The Life Cycle Assessment of Platinum Group Metals

Reference year 2022

A summary of the third global cradle-to-gate LCA on primary and secondary PGM production, including a CO_2 scenario for primary production in 2030

sphera

IPA
INTERNATIONAL PLATINUM GROUP METALS ASSOCIATION

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DISCLAIMER

In secondary production, the PGM industry typically processes a mixed feed of materials, which may include automotive and industrial catalysts and electronic scrap. As a result, allocating the environmental footprint of a specific process to individual metals or to a particular feed, such as autocatalysts, is challenging in an LCA.
To address this complexity, the IPA LCA study adopted a pragmatic approach by using a mixed feed to model the average environmental footprint for secondary PGM production. Therefore, while the LCA results provide an accurate industry average, they are not suitable for analysing specific secondary production processes, particularly for comparison purposes. Similarly, the LCA results for primary production are based on inputs from mining operations that vary in ore characteristics and should not be used to analyse a specific mine, participating company, or their production processes.

EXECUTIVE SUMMARY

The International Platinum Group Metals Association (IPA) has completed its latest life cycle assessment (LCA) on global platinum group metals (PGMs) production, updating the previous 2017 study. As industry processes and technologies continue to evolve, regular updates every 3-5 years ensure the most accurate and relevant sustainability data. This third industry-wide assessment (LCA 3), based on 2022 production data, also enhances usability by aligning with the widely adopted EF 3.1 impact categories.

The analysis reflects a dynamic industry that is actively adapting to global changes. While the global warming potential (GWP) for primary PGM production in South Africa increased between 2017 and 2022, this was driven by temporary external factors such as:

1. Higher CO_2 emissions from the South African electricity mix due to a decreased efficiency of the South African hard coal power plants;
2. The influence of the increased market price (10-year average) for PGMs;
3. Shifts in ore grades.
4. In addition, the metals sector in general is affected by (planned or unplanned) maintenance cycles which can lead to reduced efficiency in specific years.

However, looking ahead, the increase in GWP for primary production appears to be just a snapshot in time. Importantly, the identified hotspot concerning the electricity source has already spurred rapid progress: between 2019[1] (IEA data) and 2023[2] , South Africa's reliance on coal-powered electricity decreased significantly, from 87.4% to 76%, showcasing the country's accelerating transition to cleaner energy.

The outlook for PGMs is strong, with substantial investments in decarbonization underway. Both the South African government and South African PGM producers are committing to renewable energy solutions, improving energy efficiency, and enhancing sustainability across the value chain.

Our CO_2 scenario outlook performed for 2030 highlights the potential for even greater reductions in emissions as these efforts gain momentum, reinforcing the sector's long-term commitment to greener production.

Overall, the estimated reduction in GWP varies between 35% and 61%, depending on the changes implemented in the 2030 scenario for the South African power supply per PGM producer. Due to the high share of production volumes from South African producers in our overall primary production volumes, and the high reliance on hard-coal generated electricity up to 2022, the scenario focuses on improvements in South Africa only and does not integrate potential improvements in other PGM-producing regions (USA, Russia).

Additionally, the LCA 3 results for secondary production, showcasing a significantly lower footprint assigned to the recycling of end-of-life (EoL) material, underscore the vital role of recycling in ensuring the circularity of PGMs.

While direct comparisons for secondary production between 2017 and 2022 were not possible due to changes in participating companies, the latest data is of significantly higher quality and further confirms the strong environmental benefits of PGM recycling.

With the sector advancing toward cleaner, more efficient production methods, the future of PGMs remains highly promising. Stakeholders can look forward to a more resilient, sustainable, and forward-thinking industry that is well-positioned to meet the growing global demand for critical metals.

[1] Data from the International Energy Agency always reflect a delay of three years, in this case, 2019 was used for the 2022 study.
[2] 2023 data was used to model CO_2 scenario, based on South Africa's Department for Mineral Resources and Energy Integrated Resource Plan (IRP) 2023, published January 2024. https://www.gov.za/sites/default/files/gcis_document/202401/49974gon4238.pdf

1. INTRODUCTION

Platinum group metals (PGMs) are essential for various industrial applications, particularly in automotive, chemical, electronics, and medical sectors. They are critical metals for the development of clean and strategic applications including fuel cell electric vehicles and electrolysers for green hydrogen production.

The IPA regularly updates its Life Cycle Assessment (LCA) of PGMs to evaluate environmental impacts across the production life cycle. The latest critically reviewed study, referred to as LCA 3[3], is based on data from the 2022 production year and covers five primary PGMs (platinum, palladium, rhodium, iridium, and ruthenium) as well as three secondary PGMs (Pt, Pd, Rh). While the study primarily focuses on Global Warming Potential (GWP) and water impacts, it also considers other impact categories assessed in previous studies.

To conduct this update on the environmental performance of the PGM industry for the 2022 reference year, IPA commissioned the consultancy firm Sphera. Additionally, a critical review was performed by Professor Dr. Matthias Finkbeiner from the Technical University of Berlin, Germany, to ensure compliance with ISO 14040/44 standards[4].

Table 1: LCA Study Quick Facts

Life cycle stage	Primary PGM Production	Secondary PGM Production
Geographical coverage	Russia, South Africa, USA, Zimbabwe	China, Germany, Japan, South Africa, UK, USA
Industry coverage	95% of global supply	approx. 60% of global supply
Overall industry representation	10 out of 12 Members of the IPA	
Time coverage	Production year 2022	
Technology coverage	• Global production and technology mix covered • Technological representation for each stage of production process given • Both pyrometallurgical and hydrometallurgical technologies considered	
Methodology	• Cradle-to gate Life Cycle Inventory • LCA model created using LCA for Experts software system (Sphera) • Life cycle inventory data taken from MLC database 2023.2 • Combination of mass and economic allocation for PGM production	
Functional unit	The functional unit is the reference value for which the results of the study are calculated. Generally, a functional unit should reflect the function provided by the product being assessed. The following mass-based functional units, equal to the reference flow, have been designated for this study:	
	• 1 kg of Platinum (Pt) (>99,95%), • 1 kg of Palladium (Pd) (>99,95%), • 1 kg of Rhodium (Rh) (>99,90%) • 1 kg of Iridium (Ir) (>99,90%), and • 1 kg of Ruthenium (Ru) (>99,90%)	• 1 kg of Platinum (Pt) (>99,95%), • 1 kg of Palladium (Pd) (>99,95%), and • 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 assurance	• Conducted by renowned consultancy (Sphera) in conformity to ISO 14040 (2006) and ISO 14044 (2006). • Critical Review by Prof. Dr. Matthias Finkbeiner, Technical University Berlin, in accordance with ISO 14044 section 6.2 and ISO 14071	

[3] IPA Study "LCA on the global production of Platinum Group Metals, Platinum, Palladium, Rhodium, Iridium, and Ruthenium", reference year 2022, February 2025, performed by Sphera.

[4] Prof. Finkbeiner acted as independent expert reviewer, not as official representative of his organization.

This LCA Fact Sheet provides technical and methodological insights and presents results for key impact categories. To supplement the findings of the LCA study, the IPA has commissioned a CO_2 scenario analysis for the global primary production of PGMs in 2030.

The scenario modelling is based on investment plans by South Africa's electricity provider, Eskom, to increase the share of renewable energy in the national grid by 2030, as well as planned investments in renewable energy by South African PGM producers. While this outlook is not part of the critically reviewed ISO report, it aims to inform stakeholders about the decarbonization strategy of South African primary producers and its projected impact on the global GWP of PGMs in 2030.

