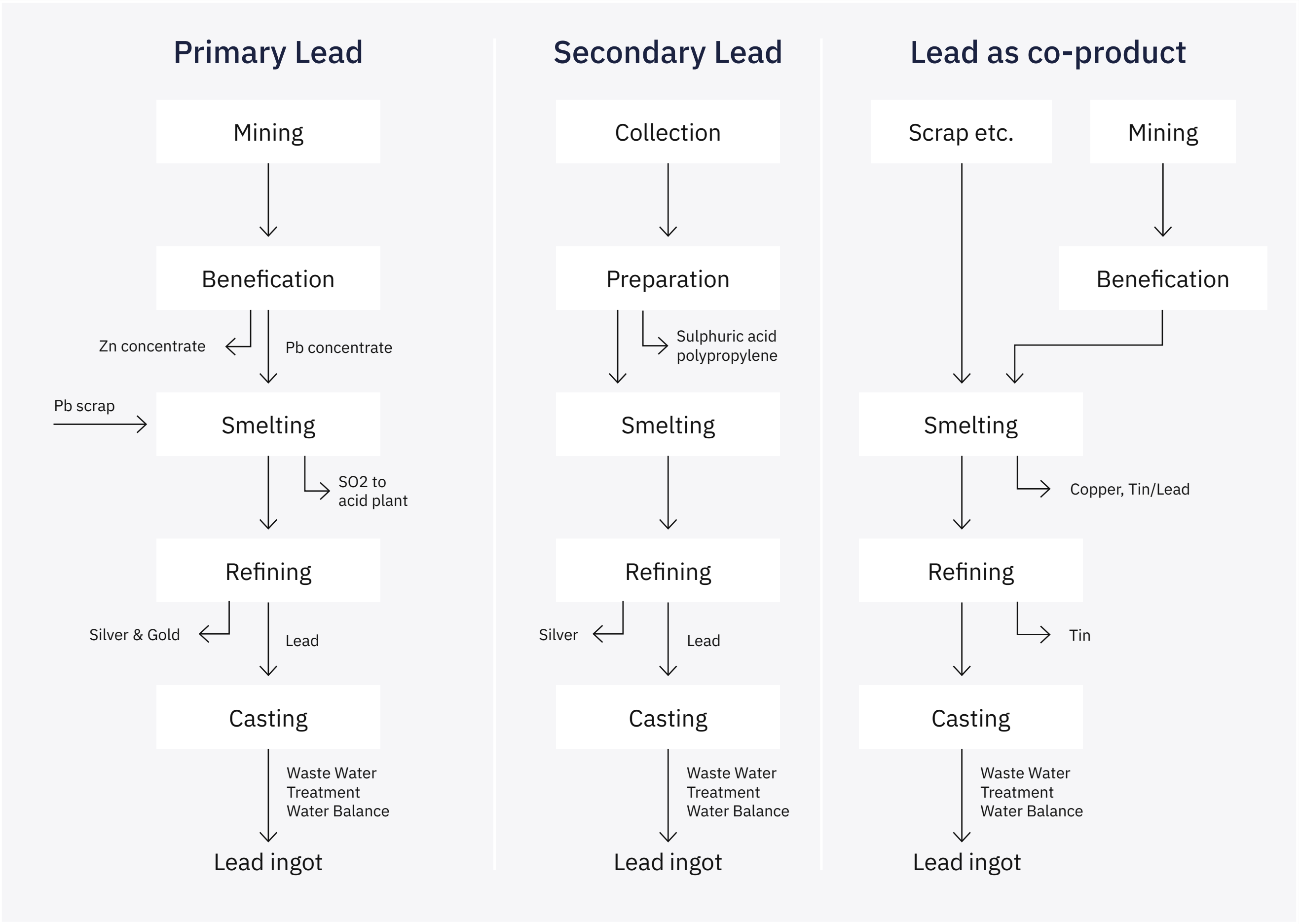


Figure 1: System boundaries for primary and secondary refined lead production

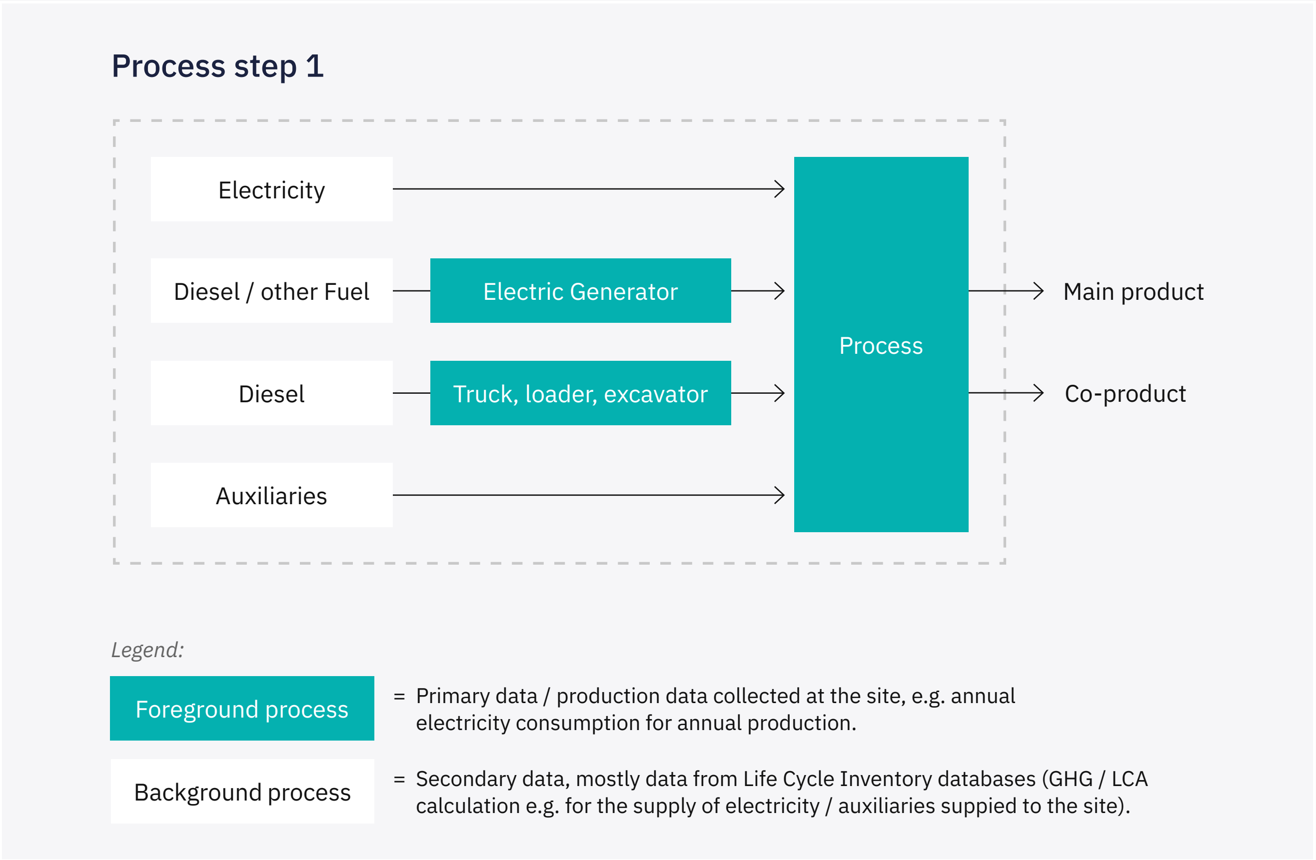


Figure 2: Generic system boundary of one process step

The system boundaries need to include the relevant process steps, for secondary lead:

- Collection (transport)
- Preparation (e.g. removal of acid, dismantling, separation of metallic and polymeric components)
- Smelting
- Refining
- Casting

Primary and secondary lead can be produced with different technologies as described above. To account for this variability in the process flow and therefore in the system boundary setting, Figure 1 shows the generic system boundaries for primary and secondary refined lead production. Those major process step can be separated into more granular process steps depending on the production data availability (e.g. if a company has two different furnaces and a separate preparation step for the input materials the smelting “blackbox” (shown in Figure 1) can be disaggregated to the available granularity). Figure 2 is showing the generic approach taken in this guidance per process step where data is available.

For each process step the major GHG relevant input and output parameters (consumption and production data) need to be collected for the production period of one year (fiscal or calendar) as shown in a generic format in Table 2.

Additionally, the GHG emissions released during the production of fuels, utilities, and auxiliary materials which are required throughout the production of refined lead must be considered. The incoming “co-products” (or “waste streams”) are related to an impact / burden free (see Annex A). Co-products which might be produced during production need to be included in the calculation (explained in section 7). The system boundaries do not include the manufacture of downstream products, use, or end-of-life as this guidance is for an intermediate product (refined lead) that can be used in many different products.

The inclusion and exclusion of input and output parameters is related to the definitions provided in the standards [2],[3],[4] and the applicable cut-off criteria. The cut-off criterion which shall be used here:

