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PLATINUM-GROUP METALS [ADVANCE RELEASE]

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Platinum-Group Metals

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The platinum-group metals (PGMs) are iridium, osmium, palladium, platinum, rhodium, and ruthenium. The PGMs occur together in nature, but economic deposits are rare. PGMs are produced from deposits that are mined primarily for PGMs and are also produced as byproducts of chromite or nickel-copper mines.

In 2021, the United States ranked fourth in the world in the production of palladium and ranked fifth in the production of platinum (table 5). Sibanye-Stillwater Ltd. (South Africa), the only domestic mine producer of non-byproduct PGMs, recovered PGMs from its Stillwater and East Boulder Mines in Montana. Domestic production of palladium was 13,700 kilograms (kg), a decrease of 6% compared with production in 2020. Domestic production of platinum was 4,020 kg, a decrease of 4% compared with production in 2020 (table 1). Recycling was a significant source of PGMs as well, accounting for about 28% of the total global supply of palladium, platinum, and rhodium in 2021. In the United States, approximately 40,000 kg of palladium and 11,000 kg platinum were recovered from automobile catalytic converters (Cowley, 2022, p. 21, 29, 33).

In 2021, the automobile industry continued to be the major consumer of PGMs. Catalytic converters accounted for approximately 92% of global rhodium consumption, 83% of primary palladium consumption, and 35% of platinum consumption (Cowley, 2022, p. 21, 29, 33). The annual average prices for PGMs increased in 2021. Prices for iridium more than tripled and for ruthenium more than doubled. The average annual prices increased for rhodium by 81%, for platinum by 24%, and for palladium by 10%, compared with the average annual prices in 2020 (fig. 1, table 1). Thefts of catalytic converters increased in the United States as the price of rhodium reached record highs in 2020 and 2021. PGMs including palladium, platinum, and rhodium were used in catalytic converters to filter fumes and toxic pollutants from automobile exhaust (Kraker, 2021; Wroughton and Bearak, 2021).

In 2021, excluding waste and scrap, imports of PGMs were unchanged, and exports decreased by 5%. Note that U.S. exports of iridium, osmium, and ruthenium are reported in gross weight because exports of those PGMs are not reported separately by the U.S. Census Bureau (tables 1, 4). World mine production of PGMs totaled 472,000 kg, a 12% increase compared with the total (revised) in 2020. Most of the world's mine supply of PGMs was produced in South Africa and Russia, which accounted for 61% and 23%, respectively, of global PGM mine production (table 5).

Government Actions and Legislation

The Defense Logistics Agency Strategic Materials, U.S. Department of Defense, announced the potential disposal of PGM materials under its fiscal year 2021 (October 1, 2020, through September 30, 2021) Annual Materials Plan (AMP). Maximum disposal limits in the 2021 AMP for PGM materials were set at 261 kg of platinum and 15 kg of iridium (Defense Logistics Agency Strategic Materials, 2020). At yearend, the National Defense Stockpile contained 15 kg of iridium, 261 kg of platinum, and less than 1 kg each of palladium and palladium-cobalt wire.

Production

Mine.—During 2021, U.S. palladium and platinum mine production was 13,700 kg and 4,020 kg, respectively. Compared with production in 2020, palladium and platinum production in 2021 was 6% and 4% less, respectively (table 1).

Sibanye-Stillwater Ltd. produced PGMs from two mines in the United States, the Stillwater and the East Boulder Mines in Montana. In 2021, the Stillwater Mine produced 10,800 kg of PGMs, and the East Boulder Mine produced 7,000 kg of PGMs. PGM production in the Stillwater Mine was affected by the suspension of mining blocks and the implementation of rail safety restrictions following a fatal safety incident in June 2021. PGM production also was affected in the East Boulder Mine in December 2021 owing to electrical outages caused by severe weather conditions (Sibanye-Stillwater Ltd., 2022a, p. 31, 104, 105).

Sibanye-Stillwater processed 1.47 million metric tons (Mt) of ore from the mines with a combined mill-head grade of 13 grams per metric ton PGMs and a PGM mill recovery rate of almost 90% (Sibanye-Stillwater Ltd., 2022a, p. 106). The concentrates from the mines were smelted and then processed at the base-metal refinery at Sibanye-Stillwater's metallurgical complex in Columbus, MT, producing a PGM-rich filter cake. Final refining of PGMs to commercial grade was done by Johnson Matthey Plc in one of its facilities in the United Kingdom.

At yearend 2021, Sibanye-Stillwater reported proven and probable reserves at its Montana mines of 68.3 Mt of ore with a palladium-to-platinum ratio ranging from 3.4:1 to 3.6:1 and about 849,000 kg of contained palladium and platinum. These reserves occur in the J-M Reef, an ore body within the layered mafic and ultramafic igneous rocks of the Stillwater Complex (Sibanye-Stillwater Ltd., 2022a, p. 113; 2022b, p. 34, 40).

Refinery.—The U.S. Geological Survey surveyed domestic precious metals refinery producers on an annual basis. Of the 17 companies that were surveyed for commercial-grade PGM refinery production for 2021, 4 companies responded. Refinery production for the companies that did not respond to the survey was estimated based on prior reports or on information from other sources; however, it likely was underestimated.

Using these data, U.S. refinery production during 2021 was 92,000 kg of palladium and 47,400 kg of platinum. Compared with revised values from 2020, this represented increases of 38% for palladium and 5% for platinum (table 1). In May,

BASF SE (Germany) announced plans to expand its PGM refining plant in Seneca, SC. The expansion project would increase capacity to recycle precious metals from spent catalysts, including automobile catalytic converters (BASF SE, 2021). Precious metals refiner Hauser & Miller announced that it was closing at the end of 2020 and ceased refining operations in 2021 (Hauser & Miller, undated).

Recycling.—In 2021, PGMs were recycled from three main sources—catalytic converters, electronics, and jewelry. Globally, almost 168,000 kg of secondary PGMs was recovered, accounting for approximately 28% of the global supply of PGMs. Recycled catalytic converters were the predominant source of secondary PGMs (Cowley, 2022, p. 21, 29, 33). Based on industry information and previously reported data, an estimated 38,900 kg of PGMs was theoretically available for recovery from catalytic converters in the United States, which would be about 40% of the world total catalytic converter supply (CPM Group, 2019, p. 180; 2022, p. 47–48, 132).

