



On behalf of Hindustan Zinc Limited

Product Carbon Footprint of Average Special High Grade Zinc (SHGZ) Product and Average Low Carbon Special High Grade Zinc (SHGZ)

Client: Hindustan Zinc Limited (HZL)

Title: Product Carbon Footprint of Average Special High-Grade Zinc (SHGZ) Product and Average Low Carbon Special High-Grade Zinc (SHGZ) Product

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List of Acronyms

CSC	Chanderiya Smelting Complex
DSC	Dariba Smelting Complex
GHG	Greenhouse Gas
GWP	Global Warming Potential
HZL	Hindustan Zinc Limited
ISF	Imperial Smelting Furnace
ISO	International Organization for Standardization
KM	Kayd Mines
LCA	Life Cycle Assessment
LCI	Life Cycle Inventory
LCIA	Life Cycle Impact Assessment
LUC	Land Use Change
PCF	Product Carbon Footprint
PMP	Pantnagar Metal Plant
RAM	Rampura Agucha Mines
RDM	Rajpura Dariba Mines
SHGZ	Special High-Grade Zinc
SKM	Sindesar Khurd Mines
ZM	Zawar Mines
ZSD	Zinc Smelter Debari

Glossary

Carbon footprint of a product (CFP):

Sum of greenhouse gas emissions and removals in a product system, expressed as CO₂ equivalents and based on a life cycle assessment using the single impact category of climate change.

Life Cycle

A view of a product system as “consecutive and interlinked stages ... from raw material acquisition or generation from natural resources to final disposal” (ISO 14040:2006, section 3.1). This includes all material and energy inputs as well as emissions to air, land and water.

Life Cycle Assessment (LCA)

“Compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle” (ISO 14040:2006, section 3.2)

Life Cycle Inventory (LCI)

“Phase of life cycle assessment involving the compilation and quantification of inputs and outputs for a product throughout its life cycle” (ISO 14040:2006, section 3.3)

Life Cycle Impact Assessment (LCIA)

“Phase of life cycle assessment aimed at understanding and evaluating the magnitude and significance of the potential environmental impacts for a product system throughout the life cycle of the product” (ISO 14040:2006, section 3.4)

Life Cycle Interpretation

“Phase of life cycle assessment in which the findings of either the inventory analysis or the impact assessment, or both, are evaluated in relation to the defined goal and scope in order to reach conclusions and recommendations” (ISO 14040:2006, section 3.5)

Functional Unit

“Quantified performance of a product system for use as a reference unit” (ISO 14040:2006, section 3.20)

Allocation

“Partitioning the input or output flows of a process or a product system between the product system under study and one or more other product systems” (ISO 14040:2006, section 3.17)

Closed-loop and Open-loop Allocation of Recycled Material

“An open-loop allocation procedure applies to open-loop product systems where the material is recycled into other product systems and the material undergoes a change to its inherent properties.”

“A closed-loop allocation procedure applies to closed-loop product systems. It also applies to open-loop product systems where no changes occur in the inherent properties of the recycled material. In such cases, the need for allocation is avoided since the use of secondary material displaces the use of virgin (primary) materials.”

(ISO 14044:2006, section 4.3.4.3.3)

Foreground System

“Those processes of the system that are specific to it ... and/or directly affected by decisions analysed in the study.” (JRC, 2010, p. 97) This typically includes first-tier suppliers, the manufacturer itself and any downstream life cycle stages where the manufacturer can exert significant influence. As a general rule, specific (primary) data should be used for the foreground system.

Background System

“Those processes, where due to the averaging effect across the suppliers, a homogenous market with average (or equivalent, generic data) can be assumed to appropriately represent the respective process ... and/or those processes that are operated as part of the system but that are not under direct control or decisive influence of the producer of the good....” (JRC, 2010, pp. 97-98) As a general rule, secondary data are appropriate for the background system, particularly where primary data are difficult to collect.

Third Party Review

“Process intended to ensure consistency between a product carbon footprint and the principles and requirements of the International Standards on product carbon footprint and life cycle assessment” (ISO 14067:2018 and ISO 14044:2006).

1. Goal of the Study

Hindustan Zinc, a Vedanta Group company in Zinc-Lead and Silver business is world's 2nd largest integrated Zinc producer and now the 3rd largest Silver producer. The company has a market share of ~75% of the growing Zinc market in India with its headquarters at Zinc City, Udaipur along with Zinc-Lead mines and smelting complexes spread across the state of Rajasthan.

Hindustan Zinc is self-sufficient in power with captive thermal power plants and has ventured into green energy by setting-up wind power plants. The company ranked first in the S&P Global Corporate Sustainability Assessment in 2023 amongst Metals & Mining companies reflecting & reaffirming its constant commitment towards sustainable and responsible mining practices. Hindustan Zinc is a certified Water Positive company. Hindustan Zinc is also the only Indian company in Mining sector with validated & approved SBTi targets in alignment with 1.5 °C target.

The company takes pride in having some of the best-in-class people practices and employee-centric initiatives, which have certified Hindustan Zinc as – 'Great Place to Work 2023', 'Company with Great Managers 2022' by People Business and the 'People-first HR Excellence Award'. Along with that, Hindustan Zinc has been recognized with the coveted CII HR Excellence Award, leading in HR innovation with a 600+score.

As a socially responsible corporate, Hindustan Zinc has been relentlessly working towards transforming lives of 1.9 million people in 3,685 villages in the states of Rajasthan and Uttarakhand with a spend base of INR 269.3 crores in FY24 for various community development initiatives and is amongst the Top 10 CSR Companies in India. Learn more about Hindustan Zinc on – <https://www.hzindia.com/home/>

The goal of this study is to assess the product carbon footprint (PCF) of Average Special High-Grade Zinc (SHGZ) Product and Average Low Carbon Special High-Grade Zinc (SHGZ) Product following a “cradle to gate” approach as per ISO 14067: 2018 standard and GHG Protocol Product Life Cycle Accounting and Reporting Standard (the GHG Protocol Standard).

Hindustan Zinc Limited (HZL), the world's largest integrated Zinc-Lead producer; and one of the lowest cost producers in the world has able to produce and supply a Special High-Grade Zinc (SHGZ) with a low carbon footprint.

The objective of the study is to assess and allocate the quantity of low carbon special high-grade zinc (SHGZ) product to the actual production of conventional special high-grade zinc (SHGZ) produced at HZL. This evaluation is based on mass balance approach with the allocation of the gradual increase of renewable electricity projects implemented to source electricity in the electricity mix of HZL over the next two financial years. Mass balance approach is a method of assigning specified characteristics of input materials to outputs/products when mixing raw materials of different characteristics, in general. HZL utilizes the mass balance approach in the form of pooling GHG or CO₂ emission reductions from reduction projects within the organization and allocating the reductions to low carbon SHG zinc product to be supplied along with certificate.

The further objective is to identify the main contributors to Global Warming Potential (GWP) impacts in the value chain of the product. This is a comprehensive cradle to gate analysis of production of 1 tonne of Average Special High Grade Zinc (SHGZ) product and 1 Tonne of Average Low Carbon Special High-Grade Zinc (SHGZ) Product manufactured at various location in India (HZL have smelting facilities located in Dariba, Debari and Chanderiya, and mining facilities located in Rampura Agucha, Sindesar Khurd, Rajpura Dariba, Kayad and Zawar in the state of Rajasthan, India along with zinc-lead processing & refining and a silver refinery at Pantnagar in the state of Uttarakhand, India). The LCI data consists of the total inputs and outputs of the product system for the year 2023-24 (e.g., carbon dioxide emissions); while the Life Cycle Impact Assessment (LCIA) uses the LCI data to assess Global Warming Potential (GWP). Consistent methodology and modelling have been used for this study and are specific to Average Special High-Grade Zinc (SHGZ) product manufacturing in India (HZL).

The study covers the cradle to gate system boundary which includes production of raw materials, upstream transportation, and manufacturing processes at the HZL's different sites.

Hindustan Zinc Limited (HZL), has entrusted Sphera Solutions to carry out the Product Carbon Footprint of Average Special High-Grade Zinc (SHGZ) product and Average Low Carbon Special High-Grade Zinc (SHGZ) product as per ISO 14067:2018 Greenhouse gases - Carbon footprint of products – Requirements and guidelines for quantification standard, GHG Protocol - Product life cycle accounting and reporting standard (the GHG Protocol Standard) and International Zinc Association (IZA) guidance over the cradle to gate system boundary.

The intended audience for this study includes HZL management, operational and marketing departments, and other internal stakeholders. HZL will use the information from this study in an aggregated manner for public communications, to develop marketing materials for potential customers.

This technical report will not be publicly available but can be made accessible to interested parties upon request to the study commissioner (HZL). The study commissioner may use the study report to prepare and provide information materials, e.g., a technical summary of the report, an article, a flyer addressing the major outcomes of the study, etc.

A third-party review of the study according to ISO 14067:2018 Greenhouse gases - Carbon footprint of products – Requirements and guidelines for quantification standard and GHG Protocol - Product life cycle accounting and reporting standard (the GHG Protocol Standard) has been carried out by independent reviewer. The details of the reviewer are as follows:

- Dr. Hüdai Kara, PhD, Managing Director, Metsims Sustainability Consulting, UK.

The final review statement is documented in Annex A: Third Party Review of the report.

For more information on the HZL, readers can visit: <https://www.hzlindia.com/home/>

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2. Scope of the Study

The following sections describe the general scope of the project to achieve the stated goals. This includes, but is not limited to, the identification of specific product systems to be assessed, the product function(s), functional unit and reference flows, the system boundary, allocation procedures, and cut-off criteria of the study.

2.1. Product System

The scope covers the ecological information to be divided into raw material production, transportation, and special high grade zinc production. The raw material production includes the raw material extraction, production of the raw materials and auxiliary materials. The production contains the supplier's manufacturing and the in-house manufacturing processes. The transportation includes transport of raw materials from supplier to the factory gate. The zinc production includes the manufacturing of Special High-Grade Zinc (SHGZ) product at various unit of HZL.

The scope of study covers the following sites:

- Dariba Smelting Complex (DSC),
- Chanderiya Smelting Complex (CSC)
- Zinc Smelter Debari (ZSD)
- Pantnagar Metal Plant (PMP)
- Captive mines - Rajpura Dariba Mine (RDM), Sindesar Khurd Mine (SKM), Rampura Agucha Mines (RAM), Zawar Mines (ZM) and Kayad Mines (KM).

Hindustan Zinc Limited manufactures the zinc product predominantly by two process routes i.e. hydrometallurgical zinc smelting route and pyro-metallurgical zinc smelting route which are conformed to BS EN, ASTM and IS standards.

2.1.1. Special High-Grade Zinc (SHGZ) Production Process

There are two main processes used to produce SHG zinc from zinc concentrate and zinc containing wastes, hydrometallurgical zinc smelting and pyro-metallurgical zinc smelting. Worldwide, hydrometallurgical smelting produces over 95% of refined zinc.

Zinc Concentrate Production Process

Zinc concentrate production involved three major processes: mining, comminution, and flotation. Often, the last two processes are collectively called beneficiation.

Mining

Access is via vertical shafts or inclined roadways. There are usually two access routes (one for mining personnel and materials and one for the ore) for safety and for ease of ventilation (fresh air comes in one and is then exhausted out of the other). Once the correct depth has been reached, horizontal tunnels are driven to reach the ore deposit. These are often temporary, so the support requirements are less substantial. Transport for personnel and materials can be by train, truck, or conveyor belts. The largest share of the consumed fuels is diesel followed by electricity. Other major inputs include explosives and water.

Beneficiation (comminution and flotation)

Zinc ore is milled to recover a fine concentrate by gravity and elutriation techniques. During this process, the ore is milled and mixed with water. The separation process of the metal is realized through the addition of various floatation chemicals. The Figure 1 below shows the flow diagram of zinc concentrate production.

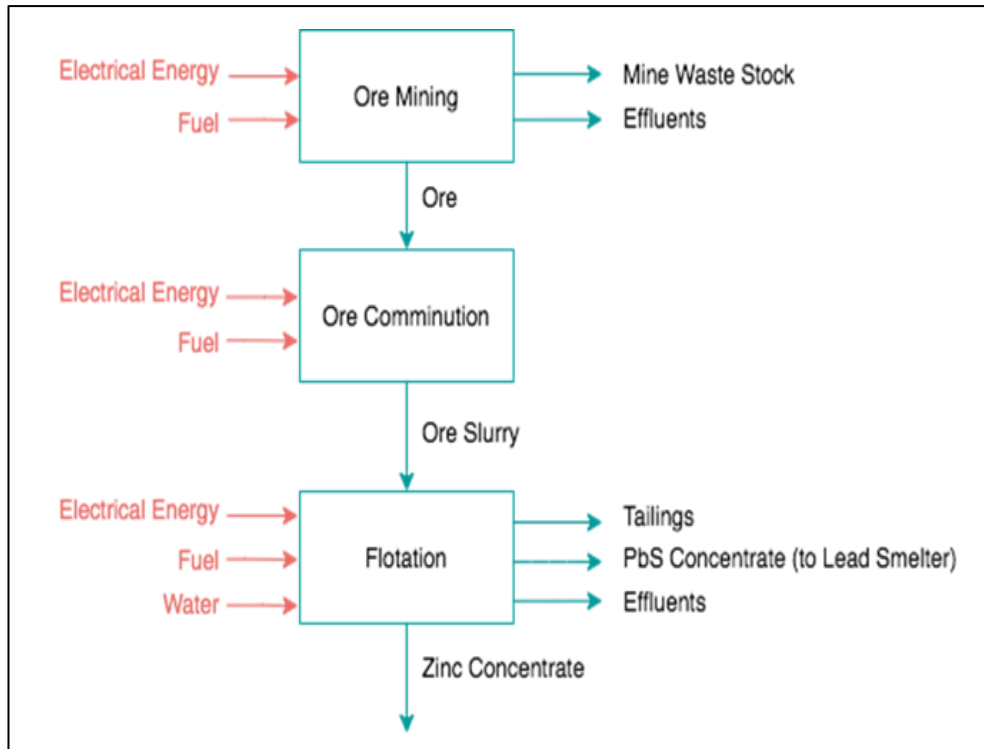


Figure 1 Flow Diagram for Zinc Concentrate Production

Hydrometallurgical zinc smelting

The main unit processes for hydrometallurgical zinc smelting are roasting, leaching, purification, electrolysis, and melting. In both hydrometallurgical and pyro-metallurgical zinc production routes, the first step is to remove the sulfur from the concentrate. Roasting or sintering achieves this. The concentrate is heated in a furnace with operating temperature above 900 °C (exothermic, autogenous process) to convert the zinc sulfide to calcine (zinc oxide). Simultaneously, sulphur reacts with oxygen to produce sulphur dioxide, which is subsequently converted to sulfuric acid in acid plants, usually located with zinc-smelting facilities.

During the leaching process, the calcine is dissolved in dilute sulfuric acid solution (re-circulated back from the electrolysis cells) to produce aqueous zinc sulphate solution. The iron impurities dissolve as well and are precipitated out as jarosite or goethite in the presence of calcine and possibly ammonia. Jarosite and goethite are usually disposed of in tailing ponds. Adding zinc dust to the zinc sulphate solution facilitates purification. The purification of leachate leads to precipitation of cadmium, copper, and cobalt as metals. In electrolysis, the purified solution is electrolyzed between lead alloy anodes and aluminium cathodes. The high-purity zinc deposited on aluminium cathodes is stripped off, dried, melted, and cast into SHG zinc ingots (99.99 % zinc). Figure 2 below shows flow diagram of zinc smelting process via hydrometallurgical smelting.

