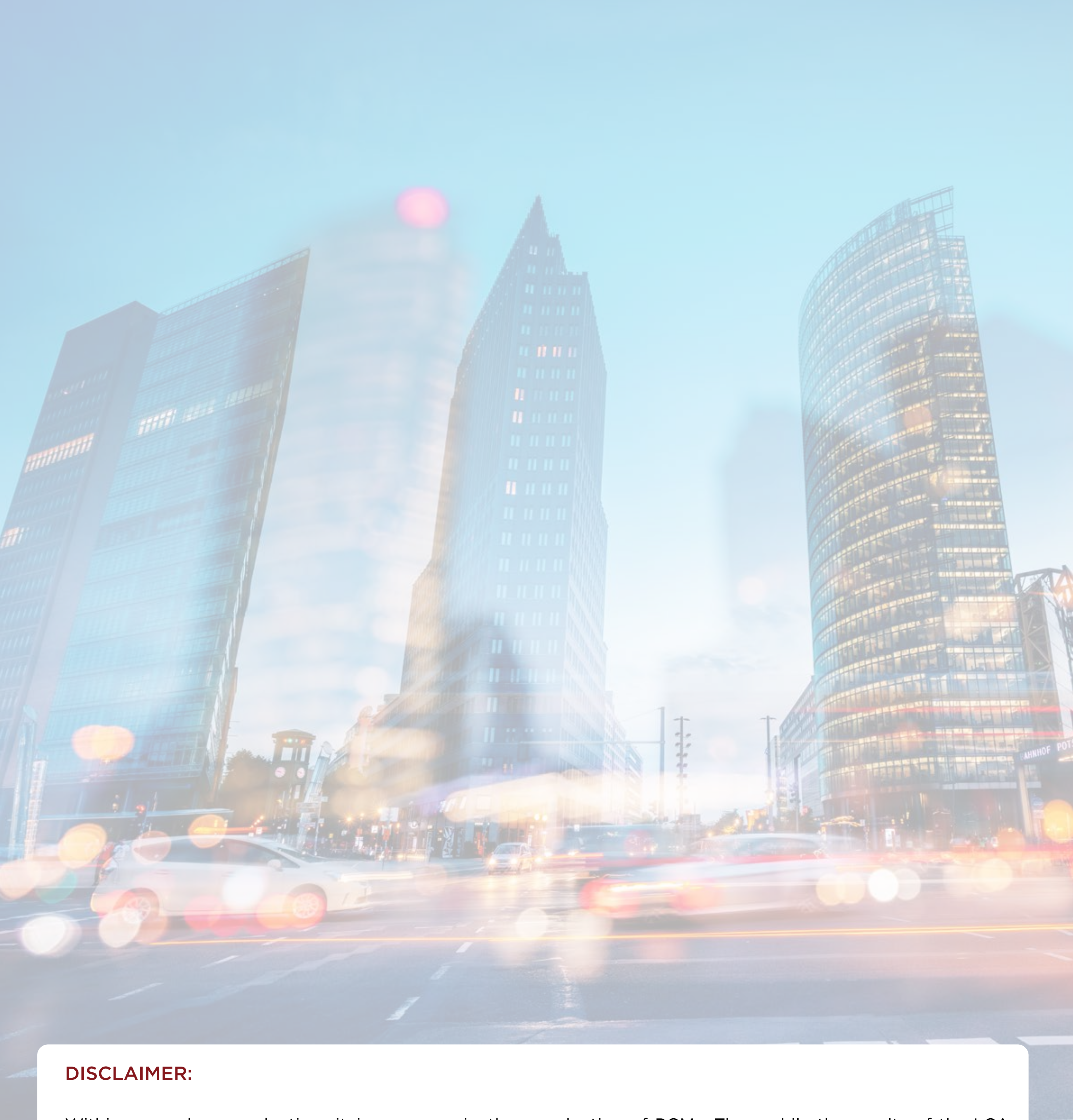
LCA

THE LIFE CYCLE ASSESSMENT OF PLATINUM GROUP METALS (PGMs)

Reference Year 2017

IPA

INTERNATIONAL PLATINUM GROUP METALS ASSOCIATION



DISCLAIMER:

Within secondary production, it is common in the PGM industry to treat a mixed feed of materials, which may include automotive and industrial catalysts, electronic scrap, and by-product materials. Consequently, it is challenging for an LCA to allocate the environmental footprint of a particular process either to individual metals or to an individual feed such as autocatalysts. The IPA LCA study has adopted a pragmatic approach and has used a mixed feed to model the average footprint for the secondary production of PGMs. Thus, while the results of the LCA study are valid as an industry average, they are not suited for the analysis of specific secondary production processes, especially for comparison purposes.

Similarly, the LCA results for primary production are averaged from inputs from mining operations which vary between one another in terms of the characteristics of their ores and should not be used to analyse one particular mine or participating company, or their production processes.

The Life Cycle Assessment of Platinum Group Metals (PGMs) – Update with 2017 Production Data

BACKGROUND

In response to growing demand from stakeholders for robust, credible, and independent data regarding the environmental footprint of Platinum Group Metals (PGMs) and PGM-containing products, the International Platinum Group Metals Association (IPA) and its members conducted in 2010 a first Life Cycle Assessment (LCA) of PGMs.

IPA commissioned the consultancy firm Sphera to undertake an update of this study, reflecting the PGM industry's environmental performance for the year 2017. This second study was finalized in 2020.

