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Product Carbon Footprint of Refractory Products

The refractory industry is part of the most CO_2-intensive value chains in the global economy and increasingly final customers are requesting the decarbonisation of these value chains (e.g., automobile production and construction industry). Therefore, final producers must report not only their direct CO_2 emissions but all CO_2 emissions inherent to their product. A product carbon footprint (PCF) provides greenhouse gas (GHG) information of a product from cradle-to-gate and is an important input to customer industries to declare their products' carbon footprint accurately. RHI Magnesita is the first refractory producer to implement a PCF on the technical data sheets of nearly all its products. To achieve this milestone, a quantification approach for the product-specific carbon footprint was defined and executed by a cross-functional team. The article aims to illustrate this approach, its implementation, as well as the limitations and way forward. Furthermore, a case study of a basic mix is presented to show the specific source and percentage of GHG emissions in a cradle-to-gate PCF.

Introduction

The climate crisis is affecting most parts of the world and global emissions are reaching record levels every year. At the same time, society as a whole and stakeholders are gaining an ever better understanding that urgent actions are imperative. The global cement and steel production—RHI Magnesita's key customer groups—cause approximately 14% of the global energy- and process-related emissions [1], types of emissions that are responsible for around 75% of global greenhouse gas (GHG) emissions [2]. This puts the steel and cement industry value chain under great pressure to be transparent and take meaningful actions to reduce their emissions.

Currently, GHG emissions from refractory materials contribute less than 1% of the total emissions in steel production according to an internal RHI Magnesita estimation. However, with the increasing drive towards green steel, this share will increase and put stronger focus and pressure to reduce the GHG intensity of refractories. RHI Magnesita has taken meaningful initial steps to reduce the GHG intensity of its products by becoming more circular and using secondary raw materials (i.e., 10% use of secondary raw materials in 2022). Additionally, in 2022 RHI Magnesita introduced product carbon footprint (PCF) information as a standard on its technical data sheets to increase climate transparency for its customers.

The PCF is a way to show the GHG emissions in direct relation to a product. A PCF is a life cycle environmental impact assessment focusing on the so-called "global warming potential" of a product expressed in tonnes of CO_2 equivalent (CO_2e) [3]. Typically, the PCFs are either cradle-to-gate or cradle-to-grave. Cradle-to-gate covers all GHG emissions from upstream sources and the direct manufacturing of a product. Commonly, this includes mining, raw material processing, transportation, and production of the product. Cradle-to-grave also considers transportation to the customer, emissions from product use, and emissions at the end of a product's life (e.g., from incineration or landfilling of the used product and transportation for disposal) [4].

In the refractory industry, RHI Magnesita is the first refractory producer providing PCFs systematically for most of its products as part of the standard product information on the technical data sheet. While the majority of refractory producers do not provide any product-specific GHG information, the first competitors have published PCF information as part of a complete environmental impact assessment but only on a selective basis for certain products. In the wider industry, front-runners have already created a comprehensive PCF portfolio (e.g., BASF in the chemical industry [5]).

Calculation Approach

Calculation of the PCF for RHI Magnesia products follows the principles of ISO 14067 (Greenhouse gases — Carbon footprint of products — Requirements and guidelines for quantification):

- Relative approach and functional or declared unit: To calculate the PCF of a product a reference unit is required. The declared unit for calculating the PCF of a refractory product is one metric tonne of refractory product.
- Relevance and completeness: The chosen approach to calculate the PCF must be appropriate to determine the relevant GHG emissions arising from the examined product and must be complete to cover significant emissions.
- Consistency and accuracy: The approach must be consistently applied for all products covered and results must be as accurate as possible.
- Transparency: Assumptions, data sources, as well as shortcomings and limitations must be transparently documented and disclosed.
- Life cycle perspective.

The defined life cycle is from cradle-to-gate. This means that all relevant emissions in the production of a refractory product and its precursors, as well as operating supplies must be considered. For refractory products from RHI Magnesita this entails its own raw material production including mining and sintering, as well as the actual refractory production (Figure 1). Indirect emissions from precursors include purchased raw materials and resale goods as well as inbound and intra-company transport. Additionally, indirect emissions of fuels (e.g., from methane emissions at natural gas mining sites) and electricity consumed at RHI Magnesita's operations are relevant emission sources. Downstream emissions such as transport from RHI Magnesita to the customer or GHG emissions from refractories at the customer are not considered as they are customer specific. From a customer perspective, the scope of the PCF covers upstream scope 3 emissions of refractory products excluding the transport from RHI Magnesita to the customer site. From a RHI Magnesita perspective, the PCF covers indirect upstream scope 3 emissions, indirect electricity emissions (scope 2), and direct emissions (scope 1).

