Life Cycle Assessment of Boliden Products

November 2024

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Abstract

A LCA has been produced for the following products at Boliden, Copper, Zinc, Lead, Nickel & Sulphuric acid. The calculations are made per value chain, meaning adding the environmental impact per mine, mine to smelter transportation and smelting & refining together, representing the cradle-to-gate environmental impact for each specific value chain. Allocation methods has been used when suitable allowing Boliden to present the environmental impact on primary and secondary products.

For this study, a combination of economic value and mass allocation have been used. A conservative approach has been taken in most of the cases, meaning all relevant inventory for the final cradle to gate results have been included. Boliden excludes credits from energy and by-products.

The study concludes that the majority environmental impacts originate from supply of raw materials. The environmental impact results also show that Boliden owned mines and smelters are well positioned compared to global average. Intertek was commissioned by Boliden to perform an independent assurance against the *Greenhouse Gas Protocol – Product Life Cycle Accounting and Reporting Standard*, ISO 14067:2018 *Greenhouse gases – Carbon Footprint of Products – Requirements and Guidelines for Quantification*, ISO 14040:2006 *Environmental management – Life cycle assessment – Principles and framework*, and ISO 14044:2006 *Environmental management – Life cycle assessment – Requirements and guidelines.*

About Boliden

Boliden is a metals company with roots from the Nordics acting on global market. By caring for people, the environment and society Boliden provides metals that are essential for the development of society. From our own mines and smelters, we extract and produce high-quality metals with good climate performance. Boliden has around 6,000 employes and un annual turnover of Sek 80 billion. The share is listed in the Large Cap segment on NASDAQ OMX Stockholm.

www.boliden.com

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Introduction

There is a growing global demand for metals to contribute towards overcoming social challenges, including climate change. Boliden acknowledges the urgent need to address climate change and its widespread impacts. Boliden´s vision is to be the most climate friendly and respected metal provider in the world. We are committed to be part of the solution by reducing our impact on the environment and provide the products needed for a low carbon future by committing to reduce corporate absolute Scope 1 and 2 emissions with 42% and Scope 3 with 30% by 2030 compared to base year 2021. Additionally, we are committed to minimizing the average environmental impact of the metals produced by Boliden through a cradle-to-gate approach.

A life cycle assessment enables the possibility to calculate the studied environmental impact and to identify significant emission hotspots.

The goal of the study is to provide environmental impact per ton of product produced, from cradle-to-Boliden gate, where the functional units are:

- 1 ton of Copper Cathode (Cu 99,999%), from Harjavalta & Rönnskär
- 1 ton of Nickel Matte[1]. from Harjavalta
- 1 ton of Nickel (Ni 99,8%), Nickel Matte from Harjavalta and downstream Refinery
- 1 ton of special High-Grade Zinc (Zn 99,995%), from Odda & Kokkola
- 1 ton of lead (Pb 99,98), from Bergsöe and Rönnskär
- 1 ton of Sulphuric acid, from Harjavalta, Rönnskär, Odda & Kokkola

The environmental impact for each metal and production site, is distributed per value chain for primary raw materials and secondary raw materials. Secondary raw material is defined as any raw material originating from end-of-life waste streams or waste streams from other metal processing industries.

Software, impact assessment method and database

The software GaBi Professional version 10.6.1.35 from Sphera Solutions GmbH was used together with the latest MLC database provided by Sphera and data from the non-ferrous metals associations for the modelling. The CML impact assessment methodology framework (CML 2001, August 2016) has been selected for this study.

[1] Metal content in matte is not for public disclosure

General Information and Scope

The study describes the production sites of Boliden with reference year in:

- Copper
    - Rönnskär (Sweden, Smelter, 2021)
    - Harjavalta (Finland, Smelter, 2021)
    - Aitik (Sweden, Mine, 2019-2021)
    - Kevitsa (Finland, Mine, 2019-2021)
    - Boliden Area (Sweden, Mine, 2019-2021)
    - Garpenberg (Sweden, Mine, 2019-2021)
- Lead
    - Bergsöe (Sweden, Smelter, 2021)
    - Rönnskär (Sweden, Smelter, 2021)
    - Boliden Area (Sweden, Mine, 2019-2021)
    - Garpenberg (Sweden, Mine, 2019-2021)
    - Tara (Ireland, Mine, 2019-2021)
- Zinc
    - Kokkola (Finland, Smelter, 2021)
    - Odda (Norway, Smelter, 2021)
    - Garpenberg (Sweden, Mine, 2019-2021)
    - Boliden Area (Sweden, Mine, 2019-2021)
    - Tara (Ireland, Mine, 2019-2021)
- Nickel
    - Harjavalta (Finland, Smelter, 2021)
    - Kevitsa (Finland, Smelter, 2019-2021)
- Sulphuric Acid
    - Rönnskär (Sweden, Smelter, 2021)
    - Harjavalta (Finland, Smelter, 2021)
    - Kokkola (Finland, Smelter, 2021)
    - Odda (Norway, Smelter, 2021)

The reference year 2021 was selected for the smelters since Boliden aims to redo its Life Cycle Assessment every third year, and the last assessment was done with the reference year 2018 for the majority of our smelters. For the mines the results are based on an average of three years production data, hence the reference years was 2019, 2020 and 2021.

Commodities, which are the functional unit in this study, have the same characteristics and function downstream, independent of which path of further refining, production or usage processes they take. All though a cradle-to-grave study boundary is more comprehensive and would in fact provide a more accurate reflection of the environmental impact of metals since it would capture many of the benefits of using metals[2] has chosen to exclude all downstream impact categories for the case of this study and comparability reasons since many of the metals associations which Boliden is a member of have conducted a cradle-to-gate carbon footprint study.