Sibanye-Stillwater reported that it recovered 23,500 kg of PGMs from spent catalytic converters and other industrial sources at its metallurgical complex in Montana in 2021, 10% less than the amount recycled in 2020. Of the total recycled, Sibanye-Stillwater toll-refined 393 kg of PGMs, 87% less than that in 2020. In 2021, Sibanye-Stillwater sold 24,300 kg of PGMs from secondary sources. The decrease in recycling compared with that in 2020 was attributed to supply chain constraints and reduced automobile manufacturing owing to semiconductor chip shortages (Sibanye-Stillwater Ltd., 2022a, p. 31; 2022c, p. 17, 21).

In July, Elemental Holding S.à.r.l. (Luxembourg) acquired Maryland Core, Inc., a PGM recycling center in Baltimore, MD, in coordination with the Polish International Development Fund. The recycling center received, stored, processed, and sold separated recyclable automotive and scrap material, such as catalytic converters, to domestic and global refineries (Maryland Core, Inc., undated). In September, Elemental Holding also acquired Legend Smelting and Recycling, which had catalytic converter recycling facilities in California, Illinois, Indiana, Ohio, and Texas. Legend Smelting and Recycling was a full-service processor that graded, cut, milled, and assayed converter material before it goes to a refinery (Legend Smelting and Recycling, undated). The two acquisitions expanded Elemental Holding's PGM and strategic materials recycling capabilities in the United States (American Recycler News, Inc., 2021; Elemental Holding S.à.r.l., 2021).

Consumption

PGMs were consumed in a variety of industries in the United States, and often different PGMs were used together in the same applications. Owing to similar atomic structures and chemistries, they exhibit similar properties, which include biocompatibility; catalytic, conductive, and electrical properties; high melting temperature; and resistance to chemical corrosion and oxidation. The primary uses for PGMs were in automotive catalytic converters, chemical and petroleum catalysts, electronics, glassmaking, investment, jewelry, and medical and dental devices.

The dominant application for PGMs since 1979 has been in catalytic converters. Palladium, platinum, and rhodium were used in catalytic converters to capture harmful exhaust emissions, such as carbon monoxide, hydrocarbons, and nitrogen oxides. Palladium, platinum, and rhodium compose the catalyst component of catalytic converters. Platinum catalysts oxidize gases such as carbon monoxide and hydrocarbons in the exhaust system of automobiles as well as reduce nitric oxide. Palladium also was used as an oxidation catalyst, and rhodium was used as a reduction catalyst to reduce the production of nitric oxide and nitrogen dioxide (Shishu and Kowalczyk, 1974; Johnson Matthey Plc, 1990; Lintz and Oerter, 1993). The catalytic properties of the PGMs also were used in the chemical and petroleum industries. In the chemical industry, platinum and rhodium catalyze the reaction that generates nitric acid, which was used in the production of explosives, fertilizers, and some plastics. Additionally, platinum catalysts are necessary for the production of silicone. In the petroleum industry, platinum was used as a catalyst in the refining of crude oil, reforming, and other processes used in the production of aromatic compounds and high-octane gasoline.

Uses of PGMs in electronics included hard-drive disks, multilayer ceramic capacitors, plasma-display panels, and semiconductor thermocouples. Iridium was used specifically as a crucible material for the production of high-quality single crystals. Owing to their resistance to chemical corrosion and degradation at high temperatures, platinum and rhodium were used in glassmaking primarily for manufacture of liquid-crystal displays. Because of biocompatibility and nonreactivity of the metals with organic tissue, PGMs were used in dental and medical devices as well as in jewelry. Resistance to chemical corrosion and oxidation and relative rarity on Earth also make them appealing for jewelry as well as physical investments in the form of coin and bullion.

Palladium.—In 2021, domestic palladium apparent consumption, defined as primary mine production plus secondary production from spent automobile catalysts plus imports minus exports, excluding imports and exports of waste and scrap, was 108,000 kg, a 6% increase from that in 2020. The leading end use for palladium in 2021 was in the production of automobile catalytic converters, which accounted for 68% of consumption in North America. Other uses, including chemical and petroleum catalysts, electronics, dental, and jewelry, accounted for the remaining 32% (CPM Group, 2022, p. 137).

Platinum.—In 2021, domestic platinum apparent consumption, defined as mine production plus recycling from spent automobile catalysts plus imports minus exports, excluding imports and exports of waste and scrap, was 49,900 kg, an increase of 6% compared with apparent consumption in 2020. The leading end uses for platinum in 2021 were in the production of catalytic converters and in chemical and petroleum refining, which accounted for 56% and 20% of consumption in the United States, respectively. Other uses accounted for 24% and included dental and medical devices, electronics, and jewelry (CPM Group, 2022, p. 53).

Other PGMs.—In 2021, adequate data were not available to determine the apparent consumption of iridium, osmium, rhodium, or ruthenium. The leading end use for rhodium in

2021 was in the production of catalytic converters, which accounted for 90% of consumption in the United States. Other uses that accounted for the remaining 10% included chemicals, electronics, and glass (CPM Group, 2022, p. 195).

Prices

According to S&P Global Platts Metals Week, in 2021, the Engelhard unfabricated annual average price for iridium more than tripled and the average annual average price for ruthenium more than doubled. The annual average prices for rhodium, platinum, and palladium increased by 81%, 24%, and 10%, respectively, compared with the annual average prices in 2020 (table 1). The PGM price increases in the past year were related to processing outages at refineries in South Africa and production delays caused by the global coronavirus disease 2019 (COVID-19) pandemic (Cowley, 2021, p. 5). However, year-on-year price increases—despite being substantial—were mitigated by a reduction in automobile manufacturing that took place in response to shortages in semiconductor chips and shipping delays that stemmed from COVID-19 restrictions, thus decreasing the demand for PGMs used in automobile catalysts. Figure 1 illustrates the average monthly prices from 2017 through 2021.

