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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 mining.

In 2020, the United States ranked fourth in the world in the production of palladium and 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 and platinum was 14,600 kilograms (kg) and 4,200 kg, respectively, each slightly higher than that in 2019 (table 1). Recycling was also a significant source of PGMs, accounting for 31% of the total global supply of palladium, platinum, and rhodium in 2020 (Cowley, 2021, p. 15, 22, 27).

In 2020, the automobile industry continued to be the leading consumer of PGMs. Catalytic converters accounted for approximately 93% of global primary rhodium consumption, 85% of primary palladium consumption, and 31% of primary platinum consumption (Cowley, 2021, p. 15, 22, 27). The annual average prices for PGMs increased in 2020 compared with those in 2019—the price for rhodium nearly tripled; prices increased by 43% for palladium, by 10% for iridium, and by 4% for ruthenium; and the platinum price increased slightly (fig. 1, table 1). In 2020, excluding waste and scrap, imports of PGMs increased by 15% and exports increased by 6%. Note that U.S. exports of iridium, osmium, and ruthenium are reported together in gross weight because exports of those PGMs are not reported separately by the U.S. Census Bureau (table 1). World mine production of PGMs totaled 443,000 kg, a 7% decrease compared with the revised total in 2019. Most of the world's mine supply of PGMs was produced in South Africa and Russia, which accounted for 54% and 27%, respectively, of global PGM mine production (table 5).

Legislation and Government Programs

The Defense Logistics Agency Strategic Materials, U.S. Department of Defense, announced the potential disposal of PGM materials under its fiscal year 2020 (October 1, 2019, through September 30, 2020) Annual Materials Plan (AMP). Maximum disposal limits in the 2020 AMP for PGM materials were set at 261 kg of platinum and 15 kg of iridium (Defense Logistics Agency Strategic Materials, 2019). At yearend, the National Defense Stockpile contained 261 kg of platinum, 15 kg of iridium, and less than 1 kg each of palladium and palladium-cobalt wire.

Production

Mine.—During 2020, U.S. palladium and platinum mine production was 14,600 kg and 4,200 kg, respectively. Compared with that in 2019, production of palladium and platinum was slightly higher for each (table 1).

Sibanye-Stillwater Ltd. produced PGMs from two mines in the United States, the Stillwater Mine and the East Boulder Mine in Montana. In 2020, the Stillwater Mine produced 11,600 kg of PGMs, and the East Boulder Mine produced 7,140 kg of PGMs. Sibanye-Stillwater processed 1.49 million metric tons (Mt) of ore from the mines with a combined mill-head grade of 14 grams per metric ton PGMs and a PGM mill recovery rate of 90% (Sibanye-Stillwater Ltd., 2021a, p. 171, 173–174). The concentrates from the mines were smelted and then processed at the base-metals 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 2020, Sibanye-Stillwater reported proven and probable reserves at its Montana mines of 58.2 Mt of ore with a palladium-to-platinum ratio ranging from 3.4:1 to 3.6:1 and about 837,000 kg of contained palladium and platinum. These reserves are contained in the J-M Reef, an ore body within the layered mafic and ultramafic igneous rocks of the Stillwater Complex. Production continued from the Blitz development project, a mine expansion project adjacent to the Stillwater Mine, producing about 3,100 kilograms per year (kg/yr) of PGMs. Full production from the Blitz project was delayed until 2024 owing to water inflow in the Benbow section and disruptions related to the global coronavirus disease 2019 (COVID-19) pandemic. Capacity was expected to be about 9,300 kg/yr of PGMs when fully operational (Sibanye-Stillwater Ltd., 2021a, p. 5, 22, 170-171; 2021b, p. 13, 27, 30).

Sibanye-Stillwater also reported that the expansion project at the East Boulder Mine, known as Fill the Mill, was completed in 2020, 1 year ahead of schedule. The project reached the full production rate of approximately 1,200 kg/yr of PGMs in December. Continued resource-definition drilling identified an additional 180,000 kg of PGM mineral reserves at the East Boulder Mine, which increased total mineral reserves by 7% from those reported in 2019 (Sibanye-Stillwater Ltd., 2020a, p. 32; 2021a, p. 170, 286).

In 2020, two PGM exploration projects in the Duluth Complex of Minnesota continued to progress toward development. At the end of 2019, Twin Metals Minnesota, LLC, a subsidiary of Antofagasta PLC (United Kingdom),

submitted a Mine Plan of Operations to the Bureau of Land Management (BLM) and a Scoping Environmental Assessment Worksheet Data Submittal to the Minnesota Department of Natural Resources (MDNR). The Twin Metals project, planned as an underground mine, included three deposits in close proximity—the Birch Lake, Maturi, and Spruce Road deposits. In submitting a Mine Plan of Operations, Twin Metals began a multiyear scoping and environmental review process for the construction of an underground cobalt, copper, nickel, and PGM mine in Minnesota (Twin Metals Minnesota, LLC, 2019). In March 2020, the U.S. District Court upheld the 2017 reinstatement of two hard-rock mineral leases in the Superior National Forest in northeastern Minnesota after legal challenges by environmental groups (Twin Metals Minnesota, LLC, 2020b). In June, the BLM issued a notice of intent to Twin Metals, informing the company that the BLM would assess and prepare an environmental impact statement for its proposed mine under the National Environmental Policy Act (Twin Metals Minnesota LLC, 2020a).

