REPORT

Life Cycle Assessment of Aurubis Tin

What is Life Cycle Assessment?

LCA is a decision-making tool used to identify environmental burdens and evaluate the potential environmental impacts of goods or services over their life cycle.

The benefit of using an LCA approach means that negative impacts can be identified and possibly minimized while avoiding the transfer of these impacts from one life cycle stage to another. When applied to product design, production processes, and a decision-making aid, LCA is a meaningful tool for implementing effective sustainability strategies.

Goal

To evaluate our environmental performance and contribution to sustainable development, we carried out a life cycle assessment (LCA) for the tin ingot produced by Aurubis. This study was performed with the help of Sphera as part of the study of the Life cycle assessment of global refined tin by the International Tin Association (ITA[1]. We updated the assessment for Aurubis Tin using 2022 data. The study is consistent with the methodology adopted by the International Tin Association.

This study helps in tracking the improvement progress and identifying opportunities for further improving our environmental performance.

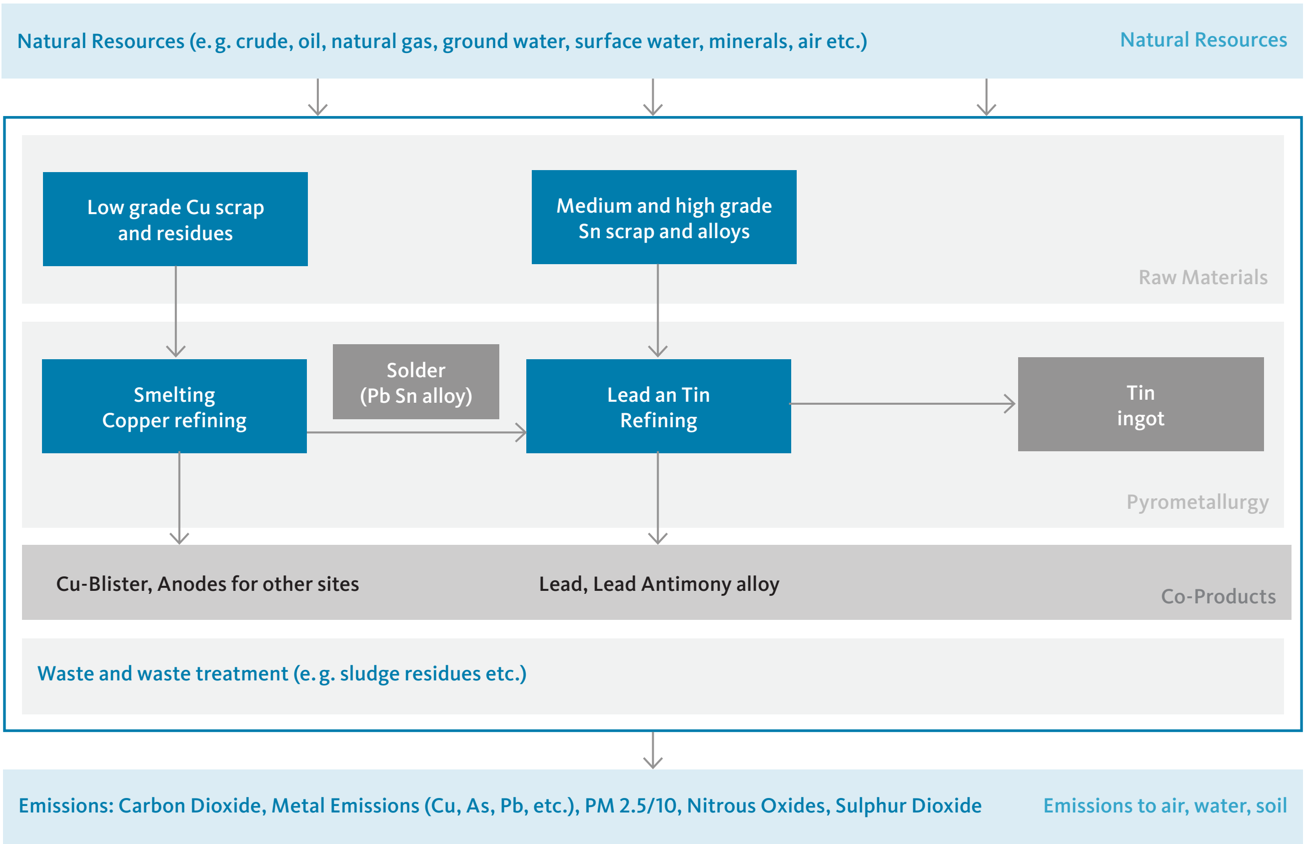
Scope

The study was conducted in conformance with the standards ISO 14040 (ISO 14040:2021 Environmental management — Life cycle assessment — Principles and framework) and ISO 14044 (ISO 14044:2021 Environmental management — Life cycle assessment — Requirements and guidelines) on LCA.

Product and declared unit	Tin (>99,95 % Sn , ingot), 1 ton
Aurubis profile	Tin ingot produced at the Aurubis Beerse plant
Considered production system (system boundaries)	Cradle-to-gate, production of tin ingot
Time coverage	Reference calendar year 2022

The system boundary of the study included a cradle-to-gate life cycle inventory from the extraction of the raw materials to the production of Tin ingot. It does not include the manufacture of downstream products, use, end-of-life, or secondary materials recovery schemes.

[1] International Tin Association, Life cycle assessment of average tin production, reference year 2020



Process description
Tin is produced by pyrometallurgical smelting and refining of secondary raw materials.

A broad range of secondary Cu, Sn, Pb bearing raw materials is processed in the plants in Beerse and Berango, including

- copper scrap