The study results are not intended for use in comparative assertions for public disclosure. However, it is recognized that others may use the provided data for such comparisons. Any comparative assertions should be made at the product system level and must comply with ISO 14040/14044 standards, including an additional critical review by a panel.

2. GOAL AND SCOPE OF THE LCA 3 STUDY

The IPA LCA Study evaluates the cradle-to-gate environmental impact of both primary and secondary PGM production. It encompasses all impacts from resource extraction to the point where the refined product exits the factory gate.

For the primary production route, the study includes the environmental impact of mining PGM ore. In contrast, for the secondary route, end-of-life (EoL) PGM-containing materials enter the system boundary burden-free, following the cut-off approach. As a result, the findings for secondary production reflect the environmental benefits of recycling EoL materials.

The cut-off approach taken in LCA 3 aligns with previous IPA studies and aims to highlight the high recyclability of PGMs and the increasing importance of circularity for PGM users.

The cradle-to-gate Life Cycle Inventory (LCI) encompasses the resource consumption and emissions associated with all electricity, energy, and material inputs in PGM production. Based on data from 10 out of 12 IPA members, the study covers both primary and secondary PGM production.

The study was conducted in accordance with ISO 14040 (2006) and ISO 14044 (2006) standards. The scope was thoroughly reviewed and confirmed to be aligned with the achievement of its stated objectives. Being the third study conducted by IPA, the methodology and procedures have attained a high level of maturity.

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2.1 LCA SYSTEM BOUNDARIES

The system boundary defines the processes considered within the cradle-to-gate assessment of primary and secondary PGM production. The LCA study considers impacts associated with the extraction of resources from nature (through mining) through 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. For the secondary route, EoL PGM-containing material enters the system boundary burden-free; the first impact is the transport from the pre-processing to further dissolving and refining.

Figures 1 and Figure 2 below illustrate the system boundaries (depicted by the red border) for both production routes.

Data included or excluded from the study is dependent on the system boundaries identified during the goal and scope definition.

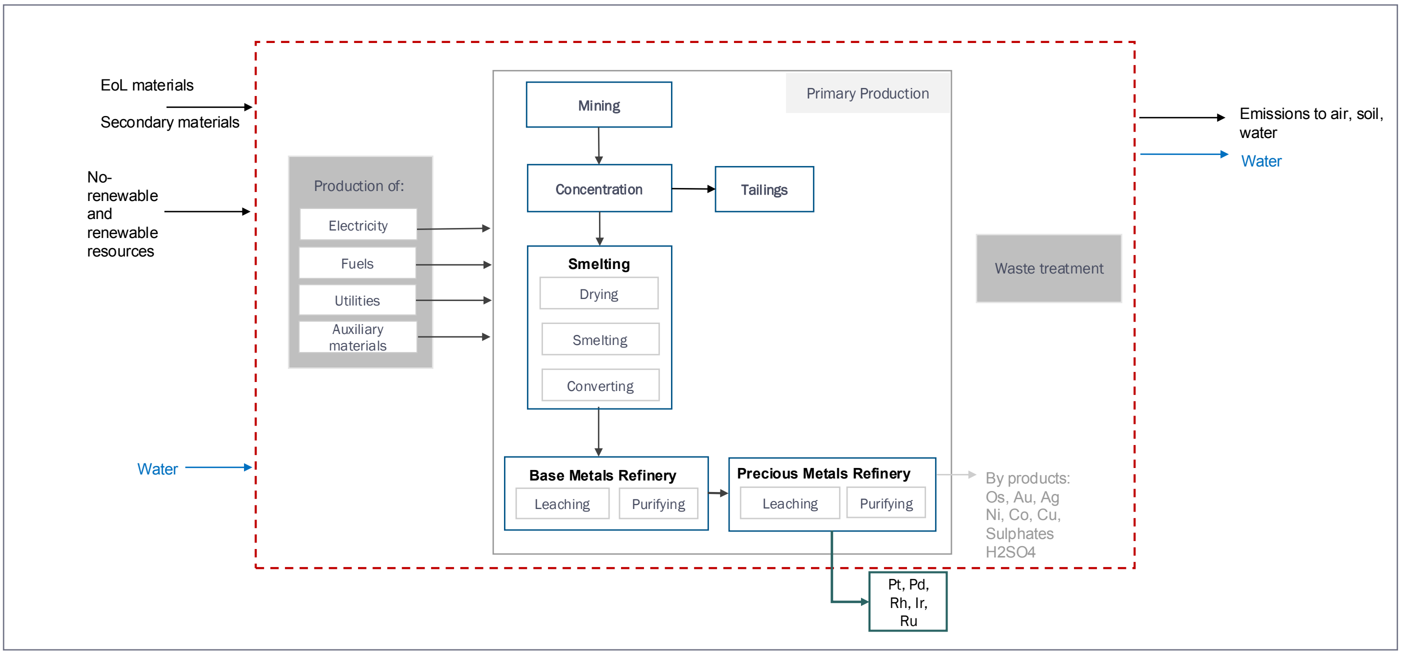

Figure 1: System boundary for primary production

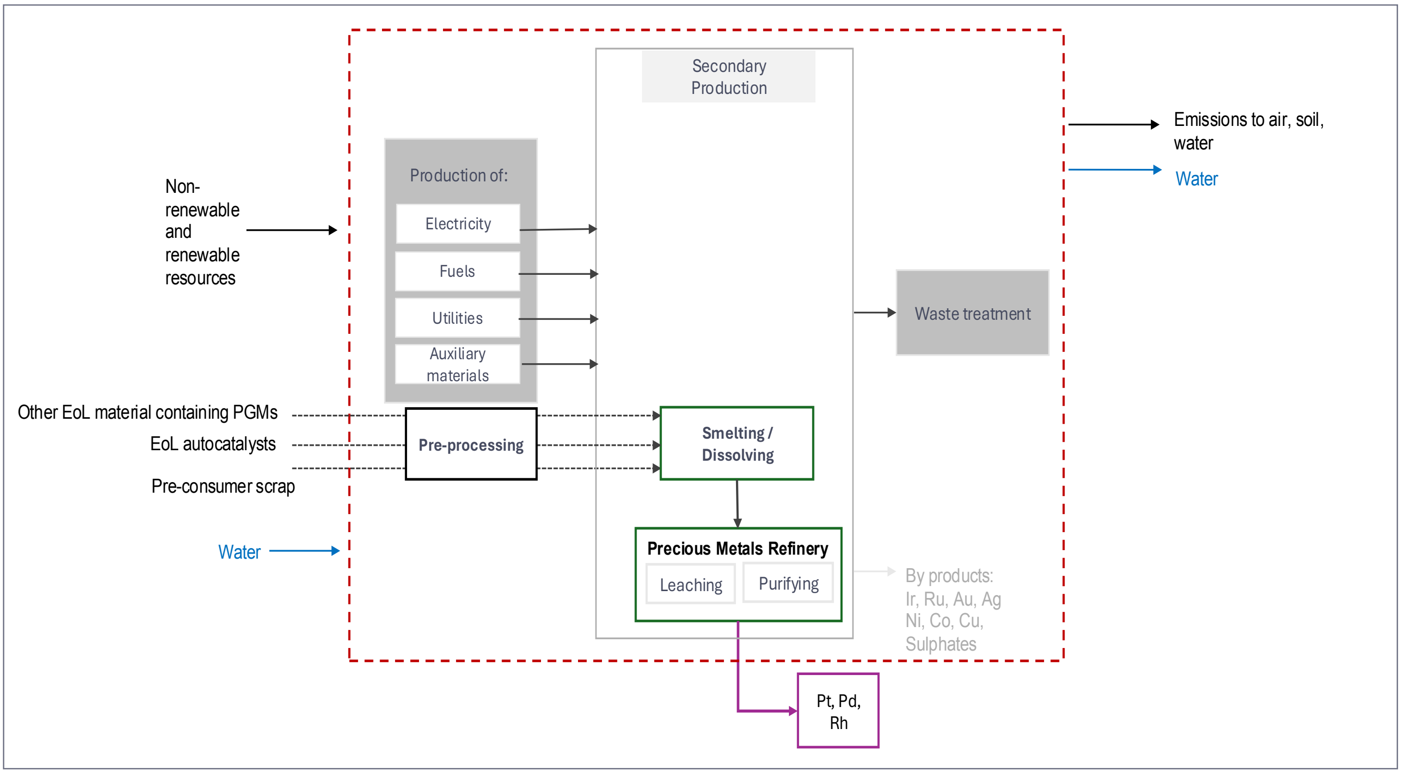

Figure 2: System boundary for secondary production

Table 2 shows the major process steps considered within the system boundaries. Not all processes will apply to every manufacturer or processing route.