In November 2018, PolyMet Mining Corp. (Canada) received a Permit to Mine from the MDNR for its NorthMet copper-nickel-PGM project in the Duluth Complex. The MDNR permits also included dam safety, water use agreements, endangered and threatened species takings, public water work permits, and Wetland Conservation Act approval. In December 2018, the Minnesota Pollution Control Agency (MPCA) granted PolyMet water quality and air emission permits and Section 401 Certification under the Clean Water Act. In March 2019, PolyMet announced that it had received a wetlands permit from the U.S. Army Corps of Engineers. The wetlands permit was the last permit required to construct and operate the NorthMet project. After legal challenges were filed in 2019 and early 2020, PolyMet petitioned the Minnesota Supreme Court in February 2020 to review lower court decisions regarding the Permit to Mine, dam safety permits, and air permit that had been remanded to the MDNR and MPCA. Rulings were expected by June 2021 (PolyMet Mining Corp., 2020a, p. 4; 2020b, c).

Refinery.—The U.S. Geological Survey canvassed domestic precious metals refinery producers on an annual basis. Of the 22 companies that were surveyed in 2020 for commercial-grade PGM refinery production, 7 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, production was likely underestimated.

Based on these data, U.S. palladium and platinum refinery production during 2020 was 63,000 kg and 32,600 kg, respectively. Compared with that in 2019, this represented increases of 41% for palladium and 20% for platinum (table 1).

Recycling.—In 2020, PGMs were recycled from three main sources—catalytic converters, electronics, and jewelry. Globally, almost 161,000 kg of secondary PGMs were recovered, accounting for approximately 31% of the global supply of PGMs. Recycled catalytic converters were the predominant source of secondary PGMs (Cowley, 2021, p. 15, 22, 27). Based on industry information and previously reported data, an estimated 39,100 kg of PGMs was theoretically available for recovery from catalytic converters in the United States, accounting for about 42% of the world total catalytic converter supply (CPM Group, 2019, p. 180; 2020, p. 28, 121).

Sibanye-Stillwater Ltd. reported that it recovered 26,100 kg of PGMs from spent catalytic converters and other industrial sources at its U.S. metallurgical complex in Montana in 2020. Of the total recycled, Sibanye-Stillwater Ltd. toll-refined 3,110 kg of PGMs. In 2020, Sibanye-Stillwater Ltd. sold 21,000 kg of secondary PGMs (Sibanye-Stillwater Ltd., 2021a, p. 171).

Consumption

PGMs are consumed in a variety of industries in the United States, and often different PGMs are used together in the same applications. Owing to similar atomic structures and chemistries, PGMs 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 are 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 are used in catalytic converters to facilitate the conversion of harmful exhaust emissions, such as carbon monoxide, hydrocarbons, and nitrogen oxides. Palladium, platinum, and rhodium comprise 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 is used as an oxidation catalyst, and rhodium is 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 are used in the chemical and petroleum industries. In the chemical industry, platinum and rhodium catalyze the reaction that generates nitric acid, which is 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 is 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 include hard-drive disks, multilayer ceramic capacitors, plasma-display panels, and semiconductor thermocouples. Iridium is used specifically as a crucible material for the production of high-quality single oxide crystals. Owing to their resistance to chemical corrosion and degradation at high temperatures, platinum and rhodium are used in glassmaking primarily for manufacture of liquid-crystal displays. Because of biocompatibility and nonreactivity of the metals with organic tissue, PGMs are used in dental and medical devices and 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 2020, domestic palladium apparent consumption (defined as primary mine production plus secondary production from spent auto catalysts plus imports minus exports, excluding imports and exports of waste and scrap) was 71,900 kg, a 15% increase from that in 2019. The leading end use for palladium in 2020 was in the production of

automobile catalytic converters, which accounted for 66% of consumption in North America. Other uses, including chemical and petroleum catalysts, electronics, dental, and jewelry, accounted for the remaining 34% (CPM Group, 2020, p. 127).

Platinum.—In 2020, domestic platinum apparent consumption (defined as mine production plus recycling from spent auto catalysts plus imports minus exports) was 46,600 kg, an increase of 27% compared with apparent consumption in 2019. The leading end uses for platinum in 2020 were in the production of catalytic converters and in chemical and petroleum refining, which accounted for 62% and 11% of consumption in the United States, respectively. Other uses accounted for 27% and included dental and medical devices, electronics, and jewelry (CPM Group, 2020, p. 33).

Other PGMs.—In 2020, adequate data were not available to determine the apparent consumption of iridium, osmium, rhodium, or ruthenium.

Prices

According to S&P Global Platts Metals Week, in 2020, the Engelhard unfabricated annual average price for rhodium nearly tripled and the average annual average prices for iridium, palladium, and ruthenium increased by 10%, 43%, and 4%, respectively. The annual average prices for platinum increased slightly compared with the annual average price in 2019 (table 1). Figure 1 illustrates the average monthly prices from 2016 through 2020.

Iridium.—The annual average iridium price in 2020 was $1,634 per troy ounce, which was 10% greater than that in 2019. The iridium price began the year at $1,490 per troy ounce and ended the year at $2,600 per troy ounce. The average annual price increase for iridium in 2020 was primarily attributed to two factors: (1) an increased use of iridium crucibles to produce lithium tantalite in fifth-generation (5G) smartphones and (2) an increased use of iridium and ruthenium oxide-coated cathodes to disinfect seawater in ship ballast water treatment systems through electro-chlorination. Ballast water management legislation—known as the International Convention for the Control and Management of Ships' Ballast Water and Sediments—was enacted by the International Maritime Organization in 2017 and required all ships to install approved ballast water treatment systems by September 2024 (Heraeus Precious Metals GmbH & Co. KG, 2020a, p. 10; International Maritime Organization, undated).

