September 2021

Carbon footprint of Boliden Main Metals

Copper, Nickel matte, Zinc, Lead

Commissioned and performed by:

NEW BOLIDEN

Supported by:

sphera™

Owner of this report:
Boliden Mineral AB

Title:
This executive summary is an extract of the full verified report:
Carbon Footprint of Boliden Main Metals, 2021

Report version:
v.1.4

Report date:
08-September-2021

Document prepared by:
Project Manager
Sara Olsson, Boliden Mineral AB
sara.olsson@boliden.com

Project Support and Technical Review
Arziv Babikian, Boliden Mineral AB
arziv.babikian@boliden.com

Technical quality assurance and support:
Principle Consultant, Director Consulting,
Dr. Johannes Gediga, Sphera Solutions GmBH

Third party assurance:
Sustainability Project Manager
Kim Allbury, Intertek Certification GmbH

Sustainability Project Manager
Dr. Matthew Fishwick, formally with **Intertek Certification GmbH**

Abstract

Boliden wants to set a standard for the mining and metals industry to pioneer for low-carbon metals. In this study carbon footprints for copper, zinc, nickel matte and lead, has been produced. The mass balance principle has been used for the final carbon footprints, which allows Boliden's metals to be presented distributed per raw material source from: secondary raw materials, primary raw material from Boliden's own mines and primary raw material from external mines.

For this study, a combination of economic value and mass allocation have been used. A conservative approach has been taken in the majority of the cases, meaning all categories in the Greenhouse Gas Protocol with a relevant impact on the final carbon footprint from cradle-to-Boliden gate has been included, and credits from energy and by-products have been excluded. The study concludes that the majority of the greenhouse gas emissions originates from supply of raw materials. The results also show that Boliden's carbon footprints is well positioned compared to global averages. Intertek was commissioned by Boliden to perform an independent assurance to the Greenhouse Gas Protocol – Product Life Cycle Accounting and Reporting Standard, and a critical review to the principles stipulated in ISO 14064-3.

[1] https://ghgprotocol.org/

About Boliden

Boliden is a metals company with a focus on sustainable development. Our roots are Nordic, our market global. Our core competence lies within the fields of exploration, mining, smelting and metal recycling. Boliden has around 6,000 employees and an annual turnover of SEK 50 billion. The share is listed in the Large Cap segment on NASDAQ OMX Stockholm.

www.boliden.com

NEW BOLIDEN

Contents

NEW BOLIDEN

Executive Summary

1.1. INTRODUCTION

There is a growing global demand for metals to contribute toward overcoming societal challenges, including climate change. The greater use of renewable energy and the electrification of society needed to combat climate change require more of Boliden metals, such as nickel, copper, lead and zinc.

As a sustainability leader in the metals and mining sector, Boliden has a role to play in significantly reducing its climate impact – and in driving positive change throughout the industry. Boliden wants to set an example for the mining and metals industry to produce low-carbon metals.

A life cycle assessment enables the possibility to calculate the studied metals CO2 footprint and to identify significant emitters.

The goal of this study is to produce a Carbon Footprint per ton of metal produced, from cradle-to–Boliden-gate, where the functional units are:

(i) **1 ton of Copper Cathodes (Cu 99,999 %), from Harjavalta & Rönnskär**
(ii) **1 ton of Nickel Matte, from Harjavalta**
(iii) **1 ton of Special High Grade Zinc (Zn 99,995 %), from Odda and Kokkola.**
(iv) **1 ton of Secondary Lead, from Bergsöe**

The Carbon Footprint for each metal and production site, is distributed per raw material source from secondary raw materials, primary raw material from Boliden's own mines and primary raw material from external mines. Secondary raw material is defined as any raw material originating from end-of-life waste streams or waste streams from other metal processing industries.

1.2. GENERAL INFORMATION AND SCOPE

The study describes the following production sites of Boliden in:

Rönnskär Copper (Sweden)	Harjavalta Copper and Nickel (Finland)	Kokkola Zinc (Finland)	Odda Zinc (Norway)	Bergsöe Lead (Sweden)

The results of the study are based on 100 % of the produced copper cathodes in Harjavalta and Rönnskär during the reference year 2018, 100 % of the special high grade zinc produced in Odda and Kokkola during the reference year 2018, 100 % of the nickel matte produced in Harjavalta during the reference year 2017 and 100% of the lead produced in Bergsöe during the reference year 2019. These years have been selected as they represent the most stable and representative years for production of the respective products.

Generally, a functional unit should reflect the function provided by the product being assessed. Commodities, which are the functional units in this study, have the same characteristics and function downstream, independent of which path of further refining, production or usage processes they take. Changes in data sources in subsequent inventories therefore have a minor impact on the results of this study.

The data in this study have been collected in connection and collaboration with LCA studies conducted by the metal associations International Zinc Association (IZA) 2019-2020, International Copper Association (ICA) 2020-ongoing, Nickel Institute (NI) 2020. Additional data has been collected and separate quality assurance has been carried out. Comparative assertions of the results from this study to results from other LCA models or greenhouse gas (GHG) intensity's should only be made to LCA studies conducted within the metal associations' scope. Attention could be given to results of the ICA study as it has not yet been completed. The main limitations posed by this study for comparative assertions with the association studies are related to:

1. Changes in metal prices, which has been used for economic value allocation. The impact of the processes and related products and co-products to economic value allocation is limited due to balancing mechanisms in the market, and has a minor impact on final results.

2. Differences in use of data sets. For this study, the most recent available data sets in GaBi[2] have been used to assess the Global Warming Potential (GWP) for each commodity. These may not be the same for the associations' models. Such an issue has been identified for explo sives.

1.2. GENERAL INFORMATION AND SCOPE

The analysed GHG emissions covered in the inventory for this study are CO2, CH4, N2O, and SF6. PFC & HFC has been excluded as they are assumed to be insignificant [1]. Detailed contribution of the different GHG emissions within mining and smelting activities can be seen in Figure 1 and Figure 2. CO2 is the major source of GHG emissions. CO2, N2O and CH4 represent all GHG emissions related to Boliden Mines and Smelters GWP. SF6 and NF3 have none or below cut-off criteria impact (<1 %) and are therefore not visible in the pie charts.