Input parameters (such as the production of specific auxiliary materials) and output parameters (such as the treatment of specific waste streams) which contribute less than 1% to the total GHG emissions of refined lead production can be excluded if the total amount of excluded parameters do not exceed 3% of the total GHG emissions. This approach is also aligned with the EU Product Environmental Footprint Guidance. [8]

Process steps as well as in- and output parameters in- and excluded from the system boundaries for refined lead production are listed in Table 3. This is based on experience from the collection of life cycle data for refined lead production in the LCA of refined lead (primary and secondary) by the International Lead Association (ILA) in cooperation with Sphera [7] as well as from recent work with primary and secondary lead producers. The processes excluded from the system boundaries are below the above shown cut off criteria.

Material	Unit	Annual Data	Specification
Input			
Raw materials (e.g. concentrates, secondary materials, alloying elements, etc.)			Assay data (Pb content to provide Pb balance)
Electricity			See chapter electricity hierarchy
Fuels (e.g. diesel, LNG, Propane, hydrogen)			
External supply of heat and / or steam (purchased)			Specify used source (or if allocation by supplier is done)
Auxiliaries (e.g. chemicals, minerals etc.)			Bulk materials
Reductants (fossil)			
Water (e.g. tap, deionized, desalinated)			Please make sure that it is not produced onsite and included in electricity
Output			
Main Product			Assay data (Pb content to provide Pb balance)
Co-product			Assay data (Pb content to provide Pb balance)
Slag (co-product)			Assay data (Pb content to provide Pb balance)
Waste (e.g. slag) for landfill or incineration			
Waste for recovery (e.g. used oil)			
Waste water for treatment			
CO_2 (fossil)			Calculated based on reductants
CO_2 (fossil)			Calculated based on combustion of fuels
Other GHG gases			See Table 5

Table 2: Relevant input and output data (generic) for process steps within the refined lead production