The main goal of the study was to assess the current cradle-to-gate LCA profile and potential environmental impacts of PGMs for both the primary and secondary production routes. A further goal was to understand the use phase performance of PGMs in an autocatalyst application to control tailpipe emissions from vehicles meeting the European Euro 6d-TEMP emissions standards, including testing under RDE (Real Driving Emissions), and reflecting improved autocatalyst technologies.

This LCA Fact Sheet focuses on technical and methodological information and presents the results for key categories. The document belongs to a series of fact sheets reflecting the results of the second IPA LCA Study.

GOAL AND SCOPE OF THE IPA LCA STUDY 2017

The IPA LCA considers the cradle-to-gate primary and secondary production of PGMs. It covers impacts associated with the extraction of resources from nature up to the point at which the refined product leaves the factory gate. For the primary route, the impact associated with the mining of PGM ore is considered, while for the secondary route end of life (EOL) PGM-containing material enters the system boundary burden free.

The cradle-to-gate Life Cycle Inventory (LCI) includes the associated use of resources and the emissions of all electricity, energy and materials inputs to PGM production.

Based on input from eleven out of twelve IPA members, the study focused on the primary and secondary production of PGMs. The use phase performance of PGMs was represented by their application in an autocatalyst system in Euro 6d-TEMP diesel and gasoline cars, assuming a lifetime of 160,000 km and that one catalyst system lasts this vehicle lifetime. This enabled the evaluation of the benefits of PGMs during the vehicle´s lifetime.

The study has been carried out in conformity with ISO 14040 (2006), ISO 14044 (2006) and ISO/TS 14071 (2014). As the ISO reviewer confirmed in his statement, the defined and achieved scope for this study was found to be appropriate to achieve the stated goals. Being the second version of the study, the methodology and procedures reached a high level of maturity.

KEY ACHIEVEMENTS

The outstanding feature of this study is the large increase in the amount of primary data collected to reach representative results for global PGM production. The eleven contributing members of the IPA represent more than 95% of primary PGM production, more than 70% of secondary PGM production, and over 90% of autocatalyst fabrication. Compared to the 2010 study, this has increased the industry coverage for primary production by 40% and for secondary production by more than 130%. The geographical coverage of PGM operations (production as well as fabrication of autocatalysts) was broadened by including production sites in Russia, France, Poland, Macedonia, and China.

The 2017 LCA improves on the 2010 study in several aspects. The quality of the data was enhanced by including assay data; measuring a greater range of scrap materials in secondary production; collecting data on the production of chrome concentrates, which is a by-product at some PGM mines in South Africa; and by using the GaBi[1] 2017 database for data on fuel and electricity inputs and upstream and downstream raw materials and unit processes.

Enhanced reporting elements include: presenting results for the Global Warming Potential (GWP) or impact from GHG emissions of primary and secondary

1) Ganzheitliche Bilanzierung (German for holistic balancing / life cycle engineering).

production split into Scopes 1, 2 and 3, as defined in the GHG Protocol for corporate reporting; the addition of results for the impact of production on Blue Water Consumption; and separate impact assessments (segregated data) for primary and secondary production, which were aggregated in the 2010 study.

LCA Study Quick Facts			
Life cycle stage	**Primary**	**Secondary**	**Autocatalyst fabrication**
Geographical coverage	South Africa, Zimbabwe, USA, Russia	Belgium, UK, Germany, Japan, USA, China	South Africa, UK, Germany, Belgium, Poland, Macedonia, France
Industry coverage	95%	>70%	90%
Overall industry representation	Eleven out of twelve IPA members		
Time coverage	• Fiscal year 2017 • GaBi (2017) database for upstream process data (non-primary data such as data of consumed material, energy carriers etc.)		
Methodology	• Cradle-to-gate LCI • LCA model created using GaBi (2017) software system (Sphera) • Combination of mass and economic allocation for PGM production • Use phase: modelled on European region using a Euro 6d-TEMP model vehicle (gasoline and diesel) from the GaBi (2017) database, and an assumed lifetime of 160,000 km		
Functional unit	• 1 kg of platinum (Pt) (>99.95%), 1 kg of palladium (Pd) (>99.95%), • 1 kg of rhodium (Rh) (>99.90%)		
Impact categories and indicators used	• Primary Energy Demand • Global Warming Potential • Acidification Potential • Eutrophication Potential • Photochemical Ozone Creation Potential • Blue Water Consumption		
Quality	• Conducted by renowned consultancy (Sphera) according to ISO 14040 (2006) & 14044 (2006) and ISO/TS 14071 (2014) • ISO Review by Prof. Dr. Matthias Finkbeiner, Technical University Berlin • Data reviewed for quality and accuracy by independent technical expert William J. Middleton of WJM Environmental		

Table 1: LCA Quick Facts for the IPA LCA Study 2017

LCA SYSTEM BOUNDARIES

Data included or excluded from the study is dependent on the system boundaries identified during the goal and scope definition. Figure 1 below shows the various processes considered in this system, including the use phase, while the system boundary of the main study is depicted by the red box, i.e. for the production of PGMs.

By-products of the primary and secondary production of PGMs such as base metals, their salts and other precious metals are part of the scope of the study. These by-products have been allocated using the approach described under "Allocation" on page 7.

The canning of autocatalysts is not considered in this study as it belongs to the vehicle manufacturing process. The collection of spent autocatalysts is also not within the boundaries of the study; therefore, dismantling of autocatalysts is excluded. The transport of fuels and auxiliaries was excluded due to a lack of data; however, the impact is expected to be considerably smaller than the impacts of transport of ore, concentrate, and EoL materials.