Palladium.—The annual average palladium price in 2020 was $2,205 per troy ounce, which was 43% greater than that in 2019. The palladium price began 2020 at $1,952 per troy ounce and fluctuated throughout the year with a general upward trend, ending the year at $2,440 per troy ounce. The price increase was attributed to a continued supply deficit from previous years and additional decreases in mine production resulting from COVID-19 pandemic-related restrictions worldwide (CPM Group, 2020, p. 107; 2021, p. 110; Heraeus Precious Metals GmbH & Co. KG, 2020b, p. 53–54).

Platinum.—In 2020, the annual average platinum price was $886 per troy ounce, which was slightly more than the annual average price in 2019. The spot-market price of platinum began the year at $990 per troy ounce and fluctuated throughout the year, ending the year at $1,085 per troy ounce.

Rhodium.—The annual average rhodium price in 2020 was $11,205 per troy ounce, which was nearly three times that in 2019. The rhodium spot-market price began the year at $6,100 per troy ounce and generally trended upward until March when prices began to fluctuate until the end of June, after which prices began to steadily increase, ending the year at a record high of $17,150 per troy ounce. The price increase for rhodium in 2020 was attributed to limited availability of refined rhodium and increased demand for rhodium in the automotive sector, where rhodium was used to achieve higher fuel efficiency standards (Heraeus Precious Metals GmbH & Co. KG, 2020a, p. 8).

Ruthenium.—The annual average ruthenium price in 2020 was $272 per troy ounce, which was 4% greater than that in 2019. The ruthenium spot-market price began the year at $255 per troy ounce and increased gradually to $280 per troy ounce by yearend. The overall increase in the spot-market price for ruthenium in 2020 was primarily the result of a decrease in mine production in South Africa, which accounted for 92% of the ruthenium supply in 2020 (table 5; Heraeus Precious Metals GmbH & Co. KG, 2020a, p. 9; 2021, p. 35–36).

Foreign Trade

In 2020, imports for consumption of palladium, excluding waste and scrap, decreased by 9% to 76,400 kg from 84,300 kg in 2019. The imports were sourced predominantly from Russia (31%), South Africa (27%), and Italy (17%). In 2020, imports for consumption of platinum, excluding waste and scrap, increased by 53% to 64,800 kg from 42,300 kg in 2019. The leading sources of platinum imports were Switzerland (29%), South Africa (24%), and Germany (14%). Imports for consumption of rhodium increased by 38% to 20,700 kg from 15,000 kg in 2019. The leading sources of rhodium imports were South Africa (36%), Italy (31%), and Germany (16%). Combined imports of iridium, osmium, and ruthenium increased by 29% to 15,600 kg. Leading import sources for iridium, osmium, and ruthenium in 2020 were South Africa (51%), Germany (20%), and the United Kingdom (18%) (tables 1–3).

In 2020, exports of palladium, excluding waste and scrap, totaled 48,600 kg, a 12% decrease from exports in 2019. Exports of platinum, excluding and waste and scrap, totaled 28,900 kg, an increase of 65% compared with exports in 2019. Exports of PGM waste and scrap, rhodium, and combined exports of iridium, osmium, and ruthenium increased by 60%, 21%, and 8%, respectively, compared with exports in 2019 (tables 1, 4).

World Review

In 2020, world mine production of PGMs decreased by 7% to 443,000 kg from 476,000 kg (revised) in 2019 (table 5). South Africa accounted for the largest share of total PGM mine production, accounting for 54% of global production, followed by Russia, 27%; Zimbabwe, 7%; Canada, 6%; the United States, 4%; and other countries, 2%. Global mine production of palladium decreased by 5% to 217,000 kg; Russia accounted for 43%; South Africa, 34%; Canada, 9%; the

United States, 7%; and Zimbabwe, 6%. In 2020, world platinum mine production decreased by 11% to 166,000 kg; South Africa accounted for 68%; Russia, 14%; Zimbabwe, 9%; Canada, 4%; the United States, 3%; and other countries, 2%. World mine production of other PGMs (iridium, rhodium, and ruthenium) decreased by 3% in 2020 compared with that in 2019, and South Africa accounted for 88% of global production.

Canada.—Production at Impala Canada Ltd. was negatively affected by the global COVID-19 pandemic. The Lac des Iles PGM mine camp was placed on care-and-maintenance status for 6 weeks following an outbreak of the virus. Travel limitations and staffing shortages after the outbreak also limited production (Impala Platinum Holdings Ltd, 2021, p. 91, 155).

Generation Mining Ltd. completed a preliminary economic assessment for the Marathon Palladium-Copper Project in Ontario, enabling the company to earn an 80% interest in the project. Generation Mining had acquired a 51% interest in the project from Sibanye-Stillwater Ltd. in 2019 with the option to increase its interest to 80% by completing the assessment and other conditions, which were met (Generation Mining Ltd., 2020).

Mineworx Technologies Ltd. signed a letter of intent with EnviroLeach Technologies Inc. to use EnviroLeach Technologies' process to recover PGMs from catalytic converters. Mineworx Technologies agreed to fund further development of EnviroLeach Technologies' PGM recovery research (Mineworx Technologies Ltd., 2020).