The production data (inputs and outputs) has been collected in collaboration with Boliden production units & commercial. Production data has been collected on process level enabling allocation of environmental impacts to be conducted on process level. An iterative approach was used to ensure a minimal gap in the data input vs output.

The main limitation posed by this study for comparative assertion with the associations and peer´s studies are related to:

i. Changes in metal prices, which has been used for economic value allocation. The impact of the processes and related product and co-products to economic value allocation is limited due to balancing mechanism in the market and has a minor impact on the results.
ii. Differences in use of datasets. For this study, the most recent datasets available in the Life Cycle Assessment software tool, GaBi was used. These might not be the same when other software tools are used.
iii. Credits from System expansion, Boliden does not account for any environmental credits retrieved production of energy and by-products in the results presented. Those should be excluded for comparison
iv. Average intensity figures, Boliden does not present the average environmental impact when communicating, but rather specific value chains and/or the average environmental impact of specific blends of raw materials to separate the low carbon value chains from high carbon value chains.

The analyzed environmental impacts are, Global Warming Potential, Eutrophication Potential, Acidification Potential, Ozone Depletion Potential (ODP), Photochemical Ozone Creation Potential (POCP) and Primary Energy Demand (PED).

[2] Santero, Nicolas, och Josh Hendry. 2016. "Harmonization of LCA methodologies for the metal and mining industry." *The International Journal of Life Cycle Assessment* 21. doi:https://doi.org/10.1007/s11367-015-1022-4.

Boundary Setting

The system boundary for this study, which includes the products copper, zinc, nickel, lead, and sulphuric acid, is based on a cradle-to-gate approach. The study is conducted both on Boliden own mines and smelters and external mines. The mines are both open-pit and underground. Boliden sources raw material on a global level while its own mines are located in Sweden, Finland and Ireland. The smelters are located in the Nordics, see *General Information and Scope*.

The cradle-to-gate approach includes mining and milling, transportation of raw material to smelter, and smelting and refining process steps. Mining and milling are both Scope 1, 2 and 3 emissions when its Boliden owned mines. The external raw material suppliers, and transportation of raw material to Boliden smelters are part of Scope 3. Smelting and refining are Scope 1, 2 and 3.

One of Boliden's products is nickel matte, an intermediate product refined to nickel by our downstream customers, the downstream refining is included as Scope 3. See *Figure 1* for a generic system boundary of Boliden products.

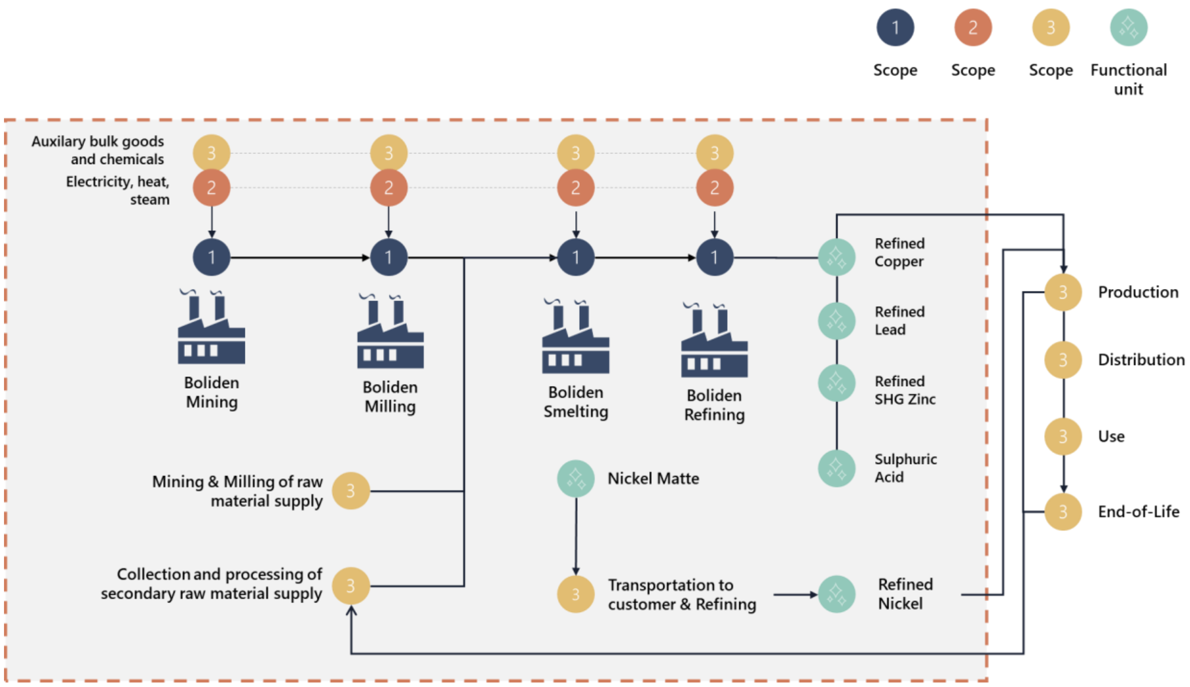

Figure 1 Generic system boundary for Boliden products

In June 2023, a fire broke out in the tank house at the Rönnskär smelter, halting the refining of anodes. As a result, a new logistical route was established for the copper production chain from Rönnskär. Copper anodes produced in Rönnskär, which could no longer be processed at the site, began to be shipped to the Harjavalta smelter in Pori for refining.

