



Publication of Unique, Detailed Study of PGM Scrap

Reserves at Germany's PGM 'Mine-in-Products' Put at 240 tonnes - enough to cover almost half its gross annual PGM demand

These two statistics - that Germany's inventory of PGMs in fabricated products stands at around 240 tonnes and that recycling from this covers just under half its annual gross demand - are some of the key findings in a unique and highly detailed report on PGM recycling in Germany, '*Materials Flow of Platinum Group Metals*', published today.

The initial research behind this report was carried out by the well known refiner and fabricator of PGM products, **Umicore**, and by Germany's leading environmental research institute, **Öko-Institut**, with funding from Germany's Federal Ministry of Education & Research. **GFMS** then drew up a section placing the German results in a global context, assessed whether any material changes had occurred since the early research was carried out and added an executive summary.

The first section of the report concerns estimates of the division of gross PGM demand by end-use sector and how much of each sector's requirements are met by recycled PGMs, generating a figure for the amount of PGMs 'irretrievably lost' each year. This research was then extended to assess the standing inventory of PGMs in each sector of end-use.

The second section covers future possible improvements to the amount that can be recycled; a major reason behind the report's ministerial funding being a desire to raise recycling efficiencies. This in turn was based on environmental concerns as recovery from scrap tends to generate far less carbon dioxide and sulphur dioxide than does primary mining. To that end, the report recommends various measures to improve recovery rates.

As for its global relevance, Germany makes an excellent case study. Not only is it a major industrial consumer of PGMs (being, for example, the world number three car producer), but the country is frequently 'ahead of the game' on environmental matters. Pointers can therefore be deduced as to what is already achievable with current technologies and practices and where recovery rates might be going as we move forward.

Main Highlights

The contribution of recycling

- » Germany's gross demand for PGMs in the base year (2001) was approximately 1.2m ounces (38 tonnes) of which platinum comprised 58%, palladium 37% and rhodium 5%.
- » Autocatalyst production accounted for 40% of gross demand, chemical industry catalysts 22% and glass industry products 13%. Jewellery accounted for 9% of gross demand.
- » 45% of gross demand was satisfied by recycled PGMs. New purchases represented only 55%.
- » Recycling of glass industry products and industrial catalysts accounted for over two-thirds of the total amount of PGMs recycled in Germany.
- » 85% of gross demand in the glass and industrial catalyst sectors was satisfied by recycling.
- » PGMs recycled from scrapped autocatalysts represented only 12% of gross autocatalyst demand.





- » In the base year 320,000 ounces (10 tonnes) of PGMs escaped recycling and were considered "lost". 50% of this was platinum with palladium comprising 40% and rhodium 10%.

Germany's PGM inventory

- » Germany's national inventory of PGMs was estimated in the region of 240 tonnes in the base year. This comprised 50% platinum, 45% palladium with the balance rhodium.
- » The majority of the national inventory is contained in consumer durable products held by private individuals. End-of life PGM recycling from these sources is conducted through "indirect cycles".
- » 42% of the country's inventory is contained in autocatalysts fitted to vehicles in service.
- » Electronic hardware and jewellery each accounted for approximately 18% of inventory with PGMs contained in dental prosthetics representing a further 10%.
- » Only 12% of the national inventory resides in industrial processes. In the main this comprises PGMs contained in industrial catalysts and in equipment used to manufacture high purity glass. PGMs recovered from industrial processes are recycled through "direct cycles".

Recycling systems

The report identifies two distinctly different forms of recycling structures, "direct cycles" and "indirect cycles". These are commonly referred to as closed (direct) and open loop (indirect) systems.

Closed loops – key characteristic: recycling from industrial processes.

- » Closed loops prevail in industrial processes where PGMs are used to enable the manufacture of products or intermediates which typically contain no PGMs. An example of this is PGM catalysts used in the oxidation of ammonia to produce nitric acid.
- » The PGMs invariably survive the process in which they are used. Their physical location is confined to the immediate vicinity of the user's plant. The user retains ownership of the PGMs and the system boundaries are restricted and well defined.
- » In such processes the technical performance of the PGM products used (e.g. catalysts) is critical. As a result, close relationships exist between users of the PGM products and their providers. Third parties are rarely involved.
- » Typically, the provider of the PGM product operates (or can access) refining facilities through which PGMs contained in spent products can be recycled into new PGM products.
- » As a result, closed loop systems are inherently efficient and more than 90% of the PGMs used in industrial processes is typically recovered and recycled.