Relevant processes included in the system boundary for primary refined lead production	
Included	**Excluded**
✓ Mining of lead ore ✓ Beneficiation of ore to concentrate's ✓ Transport to smelters ✓ Smelting considering all processes onsite ✓ Lead refining including all processes onsite ✓ Production and transport of auxiliary materials (materials consumed in the production – e.g. flocculants, fluxes, chemicals, etc.) ✓ Collection and related transport of scrap / End-of- Life material into primary smelter ✓ Waste Water Treatment onsite / offsite ✓ Offsite waste disposal ✓ Internal transportation of materials (i.e., within a facility), ✓ On and offsite oxygen, nitrogen, argon production ✓ On and offsite power production, ✓ Energy production onsite and offsite ✓ Electricity production onsite and offsite (supplier specific)	× Production of capital equipment × Manufacture and transport of packaging materials × Packaging of products × Personnel lodging, transport, etc. × Distribution, use, and end-of-life of lead products × Effect of potential volume of acid mine drainage from waste rock and tailings

Table 3: Relevant processes included in the system boundary for primary refined lead production

Relevant processes included in the system boundary for secondary refined lead production	
Included	**Excluded**
✓ Collection and related transport of scrap / End-of-Life material ✓ Preparation of the scrap and End-of-Life material ✓ Smelting considering all processes onsite ✓ Lead refining including all processes onsite ✓ Production and transport of auxiliary materials (materials consumed in the production – e.g. flocculants, fluxes, chemicals, etc.) ✓ Waste Water Treatment onsite / offsite ✓ Offsite waste disposal ✓ Internal transportation of materials (i.e., within a facility), ✓ On and offsite oxygen, nitrogen, argon production ✓ On and offsite power production, ✓ Energy production onsite and offsite ✓ Electricity production onsite and offsite (supplier specific)	× Production of capital equipment × Manufacture and transport of packaging materials × Packaging of products × Personnel lodging, transport, etc. × Distribution, use, and end-of-life of lead products

Table 4: Relevant processes included in the system boundary for secondary refined lead production

5 Greenhouse Gas Emissions

5.1 Relevant Emissions

The mechanism of the greenhouse effect can be observed on a small scale in a greenhouse; incoming solar energy is trapped, causing the internal temperature to rise. This effect also occurs on a global scale. When short-wave ultraviolet radiation from the sun meets the earth's surface some energy is reemitted as longer wave infrared radiation. Instead of directly heading back out to space, some of this infrared radiation is absorbed by greenhouse gases in the troposphere and re-radiated in all directions, including back to earth. This results in a warming effect at the earth's surface. In addition to the natural mechanism, the greenhouse effect is enhanced by human activities.

Several gases contribute to the global warming potential. The predominant greenhouse gas emitted is carbon dioxide (CO_2). It enters the atmosphere through the combustion of fuels (coal, natural gas, oil), waste or other carbon-containing materials such as biomass. It also can result from process reactions (e.g. carbon containing reductants, etc.), as well as from decomposition, respiration, deforestation, and cement production.

Other relevant gases contributing to the global warming potential are methane (CH_4) which is emitted during the production of coal, natural gas, and oil as well as due to leakage during transport or direct at a coal mines. It may also be emitted from livestock and other agricultural practices. Nitrous oxide (N_2O) and fluorinated gases are other climate relevant gases contributing to climate change [9]. The Intergovernmental Panel on Climate Change (IPCC) published the values of the 100- year global warming potential (GWP) for different greenhouse gases. These values are recommended to be used to convert life cycle inventory results to an indicator of climate change impact (kg CO_2-equivalent). Values for the most relevant greenhouse gases and their global warming potential, taken from the IPCC's six' Assessment Report completed in 2023, are shown in Table 5. The IPCC updates the GWP values for the most relevant greenhouse gases on a regular basis. This guidance recommends using the latest version of IPCC.

Greenhouse Gas Name	Chemical Formula	GWP- values for 100 year time horizon
Carbon dioxide	CO_2	1
Methane – non fossil	CH_4	27
Methane –fossil	CH_4	29,8
Nitrous oxide	N_2O	273
Nitrogen trifluoride	NF_3	17400
Sulfur hexafluoride	SF_6	24300
Chlorofluorocarbons (CFCs)		0,021 – 16200
Hydrofluorocarbons (HFCs)		0,005 – 14600
Fully Fluorinated Species		0,004 – 18500
Halogenated Alcohols, Ethers, Furans, Aldehydes, Ketones		0,007 – 14300
Bromocarbons, Hydrobromocarbons and Halons		0,052 – 7200
Chlorocarbons and Hydrochlorocarbons		0,007 – 2200
Hydrochlorofluorocarbon - includes unsaturated species		0,004 - 2300

Table 5: GWP Values (version IPCC AR 6) for most relevant Greenhouse Gases [19] [21]

Note: When gathering LCA data, carbon dioxide emissions from fossil fuels and biomass should be reported separately.

5.2 Greenhouse Protocol: Determining Scope Emissions

The predominant greenhouse gas emitted during primary and secondary refined lead production is carbon dioxide (CO_2). Other gases relevant to global warming potential, such as methane or nitrous oxide, are or have the potential to be released during the steps of mining, beneficiation, smelting, refining and casting for the production of refined lead.

The Corporate Accounting and Reporting Standard by Greenhouse Gas Protocol [1] classifies a company's GHG emissions into three main category types: Scope 1, Scope 2 and Scope 3. This approach is commonly used to demonstrate whether emissions occur onsite, are related to indirect electricity / energy related offsite processes or associated with upstream processes.