Cut-off criteria

The following cut-off were applied:

a) Mass – If a flow is less than 1% of the product mass of all the input and outputs of the model, it may be excluded, providing its environmental relevance is not a concern.
b) Energy – If a flow is less than 1% of the cumulative energy of all the inputs and model, it may be excluded, providing its environmental relevance is not a concern.
c) Environmental relevance – If a flow meets above criteria for exclusion, and has a negligible environmental impact, it will be excluded. Material flows which leave the system with greater environmental impact than 1% are included and if they are below 1% of the overall environmental impact are excluded. The judgement was done based on consistency check with respective upstream data.

The sum of the excluded material flows does not exceed 5% of mass, energy and environmental relevance. For theses cut off criteria are used preliminary to exclude "known" negligible processes such as transport of workers and capital expenditure.

For the processes within the system boundary, all available energy and material flow data have been included in the model. In cases where no matching life cycle inventories are available to represent a flow, proxy data have been applied based on conservative assumptions regarding environmental impacts.

Allocation

A combination of economic and mass allocation is used in this study. This approach is consistent with the recommendation by the metals and minerals industry and set out in a peer reviewed article by Sentero & Hendry, 2016[3].

Economic allocation is used where base metals and precious metals occur together and when the main purpose of the process is to treat raw materials with precious metals such as the secondary treatment process in Rönnskär, the E-Kaldo treating electronic materials. A mass allocation would not represent the value of the products, nor the rationale for producing the different metals. Where only base metals occur together, mass allocation is applied since there is typically not a vast physical and economical difference. Data was gathered on process level and allocation has been applied in the modelling phase.

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

System expansion was considered but not applied since Boliden does not account for the environmental credits retrieved from production of by-products. 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 metals 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-products. The sulphuric acid is produced from the recovery of oxidised sulphur of sulphide ores and 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. As this study does not apply system expansion, a cut off approach is used. Meaning that the off gases (SO_2) are defined as residues and further treated in the sulphuric acid plant in Boliden smelters. The gases are treated with zero upstream environmental burden.

Value chain based product offering

In order to separate the environmental impact for the products produced from low-carbon mines, other primary raw material and secondary raw material a mass balance principle is applied. The fundamentals of the mass balance principle is that the share of claimed material that enters the process is equivalent to the share of the claimed material leaving, see *Figure 2*.

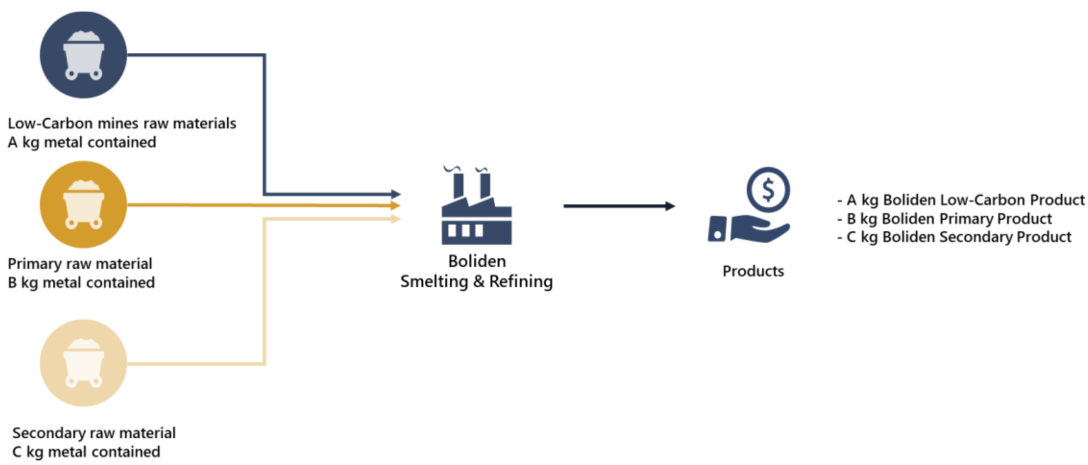

Figure 2 Principle of the value chain based product offering

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Validation of data

The data used to create the inventory model shall be as precise, complete, consistent and representative as possible with regards to the goal and scope of the study under given time and budget constraints.

- Measured primary data are of the highest precision, followed by calculated data, literature data and estimated data. The goal is to model all relevant foreground processes using measured or calculated primary data and only make assumption when justified.
- Completeness is judged based on the completeness of the inputs and outputs per unit process and the completeness of the unit processes themselves. The goal is to capture all relevant data in this regard.
- Consistency refers to modelling choices and data sources. The goal is to ensure that differences in results reflect actual differences between product systems and are not due to inconsistencies in modelling choices, data sources, emissions factors, or other artifacts.
- Reproducibility expresses the degree to which third parties would be able to reproduce the results of the study based on the information contained in this report. The goal is to provide enough transparency with this report so that third parties are able to approximate the reported results. This ability may be limited by the exclusion of confidential primary data and access to the same background data sources.
- Representativeness expresses the degree to which the data matches the geographical, temporal, and technological requirements defined in the study's goal and scope. The goal is to use the most representative primary data for all foreground processes and the most representative industry-average data for all background processes. Whenever such data were not available (e.g., no industry-average data available for a certain country), best-available proxy data were employed.

In the table below scoring criteria are described for representativeness in terms of technology, time, geography, completeness and reliability.