Platinum Group Metals Ltd. and Lion Battery Technologies Inc. announced that a patent was issued to Florida International University by the United States Patent and Trademark Office for battery technology that uses PGMs to enhance lithium battery performance. The funding for the research and patent was provided by Lion Battery Technologies Inc., a joint venture between Platinum Group Metals Ltd. and Anglo American Platinum Ltd. (South Africa), as part of a 3-year and $3 million sponsored agreement with Florida International University. Increased popularity of electric vehicles (EVs) could contribute to declining demand for PGM catalysts in conventional vehicles and even in petroleum refining for automotive fuels. However, the use of PGMs in EV batteries could create new demand for PGMs used in automobiles (Evans, 2020; Platinum Group Metals Ltd., 2020a).

Russia.—In 2020, MMC Norilsk Nickel PJSC (Nornickel) announced that it made 3,000 kg of palladium ingots available from its stocks to temporarily increase the supply of palladium in the market. The release of palladium was related to power outages in South Africa that disrupted production and hit the market at a time when supply was already tight from increased demand related to more stringent environmental regulations in the automotive sector (Thomson Reuters Corp., 2020).

Nornickel signed an operational agreement with Russian Platinum Co. to continue developing the copper, nickel, and PGM deposits in the Chernogorskoye field near the city of Norilsk in Siberia. The agreement stipulated that Nornickel would provide Russian Platinum access to infrastructure available in the Norilsk Industrial District through long-term contracts, including electricity and transportation. Russian Platinum agreed to sell Nornickel ore from the Chernogorskoye deposit through a separate long-term offtake agreement (PJSC MMC Norilsk Nickel, 2020b). PGM-containing ore from Nornickel's Polar Division was concentrated at the Talnakh Concentrator, which underwent preparatory work in 2019 for Stage 3 upgrades. Plans for Stage 3 upgrades included new concentration technology, which would increase throughput ore-processing capacity from 10 million metric tons per year (Mt/yr) to 18 Mt/yr. Stage 1 and Stage 2 upgrades were completed in 2015 and 2018, respectively (PJSC MMC Norilsk Nickel, 2020a, p. 37).

South Africa.—The President of South Africa announced a nationwide 21-day lockdown beginning on March 26 to slow the spread of the COVID-19 pandemic. As a result, many mining operations and processing plants suspended operations, including those of Sibanye-Stillwater Ltd. (Sibanye-Stillwater Ltd., 2020b). In response, Sibanye-Stillwater Ltd., Anglo American Platinum Ltd. (Anglo), and Impala Platinum Holdings Ltd. (Implats) declared force majeure owing to their inability to supply customers during the lockdown (Heiberg and Shabalala, 2020). By declaring force majeure, the companies were not penalized when they were unable to meet the terms of contracts.

In mid-April, mines in South Africa were given permission by the Government to resume operations at up to 50% of capacity. The easing of restrictions was in response to considerations including the potential instability of deep mines if left unmonitored, such as those that are nearly 4 kilometers (km) below ground, as are many PGM mines. To resume operation, companies were required to screen employees for COVID-19 symptoms and provide quarantine facilities as well as travel arrangements when necessary (CRU Group, 2020).

In response to the easing of pandemic-related restrictions, Implats announced plans to gradually restart operations at its Rustenburg and Marula PGM mines (Impala Platinum Holdings Ltd., 2020a, p. 2). Jubilee Metals Group Plc (United Kingdom) also announced that it would resume mining operations in accordance with the revised pandemic-related lockdown guidelines at its Inyoni surface PGM and chrome operation as well as its Windsor joint-venture PGM operation (Jubilee Metals Group Plc, 2020b). Underground operations at Sibanye-Stillwater Ltd.'s South African gold and PGM mining operations also restarted in accordance with guidelines from the Government of South Africa (Sibanye-Stillwater Ltd., 2020a, c).

In May, however, Implats reported the temporary suspension of operations at its Marula Mine in Limpopo Province following a cluster of positive COVID-19 cases. All individuals with positive test results were secluded at the mine's isolation site, in Government-approved facilities, or at home in accordance with Government protocols (Impala Platinum Holdings Ltd., 2020b). Implats also gave formal notice to Platinum Group Metals Ltd. (Canada) that it would not acquire additional interest in the Waterberg JV Resources Pty Ltd. project, citing economic uncertainty caused by the global COVID-19 pandemic. Impala retained its 15% vested interest in the joint venture and agreed to discuss future offtake arrangements for the project (Platinum Group Metals Ltd., 2020b).

In early March, Anglo declared force majeure owing to the temporary shutdown of the Anglo Converter Plant (ACP) at its Waterval smelter in Rustenburg, South Africa. The ACP was closed following an explosion in Phase A of the converter

plant in February 2020 and discovery of water in the Phase B unit. In May, Anglo announced the completion of repairs to the Phase B unit of the ACP. In June, however, Anglo announced another temporary closure of the ACP Phase B unit owing to a water leak in the high-pressure cooling section. The company reported that the water leak was unrelated to repair work that was completed on the Phase B unit in early May. As a result, the previously declared force majeure for concentrate deliveries would be in effect until May 12, whereas the force majeure for refined metal customers would remain until PGM refining resumed normal operations (Anglo American Platinum Ltd., 2020a, c, e).

In November, Anglo shut down the ACP Phase B unit for a full rebuild rather than for repairs. The decision for the full rebuild came after a full assessment of the plant and the discovery of additional water leaks, and the rebuild was scheduled for 2021 (Anglo American Platinum Ltd., 2020b). Repairs to the Phase A unit were completed ahead of schedule in December 2020. As a result, an increase in work-in-progress orders was expected, and the company revised its 2020 refined production and sales guidance to between 81,000 kg and 84,000 kg of PGMs (Anglo American Platinum Ltd., 2020d).