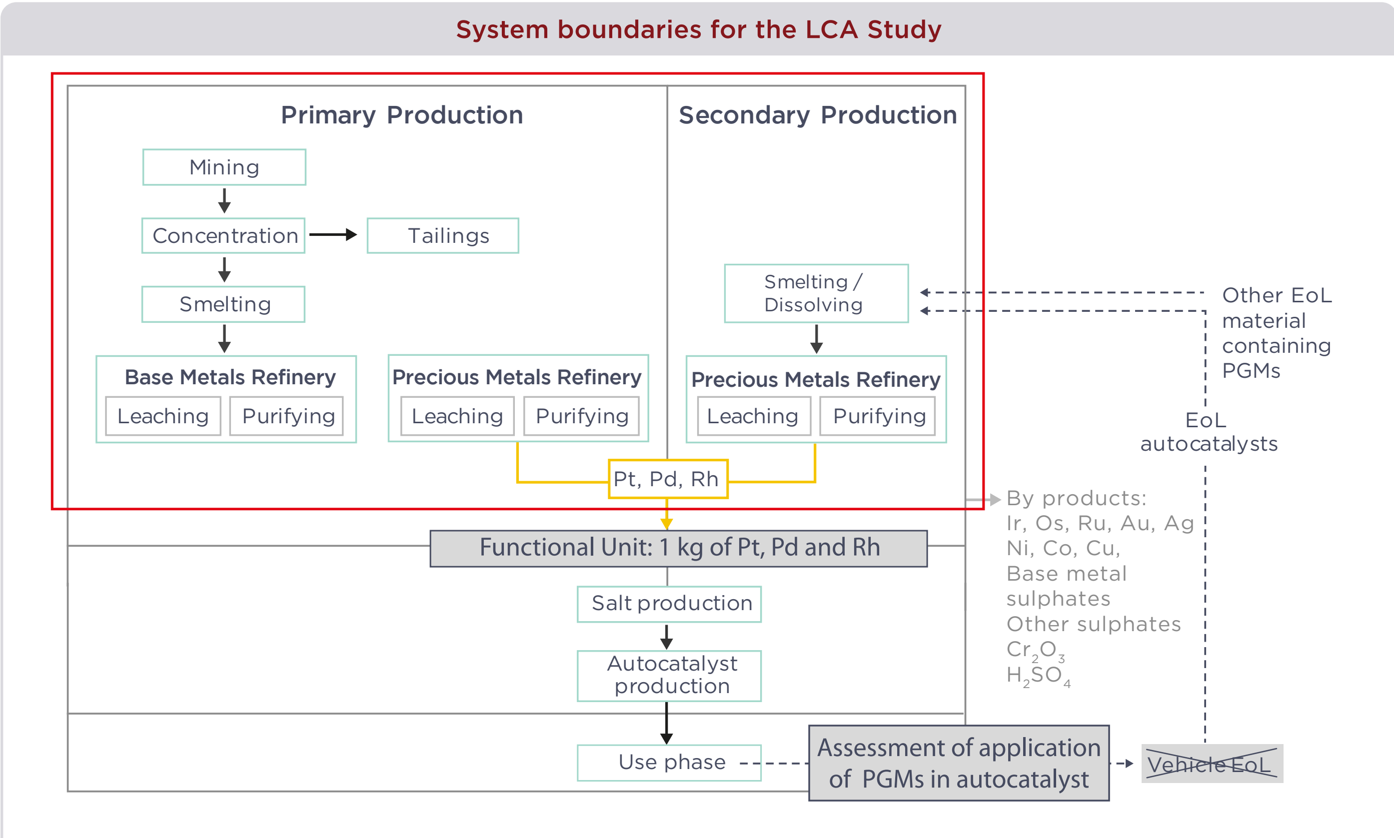


Figure 1: System boundaries of the IPA LCA Study 2017 "Life Cycle Assessment of Global Platinum Group Metals Production – Reference Year 2017", issued by Sphera in October 2020

IMPACT CATEGORIES

The impact potentials for the primary production of 1 g of platinum, 1 g of palladium and 1 g of rhodium are presented in six categories detailed in tables 1 and 2[2)].

Global Warming Potential (GWP) and non-renewable Primary Energy Demand (PED) were chosen because of their relevance to climate change and energy efficiency, which are strongly interlinked, and of high public and institutional interest. Eutrophication (EP), Acidification (AP), and Photochemical Ozone Creation Potentials (POCP) were chosen because they are closely connected to air, soil, and water quality, and capture the environmental burdens.

Freshwater scarcity is another increasingly pressing environmental issue. Hence, water use, an umbrella term for all types of anthropogenic water uses, has also been addressed in the study. The mining and metals industry is aware of the physical, regulatory, and reputational risks posed by water use. Nevertheless, collecting data on water consumption and water use remains a challenge. The 2017 study addresses, as a first step, Blue Water Consumption defined as freshwater leaving a watershed.

Primary production of 1 gram of PGMs				
Impact Category	**Unit**	**Platinum**	**Palladium**	**Rhodium**
Global Warming Potential	kg CO_2-eq/g	41.8	25.3	36.9
Primary Energy Demand	MJ/g	464.6	318.9	414.2
Acidification Potential	kg SO_2-eq/g	0.934	1.595	0.412
Eutrophication Potential	kg PO_4-eq/g	0.025	0.013	0.020
Photochemical Ozone Creation Potential	kg Ethene-eq/g	0.041	0.066	0.020
Blue Water Consumption	kg/g	265.1	172.5	242.8

Table 2: Summary result for the LCA for the primary production of 1 gram of PGMs

Secondary production of 1 gram of PGMs				
Impact Category	**Unit**	**Platinum**	**Palladium**	**Rhodium**
Global Warming Potential	kg CO_2-eq/g	0.63	0.72	0.84
Primary Energy Demand	MJ/g	10.1	11.7	12.6
Acidification Potential	kg SO_2-eq/g	0.0029	0.0035	0.0043
Eutrophication Potential	kg PO_4-eq/g	0.00035	0.00039	0.00046
Photochemical Ozone Creation Potential	kg Ethene-eq/g	0.00013	0.00016	0.00018
Blue Water Consumption	kg/g	6.039	7.035	8.622

Table 3: Summary result for the LCA for the secondary production of 1 gram of PGMs

2) Numbers are presented in grams, not kilograms, as the usual PGM loading on a passenger car ranges between 3-9 grams, depending on the type of internal combustion engine.