Score	Representativeness to the process in terms of:				
	Technology	Time	Geography	Completeness	Reliability
Very good	Data generated using the same technology	Data with less than 3 years of difference	Data from the same area	Data from all relevant process sites over an adequate time period to even out normal fluctuations	Verified data based on measurements
Good	Data generated using a similar but different technology	Data with less than 6 years of difference	Data from a similar area	Data from more than 50 percent of sites for an adequate time period to even out normal fluctuations	Verified data partly based on assumptions or non-verified data based on measurements

Fair	Data generated using a different technology	Data with less than 10 years of difference	Data from a different area	Data from less than 50 percent of sites for an adequate time period to even out normal fluctuations or from more than 50 percent of sites but for shorter time period	Non-verified data partly based on assumptions or a qualified estimate (e.g., by sector expert)
Poor	Data where technology is unknown	Data with more than 10 years of difference or the age of the data are unknown	Data from an area that is unknown	Data from less than 50 percent of sites for shorter time period or representativeness is unknown	Non-qualified estimate

Data quality assessment

Inventory data quality is judged by its precision (measured, calculated, or estimated), completeness (e.g., unreported emissions) consistency (degree of uniformity of the methodology applied) and representativeness (geographical, temporal, and technological).

To cover these requirements and ensure reliable results, supplier specific and site-specific data has been used in combination with consistent background LCA information from LCA databases. The LCI datasets have been used in LCA models worldwide in industrial and scientific application. These datasets are cross checked with other databases and values from industry and science. Full description of each dataset is available in the LCA tool used.

- **Technological Representativeness**: As most of the relevant foreground data for the sites Boliden owns are measured or calculated data based on primary information sources. Precision is therefore considered to be very good. All background data are sources with an LCA documented, and the majority is data generated using a similar but different technology. Quality is therefore scored as good.
- **Completeness:** Each foreground process was checked for mass balance and completeness of the emissions inventory. Completeness of foreground unit process data is scored as very good. All background data are sources with an LCA documented.
- **Reliability:** To ensure data consistency, the same LCA document was sent to all sites with the same data requests. However, sites were not consistent in the level of detail they were ultimately able to provide due to the data management maturity level differences in the sites and the time of the data gathering e.g., summer holidays might have affected the data quality. Yet, data has been checked several times overtime and the consistency is considered to be high. Reproducibility is supported as much as possible through the disclosure of input – output data, dataset choices and modelling approaches in this report. Based on this information, any third party should be able to approximate the results of

this study using the same data and modelling approach. Overall the reliability is scored as good.

- **Temporal Representativeness**: All primary data from five mines and five smelters were collected between the years 2022 and 2023. For mines three full years of data was gathered, 2019-2021. While for smelters, one year, 2021, of annual data was gathered. For all mines Boliden does not on and provide raw material to our smelters, primary data is used when available and secondary data from the representative associations of the years 2018-2021. As the study intended to present the intensity figure and an average of three years production data from the mines has been considered, risk volatility is considered to be low, hence temporal representativeness is scored as good.
- **Geographical Representativeness:** The data collected for this study represent the production of the functional units at each site and the value chains delivering material to Boliden smelters. All primary and secondary data were collected specific to the countries or regions under study. Where country specific or region-specific data where unavailable, proxy data were used. The geographical representativeness is scored as very good for primary data and good for the global average data.
- **Modelling Completeness:** All relevant process steps for each product system were considered and modelled to represent each specific situation. The process chain is considered sufficiently complete and detailed with regard the goal and scope of the study.
- **Modelling Consistency:** All assumptions, methods and data are consistent with each other and with the study´s goal and scope. Differences in background data quality is minimized by using one tool to do all the models in and extract results from, GaBi, 2021 MLC databases. System boundaries, allocation rules and impact assessment methods have been applied consistently throughout the study.

Uncertainty

As far as possible, the process steps have been defined and data has been collected in accordance with the production processes for each production site and modelled accordingly. The main assumption made in this study to close data gaps have been when environmental data from the associations, International Zinc Associations (IZA), The international Copper alliance (ICA), Nickel Institute (NI) & International Lead Associations (ILA), have been used to close raw material suppliers' data gaps.

Examples of assumption and limitation are noted below:

- Raw material environmental impact from suppliers where Boliden does not have primary data nor quality data on full LCA data.
- The environmental impact data (upstream burden) for electronic Scrap and other scrap material was set to zero with the assumption that the emissions from collecting and sorting this material has an insignificant impact on the environment.
- Based on the same background as for electronic scrap, the upstream overburden for collection of Lead Acid Batteries was assumed to be zero. The transportation of the batteries is included as an average and modelled in GaBi.
- Three years production data was gathered from the mines and the average of three years material and energy usage was modelled. When data was not available for one year but available for the others, e.g., water usage, the number of that year used an average.
- Water consumption data per process is a key limitation in this LCA, to measure and model since this data is not available at site and is not being measured. An assumption has been made to allocate water consumption equally, based on mass on all metals. The various uses and fates of water at the site make it difficult to meter loss rates and sub-process level detail for water was not available for many processes. Often, water input data was available, either at the sub-process or total facility level, but information on outputs of water was not. Where data input/output was reported, or if the output did not balance with the input, water was assumed to evaporate due to process losses or after being deposited in tailings ponds. For example, water is used for dust suppression during mining. Mines are dewatered, and output water is sent to treatment or tailing ponds. To simplify the modelling, the water balance was made on site level and not on processes level.
- Data availability of land use was limited and not gathered.

Treatment of missing data

Several assumptions and estimations have been applied to fill in the data gaps and to process the data in a meaningful way.