Table 2: System boundaries

Included	Excluded
✓ Mining (underground, open cast / surface and open pit including overburden and waste rock)	✗ Geological explorations and project phases
✓ Concentration	✗ Effect of potential acid mine drainage from waste rock
✓ Smelting (primary production and recycling)	✗ Dismantling / separation of EoL catalytic converters and secondary materials
✓ Pre-treatment of EoL material if this is done outside the recycler's site	✗ Packaging
✓ Dissolving processes in the case of recycling	✗ Collection and transport of EoL materials to recycling plants
✓ Base metal refining	✗ Transport of fuels / ancillary / auxiliary materials to site
✓ Precious metal refining	✗ Transport of final products (PGMs) to customer
✓ Transport of ore, concentrate, and pre-treated EoL material to fabricator	✗ Transport of wastes from production processes
✓ All associated energy and fuels	✗ Production of capital equipment and infrastructure
✓ Ancillary / auxiliary materials used onsite	✗ Use phase
✓ All relevant water inputs and outputs	
✓ Onsite (direct) emissions to air (emissions from combustion)	
✓ Onsite water treatment and water emissions	
✓ Overburden, tailings, and other mining wastes that are deposited onsite	
✓ Treatment of wastes off-site and wastewater treated onsite and off-site	

By-products from both primary and secondary PGM production, such as base metals and other precious metals, are included within the scope of this study. These by-products have been allocated based on the methodology outlined in the allocation section. However, packaging used for transporting products to customers is excluded, as it is not expected to significantly impact the results.

The study does not cover the collection of spent catalytic converters, and consequently, the dismantling process is also excluded due to a lack of available data from recyclers.

The transport of fuels, ancillary, and auxiliary materials is omitted due to data collection challenges but is expected to have a significantly lower impact compared to the transportation of ore, concentrates, and EoL materials. Additionally, the production and maintenance of capital goods are excluded unless included in relevant background datasets (e.g., renewable energy). It is assumed that these impacts are negligible relative to the environmental impact of equipment operation over its lifetime.

As a cradle-to-gate study, the transport of final products to customers, the transport of waste beyond the site, and the use phase are all outside the system boundary.

2.2 IMPACT CATEGORIES & INDICATORS USED

Impact categories

This assessment is predominantly based on the Environmental Footprint EF 3.1 impact assessment methodology. The CML impact assessment methodology framework (CML 2001 update January 2016) is used for comparing 2022 with 2017 results, as these impact assessment categories have been used previously and therefore allow a benchmark.

Global Warming Potential (GWP) based on fossil fuels was chosen because of the relevance to climate change and of its high public and institutional interest. The GWP impact category is assessed based on the current IPCC characterisation factors taken from the 6th Assessment Report[5] for a 100-year timeframe (GWP 100) as this is currently the most used metric.

[5] IPCC, Climate Change 2021: The Physical Science Basis. Geneva, Switzerland, 2021.

The GWP results include the photosynthetically bound carbon (also called biogenic carbon) as well as the release of that carbon during the use or end-of-life phase as carbon dioxide (CO_2) and/or methane (CH_4).

Eutrophication Potential (EP), *Acidification Potential* (AP), and *Photochemical Ozone Creation Potential* (POCP) were chosen because they are closely connected to air, soil, and water quality and capture the environmental burdens associated with commonly regulated emissions such as nitrogen oxides (NOx), sulphur dioxide (SO_2), volatile organic compounds (VOC), and others. These methods are based on the EF 3.1 impact category method.

Environmental indicators

The assessment includes *Primary Energy Demand* (PED), a measure of the total amount of primary energy extracted from the earth. PED is expressed in energy demand from non-renewable resources (e.g., petroleum, natural gas, etc.) and energy demand from renewable resources (e.g., hydropower, wind energy, solar, etc.). Efficiencies in energy conversion (e.g., power, heat, steam, etc.) are considered.

Freshwater scarcity is recognized as one of the most pressing environmental issues today and in the future. Water use is understood as an umbrella term for all types of anthropogenic water uses. In most cases water use is determined by total water withdrawal (water abstraction). Particularly in the mining and metals industry, water poses a great risk and can generally be categorised into physical, regulatory, and reputational risks.

Freshwater consumption (consumptive freshwater use) describes all freshwater losses on a watershed level which are caused by evaporation, evapotranspiration from plants, freshwater integration into products, and release of freshwater into sea (e.g. from wastewater treatment plants located on the coastline). It does not equal the total water use (total water withdrawal), but rather the associated losses during water use. Typically, the consumption of rainwater is neglected. The rationale behind this approach is the assumption that there is no environmental impact of green water (i.e., rainwater) consumption. This study endeavours to address, as a first step, water accounting by assessing *Blue Water Consumption*.

It must be noted that the assessment in this study only serves as an indicator for water accounting since it is at an aggregated level. It is not a water footprint as results are not assessed at the level of environmental impact. Regional flows could not be used for confidentiality reasons, as in some countries only one participating company was located.

2.3 KEY RESULTS

Primary production

The impact potentials for the primary production of 1 kg of PGMs are presented for the six selected impact categories in Table 3.

Table 3: Summary of primary production results per kg of metal

Impact Category	Pt	Pd	Rh	Ir	Ru
Global Warming Potential [kg CO_2 eq.]	36,828	28,094	38,027	42,096	42,000
Primary Energy Demand [MJ]	494,563	425,546	508,222	548,987	547,114
Acidification Potential [Mole of H+ eq.]	1,687	4,507	1,446	887	926
Eutrophication Potential [Mole of N eq.]	687	450	715	812	811
Photochemical Ozone Creation Potential [kg NMVOC eq.]	258	380	249	236	238
Blue Water Consumption [kg]	297,006	243,960	305,879	335,220	329,931

Figure 3 illustrates the various contributors to the GWP impact. The primary source is electricity supply, largely due to South Africa's reliance on hard coal-based power generation.

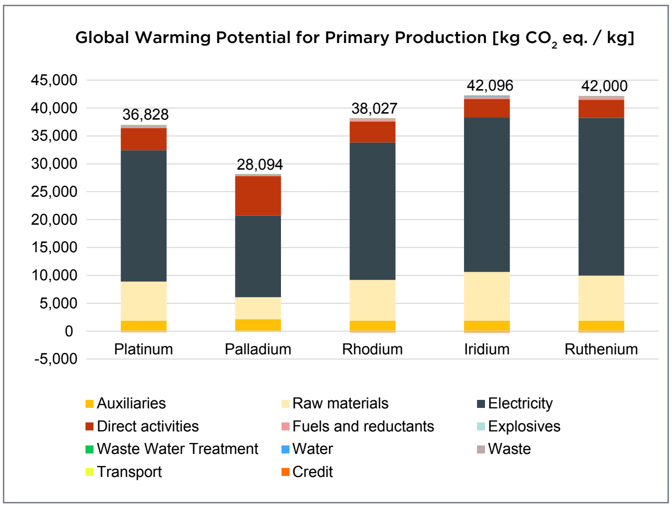

Figure 3: Contribution of impact sources to GWP for the primary production of 1 kg of PGMs

The second-largest contributors are raw materials, i.e. purchased concentrates from third parties. Direct activities rank third, mainly driven by fuel combustion.