Jubilee Metals Group announced the completion of a processing agreement with an undisclosed company to recommission and operate its chromium beneficiation plant associated with its Inyoni operations in South Africa. The agreement guaranteed the supply of 40,000 metric tons per month (t/mo) of chromium and PGM run-of-mine ore. An option to increase to 75,000 t/mo was included in the agreement. Additional processing of the plant's PGM tailings would take place at the Inyoni PGM recovery plant (Jubilee Metals Group Plc, 2020a).

United Kingdom.—Johnson Matthey Plc reported temporarily curtailing the intake of new PGM material into its PGM refineries in the United Kingdom and a decrease in production capacity in response to the global COVID-19 pandemic. The company also reported that it made improvements to its furnace burner at its Brimsdown PGM refinery in the United Kingdom. These efforts enabled the company to streamline its refining processes and reduce backlogs (Johnson Matthey Plc, 2020, p. 10, 99; 2021, p. 18, 68).

Zimbabwe.—Although the Government of Zimbabwe announced a national lockdown in March 2020 related to the global COVID-19 pandemic, mining was regarded as an essential service. Accordingly, PGM producers were able to remain operational. However, PGM matte deliveries to Zimbabwe Platinum Mines (Pvt) Ltd. (Zimplats), a subsidiary of Implats, were interrupted resulting from a force majeure declared by Impala Refining Services in South Africa, which affected overall sales for Zimplats (Impala Platinum Holdings Ltd., 2021, p. 9, 50).

The African Export-Import Bank completed a due diligence study in 2020, which enabled it to move forward with a $500 million syndicated funding program for development of Phase 1 of the Darwendale platinum deposit, 65 km southwest of Zimbabwe's capital, Harare. The Darwendale project was operated by Great Dyke Investments (Pvt) Ltd.—a 50–50 joint venture between Vi Holding Group (Russia) and Landela Mining Venture (Pvt) Ltd. Full annual production and capacity of the mine and associated recovery plant was expected to be 26,700 kg of PGMs and gold (Marawanyika, 2020; Dzirutwe, 2020).

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 industries, which requires catalytic converters, will have the greatest impact on future consumption of these PGMs. New environmental regulations on diesel vehicles in Europe and the move toward more EVs globally, particularly in China, are likely to decrease the demand for PGMs in the long term. However, the decrease may be offset by the production of gasoline-powered vehicles in markets where air quality regulations are less stringent or 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]

		2016	2017	2018	2019	2020
United States:						
Mine production:[2]						
Palladium, palladium (Pd) content:						
Quantity	kilograms	13,100	14,000 e	14,300	14,300	14,600
Value	thousands	$259,000	$380,000 e	$475,000	$711,000	$1,030,000
Platinum, platinum (Pt) content:						
Quantity	kilograms	3,890	4,000 e	4,160	4,150	4,200
Value	thousands	$124,000	$120,000 e	$118,000	$116,000	$120,000
Refinery production:[3]						
Palladium, Pd content:						
Quantity	kilograms	39,100 r	38,000	40,900	44,700	63,000
Value	thousands	$775,000 r	$1,070,000	$1,360,000	$2,220,000	$4,470,000
Platinum, Pt content:						
Quantity	kilograms	26,100	27,800	24,800	27,200	32,600
Value	thousands	$832,000	$850,000	$704,000	$758,000	$930,000
Imports for consumption, refined:						
Iridium, iridium (Ir) content	kilograms	1,300	1,420	1,020	875	1,620
Osmium, osmium (Os) content	do.	27	856	25	(4)	1
Palladium, Pd content	do.	80,400	86,000	92,900	84,300	76,400
Platinum, includes coins, Pt content	do.	42,300	53,200	58,500	42,300	64,800
Rhodium, rhodium (Rh) content	do.	10,700	11,600	14,500	15,000	20,700
Ruthenium, ruthenium (Ru) content	do.	8,410	14,600	17,900	11,200	13,900
Waste and scrap, Pt content	do.	154,000	354,000	40,700	35,200 r	188,000
Exports, refined:	do.					
Iridium, osmium, and ruthenium, gross weight	do.	736	939	2,500	1,330	1,440
Palladium, Pd content	do.	17,500	52,300	52,900	55,500	48,600
Platinum, Pt content	do.	14,000	16,700	18,900	17,400	28,900
Rhodium, Rh content	do.	794	844	2,010	1,210	1,470
Waste and scrap, Pt content	do.	48,100	37,200	31,700	20,800	33,200
Stocks, National Defense Stockpile, December 31:						
Iridium, Ir content	do.	15	15	15	15	15
Platinum, Pt content	do.	261	261	261	261	261
Price, average:[5]						
Iridium	dollars per troy ounce	586.90	908.35	1,293.27	1,485.80	1,633.51
Palladium	do.	617.39	874.30	1,036.43	1,544.31	2,205.27
Platinum	do.	989.52	951.23	882.66	866.94	886.02
Rhodium	do.	696.84	1,112.59	2,225.30	3,918.78	11,205.06
Ruthenium	do.	42.00	76.86	244.41	262.59	271.83
Employment		1,430	1,510	1,630	1,790	1,880
World, mine production, platinum-group-metal content[6]	kilograms	460,000	458,000 r	472,000 r	476,000 r	443,000

eEstimated. rRevised. do. Ditto.