Mining – Production data for three years was collected to calculate the average emission.
Smelters – Allocation of emissions to air is emitted from a central chimney most of the time in Boliden smelters. Hence, to allocate direct emissions per process an assumption is made based on the data input that has been gathered and allocated fairly per process based on the carbon content of each material treated in the process. In Kokkola and Odda, most of the emissions are assumed to be emitted from the roaster, hence no allocation is applied.

Results

In the following chapter results for the environmental impact categories included in this study will be presented.

Results for base metals

The following sections results will be presented per environmental impact category.

Global Warming Potential

The results for *Global Warming Potential (GWP 100 years), excl biogenic carbon* below are presented by kg CO_2e per ton of product.

	Rönnskär Cu[4]	Rönnskär Pb	Harjavalta Cu	Harjavalta Class 1 Ni[5]	Kokkola Zn	Odda Zn	Bergsöe Pb
Kevitsa	3 220	x	3 290	5 310	x	x	x
Boliden Area	1 200	1 800	1 260	x	1 900	1 110	x
Garpenberg	600	910	670	x	1 260	470	x
Tara	x	1 100	x	x	1 440	650	x
Aitik	1 630	x	1 690	x	x	x	x
External concentrates	4 040	990	4 090	11 090	1 930	1 130	x
Recycled	1 040	x	520	x	3 460	3 870	980

Acidification Potential

The results for *Acidification Potential (AP)* below are presented by kg SO_2e per ton of product.

	Rönnskär Cu[4]	Rönnskär Pb	Harjavalta Cu	Harjavalta Class 1 Ni	Kokkola Zn	Odda Zn	Bergsöe Pb
Kevitsa	25,05	x	14,87	x	x	x	x
Boliden Area	13,55	5,62	3,37	x	24,17	4,04	x
Garpenberg	11,75	0,85	1,57	x	22,03	1,90	x
Tara	x	1,04	x	x	22,20	2,08	x
Aitik	16,55	x	6,37	x	x	x	x
External concentrates	x	x	x	x	x	x	x
Recycled	14,44	x	0,09	x	x	x	4,66

[4] Results for the temporary route established where raw material is refined to anodes in Rönnskär, transported to Pori and further refined to cathodes in Pori (Harjavalta electrolytic refining)

[5] The Class 1 Nickel results include downstream refining based on data from Nickel Institute, reflecting the average refining footprint of its member companies.

Eutrophication Potential

The results for *Eutrophication Potential (EP)* below are presented by kg Phosphate eq. per ton of product.

	Rönnskär Cu[6]	Rönnskär Pb	Harjavalta Cu	Harjavalta Class 1 Ni	Kokkola Zn	Odda Zn	Bergsöe Pb
Kevitsa	115,88	x	115,79	x	x	x	x
Boliden Area	15,78	24,34	15,69	x	16,55	2,73	x
Garpenberg	7,88	2,44	2,79	x	2,74	0,59	x
Tara	x	0,21	x	x	0,52	0,76	x
Aitik	30,48	x	30,39	x	x	x	x
External concentrates	x	x	x	x	x	x	x
Recycled	0,47	x	0,21	x	x	x	0,10

Ozone Layer Depletion Potential

The results for *Ozone Layer Depletion Potential (ODP, steady state)* below are presented by kg R11 eq. per ton of product.

	Rönnskär Cu[6]	Rönnskär Pb	Harjavalta Cu	Harjavalta Class 1 Ni	Kokkola Zn	Odda Zn	Bergsöe Pb
Kevitsa	5,03E-10	x	x	x	x	x	x
Boliden Area	7,98E-10	2,45E-10	8,25E-10	x	5,98E-10	2,41E-09	x
Garpenberg	6,61E-10	4,31E-10	6,88E-10	x	2,41E-09	2,41E-09	x
Tara	x	2,41E-09	x	x	4,43E-10	5,98E-10	x
Aitik	3,47E-10	x	3,74E-10	x	x	x	x
External concentrates	x	x	x	x	x	x	x
Recycled	3,05E-10	x	5,88E-10	x	x	x	6,91E-11

[6] Results for the temporary route established where raw material is refined to anodes in Rönnskär, transported to Pori and further refined to cathodes in Pori (Harjavalta electrolytic refining)

Photochemical Ozone Creation Potential

The results for *Photochemical Ozone Creation Potential (POCP)* below are presented by kg Ethene eq. per ton of product.

	Rönnskär Cu[7]	Rönnskär Pb	Harjavalta Cu	Harjavalta Class 1 Ni	Kokkola Zn	Odda Zn	Bergsöe Pb
Kevitsa	1,05	x	0,72	x	x	x	x
Boliden Area	0,47	0,37	0,13	x	1,15	0,15	x
Garpenberg	0,52	0,12	0,19	x	1,02	0,03	x
Tara	x	0,13	x	x	1,03	0,03	x
Aitik	0,48	x	0,15	x	x	x	x
External concentrates	x	x	x	x	x	x	x
Recycled	0,40	x	0,22	x	x	x	0,21

Primary energy demand from ren. and non ren. resources

The results for *Primary energy demand from ren. and non ren. resources (gross cal. value)* below are presented by MJ per ton of product.

	Rönnskär Cu[7]	Rönnskär Pb	Harjavalta Cu	Harjavalta Class 1 Ni	Kokkola Zn	Odda Zn	Bergsöe Pb
Kevitsa	61 070	x	57 300	x	x	x	x
Boliden Area	33 750	46 260	29 980	x	65 540	34 120	x
Garpenberg	25 440	21 830	21 670	x	47 690	30 700	x
Tara	x	18 800	x	x	44 290	51 970	x
Aitik	68 450	x	64 680	x	x	x	x
External concentrates	x	x	x	x	x	x	x
Recycled	15 340	x	23 920	x	x	x	7 770

[7] Results for the temporary route established where raw material is refined to anodes in Rönnskär, transported to Pori and further refined to cathodes in Pori (Harjavalta electrolytic refining)

Primary energy from renewable resources

The results for *Primary energy from renewable resources (net cal. value)* below are presented by MJ per ton of product.