Iridium.—The annual average iridium price in 2021 was $5,158 per troy ounce, which was more than three times greater than that in 2020. The iridium spot-market price began the year at $3,000 per troy ounce and reached a record high of $6,400 per troy ounce in May before decreasing to end the year at $4,150 per troy ounce. The price increases in iridium were largely attributed to a temporary lack of liquidity that resulted from outages at one of the largest iridium refiners, Anglo American Platinum Ltd. (South Africa), and flooding in a copper-nickel-PGM (Cu-Ni-PGM) mine owned by PJSC MMC Norilsk Nickel (Nornickel) (Russia) on the Taimyr Peninsula in Russia. The increase in the average annual price for iridium in 2021 was also attributed to an increased use of iridium crucibles to produce lithium tantalite in fifth-generation (5G) smartphones. Investors have also taken an interest in iridium for its potential use in the production of green hydrogen, which can be used to store renewable electricity (Cowley, 2021, p. 30–31; de Liz, 2021; Heraeus Precious Metals GmbH & Co. KG, 2022, p. 11).

Palladium.—The annual average palladium price in 2021 was $2,419 per troy ounce, which was 10% greater than that in 2020. The palladium spot-market price began 2021 at $2,469 per troy ounce and fluctuated throughout the year with a general upward trend until September when prices began to decline, ending the year at $1,900 per troy ounce. The price increases were attributed to a continued supply deficit from previous years as well as processing outages at refineries in South Africa, mine production delays caused by the global COVID-19 pandemic, and flooding in the Nornickel Cu-Ni-PGM mine. However, prices decreased as processing issues were resolved and the Nornickel mine resumed operations. In addition, a decrease in the production of internal combustion engine (ICE) automobiles decreased the demand for PGMs in automobile catalysts as car manufacturers dealt with ongoing supply issues related to the COVID-19 pandemic and a shortage of semiconductor chips (Cowley, 2021, p. 5, 12; de Liz, 2021; Heraeus Precious Metals GmbH & Co. KG, 2022, p. 8).

Platinum.—In 2021, the annual average platinum price was $1,094 per troy ounce, which was 24% more than the annual average price in 2020. The spot-market price of platinum began the year at $1,121 per troy ounce and fluctuated throughout the year, ending the year at $970 per troy ounce. The annual average price increase in platinum was attributed to a decrease in production owing to flooding in the Nornickel Cu-Ni-PGM mine in Russia and a decrease in demand for new ICE vehicles owing to a semiconductor chip shortage (Heraeus Precious Metals GmbH & Co. KG, 2022, p. 6).

Rhodium.—The annual average rhodium price in 2021 was $20,254 per troy ounce, which was 81% more than that in 2020. The rhodium spot-market price began the year at $17,650 per troy ounce and trended upward until March 22 when the price reached a record high of $30,000 per troy ounce, after which prices began to decrease, ending the year at $14,250 per troy ounce. The price increase for rhodium in 2021 was attributed to limited availability of refined rhodium and increased demand for rhodium in the automotive sector, which uses rhodium to achieve higher fuel efficiency and emission standards in three-way automobile catalysts to reduce emissions of oxides of nitrogen. Recent introduction of higher standards in the United States and Europe has thus increased rhodium demand (Heraeus Precious Metals GmbH & Co. KG, 2022, p. 6, 9).

Ruthenium.—The annual average ruthenium price in 2021 was $576 per troy ounce, which was more than double that in 2020. The ruthenium spot-market price began the year at $280 per troy ounce and increased gradually until June when it reached a record high of $800 per troy ounce, after which the price decreased, ending the year at $575 per troy ounce. The increase in the spot-market price for ruthenium in 2021 was attributed to processing problems at refineries in South Africa and flooding in the Nornickel Cu-Ni-PGM mine, which caused reductions in supply. Once refineries resumed normal operations in South Africa, prices began to decrease as the metal became more available (table 5; Heraeus Precious Metals GmbH & Co. KG, 2022, p. 10).

Foreign Trade

In 2021, imports for consumption of palladium, excluding waste and scrap, decreased by 5% to 72,600 kg from 76,400 kg in 2020. The imports were sourced predominantly from South Africa (32%), Russia (30%), and Belgium (11%). In 2021, imports for consumption of platinum, excluding waste and scrap, increased by 5% to 67,800 kg from 64,800 kg in 2020. The leading sources of platinum imports were South Africa (39%), Germany (11%), Switzerland (11%), and Belgium (10%). Imports for consumption of rhodium decreased by 20% to 16,500 kg from 20,700 kg in 2020. The leading sources of rhodium imports were South Africa (43%), Germany (21%), and Italy (12%). Combined imports of iridium, osmium, and ruthenium increased by 30% to 20,300 kg. Leading import sources for iridium, osmium, and ruthenium in 2021 were South Africa (48%), Germany (18%), the United Kingdom (17%), and Italy (13%) (tables 1–3).

In 2021, exports of palladium, excluding waste and scrap, totaled 43,900 kg, a 10% decrease from exports in 2020. Exports of platinum, excluding and waste and scrap, totaled

29,400 kg, a slight increase compared with exports in 2020. Combined exports of iridium, osmium, and ruthenium increased by 47%, exports of PGM waste and scrap increased by 13%, and exports of rhodium decreased by 9% compared with exports in 2020 (tables 1, 4).

World Review

In 2021, world mine production of PGMs increased by 12% to 472,000 kg from 422,000 kg (revised) in 2020 (tables 1, 5). South Africa accounted for the largest share of total PGM mine production, accounting for 61% of global production, followed by Russia, 23%; Zimbabwe, 6%; Canada, 5%; the United States, 4%; and other countries, 1%. Global mine production of palladium increased by 5% to 214,000 kg; Russia accounted for 40%; South Africa, 39%, Canada, 7%; the United States, 6%; Zimbabwe, 6%; and other countries, 2%. In 2021, world platinum mine production increased by 17% to 192,000 kg; South Africa accounted for 74%; Russia, 11%; Zimbabwe, 8%; Canada, 3%; the United States, 2%, and other countries, 2%. World mine production of other PGMs (iridium, rhodium, and ruthenium) increased by 20% in 2021 compared with that in 2020; South Africa accounted for 90% of the global production of other PGMs (table 5).