METHODOLOGICAL BACKGROUND

The LCA study was conducted according to the requirements of the International Standard Organization ISO 14040 (2006), ISO 14044 (2006) and ISO/TS 14071 (2014) and received ISO certification.

The study is based on the CML[3)] impact assessment methodology as CML characterisation factors are applicable for use in the European context and are widely used and respected in the LCA community. They are also favoured by the metals industry and were used in the first study.

The primary production of PGMs typically yields several other base metal products such as nickel, copper, and cobalt due to these metals being a component of the PGM ore body. In South Africa, mining the UG2 Reef delivers a chromium concentrate (Cr_2O_3) by-product. The precious metals iridium (Ir), osmium (Os), ruthenium (Ru), silver (Ag), and gold (Au) are other by-products. The secondary production of PGMs yields other by-products depending on the composition of scrap (EoL material) feed. These base metal and precious metal products were included within the scope of the study and were therefore treated as by-products by means of an allocation.

In the precious metals industry, a combination of economic value and mass allocation is used. This approach was defined in the 2010 study and is consistent with the methodology adopted and recommended by the metals industry in general[4)].

Allocation

Allocation consists of allocating the process inputs and outputs proportionally to the product and co-products, according to a parameter such as mass, feedstock energy or even monetary/economic value.

To allocate based on mass, the amount of co-product produced per (e.g. ton) of main product is needed. Based on this information an allocation factor(s) for the main product and for each co-product can be calculated by division (i.e. the amount of main product by the sum of main product and co-products produced). The resulting allocation factor will be a fraction. The calculated allocation factor(s) is used to define how much of the inputs and outputs of the system will be allocated to the co-product.

Economic allocation is used between the processes upstream from the precious metal refinery where precious metals and base metals occur together due to the vast difference in economic values between these metals. Where only precious metals occur together, as in the precious metals refinery (PMR), a mass allocation is used to define the environmental profile since the precious metals spend broadly the same amount of time circulating in the precious metals refinery, and therefore use the same amount of energy and consumables, to achieve maximum recovery. This allocation method was considered the best approach for the system under study. The prices used in the assessment were averaged over 3 years (2015-2017).

An indication of where within the production process the method of allocation is applied is provided in figure 3 and figure 4 on the next page.

A sensitivity analysis has been performed on the choice of allocation used in the precious metal refinery for both primary and secondary production.

Results showed that in the primary production of platinum and rhodium, applying an economic allocation in the PMR will increase the impact categories considered here by at least 20%. Results of the sensitivity on the primary production of palladium cannot be disclosed due to limited data to conduct the analysis that would affect confidentiality of data.

In the secondary production of platinum and rhodium, applying an economic allocation in the PMR will increase the impact categories considered here by at least 20%, while the result for palladium will decrease by almost 10%. This result can be explained by the lower price of palladium (over 20% lower) in the study compared to platinum and rhodium.

The main non-metal by-products occurring in the production of PGMs are sulphuric[4)] acid and ammonium or sodium sulphate[5)]. Sulphuric acid is produced at those sites which capture sulphur dioxide and treat it in an acid plant to produce saleable sulphuric acid, while some sites capture sulphur in the form of gypsum which could be sold or treated as waste. To account for this, system expansion is used to apply an environmental credit for the avoided environmental burden of the production of these virgin materials.

3) Centre of Environmental Science at Leiden.
4) PE International AG (now Sphera), Harmonization of LCA Methodologies for Metals, Ottawa, Canada, 2014
5) Either ammonium or sodium sulphate is produced, not both.