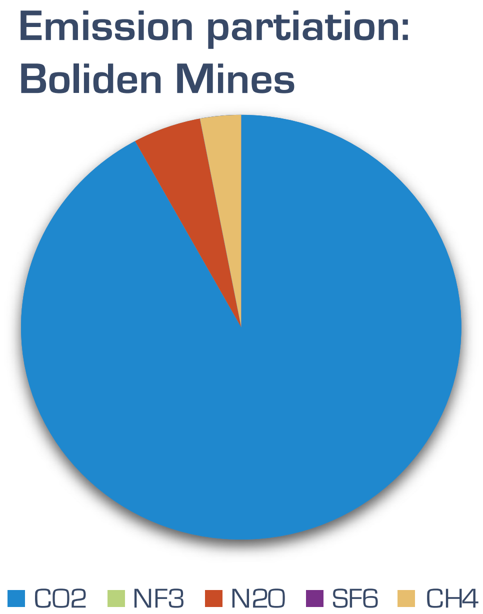

Figure 1. Distribution of GHG emissions within Boliden mining activities

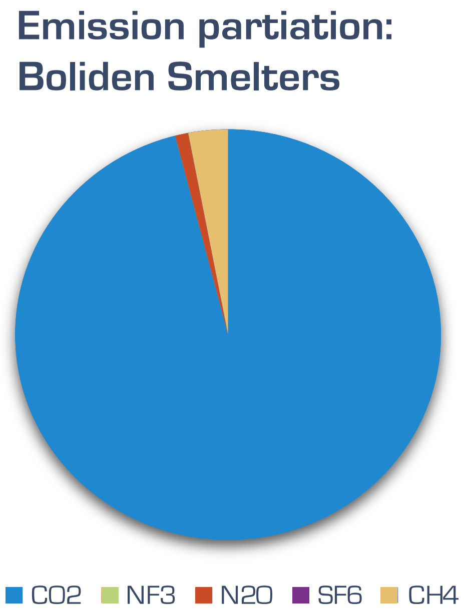

Figure 2. Distribution of GHG emissions within Boliden smelters activities

[2] GaBi is the Life Cycle Assessment (LCA) modelling and reporting software and provider of databases used in this study

1.3. BOUNDARY SETTING

The production of copper, zinc, nickel matte, and lead from cradle-to-Boliden-gate includes mining and milling, transportation, smelting and refining. Production of nickel matte does not include refining.

GHG emissions from mining and milling includes all three scopes, depending if the mine is owned by Boliden or by an external supplier. Smelting and refining includes scope 1 and 2, while transportation and auxiliary bulk goods & chemicals used in the process of producing metals are scope 3. The life cycle stages of the production of the product in this study is seen in Figure 3.

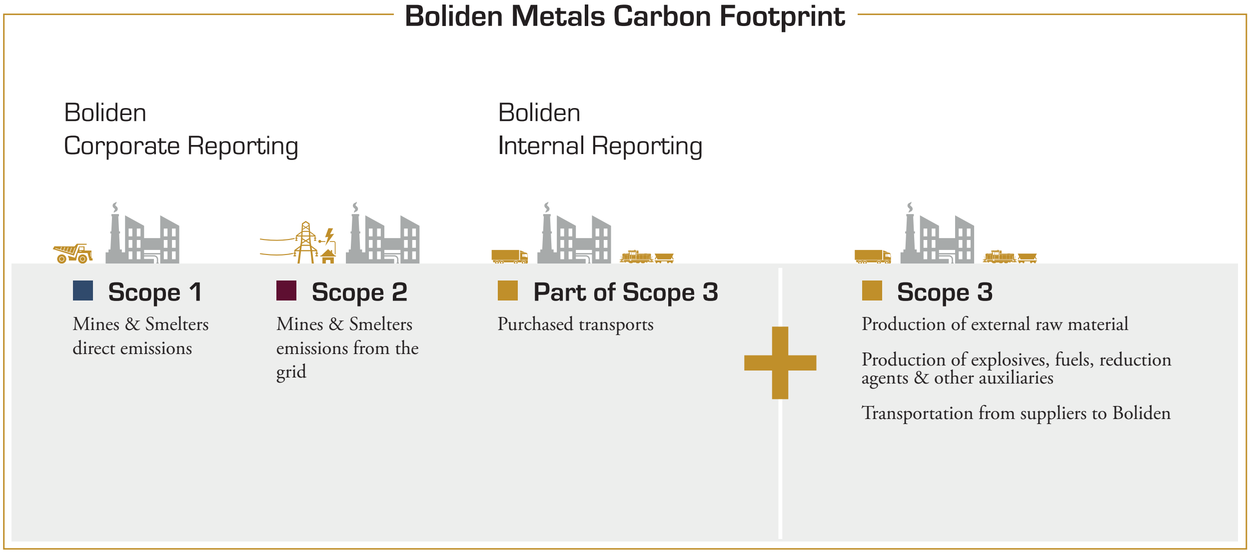

Figure 3. The product life cycle emissions included in this study.

Since this is a cradle-to-Boliden-gate inventory study, any downstream GHG emissions are excluded. A schematic overview of the attributable processes included and excluded in the system boundary can be seen in Figure 4.