[1]Table includes data available through June 14, 2021. 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]

(Kilograms, platinum content, and thousand dollars)

	Grain and nuggets		Sponge		Other unwrought		Semimanufactured forms		Coins	
Country or locality	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
2019	360	12,700	26,200	726,000	3,880	168,000	10,600	320,000	1,320	40,600
2020:										
Australia	--	--	--	--	--	--	3	55	1,190	36,000
Austria	--	--	--	--	2	64	177	11,100	145	4,630
Belgium	--	--	4,040	115,000	--	--	--	--	--	--
Brazil	--	--	13	333	--	--	--	--	--	--
Canada	138	4,060	--	--	--	--	363	11,100	584	19,500
China	--	--	--	--	--	--	(2)	7	20	553
Colombia	8	187	(2)	3	313	8,850	--	--	--	--
Costa Rica	--	--	--	--	--	--	995	34,600	--	--
Czechia	--	--	--	--	--	--	22	946	--	--
France	--	--	54	1,640	--	--	123	3,910	--	--
Germany	(2)	4	4,620	134,000	739	25,100	3,830	192,000	5	212
India	--	--	116	3,310	9	462	(2)	2	--	--
Italy	(2)	6	3,310	94,200	1	22	7	155	--	--
Japan	--	--	874	25,200	804	22,600	19	485	1	6
Korea, Republic of	--	--	63	1,840	--	--	11	392	--	--
Mexico	2	60	--	--	--	--	44	1,740	--	--
Norway	--	--	249	6,700	--	--	94	4,620	--	--
Poland	--	--	--	--	--	--	1	65	--	--
Russia	--	--	1,970	50,600	88	2,220	(2)	12	(2)	4
Singapore	--	--	--	--	1,230	127,000	247	8,730	--	--
South Africa	--	--	14,100	400,000	993	30,700	53	1,940	471	11,800
Switzerland	15	463	636	17,700	1,080	34,300	17,000	492,000	--	--
Taiwan	--	--	--	--	--	--	952	23,500	--	--
Thailand	--	--	--	--	2	72	(2)	14	--	--
United Kingdom	--	--	894	22,900	114	3,220	1,870	65,300	88	2,600
Other	--	--	(2)	3	1	34	2	56	(2)	2
Total	162	4,780	30,900	874,000	5,370	255,000	25,900	853,000	2,510	75,300

[r]Revised. -- Zero.
[1]Table includes data available through June 9, 2021. Data are rounded to no more than three significant digits; may not add to totals shown.
[2]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	Palladium content (kilograms)	Value (thousands)	Iridium content (kilograms)	Value (thousands)	Osmium content (kilograms)	Value (thousands)	Ruthenium content (kilograms)	Value (thousands)	Rhodium content (kilograms)	Value (thousands)	Platinum content (kilograms)	Value (thousands)
2019	84,300	$3,770,000	875	$38,300	(3)	$2	11,200	$91,600	15,000	$1,660,000	35,200 r	$1,100,000
2020:												
Australia	--	--	--	--	--	--	--	--	--	--	326	11,500
Austria	78	4,950	--	--	--	--	--	--	--	--	--	--
Belgium	4,850	328,000	--	--	--	--	--	--	1,360	357,000	181	7,000
Brazil	--	--	--	--	--	--	--	--	--	--	2,950	46,100
Canada	5,780	377,000	--	--	--	--	--	--	9	506	8,440	311,000
China	1	40	--	--	1	17	--	--	(3)	24	186	14,600
Colombia	--	--	--	--	--	--	--	--	--	--	92	2,620
Dominican Republic	1	3	--	--	--	--	--	--	--	--	145	3,810
Egypt	--	--	--	--	--	--	--	--	--	--	300	9,230
France	(3)	12	--	--	--	--	--	--	--	--	587	20,300
Germany	3,530	174,000	310	10,300	--	--	2,800	24,900	3,390	1,170,000	3,170	169,000
Hungary	--	--	--	--	--	--	--	--	--	--	107	7,440
Italy	12,600	228,000	4	154	--	--	1,170	11,400	6,370	250,000	1,630	53,200
Japan	1,100	24,500	56	1,540	--	--	129	925	77	20,100	6,250	180,000
Korea, Republic of	485	34,300	--	--	--	--	6	41	150	54,300	--	--
Malaysia	--	--	--	--	--	--	--	--	(3)	5	478	11,700
Mexico	28	872	--	--	--	--	--	--	--	--	9,080	266,000
Netherlands	--	--	--	--	--	--	--	--	--	--	239	5,620
New Zealand	--	--	--	--	--	--	--	--	--	--	97	3,190
Norway	180	12,100	--	--	--	--	--	--	24	8,770	(3)	14
Poland	--	--	--	--	--	--	--	--	--	--	279	10,400
Russia	23,800	1,680,000	163	7,210	--	--	133	1,150	1,410	456,000	--	--
Saudi Arabia	--	--	--	--	--	--	--	--	--	--	1,430	52,200
Singapore	--	--	--	--	--	--	--	--	--	--	1,180	47,800
South Africa	20,500	1,390,000	960	45,200	--	--	7,050	56,100	7,510	2,200,000	86	5,340
Sweden	--	--	--	--	--	--	--	--	--	--	218	22,100
Switzerland	1,840	128,000	--	--	--	--	--	--	36	11,900	1	32
Thailand	--	--	--	--	--	--	--	--	--	--	1,270	41,600
United Arab Emirates	--	--	--	--	--	--	--	--	--	--	514	27,900
United Kingdom	1,580	108,000	128	5,680	--	--	2,660	22,700	337	67,500	148,000	152,000
Other	30	443	--	--	--	--	--	--	(3)	9	686	21,600
Total	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

rRevised. -- Zero.
[1]Table includes data available through June 9, 2021. Data are rounded to no more than three significant digits; may not add to totals shown.
[2]Unwrought and other forms.
[3]Less than ½ unit.