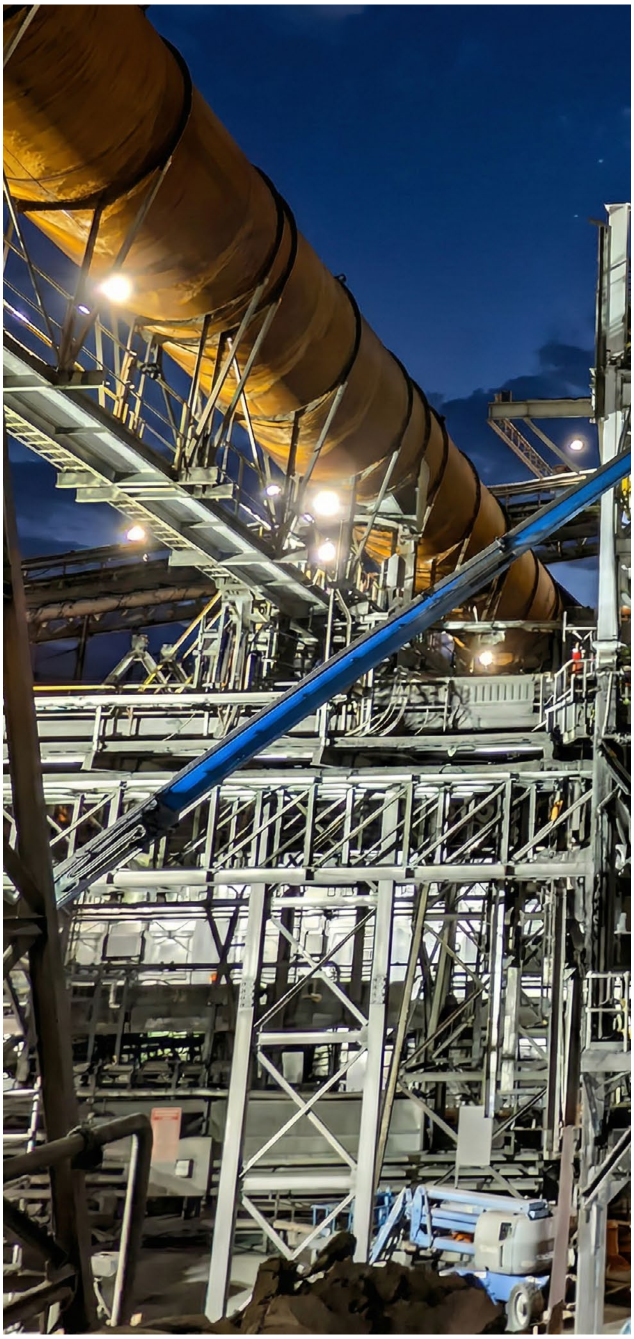
The definition of scope 1 to 3 emissions is as follows [1]:

- **Scope 1:** "Direct GHG emissions occur from sources that are owned or controlled by the company, for example, emissions from combustion in owned or controlled boilers, furnaces, vehicles, etc.; emissions from chemical production in owned or controlled process equipment".

- **Scope 2:** "Scope 2 accounts for GHG emissions from the generation of purchased electricity consumed by the company. Purchased electricity is defined as electricity that is purchased or otherwise brought into the organizational boundary of the company. Scope 2 emissions physically occur at the facility where electricity is generated".

- **Scope 3:** "Scope 3 is an optional reporting category that allows for the treatment of all other indirect emissions. Scope 3 emissions are a consequence of the activities of the company but occur from sources not owned or controlled by the company. Some examples of scope 3 activities are the extraction and production of purchased materials; the transportation of purchased goods; and use of sold products and services.".

To maintain data consistency and comparability across the industry, classification according to the GHG Protocol corporate standard into Scope 1, 2 and 3 emissions is recommended to be done based on the production processes in the value chain. Table 6 lists some of the main contributors to GHG emissions in the production of refined lead and their assignment to the Scope according to the GHG Protocol.



GHG emissions in refined lead production according to Greenhouse Gas Protocol		
Contributors	**Description**	**Emission Scope**
Direct activities	Combustion emissions associated with fuels, reductants and other process emissions (air emissions) like for instance plastic coming from electronic scrap	Scope 1
Electricity onsite	Emissions associated with electricity generated on site	Scope 1
Electricity	Electricity from the national or local electricity grid (cradle-to-customer basis)*	Scope 2
Raw materials	Lead containing raw materials sourced from third parties (e.g., concentrates, co-product streams such as leach residues from zinc smelters, other secondary raw materials)	Scope 3
Auxiliaries	GHG emissions associated with production of auxiliary materials such as e.g., minerals, chemicals	Scope 3
Fuels, reductants	Production of fuels used in the process	Scope 3
Lubricants	Production of lubricants used in the process	Scope 3
Explosives	Production of explosives used in mining	Scope 3
Wastewater	Municipal wastewater treatment. The emissions associated with onsite water treatment fall under direct activities	Scope 3
Water	The upstream production of tap/process water (if not done onsite)	Scope 3
Transport	Includes the fuel production for transport of raw and auxiliary materials and combustion of associated fuels (well to wheel)	Scope 3
Credit	Impact associated with the credit of co-product from end-of -life battery preparation such as polypropylene and sulphuric acid	Scope 3

Table 6: GHG emissions in refined lead production according to Greenhouse Gas Protocol

* *In LCA-related databases, fuel combustion, fuel supply and grid losses are not reported separately. These are, therefore, all assigned to the Scope 2 category of emissions from production processes*

6 Assessing the Impact of GHG Emissions

In accordance with ISO 14040 [2] and 14044 [3], a GHG impact assessment is derived from the GHG inventory, in which process inputs and outputs have been determined.