Canada.—In March, Canada's Minister of Natural Resources announced a list of 31 minerals considered critical for the sustainable economic success of Canada and its allies. This list included PGMs (Bedder, 2021).

Generation Mining Ltd. signed a binding acquisition agreement between its subsidiary Generation PGM Inc. and Stillwater Canada Inc., a subsidiary of Sibanye-Stillwater, for the remaining interest in the Marathon Palladium-Copper Project in Ontario Province. The transaction enabled the company to earn a 100% interest in the project and greater control of financing and project development (Generation Mining Ltd., 2021).

Russia.—Nornickel reported that its Cu-Ni-PGM mine at Oktyabrsky on the Taimyr Peninsula in Russia had resumed full operations on May 13, 2021, following underground flooding that began in February. The Oktyabrsky Mine was operating at 60% capacity in April, but continued water pumping allowed the company to restore operations to a full capacity of 14,100 metric tons per day of ore in May (de Liz, 2021).

Nornickel also signed several service contracts with Chernogorskoye Mining Co., a subsidiary of Russian Platinum Co., to supply electricity, gas, oil products, and transportation services to Chernogorskoye Mining Co. and included shipment of cargo at the Dudinka, Krasnoyarsk, Lesosibirsk, Arkhangelsk, and Murmansk ports. The service agreements followed an operational partnership between Nornickel and Russian Platinum for the development of copper, nickel, and PGM deposits in the Chernogorskoye field near the city of Norilsk in Siberia, which was signed in July 2020 (PJSC MMC Norilsk Nickel, 2020, 2021).

PGM-containing ore from Nornickel's Polar Division was concentrated at the Talnakh Concentrator, which underwent construction in 2021 as part of stage 3 upgrades that began in 2019. The upgrades were scheduled for completion in 2023, with a full capacity reaching 18 million metric tons per year (Mt/yr) by 2024. Stage 1 and stage 2 upgrades were completed in 2015 and 2018, respectively (PJSC MMC Norilsk Nickel, 2022, p. 34).

South Africa.—In January, Eastern Platinum Ltd. (Eastplats) (Canada) reported that it produced 134 metric tons (t) of pressed filter cake PGM concentrate in 2020 and delivered 32.18 t in December 2020 from its tailings retreatment project located at the Crocodile River Mine operation. The concentrate was produced under an offtake agreement between Barplats Mines (Pty) Ltd. (a subsidiary of Eastplats), and Impala Platinum Ltd. (Implats) (Eastern Platinum Ltd., 2021). In April, as part of its Retreatment Project, Eastplats refurbished the PGM Main Circuit B at the Crocodile River Mine, which was then commissioned in October (Eastern Platinum Ltd., 2021; 2022, p. 13).

In February 2021, the Department of Mineral Resources and Energy informed Platinum Group Metals Ltd. (Canada) that the mining right for the Waterberg Project, a PGM and gold mine located in the northern limb of the Bushveld Complex, had been approved. The mining right was effective for 30 years and could be renewed for additional time upon expiration (Platinum Group Metals Ltd., 2021a). In March and April, Platinum Group Metals Ltd. received notices that the mining right for the Waterberg Project was being appealed. The Department of Mineral Resources and Energy had 130 days to consider the appeal; however, the mining right would remain active with Waterberg JV Resources (Pty) Ltd. (Waterberg) and was notarized as effective on April 13th (Platinum Group Metals Ltd., 2021c, d). In July, Waterberg completed registration of the Waterberg Mining Right with the Minerals and Petroleum Titles Registration Office (Platinum Group Metals Ltd., 2021b).

During June, Jubilee Metals Group Plc (United Kingdom) announced the acquisition of additional chromite tailings from the Eastern Limb of the Bushveld Complex containing an estimated 1,950 kg of PGMs, which would be processed at its Inyoni PGM plant. In addition, Jubilee announced a new long-term PGM supply agreement with an unspecified chromite mining company to deliver PGM-rich feed from the Bushveld Complex containing an estimated 451 kilograms per year (Jubilee Metals Group Plc, 2021a, c). Expansion of Inyoni's processing capacity from 50,000 metric tons per month (t/mo) to 75,000 t/mo began in February 2021 and was completed in October 2021 and included an extended recovery circuit, allowing the plant to accommodate a variety of feed sources (Jubilee Metals Group Plc, 2021b, p. 6, 10).

Amplats entered discussions with African Rainbow Minerals Ltd. (ARM) in December for the purchase of its Bokoni platinum mine, located in the Eastern Limb of the Bushveld Complex. Amplats ceased mining operations at the Bokoni Mine in 2017 (Mining Review Africa, 2021; Thomson Reuters, 2021). Amplats completed a sales and purchase agreement with ARM in December to divest its 49% interest in the Bokoni platinum mine. The final transaction was expected to be fulfilled in 2022 after receiving Government approval. Although Amplats ceased mining operations at the Bokoni Mine in 2017, technical studies in 2019 determined the mine could be restarted with additional investment. Once ARM has the mine operational again, Amplats agreed to purchase PGM concentrate from the mine for 23 years (Anglo American Platinum Ltd., 2021a).

Amplats also announced in December the approval of a mine extension project into the Der Brochen ore body at the Mototolo platinum mine, located along the Eastern Limb of the Bushveld Complex. The project would extend the life of the mine beyond 30 years. Project development was expected to begin the first quarter of 2022 (Anglo American Platinum Ltd., 2021b).

Zimbabwe.—Zimplats Holdings Ltd. (Zimplats) [Guernsey (United Kingdom)] and operating subsidiary Zimbabwe Platinum Mines (Pvt) Ltd. mined and processed PGMs from five underground mines in the Great Dyke deposit and three processing facilities and sold the resultant PGM matte and concentrates to Implats. A high wall in the western boxcut of the Ngwarati Mine partially collapsed in February 2021, resulting in a fatality, and Zimplats subsequently closed the mine for precautionary measures. The closure, however, did not affect its production targets, and the mine resumed operations in July 2021 (Zimplats Holdings Ltd., 2021, p. 10, 23, 32).