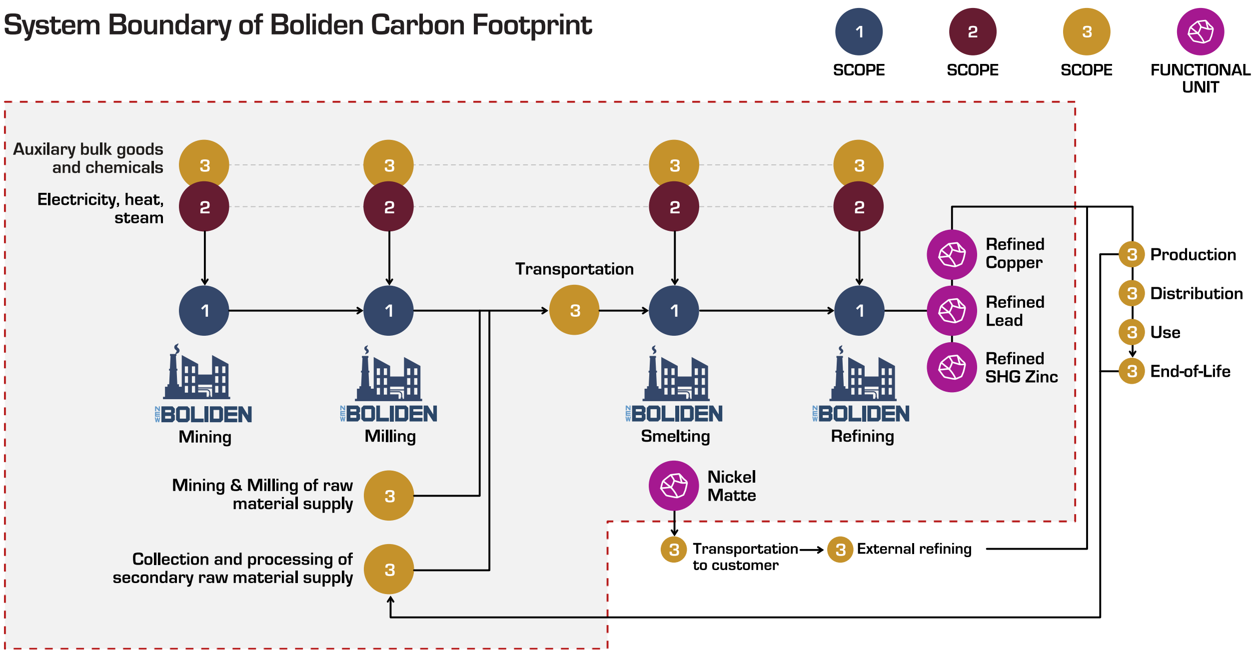

Figure 4. Process map of the attributable processes included in the system boundary.

1.4. ALLOCATION

Allocation methods

In this study a combination of economic value and mass allocation is used. This approach is consistent with the recommendations by the metals and minerals industry, and set out in a peer reviewed article by Santero & Hendry, 2016 [2].

Economic allocation is used where base metals and precious metals occur together because they tend to have vastly different economic values and production volumes (e.g. platinum [low production volume, high market value] versus copper [high production volume and lower market value]). Therefore, a mass allocation would not represent the value of the products, and the rationale for producing the different metals. Where only base metals occur together, a mass allocation is used to define the environmental profile since typically there is not a vast physical and economical difference. This allocation method was considered the best approach for the system under study as opposed to, for example, system expansion allocation which considers the existence of an alternative route for the production of the by-product(s).

Multi-output allocation is used in the study for waste processes including energy recovery, landfill and wastewater treatment. When allocation becomes necessary during the data collection phase, the allocation rule most suitable for the respective process step is applied.

The principle of system expansion is based on the fact that the by-product saves or avoids another product with equivalent function. It requires that this inventory (of the by-product) will be included into the system boundaries and inverted (i.e. subtracted from the analysed system). This results in an environmental credit for the system analysed according to the amount of by-product produced. System expansion is not used for the metal by-products in this study.

By-products

The production of copper, zinc and nickel matte typically yields several other metal products due to these metals being a component of the respective ore bodies. Base metals are nonferrous metals that are neither precious nor noble metals. Platinum group metals (PGMs) and other precious metals which belong to the group of precious metals, may also occur in the ore bodies and are produced as a by-product.
Certain non-metal by-products are also produced, such as sulphuric acid, as well as some other by-product. Sulphuric acid is produced from the recovery of oxidised sulphur of sulphide ores. Sulphuric acid derived from the sulphidic ores is either used internally or is sold to other industries as a by-product. In both cases, this by-product receives an environmental credit by means of system expansion, as it replaces the environmental burden to produce an equivalent quantity of sulphuric acid elsewhere, or from virgin materials. The credits received in this study are presented separately and not included in the total footprint of the metals.

1.4. ALLOCATION

Chain-of-custody (to Boliden gate)

In order to separate GWP for the products produced solely from Boliden owned mines, secondary sources and other external mines and smelters a mass balance principle has been applied. The fundamentals of the mass balance principle is that the volume of claimed material that enters the process is equivalent to the volume of claimed material leaving (the process) [3]. The principle is illustrated in Figure 5. In the Boliden smelting & refining unit process steps, a mass based allocation has been applied to identify emissions relevant to primary and secondary material.

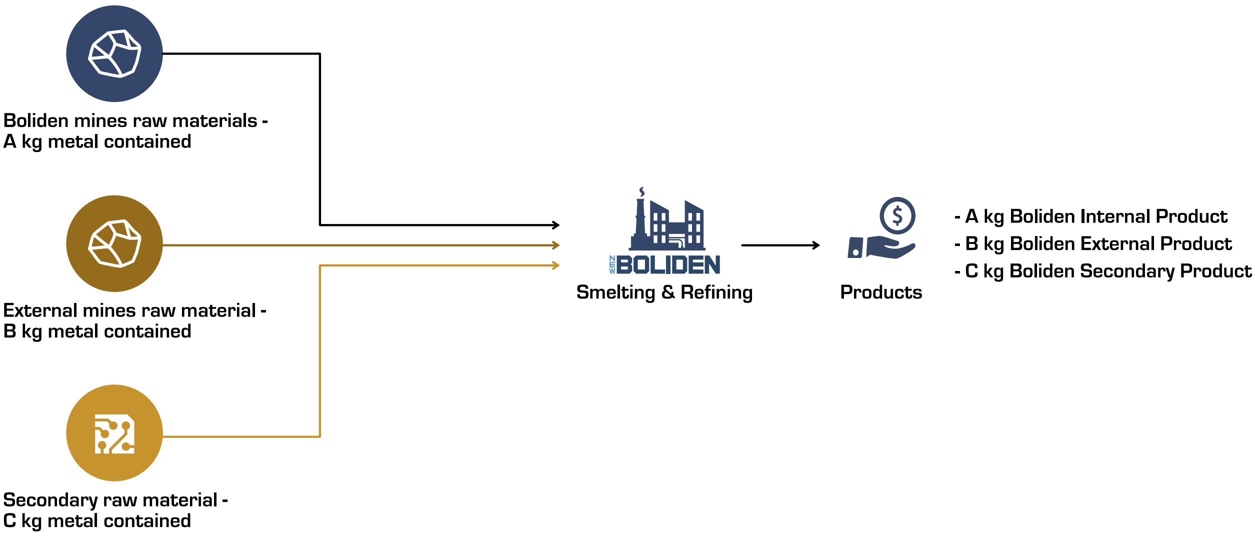

Figure 5. Illustration of the Mass Balance Principle applied for the GWP in this study.