An environmental credit has been given to the production of non-metal by-products such as sulphuric acid and ammonium or sodium sulphate (either one is produced at a site, not both), following the system expansion approach. This accounts for the avoided environmental burden of the production of these virgin materials.[6]

Figure 4 highlights the contribution of the different process steps to GWP, with mining and concentration being the main drivers.

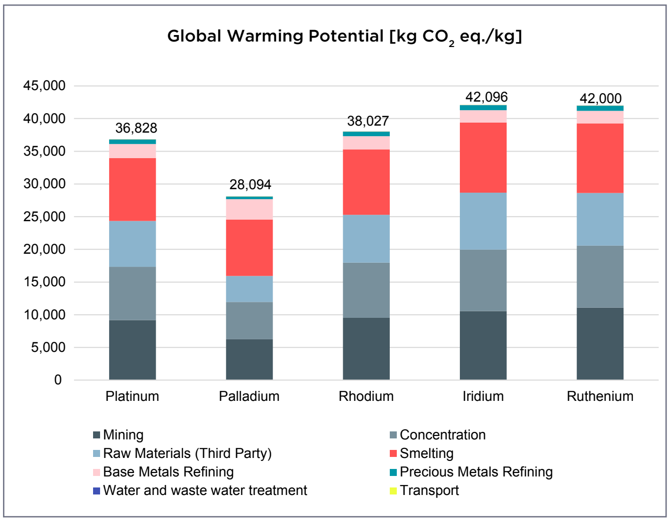

Figure 4: Contribution of process steps to GWP for primary production of 1 kg of PGMs

Secondary production

The potential impacts for the secondary production of 1 kg of the selected PGMs are presented in Table 4.

Table 4: Summary of secondary production results per kg of metal

Impact category	Pt	Pd	Rh
Global Warming Potential [kg CO_2 eq.]	477	497	497
Primary Energy Demand [MJ]	9,976	10,370	10,402
Acidification Potential [Mole of H+ eq.]	1.26	1.29	1.30
Eutrophication Potential [Mole of N eq.]	3.68	3.70	3.77
Photochemical Ozone Creation Potential [kg NMVOC eq.]	0.95	0.95	0.97
Blue Water Consumption [kg]	2,419	3,654	3,458

Figure 5 clearly shows that auxiliaries, primarily chemicals, are the largest contributors, followed by direct activities driven by fuel combustion.

The raw materials share in Figure 5 represents EoL pre-processed material (e.g., smelting), as the incoming EoL scrap is modelled as burden-free. One limitation of the results for secondary production is the exclusion of incoming logistics (transport of scrap to fabricators) due to data unavailability. This aspect should be addressed in the next update.

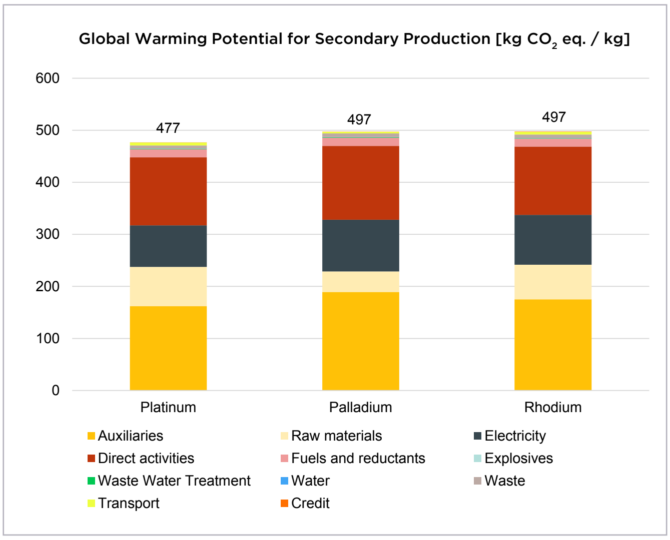

Figure 5: Contribution of impact sources to GWP for the secondary production of 1 kg of PGMs

[6] The credit given (not visible in the graph due to the scale) ranges from 101 kg CO_2 eq./kg for palladium, to 184 kg CO_2 eq./kg for rhodium.

3. METHODOLOGICAL BACKGROUND

Multi-output allocation

Multi-output allocation generally follows the requirements of ISO 14044, section 4.3.4.2, with the allocation rule most suitable for the respective process step applied within the process. No foreground processes required multi-input allocation; however, multi-input allocation was applied for waste processes including landfill and wastewater treatment. When allocation becomes necessary during the data collection phase, the allocation rule most suitable for the respective process step is applied and documented.

The primary production of PGMs typically yields several base metal by-products, including nickel, copper, and cobalt/cobalt compounds, as these metals are naturally present in PGM ore bodies. In South Africa, mining the UG2 reef also produces chromium concentrate (Cr_2O_3) as a by-product. Additionally, other precious metals such as osmium (Os), silver (Ag), and gold (Au) are recovered due to their presence in the ore.

The secondary production of PGMs may also generate by-products, depending on the recycler and the composition of scrap and EoL material feed. These base and precious metal by-products are included within the scope of this study and are accounted for through allocation methods.

ALLOCATION METHODOLOGY

PGM production involves multiple co-products, requiring allocation methodologies:

- **Economic Allocation:** Used in upstream processes where PGMs and base metals are co-produced, attributing environmental burdens based on market value.
- **Mass Allocation:** Used in refining, as all PGMs undergo similar refining steps.
- **Cut-off Approach:** Applied for secondary PGMs, where recycled PGMs enter the system without upstream burden.

In the precious metals industry, a combination of *economic* and *mass allocation* is used. This methodology, first defined in the 2010 study[7], was reaffirmed at the study's kick-off meeting as the most appropriate approach for ensuring comparability between the 2017 and 2022 results. Economic allocation is applied upstream of the precious metals' refinery, where precious metals, silver, and base metals are separated.