- copper alloyed scrap
- low-grade copper-bearing scrap
- iron based scrap
- copper bearing ashes, residues, slags
- tin and lead bearing scraps and residues
- silica-based products

All cupriferous raw materials with a relatively low copper content are smelted in a furnace to produce impure copper metal (black copper). The black copper is further processed together with scrap in a refining furnace. The refined copper is transferred to the anode furnace, where it is deoxidized and cast into copper anodes. The slag from the refining furnace is treated in the TBRC slag furnaces where crude Pb/Sn alloy is generated.

The Pb/Sn alloy is further processed for tin and lead refining. Pb/Sn bearing scraps can directly enter the Pb/Sn refining process. In the vacuum distillation plant the lead-tin alloy (solder) is treated under vacuum and at high temperature in three steps. Sn and Pb will be separated from each other by distillation in several stages. The products of the installation are tin, lead and a lead/antimony alloy.

Life cycle inventory
Aurubis produces Tin ingot via the pyrometallurgical smelting and refining of tin-bearing secondary materials.

Specific primary data were collected for the Aurubis sites — Berango and Beerse. The data collection covered representative annual data for the calendar year 2022. The data covered all relevant processes associated with tin ingot production:

- Raw material drying/pre-treatment
- Smelting
- Copper refining and anode furnace
- Lead and tin refining
- All related auxiliary processes: On-site wastewater treatment (treatment of process waters, direct cooling water, and surface runoff water), Gas cleaning systems (for primary and secondary off-gases).

[1] www.aurubis.com/en/responsibility/reporting-kpis-and-esg-ratings

All the above processes are operated in the Beerse plant. The plant in Berango only operates smelting of low-grade copper-bearing materials to black copper. This black copper is further processed at the Beerse plant. The Berango plant also processes lead-tin bearing materials for the production of solder (Pb/Sn alloy), which is further refined in the Beerse plant.

The data included all known inputs and outputs for the processes. Inputs are the use of energy (fuels, electricity, steam), water, primary and secondary raw materials, fluxes, reagents, etc. Outputs are the products, co-products, intermediates, emissions to air and water, and waste.