1.5. DATA COLLECTION & QUALITY

A process that contributes a substantial amount of GHG emissions relative to the total life cycle emissions is significant. Based on that definition, the most significant sources has been chosen as any source contributing to >10 % of the functional units GWP.

The significant processes in this study varies for the functional units and production sites due to factors such as national electricity grid mix, raw material sources and carbon content of raw materials.

1.5. DATA COLLECTION & QUALITY

The significant processes are:

- **Copper cathodes**: Mining scope 1 and 3 (fuel combustion, explosives and external concentrates), transportation of raw materials and smelting scope 1 (smelting of electronic scrap).
- **Nickel Matte**: Mining scope 1, 2 & 3 (fuel combustion, electricity and external concentrate), raw material transport and smelting scope 1 and 3 (reduction process).
- **Special high grade zinc**: Mining scope 1 & 3 (fuel combustion and external concentrate), raw material transportation and & refining scope 2 (electricity use in electrolysis) and secondary zinc processing.
- **Secondary Lead**: Smelting scope 1 (shaft furnace reduction process)

The significant processes data has been assessed based on the scores *Poor, Fair, Good* or *Very Good* for the GHG Protocol Quality Indicators [4]:

✓ **Completeness**: Data has been collected for all significant processes. Seasonal variations are balanced out by annual production data for these processes in the data collection. The completeness is considered *very good* for all significant processes.

✓ **Reliability:** For most significant processes except raw material transportation, data has been collected from verified and measured data. For all gate-to-gate data, which is the data collected for the Boliden production sites, the data has been collected from verified sources. In addition, all data and processes in the models has been reviewed by senior engineers and environmental specialists at each site. For these the reliability is considered *very good*. Raw material transportation are based on verified but partly assumed data, of which the reliability is considered *good*.

✓ **Temporal representativeness:** The primary data for nickel matte were collected for the year 2017, all primary data for copper and zinc were collected for the year of 2018, and all primary data for Lead were collected for the year of 2019. These years were chosen as they were the most representative for a stable production at the related sites. All secondary data come from the GaBi 2019 databases and are representative of the years 2016-2021. The temporal representativeness for the primary data is considered very good and good for the background data.

1.5. DATA COLLECTION, QUALITY

- ✓ **Geographical representativeness:** All primary and secondary data were collected specific to the countries or regions under study. Where country-specific or region-specific data were unavailable, proxy data were used. Geographical representativeness is considered to be *very good* for the primary data collected, and *good* for the global average data.

- ✓ **Technological representativeness:** All primary and secondary data were modelled to be specific to the technologies or technology mixes under study. Where technology-specific data were unavailable, proxy data were used. Technological representativeness is considered to be *very good*.

1.6. UNCERTAINTY

For this study, Boliden have partly used a conservative approach, which is the preferred approach within LCA. The background to using a conservative approach is a number of uncertainties, and where not used with the aim to be transparent and accurate to which commodity the GHG emissions belong.

The uncertainties, and linked approach are;

- The system boundary includes the sulphuric acid plants and its production of sulphuric acid as by-product from the main processes. Using system expansion, a credit is given for each ton of sulphuric acid produced. The assessment made, concluded that there is a risk for double-counting to include this figure in the total footprint of the metals. This conclusion was based on a demand for GWP figures on sulphuric acid products. Decision was made in the study to report credits from production of sulphuric acid separately. Therefore, the credits given from such production will be presented separately, and not granted in the total footprint figures.

- For the same reason as above, the GHG emissions impact from the sulphuric acid plants in the copper and nickel matte production sites, has been presented separately and not added to the total footprint. Separation of emissions from sulphuric acid plant was not possible for the zinc studies, as they were not separately modelled.

- Additionally, there is an insignificant difference on the impact of the sulphuric acid plant on the emissions for the Harjavalta nickel matte production line compared to the Harjavalta copper production line, while there is a vast difference on the sulphuric acid credits. This provides a clear example of the uncertainties in credits achieved for sulphuric acid production as a by-product and background data, which adds certainty to the decision to exclude these credits from the total footprint.

1.6. UNCERTAINTY

- For economic value allocation, a 10 year average of metal prices is used to minimize the impact on price fluctuations to the allocated CO2 emissions. Boliden has decided to apply the economic value allocation to the specific process that separates the main metals from the precious metals and the E-kaldo, as this process is economically carried by both copper and precious metals. However, impact from fluctuations of metal prices may add uncertainty to the final result, especially for secondary copper. Secondary copper raw materials includes valuable levels of precious metals. Using economic allocation where secondary copper raw materials enter may impact result to fluctuate 5-15 % depending on metal prices, despite using 10 year averages. It is expected that such variations would be limited due to balancing market mechanisms.

- Any other uncertainty of data, depends on the background data. For this reason, the latest available and verified GaBi datasets has been used for auxiliary bulk goods, chemicals and fuels [5]. Verified scope 1 and 2 GHG emissions from external mine supply, provided by the supplier has been used. The scope 3 data has been assumed to be negligible in comparison to scope 1 & 2 data. For suppliers where data was not possible to receive, data from the latest available and verified LCA studies conducted by the metal associations [6], [7], [8] has been used. This variance of different datasets adds to uncertainty in the secondary data. Recognised under Chapter 1.2: GWP data for explosives can vary significantly for different sources.

1.7. RESULTS

For the GWP factor, in GaBi the latest available IPCC AR5 GWP100, excl. biogenic carbon has been used. Biogenic carbon considers GHG emissions absorbed by plants over the calculated time period, which consequently has been excluded in this study. The GWP for each metal in this study and the different GHG scopes is illustrated in Figure 6 to Figure 9 below.