The production processes and associated substances which have been considered for GHG emissions and the selected characterization factors for global warming potential, as shown in Table 3, should be reported.

The potential climate change impact of each GHG emitted and removed in the course of primary and secondary refined lead production is calculated by multiplying the mass of GHG released with the 100-year global warming potential characterization factor given by the IPCC (Table 5) for the particular gas in units of kg CO_2-equivalent per kg emission. The total carbon footprint, or GHG inventory, is the sum of these calculated impacts.

The carbon footprint data of refined lead should be updated at least in a five-year cycle or whenever a significant change occurs in the production process or any other parameters affecting the emission intensity of refined lead (e.g. significant changes in energy sources due to changes in the proportion of renewable energy or major changes in logistics). A five-year update cycle is in line with requirements formulated by e.g., the European Commission in their Product Environmental Footprint [12]. Due to the increasing share of renewable electricity sources in electricity grid supplies and the decarbonization within companies it is recommended to have shorter update cycles then 5 years.

The following points, as mentioned in the GHG Protocol, will trigger a significant change:

1. Structural changes in refined lead production, including significant process change in operation, technology advancement, raw material, or energy/electricity.
2. Changes in calculation methodology or improvements in the accuracy of emission factors or activity data or inclusion of new types of sources that result in a significant impact on the emissions data.
3. Discovery of significant errors, or cumulative errors that are collectively significant.

The frequency of inventory data collection should be informed by the frequency of significant changes in emissions intensity of the process(es) under study.

7 Modelling Parameters and Assumptions

7.1 Allocation

When a production process delivers co-products with economic value alongside the main product for which GHG emissions are intended to be calculated, the GHG emissions associated with the production processes should be partitioned between the main product or products and their co-products.

The production of refined lead typically yields several other products which have economic value at the factory gate, including:

- antimony, bismuth, blister copper, copper cathode, tin, etc.
- precious metals such as silver and gold
- Other non-metallic co-products such as sulphuric acid, gypsum (calcium sulfate), sodium sulfate, polypropylene

Partitioning of emissions is carried out by means of a multi-output allocation, the method typically applied in industries where a range of different products occur together. Multi-output allocation generally follows the requirements of ISO 14044, section 4.3.4.2, with the allocation rule most suitable for each respective process step applied within that process. To determine which allocation rule to use, ISO proposes a stepwise procedure:

Step 1: Where possible, allocation is to be avoided, either by dividing the unit process into two or more subprocesses; or by expanding the product system (system expansion) to eliminate a co-product from the product system.

Step 2: Where allocation cannot be avoided, the inputs and outputs shall be partitioned between the different products reflecting their underlying physical relationships.

Step 3: Where allocation cannot be avoided and no physical relationships can be established, the inputs and outputs shall be allocated in a way that reflects other relationships between the main products and co-products, such as e.g., economic value, mass, or a combination of economic value and mass.

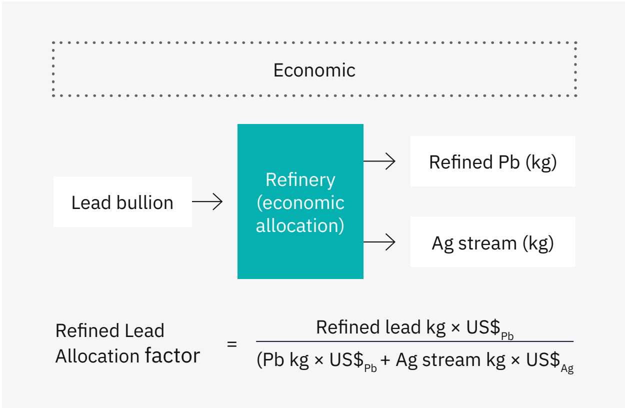


Figure 3: Generic example for economic allocation in lead refinery

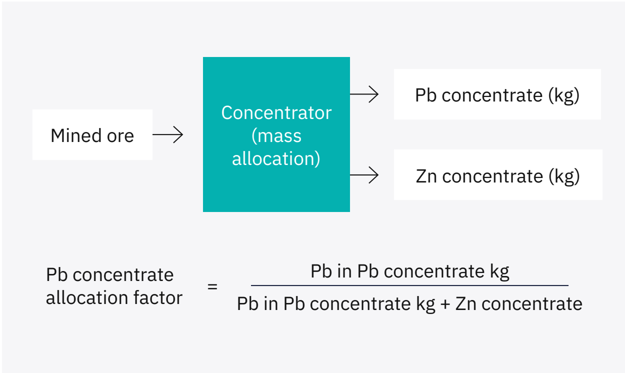


Figure 4: Generic example for mass allocation (metal content) in concentrator

In primary refined lead production, it is difficult to avoid allocation, because the lead and the co-products are typically available together until the refinery stage of the production process. The different metals have different economic values and production volumes (e.g., silver [low production volume, high market value] versus lead [high production volume and lower market value]). Economic allocation can be used in such situation where base metals and precious metal occur together. If economic allocation is used, the prices utilised should be multi-year period averages (e.g. 10-year average) [17] to avoid market-based fluctuation with their sources documented. An example of economic allocation is shown in Figure 3. The ICMM harmonization paper recommends economic allocation if there is a price difference above factor 4 [17]. Where economic or mass allocation is used, the approach should be transparent and include comparative sensitivity analysis.