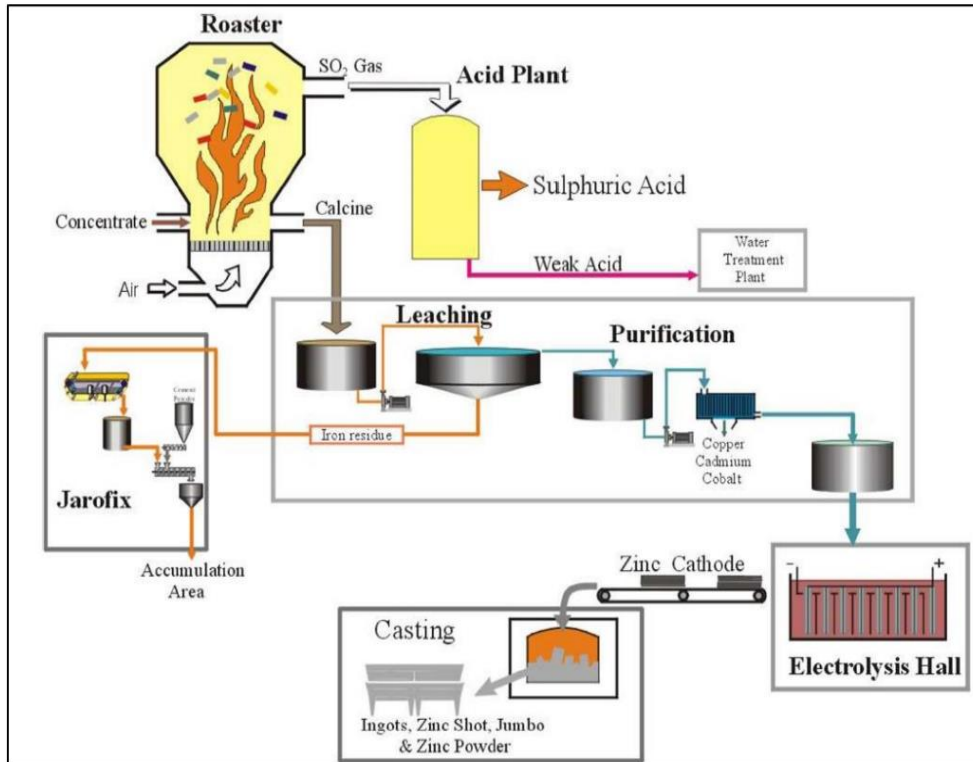


Figure 2 Flow Diagram of SHGZ Production via Hydrometallurgical Smelting

Pyro-metallurgical smelting

For pyro-metallurgical smelting sites, boundary conditions for the following unit processes were similar to the hydrometallurgical system: sintering, imperial smelting furnace, and refining. The pyro-metallurgical smelting process is based on the reduction of zinc and lead oxides into metal with carbon in an imperial smelting furnace. The sinter, along with pre-heated coke, is charged from the top of the furnace and injected from below with pre-heated air. This ensures that temperature in the center of the furnace remains in the range of 1000–1500 °C. Figure 3 below shows flow diagram special high-grade zinc production via pyrometallurgical smelting.

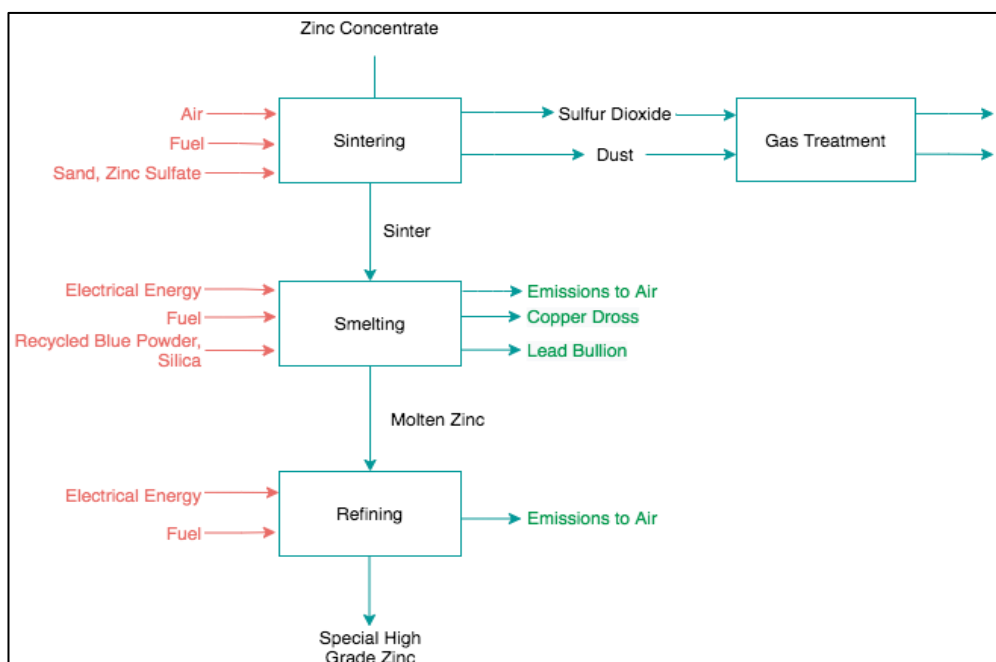


Figure 3 Flow Diagram of SHGZ Production via Pyrometallurgical Smelting

2.1.2. Low Carbon Special High-Grade Zinc (SHGZ) Production Process

Zinc mining and smelting activities are known to generate significant amounts of greenhouse gas emissions. Hindustan Zinc Limited (HZL), the world's largest integrated Zinc-Lead producer; and one of the lowest cost producers in the world has able to produce and supply a Special High-Grade Zinc (SHGZ) with a low carbon footprint through introduction of more renewable electricity in the overall electricity mix required to produce zinc. This low carbon footprint SHG zinc is also produced via hydrometallurgical and pyrometallurgical route at various location of HZL as described in Section 2.1.1.

HZL has produced low carbon special high-grade zinc by using allocation of 100% renewable electricity at their mines (RAM, RDM, SKM, KM, and ZM), smelters (CSC, DSC and ZSD) and melting & casting plant (PMP) to the apportioned production of zinc product, which has GWP, fossil GHG emissions less than 1 t-CO₂ eq. per tonne of SHG Zinc.

This calculation reflects the actual emissions generated from the electricity source that a company has purposefully chosen, such as renewable energy with Guarantees of Origin (GoO) certificates and supplier certificate. Firstly, inventory of baseline data 2023-24 has been prepared along with the actual electricity mix with details of sourcing of renewable electricity and captive electricity mix. Then based on the baseline data, GHG emission intensity (product carbon footprint) for 1 tonne of Special High-Grade Zinc has been calculated for a cradle to gate system boundary applying ISO 14067 standard. The percentage (%) renewable electricity in electricity consumption (mix) to the average special high grade zinc product has been calculated for baseline of FY 2023-24 and then percentage (%) of average low carbon special high-grade zinc (SHGZ) production has been calculated based on percentage (%) renewable electricity in electricity mix based mass balance approach for HZL. Further details about mass balance approach are given in the [Section 4.3](#) of the report.

2.2. Product Function and Functional Unit

Zinc product is used as raw material in various industries such as construction, steel, alloys, pharmaceutical, fertilizers etc. With each application the functional unit may differ depending on the actual function of the product.

The functional unit is a reference for the product whose lifecycle impact is being assessed. The functional unit allows quantification of the environmental impacts of the product over cradle-to-gate. These environmental impacts are calculated based on the functional unit wherein each flow related to material consumption, energy consumption, emissions, effluent, and waste is scaled to the reference flow.

The functional unit is 1 tonne (1000 kg) of Average Special High-Grade Zinc (SHGZ) product.

The functional unit is 1 tonne (1000 kg) of Average Low Carbon Special High-Grade Zinc (SHGZ) product.

2.3. System Boundary

The PCF model for the study represents a Cradle-to-Gate approach. This includes production of raw materials, upstream transportation, manufacturing process, electricity and steam generation within HZL's facilities for special high-grade zinc (SHGZ) production. Figure 4 shows the system boundary for the study.

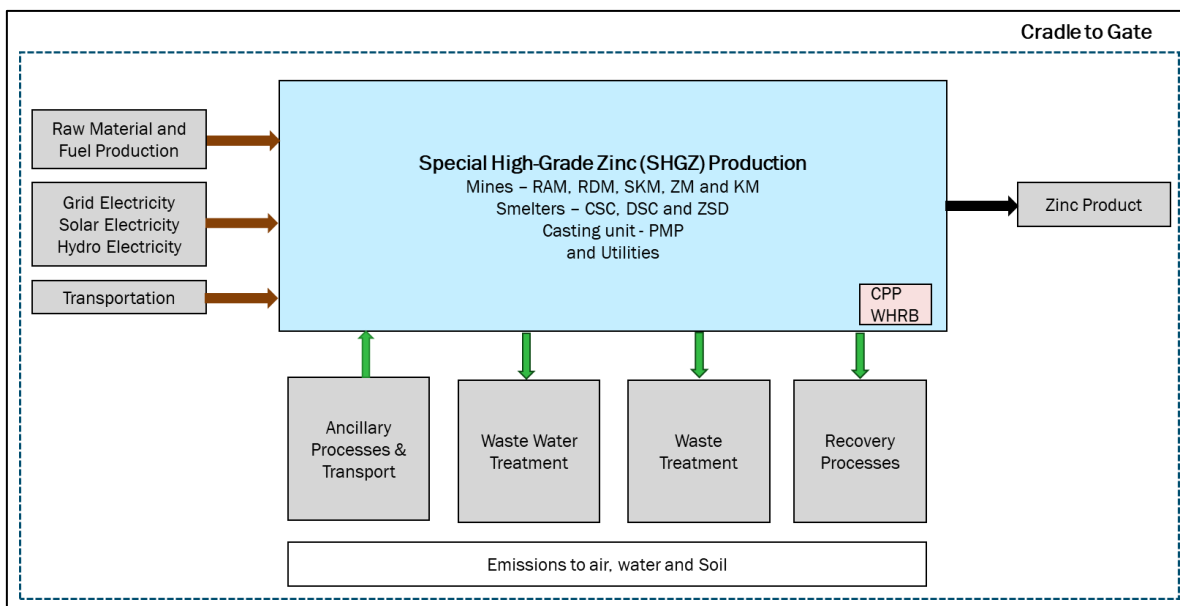


Figure 4 System Boundary for Special High-Grade Zinc (SHGZ) Production

The Table 1 below describes the Inclusion in the system boundary and exclusion as a cut-off are defined for our study.

Table 1 Inclusions and Exclusions in System Boundary

Included	Excluded
<ul style="list-style-type: none"> ✓ Acquisition of raw materials ✓ Upstream Transport of raw materials ✓ Manufacturing processes including mining, milling, roasting, leaching & purification, electrolysis, melting & casting, sintering, imperial smelting furnace, zinc recovery process, utilities etc. 	<ul style="list-style-type: none"> ✗ Human labour ✗ Construction of equipment ✗ Maintenance and operation of support equipment ✗ Services

2.3.1. Time Coverage

The data collection is related to one year of operation. All data were collected for the year 2023-24 (FY2024) and is believed to be representative of Average Special High Grade Zinc production at HZL, India during this time frame.

2.3.2. Technology Coverage

The exact technological configuration was used for the various process operation of its plants for efficient performance in production and minimizing environmental impacts. It was assumed that secondary data from databases that were used for this assessment, were temporally and technologically comparable to that of primary data and within the temporal coverage already addressed.

The LCI data for production is collected as 12-month averages representing the year 2023-24 to compensate seasonal influence of data. Background data have reference years between 2020 and 2023 - for electricity and thermal energy processes this is 2020. The dataset is valid until substantial technological changes in the production chain occurs.

2.3.3. Geographical Coverage

The geographical coverage of this study covers the average special high-grade zinc (SHGZ) product at HZL's various sites. Indian boundaries wherever possible have been adapted and other dataset were chosen from global and EU if no Indian datasets were available. In addition, raw materials imported from other geographies are also applied in this study.

2.4. Allocation

2.4.1. Multi-output Allocation

The GHG Protocol Standard recommends that companies consider various techniques, such as process subdivision, to minimize the use of allocation in the product inventory. When allocation becomes unavoidable, the GHG Protocol Standard recommends that companies allocate emissions based on the underlying physical relationships between the product and co-products.

Multi-output allocation applied follows the requirements of ISO 14044, section 4.3.4.2. Allocation is applied to arrive at impacts of Special High Grade Zinc Production. The allocation of zinc and lead in the concentrates coming from RAM, SKM, ZM, RDM and KM has been calculated using percentage metal content in concentrate, provided by HZL. Details about metal content of concentrate is given in Table 2 below.

The allocation of zinc sulphate and purification cake in the smelting process, Lead bullion and furnace zinc produced from Imperial Smelting Furnace, zinc ingot and hard zinc produced in the zinc refining process (Table 3) has been calculated using percentage metal content provided by HZL. While price allocation is applied between zinc calcined and sulphuric acid produced from roasting plant. Details about price allocation of zinc calcined and sulphuric acid is given in the Table 4 below.

Table 2 Metal Content of Concentrate

Metal Content				
Sites	Zinc concentrate		Lead concentrate	
	Zinc (%)	Lead (%)	Zinc (%)	Lead (%)
RAM+KM	50.62%	6.87%	1.31%	61.70%
RDM	45.02%	2.31%	5.14%	30.30%
SKM	47.73%	2.37%	5.29%	57.48%
ZM	52.00%	1.79%	4.54%	63.88%

Table 3 Metal Content of Zinc and Lead Products for Allocation - CSC Pyro

CSC – (Pyrometallurgical)		
Process	Product(s)	Metal Content
Imperial Smelting Furnace (ISF)	Furnace Zinc	~99.9%
	Lead Bullion	~99.1%
Zinc Recovery Process (ZRP)	SHG Zinc	~99.99%
	Hard Zinc	~92.30%

Table 4 Price Allocation of Zinc Calcined and Sulphuric Acid

Price Allocation (%)					
Process	Product(s)	CSC H1	CSC H2	DSC	ZSD
Roasting + Acid Plant	Sulphuric Acid	07.8%	07.2%	10.2%	07.6%
	Zinc Calcined	92.2%	92.8%	89.8%	92.4%

Allocation procedure-

ISO 14044:2006 says, in cases such as the integrated zinc making process (namely the concentrate production, smelting process, and zinc refining) where a process has more than one product, the allocation procedure must be applied. Further the standard gives following guidelines to apply allocation in LCA.

Step 1: Wherever possible allocation should be avoided by:

- dividing the unit process to be allocated into two or more sub-processes and collecting the input and output data related to these sub-processes, or
- expanding the product system to include the additional functions related to the co-products.

Step 2: Where allocation cannot be avoided, the inputs and outputs of the system should be partitioned between its different products or functions in a way that reflects the underlying physical relationships between them, i.e. they should reflect the way in which the inputs and outputs are changed by quantitative changes in the products or functions delivered by the system.

Step 3: Where physical relationship alone cannot be established or used as the basis for allocation, the inputs should be allocated between the products and functions in a way that reflects other relationships between them. For example, input and output data might be allocated between co-products in proportion to the economic value of the products.

Allocation of background data (energy and materials) taken from the Sphera 2024 databases (Managed LCA Content – 2024) is documented online (Sphera Solutions Inc., 2024) <https://sphera.com/life-cycle-assessment-lca-database/>.

2.5. Cut-off Criteria

In the foreground processes, all relevant flows are considered, with no significant cut-off of material and energy flows. As summarized in section 2.3, the system boundary was defined based on relevance to the goal of the study. 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.

No cut-off criteria were considered for average special high grade zinc product in this study.

2.6. Data Quality Requirements

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.
- 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, emission factors, or other artefacts.
- 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 can 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.