Source: U.S. Census Bureau.

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

	Palladium		Platinum		Iridium, osmium, ruthenium		Rhodium		Waste and scrap	
Country or locality	Palladium content (kilograms)	Value (thousands)	Platinum content (kilograms)	Value (thousands)	Gross weight (kilograms)	Value (thousands)	Rhodium content (kilograms)	Value (thousands)	Platinum content (kilograms)	Value (thousands)
2019	55,500	$1,620,000	17,400	$547,000	1,330	$19,300	1,210	$152,000	20,800	$724,000
2020:										
Australia	63	2,090	73	1,800	79	2,090	--	--	--	--
Austria	1	6	1	32	--	--	--	--	2	56
Belgium	914	61,000	451	13,000	(2)	3	116	39,300	1,980	68,700
Brazil	402	29,000	268	7,450	(2)	3	11	4,890	--	--
Canada	3,410	236,000	329	11,500	1	8	17	5,770	12	374
China	770	36,800	236	5,670	108	1,390	120	26,700	--	--
Costa Rica	14	530	894	16,100	12	392	--	--	--	--
Czechia	5	200	--	--	--	--	--	--	2	131
Denmark	4	176	--	--	--	--	--	--	--	--
Dominican Republic	(2)	4	7	266	--	--	--	--	--	--
Estonia	(2)	21	7	197	--	--	--	--	--	--
Finland	7	111	(2)	4	--	--	--	--	--	--
France	218	5,250	74	1,910	70	770	--	--	--	--
Germany	4,090	202,000	3,230	135,000	284	2,490	112	38,500	8,140	436,000
Hong Kong	701	39,200	197	5,160	121	4,620	129	38,700	15	459
Hungary	1	3	3	51	--	--	--	--	--	--
India	864	59,500	616	17,300	4	55	3	879	--	--
Indonesia	54	240	(2)	3	--	--	--	--	--	--
Ireland	134	2,520	345	9,210	2	19	--	--	--	--
Israel	242	9,650	14	343	--	--	--	--	--	--
Italy	5,460	387,000	2,180	63,000	146	3,290	19	7,250	508	18,600
Japan	1,290	81,500	2,100	71,200	233	3,170	95	34,500	12,000	430,000
Korea, Republic of	903	53,800	2,260	85,900	1	14	212	54,300	(2)	10
Kuwait	5	239	--	--	--	--	--	--	--	--
Laos	--	--	9	357	--	--	--	--	--	--
Macau	3	100	3	36	--	--	--	--	--	--
Malaysia	3	39	1	25	3	46	--	--	2	80
Mexico	94	2,520	1,260	36,600	36	452	1	409	--	--
Netherlands	2	86	3	102	--	--	--	--	--	--
New Zealand	16	737	3	84	--	--	(2)	27	--	--
Norway	8	47	27	1,040	--	--	--	--	--	--
Poland	6	82	2	74	--	--	--	--	--	--
Russia	--	--	52	1,740	--	--	--	--	3	190
Singapore	34	875	675	19,800	--	--	--	--	1	16
South Africa	3	21	372	21,900	7	129	519	134,000	87	4,050
Switzerland	13,300	616,000	9,340	269,000	129	4,430	56	20,200	1,330	41,400
Taiwan	1,080	52,600	106	3,210	182	1,020	(2)	24	(2)	9
Thailand	108	3,050	50	1,330	1	41	--	--	--	--
United Kingdom	14,300	1,020,000	3,630	129,000	19	420	64	20,700	9,170	398,000
Vietnam	2	47	15	446	--	--	--	--	--	--
Other	10	229	13	407	(2)	14	(2)	49	1	40
Total	48,600	2,900,000	28,900	930,000	1,440	24,900	1,470	426,000	33,200	1,400,000