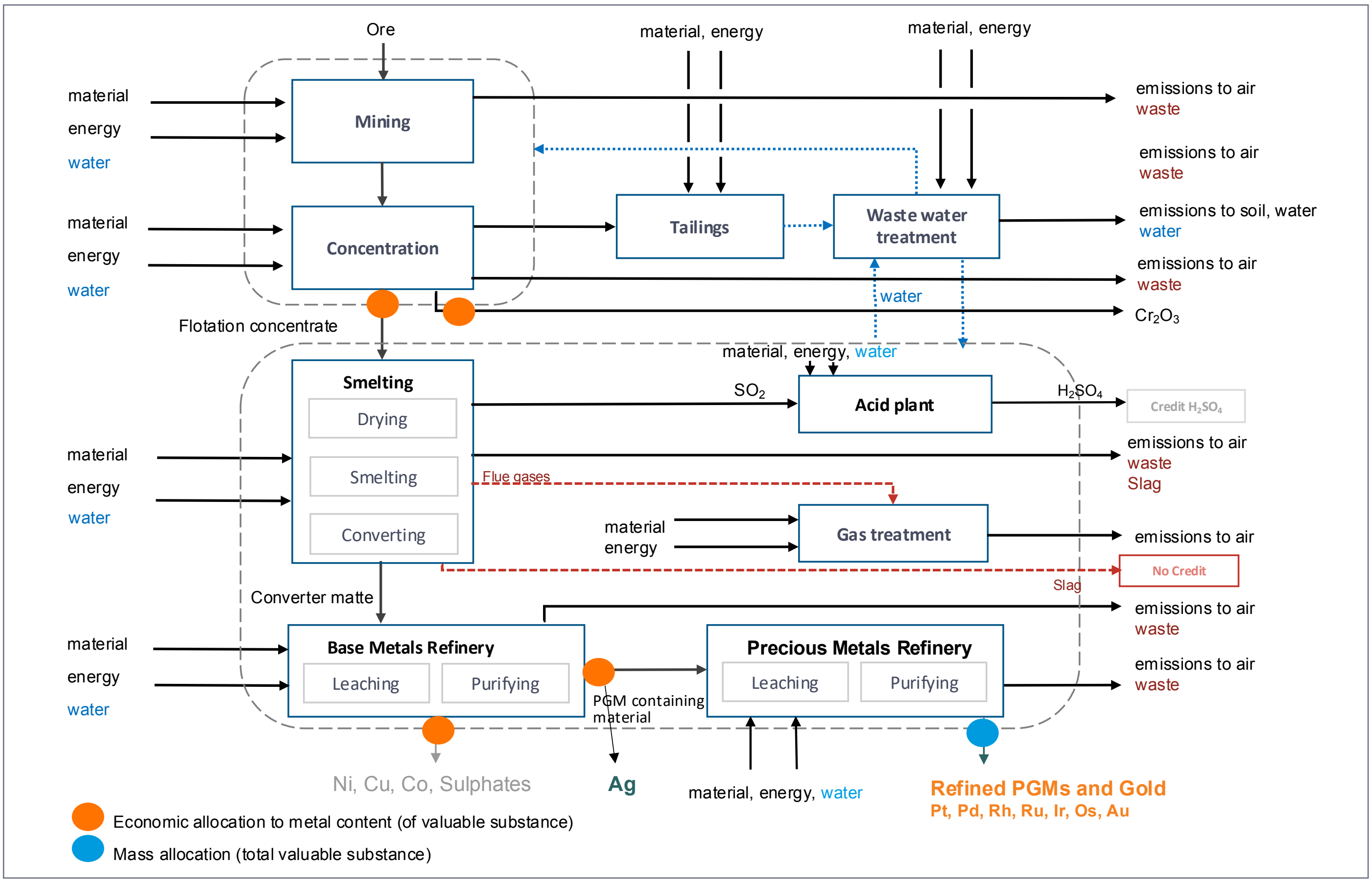

Figure 6: Application of allocation for the primary production of PGMs

[7] IPA Study: "Global Average Platinum Group Metals Life Cycle Assessment (LCA) Study", reference year 2010

Since the industry primarily focuses on PGMs rather than base metals, economic allocation is used to reflect market value. If mass allocation was applied instead, most of the impact would be attributed to the base metal stream.

However, within the precious metals refinery (PMR), where only precious metals are processed together, mass allocation is used. This approach assumes that all precious metals undergo the same refining processes, consuming equal amounts of energy and consumables to achieve maximum recovery. This allocation method was deemed the most suitable for the system under study[8].

A sensitivity analysis conducted using economic allocation in the precious metals refinery (see Table 5 on the right) as opposed to mass allocation clearly demonstrated a significant impact on the GWP results for most PGMs, depending on market prices; this results, e.g., in lower environmental impacts being assigned to platinum and palladium.

Table 5: Sensitivity analysis using economic allocation in the PMR

Allocation Method	Pt	Pd	Rh	Ir	Ru
Mass allocation	36,828	28,094	38,027	42,096	42,000
Economic allocation	28,128	27,198	161,771	49,709	6,016

EoL allocation generally follows the requirements of ISO 14044, section 4.3.4.3.

Material recycling (cut-off approach): Secondary material inputs into secondary PGM production remain burden-free. This follows the recommendation for harmonization of LCA Methodologies for metals[9]. If PGM scrap on the input side is modelled burden-free, as in this study, no credits for PGMs should be given to any proportion of secondary PGMs at the EoL when conducting product LCA studies using primary PGMs.

The system boundary in this study is at the gate of the PGM production facility. The collection of the PGM-containing EoL scrap is not considered in this cradle-to-gate study since no data was available from the recyclers.

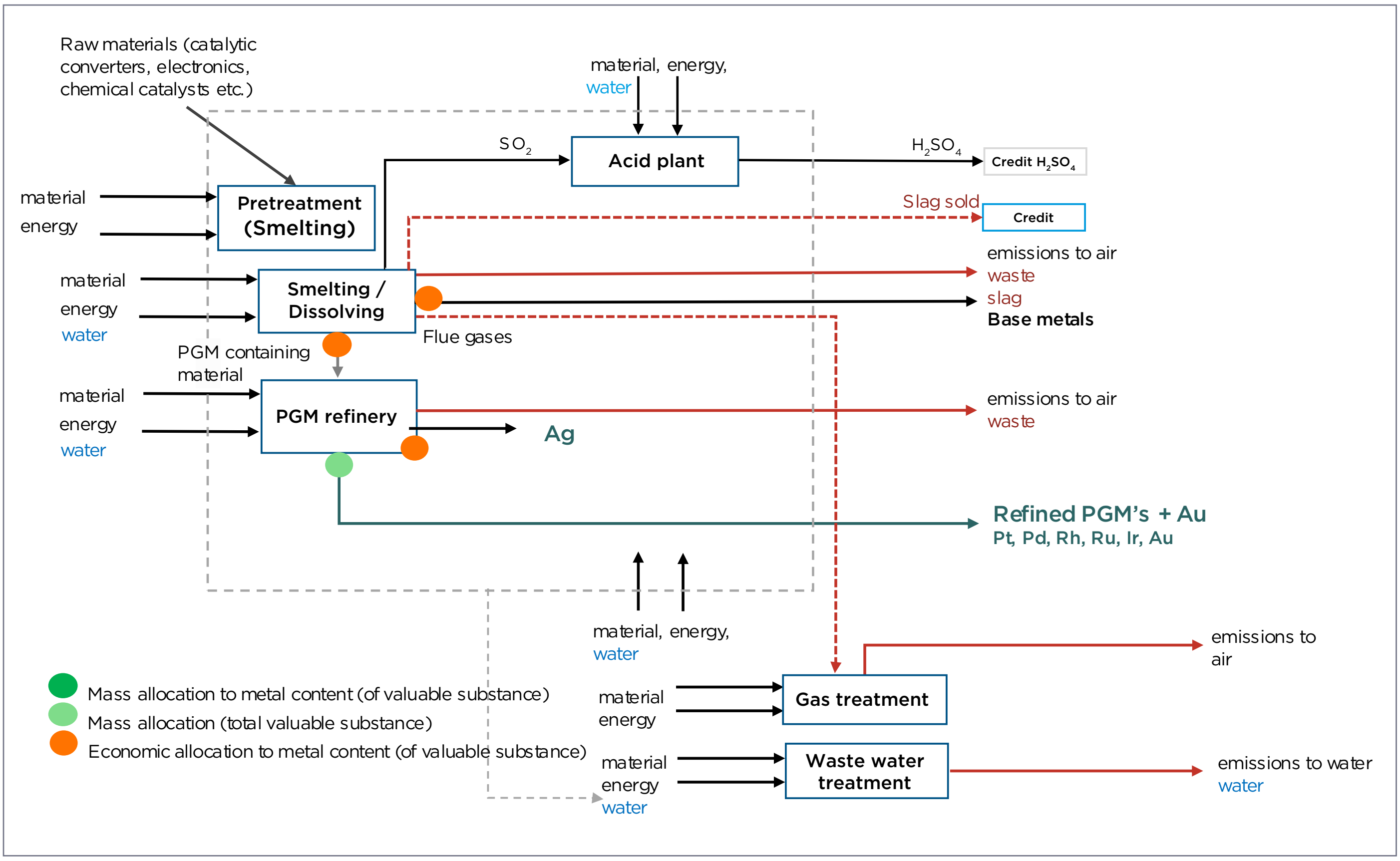

Figure 7: Application of allocation for the secondary production of PGMs

[8] The Carbon Footprint of Platinum Group Metals - A Best Practice Guidance for the Calculation of Greenhouse Gas Emissions of primary produced PGMs, 2023, IPA.
[9] PE International (2014): Harmonization of LCA Methodologies for Metals. Ottawa, Canada.