2.7. Type and Format of the Report

In accordance with the ISO requirements (ISO, 2006) this document aims to report the results and conclusions of the PCF completely, accurately and without bias to the intended audience. The results, data, methods, assumptions, and limitations are presented in a transparent manner and in sufficient detail to convey the complexities, limitations, and trade-offs inherent in the PCF to the reader. This allows the results to be interpreted and used in a manner consistent with the goals of the study.

2.8. Software and Database

The PCF model was created using the LCA FE 10.7 Software (formerly known as GaBi) system for life cycle engineering, developed by Sphera Solutions Inc. The Sphera 2024.1 LCI database provides the life cycle inventory data for several of the raw and process materials obtained from the background system.

2.9. Third Party Review

In accordance with ISO 14067:2018 Greenhouse gases - Carbon footprint of products – Requirements and guidelines for quantification standard and GHG Protocol - Product life cycle accounting and reporting standard (the GHG Protocol Standard), a review of this study is undertaken by an independent external reviewer to ensure conformity with standards. As such a review is not imperative, since there are no comparative assertions intended to be made to the public. However, to communicate the PCF outcomes internally and externally and to achieve high level of independence and credibility, a third-party review of a single external reviewer has been commissioned.

To decrease the likelihood of misunderstandings or negative effects on external interested parties, an independent reviewer conducted the review on PCF studies where the results were intended to be used and disclosed to the public. Because the study was intended to support external communications, a third-party review was conducted.

The third-party review statement is given in Annex A of the report.

3. Life Cycle Inventory Analysis

3.1. Data Collection Procedure

Primary data were collected using customised data collection templates, which were sent out by email to the respective data providers in the HZL units. Upon receipt, each questionnaire was cross-checked for completeness and plausibility using mass balance, stoichiometry, as well as internal and external benchmarking. If gaps, outliers, or other inconsistencies occurred, Sphera engaged with the data provider to resolve any open issues.

Wherever feasible, the coefficient of variation was established for the different inputs and outputs, either across different data providers or across the reported time-period if a breakdown into smaller increments (e.g., 12 months) was available.

3.2. Product System

3.2.1. Overview of Product System

For the considered product, LCA FE models for production of special high-grade zinc representing the Cradle to Gate life cycle perspective were prepared as explained in the following sub-sections.

3.2.2. Raw Material

Life Cycle Inventory for special high grade zinc production is given in Annex B1: LCI (Confidential data)

3.2.3. Manufacturing phase

The PCF model for 1 tonne of average special high grade (SHGZ) production was set up in LCA FE 10.7 LCA software tool. A Cradle to Gate model was created to generate results by feeding the 2023-24 production data. Figure 5 below shows the LCAFE model snapshot for average special high grade zinc production.

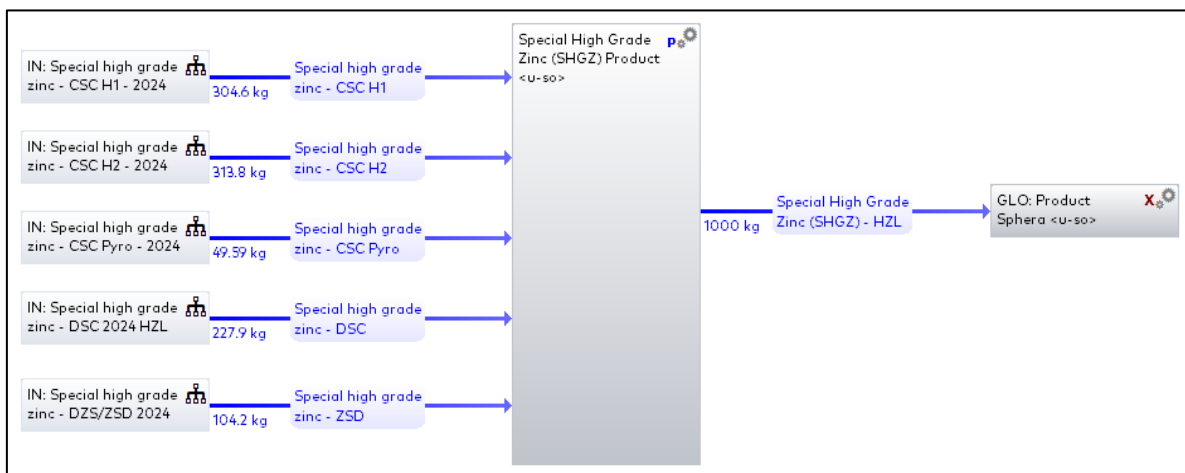


Figure 5 Cradle-to-Gate LCA FE Snapshot for Average Special High-Grade Zinc (SHGZ) Production

Details about mines, smelting complex and casting unit of HZL is given in the Table 5 below:

Table 5 Details of Mines, Smelter and Casting Facilities of HZL

Site Name	Processes	Product(s)
Rampura Agucha Mines (RAM) + Kayad Mines (KM)	Mining & Milling	Zinc concentrate, Lead concentrate
Rajpura Dariba Mines (RDM)	Mining & Milling	Zinc concentrate, Lead concentrate
Sindesar Khurd Mines (SKM)	Mining & Milling	Zinc concentrate, Lead concentrate
Zawar Mines (ZM)	Mining & Milling	Zinc concentrate, Lead concentrate
Chanderiya Smelting Complex (CSC)	Smelting & Casting	Zinc cathode and Zinc Ingot (SHGZ)
Dariba Smelting Complex (DSC)	Smelting	Zinc cathode
Zinc Smelter Debari (ZSD)	Smelting & Casting	Zinc cathode and Zinc Ingot (SHGZ)
Pantnagar Metal Plant (PMP)	Melting & Casting	Zinc Ingot (SHGZ)
Captive Power Plant - CSC	Power generation	Electricity
Captive Power Plant - DSC	Power generation	Electricity
Captive Power Plant - ZM	Power generation	Electricity

3.2.4. Use

Not in the scope of this study.

3.2.5. End-of-Life

Not in the scope of this study.

3.3. Background Data

Documentation for all Sphera (MLC) datasets can be found online (Sphera Solutions Inc., 2024). Every effort has been made to implement the most credible, representative, and up-to-date information available. The data of materials, fuels, water consumption and energy for all the models have been entered in LCA FE 10.7 software. The most relevant LCI datasets used in modelling the product systems with relevant attributes were obtained from the Sphera 2024.1 database.

The Sphera LCI database provides the life cycle inventory data for several of the for Raw materials, Fuel and Energy, and upstream transportation obtained from the background system and are given in Annex B2: Background data.

4. PCF Results

This chapter contains the results for the impact category as per ISO 14067:2018 standard. It shall be reiterated at this point that the reported impact categories represent impact potentials, i.e., they are approximations of environmental impacts that could occur if the emissions would (a) follow the underlying impact pathway and (b) meet certain conditions in the receiving environment while doing so. In addition, the inventory only captures that fraction of the total environmental load that corresponds to the chosen functional unit (relative approach).

4.1. PCF Results – Average Special High-Grade Zinc (SHGZ) Product

The Cradle to Gate Product Carbon Footprint (PCF) results for 1 tonne of Average Special High Zinc (SHGZ) Product (HZL) are given in Table 6.

Table 6 Product Carbon Footprint Results for 1 Tonne of Average Special High-Grade Zinc (SHGZ) Product

PCF Indicators	Unit	Total – Average Special High-Grade Zinc (SHGZ) Product
ISO14067 GWP100, Aircraft emissions	kg CO ₂ eq.	2.44E-04
ISO14067 GWP100, Biogenic GHG emissions	kg CO ₂ eq.	130.32
ISO14067 GWP100, Biogenic GHG removal	kg CO ₂ eq.	-121.31
ISO14067 GWP100, Emissions from land use change (dLUC)	kg CO ₂ eq.	1.30
ISO14067 GWP100, Fossil GHG emissions	kg CO₂ eq.	5882.10

The Cradle to gate GWP100, fossil GHG emissions for 1 tonne of average special high grade zinc production is 5882.10 kg CO₂ eq. While Cradle to gate GWP100, biogenic GHG emissions for 1 tonne of average special high grade zinc production is 130.32 kg CO₂ eq.

4.1.1. Source-Wise PCF Results - Average Special High-Grade Zinc (SHGZ) Product

The Table 7 below shows the Product Carbon Footprint (PCF) results for 1 tonne of average special high grade zinc product for source wise relative contributions from various sources such as raw material production, transportation (includes impact from transportation of raw materials, transportation of concentration to smelting location and transportation of zinc cathode to PMP), electricity, energy (includes impact from fuel consumption like LPG, diesel, propane etc.), process emissions (includes impact of direct process emission from roasting, leaching & purification, electrolysis, sintering, ISF processes mainly due limestone, dolomite, coke etc. consumptions) and waste management (includes impact from wastewater treatment and solid waste handling and treatment).

Table 7 Source-wise Cradle to Gate PCF Results for 1 Tonne of Average Special High-Grade Zinc (SHGZ) Product

PCF Indicators	Unit	Total	Raw Materials	Transportation	Electricity	Energy	Process Emissions	Waste Management
GWP100, Air craft emissions	kg CO ₂ eq.	2.44E-04	1.12E-05	4.01E-07	1.99E-04	2.61E-06	7.25E-08	3.13E-05
GWP100, Biogenic GHG emissions	kg CO ₂ eq.	130.32	2.82	1.50	114.04	8.80	1.14E-02	3.14
GWP100, Biogenic GHG removal	kg CO ₂ eq.	-121.31	-2.65	-1.19	-112.50	-1.61	-1.11E-02	-3.36
GWP100, Emissions from land use change (dLUC)	kg CO ₂ eq.	1.30	3.58E-02	3.86E-02	1.14	4.71E-02	1.12E-04	4.15E-02
GWP100, Fossil GHG emissions	kg CO₂ eq.	5882.10	399.03	32.79	5042.19	253.02	126.08	28.98

Figure 6 below shows the graphical representation of GWP100, fossil GHG emissions to produce 1 tonne average special high grade zinc product.

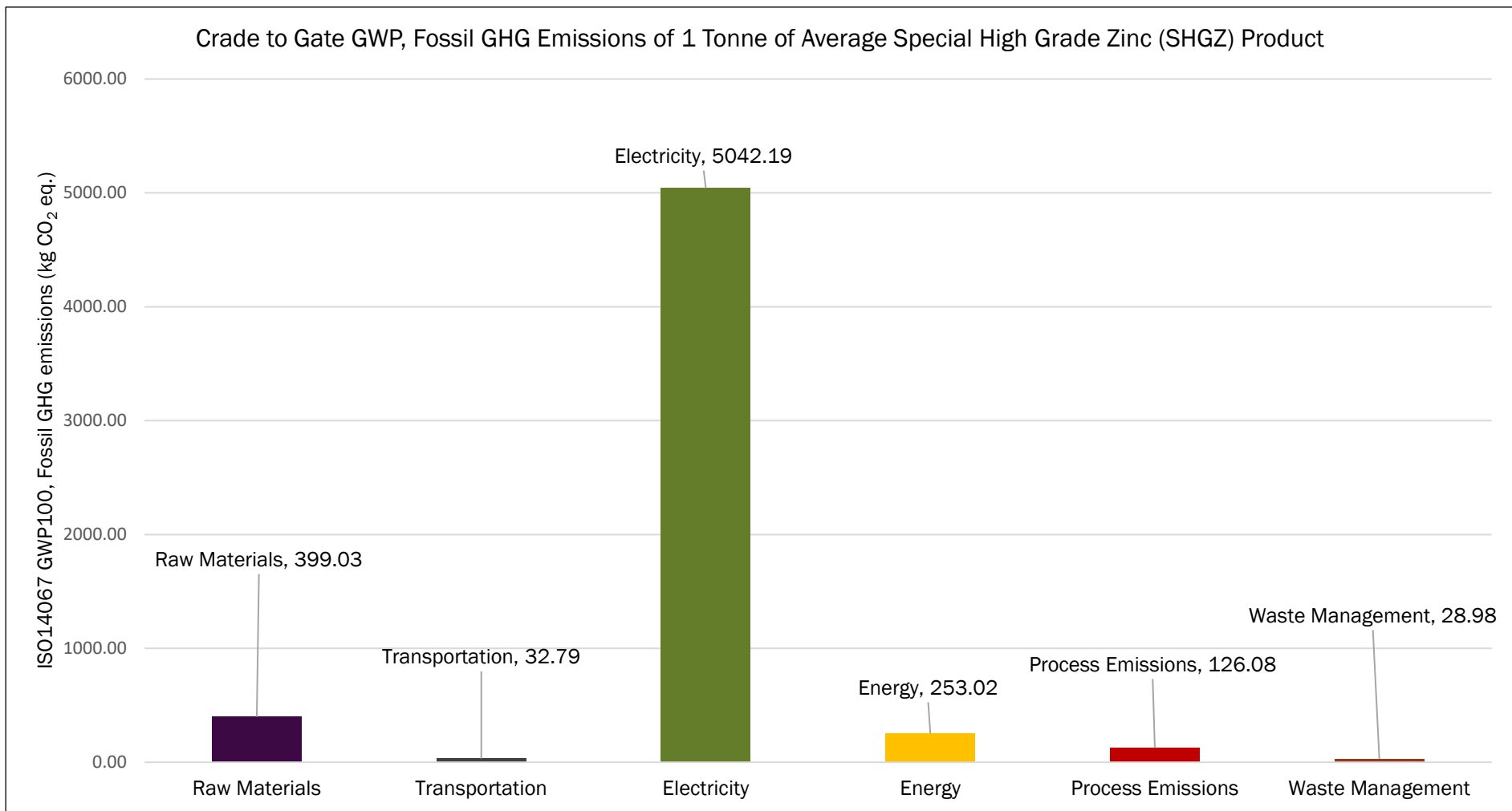


Figure 6 Source wise GWP, Fossil GHG Emissions of 1 Tonne of Average Special High Grade Zinc Product

As shown in above Figure the cradle to gate GWP100, fossil GHG emissions of 1 tonne of average special high grade zinc product is 5882.10 kg CO₂ eq, with major contribution from electricity (~86%), followed by raw materials (~7%), energy (~4%), and process emissions (~2%).

4.2. PCF Results – Average Low Carbon Special High-Grade Zinc (SHGZ) Product

The low carbon SHG zinc of HZL is also produced via hydrometallurgical and pyrometallurgical route at various location of HZL as described in Section 2.1.1. HZL has produced low carbon special high-grade zinc by using **100% renewable electricity** at their mines (RAM, RDM, SKM, KM, and ZM), smelters (CSC, DSC and ZSD) and melting & casting plant (PMP).

The Cradle to Gate Product Carbon Footprint (PCF) results for 1 tonne of Average Low Carbon Special High Zinc (SHGZ) Product (HZL) are given in Table 8.

Table 8 Product Carbon Footprint Results for 1 Tonne of Average Low Carbon Special High-Grade Zinc (SHGZ) Product

PCF Indicators	Unit	Total – Average Low Carbon Special High-Grade Zinc (SHGZ) Product
ISO14067 GWP100, Aircraft emissions	kg CO ₂ eq.	3.30E-03
ISO14067 GWP100, Biogenic GHG emissions	kg CO ₂ eq.	22.62
ISO14067 GWP100, Biogenic GHG removal	kg CO ₂ eq.	-15.78
ISO14067 GWP100, Emissions from land use change (dLUC)	kg CO ₂ eq.	0.22
ISO14067 GWP100, Fossil GHG emissions	kg CO₂ eq.	939.95

The Cradle to gate GWP100, fossil GHG emissions for 1 tonne of average low carbon special high grade zinc production is 939.95 kg CO₂ eq. While Cradle to gate GWP100, biogenic GHG emissions for 1 tonne of average special high grade zinc production is 22.62 kg CO₂ eq.