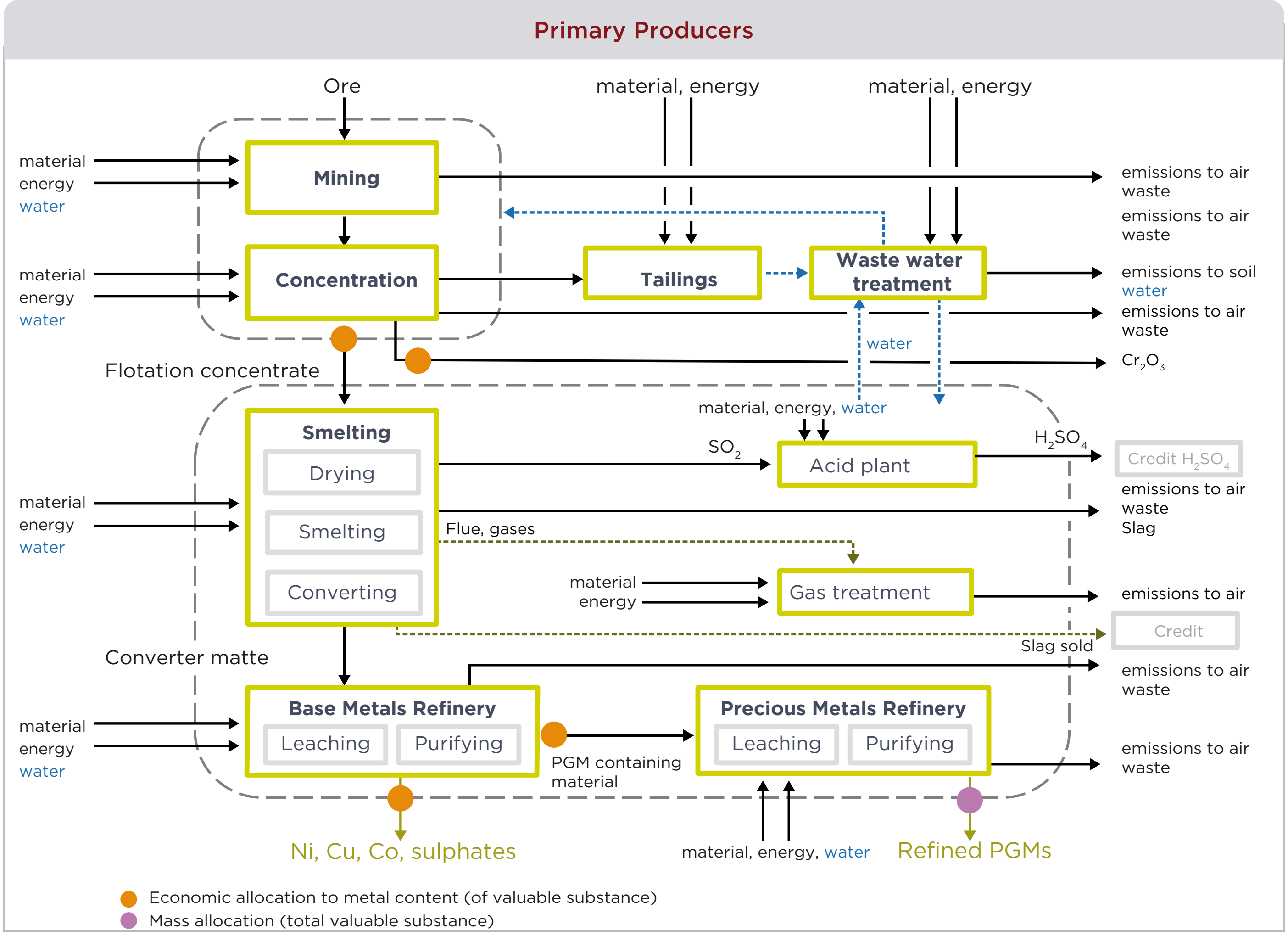


Figure 3: Allocation for the primary production route

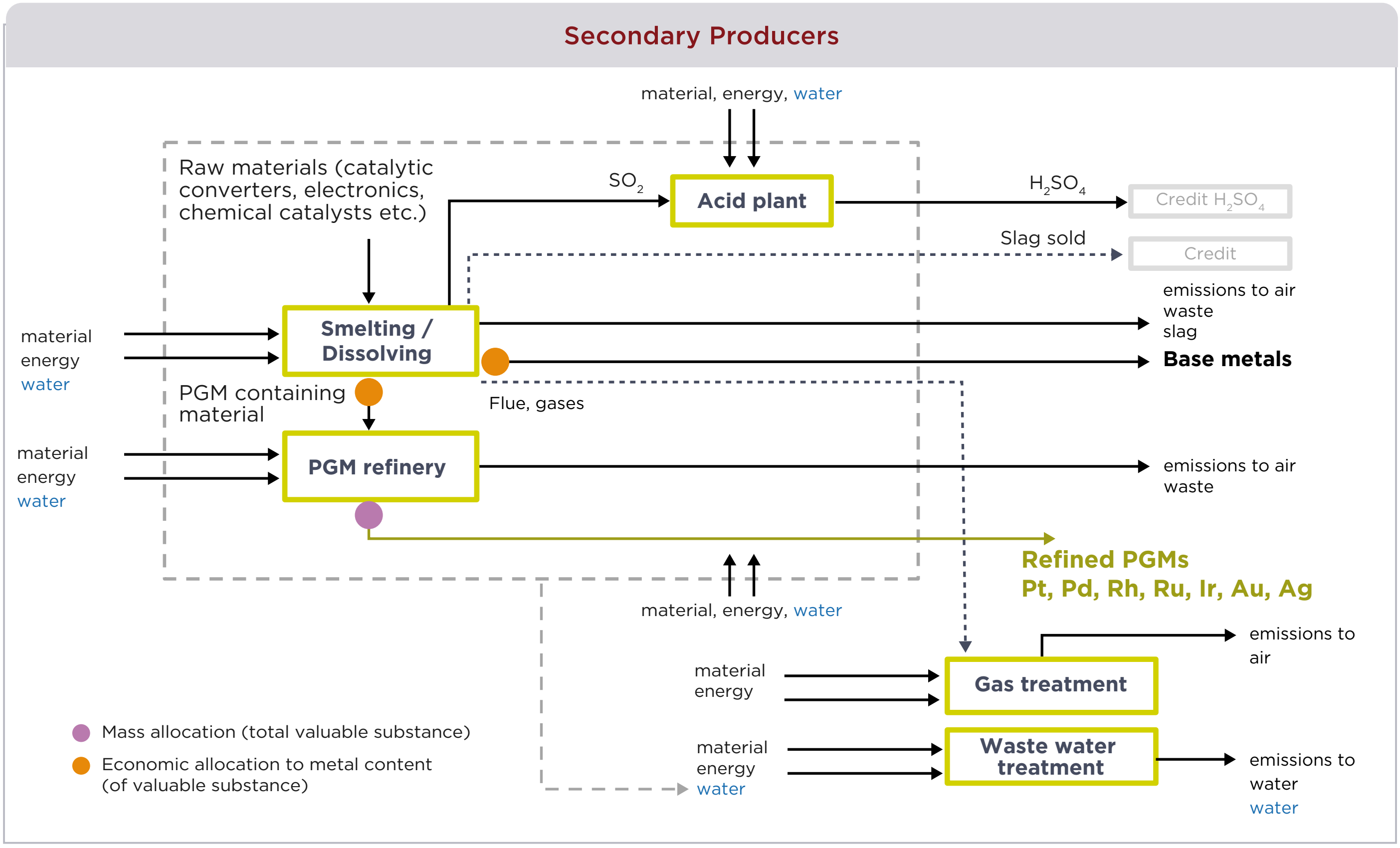


Figure 4: Allocation for the secondary production route

Use phase modelling

The use phase scenario in this study examined the life cycle impact of PGMs by assessing their application in an autocatalyst to control tailpipe emissions from vehicles manufactured to Euro 6d-TEMP emissions standards.

The use phase data was based on industry literature and measurements of vehicle performance provided by participating companies. For this study, the use phase was modelled on the European region as it provides the most consistent regulation on emissions.

The results demonstrate an overall reduction in the regulated local emissions CO, HC, and NOx, compared to the same emissions generated in manufacturing the autocatalyst