Where exclusively base metals occur together, a mass or metal content allocation is the widely used methodology to define the environmental profile. Typically, there is not a vast physical and economic difference. This allocation method has been recommended in a multi-metal project coordinated by ICMM [17]. To allocate based on mass, the amount of co-product produced per unit (e.g., ton) of main product is needed. Based on this information, an allocation factor for the main product and for each co-product can be calculated by division (i.e., dividing the amount of main product by the sum of main product and co-products produced). The resulting allocation factor is a fraction or percentage. The calculated allocation factor(s) is (are) used to define how much of the inputs and outputs of the system are allocated to the co-product.

Different co-products can occur during the production of lead. Multi-output allocation generally follows the requirements of ISO 14044, section 4.3.4.2 [3] and Product Life Cycle Accounting and Reporting Standard, section 9 [4]. For primary and secondary lead sub-division, system expansion, mass and economic allocation is used. The allocation method applied for the respective process step must be documented and explained in a transparent way. The most common co-products are shown in Figure 5.

The chosen allocation method for co-products typically occurring in refined lead production is summarized in Table 7 and Table 8.

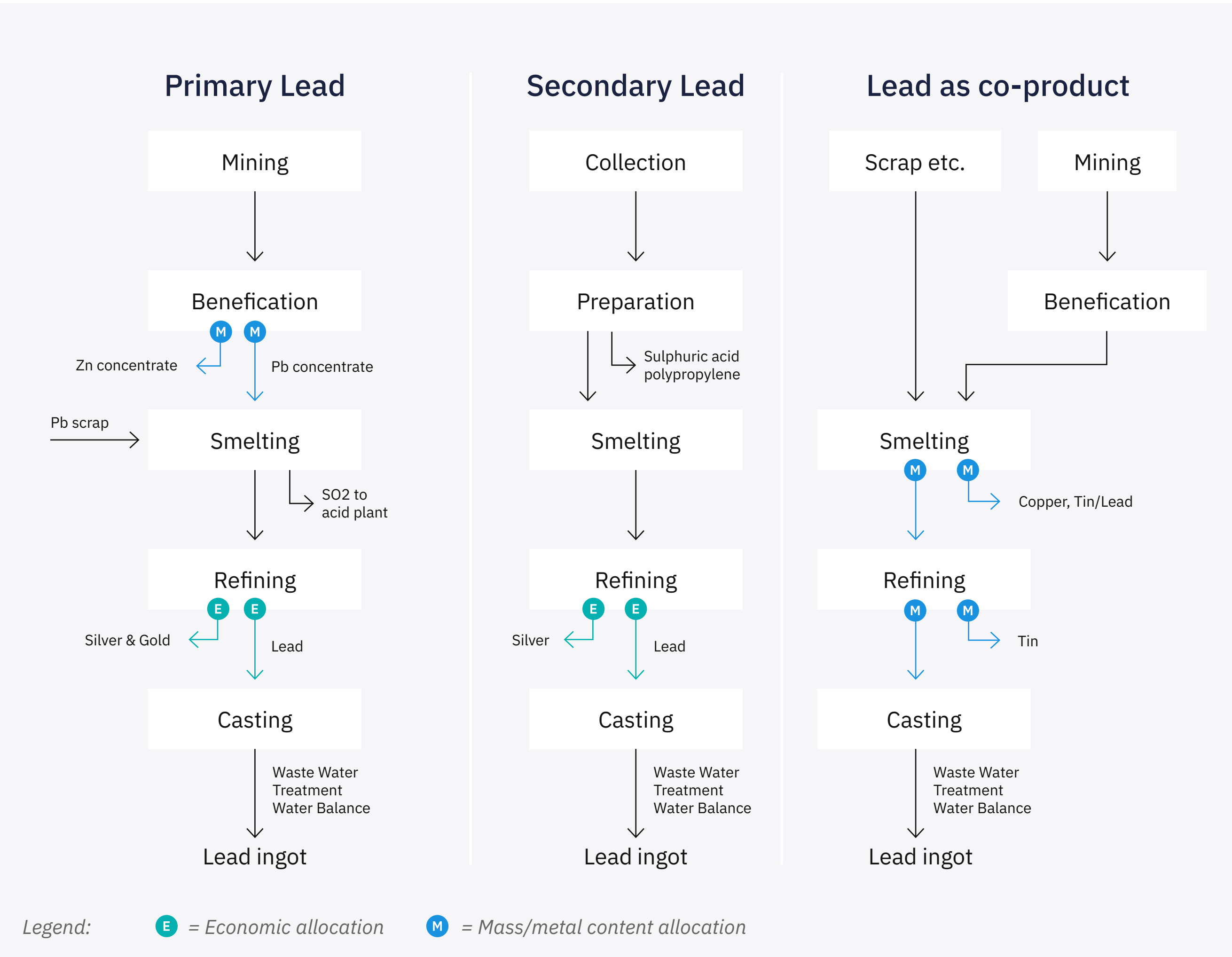


Figure 5: Major co-products in primary and secondary refined lead production

Summary of recommended product and co-product allocation methods primary lead production		
Process step	**Products & co-products**	**Allocation method**
Mining and beneficiation	Zinc, lead, and copper concentrates	metal content allocation to valued co-products
Smelting	Lead bullion, copper, other co-products with metal content to be further treated	metal content allocation to valued co-products and economic allocation in case of precious metals
	Sulphuric acid, slags	Sub-division or system expansion
Refining	Refined lead, silver, antimony, bismuth, tin, etc.	Economic allocation if precious metals are separated from lead; in case only metals are separated then mass allocation if the price difference is below a factor 4 [17]