4.2.1. Source-Wise PCF Results - Average Low Carbon Special High-Grade Zinc (SHGZ) Product

The Table 9 below shows the Product Carbon Footprint (PCF) results for 1 tonne of average low carbon special high grade zinc product for source wise relative contributions from various sources such as raw material production, transportation (includes impact from transportation of raw materials, transportation of concentration to smelting location and transportation of zinc cathode to PMP), electricity, energy (includes impact from fuel consumption like LPG, diesel, propane etc.), process emissions (includes impact of direct process emission from roasting, leaching & purification, electrolysis, sintering, ISF processes mainly due limestone, dolomite, coke etc. consumptions) and waste management (includes impact from wastewater treatment and solid waste handling and treatment).

Table 9 Source-wise Cradle to Gate PCF Results for 1 Tonne of Average Low Carbon Special High-Grade Zinc (SHGZ) Product

PCF Indicators	Unit	Total	Raw Materials	Transportation	Electricity	Energy	Process Emissions	Waste Management
GWP100, Air craft emissions	kg CO ₂ eq.	3.30E-03	1.12E-05	4.01E-07	3.26E-03	2.61E-06	7.25E-08	3.15E-05
GWP100, Biogenic GHG emissions	kg CO ₂ eq.	22.62	2.82	1.50	6.35	8.80	1.14E-02	3.14
GWP100, Biogenic GHG removal	kg CO ₂ eq.	-15.78	-2.65	-1.19	-6.98	-1.61	-1.11E-02	-3.36
GWP100, Emissions from land use change (dLUC)	kg CO ₂ eq.	0.22	3.58E-02	3.86E-02	0.06	4.71E-02	1.12E-04	4.14E-02
GWP100, Fossil GHG emissions	kg CO₂ eq.	939.95	399.03	32.79	100.40	253.02	126.08	28.63

Figure 7 below shows the graphical representation of GWP100, fossil GHG emissions to produce 1 tonne average low carbon special high grade zinc product.

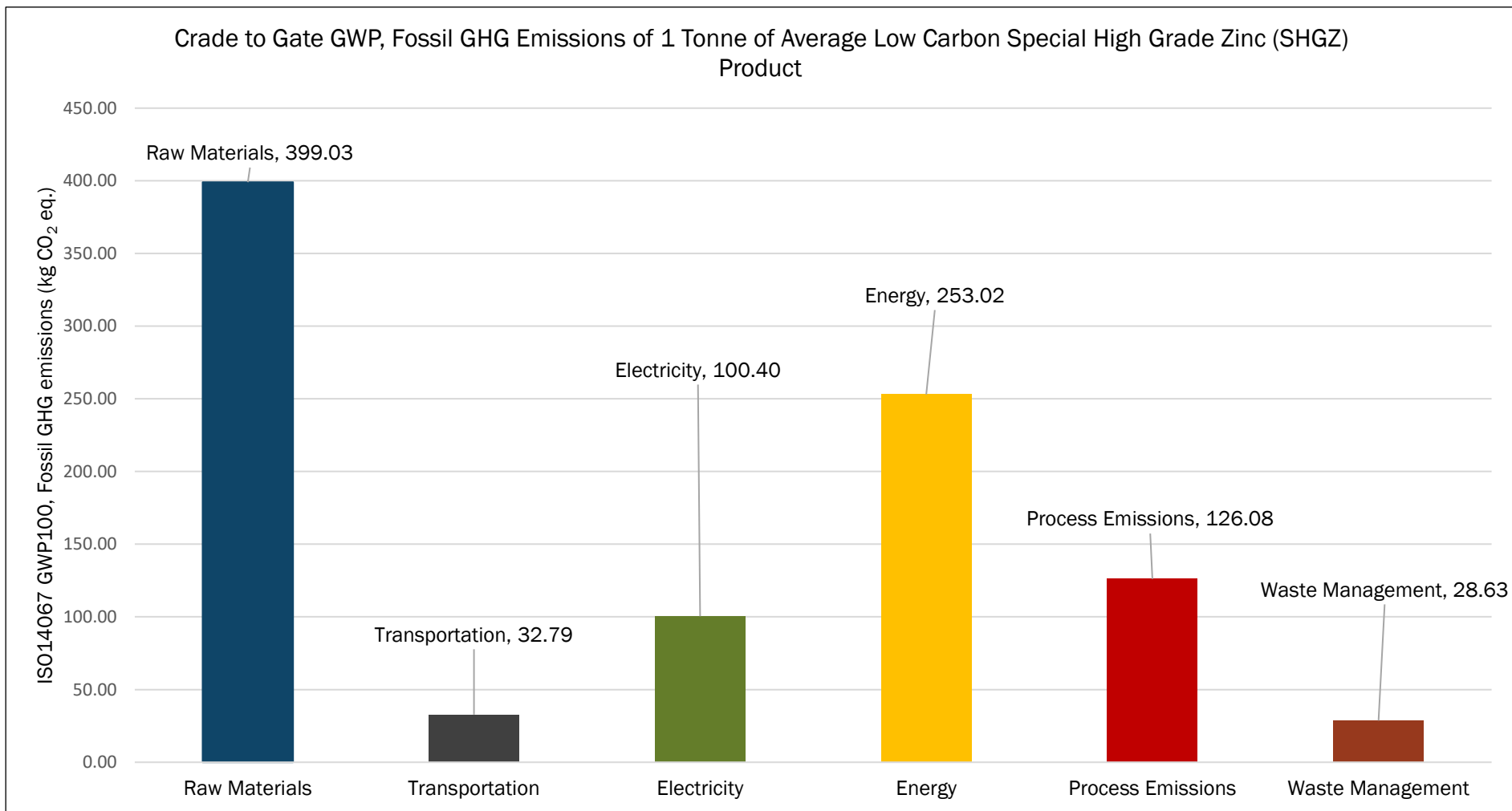


Figure 7 Source wise GWP, Fossil GHG Emissions of 1 Tonne of Average Low Carbon Special High Grade Zinc Product

As shown in above Figure the cradle to gate GWP100, fossil GHG emissions for 1 tonne of average low carbon special high grade zinc product is 939.95 kg CO₂ eq, with major contribution from raw materials (~42%), followed by energy (~27%), and process emissions (~13%).

4.3. Mass Balance Approach – Average Low Carbon Special High-Grade Zinc (SHGZ)

4.3.1. Mass Balance Approach for Average SHGZ for FY 2023-24

Mass balance approach is a method of assigning specified characteristics of input materials to outputs/products when mixing raw materials of different characteristics, in general. HZL utilizes the mass balance approach in the form of pooling GHG or CO₂ emission reductions from reduction projects within the organization and allocating the reductions to low carbon SHG zinc product to be supplied along with certificate. This is a method of pooling greenhouse gas (GHG) emission reductions or CO₂ emission reductions from emission reduction projects implemented by companies, allocating the reductions to any product, and supplying products with certificates that are capable of reducing customers' Scope 3 emissions.

The mass balance system is a central element of this low carbon zinc product certification process for HZL. It establishes a connection between carbon footprint related to raw materials, intermediate and final products and its relation to the renewable electricity mix application to the product under consideration. It is an essential component of the certification which ensures that information about the raw materials, intermediate and final products, energy carriers are credible in relation to its origin and consumption/production and can be verified along the entire production and supply chain.

This method consists of three steps. First, calculate the GHG emissions intensity of the Zinc products applying this method using PCF accounting standard. Second, identify GHG emission reduction projects such as increasing the renewable mix of electricity consumption across the value chain of zinc product through sourcing of electricity from solar plants and determine their GHG emission reduction in proportion to the substitution of renewable electricity while replacing the grid consumption in the electricity mix of HZL. Third, issue reduction certificates not to exceed the total GHG emission reduction amounts and supply zinc products with reduction certificates if needed in the future subjected to HZL management decisions. All steps must be verified by third-party review and certification.

Methodology followed for Average Low Carbon Special High-Grade Zinc (SHGZ) Product of HZL:

- Step: 1 - Inventory of Baseline data 2023-24 has been prepared along with the quality related to use of actual data, geographic coverage, technology coverage and time related coverage are ensured.
- Step: 2 - Actual electricity mix has been calculated for the baseline year along with sourcing of renewable electricity and captive electricity mix and their documentations.
- Step: 3 - Evidence related to consumption, production and electricity mix has been ensured.
- Step: 4 - GHG emission intensity (product carbon footprint) has been calculated for 1 Tonne of Special High-Grade Zinc over cradle to gate system boundary applying ISO 14067 with development of PCF model.
- Step: 5 - Actual supply of renewable electricity and its contribution to total electricity mix calculation for 1 Tonne of Special High-Grade Zinc has been implemented and assessed.
- Step: 6 - Development of mass balance approach model of electricity mix to the zinc product.

- Step: 7 – Percentage (%) renewable electricity in electricity consumption (mix) to the Average Special High Grade Zinc Product has been calculated for baseline of FY 2023-24.
- Step: 8 – Percentage (%) of Average Low carbon Special High-Grade Zinc (SHGZ) Product has been calculated based on % renewable electricity in electricity mix (mass balance approach) for HZL.

Based on the PCF model for production of 1 tonne SHG zinc, electricity consumption in the value chain and its breakup to fossil and renewables have been presented in below Table 10 and Table 11 respectively. Overall contribution of renewable electricity in the production of 1 tonne of zinc is allocated in proportion to the overall production of zinc at HZL to obtain and claim the total amount of low carbon zinc production having below 1 t CO₂ eq./t Special High-Grade Zinc.

Table 10 Process-wise Electricity Consumption for 1 Tonne of Average Special High-Grade Zinc (SHGZ) Product

Electricity	Unit	Amount
Mining Processes	kWh/tonne of SHGZ	734.26
Smelting and Casting Processes	kWh/tonne of SHGZ	3980.53
Total (Mining + Smelting+ Casting)	kWh/tonne of SHGZ	4714.79

Attribution of renewable electricity and fossil electricity for 1 tonne of average special high grade zinc product is given in the Table 11 below.

Table 11 Electricity Consumption for 1 Tonne of Average Special High Grade Zinc Product of HZL

Electricity	Unit	Amount	% Electricity
Electricity - Total	kWh/tonne	4714.79	100%
Electricity - Fossil	kWh/tonne	4320.01	91.63%
Electricity - Renewable	kWh/tonne	394.78	8.37%

Therefore, production of Average Low Carbon SHGZ for baseline Year (FY 2024) based on mass balance approach is given in the Table 12 below:

Table 12 Production of Average Low Carbon Special High-Grade Zinc (SHGZ) for Baseline Year (FY 2024) at HZL

Production of Average Low Carbon Special High-Grade Zinc (SHGZ) Based on Mass Balance Approach	
Total Production of Special High-Grade Zinc (SHGZ) Product (tonne)	750752
Average Low Carbon SHGZ Production based on mass balance approach (%)	8.37%
Average Low Carbon SHGZ Production based on mass balance approach (tonne)	~62862

Therefore, HZL have ~8.37% of Low Carbon SHGZ product of total SHGZ production for baseline year 2023-24 (FY 2024).

4.3.2. Projection of Average Low Carbon SHGZ product Based Mass Balance Approach for FY 2025 and FY 2026

Hindustan Zinc Limited is continuously increasing the renewable electricity (solar, wind, etc.) in their total electricity consumption mix. Therefore, in line with the increase in renewable electricity, projection of Average Low Carbon Special High-Grade Zinc (SHGZ) (percentage (%) Low Carbon SHGZ) for FY 2025 and FY 2026 has been calculated. The HZL's plan for renewable electricity for FY 2025 and FY 2026 has been shown in Table 13 below.

Table 13 HZL's Projection of Renewable Electricity for FY 2025 and FY 2026

Month	Existing Solar Electricity (kWh) – FY 2024	Renewable Electricity (kWh) - FY 2025	Renewable Electricity (kWh) - FY 2026
April	6606275		79200000
May	7135141	3570000	95040000
June	6236074	32947200	87120000
July	5833405	32249657	103680000
August	5471135	35044266	107136000
September	6125525	50400000	112320000
October	7305034	56544000	117504000
November	6042849	51840000	114048000
December	6419216	48960000	110592000
January	6624574	54720000	108864000
February	7258553	57792000	115776000
March	7809011	66240000	120960000
Total (Million kWh)	78.87	490.31	1272.24

The projection for Low Carbon SHGZ product for FY 2025 and FY 2026 has been calculated based on the projected electricity mix. Firstly, total electricity consumption has been projected with the target production of zinc, lead and silver production of FY 2025 and FY 2026 and then percentage (%) of renewable electricity in the total electricity consumption mix has been calculated. After that percentage (%) of Average Low Carbon Special High Grade Zinc Product has calculated based on based mass balance approach of renewable electricity and total electricity consumption mix.

The Table 14 below shows the electricity mix of baseline year (FY 2023-24) and projected electricity consumption mix for FY 2025 and FY 2026.

Table 14 Projection of Electricity Consumption Mix for FY 2025 and FY 2026 - HZL

Electricity Source	FY 2023-24		April'2024		May'2024		June'2024	
	Electricity (GJ)	Electricity (%)	Electricity (GJ)	Electricity (%)	Electricity (GJ)	Electricity (%)	Electricity (GJ)	Electricity (%)
Grid	1611223.67	12.64%	169373	11.92%	338746	11.86%	508119	11.56%
CPP - CSC	6626384.41	52.00%	649825	45.73%	1299651	45.49%	1949476	44.36%
CPP - DSC	2417695.60	18.97%	328562	23.12%	657124	23.00%	985686	22.43%
CPP - ZM	1178653.15	9.25%	173803	12.23%	347606	12.17%	521409	11.86%
WHRB	599830.35	4.71%	63835	4.49%	127669	4.47%	191504	4.36%
Solar	193289.83	1.52%	23783	1.67%	62321	2.18%	203381	4.63%
Hydro	115615.81	0.91%	11794	0.83%	23588	0.83%	35381	0.81%
Electricity Source	October'2024		December'2024		March'2025		March'2026	
	Electricity (GJ)	Electricity (%)	Electricity (GJ)	Electricity (%)	Electricity (GJ)	Electricity (%)	Electricity (GJ)	Electricity (%)
Grid	1185612	11.08%	1524358	10.96%	2032477	10.80%	0	0.00%
CPP - CSC	4548777	42.51%	5848427	42.07%	7797903	41.44%	7516719	39.95%
CPP - DSC	2299934	21.49%	2957058	21.27%	3942744	20.95%	3800573	20.20%
CPP - ZM	1216621	11.37%	1564227	11.25%	2085636	11.08%	2010430	10.69%
WHRB	446843	4.18%	574513	4.13%	766017	4.07%	766017	4.07%
Solar	919684	8.60%	1327427	9.55%	2049026	10.89%	4580064	24.34%
Hydro	82556	0.77%	106144	0.76%	141525	0.75%	141525	0.75%

The Table 15 below shows the percentage of biomass and fossil fuel consumed in CPP for electricity production at CSC, DSC and ZM.

Table 15 Percentage of Biomass Fuel and Fossil Fuel in CPP at HZL

	CSC - CPP	DSC - CPP	ZM - CPP
Fossil (%)	98.64%	98.37%	97.56%
Biomass (%)	1.36%	1.63%	2.44%

Therefore, biomass consumption in captive power plant at CSC, DSC and ZM is calculated and then percentage (%) of renewable electricity has been calculated by considering electricity from WHRB, Solar, hydro power and biomass (%) of CPP as a renewable electricity consumption at HZL. The Table 16 below shows the percentage (%) of renewable electricity in total electricity consumption mix for FY 2025 and FY 2026 of HZL.

Table 16 Projection of Fossil Electricity and Renewable Electricity in Total Electricity Consumption Mix - HZL

Percentage of Renewable Electricity and Fossil Electricity for Baseline year (FY 2024), FY 2025 and FY 2026 - HZL								
	March (FY 2024)	April'2024	May'2024	June'2024	October'2024	December'2024	March'2025 (FY 2025)	March'2026 (FY 2026)
Fossil Electricity (%)	91.63%	91.71%	91.23%	88.95%	85.25%	84.36%	83.11%	69.70%
Renewable Electricity (%)	8.37%	8.29%	8.77%	11.05%	14.75%	15.64%	16.89%	30.30%

After that the production projection of Average Low Carbon Special High Grade Zinc Product has been calculated based on based mass balance approach of renewable electricity and total electricity consumption mix and shown in Table 17 below.