Zimplats also reported that the development of the Mupani Mine was ahead of schedule and expected to be completed in September 2024. The Mupani Mine would replace the Rukodzi and Ngwarati Mines, which were expected to be depleted in 2022 and 2025, respectively. During the second quarter of the year, a feed preparation plant at the Selous Metallurgical Complex concentrator was commissioned and increased milling rates as well as metal recovery rates from the Ngwarati and Rukodzi Mines. A third concentrator plant at Ngezi, with an estimated production capacity of 0.9 Mt/yr, began construction in 2021 and was expected to be commissioned in August 2022 (Zimplats Holdings Ltd., 2021, p. 29, 33–34).

Great Dyke Investments (Pvt) Ltd., a 50–50 joint venture between Vi Holding Group (Russia) and Landela Mining Venture (Pvt) Ltd., began phase 1 of development on the Darwendale platinum deposit in 2020 after acquiring $500 million in funding (Marawanyika, 2020). Kuvima Mining House (Pvt) Ltd., a limited liability company owned by the Government, took over the assets of Landela Mining in June 2021 (Banya, 2021). Operations at the Darwendale project were abandoned in 2021, however, owing to lack of additional capital from Vi Holding and failure to attract new investors. Kuvimba reported, however, that the Darwendale project would continue to develop its mine plan (Njini and others, 2022).

Outlook

Palladium, platinum, and rhodium are used primarily in catalytic converters in automobiles to decrease harmful emissions; therefore, the performance of the gasoline and hybrid automobile industry, which require catalytic converters, will have the greatest effects on future consumption of these PGMs. Ongoing semiconductor chip shortages, which began in 2020 and continued in 2021, may affect automobile manufacturing and thus PGM demand. In addition, environmental regulations on diesel vehicles in Europe and the move toward more electric vehicles globally, particularly in China, are likely to decrease the demand for PGMs in the long term. However, the decrease may be offset by an increase in production of fuel cell electric vehicles, which require more platinum than traditional combustion engines.

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TABLE 1
SALIENT PLATINUM-GROUP METALS STATISTICS[1]

		2017	2018	2019	2020	2021
United States:						
Mine production:[2]						
Palladium, palladium content:						
Quantity	kilograms	14,000 e	14,300	14,300	14,600	13,700
Value	thousands	$380,000 e	$475,000	$711,000	$1,030,000	$1,070,000
Platinum, platinum content:						
Quantity	kilograms	4,000 e	4,160	4,150	4,200	4,020
Value	thousands	$120,000 e	$118,000	$116,000	$120,000	$141,000
Refinery production:[3]						
Palladium, palladium content:						
Quantity	kilograms	42,800 r	63,600 r	59,400 r	66,700 r	92,000
Value	thousands	$1,200,000 r	$2,120,000 r	$2,950,000 r	$4,730,000 r	$7,160,000
Platinum, platinum content:						
Quantity	kilograms	38,100 r	39,500 r	40,600 r	45,100 r	47,400
Value	thousands	$1,160,000 r	$1,120,000 r	$1,130,000 r	$1,280,000 r	$1,670,000
Imports for consumption, refined:						
Iridium, iridium content	kilograms	1,420	1,020	875	1,620	2,310
Osmium, osmium content	do.	856	25	(4)	1	1
Palladium, palladium content	do.	86,000	92,900	84,300	76,400	72,600
Platinum, includes coins, platinum content	do.	53,200	58,500	42,300	64,800	67,800
Rhodium, rhodium content	do.	11,600	14,500	15,000	20,700	16,500
Ruthenium, ruthenium content	do.	14,600	17,900	11,200	13,900	18,000
Waste and scrap, platinum content	do.	354,000	40,700	35,200	188,000	187,000
Exports, refined:						
Iridium, osmium, and ruthenium, gross weight	do.	939	2,500	1,330	1,440	2,120
Palladium, palladium content	do.	52,300	52,900	55,500	48,600	43,900
Platinum, platinum content	do.	16,700	18,900	17,400	28,900	29,400
Rhodium, rhodium content	do.	844	2,010	1,210	1,470	1,340
Waste and scrap, platinum content	do.	37,200	31,700	20,800	33,200	37,600
Stocks, National Defense Stockpile, December 31:						
Iridium, iridium content	do.	15	15	15	15	15
Platinum, platinum content	do.	261	261	261	261	261
Price, average:[5]						
Iridium	dollars per troy ounce	908.62 r	1,293.45 r	1,485.80	1,633.51	5,158.40
Palladium	do.	873.31 r	1,034.04 r	1,544.31	2,205.27	2,419.18
Platinum	do.	951.16 r	882.80 r	866.94	886.02	1,094.31
Rhodium	do.	1,108.48 r	2,222.83 r	3,918.78	11,205.06	20,254.10
Ruthenium	do.	75.81 r	244.44 r	262.59	271.83	576.12
Employment		1,510	1,630	1,790	1,880	1,970
World, mine production, platinum-group metal content[6]	kilograms	458,000	472,000	480,000 r	422,000 r	472,000

eEstimated. rRevised. do. Ditto.
[1]Table includes data available through June 7, 2022. Data are rounded to no more than three significant digits, except prices.
[2]Source: Sibanye-Stillwater investor reports. Data for 2017 were partially estimated for the months prior to Sibanye Gold Ltd.'s acquisition of Stillwater Mining Co. in May 2017.
[3]Data sourced from publicly available reports. Iridium, rhodium, and ruthenium were recovered as well, but data were withheld to avoid disclosing company proprietary data.
[4]Less than ½ unit.
[5]Source: S&P Global Platts Metals Daily. Price data are annual averages of daily Engelhard unfabricated quotations.
[6]May include estimated data.