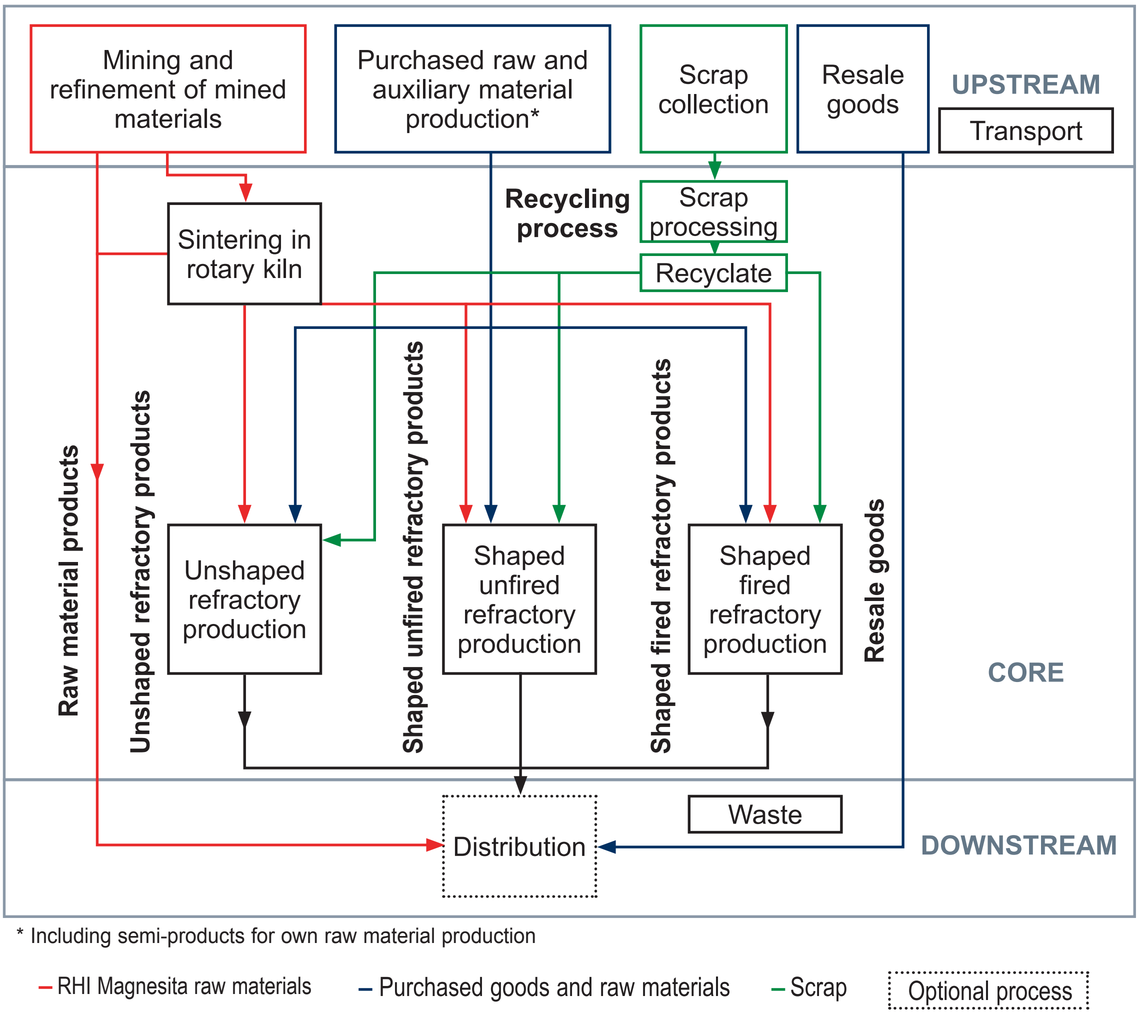
These scopes refer to a RHI Magnesita company perspective, if not stated differently. Scope 1 refers to direct emissions of an organisation (e.g., combustion of fuels), scope 2 refers to indirect emissions of an organisation directly associated with the provision of energy (e.g., emissions from a coal electricity power plant), and scope 3 refers to other indirect emissions upstream or downstream of an organisation (e.g., purchased raw materials and third-party transport).