Table 17 Production Projection of Average Low Carbon Special High-Grade Zinc Based on Mass Balance Approach

Production Projection of Average Low Carbon Special High-Grade Zinc (SHGZ) for FY 2025 and FY 2026 Based on Mass Balance Approach								
Production Projection	(FY 2024)	April'2024 (FYTD)	May'2024 (FYTD)	June'2024 (FYTD)	October'2024 (FYTD)	December'2024 (FYTD)	(FY 2025)	(FY 2026)
Total Production of (SHGZ) Product (tonne)	750752	76000	152000	228000	532000	684000	912000	912000
Average Low Carbon SHGZ Product – Share (%)	8.37%	8.29%	8.77%	11.05%	14.75%	15.64%	16.89%	30.30%
Average Low Carbon SHGZ Product (tonne)	62862	6303	13325	25190	78462	106961	154028	276324

*Note – FY: 12-month period between April-March

Therefore, as per mass balance approach HZL have ~8.37% of Average Low Carbon SHGZ product of total SHG Zinc production for baseline year 2023-24 (FY 2024), will reach ~16.89% of low carbon SHG zinc production at end of FY 2025 and ~30.30% of Low Carbon SHG zinc production at end of FY 2026.

5. Conclusions

5.1. Identification of Relevant Findings

Average Special High-Grade Zinc (SHGZ) Product:

- Cradle to gate GWP100, fossil GHG emissions of 1 tonne of average special high-grade zinc (SHGZ) product is “5882.10 kg CO₂ eq.”, with major contribution from electricity (~86%), followed by raw materials (~7%), energy (~4%), and process emissions (~2%).
- Cradle to gate GWP100, biogenic GHG emissions of 1 tonne of average special high-grade zinc (SHGZ) product is “130.32 kg CO₂ eq.”, with major contribution from electricity (~88%), followed by energy (~7%), and raw materials (~2%).

Average Low Carbon Special High-Grade Zinc (SHGZ) Product:

- Cradle to gate GWP100, fossil GHG emissions of 1 tonne of average low carbon special high-grade zinc (SHGZ) product is “939.95 kg CO₂ eq.” with major contribution from raw materials (~42%), followed by energy (~27%), and process emissions (~13%).
- Cradle to gate GWP100, biogenic GHG emissions of 1 tonne of average low carbon special high-grade zinc (SHGZ) product is “22.62 kg CO₂ eq.” with major contribution from energy (~39%), followed by electricity (~28%), waste management (~14%), and raw materials (~12%).
- As per mass balance approach, HZL have ~8.37% of Low Carbon SHGZ product of total SHG Zinc production for baseline year 2023-24 (FY 2024), will reach ~16.89% of low carbon SHG zinc production at end of FY 2025 and ~30.30% at end of FY 2026.

5.2. Assumptions, Limitations and Uncertainty

The data provided by HZL is for the year of 2023-24. Below are the assumptions and limitations made during the evaluation of life cycle information for the product.

- System expansion is not used for the metal by-products in this study.
- **Credit has not considered for sulphuric acid production in this study. Price allocation has applied between zinc calcined and sulphuric acid.**
- Special high-grade zinc produced using 100% renewable electricity at HZL has significantly lower GHG emissions as per mass balance approach than the global average (3818 kg CO₂ eq./t of SHG Zinc) presented by the International Zinc Association (IZA)¹. As per the international practices followed by leading organization (e.g., Boliden, Teck etc.), zinc product with GHG intensity lower than 1 t-CO₂ eq./t of SHGZ can be considered as Low carbon Special High-Grade Zinc^{2,3}.
- Transport of materials through trucks, rail and ship are analysed by using LCA FE datasets.
- There were very few cases where proxy data had to be used in the PCF models. This occurred when no LCI data was available for an intermediate chemical/material.

¹ https://www.zinc.org/wp-content/uploads/sites/30/2023/12/IZA_LCA_Update_Reportv1.3_FINAL.pdf

² [low-carbon-shg-zinc2.pdf \(boliden.com\)](#)

³ [Carbon-Footprint-of-Teck-Special-High-Grade-Zinc.pdf](#)

- Likewise, there were few cases where data had to be used from a different region or technology. These instances were uncommon and noted in the Data Quality section of the PCF Report.
- Services (Accounting, business, catering, etc) inputs are excluded from the study.
- LCA FE datasets provide a completely aggregated, cradle-to-gate process inventory. The use of this type of datasets had two main consequences, on the modelling exercise: (i): predefined methodological choices had to be used (e.g. regarding multifunctionality), making it difficult to ensure consistency within the same product life cycle and across the different analysed scenarios; and (ii) the level of granularity of the contribution analysis was bound to the level of aggregation of the used datasets, which is particularly high for processes in the upstream part of the supply chain.
- For the Global Warming Potential (GWP) factors, the Intergovernmental Panel on Climate Change (IPCC) Sixth Assessment Report: Climate Change (AR6) GWP100 factors have been used. Changes to the GWP factors could add uncertainty to the CH₄ and N₂O emissions.

5.3. 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 to ensure reliable results, first-hand industry data in combination with consistent background LCA information from the Sphera 2024.1 database were used. The LCI datasets from the Sphera 2024.1 database are widely distributed and used with the LCA FE 10.7 Software. The datasets have been used in LCA/PCF models worldwide in industrial and scientific applications in internal as well as in many critically reviewed and published studies. In the process of providing these datasets they are cross-checked with other databases and values from industry and science.

5.3.1. Precision and Completeness

- ✓ **Precision:** As most of the the relevant foreground data are measured data or calculated based on primary information sources of the owner of the technology, precision is considered to be high. Seasonal variations/variations across different manufacturing sites were balanced out by using yearly averages/weighted averages. All background data are sourced from Sphera databases with the documented precision.
- ✓ **Completeness:** Each foreground process was checked for mass balance and completeness of the emission inventory. No data were knowingly omitted. Completeness of foreground unit process data is high. All background data are sourced from Sphera databases with the documented completeness.

5.3.2. Consistency and Reproducibility

- ✓ **Consistency:** To ensure data consistency, all primary data were collected with the same level of detail, while all background data were sourced from the Sphera databases.
- ✓ **Reproducibility:** 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 approaches.

5.3.3. Representativeness

- ✓ **Temporal:** All primary data were collected for FY 2023-24. All secondary data come from the Sphera 2024.1 databases and are representative of the years 2020-2023. As the study intended

to compare the product systems for the reference year 2023-24, temporal representativeness is considered to be high.

- ✓ **Geographical:** 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 high.
- ✓ **Technological:** 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 high.

5.4. Model Completeness and Consistency

5.4.1. 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 regards to the goal and scope of this study. The completeness is considered very good for all significant processes.

5.4.2. Consistency

All assumptions, methods and data are consistent with each other and with the study's goal and scope. Differences in background data quality were minimised by exclusively/predominantly using LCI data from the Sphera 2024.1 databases. System boundaries, allocation rules, and impact assessment methods have been applied consistently throughout the study.

5.5. Recommendations

Based on the observations of the study, the following recommendations as follows:

- In order to further reduce the global warming impacts contributed from manufacturing operations due to electricity consumption, it is suggested to HZL to source electricity from renewables such as solar, wind, etc., or purchase renewable energy certificates and by utilizing waste heat for electricity generation.
- Partial or full replacement of fossil fuel by biomass/briquette-based in captive power plant should be considered for reducing the impacts during thermal energy generation process.
- Optimization of resource consumptions may lead to reduce wastes, which might lead to higher yield of the product and result in lowering the various environmental impacts.

5.6. Disclaimer

The findings presented in this report reflect only the analysis performed by Hindustan Zinc Limited in respect of Average Special High-Grade Zinc (SHGZ) and Average Low Carbon Special High-Grade Zinc produced at their various manufacturing facilities during the FY 2023-24 based on the methodologies set out in this Report. All of the assumptions and uncertainties mentioned in this report apply to the data gathered in compliance with it as well as its conclusions. The conclusions drawn herein could be significantly impacted by modifications to the methodology or data sources. The results should not be used as a comparative tool directly against other products as the differences in assumptions and practices may produce incomparable results.

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Annex A: Third Party Review Statement

PRODUCT CARBON FOOTPRINT

REVIEW STATEMENT



This is to certify that

The GHG inventory of

Average Special High-Grade Zinc (SHGZ) Product & Average Low Carbon Special High-Grade Zinc (SHGZ) Product

Manufactured by

“Hindustan Zinc Limited (HZL)”

has been verified based on ISO 14067:2018 Greenhouse gases - Carbon footprint of products – Requirements and guidelines for quantification standard and GHG Protocol - Product life cycle accounting and reporting standard (the GHG Protocol Standard).

Quantification Standard: ISO 14067:2018 Greenhouse gases - Carbon footprint of products – Requirements and guidelines for quantification standard and GHG Protocol – Product life cycle accounting and reporting standard (the GHG Protocol Standard).

Product producer (manufacturer): Hindustan Zinc Limited

Production Location: Mines (RAM, RDM, SKM, ZM & KM), Smelters (CSC, DSC & ZSD) and Casting unit (PMP), India.

Average Special High-Grade Zinc (SHGZ) Product

System Boundary: Cradle to gate
Functional unit: 1 tonne (1000 kg)
Product Carbon Footprint Result (CO₂-eq): 5882.10 kg CO₂-eq

Average Low Carbon Special High-Grade Zinc (SHGZ)¹ Product

System Boundary: Cradle to gate
Functional unit: 1 tonne (1000 kg)
Product Carbon Footprint Result (CO₂-eq): 939.95 kg CO₂-eq

Review Details

Statement No: MET-2024013

Issue date: 2024.06.01

Expiration date: 2026.05.31

Reviewer Name: Dr Hüdai Kara

Reviewer Signature:

Designation: Founder & CEO

Review Company: Metsims Sustainability Consulting

Company Address: 4 Clear Water Place, Oxford OX2 7NL United Kingdom
www.metsims.com

Carbon Footprint Consultant: Dr. Rajesh Kumar Singh Sphera Solutions, India

Production Projection of Average Low Carbon Special High-Grade Zinc (SHGZ) for FY 2025 and FY 2026 at HZL based on MBA ⁽¹⁾								
Production Projection	FY 2024	April 2024	May 2024 (FYTD)	June 2024 (FYTD)	Oct. 2024 (FYTD)	Dec. 2024 (FYTD)	FY 2025	FY 2026
Total Production of Average SHGZ Product (tonne)	750,752	76,000	152,000	228,000	532,000	684,000	912,000	912,000
Average Low Carbon SHGZ Product - Share (%)	8.37%	8.29%	8.77%	11.05%	14.75%	15.64%	16.89%	30.30%
Average Low Carbon SHGZ Product (tonne)	62,862	6,303	13,325	25,190	78,462	106,961	154,028	276,324

Note: FY: 12-month period between April- March

⁽¹⁾ This result is based on mass balance approach (MBA) with the allocation of the gradual increase of renewable electricity projects implemented to source electricity in the total electricity mix of HZL over the next two financial years by pooling GHG or CO₂ emission reductions from reduction projects within the organization and allocating the reductions to Average Low Carbon SHGZ product to be supplied along with certificate.

Third Party Review Statement

PRODUCT CARBON FOOTPRINT

THIRD PARTY REVIEW STATEMENT

Metsims Sustainability Consulting was commissioned by Hindustan Zinc Limited to provide independent thirdparty review/verification on the carbon footprint (greenhouse gas emissions) for Average Special High-Grade Zinc and Average Low Carbon Special High Grade Zinc over a cradle to gate system boundary.

The review exercise was performed against the general principles of ISO 14067:2018 Greenhouse gases - Carbon footprint of products – Requirements and guidelines for quantification standard and GHG Protocol – Product life cycle accounting and reporting standard (the GHG Protocol Standard).

The objective of the study is to assess and allocate the quantity of low carbon special high-grade Zinc (SHGZ) product to the actual production of conventional special high-grade Zinc (SHGZ) produced at HZL. This evaluation is based on mass balance approach with the allocation of the gradual increase of renewable electricity projects implemented to source electricity in the energy mix of HZL the next two financial years. Mass balance approach is a method of assigning specified characteristics of input materials to outputs/products when mixing raw materials of different characteristics, in general. HZL utilizes the mass balance approach in the form of pooling GHG or CO₂ emission reductions from reduction projects within the organization and allocating the reductions to low carbon special high grade zinc product to be supplied along with certificate.

Sustainability Consulting



The study has been performed in a professional manner using engineering expertise, state-of-the-art PCF methods, adequate PCF models and suitable background data, The data quality of the foreground processes using primary data sources are found to be very high. As a result, the report is closer to representative for the production processes at HZL.

Description of the studied product

The following HZL metal products were included within the scope of this work:

Average Special High-Grade Zinc (Zn – 99.99%)

Average Low Carbon Special High-Grade Zinc (Zn – 99.99%)

The study covers the cradle to gate system boundary which includes production of raw materials, upstream transportation, and manufacturing processes at HZL's different sites.

HZL has produced average special high-grade zinc their mines (RAM, RDM, SKM, KM, and ZM), smelters (CSC, DSC and ZSD) and melting & casting plant (PMP). HZL has also produced average low carbon special high-grade zinc by using allocation of 100% renewable electricity at their mines (RAM, RDM, SKM, KM, and ZM), smelters (CSC, DSC and ZSD) and melting & casting plant (PMP) to the apportioned production of SHG zinc product.

Data collection period – FY 2023-24

Details of manufacturing processes at HZL:

Site Name	Processes	Product(s)
Rampura Agucha Mines (RAM) + Kayad Mines (KM)	Mining & Milling	Zinc concentrate, Lead concentrate
Rajpura Dariba Mines (RDM)	Mining & Milling	Zinc concentrate, Lead concentrate
Sindesar Khurd Mines (SKM)	Mining & Milling	Zinc concentrate, Lead concentrate
Zawar Mines (ZM)	Mining & Milling	Zinc concentrate, Lead concentrate
Chanderiya Smelting Complex (CSC)	Smelting & Casting	Zinc cathode and Zinc Ingot (SHGZ)
Dariba Smelting Complex (DSC)	Smelting	Zinc cathode
Zinc Smelting Debari (ZSD)	Smelting & Casting	Zinc cathode and Zinc Ingot (SHGZ)
Pantnagar Metal Plant (PMP)	Melting & Casting	Zinc Ingot (SHGZ)

The intended audience for this study includes HZL management, operational and marketing departments, and other internal stakeholders. HZL will use the information from this study in an aggregated manner for public communications, to develop marketing materials for potential customers.

Roles and Responsibilities

The calculation and determination of the carbon footprints for the Zinc products of HZL are the sole responsibility of HZL. Metsims's responsibility is to express an independent review opinion as to whether the carbon footprints calculated for HZL's Zinc products have been prepared in accordance with the relevant standard.

Description of Third Party Review Process and Criteria

Metsim's review process was carried out to ensure that:

- Methods used to carry out the product inventory are transparent and consistent with the relevant Standard
- Methods used to carry out the product inventory are scientifically and technically valid.
- Information and Data used are appropriate and reasonable in relation to the goal of the study.
- The inventory report, mass allocation for low carbon SHG zinc and any conclusions based on the results are appropriate for GHG-only inventories.
- The inventory report and mass allocation for low carbon SHG zinc is transparent and consistent.
- The interpretations reflect the limitations identified and the goal of the study.
- The report is intended to support public disclosure.