	Rönnskär Cu[8]	Rönnskär Pb	Harjavalta Cu	Harjavalta Class 1 Ni	Kokkola Zn	Odda Zn	Bergsöe Pb
Kevitsa	13 890	x	7 650	x	x	x	x
Boliden Area	37 670	21 080	31 430	x	32 290	21 020	x
Garpenberg	12 280	3 650	6 040	x	15 430	22 370	x
Tara	x	3 320	x	x	14 930	21 880	x
Aitik	79 470	x	73 230	x	x	x	x
External concentrates	x	x	x	x	x	x	x
Recycled	8 350	x	6 940	x	x	x	1 810

Results for Sulphuric acid

Impact category/inventory Metric and units	Rönnskär	Harjavalta	Kokkola	Odda
Acidification Potential (AP) [kg SO2 eq.]	0,29	0,61	0,06	0,10
Eutrophication Potential (EP) [kg Phosphate eq.]	0,01	0,01	0,01	0,00
Global Warming Potential (GWP 100 years), excl biogenic carbon [kg CO2 eq.]	3	22	19	3
Ozone Layer Depletion Potential (ODP, steady state) [kg R11 eq.]	8,65E-12	2,66E-11	2,45E-11	9,55E-12
Photochem. Ozone Creation Potential (POCP) [kg Ethene eq.]	0,01	0,03	0,01	0,00
Primary energy demand from ren. and non ren. resources (gross cal. value) [MJ]	220	940	820	360
Primary energy from renewable resources (gross cal. value) [MJ]	180	320	240	330

[8] Results for the temporary route established where raw material is refined to anodes in Rönnskär, transported to Pori and further refined to cathodes in Pori (Harjavalta electrolytic refining)

Conclusion

Copper

The results show that the primary energy demand for primary copper production is driven by the electricity usage in the milling phase of the mining and milling. As the total volume of processed ore is approximately 10 times higher than the volume of concentrate produced at the mining sites. For copper production, the smelting and refining phase requires a relatively lower amount of energy as the concentrates contain Sulphur which is utilized in the roaster.

Impact on photochemical ozone creation potential (POCP) is negative for Boliden internal mines in Scope 1, which is a result of diesel combustion. Negative results in POCP can occur when nitrogen monoxide is released which, in combination with carbon monoxide, can reduce ground-level ozone to NO_2, CO_2 and O_2. For secondary copper production the major contributor to the POCP impact comes from direct emissions in the converter. Emissions influencing POCP are CO, NOx, SO_2 and VOCs.

Further, the major impact on ODP is a result of the electricity grid mix in smelters Scope 2. For secondary production ODP is also relatively high due to Scope 2. When looking further into the reasons why Scope 3 from smelting and refining was a significant contributor, the consumed chemicals such as sodium hydroxide were identified as the source. The reason being significant usage of electricity in the production processes of the chemicals.

Regarding GWP, the raw material extraction contributes to around 90 percent in which Scope 3 is the largest part including both externally sourced raw material and Scope 3 for Boliden internal mines. The activity contributing to the impact in Scope 1 for concentrates is the fuel consumption in the internal mines. Comparing the results from primary production in Rönnskär and Harjavalta, the Scope 3 impact from concentrates is relatively higher as a larger amount of raw material is sourced externally in Harjavalta. For secondary production the main emitter is the E-kaldo where plastic from e-material is combusted and used as a heating source in the process.

Results for EP show that the impact for primary production is a result from explosives usage in the mining phase. Regarding secondary production, combustion of fuels is the relatively largest contributor, originating from both combustion in the smelter and transportation of the raw material.

AP is mainly associated with SO_2 emissions within this study and because of the sulphur content in the raw material, the SO_2 flow is high. Most of the SO_2 is collected and treated in the sulphuric acid plant, despite this there are still direct SO_2 emissions from the smelter.

Zinc

This study found that production of Zinc is a high consumer of electricity and was the biggest contributor to life cycle impacts of SHG Zinc. The location of the site has a significant impact due to the electricity grid mix used dictating to some extent the environmental impact as well. The main consumption of electricity is in smelting and refining steps, where the electricity is used for the zinc ions to form into zinc anodes.

Since electricity is the main contributor to the environmental impact and our Zinc smelters are located in Norway and Finland. The environmental of the electricity grid mix in Norway is close to zero. Hence the GWP is significantly lower than in Finland. Regarding GWP, one difference shown in the results of Kokkola and Odda is the contribution of secondary material to GWP. As Odda receives more secondary raw material compared to Kokkola, secondary material has a larger relative impact on the SHG zinc refined in the Norwegian smelter.

The results show that POCP is mainly impacted by the direct emissions from the roasting which is the first process of the smelting phase. In Odda, the results show that transportation within Boliden internal mines contributes to a negative impact on POCP. Negative results in POCP can occur when nitrogen monoxide is released which, in combination with carbon monoxide, can reduce ground-level ozone to NO_2, CO_2 and O_2.