4. COMPARISON OF 2022 WITH 2017 RESULTS

The LCA 3 study improved compared to the LCA 2 study (reference year 2017[10]) in several aspects. The quality of the data was enhanced for water as well as for electricity supply. Additionally, all end-of-life pre-treatment (outside the fabricators' system boundaries) was estimated based on available pre-treatment data from two member companies.

If primary production results from 2017 (using 2022 background data from GaBI database) are compared with the results of this study, an increase of GWP can be identifed, as shown in Figure 8 below.

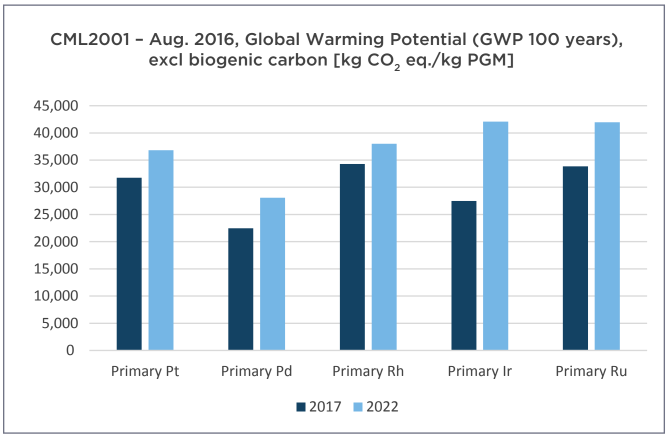

Figure 8: GWP comparison for primary production of 1 kg PGM between 2017 and 2022 production data

The rise in CO_2 emissions can be attributed to several aspects:

- Higher CO_2 emissions from the South African electricity mix which are caused by the decreased efficiency of the South African hard coal power plants[11].
- The influence of the increased market price (10-year average) for PGMs (see Table 6) which causes a rise of the environmental impact share attributed to the PGMs when allocation between base metals and PGMs is carried out.
- Increased mining of the Platreef ore body, a low-grade ore. Given the low grade, higher ore volumes were required to meet PGM production requirements downstream, resulting in higher energy consumption and GHG emissions.
- Another aspect of most of the ore mined in 2022 compared to 2017 is the concentrates' high matte fall[12] characteristics observed at smelters, which led to higher smelter throughput and base metal production.

Table 6: Metal prices 10-year average 2012-2021

Metal	USD/kg	Reference
Platinum	35,789	(LPPM am-pm, n.d.)
Palladium	36,991	(LPPM am-pm, n.d.)
Rhodium	130,584	(NYD (New York Dealers), n.d.)
Osmium	12,860	(Metalary, n.d.)
Iridium	41,768	(NYD (New York Dealers), n.d.)
Ruthenium	4,899	(NYD (New York Dealers), n.d.)
Gold	45,796	(LBMA am-pm , n.d.)
Silver	648	(LBMA am-pm , n.d.)
Nickel	14	(LME cash settlment, n.d.)
Cobalt	40	(Metal Bulletin (99.3 low), n.d.)
Copper	6.66	(LME cash settlment, n.d.)
Chrome concentrate (42% Cr_2O_3)	Confidential[13]	

Due to the shift in participation from secondary producers between the current LCA 3 and the last study (LCA 2), the comparability of the results of the two studies is limited, also due to the difference in the volumes and in the production technology mix reported.

Nevertheless, the results for secondary production are still highly representative as they cover roughly 60% of the world production.

The results for secondary production improved in many aspects:

- The data quality as such has considerably improved for the current LCA (e.g. detailed information about supplier specific power supplies, higher granularity of process steps which allowed process specific allocations).
- More accurate data for GWP and water could be collected across all regions.
- The efficiency of many processes has increased.
- More accurate modelling of toll refining activities has been carried out on behalf of mines.
- All end-of-life pre-treatment has been modelled based on data from two companies.

[10] IPA Study "Life Cycle Assessment of Platinum Group Metals Production", reference year 2017, October 2020, performed by Sphera.
[11] International Energy Agency data from 2019.
[12] The percentage of the mass of matte formed per ton of concentrate is termed matte fall.
[13] Confidential information provided by a single company.

5. OUTLOOK: CO_2 SCENARIO FOR 2030 – EFFECTS OF DECARBONIZATION ON THE GWP OF PRIMARY PGM PRODUCTION

The IPA has commissioned a scenario analysis to complement the critically reviewed LCA 3 study, aiming to quantify potential improvements in the global carbon footprint of primary produced PGMs by 2030. The analysis focuses exclusively on South African PGM producers due to the significant impact of electricity supply from Eskom, the South African power utility.

The scenario model is based on the following two factors:

1. The projection of Eskom's investment plans to increase the share of renewable energy in the national grid by 2030,
   and
2. Investment in and implementation of renewable energy by each South African PGM producer.

5.1 CHANGES TO SOUTH AFRICA'S NATIONAL ELECTRICITY GRID (ESKOM)

The model underlying the Eskom scenario has been based on the draft Integrated Resource Plan (IRP) of the Department of Mineral Resources and Energy, published in January 2024[14] . The draft IRP 2023 outlines a roadmap from 2023 to 2030 for the development of new power capacities within the South African power grid.

The following Table 7 shows the Eskom power grid mix 2023 compared to the 2030 projection, with the rise of share in percentage of different power sources.

The power grid used in this LCA 3 is based on the 2019 reference year, as reported in the International Energy Agency (IEA) publication, which reflects a three-year delay in data availability.

Table 7: Eskom power grid mix 2023 versus 2030[15]

	Current base 2023				2030			2030 incl. availability factor		
	MW	EAF	MW	Share in [%]	additional MW	MW	Share in [%]	EAF	MW	Share in [%]
Coal	38,800	91,7%	35,580	76%	1,440	40,240	57%	91,7%	36,900	62%
Gas	3,830	85,7%	3,282	7%	7,220	11,050	16%	85,7%	9,469.9	16%
Nuclear	1,860	92%	1,711	4%	0	1,860	3%	92%	1,711	3%
Hydro	3,332	75%	2,499	5%	0	3,332	5%	75%	2,499	4%
Solar	2,787	25%	697	1%	3,715	6,502	9%	25%	1,626	3%
Wind	3,443	94%	3,236	7%	4,468	7,911	11%	94%	7,436	12%

[14] Integrated Resource Plan as published by the Department of Mineral Resources and Energy of South Africa: https://www.dmre.gov.za/mining-minerals-energy-policy-development/integrated-resource-plan/irp-2023
[15] Modelled from https://www.gov.za/sites/default/files/gcis_document/202401/49974gon4238.pdf); EAF taken from Supply-Side Cost and Performance Data for Eskom Integrated Resource Planning 2020–2021 Update, available on https://www.dmre.gov.za

Table 8: Eskom power grid mix 2019 (IEA) used for LCA 3 from MLC database of Sphera

	Power grid 2019	Power grid 2030
	Share in [%]	Share in [%]
Coal	87.4	62
Gas	0	16
Nuclear	5	3
Hydro	3	4
Solar	3	3
Wind	2.6	12
Emissions factor in kg CO_2 eq. / kWh	**1.09**	**0.83**

The share of electricity generated from hard coal has already declined from 87.4% in 2019 (according to IEA data; see Table 8) to 76% in 2023. This trend is expected to continue, with a further 14% reduction between 2023 and 2030, bringing the share of hard coal in electricity generation down to 62% by 2030.