TABLE 2
U.S. IMPORTS FOR CONSUMPTION OF PLATINUM, BY COUNTRY OR LOCALITY[1]

Country or locality	Grain and nuggets		Sponge		Other unwrought		Semimanufactured forms		Coins	
	Quantity, Pt content[2] (kilograms)	Value (thousands)	Quantity, Pt content[2] (kilograms)	Value (thousands)	Quantity, Pt content[2] (kilograms)	Value (thousands)	Quantity, Pt content[2] (kilograms)	Value (thousands)	Quantity, Pt content[2] (kilograms)	Value (thousands)
2020	162	$4,780	30,900	$874,000	5,370	$255,000	25,900	$853,000	2,510	$75,300
2021:										
Argentina	--	--	--	--	25	2,290	--	--	--	--
Australia	--	--	--	--	2	130	1	37	733	23,900
Austria	--	--	--	--	(3)	10	236	17,200	161	5,970
Belgium	--	--	6,470	231,000	--	--	7	90	--	--
Canada	236	8,360	--	--	1	33	586	21,600	363	14,100
China	--	--	--	--	--	--	(3)	8	4	129
Colombia	11	322	--	--	529	18,000	--	--	--	--
Costa Rica	--	--	--	--	1	356	947	35,000	--	--
Czechia	--	--	--	--	--	--	42	1,880	--	--
France	--	--	75	2,460	--	--	194	5,560	(3)	6
Germany	100	3,190	3,240	118,000	952	37,000	3,470	222,000	29	919
Hong Kong	1	53	64	2,190	25	889	(3)	3	--	--
India	--	--	31	1,020	--	--	--	--	--	--
Ireland	--	--	--	--	1	68	5	115	--	--
Italy	--	--	5,430	198,000	(3)	11	33	1,340	--	--
Japan	3	119	121	4,280	566	23,000	185	5,980	--	--
Korea, Republic of	--	--	298	9,620	--	--	--	--	1	8
Mexico	4	115	--	--	--	--	5	192	1	10
Portugal	--	--	--	--	--	--	(3)	19	1	27
Russia	--	--	1,620	57,900	104	3,300	78	3,210	--	--
Singapore	--	--	--	--	508	52,200	157	6,260	--	--
South Africa	--	--	26,400	940,000	406	24,000	19	608	8	201
Switzerland	195	7,430	636	22,000	2,050	76,600	4,570	170,000	56	2,220
Taiwan	--	--	--	--	--	--	1,560	31,400	--	--
United Kingdom	39	1,260	322	11,900	232	8,720	3,690	139,000	45	1,600
Other	--	--	--	--	(3)	6	1	34	2	80
Total	590	20,800	44,700	1,600,000	5,400	247,000	15,800	662,000	1,400	49,200

-- Zero.
[1]Table includes data available through May 24, 2022. Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Platinum is abbreviated Pt.
[3]Less than ½ unit.

Source: U.S. Census Bureau.

TABLE 3
U.S. IMPORTS FOR CONSUMPTION OF PLATINUM-GROUP METALS, BY COUNTRY OR LOCALITY[1]

	Palladium[2]		Iridium[2]		Osmium[2]		Ruthenium[2]		Rhodium[2]		Waste and scrap	
Country or locality	Quantity, Pd content (kilograms)	Value (thousands)	Quantity, Pd content (kilograms)	Value (thousands)	Quantity, Pd content (kilograms)	Value (thousands)	Quantity, Pd content (kilograms)	Value (thousands)	Quantity, Pd content (kilograms)	Value (thousands)	Quantity, Pd content (kilograms)	Value (thousands)
2020	76,400	$4,490,000	1,620	$70,100	1	$17	13,900	$117,000	20,700	$4,590,000	188,000	$1,500,000
2021:												
Australia	--	--	--	--	--	--	--	--	--	--	467	20,900
Belgium	7,710	386,000	--	--	--	--	--	--	1,440	892,000	34	3,310
Brazil	--	--	--	--	--	--	--	--	--	--	4,310	69,600
Canada	4,520	361,000	--	--	--	--	--	--	39	1,050	14,300	455,000
Colombia	--	--	--	--	--	--	--	--	--	--	185	6,320
Egypt	--	--	--	--	--	--	--	--	--	--	304	11,000
France	(3)	24	--	--	--	--	--	--	--	--	655	20,900
Germany	2,220	174,000	206	29,000	--	--	3,500	57,300	3,440	2,360,000	25,400	477,000
Guatemala	--	--	--	--	--	--	--	--	--	--	124	4,090
Hungary	--	--	--	--	--	--	--	--	--	--	308	22,300
India	--	--	--	--	--	--	--	--	36	31,200	143	12,200
Italy	4,400	264,000	46	4,260	--	--	2,560	24,100	2,040	513,000	2,780	93,900
Japan	743	40,500	165	18,000	--	--	91	1,590	12	5,970	4,340	141,000
Korea, Republic of	3,740	295,000	--	--	--	--	--	--	387	278,000	33	2,490
Malaysia	--	--	--	--	--	--	--	--	--	--	466	15,300
Mexico	51	1,950	--	--	--	--	--	--	--	--	16,900	521,000
New Zealand	--	--	--	--	--	--	--	--	--	--	699	22,000
Nigeria	--	--	--	--	--	--	--	--	--	--	743	24,200
Norway	65	10,200	--	--	--	--	--	--	27	20,800	39	1,260
Poland	--	--	--	--	--	--	--	--	--	--	374	18,700
Portugal	--	--	--	--	--	--	--	--	--	--	324	10,900
Russia	21,900	1,690,000	118	18,000	--	--	398	9,570	1,150	673,000	--	--
Saudi Arabia	--	--	--	--	--	--	--	--	8	6,820	1,090	41,300
Singapore	--	--	--	--	--	--	--	--	19	12,900	194	10,900
South Africa	23,300	1,870,000	1,270	170,000	--	--	8,510	113,000	7,070	4,550,000	463	25,200
Switzerland	3,420	263,000	--	--	--	--	--	--	21	18,200	--	--
Taiwan	(3)	6	--	--	--	--	--	--	--	--	25,300	16,300
Thailand	--	--	--	--	--	--	--	--	(3)	8	744	32,000
United Arab Emirates	--	--	--	--	--	--	--	--	--	--	2,880	93,900
United Kingdom	379	29,800	498	46,600	--	--	2,920	40,600	806	490,000	82,600	179,000
Other	111	6,870	1	73	1	17	2	22	10	1,140	1,050	28,900
Total	72,600	5,390,000	2,310	285,000	1	17	18,000	247,000	16,500	9,850,000	187,000	2,380,000

-- Zero.