The review process entailed review of the carbon footprint report prepared by Hindustan Zinc Limited with support by Sphera Solutions. 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 HZL all comments in detail. Outcomes were addressed within an updated version of the carbon footprint report which was subsequently checked by the reviewer. A materiality check was applied for cut-off criteria. Furthermore, an examination of the process models within the LCA software (LCA FE) was an integral part of this review.

The reviewer acknowledges the unrestricted access to all requested information as well as the open and constructive dialogue during the review process. Various assumptions were addressed and backed by sensitivity analyses of data and methodological choices. The system under study was very carefully defined and modelled. The assumptions are transparently described and are found to be suitable and acceptable concerning the conclusions.

Conclusion and Review Opinion

The reviewer found the overall quality of the methodology and its execution to be adequate. The study is reported in a very comprehensive manner including a transparent documentation of its scope. The used secondary data sources, the used software and background data, the transparent documentation, as well as the discreet and careful interpretation make this report and its results very consistent, applicable and valuable.

Based on the review activities undertaken, nothing has come to our attention that would cause us to believe that HZL have not disclosed accurate and reliable carbon footprint data and production projection of Low Carbon Special High Grade Zinc based on Mass Balance Approach and in conformance with the requirements ISO 14067:2018, GHG Protocol Life Cycle Accounting and Reporting Standard (the GHG Protocol Standard).

Hudai Kara BSc MSc DPhil IMMM

1st of June 2024

Oxford, United Kingdom



Annex B1: LCI (Confidential data)

Mining Data:

Rampura Agucha Mine (RAM)

Rampura Agucha Mine (RAM)			
Mining - RAM			
Input	Unit	Total (2024)	Comments
Cement	kg	239289390	
Electricity - Total	MJ	641662913.2	
Explosives	kg	486605.085	
Diesel	kg	30017461.08	
Gasoline	kg	0	
Natural gas	kg	0	
Lubricant	kg	1642349	
Zinc_ore	kg	7361548278	
Ground water	kg	0	
Lake water	kg	0	
Rainwater	kg	0	
River water	kg	0	
Water from WTP	kg	0	
		0	
Output	Unit		Comments
Hazardous waste for incineration	kg	760280	
Hazardous waste for landfill	kg	0	
Ore mined	kg	5531195000	
Overburden	kg	1925749140	Stockpile goods]
Waste for recovery	kg	125380	
Wastewater	kg		
Concentration - RAM			
Input	Unit	Quantity (FY 2024)	Comments
Cement	kg	0	cement
CuSO4	kg	3654000	Copper sulphate
Electricity - Total	MJ	836927217	
Flocculant	kg	0	
Frother	kg	144570	
HFO	MJ	0	thermal energy from heavy fuel oil
Limestone	kg	191650	limestone
Lubricant	kg	1552879	lubricants
NaCl	kg	0	sodium chloride
NaCN	kg	74000	sodium cyanide
Ore	kg	5531195000	kg ore received
Ground water	kg	0	
Lake water	kg	0	
Rainwater	kg	0	

River water	kg	0	
Xanthate	kg	805700	
Zinc sulphate (ZnSO4)	kg	0	
Output	Unit	Quantity (FY 2024)	Comments
Lead concentrate	kg	90106000	
Particulates (PM)	kg	7880	
Hazardous waste for landfill	kg	0	
Tailings	kg	4373291000	
Water - evaporated	kg	0	
Zinc concentrate	kg	1084225000	

Rajpura Dariba Mine (RDM)

Rajpura Dariba Mine (RDM)			
Mining - RDM			
Input	Unit	Quantity (FY 2024)	Comments
Cement	kg	20720600	Cement_auxilliary
Electricity from Grid	MJ	0	Electricity from Grid
Electricity from Solar	MJ	0	Electricity from Solar
Electricity from Wind	MJ	0	Electricity from Wind
Electricity from other sources - CPP DSC	MJ	0	Electricity from other sources
Electricity - Total	MJ	137272250	
Explosives	kg	1308369.5	Explosives
Diesel	kg	3216369.9	
Gasoline	kg	0	
LPG	kg	12230	
Natural gas	kg	0	
Lubricant	kg	530360	
Zinc_ore	kg	1658935000	
Ground water	kg	0	
Water from WTP	kg	0	
Output	Unit	Quantity (FY 2024)	Comments
Hazardous waste for incineration	kg	9360	
Hazardous waste for landfill	kg	47680	
Ore mined - Zn ore production	kg	1343829706	
Overburden	kg	312959000	
Waste for recovery	kg	474996000	Not considered
Wastewater	kg	0	
Concentration - RDM			
Input	Unit	Quantity (FY 2024)	Comments
Cement	kg	0	cement
CuSO4	kg	219780	Copper sulphate
Electricity - Total	MJ	154095778.8	Value provided over a call
Flocculant	kg	0	
Frother	kg	57680	
HFO	MJ	0	thermal energy from heavy fuel oil
Limestone	kg		limestone

Lubricant	kg	530360	lubricants
NaCl	kg	0	sodium chloride
NaCN	kg	28950	sodium cyanide
Ore	kg	1343829706	kg ore received
Ground water	kg	0	
Xanthate	kg	118550	
Zinc sulphate (ZnSO4)	kg	369650	
Output	Unit	Quantity (FY 2024)	Comments
Lead concentrate	kg	18427603	
Particulates (PM)	kg	3210	
Tailings	kg	815666190	
Hazardous waste for landfill	kg	47680	
Water - evaporated	kg	0	
Zinc concentrate	kg	79954113	

Sindesar Khurd Mine (SKM)

Sindesar Khurd Mine (SKM)			
Mining - SKM			
Input	Unit	Quantity (FY 2024)	Comments
Cement	kg	170455510	Cement_auxilliary
Electricity from Grid	MJ	431413000	Electricity from Grid
Electricity from Solar	MJ	0	Electricity from Solar
Electricity from Wind	MJ	0	Electricity from Wind
Electricity from other sources	MJ	0	Electricity from other sources
Total - Electricity	MJ	431413000	
Explosives	kg	2513140	Explosives
Diesel	kg	16168562.87	Diesel
Gasoline	kg	0	
LPG	kg	0	
Natural gas	kg	0	
Lubricant	kg	0	
Zinc_ore	kg	6661328000.00	
Ground water	kg	0	
Water from WTP	kg	0	
Output	Unit	Quantity (FY 2024)	Comments
Hazardous waste for incineration	kg	0	
Hazardous waste for landfill	kg	0	
Ore mined	kg	5650484700	
Overburden	kg		
Waste for recovery	kg	472010	
Wastewater	kg	0	
Concentration - SKM			
Input	Unit	Quantity (FY 2024)	Comments
Cement	kg	0	cement
CuSO4	kg	1287020	Copper sulphate
Electricity - Total	MJ	630910191	
Flocculant	kg	0	
Frother	kg	99630	
HFO	MJ	0	thermal energy from heavy fuel oil
Limestone - Hydrated lime	kg	157450	limestone
Lubricant	kg	962150	lubricants
NaCl	kg	0	sodium chloride
NaCN	kg	0	sodium cyanide

Ore	kg	5650484700	kg ore received
Ground water	kg	0	
Xanthate	kg	243050	
Zinc sulphate (ZnSO4)	kg	2924260	
Output	Unit	Quantity (FY 2024)	Comments
Lead concentrate	kg	289091948	
Particulates (PM)	kg	0	
Tailings	kg	5024537772	
Water - evaporated	kg	0	
Zinc concentrate	kg	336854980	

Zawar Mine (ZM)

Zawar Mine (ZM)			
Mining - Zawar Mine (ZM)			
Input	Unit	Quantity (FY 2024)	Comments
Cement	kg	23103790	Cement_auxilliary
Electricity - Total	MJ	319345530.77	22 kWh/tonne of Ore production - ZM
Explosives	kg	725500	Explosives
Diesel	kg	14227293.41	Diesel
Gasoline	kg	0	
LPG	kg	0	
Natural gas	kg	0	
Lubricant	kg	289560	
Zinc_ore	kg	5072917600	
Ground water	kg	0	
Water from WTP	kg	0	
Output	Unit	Quantity (FY 2024)	Comments
Hazardous waste for incineration	kg	1770	
Hazardous waste for landfill	kg	520	
Ore mined	kg	4032140540	
Overburden	kg	1163498490	
Waste for recovery	kg	640340	
Wastewater	kg	0	
Milling - ZM			
Input	Unit	Quantity (FY 2024)	Comments
Acetylene	kg	0	acetylene
Cement	kg	0	cement
CuSO4	kg	526910	Copper sulphate
Electricity - Total	MJ	377408354.54	
Flocculant	kg		
Frother	kg	104650	
HFO	MJ	0	thermal energy from heavy fuel oil
Limestone	kg	0	limestone
Lubricant	kg		lubricants
NaCl	kg	0	sodium chloride
NaCN	kg	6740	sodium cyanide
Ore	kg	4032140540	kg ore received
Ground water	kg	0	

Lake water	kg	0	
Rainwater	kg	0	
River water	kg	0	
Xanthate	kg	185650	
Zinc sulphate (ZnSO4)	kg	568730	
Output	Unit	Quantity (FY 2024)	Comments
Lead concentrate	kg	99524090	
Particulates (PM)	kg	0	
Tailings	kg	3687150000	
Hazardous waste for landfill	kg	520	
Non-Hazardous waste for landfill	kg	0	
Water - evaporated	kg	0	
Zinc concentrate	kg	221920190	

Smelters Data:

Chanderiya Smelting Complex (CSC) – H1 (Hydrometallurgical 1)

Chanderiya Smelting Complex (CSC) - H1			
Roasting: CSC (H1)			
Input	Unit	Quantity (FY 2024)	Comments
Chlorine (Cl2)	kg	0	chlorine
Electricity - Total	MJ	158667878.9	Taken from consolidated sheet
Hydrazine	kg	0	
Sodium silicate	kg	0	
NaOH	kg	0	sodium hydroxide
Thermal energy from HFO	MJ	0	
Thermal energy from LPG	MJ	0	
TSP (trisodium phosphate)	kg	0	
V2O5 (vanadium pentoxide)	kg	0	
River water	kg	0	
Process water	kg	0	
Zinc Concentrate form RAM	kg	220496000	zinc concentrate RAM
Zinc Concentrate form RDM	kg	15970000	zinc concentrate RDM
Zinc Concentrate form SKM	kg	63095000	zinc concentrate SKM
Zinc Concentrate form ZM	kg	15412000	zinc concentrate ZM
Zn_dross	kg	5508000	
ZnO (Zinc oxide)	kg	0	zinc oxide/Waelz oxide
Cement			
Output	Unit	Quantity (FY 2024)	Comments
Sulphuric acid (H2SO4)	kg	286596000	
H2SO4 Mist	kg		sulfuric acid mist to air
Sulphur dioxide to air	kg	290705.5714	sulfur dioxide emissions to air
Steam Produced	kg		steam output
Solid waste	kg		waste for recovery
Zinc calcined	kg	294791000	
Leaching & Purification: CSC (H1)			

Input	Unit	Quantity (FY 2024)	Comments
Activated Carbon	kg	9000	
Cement	kg	23078130	
Electricity - Total	MJ	95866472.44	Taken from consolidated sheet
Flocculant	kg	65000	
H2SO4	kg	54914000	sulphuric acid
H2SO4_Recycled	kg		recycled H2SO4
KMnO4	kg	250	potassium permanganate
Limestone	kg	0	limestone
MnO2	kg	0	manganese dioxide
Na2SO4	kg	13859590	sodium sulphate
Steam	kg	0	Not measured - from WHRB
Zinc calcined	kg	294791000	
Zinc calcined from ZSD	kg	60194790	
Zinc calcined from DSC	kg	59673800	
Zinc powder	kg	0	
Hydrated Lime	kg	37290840	
PAT	kg	21580	For WWTP
Output	Unit	Quantity (FY 2024)	Comments
Purification cake	kg	6732721.37	
Jarosite	kg	209359817	
Particulates (PM)	kg		particulate 2.5 to 10 microns
Zinc Sulphate (ZnSO4)	kg	3577627900	
Electrolysis: CSC (H1)			
Input	Unit	Quantity (FY 2024)	Comments
Electricity -Total	MJ	3060318581	Taken from consolidated sheet
Gelatin	kg	13960	gelatin (gum arabic)
NH4Cl	kg	135000	ammonium chloride
SrCO3	kg	191520	strontium carbonate
Steel	kg	0	steel band
Thermal energy from HFO	MJ		
Thermal energy from Propane	MJ	31412560	
Process water	kg		
Zinc sulphate (ZnSO4)	kg	3577627900	
Output	Unit	Quantity (FY 2024)	Comments
Anode_sludge	kg		
Cooler cake	kg	2905500	
Spent acid	kg		
Solid waste	kg		waste for recovery (cooler cake)
Wastewater in loop	kg		waste water keep in the process
Wastewater	kg		waste water untreated
Water - evaporated	kg		water losses due to evaporation
Zinc cathode	kg	243612000	Zn cathode
Melting: CSC			

Input	Unit	Quantity (FY 2024)	Comments
Electricity - Total	MJ	109690240.1	
NH4Cl	kg	0	ammonium chloride
Steel	kg	0	steel band
Thermal energy from HFO	MJ	0	
Thermal energy from LPG	MJ	0	
Zinc Cathode - H1	kg	240493730.5	
Output	Unit	Quantity (FY 2024)	Comments
High Grade Zinc	kg	228673000	
Zinc dross	kg	11820730.5	

Chanderiya Smelting Complex (CSC) – H2 (Hydrometallurgical 2)

Chanderiya Smelting Complex (CSC) - H2			
Roasting: CSC (H2)			
Input	Unit	Quantity (FY 2024)	Comments
Chlorine (Cl2)	kg		chlorine
Electricity - Total	MJ	162568804.6	Taken from consolidated sheet
Hydrazine	kg	0	
Sodium silicate	kg	0	sodium hydroxide
NaOH	kg	0	
Thermal energy from HFO	MJ	0	
Thermal energy from LPG	MJ	0	
Thermal energy from Propane	MJ	24000470	
TSP (trisodium phosphate)	kg	0	
V2O5 (vanadium pentoxide)	kg		
River water	kg		
Process water	kg		
Zinc Concentrate form RAM	kg	190357000	zinc concentrate RAM
Zinc Concentrate form RDM	kg	12260000	zinc concentrate RDM
Zinc Concentrate form SKM	kg	76348000	zinc concentrate SKM
Zinc Concentrate form ZM	kg	44286000	zinc concentrate ZM
Zn_dross	kg	8624280	
ZnO (Zinc oxide)	kg		zinc oxide/Waelz oxide
Output	Unit	Quantity (FY 2024)	Comments
Sulphuric acid (H2SO4)	kg	273911000	
H2SO4 Mist	kg	0	sulfuric acid mist to air
Sulphur dioxide to air	kg	203305.6565	sulfur dioxide emissions to air
Steam Produced	kg		To WHRB
Solid waste	kg	0	waste for recovery
Zinc calcined	kg	306087000	
Leaching & Purification: CSC (H2)			
Input	Unit	Quantity (FY 2024)	Comments
Activated Carbon	kg	0	
Cement	kg	21815470	
Electricity - Total	MJ	72938044.25	Taken from consolidated sheet
Flocculant	kg	43650	
H2SO4	kg	49020080	sulphuric acid
H2SO4_Recycled	kg		recycled H2SO4
KMnO4	kg	4940	potassium permanganate