Transmission losses (2.3%) and distribution losses (9.61%) were applied and derived from the "South Africa's 2021 Grid Emission Factors (GEF) Report"[16], published in 2024, following a conservative approach. Transmission losses in electricity grids refer to the energy lost as heat due to the electrical resistance in the network when electricity travels through power lines from generation sources to consumers. Distribution losses refer to the energy lost when electricity is delivered from substations to end-users (homes, businesses, industries). These losses occur in the low-voltage distribution network and are typically higher than transmission losses due to the lower voltage and higher current.

5.2 INVESTMENTS OF PGM PRODUCERS IN RENEWABLE ENERGY BY 2030

The average investment was determined using data collected from each PGM producer, including the gigawatt-hours (GWh) of renewable energy purchased and invested in by 2030.

It was assumed that power consumption in 2030 for the participating companies would remain the same as during the data collection for LCA 3 (2022 reference year). No scenario assuming increased PGM production growth was included, i.e., the volume of PGM ounces reported in 2022 was also assumed for 2030. In addition, reported consumption numbers for electricity, fuels, auxiliaries, etc. also remained unchanged.

The model developed in the 2022 study was replicated for 2030, and based on these production volumes, the weighted average of renewable energy invested in or purchased by PGM producers was calculated. On average, 65% of renewable energy available in 2030 stem from companies' own investments, while 35% can be attributed to purchased renewables from the Eskom grid.

The share of renewable energy in each PGM varies, as companies differ in their level of investment in renewable energy and their respective production volumes. Most of these investments are directed towards photovoltaic and wind energy projects in South Africa.

Additional system boundaries

To ensure transparency in the calculations, two key assumptions were made:

1. All 2022 consumption data used in the LCA results presented in this report remain unchanged for the 2030 scenario.
2. For purchased concentrates (raw materials) per PGM producer, an average was calculated across all South African mining and concentration stages.
   However, this approach has limitations, as South African producers also source concentrates from mines and companies not included in the LCA study.

To account for this uncertainty, two scenarios were considered:

a. *Conservative Scenario:* Purchased concentrates sourced from third parties remain unchanged and continue to reflect the same values as reported in the LCA study results, without incorporating renewable energy use.

b. *Best Scenario:* The environmental impact of purchased concentrates from third parties was assessed under the assumption that these sources benefit from the same average investments in and purchases of renewable energy as the participating companies. Additionally, Eskom's contribution, including the renewable energy share of the grid, was factored in.

[16] Source: https://www.dffe.gov.za/sites/default/files/reports/SA2021_gridemissionfactorsreport.pdf

5.3 RESULTS FOR GLOBAL WARMING POTENTIAL IN 2030

GWP for primary produced platinum in 2030

In Figure 9, the GWP for platinum from 2022 production is compared to two scenarios for 2030:

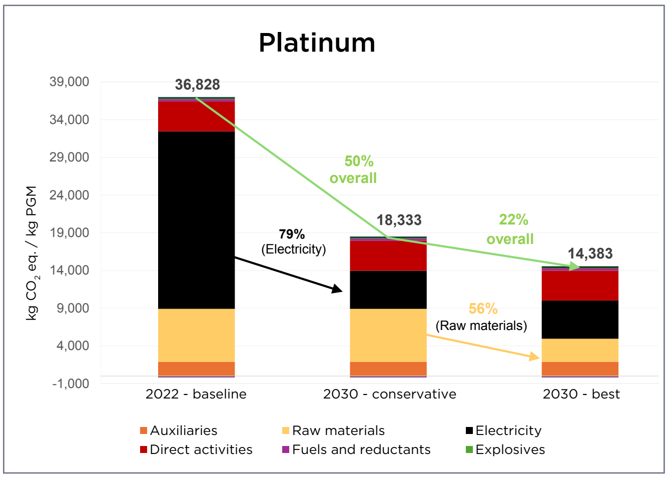

Figure 9: GWP reduction for platinum comparing 2022 baseline to two 2030 scenarios

In the conservative scenario, which assumes no improvement for the purchased concentrates (middle bar), investments in renewable energy would still lead to a decrease of GWP from electricity use by 79%. The overall reduction between the 2022 baseline and the 2030 conservative scenario for 1 kg of Pt produced in 2030 amounts to 50%.

In contrast, the results showcased in the right bar assume that the purchased raw materials will experience the same reductions as the concentrates sourced by the participating South African PGM producers.

According to this best scenario, the GWP impact from purchased material can be reduced by 56%, and the overall GWP for 1 kg of Pt produced in 2030 can be reduced by 61%, compared to the 2022 baseline.

The actual outcome is likely to fall between the two scenario results of 18,333 kg CO_2 eq. per kg of platinum and 14,383 kg CO_2 eq. per kg of platinum.

GWP for primary produced palladium in 2030

As shown in Figure 10, the reduction of the GWP for palladium is lower than for platinum (as well as for rhodium, iridium, and ruthenium). This is primarily due to the significant proportion of palladium produced in Russia and the USA, where no reduction measures were included in the 2030 scenario. In other words, the palladium GWP benefits less from the switch to renewable energy in South Africa as there is considerable production in other regions, too. The potential reduction through investments in renewable energy in other regions is a factor that might be considered in future updates on this scenario.

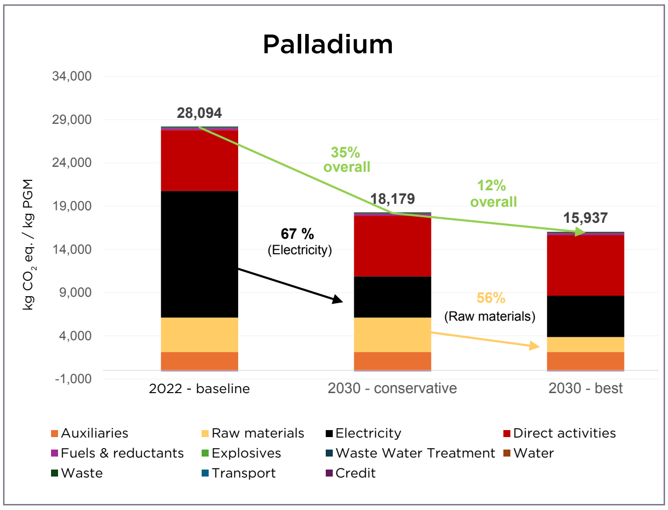

Figure 10: GWP reduction for palladium comparing 2022 baseline with two scenarios for 2030

GWP for primary rhodium, iridium, and ruthenium in 2030

The reduction in GWP for rhodium, iridium, and ruthenium is of the same order of magnitude as the GWP reduction for platinum, as most of the production of these PGMs takes place in South Africa.