systems (including the production of the PGMs) for one European 1.4 litre gasoline and one 2.0 litre diesel vehicle meeting Euro 6d-TEMP regulations.

The absolute net changes in emissions (excl. CO_2) for the diesel and gasoline systems are presented in figure 5 (below) and figure 6 (next page):

Autocatalyst definition

For definition of the autocatalyst, a typical market mix was used, assuming the catalyst to be made up of 72% primary produced PGMs and 28% recycled PGMs.

The study generated separated data for an average diesel catalyst system and an average gasoline catalyst system, assuming that one catalyst system lasts a vehicle lifetime of 160,000 km.

Absolute net change in emissions for a diesel vehicle (excl. CO_2)

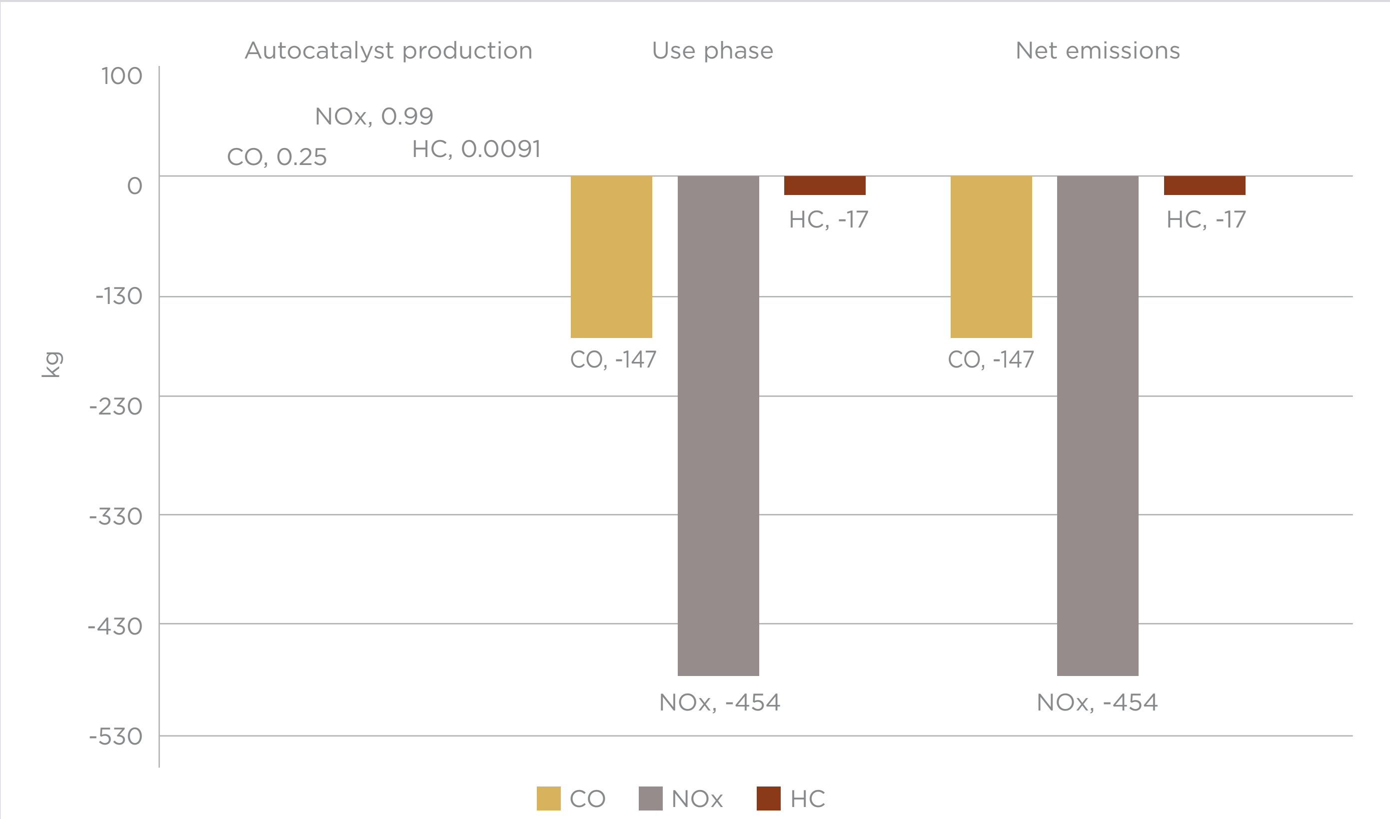


Figure 5: Absolut net change in emissions for a diesel vehicle (excl. CO_2)