Limestone	kg	6173850	limestone
MnO2	kg		manganese dioxide
Na2SO4	kg	12365420	sodium sulphate
Steam	kg		
Zinc calcined	kg	306087000	
Zinc calcined from ZSD	kg	79897430	
Zinc calcined from DSC	kg	76957800	
Zinc powder	kg	0	
Output	Unit	Quantity (FY 2024)	Comments
Purification cake	kg	3699000	
Jarosite	kg	180852880.5	
Particulates (PM)	kg		particulate 2.5 to 10 microns
Zinc Sulphate (ZnSO4)	kg	2786242100	
Electrolysis: CSC (H2)			
Input	Unit	Quantity (FY 2024)	Comments
Electricity - Total	MJ	3057944138	Taken from consolidated sheet
Gelatin	kg	13360	gelatin (gum arabic)
NH4Cl	kg	107180	ammonium chloride - Total consumption of smelter
SrCO3	kg	323280	strontium carbonate
Steel	kg		steel band
Process water	kg		
Zinc sulphate (ZnSO4)	kg	2786242100	
Output	Unit	Quantity (FY 2024)	Comments
Anode_sludge	kg		
Cooler cake	kg	2905500	
Spent acid	kg		
Solid waste	kg		waste for recovery (cooler cake)
Wastewater	kg		waste water untreated
Zinc cathode	kg	247047000	Zn cathode
Melting: CSC			
Input	Unit	Quantity (FY 2024)	Comments
Electricity - Total	MJ	159626642.8	
NH4Cl	kg	0	ammonium chloride
Steel	kg	0	steel band
Thermal energy from HFO	MJ	0	
Thermal energy from LPG	MJ	0	
Zinc Cathode - H2	kg	243928730.5	
Output	Unit	Quantity (FY 2024)	Comments
High Grade Zinc	kg	235566000	
Zinc dross	kg	8362730.5	

Dariba Smelting Complex (DSC) (Hydrometallurgical)

Dariba Smelting Complex (DSC)			
Roasting: DSC			
Z	Unit	Quantity (FY 2024)	Comments
Chlorine (Cl2)	kg	18000	chlorine
Electricity - Total	MJ	324321361.2	
Sodium silicate	kg	66940	
NaOH	kg	354400	

Thermal energy from HFO	MJ	0	thermal energy from heavy fuel oil
Thermal energy from LPG	MJ	0	thermal energy from liqueified petroleum gas
TSP (trisodium phosphate)	kg	0	
V2O5 (vanadium pentoxide)	kg	29440	
River water	kg	0	
Process water	kg	0	
Zinc Concentrate form RAM	kg	438674000	
Zinc Concentrate form RDM	kg	27418000	
Zinc Concentrate form SKM	kg	106753000	
Zn_dross	kg	5297610	
ZnO (Zinc oxide)	kg	0	zinc oxide/Waelz oxide
Output	Unit	Quantity (FY 2024)	Comments
Sulphuric acid (H2SO4)	kg	688439000	sulphuric acid
H2SO4 Mist	kg		sulfuric acid mist to air
Sulphur dioxide to air	kg	566025.9	sulfur dioxide emissions to air
Steam Produced	kg	321976100	WHR Steam - utilized in Leaching plant
Solid waste	kg		waste for recovery
Zinc calcined	kg	529615000	
Leaching & Purification: DSC			
Input	Unit	Quantity (FY 2024)	Comments
Activated Carbon	kg	25	activated carbon
Cement	kg	43962090	
Electricity - Total	MJ	79005720.96	
Flocculant	kg	69830	
H2SO4	kg	45169050	sulphuric acid
H2SO4_Recycled	kg	0	recycled H2SO4
KMnO4	kg	0	potassium permanganate
Limestone	kg	42076010	lime
MnO2	kg	0	manganese dioxide
Na2SO4	kg	13418450	sodium sulphate
Steam	kg	321976100	WHRB steam
Zinc calcined	kg	404606000	
Zinc calcined form DZS	kg	3029000	
Zinc calcined form CSC	kg	0	
Zinc powder	kg	1966150	
Output	Unit	Quantity (FY 2024)	Comments
Purification cake	kg	3921040	
Jarosite - disposal	kg	189786500	
Jarosite - Sold		0	
Particulates (PM)	kg	342660	particulate 2.5 to 10 microns
Zinc Sulphate (ZnSO4)	kg	3358854070	
Electrolysis: DSC			
Input	Unit	Quantity (FY 2024)	Comments
Electricity - Total	MJ	3075704040	Electricity from Grid
Gelatin	kg	10400	Gelatin (gum arabic)
NH4Cl	kg	731790	ammonium chloride - Total smelter
SrCO3	kg	154050	strontium carbonate
Steel	kg	1280	steel band
Thermal enegy from diesel	MJ	292279630	
Proces water	kg	2445291440	Total smelter water consumption
Zinc Sulphate (ZnSO4)	kg	3358854070	
Output	Unit	Quantity (FY 2024)	Comments
Anode sludge	kg	1132000	
Spent acid	kg	412610000	
Solid waste	kg	2947260	waste for recovery (cooler cake)

Wastewater in loop	kg	0	waste water keep in the process
Wastewater	kg	0	waste water untreated
Water - evaporated	kg	0	water losses due to evaporation
Zinc cathode	kg	253621000	Zn cathode
Melting & Casting - PMP			
Input	Unit	Quantity FY 2024 (Zinc)	Comments
BNO3_3	kg	888	
Bullion_Pb	kg	0	lead cathode/bullion
CaF2	kg	0	calcium flouride
Diesel	kg	97553.67818	
Electricity - Total	MJ	115930654.1	
High grade silver	kg	0	high grade material silver
NH4Cl	kg	70000	ammonium chloride
Nitrogen	kg	0	liquid nitrogen
Oxygen	kg	0	liquid oxygen
Pyrite	kg	0	iron pyrite
Slime Pb	kg	0	lead anode slime
Thermal energy from natural gas	MJ	7705770.3	
Thermal energy from HSD	MJ	160106	
Ground water	kg	31440.92	Ground water
Rain water	kg	14885.10	Rain Water
Water from WTP	kg	4628.82	STP recycled water
Zinc cathod - CLZS hydro	kg	6236539	zinc cathode CLZS Hydro
Zinc cathod - CLZS Pyro	kg	0	zinc cathode CLZS Pyro
Zinc cathod - DSC	kg	166632719	zinc cathode DSC
Zinc cathod - DZS	kg	2512109	zinc cathode DZS
Zinc Cathode - Total	kg	175381367	
Zinc strap	kg	27364	PP strap zinc
Output	Unit		Comments
Acid	kg	0	used Lead acid batteries
Lead (Pb) dross	kg		
Zinc (Zn) dross	kg	4736120	
Special High grade Zinc Ingot	kg	171070969	
Waste	kg	0	waste for recovery

Zinc Smelting Debari (ZSD) - (Hydrometallurgical)

Debari Zinc Smelter (DZS)			
Roasting: DZS (Roaster 2) - Total (2&3)			
Input	Unit	Quantity (FY 2024)	Comments
Chlorine (Cl2)	kg	0	chlorine
Electricity - Total	MJ	208831710	
Hydrazine	kg	0	
Sodium silicate	kg	0	
Sand	kg	0	
Thermal energy from HFO	MJ	0	thermal energy from heavy fuel oil
Thermal energy from LPG	MJ	3078047.5	thermal energy from liqueified petroleum gas
TSP (trisodium phosphate)	kg	0	
V2O5 (vanadium pentoxide)	kg	19990	
River water	kg	0	
Process water	kg	0	
Zinc Concentrate form RAM	kg	199017891	zinc concentrate RAM
Zinc Concentrate form SKM	kg	64848147	zinc concentrate SKM
RDM Concentrate	kg	12784366	

ZWM Concentrate	kg	50530000	
Output	Unit	Quantity (FY 2024)	Comments
Calomel	kg	0	
Sulphuric acid (H2SO4)	kg	274786000	
H2SO4 Mist	kg	0	sulfuric acid mist to air
Sulphur dioxide to air	kg	149450	sulfur dioxide emissions to air
Steam Produced	kg	0	Not Measured
Solid waste	kg	86929900	waste for recovery
Zinc calcined	kg	291501550	
Leaching & Purification: DZS			
Input	Unit	Quantity (FY 2024)	Comments
Activated Carbon	kg	12280	
Cement	kg		
Electricity - Total	MJ	36118202.06	
Flocculant	kg	0	
H2SO4	kg	0	sulphuric acid
H2SO4_Recycled	kg		recycled H2SO4
KMnO4	kg	12040	potassium permanganate
Limestone	kg	0	limestone
MnO2	kg	0	manganese dioxide
Na2SO4	kg	2956840	sodium sulphate
Steam	kg		
Tartrate	kg	5690	tartrate
Zinc calcined	kg	146690000	
Zinc powder	kg		
Hydrated Lime	kg	3303040	
Output	Unit	Quantity (FY 2024)	Comments
Purification cake	kg	1366500	
Jarosite	kg	82733510	
Particulates (PM)	kg		particulate 2.5 to 10 microns
Zinc Sulphate (ZnSO4)	kg	1117623000	
Electrolysis: DZS			
Input	Unit	Quantity (FY 2024)	Comments
Electricity - Total	MJ	1136530879	
Gelatin	kg	2515000	Gelatin (gum arabic)
NH4Cl	kg	47140	ammonium chloride - Total smelter
SrCO3	kg	0	strontium carbonate
Proces water	L	950507730	
Zinc Sulphate (ZnSO4)	kg	1117623000	
Output	Unit	Quantity (FY 2024)	Comments
Anode_sludge	kg	815000	
Cooler cake	kg	677400	
Spent acid	kg	23960	
Solid waste	kg	677400	waste for recovery (cooler cake)
Wastewater in loop	kg	0	waste water keep in the process
Wastewater	kg	0	waste water untreated
Water - evaporated	kg		water losses due to evaporation
Zinc cathode	kg	85187000	Zn cathode
Melting: DZS			
Input	Unit	Quantity (FY 2024)	Comments
Electricity - Total	MJ	32739256.84	110 kWh/tonne of cathode - DZS team
Steel	kg	0	steel band
Thermal energy from HFO	MJ	0	

Thermal energy from LPG	MJ	0	
Zinc Cathode	kg	82674891	
Output	Unit	Quantity (FY 2024)	Comments
High Grade Zinc	kg	78214808	
Zinc dross	kg	4460083	

Chanderiya Smelting Complex (CSC) – (Pyrometallurgical)

Chanderiya Smelting Complex (CSC) - Pyro			
Sinter: CSC (Pyro)			
Input	Unit	Quantity (FY 2024)	Comments
Ausmelt dust	kg	0	
Ausmelt slag	kg	0	
Cu cake	kg	824850	copper cake
Cu dross	kg	0	copper dross
Dross ISF	kg	0	ISF fine dross
Dross ZRP	kg	0	
Filter dust	kg	0	
Iron ore flux	kg	12876000	
Limestone	kg	32912000	limestone
Pb_Ag_cake	kg	250000	zinc oxide dust
Lead (Pb) concentrate from RAM	kg	5180000	lead concentrate RAM
Lead (Pb) concentrate from RDM	kg	9705000	lead concentrate RDM
Lead (Pb) concentrate from SKM	kg	26051000	lead concentrate SKM
Lead (Pb) concentrate from ZM	kg	66096400	lead concentrate Zawar
Powder_slurry	kg	14866184.49	blue powder slurry
Sand	kg	6454400	quartz sand
Sb_dust	kg		antimony dust
Zinc calcine from CSC H1	kg	0	zinc calcine CSC H1
Zinc calcine from DZS	kg	0	zinc calcine DZS
Zinc concentrate - Imported	kg	0	zinc concentrate imported
Zinc Concentrate - RAM	kg	21754820	zinc concentrate RAM
Zinc Concentrate - RDM	kg	103000	zinc concentrate RDM
Zinc Concentrate - SKM	kg	10425000	zinc concentrate SKM
Zinc Concentrate - ZM	kg	41215400	zinc concentrate ZM
Zinc dross	kg	0	zinc dross
Zinc oxide (ZnO) - ISF	kg	0	zinc oxide/Waelz oxide ISF
Zinc oxide (ZnO) - Debari	kg	2615610	zinc oxide/Waelz oxide Debari
Zinc oxide (ZnO) dust	kg	4620970	zinc oxide dust
Electricity - Total	MJ	144236545.4	
HYDROGEN PEROXIDE	Kg	42000	
HIGH STRESS POLYMER	Kg	140	Not considered
FLUX, DOLOMITE	Kg	636820	
CO2, LIQUID, IS 307-1966, GRADE:1	Kg	208310	
Antiscalant, PN:YIN000215	Kg	70	Not considered
NaOH	Kg	241640	Added in ISF
Saw dust	Kg	197200	Not considered
Output	Unit	Quantity (FY 2024)	Comments
HGP Cake	kg	2426020	HGP cake
H2SO4	kg	144472000	sulphuric acid
SO2 emissions	kg	222901.4798	sulphur dioxide emissions
Total - Sinter	kg	220067000	
ISF - CSC (Pyro)			
Input	Unit	Quantity (FY 2024)	Comments
Coke fines	kg	0	coke fines

Fly ash	kg	276639950	
Electricity Production	MJ	7798492800	
Electricity Production - Net	MJ	7797903133	
NOx emissions	kg	5034020.80	nitrogen oxides to air
PM 10 emissions	kg	563610.30	particulate >PM10
SO2 emissions	kg	15285705.84	sulfur dioxide emissions to air

Captive Power Plant (CPP) - DSC

Captive Power Plant (CPP) - DSC			
CPP - DSC			
Input	Unit	Quantity (FY 2024)	Comments
Alum	kg	21550	
Coal	kg	591825200	NCV - 4851 Kcal/kg
Biomass	kg	14534860	NCV - 3282 Kcal/kg
Electricity from grid (auxillary)	MJ	360854625.6	
Electrolyte	kg	50	polyelectrolyte
HSD	kg	189234	high sulfur diesel
Hydrazine	kg	850	
Morpholine	kg	1700	
NaClO	kg	718080	sodium hypochlorite
TSP	kg	115350	trisodium phosphate
Output	Unit	Quantity (FY 2024)	Comments
Fly ash	kg	103965380	
Electricity Production	MJ	4303598400	
Electricity Production - Net	MJ	3942743774	
NOx emissions	kg	1725660	nitrogen oxides to air
PM 10 emissions	kg	342660	particulate >PM10
SO2 emissions	MJ	8162990	sulfur dioxide emissions to air

Captive Power Plant (CPP) - ZM

Captive Power Plant (CPP) - ZM			
CPP - ZM			
Input	Unit	Quantity (FY 2024)	Comments
Alum	kg	11320	
Coal	kg	289309420	NCV - 5038 Kcal/kg
Biomass	kg	14688030	NCV - 3243 Kcal/kg
Electricity from grid (auxillary)	MJ	172223000	
Electrolyte	kg	940	polyelectrolyte
HSD	MJ	1878867359	high sulfur diesel
Hydrazine	kg	150	
Morpholine	kg	5200	
NaClO	kg	88510	sodium hypochlorite
TSP	kg	70	trisodium phosphate
Process water	L	1462330000	
Output	Unit	Quantity (FY 2024)	Comments
Fly ash	kg	57118100	
Electricity Production	MJ	2257859000	
Electricity Production - Net	MJ	2085636000	
NOx emissions	kg	2915100	nitrogen oxides to air

PM 10 emissions	kg	330900	particulate >PM10
SO2 emissions	kg	10079200	sulfur dioxide emissions to air

Electricity Mix – Site-wise (HZL)

Electricity Mix - CSC		
Input	Unit	Quantity (FY 2024)
Electricity from grid	GJ	232945
Net CPP - CSC	GJ	7698685
Electricity from Solar	GJ	2261
Electricity from Wind	GJ	0
WHRB	GJ	314345
OA- ZM - CPP	GJ	13958.6112
Electricity Mix – ZSD/DZS		
Input	Unit	Quantity (FY 2024)
Electricity from grid	GJ	747303
Electricity from Solar	GJ	77364
Electricity from Wind	GJ	0
WHRB	GJ	169085
OA - CSC - CPP	GJ	8953
OA- ZWM - CPP	GJ	476970
Electricity Mix - DSC		
Input	Unit	Quantity (FY 2024)
Electricity from grid	GJ	219803
Net CPP - DSC	GJ	2882716
Electricity from Solar	GJ	208
Electricity from Wind	GJ	0
WHRB	GJ	282587
OA- CSC - CPP	GJ	8185
OA- ZM - CPP	GJ	128776
Electricity Mix - ZM		
Input	Unit	Quantity (FY 2024)
Electricity from grid	GJ	15817
Net CPP - ZM	GJ	861072
Electricity from Solar	GJ	0
Electricity from Wind	GJ	0
WHRB	GJ	0
OA- CSC - CPP	GJ	18606
Electricity Mix - SKM		
Input	Unit	Quantity (FY 2024)
Electricity from grid	GJ	260148
Electricity from Solar	GJ	53
Electricity from Wind	GJ	0
CPP- DSC	GJ	804697
Electricity Mix - RAM		
Input	Unit	Quantity (FY 2024)
Electricity from grid	GJ	602861
Electricity from Solar	GJ	168594
Electricity from Wind	GJ	0
OA- CSC - CPP	GJ	63473
OA- ZM - CPP	GJ	604860

Electricity Mix - RDM		
Input	Unit	Quantity (FY 2024)
Electricity from grid	GJ	78243
Electricity from Solar	GJ	16
Electricity from Wind	GJ	0
Electricity from CPP- DSC	GJ	255330
Electricity Mix - PMP		
Input	Unit	Quantity (FY 2024)
Electricity from grid	GJ	141525
Electricity from Solar	GJ	0
Electricity from Wind	GJ	0
Electricity Mix - RAM+KM		
Input	Unit	Quantity (FY 2024)
Electricity from grid	GJ	641610
Electricity from Solar	GJ	173352
Electricity from Wind	GJ	0
OA- CSC - CPP	GJ	63473
OA- ZM - CPP	GJ	604860

Annex B2: Background data

The datasets used for the Upstream raw materials, energy, unit processes, transportation etc, are given in the table below.