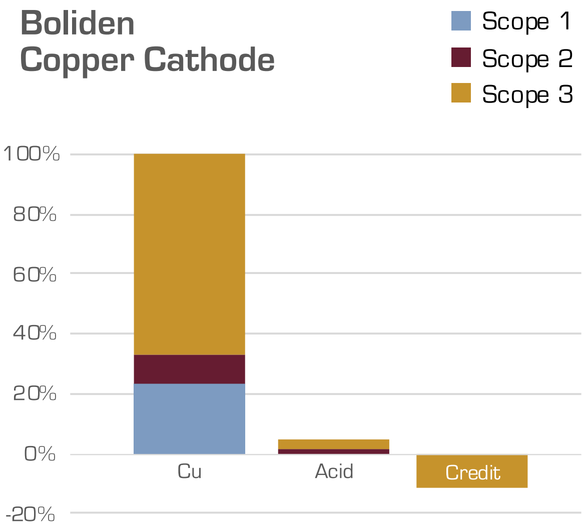

Figure 6: Contribution of scope 1, scope 2 and scope 3 to the GWP [kg CO2eq] for 1 ton Boliden copper cathode.

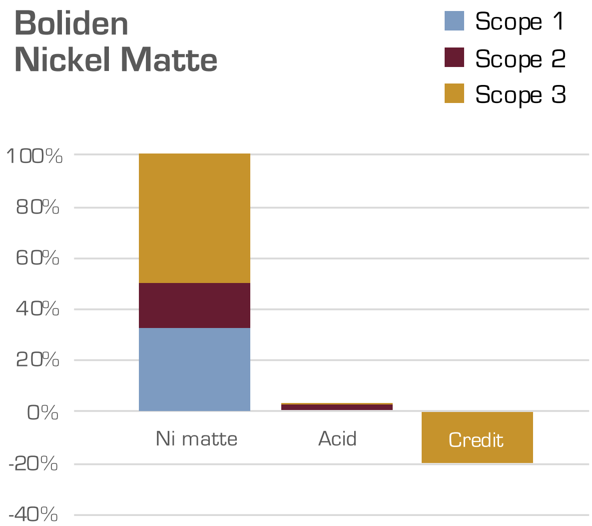

Figure 7: Contribution of scope 1, scope 2 and scope 3 to the GWP [kg CO2eq] for 1 ton Boliden nickel matte.

Acid means the impact from the acid plants, and credits includes all credits. Acid and credits are separated from metal producing processes and is presented as total percentage of GHG emissions related to copper and nickel matte production.

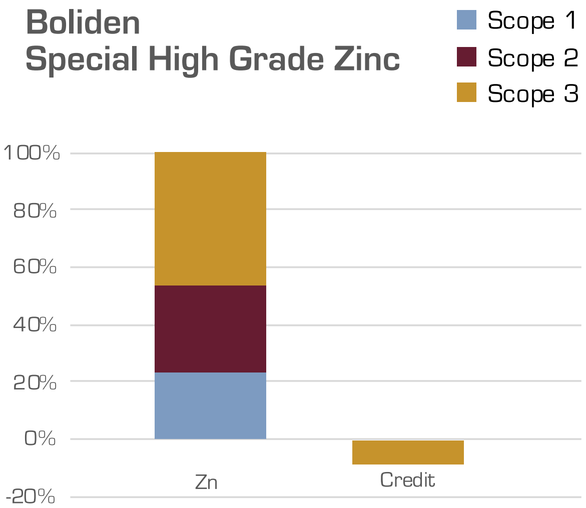

Figure 8: Contribution of scope 1, scope 2 and scope 3 to the GWP [kg CO2eq] for 1 ton Boliden special high grade zinc.

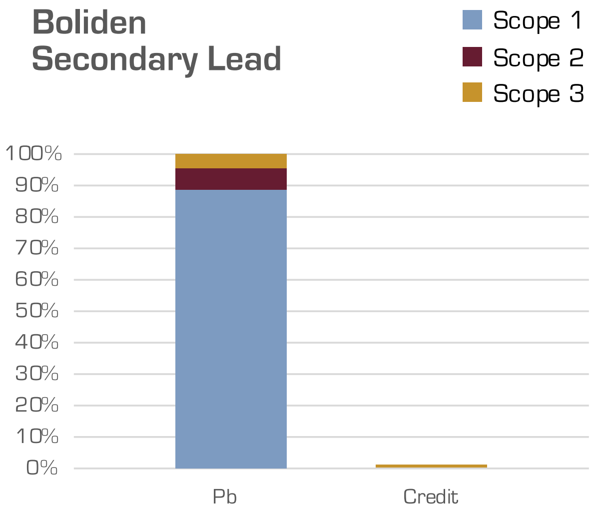

Figure 9: Contribution of scope 1, scope 2 and scope 3 to the GWP [kg CO2eq] for 1 ton Boliden secondary lead.

Credits includes all credits. Acid and credits are separated from zinc producing processes and absent from lead producing process. Credits are presented as total percentage of GHG emissions related to zinc and lead production.

1.7. RESULTS

Detailed results from the study is shown in Table 1. Table 2 and Table 3, discloses the impact of sulphuric acid production as a by-product of the functional units, and the total amount of GHG emissions and energy saved due to production of sulphuric acid, heat and steam as by-products to relation to the functional units.

ACTUAL FOOTPRINT – CRADLE TO GATE	COPPER RÖNNSKÄR	COPPER HARJAVALTA	NICKEL MATTE HARJAVALTA	ZINC KOKKOLA	ZINC ODDA	LEAD BERGSÖE
Unit	*[Kg CO2eq/ton Cu]*	*[Kg CO2eq/ton Cu]*	*[Kg CO2eq/ton Ni Matte]*	*[Kg CO2eq/ton Zn]*	*[Kg CO2eq/ton Zn]*	*[Kg CO2eq/ton Pb]*
Aitik	**1450**	**1700**	**N/A**	**N/A**	**N/A**	**N/A**
Kevitsa	**4600**	**4750**	**3750**	**N/A**	**N/A**	**N/A**
Garpenberg	**650**	**N/A**	**N/A**	**1550**	**700**	**N/A**
Tara	**N/A**	**N/A**	**N/A**	**1850**	**1050**	**N/A**
Secondary raw material	**1350**	**400**	**N/A**	**2850**	**4250**	**1000**
External raw material	**3200**	**4200**	**3450**	**2200**	**1600**	**N/A**

Table 1. Actual footprint of the functional units distributed by Boliden internal raw material source, secondary raw material source and External raw material source.