Open loops – key characteristic: recycling from consumer durables.

- » Open loop systems are prevalent in the recycling of PGMs from end-of-life consumer durable products i.e. vehicles (autocatalysts), electronic hardware (components) and dental prosthetics.
- » Consumer durables, in the main, are held by members of the general public. By the time such products reach the end of their useful lives (e.g. catalyst equipped cars) ownership may have changed hands several times and no connection remains between the final owner and its manufacturer.
- » Little or no direct financial benefit exists to encourage final owners to ensure recycling of end-of-life products. Environmental concerns and the need to find an outlet are the key drivers.



- » Once consumer products enter the recycling system there are frequently a number of parties involved in the chain before PGM bearing materials reach the stage of final refining. These include collectors, dismantlers, traders and operators of pre-treatment facilities.
- » Recovery methods and awareness of PGM values are often limited. This results in inadequate removal and segregation of PGM bearing materials and irretrievable losses e.g. to shredders.
- » The involvement of "informal" participants in the early stages of the recycling chain is not insignificant. In such operations, working practices and regulatory compliance are poor.
- » Significant numbers of end-of-life vehicles and electronic hardware (e.g. computers and mobile telephones) in Germany are exported for use in other less developed countries. As a result, the PGMs contained in such products escape recycling in Germany and may be irretrievably lost should poor recycling infrastructures and low environmental awareness prevail in the country of final use.
- » In end-of-life electronic hardware, PGM values are often extremely low and their recovery and recycling may not be economically viable.
- » Open loop systems are highly complex structures containing multiple variables and numerous opportunities for the failure of PGM recovery. Consequently, open loops are inherently inefficient and recycling falls a long way short of its potential.

Note: recycling of old jewellery items is also conducted through open loop systems. Due to its obvious value, recycling efficiency is high. However, with its unique, indeterminate life-cycle, jewellery falls largely beyond the scope of this study.

Measuring the efficiency of PGM recycling

- » The measurement of recycling efficiency is achieved by calculating recycling quotas for each PGM application. Recycling quotas (or ratios) have been calculated by the team on two fundamentally different bases, "static" and "dynamic".
- » "Static recycling ratios" compare current levels of supply from recycling with current gross demand. In an application where PGM demand is rising, a product with a lifecycle of several years (e.g. an autocatalyst) will yield an inherently low ratio. Conversely, in an application where demand has been falling (e.g. electronics) the ratio will be inherently high.
- » By contrast, "dynamic recycling ratios" compare current levels of supply from recycling with the gross demand for that application at the time the recycled products were originally manufactured. This measure eliminates the distorting effects of rising or falling demand and represents the true measure of recycling efficiency within any given application.
- » In application fields with either short lifecycles (e.g. 1 year or less) or stable levels of demand, the static and dynamic recycling measurements will both yield similar results.

Improving PGM recycling

Although it may be possible to further optimise PGM recycling within Germany's already efficient closed loop systems, the incremental benefits are likely to be relatively modest. The real challenge lies in finding ways to improve the performance of open loop systems, principally in respect of end-of-life vehicles and to a lesser extent, electronic hardware. In order to define the potential benefits the research partners have evaluated the impact of different scenarios through to 2020.

Autocatalyst recycling

Even assuming continued open loop recycling and no improvements in recycling rates, PGMs recovered from used autocatalysts will treble by 2020. This will be a natural function of:

- An increasing proportion of vehicles scrapped each year will be autocatalyst equipped.
- The rising profile of PGM consumption in respect of newly registered vehicles.