Material/Fuel Name	Object name	Owner of the data set	Reference year
V205	DE: Catalyst (Vanadium pentoxide, sodium nitrate) Sphera	Sphera Solutions GmbH	2023
Xanthate	DE: Alkali-Xanthate Sphera	Sphera Solutions GmbH	2023
Process water	RER: Process water from surface water Sphera	Sphera Solutions GmbH	2023
Explosive	RER: Explosives (ANFO) manufacturing and use phase (emissions from explosion) Sphera	Sphera Solutions GmbH	2019
Polyacrylamide	DE: Polyacrylamide (anionic) (solid) Sphera	Sphera Solutions GmbH	2020
H205	IN: Hydrogen peroxide (100%; H2O2) (Hydrogen from steam reforming) Sphera	Sphera Solutions GmbH	2023
Coke	IN: Petroleum coke at refinery Sphera	Sphera Solutions GmbH	2020
Sodium Silicate	DE: Water glass (sodium silicate) (37/40 solution) Sphera	Sphera Solutions GmbH	2023
Sand	DE: Dried quartz sand (grain size 0/2) Sphera	Sphera Solutions GmbH	2023
Strontium carbonate	DE: Strontium Carbonate <LC>	Sphera Solutions GmbH	2023
Ammonia Liquid	IN: Ammonia (NH3) by-product carbon dioxide (NH3/CO2) Sphera	Sphera Solutions GmbH	2023
Oxygen	IN: Oxygen (gaseous) Sphera	Sphera Solutions GmbH	2023
Lubricant	IN: Lubricants at refinery Sphera	Sphera Solutions GmbH	2020
Sulphuric acid	IN: Sulphuric acid (96%) Sphera	Sphera Solutions GmbH	2023
NaOH	IN: Sodium hydroxide mix (100%) Sphera	Sphera Solutions GmbH	2023
Chlorine	IN: Chlorine mix Sphera	Sphera Solutions GmbH	2023
Nitric Acid	IN: Nitric acid (98%) Sphera	Sphera Solutions GmbH	2023
Limestone	IN: Limestone (CaCO3; washed) (approximation) Sphera	Sphera Solutions GmbH	2023
NaCN	DE: Sodium cyanide Sphera	Sphera Solutions GmbH	2023
Hydrazine	DE: Hydrazine hydrate/hydrazine Sphera	Sphera Solutions GmbH	2023
Cement	IN: Cement (average) Sphera	Sphera Solutions GmbH	2023
TSP	GLO: Trisodium phosphate Sphera	Sphera Solutions GmbH	2023
Zinc sulphate	DE: Zinc sulphate (ZnSO4) (approximation) Sphera	Sphera Solutions GmbH	2023
Hazardous waste treatment	RER: Hazardous waste (statistical average) (no C, worst case scenario incl. landfill) Sphera	Sphera Solutions GmbH	2023
CO2	IN: Carbon dioxide (CO2) by-product ammonia (NH3) (economic allocation) Sphera	Sphera Solutions GmbH	2023
Diesel combustion	GLO: Diesel combustion in construction machine (18-36 kW; Stage IIIA) Sphera <u-so>	Sphera Solutions GmbH	2020
NH4Cl	DE: Ammonium chloride (Salmiac, Solvay-process) Sphera	Sphera Solutions GmbH	2023

Material/Fuel Name	Object name	Owner of the data set	Reference year
PEG	RER: Polyethylene glycol (PEG) Sphera	Sphera Solutions GmbH	2023
Hydrated lime	IN: Hydrated lime (approx. Ca(OH) ₂) slaking Sphera	Sphera Solutions GmbH	2023
Sodium nitrate	IN: Sodium nitrate (approximation) Sphera	Sphera Solutions GmbH	2023
Sodium bicarbonate	RER: Sodium bicarbonate (sodium hydrogen carbonate) Sphera	Sphera Solutions GmbH	2023
Dolomite	IN: Dolomite (ground) Sphera	Sphera Solutions GmbH	2023
Copper sulphate	DE: Copper sulphate as by-product from copper route (import from CA) Sphera	Sphera Solutions GmbH	2023
Landfill	EU-28: DUPLICATE - Glass/inert waste on landfill Sphera	Sphera Solutions GmbH	2020
Methylmorpholine	EU-28: N-Methylmorpholine (approximation) Sphera	Sphera Solutions GmbH	2023
Sodium sulphate	DE: Sodium sulphate Sphera	Sphera Solutions GmbH	2023
KMnO ₄	DE: Potassium permanganate (KMnO ₄) Sphera	Sphera Solutions GmbH	2023
NaCl	IN: Sodium chloride (rock salt) (approximation) Sphera	Sphera Solutions GmbH	2023
NaOCl	RER: Sodium hypochlorite solution Sphera	Sphera Solutions GmbH	2023
Wastewater Treatment	DE: Municipal waste water treatment (mix) Sphera	Sphera Solutions GmbH	2023
Activated carbon	CN: Activated carbon Sphera	Sphera Solutions GmbH	2023
Hazardous waste treatment	GLO: Hazardous waste (non-specific) (no C, worst case scenario incl. landfill) Sphera	Sphera Solutions GmbH	2023
Steel strap	IN: Steel section Sphera <p-agg>	Sphera Solutions GmbH	2023
Grid electricity	IN: Electricity grid mix Sphera	Sphera Solutions GmbH	2020
Wind electricity	IN: Electricity from wind power Sphera	Sphera Solutions GmbH	2020
Hydro electricity	IN: Electricity from hydro power Sphera	Sphera Solutions GmbH	2020
Solar electricity	IN: Electricity from photovoltaic Sphera	Sphera Solutions GmbH	2020
Coal	IN: Hard coal mix Sphera	Sphera Solutions GmbH	2020
Thermal energy for NG	IN: Thermal energy from natural gas Sphera	Sphera Solutions GmbH	2020
Thermal energy for diesel	US: Thermal energy from diesel Sphera	Sphera Solutions GmbH	2020
Thermal energy for propane	US: Thermal energy from propane Sphera	Sphera Solutions GmbH	2020
Thermal energy for LDO	IN: Thermal energy from light fuel oil (LFO) Sphera	Sphera Solutions GmbH	2020
Thermal energy for LPG	IN: Thermal energy from LPG Sphera	Sphera Solutions GmbH	2020
Natural gas	IN: Natural gas mix Sphera	Sphera Solutions GmbH	2020
Diesel	IN: Diesel at refinery Sphera	Sphera Solutions GmbH	2020
Thermal energy for LDO	IN: Thermal energy from heavy fuel oil (HFO) Sphera	Sphera Solutions GmbH	2020
LPG	IN: Liquefied Petroleum Gas (LPG) (70% propane, 30% butane) Sphera	Sphera Solutions GmbH	2020
Biomass (fuel)	US: Biomass (solid) for bioenergy Sphera	Sphera Solutions GmbH	2023
Truck	IN: Truck-trailer, Bharat stage IV, 34 - 40t gross weight / 27t payload capacity Sphera <u-s>	Sphera Solutions GmbH	2023

Material/Fuel Name	Object name	Owner of the data set	Reference year
Diesel	IN: Diesel mix at refinery Sphera	Sphera Solutions GmbH	2020
Rail	GLO: Rail transport cargo - average, average train, gross tonne weight 1,000t / 726t payload capacity	Sphera Solutions GmbH	2023
Ship	GLO: Container ship, 5.000 to 200.000 dwt payload capacity, deep sea	Sphera Solutions GmbH	2023
HFO	IN: Heavy fuel oil at refinery (1.0wt.% S)	Sphera Solutions GmbH	2020

Annex C: Additional Results

Site-wise PCF results of 1 tonne of Special High-Grade Zinc (SHGZ) product is given below:

The Tables below shows the Product Carbon Footprint (PCF) results for 1 tonne of special high grade zinc product for source wise relative contributions from various sources such as raw material production, transportation (includes impact from transportation of raw materials, transportation of concentration to smelting location and transportation of zinc cathode to PMP), electricity, energy (includes impact from fuel consumption like LPG, diesel, propane etc.), process emissions (includes impact of direct process emission from roasting, leaching & purification, electrolysis, sintering, ISF processes mainly due limestone, dolomite, coke etc. consumptions) and waste management (includes impact from wastewater treatment and solid waste handling and treatment).

Source-wise PCF Results of 1 Tonne of Special High-Grade Zinc (SHGZ) Product – CSC H1

PCF Indicators	Unit	Total	Raw Materials	Transportation	Electricity	Energy	Process Emissions	Waste Management
GWP100, Air craft emissions	kg CO ₂ eq.	1.80E-04	1.26E-05	1.89E-07	1.42E-04	1.84E-06	0.00	2.35E-05
GWP100, Biogenic GHG emissions	kg CO ₂ eq.	117.96	3.17	0.71	103.86	7.42	0.00	2.80
GWP100, Biogenic GHG removal	kg CO ₂ eq.	-109.16	-2.99	-0.56	-102.23	-0.43	0.00	-2.95
GWP100, Emissions from land use change (dLUC)	kg CO ₂ eq.	1.12	4.18E-02	1.82E-02	1.03	9.02E-03	0.00	2.90E-02
GWP100, Fossil GHG emissions	kg CO₂ eq.	5978.94	524.33	15.44	5235.52	177.54	0.00	26.10

Source-wise PCF Results of 1 Tonne of Special High-Grade Zinc (SHGZ) Product – CSC H2

PCF Indicators	Unit	Total	Raw Materials	Transportation	Electricity	Energy	Process Emissions	Waste Management
GWP100, Air craft emissions	kg CO ₂ eq.	1.85E-04	1.08E-05	2.06E-07	1.37E-04	2.03E-06	0.00	3.52E-05
GWP100, Biogenic GHG emissions	kg CO ₂ eq.	120.52	2.70	0.77	105.45	8.13	0.00	3.47
GWP100, Biogenic GHG removal	kg CO ₂ eq.	-111.12	-2.53	-0.61	-103.77	-0.47	0.00	-3.74
GWP100, Emissions from land use change (dLUC)	kg CO ₂ eq.	1.13	2.94E-02	1.98E-02	1.02	9.94E-03	0.00	4.68E-02
GWP100, Fossil GHG emissions	kg CO₂ eq.	5750.24	232.58	16.84	5274.45	194.01	0.00	32.36

Source-wise PCF Results of 1 Tonne of Special High-Grade Zinc (SHGZ) Product – CSC Pyro

PCF Indicators	Unit	Total	Raw Materials	Transportation	Electricity	Energy	Process Emissions	Waste Management
GWP100, Air craft emissions	kg CO ₂ eq.	1.89E-04	1.05E-05	2.50E-07	5.31E-05	1.44E-05	0.00	1.11E-04
GWP100, Biogenic GHG emissions	kg CO ₂ eq.	101.29	2.69	0.94	59.04	31.97	0.00	6.65
GWP100, Biogenic GHG removal	kg CO ₂ eq.	-92.91	-2.40	-0.74	-58.03	-23.76	0.00	-7.99
GWP100, Emissions from land use change (dLUC)	kg CO ₂ eq.	1.44	0.04	2.41E-02	0.44	7.63E-01	0.00	0.17
GWP100, Fossil GHG emissions	kg CO₂ eq.	6734.05	439.18	20.46	2461.37	1206.64	2537.15	69.24

Source-wise - PCF Results of 1 Tonne of Special High-Grade Zinc (SHGZ) Product – DSC

PCF Indicators	Unit	Total	Raw Materials	Transportation	Electricity	Energy	Process Emissions	Waste Management
GWP100, Air craft emissions	kg CO ₂ eq.	1.83E-04	1.26E-05	1.07E-06	1.52E-04	1.68E-06	3.18E-07	1.52E-05
GWP100, Biogenic GHG emissions	kg CO ₂ eq.	127.73	3.20	4.01	111.34	6.76	5.01E-02	2.38
GWP100, Biogenic GHG removal	kg CO ₂ eq.	-118.62	-3.02	-3.16	-109.72	-0.40	-4.89E-02	-2.28
GWP100, Emissions from land use change (dLUC)	kg CO ₂ eq.	1.18	4.62E-02	0.10	1.00	8.51E-03	4.91E-04	1.64E-02
GWP100, Fossil GHG emissions	kg CO₂ eq.	5783.21	578.03	87.36	4839.68	257.68	1.19	19.28

Source-wise PCF Results of 1 Tonne of Special High-Grade Zinc (SHGZ) Product – ZSD

PCF Indicators	Unit	Total	Raw Materials	Transportation	Electricity	Energy	Process Emissions	Waste Management
GWP100, Air craft emissions	kg CO ₂ eq.	7.69E-04	5.62E-06	2.21E-07	7.21E-04	3.06E-06	0.00	3.90E-05
GWP100, Biogenic GHG emissions	kg CO ₂ eq.	215.43	1.38	0.83	201.77	8.30	0.00	3.15
GWP100, Biogenic GHG removal	kg CO ₂ eq.	-206.96	-1.32	-0.65	-200.80	-0.58	0.00	-3.61
GWP100, Emissions from land use change (dLUC)	kg CO ₂ eq.	2.57	1.20E-02	2.13E-02	2.46	1.42E-02	0.00	5.56E-02
GWP100, Fossil GHG emissions	kg CO₂ eq.	5806.91	123.40	18.10	5448.77	187.34	0.00	29.30

Annex D: Additional Information

HZL is ensuring the complete details about renewable electricity supply. Renewable electricity supply is ensured by the grid. The scheduling mechanism implemented by the Grid ensures that the energy that is injected at the generating end is drawn at the consumer end. The power will be injected only from the renewable energy projects set up on captive SPV arrangement. The power transaction documentation is maintained according to the t-gna document. Below are the details of projects under execution by Serentica for HZL under captive special purpose vehicle scheme.

Serentica Global	SRI4PL	Solar	180MW	Bikaner
		wind	325MW	Kallamb
	SRI5PL	solar	220MW	Bikaner
		solar	40MW	Fatehgarh
		wind	250MW	Solapur
		wind	120MW	Kallamb