-- Zero.
[1]Table includes data available through June 9, 2021. Data are rounded to no more than three significant digits; may not add to totals shown.
[2]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]	2016	2017	2018	2019	2020
Palladium:					
Australia[e, 4]	590	600	420	380	410
Canada[e]	22,000	19,000	21,000 [r]	20,000	20,000
China	1,400	1,400	1,300	1,300	1,300 [e]
Finland	901	1,021	1,157	699	858
Russia[e]	83,000	88,000	90,000	98,000	93,000
Serbia	31	38	55	100 [r, e]	100 [e]
South Africa	76,273	80,713 [r]	80,629	80,684	73,533
United States[4]	13,100	14,000 [e]	14,300	14,300	14,600
Zimbabwe	12,222	11,822	12,094	11,600 [r]	12,890
Total	209,000	217,000 [r]	221,000 [r]	227,000	217,000
Platinum:					
Australia[e, 4]	170	170	120	110	110
Canada[e]	8,400	7,600	7,600 [r]	7,300 [r]	7,000
China	2,900	2,500	2,500	2,500	2,500 [e]
Colombia	917	566	269	163	410
Ethiopia[e]	5	4	4	2	2
Finland	1,178	1,418	1,576	953	1,277
Russia[e]	22,000	22,000	22,000	24,000	23,000
Serbia	4	2	5	10 [r, e]	20 [e]
South Africa	133,241	132,500 [r]	137,053	132,989	111,993
United States[4]	3,890	4,000 [e]	4,160	4,150	4,200
Zimbabwe	15,110	14,257	14,703	13,857 [r]	15,005
Total	188,000	185,000 [r]	190,000	186,000	166,000
Iridium:					
Canada[e]	300	200	400 [r]	300 [r]	300
Russia[e]	200	300	200	300	250
South Africa	6,624	6,057 [r]	6,357	6,464	6,786
Zimbabwe	598	619	586	845 [r]	836
Total	7,720	7,180 [r]	7,540 [r]	7,910 [r]	8,170
Rhodium:					
Canada[e]	600	60	300 [r]	700 [r]	300
Russia	2,644	2,115	1,928	2,426	1,804
South Africa	19,237	18,665 [r]	18,608	19,545	19,217
Zimbabwe	1,322	1,283	1,334	1,224 [r]	1,368
Total	23,800	22,100 [r]	22,200 [r]	23,900 [r]	22,700
Ruthenium:					
Canada[e]	300	500	700 [r]	500	400
Russia[e]	1,000	1,000	1,300 [r]	1,300	1,000
South Africa	28,278	24,821 [r]	27,999	28,386	27,518
Zimbabwe	1,174	1,102	1,155	792 [r]	1,026
Total	30,800	27,400 [r]	31,200 [r]	31,000	29,900
Grand total	460,000	458,000 [r]	472,000 [r]	476,000 [r]	443,000

[e]Estimated. [r]Revised.

[1]Table includes data available through June 9, 2021. 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.

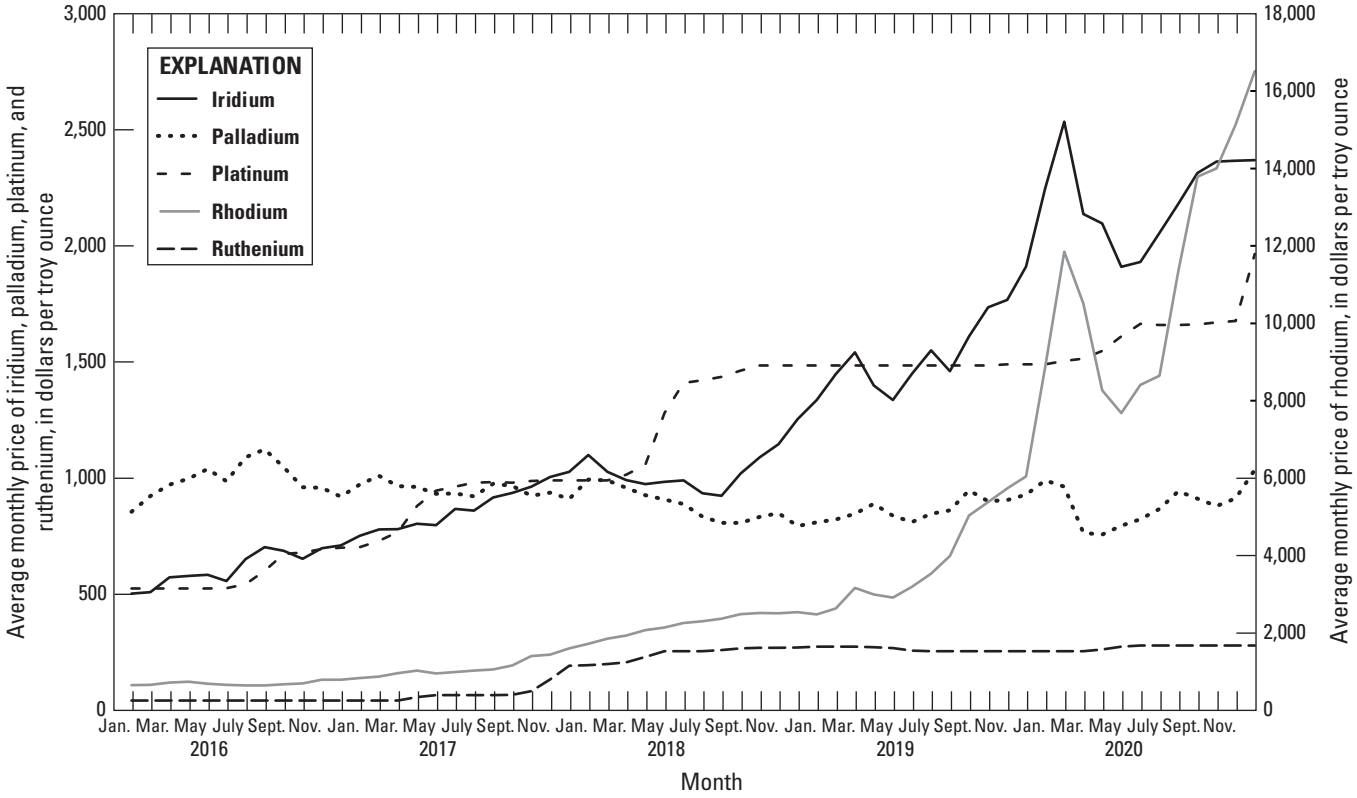

Figure 1. Engelhard unfabricated average monthly prices for the platinum-group metals (iridium, palladium, platinum, rhodium, and ruthenium), 2016–20. Source: Platts Metals Week.