SYSTEM EXPANSION	COPPER RÖNNSKÄR	COPPER HARJAVALTA	NICKEL MATTE HARJAVALTA	ZINC KOKKOLA	ZINC ODDA	LEAD BERGSÖE
Unit	*[Kg CO2eq/ton Cu]*	*[Kg CO2eq/ton Cu]*	*[Kg CO2eq/ton Ni Matte]*	*[Kg CO2eq/ton Zn]*	*[Kg CO2eq/ton Zn]*	*[Kg CO2eq/ton Pb]*
Impact Sulphuric Acid Plant (Cradle to Gate)	**150**	**100**	**100**	**N/A**	**N/A**	**N/A**
Credit Sulphuric Acid Plant (Cradle to Gate)	**-450**	**-50**	**-700**	**-130**	**-90**	**N/A**
Credit Energy Production (primary metal) (System expansion)	**-4**	**-8**	**-7**	**-120**	**0**	**N/A**
Credit Energy Production (secondary metal) (System expansion)	**-7**	**N/A**	**N/A**	**N/A**	**N/A**	**-10**

Table 2. Impact and credits from production of sulphuric acid and energy as a by-product from the production of the functional units.

1.7. RESULTS

In addition to the GWP results, in Table 3, the total amount of energy [MJ] per ton produced of the functional unit is presented. The reason for including this, is to provide additional transparency. The credits achieved for sold energy[3] as a co-product in GWP provides little information on the total amount of energy sold, since the credit is dependent on local energy mix sources, and based on the total energy sold.

SYSTEM EXPANSION	COPPER RÖNNSKÄR	COPPER HARJAVALTA	NICKEL MATTE HARJAVALTA	ZINC KOKKOLA	ZINC ODDA	LEAD BERGSÖE
Unit	*[MJ/ton Cu]*	*[MJ/ton Cu]*	*[MJ/ton Ni Matte]*	*[MJ/ton Zn]*	*[MJ/ton Zn]*	*[MJ/ton Pb]*
Credit Energy Production (primary metal) (System expansion)	**470**	**4650**	**3870**	**1630**	**0**	**N/A**
Credit Energy Production (Secondary metal) (System expansion)	**830**	**N/A**	**N/A**	**N/A**	**N/A**	**2120**

Table 3. Total amount of energy [MJ] the GWP credit from production of heat & steam as a by-product is based upon from the production of the functional units.

[3] Sold heat, steam and electricity

1.8. CONCLUSIONS

This chapter summarizes the main contributors to the GHG emission for various Boliden product footprints. The overall results show that Boliden's carbon footprints are well positioned to the global averages [9].

Copper

The main contributor to the copper footprint originates from scope 3 emissions. The most significant sources of scope 3 emissions are GHG emissions of external mine supply. The distribution of the GWP for each site varies dependent on the set-up of the value stream and country of origin for upstream activities. Furthermore, production of explosives used at Boliden mine sites has a significant impact on the scope 3 emissions.

Scope 1 emissions represent a third of the total emissions related to copper cathodes. Here, fuel combustion from trucks transporting ore at Boliden mines sites and the carbon contained in secondary sources, have the most significant impact. For the value chain of recycled copper, it is the plastics contained in the electronic scrap that is the main contributor to these emissions. The plastics are used as fuels in the Boliden process to melt the metals, which generates GHG emissions when combusted.

The scope 2 emissions plays a less significant role on to the total GHG emissions of Boliden copper, which may be explained by a relatively low use of energy from electricity and a favorable electricity grid mix in Sweden and Finland [10].

Nickel matte

The main contributor to the nickel matte footprint originates from scope 3 emissions. The most significant source of scope 3 emissions are GHG emission from external mine supply. Production of explosives and coke used at Boliden sites also have a significant impact on the scope 3 emissions.
A third of the total emissions is explained by scope 1 emissions, which derives mainly from fuel combustion from trucks transporting ore at Boliden mine sites and the reduction process in the nickel smelter.

The scope 2 emissions are mainly originating from the mine site.

1.8. CONCLUSIONS

Zinc

The main contributor to the zinc footprint originates from scope 3 emissions. The most significant source of scope 3 emissions are GHG emission from external raw material supply; zinc concentrates and Waelz oxides.

Scope 2 emissions is the second largest contributor to the total footprint, which is explained by a high consumption of electricity. More specifically, in the electrolysis, large amounts of electricity is used for the zinc ions to form into zinc anodes. In general, for zinc producers operating, it is the emissions from refining that is the main contributor of the GWP for zinc [7]. This is also the case for Boliden Zinc. The calculation of emissions to the total GWP contribution is dependent on the electricity grid mix and different country emission factors. Norwegian electricity grid mix has an electricity emission factor close to zero, Finland's is about 10 times higher. Both emissions factors are, world widely compared, considerably low. This explains why the scope 2 emissions represents a relatively small amount for the zinc produced at Boliden zinc smelters [10].

The scope 1 emissions is the lowest contributor to the total footprint. The main contributor to the scope 1 GHG emissions originates from the production zinc klinker. Zinc klinker is produced from the processing of secondary raw materials, such as dust from other metal processing plants. This material requires a reduction process using coal, which explains why the total footprint for secondary zinc is significantly larger compared to the footprint from Boliden owned mines.

Lead

For the secondary lead from Bergsöe, the smelting & refining emissions contributes to almost the full footprint. The background to this, is the use of carbon containing reduction agents in the process, and the plastics that remain from the batteries when entering the furnace. This conclusion is similar to the one made by the Lead Industry Life Cycle Analysis [11].

1.9. ASSURANCE

Intertek[4] was commissioned to provide an independent third-party limited assurance on the carbon footprint (greenhouse gas emissions) for Boliden's main metals; copper cathodes, nickel matte, special high grade zinc and secondary lead. The assurance was conducted against the Greenhouse Gas Protocol – Product Life Cycle Accounting and Reporting Standard. Additionally, a critical review assurance exercise was conducted to the ISO 14064-3 Standard (Greenhouse Gases – Part 3: Specification with Guidance for the Validation and Verification of Greenhouse Gas Assertions).