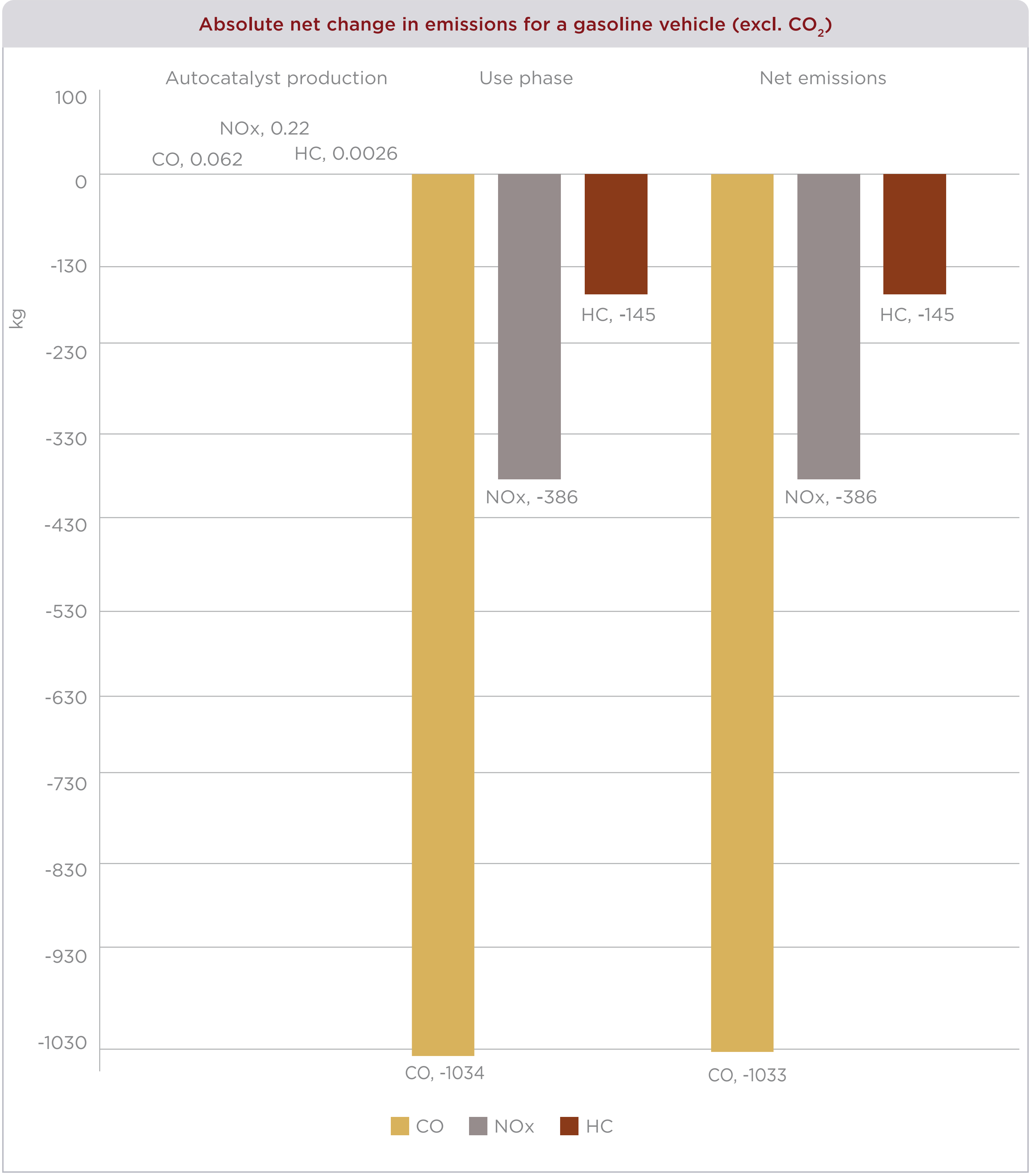


Figure 6: Absolute net change in emissions for a gasoline vehicle (excl. CO_2).