The PCF is calculated and available for nearly all RHI Magnesita's refractory products. Other products such as digital tools and services are outside the scope. For all products, product-specific direct emissions (scope 1), and product-specific indirect emissions are included (scope 2 and scope 3 from purchased raw materials). Additionally, indirect emissions in direct relation to the production process but where allocation is not possible on a product or plant level are added to each product-specific emission using an average value (i.e., overhead emissions). These overhead emissions include emissions from fuel-and-energy-related activities, upstream transportation and distribution, as well as waste generated in operations.

Specific raw material emissions depend on the actual raw material used and production processes. The carbon footprint of raw materials includes mining and production of the raw materials. In the case of carbonate raw materials, geogenic process emissions are also considered. The CO_2 footprint data of purchased raw materials is currently not available in a systematic way for each specific purchased raw material. To be able to reflect the GHG footprint of purchased raw materials, these were grouped in raw material categories. For purchased raw materials, one emission factor per raw material category (e.g., fused magnesia) is used to reflect the most plausible production

Figure 1.

Flow diagram illustrating the processes included in the product system to manufacture refractories, divided into upstream, core, and downstream processes.



process (e.g., fuel used and electricity mix) based on the best available information. The sources include emission factors provided by suppliers, information from the literature or databases, estimations based on raw material production processes, and RHI Magnesita's internal expertise in raw material processing. As a fallback for raw materials where no plausible quantification approach could be identified, a generic emission factor of 1.8 tonne CO_2e per tonne of raw material is taken. This value was defined by expert judgement as a plausible average for refractory raw materials.

The calculated PCF of products consists of various elements with varying levels of granularity:

Raw materials

- Raw material category that is specific for purchased raw materials (e.g., fused magnesia).
- Plant-specific raw material category that is specific for raw materials produced by RHI Magnesita (e.g., dead burned magnesia mined and produced by RHI Magnesita's Breitenau plant).
- Specific quantities of each raw material in the recipe.

Processes to convert raw materials into a refractory product

- Plant-specific and product-group-specific (e.g., magnesia-carbon bricks from plant Veitsch). The exception is functional products where it is without plant-specific data.

Indirect emissions from transportation, energy generation, and waste disposal

- Average value across all products.

The value of a PCF for a finished refractory product is calculated according to the following formula:

(Recipe x GHG emission factors of the used raw material categories) + GHG emissions from the conversion processes per main product group and production plant + Average scope 3 overhead emissions

For resale refractory products, which are purchased from third-party refractory producers, a generic PCF is calculated. However, assumptions have to be taken regarding the product recipe, which results in increased uncertainty, as suppliers are currently not able to provide information on the carbon footprint of their refractory products.

Implementation of the Product Carbon Footprint on Technical Data Sheets

RHI Magnesita's technical data sheets are generated using product information in the SAP quality management system. Following the definition of CO_2 emission factors for raw material categories, a new data field in the SAP master data was created for the raw-material-specific emission factor. All raw materials were manually updated by a group of experts from R&D, Sales, and the Environment & Energy departments. In parallel, the Product Master Data team created and implemented a new SAP module to calculate the emissions of specific recipes based on master data emission factors. The calculation reflects the production of equivalent products at different plants considering plant- and main product-group-specific conversion-related CO_2 emissions by weighted average. Additionally, generic overhead emissions for transport, upstream energy emissions, and emissions from production waste are added.

Emissions from raw materials constitute by far the biggest part of the PCF for refractories (see the case study of a basic mix below). Therefore, special attention was given to the emission factors of raw materials. In a perfect world, supplier data would be used. However, while for some materials the supplier data are available, the majority of emission factors for third-party raw materials are either based on literature values or in-house calculations reflecting the raw material production process. In the case of internally sourced raw materials, plant-specific data is used. Around 50% of raw materials are internally sourced, mostly dead burned magnesia and doloma.

A special case are emission factors for secondary raw materials (recycling materials) and internal reclaim that is recycled as raw materials. For externally sourced secondary raw materials an emission factor of 0 tonne CO_2e/tonne is assumed as in most cases the secondary raw material processing involves very little energy and associated transport is addressed in the generic overhead emissions. Based on the insights gained from MIRECO, the RHI Magnesita and Horn & Co. Group minerals recovery joint venture, this emission factor will be adapted to actual values but will still be very low. The emission factor for internal reclaim is calculated on the basis of an economic allocation approach reflecting the economic value of internal reclaim relative to the virgin raw material value.