The upstream processes include:

- Production of raw materials: scrap and residues
- Production and supply of fuels
- Production and supply of electricity
- Production and supply of chemicals, auxiliaries
- Transport of raw materials

Production and maintenance of capital goods is excluded from the study. It is expected that these impacts are negligible compared to the impacts associated with running the equipment over its operational lifetime. Packaging is also excluded. As this is a cradle-to-gate study, transport to the customer is outside the system boundary.

For the processing of black copper and solder from Berango in Beerse, the specific profile was used for the reference year 2022.

Purchased electricity is assessed based on specific market-based CO_2 equivalent emission factor. Background processes e.g. fuels, and auxiliary materials were modeled using the LCA for Experts MLC database 2023.1 (former GaBi database). Steam is assessed based on background data for steam production with natural gas.

For the transport of input raw materials, primary activity data were collected for the various categories of delivered raw materials during the calendar year 2022, including mode of transport (truck, ship, rail cars), region /country and approximated distance. Secondary data sets for truck, rail, and bulk ship carriers from the MLC database 2023.1 were used.

Data for fuels and auxiliary materials such as flux, chemicals, etc. are obtained from the MLC database 2023.1. The direct CO_2 emissions from the combustion of fuels and carbon present in the raw materials are calculated based on specific information about fuel consumption by source, net calorific value and emission factor (in accordance with reports on greenhouse gas emissions pursuant to Directive 2003/87).

The Life cycle inventory is not included in the report due to confidentiality reasons

Treatment of CO products

The objective of the study is to quantify the inputs and outputs associated specifically with tin production.

Tin production and recycling is associated to the recovery of other metals such as copper and lead.

In order to compile life cycle inventory data for a single product system (in this case tin ingot), it is necessary to properly address this multi-functionality.

Mass allocation was applied in the life cycle inventory of tin ingot to fairly account for the co-products.

Table 1: Summary of co-product treatment methods

Process	Co-products	Treatment method
Smelting and copper refining	Copper anodes Blister/Impure copper anodes	Mass allocation
Lead and tin refining	Lead Lead Antimony alloy	Mass allocation

Sensitivity

No sensitivity check was performed in the 2022 study.

Data quality

Data quality is judged by its completeness, reliability, consistency, and representativeness. To cover these requirements and to ensure reliable results, specific primary data in combination with consistent background LCA information from the MLC database 2023.1 were used.

Completeness: Data has been collected for all relevant processes. To ensure data consistency, all primary data were collected with the same level of detail. Each unit process was checked for mass balance and completeness of the emission inventory.

Reliability: All gate-to-gate data for the Aurubis production sites have been collected from verified sources and measured data such as emission declarations, and technical and metal balances.

Representativeness: The primary data were collected for the 2022 calendar year. All secondary data come from the MLC database 2023.1 and are representative of the years 2019-2023. The data represented the technological and geographical location of the operations. All primary and secondary data were collected specifically for the countries or regions under study and were modelled to be specific to the technologies under study. Where country /region-specific or technology-specific data were unavailable, proxy data were used.

The LCA model was created using the LCA For Expert Software system for Life Cycle Assessment, developed by Sphera Solutions GmbH. The MLC database 2023.1 provides the life cycle inventory data for all background data including materials and energy/electricity.

Life Cycle Impact Assessment

The key environmental aspects were assessed with the Environmental Footprint impact assessment method (3.0) along 16 impact categories.

The Environmental footprint method (3.0) is the most advanced impact assessment method adopted by the European Commission. The previous version of our LCA study used the now-outdated characterization method from the Centre for Environmental Studies (CML) at Leiden University in the Netherlands. For comparability throughout this transition, both CML and EF 3.0 impact assessment methods were reported in last year's life cycle assessment.

The following key impact categories were selected because they represent a broad range of relevant environmental impacts and are each determined by a well-established scientific approach: Global warming potential, Acidification potential, Eutrophication potential, Photochemical Ozone creation potential, Resource use fossil, and Water use.

Results for all 16 indicators are included in the report. However, it is important to note that "abiotic depletion potential" and "toxicity" impacts are not sufficiently robust and accurate to be used for metals.