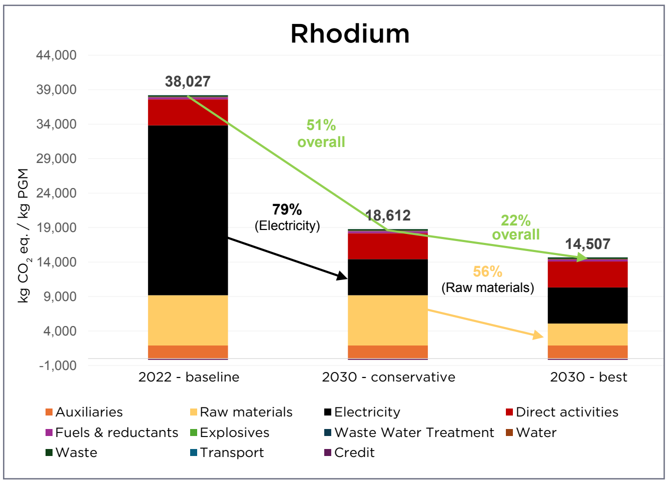

Figure 11: GWP reduction for rhodium comparing 2022 baseline with two scenarios for 2030

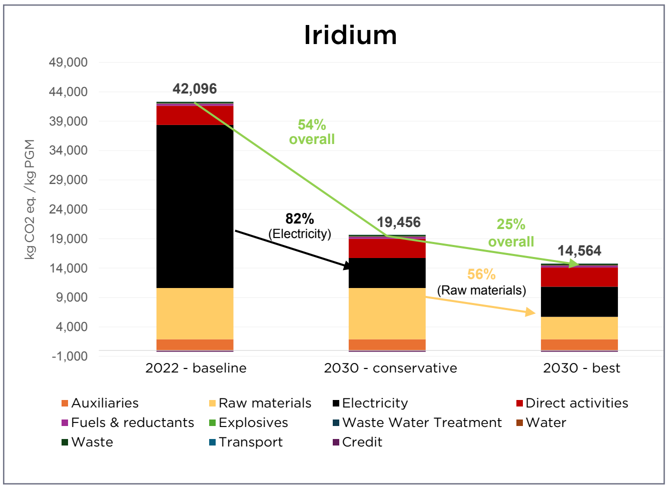

Figure 12: GWP reduction for iridium comparing 2022 baseline with two scenarios for 2030

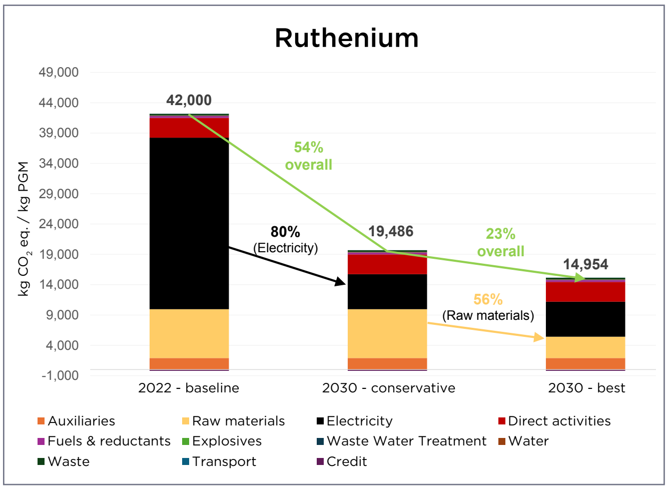

Figure 13: GWP reduction for ruthenium comparing 2022 baseline with two scenarios for 2030

5.4 CONCLUSIONS

This outlook focuses exclusively on improvements in South Africa's power supply, particularly the transition to renewable energy within the national grid and the investments or procurement of renewable energy by participating mining companies.

Overall, the estimated reduction in GWP varies between 35% and 61%, depending on the changes implemented in the 2030 scenario for the South African power supply per PGM producer.

This variability can be attributed to two key factors:

1. Differences in the scale of investment in renewable electricity among PGM producers.
2. Variations in production volumes of specific PGMs by different producers.

These factors collectively influence the potential reduction in emissions for each PGM.

Additionally, a conservative scenario was assessed in which purchased raw materials (concentrates) were assumed to have no potential for improvement, as reflected in middle column of Table 9.

Table 9: Summary of reduction potentials in 2030 compared to 2022

kg CO_2 eq. per kg	2022 Baseline	2030 Conservative Scenario	2030 Best Scenario
Platinum	36,828	18,333	14,383
Palladium	28,094	18,179	15,937
Rhodium	38,027	18,612	14,507
Iridium	42,096	19,456	14,564
Ruthenium	42,000	19,486	14,954

KEY MESSAGES & TAKE-AWAYS

- PGMs have high environmental impacts due to energy-intensive processing but are crucial metals for applications in low-carbon technologies such as green hydrogen and fuel cells.
- The value chain strives for the most resource-efficient solutions to provide PGMs to their customers while closing the material loop. Recycling of PGMs significantly reduces the environmental burden at each next life cycle.
- The GWP impact of primary production assessed for the reference year 2022 has increased compared to 2017; this can be attributed to three main factors:
  1. The higher CO_2 emissions from the South African electricity mix due to a decreased efficiency of the South African hard coal power plants.
  2. The influence of the increased market price (10-year average) for PGMs.
  3. Increased mining of low-grade ore body.
- The PGM industry has a decarbonization roadmap in place which will result in a considerable decrease in the Global Warming Potential of primary produced PGMs by 2030.
- Growing replacement of hard-coal generated electricity by renewable energy in South Africa will heavily reduce the carbon footprint of primary production by 2030.
- The overall reduction in GWP modelled for 2030 is between 35% and 61%, depending on whether a conservative or best-case scenario is modelled.
- Each PGM producer invests different volumes in renewable energy, and the production volume for each PGM varies by producer. Hence, the PGMs mainly mined in South Africa (Pt, Rh, Ir, and Ru) benefit more in our model than Pd, as decarbonization efforts of other regions (USA, Russia) were out of the scope of our CO_2 scenario.
- Increased efficiency in processing, and shifts towards greener mining technologies, are expected to further drive emissions reductions.
- The LCA study results for secondary production, showcasing a significantly lower footprint assigned to the recycling of EoL material, underscore the vital role of recycling in ensuring the circularity of PGMs.
- Secondary producers, while not having been part of the CO_2 scenario presented here, also contribute to the reduction of carbon emissions by heavily investing in the use of renewable energy and by increasing the efficiency of PGM use in applications, often referred to as thrifting.
- Future LCA updates will aim to address data gaps (such as water accounting, water impact assessment based on water scarcity for the different regions, transport of EoL scrap to recyclers, metals emissions to air) and refine impact assessments.

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COMPANIES PARTICIPATING IN THE STUDY

AngloAmerican

IMPLATS EXCELLENCE IN PGMs

NORTHAM PLATINUM LIMITED

NORNICKEL

ROYAL BAFOKENG PLATINUM MORE THAN MINING

Sibanye Stillwater we are one

Exploration, Mining & Production

BASF We create chemistry

Johnson Matthey Inspiring science, enhancing life

Heraeus

TANAKA

Fabrication & Recycling

ABOUT THE IPA

The International Platinum Group Metals Association (IPA) is a non-profit association that represents the worldwide leading mining, production and fabrication companies in the global platinum group metals (PGMs) industry, comprising platinum, palladium, rhodium, ruthenium, iridium, and osmium.

The organisation, founded in 1987, is based in Munich and holds membership meetings twice a year. Its working committees and groups meet regularly throughout the year. The association actively engages and collaborates in a strong network of partner organisations.

The primary goal of the organization is to serve as a platform for discussion and information exchange, both among its members and with external stakeholders. Additionally, the IPA acts as an early warning system for the PGM industry by monitoring relevant legislation (such as emissions control, recycling, EHS, and ESG requirements) and key industry topics, including trade, health and safety, and sustainable development.

The LCA 3 study update for the 2022 production year marks the third global, industry-wide life cycle assessment conducted by the IPA. It underscores the industry's commitment to understanding and improving the sustainability performance of PGMs.

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