Uncertainty

Uncertainty of the PCF strongly correlates with the share of third-party raw materials in the recipe (Table I). Products with a high share of raw materials produced by RHI Magnesita have a low uncertainty—which comes from the generic overhead reflecting transport and indirect fuel-related emissions. In contrast, products with a high share of purchased raw materials have a significantly higher uncertainty due to uncertainties associated with the fuels used for production (e.g., coal or natural gas), process efficiencies, and the carbon intensity of any electricity used (particularly relevant for all fused products). Uncertainty is also high for resale goods, because not knowing the precise product composition increases uncertainty.

Data Maintenance

Having rolled out the PCF on technical data sheets, the data need to be maintained. This covers newly added raw materials, new refractory products, and maintenance of existing data. To reflect the latest emission data (e.g., conversion emissions on a plant main product group level) and improved data quality (e.g., supplier-sourced emission factors for third-party raw materials), CO_2e data is reviewed annually. Active supplier engagement to gain primary CO_2e data on third-party raw materials will contribute to the continuous improvement of the overall data quality and will reduce uncertainty.

Case Study—Basic Mix

To illustrate the varying sources of GHG emissions contributing to the PCF, a case study with a basic mix is presented. The product is a basic ramming mix produced in Austria and used in the hearth of electric arc furnaces. Figure 2 shows the emissions considered in the calculation and their share in the PCF. Around 90% of the emissions result from the raw material production. The majority are internally produced (i.e., mining and sintering) and a minor part comes from third-party purchases (i.e., purchased raw materials). As the product is an unshaped mix, the raw materials do not require any additional firing or tempering. This is reflected in the barely visible production contribution. Upstream emissions and transport are generic overhead values reflected as a company average. The total PCF of the basic mix is 1.74 tonne CO_2e per tonne of product.

Table II illustrates the high impact of direct emissions from

Figure 2.

Source and percentage of GHG emissions in the basic mix PCF.

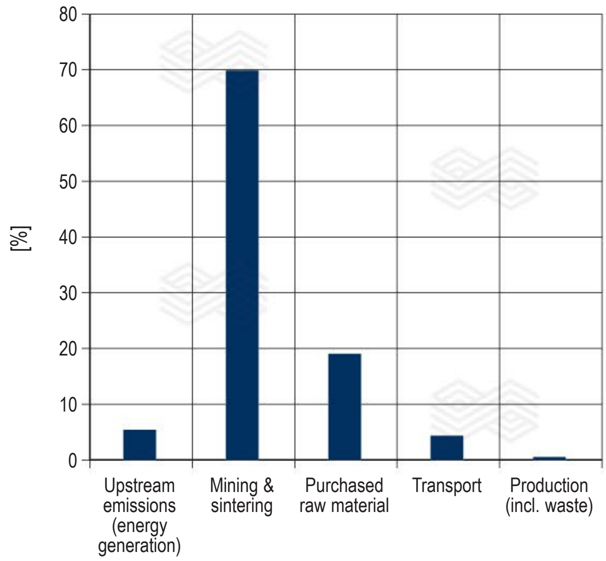


Table I.

Uncertainty assessment of data used to calculate PCFs (1 = low and 5 = high). A standard life cycle assessment uncertainty approach was used to generate the data [6].

Primary/ secondary data	Data set	Flow reliability	Complete-ness	Temporal representa-tiveness	Geographi-cal repre-sentative-ness	Technical represent-ativeness	Average
Primary data	Recipe	1	1	2	1	1	1.2
Secondary data	Upstream transport emissions	3	1	2	5	3	2.8
Primary data	Raw material emission factor from own operations	2	1	1	1	1	1.2
Primary data	Conversion	2	1	1	1	1	1.2
Primary data	Production quantity (per site)	1	1	1	1	1	1.0
Secondary data	Energy scope 3	2	2	2	2	3	2.2
Secondary data	Waste	3	1	4	4	5	3.4
Secondary data	Emission factor for purchased raw material	3	2	2	2	3	2.4
Secondary data	Refractory resale goods	3	4	4	3	5	3.8

the process (i.e., nonfuel related) as the raw material is a carbonate ($MgCO_3$) and approximately 50% of the mined raw material decomposes to CO_2. As all Austrian operations consume green electricity there are no electricity-related emissions.