[1]Table includes data available through May 24, 2022. Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Unwrought and other forms. Palladium is abbreviated Pd; iridium, Ir; osmium, Os; ruthenium, Ru; rhodium, Rh; and platinum, Pt.

[3]Less than ½ unit.

Source: U.S. Census Bureau.

TABLE 4
U.S. EXPORTS OF PLATINUM-GROUP METALS, BY COUNTRY OR LOCALITY[1]

Country or locality	Palladium[2]		Platinum[2]		Iridium, osmium, ruthenium[2]		Rhodium[2]		Waste and scrap	
	Quantity, Pd content (kilograms)	Value (thousands)	Quantity, Pd content (kilograms)	Value (thousands)	Quantity, Pd content (kilograms)	Value (thousands)	Quantity, Pd content (kilograms)	Value (thousands)	Quantity, Pd content (kilograms)	Value (thousands)
2020	48,600	$2,900,000	28,900	$930,000	1,440	$24,900	1,470	$426,000	33,200	$1,400,000
2021:										
Australia	27	2,030	178	4,520	129	2,670	--	--	(3)	17
Austria	(3)	10	20	989	1	12	--	--	2	74
Belarus	5	398	--	--	--	--	--	--	--	--
Belgium	710	52,700	342	11,700	5	53	89	49,600	2,670	98,800
Brazil	550	41,800	254	7,890	--	--	(3)	24	--	--
Canada	4,640	393,000	1,170	49,000	1	23	13	7,760	195	8,680
China	157	10,900	325	9,550	97	2,340	18	8,240	1	19
Costa Rica	43	3,460	614	14,500	18	327	--	--	2	70
Czechia	3	244	--	--	--	--	--	--	19	761
Eswatini	--	--	--	--	--	--	--	--	25	877
France	72	5,790	83	2,370	32	433	--	--	--	--
Germany	6,870	560,000	3,720	149,000	578	14,100	169	109,000	12,600	1,420,000
Hong Kong	328	24,400	753	25,000	585	12,000	148	99,900	97	3,850
India	295	24,800	476	17,000	32	520	1	499	--	--
Indonesia	7	527	--	--	--	--	--	--	--	--
Ireland	22	1,990	393	12,600	4	32	--	--	(3)	3
Israel	277	21,200	8	248	--	--	--	--	--	--
Italy	8,410	694,000	1,430	51,900	78	3,390	1	197	186	5,590
Japan	2,750	238,000	1,550	60,600	192	11,300	42	5,460	10,700	745,000
Jordan	--	--	--	--	--	--	--	--	16	468
Korea, Republic of	1,300	102,000	1,470	91,200	1	12	253	152,000	72	2,750
Laos	--	--	14	500	--	--	--	--	--	--
Malaysia	1	46	2	58	3	57	--	--	2	71
Mexico	54	4,200	2,620	107,000	3	52	--	--	--	--
Netherlands	251	22,000	4	110	3	135	9	5,290	--	--
New Zealand	10	757	6	166	--	--	(3)	37	--	--
Norway	1	60	135	6,320	--	--	1	966	--	--
Poland	2	104	3	107	--	--	--	--	--	--
Russia	--	--	91	7,990	--	--	--	--	69	2,990
Singapore	9	693	1,280	44,600	(3)	3	6	4,010	--	--
South Africa	(3)	7	770	26,900	--	--	367	239,000	1,430	63,400
Spain	1	49	2	68	--	--	--	--	5	169
Sweden	(3)	25	1	27	--	--	--	--	277	10,100
Switzerland	9,290	585,000	6,900	235,000	73	2,870	11	8,500	450	16,500
Taiwan	1,430	116,000	159	6,800	162	1,530	--	--	--	--
Thailand	36	2,780	67	2,090	6	126	--	--	(3)	18
United Arab Emirates	(3)	7	299	9,600	4	118	--	--	232	8,200
United Kingdom	6,340	463,000	4,180	157,000	109	2,220	209	113,000	8,480	971,000
Uruguay	--	--	2	95	1	5	--	--	39	2,820
Vietnam	(3)	20	40	1,600	--	--	--	--	--	--
Other	18	1,430	22	696	6	199	(3)	18	1	29
Total	43,900	3,370,000	29,400	1,110,000	2,120	54,400	1,340	803,000	37,600	3,360,000

-- Zero.

[1]Table includes data available through May 24, 2022. Data are rounded to no more than three significant digits; may not add to totals shown.

[2]Palladium is abbreviated Pd; iridium, Ir; osmium, Os; ruthenium, Ru; and rhodium, Rh.

[3]Less than ½ unit.

Source: U.S. Census Bureau.

TABLE 5
PLATINUM-GROUP METALS: WORLD MINE PRODUCTION, BY COUNTRY OR LOCALITY[1, 2]

(Kilograms, platinum-group metal content)