Table 7: Summary of recommended product and co-product allocation methods primary lead production

Summary of recommended product and co-product allocation methods secondary lead production		
Process step	**Products & co-products**	**Allocation method**
Breaking	Lead, polypropylene, H2SO4	System expansion or subdivision (in case of usable products)
Smelting	Lead bullion, copper, other co-products with metal content to be further treated	metal content allocation to valued co-products and economic allocation in case of precious metals
	Slags, dross	Sub-division or system expansion
Refining	Refined lead, silver, antimony, bismuth, tin, etc.	Economic allocation if precious metals are separated from lead; in case only metals are separated then mass allocation if the price difference is below a factor 4 [17

Table 8: Summary of recommended product and co-product allocation methods secondary lead production

End-of-Life (EoL) allocation generally follows the requirements of ISO 14044, section 4.3.4.3 [3]. As EoL is excluded from the system boundary, this section addresses the treatment of waste generated during the production of refined lead.

Material recycling:
Scrap inputs (there is no burden allocated to the scrap) into the production stage remain open for the purpose of creating the cradle-to-gate inventory. This allows flexibility for practitioners to use whichever recycling allocation method preferred. The metal industry typically favours the avoided burden with net scrap approach when modelling a cradle-to-grave system (also applied in Environmental Product Declaration [13]), where credit is given for scrap generated at EoL less the amount of scrap entering the system during production. Internally recycled materials are looped back as inputs to the production process. Co-products from third parties need to be included if burden is allocated to the co-product or if it is defined as a waste and no burden is allocated. This needs to be documented in a transparent way.

Landfilling (avoided burden approach):
In cases where materials are sent to landfills, they are linked to an inventory that accounts for waste treatment on landfills. This is also valid for H_2SO_4 in case H_2SO_4 is disposed of or neutralized for instance to form gypsum for disposal. Landfill gas capture as well as utilization rates (flaring vs power production) needs to be well documented that this is the case at the respective productions site.

Metallurgical slags can be further used or disposed. The further use of slags can be reflected in considering credits in case of the slag being used e.g., for construction purposes.

7.2 Electricity

Electricity is one of the energy sources in lead production. The emissions related to the production of electricity consumed in the system boundaries of the lead production shall be included in the inventory. GHG emissions of electricity supply can vary significantly, depending on the specific electricity power generation technology applied by a company onsite or the upstream electricity supplier. Electricity shall be included according to the requirements formulated in ISO 14067 [5] and the EU PEF Guidance [8]. The following hierarchical approach shall be used:

a. Supplier-specific electricity product shall be used if, for a country a 100% tracking system is in place, or if available and the set of minimum criteria is met to ensure the contractual instruments are reliable.
b. The supplier-specific total electricity mix shall be used if available and if the set of minimum criteria to ensure the contractual instruments are reliable is met.
c. The “country specific residual grid mix” shall be used where available. Country-specific means the country in which the activity occurs. The residual grid mix prevents double counting with the use of supplier-specific electricity mixes, but these are mainly available in Europe.
d. The average country/region representative grid mix, consumption mix, shall be used.

For the first two scenarios, contractual instruments used for electricity modelling shall meet the criteria as described in Greenhouse Gas Protocol Scope 2 Guidance [18] and ISO 14067 [5].

Country-level GHG emission factors and those for different electricity generation technologies can be found in life cycle databases or in available publications such as the IEA [15]. Further guidance on the modelling of the "country specific residual grid mix, consumption mix" can be found in ISO 14067 [5] and the EU PEF guidance [8].

Electricity generated onsite is considered as scope 1 emission (direct onsite). The emissions related to the generation of electricity onsite are calculated based on the consumed fuels (e.g. diesel) and renewables (e.g. photovoltaic). Further guidance on the modelling of onsite electricity production can be found in ISO 14067 [5] and the EU PEF guidance [8].

It is recommended in case of the first two scenarios to calculate a sensitivity using the average country/region representative grid mix (location-based approach).

7.3 Fuel combustion

The greenhouse gas emissions which are related to the combustion of fuels consumed during the production process shall be calculated by using default emission factors which are published by the Intergovernmental Panel on Climate Change in their 2006 report [15]. If emission factors from other sources are used (e.g., national inventories), they shall be mentioned in a transparent way in the report and the reason given why those EF have been used.

7.4 Secondary Data

Several auxiliary materials are used in lead production processes for which the lead producer might not obtain primary data from its supplier, such as explosives, reductants or any other materials or chemicals used in the production process as well as for the feedstock/ore/raw materials. For those materials, third-party data which commonly can be found in public and / or commercial databases shall be used and documented with geographical, time and technological representativeness. An overview of commercial and public databases can be found on the GHG Protocol website [16].

7.5 Third Party Verification

Transparent communication and interpretation of the results is of critical importance.

GHG emission calculations must always be reported in a transparent way, referring to ISO 14040 and ISO 14044 as a basis. They are to be presented with an overview of the methods and modelling parameters used and on the distribution of emissions from different scopes and credits, as well as a sensitivity analysis. This method also aligns with the requirements for environmental product declarations in the International EPD system [13] containing specific climate declarations based on ISO-14067 [5].