For ODP the results show that Scope 3 emissions from the smelting and refining phase is the major contributor in Kokkola, the product input showing the largest impact is polycarbonates for the electrolysis. For Odda both electricity demand in upstream production of chemicals and electricity in Scope 2 for smelting and refining are the two posts with largest impact to ODP.
Similar to copper production, explosives is the major contributor to EP in zinc production. In combination with electricity grid mix in Finland and combustion of fuels in transportation in Norway, these activities account for the majority of potential impact related to EP. Further, the results show that AP is mostly related to direct emissions from the smelting phase at Kokkola, probably because of the high sulphuric content in the raw material. In Odda the results show AP being related to transportation and Scope 3 emissions from the smelting and refining phase.

Nickel

The results for energy demand shows that Scope 2 for internal mines has the relatively largest impact. Energy is needed in the milling process to treat the ore.
Regarding POCP the transportation at the internal mines is the main driver. As POCS is impacted by emissions of elements such as CO, NOx, SO_2, and VOCs, it can be assumed that this is related to the combustion of fuels.

ODP is shown to be mainly impacted by indirect emissions of oxygen production in the results. Oxygen production can emit halogenated refrigerants and therefore have an impact on ozone layer depletion.

Further, Scope 3 emissions from chemicals used in internal mines and externally sourced raw material together with downstream refining are the main contributors to GWP. The refining of the intermediate nickel matte product requires a significant amount of energy to separate the different metals in the material.

In the case of nickel, the majority of emissions causing EP are related to explosives in mining. For AP, the combustion of fuels related to transport has the largest impact according to the results.

Lead

Energy demand for lead production is driven by ore milling in the primary production and crushing and smelting for secondary material. The results of primary lead production shows that Scope 1 emissions from the smelting and refining phase is the largest contributor to GWP. The largest emitter of GHG is the coal usage in the lead-kaldo. Similar to primary production, the secondary production GWP is related to coke and fuel consumption.
PCOP from production in Rönnskär is related to production of light fuel oil used in the smelting and refining phase, and electricity and cement consumption at Boliden internal mines. At the Bergsöe production, the direct emissions from the shaft furnace is the most significant PCOP contributor.

Regarding ODP, electricity usage in the smelting and refining phase and indirect electricity consumption from chemicals used in the internal mines are the two major impact factors. At the Bergsöe production, Scope 3 emissions from metallurgical coke and fuels are the main contributors to ODP.

Regarding eutrophication potential for primary lead, the explosives have by far the largest impact on the product footprint. This can be explained by the nitrate in the explosives. Comparing the results from primary production to lead production by secondary materials, the results are expected to over all have a smaller potential impact. According to the results direct emissions from shaft furnace and transport accounts for most of EF for production at Bergsöe.
AP is related to transportation and usage of coal and light fuel oils in Rönnskär. Meanwhile, direct emissions from production at Bergsöe are related to the largest impact on AP according to the results.

Sulphuric acid

Results for sulphuric acid production shows that energy demand is driven by electricity usage. Further, the GWP mainly derives from the electricity usage in the production process. The only exception is in Rönnskär where Scope 3 emissions show the relatively largest influence on GWP.
POCP is related to Scope 1 emissions from all sites except the Finish site Kokkola where Scope 2 is the largest contributor. The results for ODP electricity usage are again the main potential impact driver, the only exception being Rönnskär where Scope 3 emissions are contributing the most.

Scope 1 emissions from the Rönnskär smelter and Scope 2 emissions from the other three smelters are the primary contributors to EP according to the results. Regarding AP, the direct emissions in Scope 1 accounts for the relatively largest impact except for the Kokkola smelter where electricity usage in Scope 2 is the main contributor.

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GREENHOUSE GAS PROTOCOL – CRITICAL REVIEW STATEMENT – LIMITED ASSURANCE

Intertek Deutschland GmbH dba Intertek Assuris (hereinafter referred to as 'Intertek') was commissioned by Boliden Commercial AB (hereinafter referred to as 'Boliden') to provide independent third-party limited assurance on the life cycle assessment for Boliden's selected products.

The criteria against which assurance was conducted were the *Greenhouse Gas Protocol – Product Life Cycle Accounting and Reporting Standard* (hereafter referred to as '*Greenhouse Gas Protocol Product Standard*'), ISO 14067: 2018 *Greenhouse gases — Carbon Footprint of Products — Requirements and Guidelines for Quantification,* ISO 14040:2006 Environmental management — Life cycle assessment — Principles and framework and ISO 14044:2006 Environmental management — Life cycle assessment — Requirements and guidelines.

The critical review was performed against the general principles of ISO 14064-3: 2019 *Specification with Guidance for the Verification and Validation of Greenhouse Gas Statements*.

Objective

The objective of this limited assurance review was to confirm whether any objective evidence existed to suggest that Boliden's environmental impact under the scope of study was not accurate, complete, consistent, transparent, or suggested material errors or omissions. The boundary of the life cycle assessment was 'cradle-to-gate', of which inputs relevant to Scope 1, 2 and 3 upstream emissions were the main inputs to the life cycle assessment study. Scope 3 reflects indirect emissions other than those covered in Scope 2 that occur upstream of Boliden through to the company's gate. Capital goods excluded. Allocation of the inputs and emissions to the products is considered based on combination of mass and economic allocation as described within the report.

Roles and Responsibilities

Boliden was solely responsible for the goal and scope definition, for collecting the life cycle data, both from the audited GHG emissions inventory, and from specific complementary process data obtained from site teams to model the life cycle assessments of the carbon footprint of the products under this study. They were also responsible for the underlying GHG emissions information system, data maintenance, calculating the environmental impact of products and reporting procedures in accordance with that system.