- » However, with recycling rates remaining low and the available volume of PGMs rising, the quantity escaping the net and becoming irretrievably lost, will increase steeply. By 2020, the project partners estimate that annual losses from autocatalyst recycling could top 10 tonnes of PGMs.
- » By contrast, a progressive conversion of existing open loop recycling systems into more efficient closed loops would drive up recycling rates. The partners estimate that closed loop recycling would more than double the recovery of PGMs from used autocatalysts by 2020 and slash losses.
- » End of Life Vehicle (ELV) recycling legislation has been adopted in Germany and should be supportive of such a conversion taking place. This legislation assigns responsibility for recycling to the original manufacturer or importer of the vehicle. As a consequence, vehicle manufacturers are establishing reception and dismantling centres where "own marque" ELVs may be returned.
- » Although this is a helpful development, the partners conclude that such legislation will need to be supplemented by other initiatives if PGM recycling from used autocatalysts is to reach its full potential. These include:
 - Increasing the awareness of PGM value and the benefits of recycling.
 - Improving cooperation between participants in the recycling chain with a view to enhancing transparency and rationalising the system.
 - Optimisation of dismantling and recovery procedures plus improved decanning techniques.
 - Greater attention to improving logistics in order to optimise material flow.
 - Action by competent authorities to certify and monitor recycling participants, eliminate informal sector participation and to regulate and control ELV exports.

Recycling of electronic hardware

- » In many respects the issues relating to end-of-life electronic goods are similar to those described for used autocatalysts. However, there are key differences which relate both to the low and declining levels of PGMs contained (in other words, grade) and the absolute decline in PGM usage (specifically of palladium) over recent years.
- » The two most important application areas for PGMs in electronics are hard disk drives (HDDs) and multi layer ceramic capacitors (MLCCs).
- » In HDDs, tiny amounts of platinum and more recently ruthenium, are applied to the disks (creating high density memory layers) and to disk read heads. The disks are typically made of aluminium. At end-of-life, the value of the aluminium far outweighs that of the platinum and so disks are channelled to aluminium smelters where the platinum is lost.
- » Palladium is an ingredient of MLCCs which are used in a variety of applications including mobile phones and computer peripherals. Since 2001, when the price of palladium reached \$1,000 per ounce, there has been a substantial shift away from palladium and to nickel based MLCCs. Consequently, the palladium contained in end-of-life electronic goods will decline sharply in future years. At the same time, ongoing miniaturisation and economy of use raise questions over the future viability of recycling such materials for their palladium value.
- » Although the available market may be shrinking in terms of PGMs, the recycling of redundant electronic goods is a high profile subject. Germany has adopted legislation which is similar to its ELV laws. Whilst this will be supportive of creating more efficient recycling systems, such legislation is not a solution in itself. The issues the partners have highlighted for autocatalyst recycling are equally valid if recycling from electronic goods is also to be optimised.

The Environment

- » The project partners have concluded that the extraction of PGMs from recycled materials results in significantly lower emissions than from equivalent amounts of PGMs generated by mining.
- » In recycling, basis the total amounts of PGM resulting from recycling and mine production respectively, emission levels of carbon dioxide (equivalent) were calculated to be only 7% of those evolved during mine production. Sulphur dioxide emissions were assessed as negligible.



- » In 2001 Germany's demand for newly mined PGMs equated to emissions in mine production of 300,000 tonnes of carbon dioxide and 20,000 tonnes of sulphur dioxide (both equivalents).
- » Germany consumed only 5% of global PGM mine production in 2001. 300,000 tonnes of carbon dioxide is equivalent to that emitted in production of 168,000 tonnes of steel.
- » Optimising PGM recycling offers clear environmental benefits. The potential optimisation of open loop recycling systems would serve to increase the supply of secondary PGMs and reduce dependence on mine production. Were this to be achieved, the increased supply of secondary PGMs would represent reduced emissions in mine production of 90,000 tonnes of carbon dioxide equivalents and 7,000 tonnes of sulphur dioxide equivalents in 2020.

Materials Flow of Platinum Group Metals contains over 240 pages of statistics and analysis on all aspects of platinum, palladium and rhodium recycling in Germany and a review of these results in a global context. The publication can be ordered from GFMS for £265 / US\$495 / €395 per copy. For orders and to receive further product information please contact Ms L. Perrard on: Tel: +44 (0)20 7478 1777, Fax: +44 (0)20 7478 1779, Email: sales@gfms.co.uk, Web Site: www.gfms.co.uk. A German language version of the report (excluding the global context section and executive summary) is also available.

Note to Editors about GFMS Limited:

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