The GHG Protocol Product Life Cycle Accounting and Reporting Standard formulates several requirements when results are presented. The GHG accounting and reporting of a product inventory shall follow the principles of relevance, accuracy, completeness, consistency, and transparency. These principles shall also be applied when communicating GHG emissions from refined lead to third parties.

The ISO-based GHG report shall inform on the cradle-to-gate GHG emissions of 1 kg of refined lead. It shall include as a minimum:

- all relevant parameters chosen as listed in this guide,
- the allocation method applied together with a justification and explanation,
- the electricity mix underlying the calculations,
- the parameters used for fuel combustion,
- a distinction between primary and secondary data used (if relevant),
- a statement of the system boundary applied, identifying any excluded processes and estimating their proportion of total GHG emissions for comparison with the EU Product Environmental Footprint Guidance.

Credits included in the footprint of the functional unit should be disclosed in such a way that the reader can easily calculate the footprint both with and without the inclusion of credits in the footprint.

The report shall indicate the reference year for which the data were collected and the expected validity of the PCF.

The reported data shall be accompanied by a certificate from an independent third party confirming that the GHG data calculations were done according to these guidelines and in conformity with ISO standard.

References

[1] "A Corporate Accounting and Reporting Standard" by The GHG Protocol, revised edition, https://ghgprotocol.org/sites/default/files/standards/ghg-protocol-revised.pdf

[2] ISO 14040: "Environmental management — Life cycle assessment — Principles and framework", 2006, https://www.iso.org/standard/37456.html

[3] ISO 14044: "Environmental management — Life cycle assessment — Requirements and guidelines", 2006, https://www.iso.org/standard/38498.html

[4] ISO 14067: "Greenhouse gases — Carbon footprint of products — Requirements and Guidelines for quantification", 2018, https://www.iso.org/obp/ui/#iso:std:iso:14067:ed-1:v1:en

[5] GHG Protocol "Product Life Cycle Accounting and Reporting Standard", https://ghgprotocol.org/sites/default/files/standards/Product-Life-Cycle-Accounting-Reporting-Standard_041613.pdf

[6] ISO 14025: "Environmental labels and declarations — Type III environmental declarations — Principles and procedures", 2006, https://www.iso.org/standard/38131.html

[7] https://ila-lead.org/lifecycle-assessment/

[8] "Product Environmental Footprint Category 1 Rules Guidance", Version 6,3, 2018, https://ec.europa.eu/environment/eussd/smgp/pdf/PEFCR_guidance_v6.3.pdf

[9] "Overview of Greenhouse Gases", EPA, https://www.epa.gov/ghgemissions/overview-greenhouse-gases#carbon-dioxide

[10] "IPCC Emissions Factor data Base", Greenhouse Gas Protocol, https://ghgprotocol.org/Third-Party-Databases/IPCC-Emissions-Factor-Database

[11] "Scope 1 and Scope 2 Inventory Guidance", EPA, https://www.epa.gov/climateleadership/scope-1-and-scope-2-inventory-guidance

[12] "EU COMMISSION RECOMMENDATION of 9 April 2013 on the use of common methods to measure and communicate the life cycle environmental performance of products and organisations", https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32013H0179

[13] https://www.environdec.com/home

[14] "Emission factors 2021", IEA, https://www.iea.org/data-and-statistics/data-product/emissions-factors-2021

[15] International Panel on Climate Change, 2006 report, https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_2_Ch2_Stationary_Combustion.pdf

[16] "Life Cycle Data Bases", GHG Protocol, https://ghgprotocol.org/life-cycle-databases

[17] A Harmonised Approach to Product Carbon Footprint and Life Cycle Assessment of Non-Ferrous Metals; Prof. Markus Berger on behalf of ICMM

[18] "GHG Protocol Scope 2 Guidance – Executive Summary" by The Greenhouse Gas Protocol https://ghgprotocol.org/sites/default/files/Scope2_ExecSum_Final.pdf

[19] Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Chapter 7; Based on data from Table 7.15 page 1017 of the WG1 contribution to the Intergovernmental Panel on Climate Change's Sixth Assessment Report (AR6) (https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_Chapter07.pdf) and Table 7. SM.7 from pages 7 SM-16 onwards of the respective supplementary material (https://www.ipcc.ch/report/ar6/wg1/downloads/report/IPCC_AR6_WGI_Chapter07_SM.pdf).

[20] The World Lead Factbook 2023; INTERNATIONAL LEAD AND ZINC STUDY GROUP (ILZSG)

[21] https://ghgprotocol.org/sites/default/files/2024-08/Global-Warming-Potential-Values%20%28August%202024%29.pdf

Annex A: Guidance on input streams and allocation

The following list of input streams to the secondary and primary lead production is not finalised because some lead producers might have to add their specific input streams and define if it is waste or burden free. But this needs to be documented with the calculation method in a transparent way.

	transport	waste stream (burden free)	burden free	co-product
EoL scrap (batteries, wheel balance, pipes, sol-der, etc.)	x	x		
Pb containing scrap	x	x		
leach residue incl. Pb and Ag (Zn smelter)	x			x
Slags (purchased)	x			x
Slags internal recycled			x	
lead dross (purchased)	x			x
lead dross (internal recycled)			x	
Filter dust	x	x		
Bullion from other locations	x			x

International Lead Association

International Lead Association,
120 New Cavendish Street,
London, W1W 6XX

Tel: +44 (0)20 7833 8090
Email: enq@ila-lead.org