The full assurance statement, including description of the assurance process, assurance opinion, and statement of independence, integrity and competence, can be found attached to this document.

[4] https://www.intertek.com/

References

[1] IEA Bioenergy, "Using a Life Cycle Assessment Approach to Estimate the Net Greenhouse gas Emissions of Bioenergy," 2011.

[2] N. Santero and J. Hendry, "Harmonization of LCA methodologies for the metal and mining industry," International Journal Life Cycle Assess, 2015.

[3] Svemin, "Traceability of Sustainable Metals - a blockchain based solution," 2019.

[4] GHG Protocol, "Product Life Cycle Accounting and Reporting Standard: Table [8.2]".

[5] Sphera, "GaBi Software," Sphera, 2020. [Online]. Available: http://www.gabi-software.com/support/gabi/gabi-database-2020-lci-documentation/. [Accessed 2020].

[6] PE International, "Life Cycle Assessment of Primary Copper Cathode (global study) – Final," International Copper Assoication, 2012.

[7] PE International, "Primary Zinc Life Cycle Assessment," International Zinc Assocation, 2014.

[8] Sphera, "Life Cycle Assessment of Nickel Products," Nickel Institute, 2020.

[9] Boliden Mineral AB, "Carbon Footprint of Boliden Main Metals," 2020.

[10] International Energy Association (IEA), "Online Data Services: Emission factors," 2019.

[11] J. Gediga, S. P. Binks and A. J. Davidson, "Lead industry life cycle studies: environmental impact and lifecycle assessment of lead battery and architectural sheet production," International Journal Life Cycle Assessment, 2015.

GREENHOUSE GAS PROTOCOL – CRITICAL REVIEW STATEMENT – LIMITED ASSURANCE

Intertek Certification GmbH and Intertek Semko AB (hereinafter referred to as 'Intertek') represented in this project by the sustainability team, was commissioned by Boliden Mineral AB to provide independent third-party limited assurance on the carbon footprint (greenhouse gas emissions) for four main metals that they produce. The reporting protocol against which assurance was conducted to is the Greenhouse Gas Protocol – Product Life Cycle Accounting and Reporting Standard.

The critical review assurance exercise was performed against the general principles of ISO 14064-3 Standard (Greenhouse Gases – Part 3: Specification with Guidance for the Validation and Verification of Greenhouse Gas Assertions).

Since the issuance of the critical review statement in February 2021, Boliden have elected provide further granularity and transparency for stakeholders through disclosing cradle-to-gate footprints for their main metals distinguished by source of raw material, rather than for a specific feedmix (as previously disclosed). This information will enable stakeholders to their own calculate cradle-to gate-footprints for specific feedmixes.

This is, therefore, a second version of our limited assurance statement based on our critical review and it supersedes the original statement dated February 2021.

Description of the studied product

The following Boliden metals were included within the scope of this work:

- Copper Cathodes (Cu 99,999%), from Harjavalta & Rönnskär – reference year 2018
- Nickel matte, from Harjavalta – reference year 2017
- Special High Grade Zinc (Zn 99,995%), from Odda and Kokkola – reference year 2018
- Secondary Lead, from Bergsöe – reference year 2019

The carbon footprint for each metal and production site is distributed per raw material source from secondary raw materials, primary raw material from Boliden's own mines and primary raw material from external mines. Secondary raw material is defined as any raw material originating from end-of-life waste streams or waste streams from other metal processing industries.

Roles and Responsibilities

The calculation and determination of the carbon footprints for the Boliden four main metals are the sole responsibility of Boliden AB. Intertek's responsibility is to express an independent limited assurance opinion as to whether the carbon footprints calculated for Boliden metals have been prepared in accordance with the Product Standard.

Company Assertion

The cradle-to-gate carbon footprint associated with each of the studied products are detailed below.

Table 1: Carbon footprint of Boliden Main Metals (disclosed by source of raw material)

Cradle-to-Gate	Copper Rönnskär	Copper Harjavalta	Ni Harjavalta	Zinc Kokkola	Zinc Odda	Lead Bergsöe
Unit	[Kg CO2eq/ton Cu]	[Kg CO2eq/ton Cu]	[Kg CO2eq/ton Ni Matte]	[Kg CO2eq/ton Zn]	[Kg CO2eq/ton Zn]	[Kg CO2eq/ton Pb]
Aitik	1450	1700	N/A	N/A	N/A	N/A
Kevitsa	4600	4750	3750	N/A	N/A	N/A
Garpenberg	650	N/A	N/A	1550	700	N/A
Tara	N/A	N/A	N/A	1850	1050	N/A
Secondary	1350	400	N/A	2850	4250	1000
External	3200	4200	3450	2200	1600	N/A

Description of Assurance Process and Criteria

Intertek's critical review process was carried out to ensure that:

- Methods used to carry out the product inventory are consistent with the Product Standard
- Methods used to carry out the product inventory are scientifically and technically valid
- Data used are appropriate and reasonable for public reporting
- The inventory report and any conclusions based on the results are appropriate for GHG-only inventories
- The inventory report is transparent and consistent

The assurance process entailed review of the carbon footprint report prepared by Boliden with technical assurance and support by Sphera Solutions GmbH. The reviewer used a review checklist to log all pertinent remarks that were then internally reviewed to ensure rigorous and transparent approach before sharing and discussing with Boliden all comments in detail. Outcomes were addressed within an updated version of the carbon footprint report which was subsequently checked by the reviewer to check. A materiality level of 5% was applied. Furthermore, an examination of the process models within the LCA software (GaBi) was an integral part of this critical review.

Annex A to this Assurance Statement provides the checklist of requirements against which this limited assurance was confirmed and provided.

Conclusion and Assurance Opinion

Based on the critical review activities undertaken, nothing has come to our attention that would cause us to believe that Boliden have not disclosed accurate and reliable carbon footprint data in conformance with the requirements of the GHG Protocol Product Life Cycle Accounting and Reporting Standard.