Table 2: Life Cycle Assessment Impact Categories

Impact Category	Description
Global Warming Potential	A measure of greenhouse gas emissions, such as CO_2 and methane. These emissions are causing an increase in the absorption of radiation emitted by the earth, increasing the natural greenhouse effect. This may in turn have adverse impacts on ecosystem health, human health and material welfare.
Eutrophication Potential	Eutrophication covers all potential impacts of excessively high levels of macronutrients, the most important of which nitrogen (N) and phosphorus (P). Nutrient enrichment may cause an undesirable shift in species composition and elevated biomass production in both aquatic and terrestrial ecosystems. In aquatic ecosystems increased biomass production may lead to depressed oxygen levels, because of the additional consumption of oxygen in biomass decomposition.
Acidification Potential	A measure of emissions that cause acidifying effects to the environment. The acidification potential is a measure of a molecule's capacity to increase the hydrogen ion (H+) concentration in the presence of water, thus decreasing the pH value. Potential effects include fish mortality, forest decline and the deterioration of building materials.
Photochemical Ozone Formation	A measure of emissions of precursors that contribute to ground level smog formation (mainly ozone O_3), produced by the reaction of VOC and carbon monoxide in the presence of nitrogen oxides under the influence of UV light. Ground level ozone may be injurious to human health and ecosystems and may also damage crops.
Ressource use, fossil	A measure of the total amount fossil resources non-renewable (e.g., petroleum, natural gas, etc.) extracted from the earth used for the primary energy production.
Water use	Deprivation water consumption.

Study Results

The life cycle impact results for the key impact categories and the contributions of different activities for the tin ingot for the reference year 2021 and 2022 are presented below. The impacts are split to analyze contributions from direct emissions, transports, purchased electricity and auxiliary materials.

Figure 1: Results for 1 ton of Aurubis Beerse Tin ingot (2021) and (2022), (Environmental footprint EF 3.0)

Table 3: Results for 1 ton of Aurubis Beerse tin ingot (2022), (Environmental footprint EF 3.0)

Acidification	Mole of H+ eq./t Sn	1.02E+01
Climate Change - total	kg CO_2 eq./t Sn	1.400E+03
Climate Change, biogenic	kg CO_2 eq./t Sn	1.16E+01
Climate Change, fossil	kg CO2 eq./t Sn	1.39E+03
Climate Change, land use and land use change	kg CO_2 eq./t Sn	2.75E-01
Ecotoxicity, freshwater - total	CTUe/t Sn	1.68E+04
Ecotoxicity, freshwater inorganics	CTUe/t Sn	4.39E+03
Ecotoxicity, freshwater metals	CTUe/t Sn	1.23E+04
Ecotoxicity, freshwater organics	CTUe/t Sn	1.36E+02
Eutrophication, freshwater	kg P eq./t Sn	6.00E-03
Eutrophication, marine	kg N eq./t Sn	1.43E+00
Eutrophication, terrestrial	Mole of N eq./t Sn	1.53E+01
Human toxicity, cancer - total	CTUh/t Sn	8.85E-07
Human toxicity, cancer inorganics	CTUh/t Sn	5.40E-16
Human toxicity, cancer metals	CTUh/t Sn	5.38E-07
Human toxicity, cancer organics	CTUh/t Sn	3.47E-07
Human toxicity, non-cancer - total	CTUh/t Sn	6.51E-05
Human toxicity, non-cancer inorganics	CTUh/t Sn	5.95E-06
Human toxicity, non-cancer metals	CTUh/t Sn	5.91E-05
Human toxicity, non-cancer organics	CTUh/t Sn	1.93E-07
Ionising radiation, human health	kBq U235 eq./t Sn	8.29E+02
Land Use	Pt/t Sn	1.43E+04
Ozone depletion	kg CFC-11 eq./t Sn	3.87E-08
Particulate matter	Disease incidences/t Sn	8.67E-05
Photochemical ozone formation, human health	kg NMVOC eq./t Sn	4.04E+00
Resource use, fossils	MJ/t Sn	6.00E+04
Resource use, mineral and metals	kg Sb eq./t Sn	3.33E-04
Water use	m^3 world equiv./t Sn	2.58E+02

Interpretation

Tin ingot is produced in Aurubis Beerse completely from secondary raw materials. The environmental impact of tin is mainly driven by the purchased electricity, transport, and direct emissions.