Intertek's responsibility, as agreed with the management of Boliden, is to perform a limited assurance engagement in accordance with the requirements of the Life Cyle Assessments Standards as presented in the Assurance Criteria and express an independent limited assurance opinion on Boliden's life cycle assessment report based on our verification following the assurance scope and criteria. Intertek does not accept or assume any responsibility for any other purpose or to any other person or organization. This document represents Intertek's independent and balanced opinion on the content and accuracy of the information and data held within.

Assurance Scope

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

- Copper One ton of Electrolytic Refined Copper (99.99% Cu)
- Zinc One ton of Special High-Grade Zinc (Zn 99.99%)
- Lead (Pb 99,999%)
- Nickel Matte
- Class One Nickel (Ni 99,8%)
- Sulphuric acid

The reference year for the studied products included within the scope of this work was 2019-2021. The mining and refining sites included in the study are in Rönnskär, Bergsöe, Aitik, Boliden area, Garpenberg in Sweden, Kokkola, Harjavalta, Kevitsa in Finland, Tara in Ireland and Odda in Norway.

The scope and boundary of our work is restricted to a review of the methodology within Boliden's LCA system for the impact categories listed below:

- Global Warming Potential (GWP 100 years) [kg CO2 eq.]
- Global Warming Potential (GWP 100 years), excluding biogenic carbon [kg CO2 eq.]
- Acidification Potential (AP) [kg SO2 eq.]
- Eutrophication Potential (EP) [kg Phosphate eq.]
- Ozone Layer Depletion Potential (ODP, steady state) [kg R11 eq.]
- Photochemical Ozone Creation Potential (POCP) [kg Ethene eq.]
- Primary energy from renewable resources (gross cal. value) [MJ]
- Primary energy demand from renewable and non-renewable resources (gross cal. value) [MJ]

Assurance Criteria

Intertek conducted the verification work in accordance with the requirements of 'Limited Assurance' as per the following standard:

- ISO 14064-3: 2019 *Specification with Guidance for the Verification and Validation of Greenhouse Gas Statements*

The criteria in which the Life cycle assessment report was compared against were:

- WRI *Greenhouse Gas Protocol – Product Life Cycle Accounting and Reporting Standard*
- ISO 14067: 2018 *Greenhouse Gases — Carbon Footprint of Products — Requirements and Guidelines for Quantification*
- *ISO 14044:2006 Environmental management — Life cycle assessment — Requirements and guidelines*.

A limited assurance engagement comprises of limited depth of evidence gathering including inquiry and analytical procedures and limited sampling as per professional judgement of assurance provider. A materiality threshold level of 10% was applied. Assessment of compliance and materiality was undertaken against the stated calculation methodology and criteria.

Methodology

Intertek performed verification work using a risk-based approach to obtain the information, explanations and evidence that was considered necessary to provide a limited level of assurance. The verification was conducted by desktop review regarding product environmental impact, reporting and supporting records for the year 2021. Data and information supporting studied life cycle assessments were historical in nature and were assured by another third-party independent auditor to a limited level of assurance. Our assurance task was planned and carried out during April 2024 to September 2024. Intertek's critical review process was carried out to ensure that:

- Methods used to calculate environmental impact were consistent with the criteria and were scientifically and technically valid.
- An examination of the process models within the LCA software (GaBi) was an integral part of this critical review
- Data used, calculation formulas, assumptions and emission factors were appropriate and reasonable.
- The data used are appropriate and reasonable in relation to the goal of the study.
- The interpretations reflect the limitations identified and the goal of the study, and
- The study report is transparent and consistent.
- The Life cycle assessment report followed the requirements of the criteria.

This assurance activity does not provide any assurance on Boliden's Corporate greenhouse gas (GHG) inventory, from which the inputs for life cycle assessment were taken, which has already been covered by the pre-existing limited assurance by another party.

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Conclusion and Assurance Opinion

Following the critical review activities, Intertek concludes with limited assurance that there was no evidence that the LCA methodology for the impact categories under the scope of study in 2021 was not materially correct, was not a fair representation of the data and information or was not prepared in accordance with the criteria listed above.

The life cycle assessment report followed the criteria of the *Greenhouse Gas Protocol Product Standard*, ISO 14067: 2018 *Greenhouse Gases — Carbon Footprint of Products — Requirements and Guidelines for Quantification and ISO 14040/44.* This statement shall be interpreted with Boliden's Life Cycle assessment report (of studied products) as a whole.

Statement of Independence, Integrity and Competence

Intertek ensures the selection of appropriately qualified and impartial individuals as the verifiers. The verifiers are experienced in working on greenhouse gas accounting and verification projects. They were not involved in the preparation of Boliden's greenhouse gas emissions or life cycle assessment studies.

Intertek adheres to the requirements of ISO 14064-3 in its greenhouse gas verification works. The outcome of all assurance assessments was internally reviewed to ensure that the approach applied was rigorous and transparent. The assurance team for this work did not have any involvement in any other Intertek projects with Boliden.

On behalf of Intertek

Vijay Thakur
Senior Manager, Sustainability & LCA Lead

Myvizhi Somasundaram
Technical Manager Climate Change & Sustainability

23rd October 2024

No member of the verification team has a business relationship with Boliden, its directors or Managers beyond that is required of this assignment. No form of bribe has been accepted before, throughout and after performing the verification. The verification team has not been intimidated to agree to do this work, change and/or alter the results of the verification. The verification team has not participated in any form of nepotism, self-dealing and/or tampering. If any concerns or conflicts were identified, appropriate mitigation measures were put in place, documented and presented with the final report. The process followed during the verification is based on the principles of impartiality, evidence, fair presentation and documentation. The documentation received and reviewed supports the conclusion reached and stated in this opinion.