Statement of Independence, Integrity and Competence

Intertek exceeds the competency requirements set forth in ISO 14066, Competence Requirements for GHG Validation Teams and Verification Teams. The outcomes of all assurance assessments are internally reviewed adhering to a controlled quality management system to ensure that the approach applied is rigorous and transparent. The assurance team for this work does not have any involvement in any other Intertek projects with Boliden Mineral AB.

Signed

K. Allbury

Kim Allbury
Sustainability Project Manager

Dated: 30th September 2021

Katie Livesey

Katie Livesey
Sustainability Project Leader

Dated: 30th September 2021

Annex A: Assurance Checklist

The carbon footprint report was checked against the following Greenhouse Gas Protocol requirements as a minimum to ascertain assurance with the Product Standard.

GHG Protocol requirement	Conforms to requirement (Yes or No)	Reviewer comment
GHG accounting and reporting of a product inventory shall follow the principles of relevance, accuracy, completeness, consistency, and transparency	Yes	Described within report
A GHG product inventory shall follow the life cycle and attributional approaches	Yes	Described within report
Companies shall account for carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O), sulfur hexafluoride (SF6), perfluorocarbons (PFCs), and hydrofluorocarbons (HFCs) emissions to, and removals from, the atmosphere	Yes	Described within report
Additional GHGs included in the inventory shall be listed in the inventory report	Yes	Described within report
Companies shall define the product, unit of analysis, and reference flow	Yes	Defined within report
For all final products, companies shall define the unit of analysis as a functional unit	n/a	n/a - intermediate product
For intermediate products where the eventual function is unknown, companies shall define the unit of analysis as the reference flow	Yes	Defined within report
The boundary of the product GHG inventory shall include all attributable processes	Yes	Described within report
Companies shall report the life cycle stage definitions and descriptions	Yes	Described within report
Companies shall disclose and justify any exclusions of attributable processes in the inventory report	Yes	Described within report
Companies shall report attributable processes in the form of a process map	yes	Included within report
Companies shall report any non-attributable processes included in the boundary	Yes	Described within report
The boundary for final products shall include the complete life cycle, from cradle-to-grave	n/a	Intermediate products
The boundary of a cradle-to-gate partial life cycle inventory shall not include product use or end-of-life processes in the inventory results	Yes	Described within report
Companies shall disclose and justify when a cradle-to-gate boundary is defined in the inventory report	yes	Included in functional unit description
Companies shall report the time period of the inventory	Yes	Described within report
Companies shall report the method used to calculate land-use change impacts, when applicable	n/a	This is only applicable for biogenic products.

GHG Protocol requirement	Conforms to requirement (Yes or No)	Reviewer comment
Companies shall collect data for all processes included in the inventory boundary	Yes	Described within report
Companies shall collect primary data for all processes under their ownership or control	Yes	Described within report
During the data collection process, companies shall assess the data quality of activity data, emission factors, and/or direct emissions data by using the data quality indicators	Yes	Described within report
For significant processes, companies shall report a descriptive statement on the data sources, the data quality, and any efforts taken to improve data quality	Yes	Described within report
Companies shall allocate emissions and removals to accurately reflect the contributions of the studied product and co-product(s) to the total emissions and removals of the common process	Yes	Described within report
Companies shall avoid allocation wherever possible by using process subdivision, redefining the functional unit, or using system expansion	Yes	A combination of economic value and mass allocation have been used.
If allocation is unavoidable, companies shall allocate emissions and removals based on the underlying physical relationships between the studied product and co-product(s)	Yes	A combination of economic value and mass allocation have been used.
When physical relationships alone cannot be established or used as the basis for allocation, companies shall select either economic allocation or another allocation method that reflects other relationships between the studied product and co-product(s)	Yes	A combination of economic value and mass allocation have been used.
Companies shall apply the same allocation methods to similar inputs and outputs within the product's life cycle	yes	Energy credits have been excluded from the Actual Footprints
For allocation due to recycling, companies shall use either the closed loop approximation method or the recycled content method as defined by this standard	Yes	Described within report
When using the closed loop approximation method, companies shall report displaced emissions and removals separately from the end-of-life stage	n/a	n/a
Companies shall disclose and justify the methods used to avoid allocation or perform allocation	Yes	Described within report
When using the closed loop approximation method, companies shall report displaced emissions and removals separately from the studied product's end-of-life stage inventory	n/a	n/a
Companies shall report a qualitative statement on inventory uncertainty and methodological choices	Yes	Described within report
Companies shall apply a 100-year GWP factor to GHG emissions and removals data to calculate the inventory results in units of CO2 equivalent (CO2e)	Yes	Described within report

GHG Protocol requirement	Conforms to requirement (Yes or No)	Reviewer comment
Companies shall report the source and date of the GWP factors used	Yes	5th assessment report referenced.
Companies shall quantify and report the following: • Total inventory results in CO2e per unit of analysis, which includes all emissions and removals included in the boundary from biogenic sources, non-biogenic sources, and land-use change impacts • Percentage of total inventory results by life cycle stage • Biogenic and non-biogenic emissions and removals separately when applicable • Land-use change impacts separately when applicable • Cradle-to-gate and gate-to-gate inventory results separately or a clear statement that confidentiality is a limitation to providing this information	Yes	Described within report
Companies shall not include the following when quantifying inventory results: weighting factors for delayed emissions; offsets; and avoided emissions	Yes	Described within report
Companies shall report the amount of carbon contained in the product or its components that is not released to the atmosphere during waste treatment, if applicable	n/a	n/a
For cradle-to-gate inventories, companies shall report the amount of carbon contained in the intermediate product	n/a	n/a (applicable to biomass products)
The product GHG inventory shall be assured by a first or third party	Yes	Described within report
Companies shall choose assurance providers that are independent of, and have no conflicts of interest with, the product GHG inventory process	Yes	Independent assurance providers used
Companies shall report the assurance statement in the inventory report. The statement shall include: • The level of assurance achieved (limited or reasonable) including assurance opinion or the critical review findings • Whether the assurance was performed by a first or third party • A summary of the assurance process • The relevant competencies of the assurance providers • How any potential conflicts of interest were avoided for first party assurance	Yes	Text provided
Companies shall publicly report information detailed the GHG Protocol Product Standard Section 3.3	Yes	Described within report