For the Carbon footprint /Global warming potential, the emissions from purchased electricity are the most significant contributor. Emissions from transport also play an important role. Direct emissions have a smaller contribution.

The Primary energy demand included non-renewable energy resources for fuel production and electricity generation.

For the Acidification potential, results are mainly driven by the transport and direct SO_2 emissions from smelting, as well as SO_2 emissions from purchased electricity.

Results for Eutrophication potential are driven by NOx emissions associated with diesel combustion, during the transport of raw materials to the smelter.

Results for Photochemical Ozone creation potential are mainly driven by direct SO_2 emissions from smelting, as well as SO_2 emissions from purchased electricity.

Water use is mainly driven by direct production activities and purchased electricity.

Conclusion

The goal of the study was to evaluate the environmental profile of Tin and allow tracking of the progress and further improvement.

The environmental impacts of Aurubis Tin ingot are significantly lower than the global industry average from the International Tin Association[2] for all impact categories.

The results for water use for 2022 cannot be compared with the 2021 results because of different modeling of rain water and application of regionalized flows.

The carbon footprint of Aurubis Tin of 1,400 kg CO_2/t Tin is significantly lower than the footprint of the industry average of 6,632 kg CO_2/t Tin and lower than last year's Aurubis Tin carbon footprint of 1,620 kg CO_2/t.

This is because the recycling process of the Aurubis plant in Beerse enabled it to valorize complex non-ferrous materials by returning Tin and other metals back into the value chain. We combined innovative technology and know-how to minimize the impact of our activities on the environment and climate and preserve natural resources.

We invested in energy-efficient and low-carbon technologies at all sites across Aurubis Group and implemented measures to save energy, facilitated the switch to renewable energy.

The updated environmental impact of Aurubis Tin for 2022 is lower than the profile from 2021 for most of the impact categories.

This is mainly due to lower impact from transport and continuous efforts for the reduction of direct emissions of pollutants such as sulfur dioxide and dust as well as greenhouse gas emissions.

At the same time, our recycling as well as the efficiency of metal recovery has an important role in the results of our life cycle assessment.

The recycled content of tin produced by Aurubis Beerse is 94 %.

[2] International Tin Association, Life cycle assessment of average tin production, ref. year 2020

Critical review

An independent, external auditor reviewed the methodology, data quality, and modeling aspects of the study.

Name and contact information of the auditors:

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Alejandro Ibanez Cuesy

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The review was performed according to ISO 14040 (2021) and ISO 14044 (2021).

Note: The Certificate of Validity can be found as an Annex to this document.

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CERTIFICATE OF VALIDITY

DIN EN ISO 14040:2021 / DIN EN ISO 14044:2021
(product-related life cycle assessment - LCA)

Evidence that the application conforms to the regulations was delivered, and is herewith certified according to the TÜV NORD CERT Prüf- und Umweltgutachtergesellschaft mbH - procedure for

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Range of application

Life Cycle Assessment „Production of Tin“ (Vers. 3, 12/04/2023)

The requirements of the above-mentioned standards were evidently fulfilled by a critical review with regard to

- the scientifically justified and technically valid methods used in carrying out the LCA;
- the appropriateness of the data used in relation to the objective of the study;
- the consideration of the objective of the LCA and the identified limitations in the interpretations.

The LCA report (Ref: Production of Tin 12/04/2023) is transparent and self-consistent.

This declaration of validity refers exclusively to the functional unit at point in time of the LCA report.

Report No. 3536 1273-5

TÜV NORD CERT Prüf- und Umweltgutachtergesellschaft mbH

Hannover, 2023-12-05

Mr. Dr. Hirtz
Environmental verifier