KEY ACHIEVEMENTS & FINDINGS*

- The second IPA LCA Study increased the amount of data reported by 40% for primary production and by more than 130% for secondary production.
- The geographical coverage for PGM operations was broadened by including sites in Russia, France, Poland, Macedonia, and China, in addition to the sites in South Africa, Zimbabwe, USA, UK, Germany, Belgium, and Japan.
- The study includes enhanced reporting elements such as presenting results for GWP or impact from GHG emissions of primary and secondary production split in Scopes 1, 2, and 3, as defined in the GHG protocol; the addition of results for the impact of production on Blue Water Consumption; and separate impact assessments (segregated data vs. aggregated data in 2010) for primary and secondary production.
- Power consumption during mining and ore beneficiation has been identified as the major impact of the production of PGMs. This is because of the high electricity demand in the mines and concentrators and the composition of the South African power grid where 83%[6)] of electricity is produced from the combustion of hard coal. The source of energy is largely beyond the control of producers.
- The unit footprint for PGMs is significantly higher than for other metals. However, PGMs are used in very small quantities, with a typical PGM loading in an average passenger car ranging from 3 to 9 grams.
- The study illustrates that although PGM production has impacts on the environment, in the context of the life cycle, these impacts are relatively marginal.
- The emissions reductions as a result of the use of an autocatalyst outweigh the emissions generated during the production of the catalyst including PGMs and other related materials used in the washcoat and the process of coating of the substrate.
- Emissions harmful to human health such as carbon monoxide (CO), hydrocarbons (HC) and nitrogen oxides (NOx) are reduced by up to 98%. As demonstrated in previous studies, autocatalysts also contribute significantly to the reduction of particulate emissions from internal combustion engines, with removal efficiencies of around 99% for both particulate mass (PM) and particulate number (PN). Due to a lack of availability of validated data at the time of the study, PM was not assessed separately.
- PGMs enable car manufacturers to comply with emissions standards and enable regulators to implement tightening emissions regulations.
- Over 2 tonnes of toxic and harmful pollutants (1180 kg CO, 162 kg HC, and 839 kg NOx) are reduced by the catalytic converter systems in one Euro 6d-TEMP 1.4 litre gasoline and one Euro 6d-TEMP 2.0 litre diesel vehicle in use over 160,000 km.

* Disclaimer: These statements are based on the data collected in this study and relate to the modelled average vehicles.

6) In 2017, 83% of electricity was generated from coal. The percentage declined to 81.6% in 2020. Source: Eskom Integrated Report 2020.

COMPANIES PARTICIPATING IN THE LCA STUDY

Anglo Platinum, Implats, Northam Platinum Limited, Nornickel, Royal Bafokeng Platinum, Sibanye Stillwater

Exploration, Mining & Production

BASF, Johnson Matthey, Heraeus, Umicore, Tanaka

Fabrication

ABOUT THE IPA

The IPA is a non-profit organization representing 80% of the mining, production, and fabrication companies in the global platinum group metals (PGM) industry, comprising platinum, palladium, iridium, rhodium, osmium, and ruthenium.

In 2008, the IPA began to formulate an environmental strategy because of increased environmental awareness within the organization and in response to market, customer and regulator expectations.

In 2009, the membership developed the PGM industry's Sustainability Principles which include improving our understanding of the environmental, social, and economic impacts and benefits of our materials across their life cycle.

In 2013, the first industry-wide LCA was finalized and aggregated global average data was made available to selected stakeholders.

In committing itself to a life cycle approach, the industry determined that it will:

- Collaborate with suppliers, customers, and other stakeholders to understand the life cycle of its products and materials, and
- contribute to a global database of life cycle information and share best practices to reduce the overall footprint of PGM products.

The LCA study update supports the industry's commitment to understand and improve the sustainability performance of PGMs.

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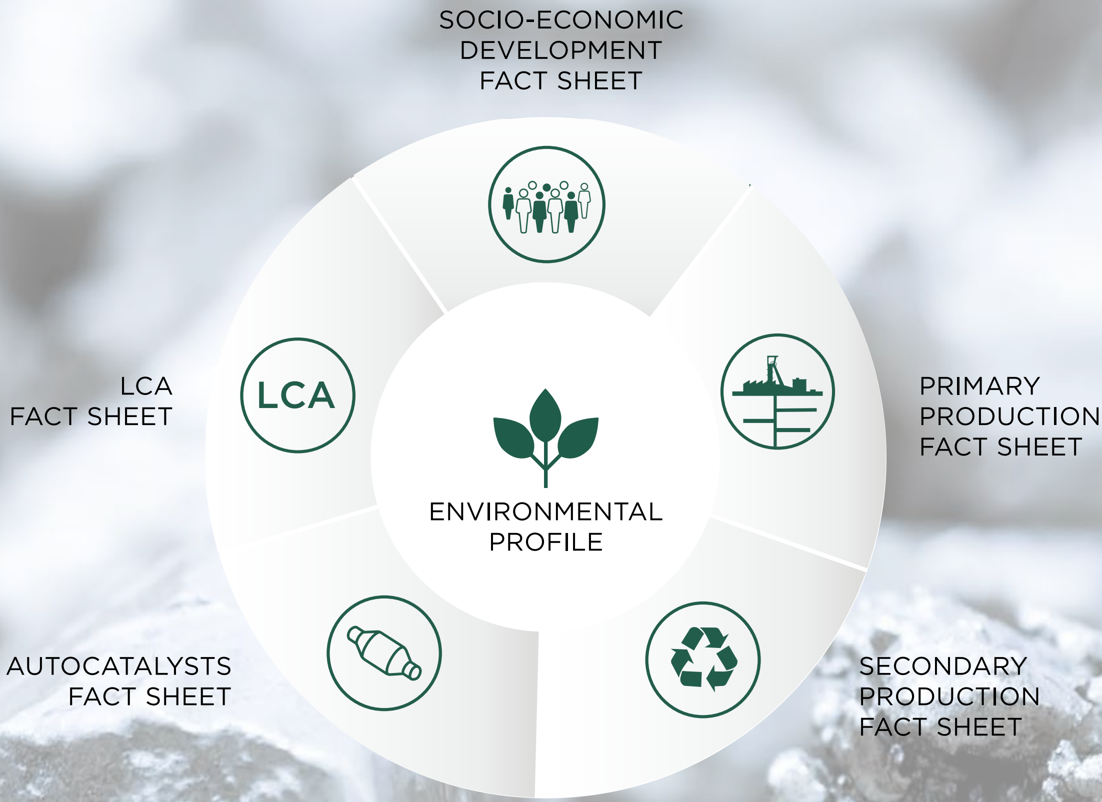

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