Country or locality[3]	2017	2018	2019	2020	2021
Palladium:					
Australia[e, 4]	600	420	380	410	350
Canada[e]	19,000	21,000	23,000 r	14,000 r	15,000
China	1,400	1,300	1,300	1,300 e	1,000 e
Finland	1,021	1,157	699	858	1,036
Russia[e]	88,000	90,000	98,000	93,000	86,000
Serbia	38	55	100 e	100 e	150 e
South Africa	80,713	80,629	80,684	66,264 r	84,336
United States[4]	14,000 e	14,300	14,300	14,600	13,700
Zimbabwe	11,822	12,094	11,640 r	12,890	12,398
Total	217,000	221,000	230,000 r	203,000 r	214,000
Platinum:					
Australia[e, 4]	170	120	110	110	100
Canada[e]	7,600	7,600	8,500 r	5,300 r	6,000
China	2,500	2,500	2,500	2,500 e	2,300 e
Colombia	567 r	270 r	178 r	414 r	400 e
Ethiopia[e]	4	4	2	2	4
Finland	1,418	1,576	953	1,277	1,447
Russia[e]	22,000	22,000	24,000	23,000	21,000
Serbia	2	5	10 e	20 e	20 e
South Africa	132,500	137,053	132,989	111,993	141,626
United States[4]	4,000 e	4,160	4,150	4,200	4,020
Zimbabwe	14,257	14,703	13,857	15,005	14,732
Total	185,000	190,000	187,000 r	164,000 r	192,000
Iridium:					
Canada[e]	200	400	400 r	-- r	--
Russia[e]	300	200	300	250	230
South Africa	6,057	6,357	6,464	6,186 r	7,006
Zimbabwe	619	586	845	836	641
Total	7,180	7,540	8,010 r	7,270 r	7,880
Rhodium:					
Canada[e]	60	300	800 r	700 r	500
Russia	2,115	1,928	2,426	1,804	1,648
South Africa	18,665	18,608	19,545	16,972 r	20,875
Zimbabwe	1,283	1,334	1,224	1,368	1,334
Total	22,100	22,200	24,000 r	20,800 r	24,400
Ruthenium:					
Canada[e]	500	700	500	-- r	--
Russia[e]	1,000	1,300	1,300	1,000	1,000
South Africa	24,821	27,999	28,386	25,058 r	31,463
Zimbabwe	1,102	1,155	792	1,026	1,278
Total	27,400	31,200	31,000	27,100 r	33,700
Grand total	458,000	472,000	480,000 r	422,000 r	472,000

[e]Estimated. [r]Revised. -- Zero.

[1]Table includes data available through June 6, 2022. All data are reported unless otherwise noted; totals may include estimated data. Totals, U.S. data, and estimated data are rounded to no more than three significant digits; may not add to totals shown.

[2]Platinum-group metal (PGM) mine production only. Does not include refinery production.

[3]In addition to the countries and (or) localities listed, Indonesia and the Philippines may have produced limited quantities of PGMs, but available information was inadequate to make reliable estimates of output.

[4]Byproduct platinum and palladium produced from gold-copper and nickel ores are excluded.

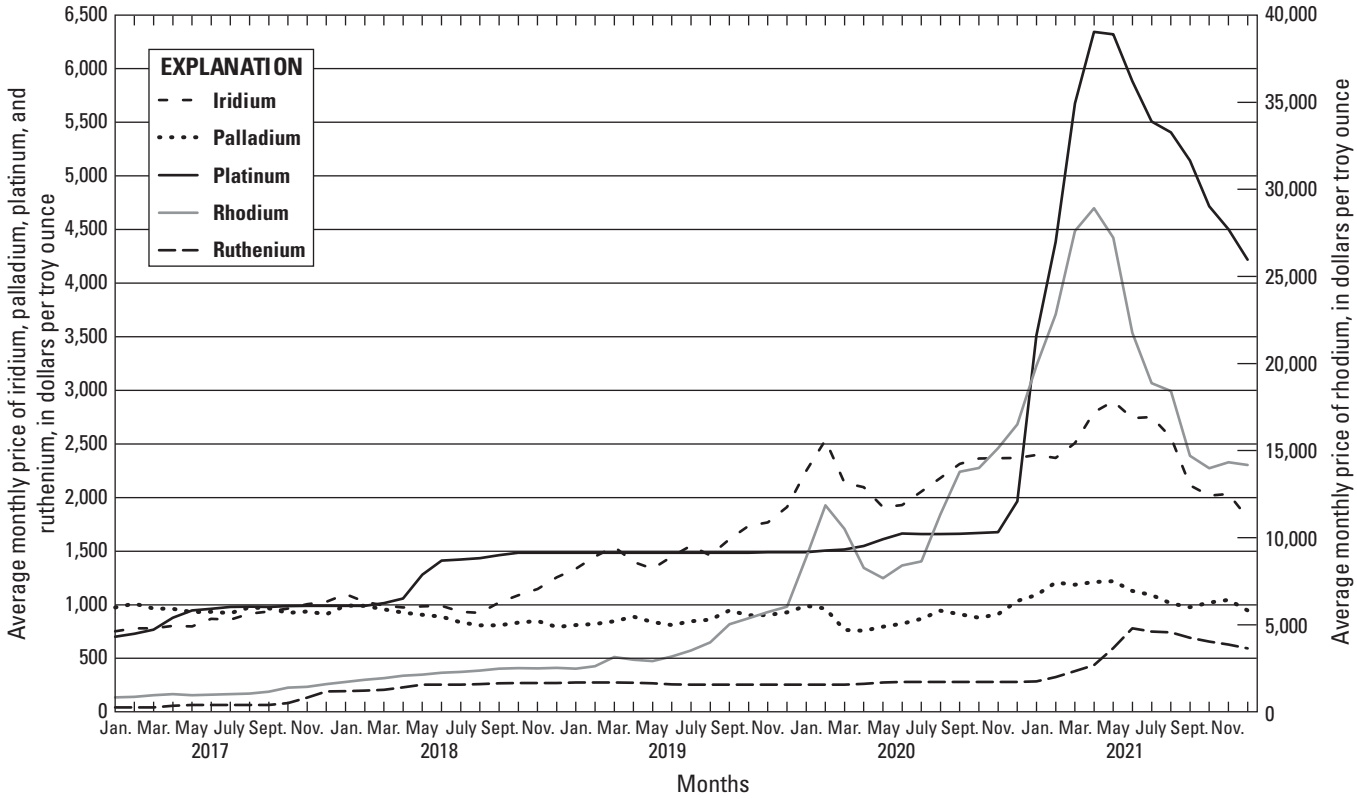

Figure 1. Engelhard unfabricated average monthly prices for the platinum-group metals (iridium, palladium, platinum, rhodium, and ruthenium), 2017–21. Source: S&P Global Platts Metals Week.