In the case study, product uncertainty mainly comes from the generic overhead emissions (e.g., energy production and upstream transportation), which is not surprising as these are average values applied to all products (Table III).

Limitations

RHI Magnesita's implementation of PCF information on its technical data sheets is a step change in climate transparency that required significant effort from several departments in the company. At the same time, it is clear that this is a first step and more needs to follow to address the limitations of the current approach.

By far the biggest limitation is uncertainty in the data. The high share of indirect emissions in the PCF (on average around 50%), in conjunction with the limited availability of supplier-specific data, mark a major limitation with regard to accuracy. This implies that current PCF values provide important indicative information but can only be used as a basis for purchasing decisions to a limited extent. However, the vertical integration of RHI Magnesita brings a unique value for the end-user in reducing the uncertainty of the calculated PCF for refractory materials.

A second source of uncertainty is the average data used for transportation and fuel generation emissions. The generic nature of these data adds relatively little uncertainty to GHG intensive products but for low carbon products, with a high share of secondary raw materials, it creates a very high overall uncertainty.

Thirdly, resale products where RHI Magnesita operates as a trader not as a producer, have the highest uncertainty because all reported emissions are indirect emissions and suppliers currently cannot provide PCF data. All these limitations, but in particular the very high uncertainty associated with resale products, prevent a third-party assurance of RHI Magnesita's PCF approach at the moment.

Table II.

Source and proportion of GHG emissions in the basic mix PCF highlighting the significant impact of geogenic process emissions (red: ≥5%, yellow: <5% to ≥1%, and green: <1%).

Source	GHG emissions [%]
Upstream energy production	5.4
Purchased raw material	19.2
Scope 1 fuel (raw material)	24.5
Electricity	0.0
Scope 1 direct process emissions	45.8
Internal scrap	0.2
Upstream transportation	4.5
Fuel (basic mix production)	0.2
Waste	0.2

The Way Forward

Having highlighted the limitations of the current PCF on technical data sheets, the way forward is very clear: First and foremost, supplier engagement is key. Therefore, RHI Magnesita is reaching out to key suppliers to inform them about our initiative and their role in providing high-quality PCF information. This is happening in a highly dynamic setting where final customers are asking for climate transparency and low carbon products. So, the whole value chain in which RHI Magnesita operates is moving in the same direction towards increased transparency. This means that within a few years the uncertainty in relation to indirect emissions should significantly decrease.

At the same time, RHI Magnesita's ability to generate and process climate-related data is continuously evolving at a high pace. This will result in moving from generic transport emission data to plant-specific or even more granular transport emission data.

Table III.

Uncertainty assessment of the basic mix PCF data.

Source	PCF [tonne CO_2e]	GHG emissions [%]	Maximum deviation range [+/-]	Uncertainty origin
Upstream energy production	0.094	5.4%	22%	Emission factors
Purchased raw material	0.335	19.2%	31%	Unknown fuel usage and process
RHI Magnesita raw material	1.229	70.5%	3%	Recipes and emission factors
Conversion	0.004	0.2%	5%	Emission factors
Upstream transportation	0.078	4.5%	77%	Use of generic data
Waste	0.003	0.2%	21%	Generic calculation approach
Total	1.743	100%		
Weighted average			16%	

The biggest step ahead is establishing a unified approach to calculate PCFs across the entire refractory industry, thereby enabling an accurate comparison of PCF data from other refractory producers. However, this requires a major refractory industry alignment to define calculation and reporting approaches. So-called product category rules are industry-specific for PCF calculations and currently product category rules do not exist for refractories. PCFs calculated on industry-specific product category rules and external verification of provided data will be the basis for making GHG intensity a purchasing-relevant aspect for refractories.

Conclusion

As refractories are part of very GHG-intensive value chains and their production is GHG-intensive, transparency and meaningful actions to reduce refractory PCFs are vital. The PCF makes GHG emissions of a specific product transparent and RHI Magnesita is the first refractory producer to implement the PCF as standard information on its technical data sheets, considering its own and third-party raw materials, conversion, and other relevant indirect emissions. Current limitations with regard to uncertainty in certain areas are expected to significantly decrease in the near future making the information even more purchasing relevant.

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