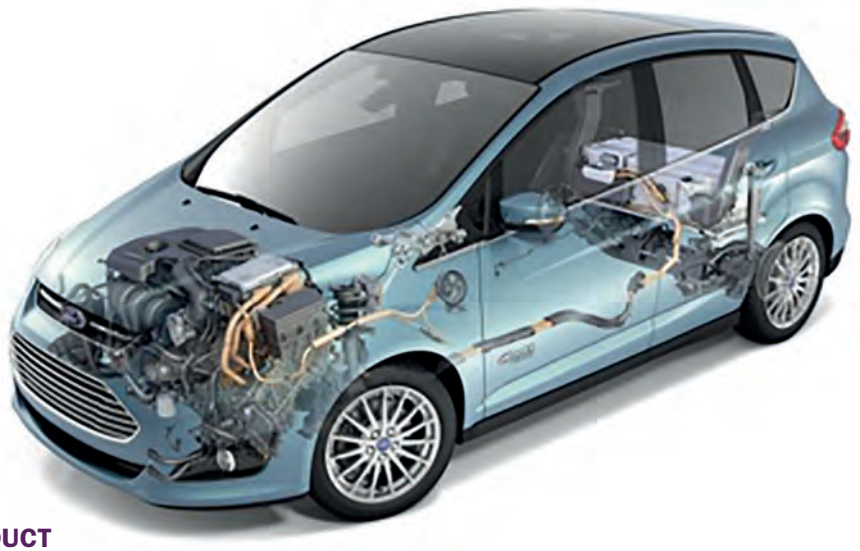
World Emissions Standards: Opportunities & Risks for PGMs in Automotive Catalysis



BY DR AMANDA JOSEY, HEAD OF GLOBAL PRODUCT MANAGEMENT, MOBILE EMISSIONS, BASF CORPORATION

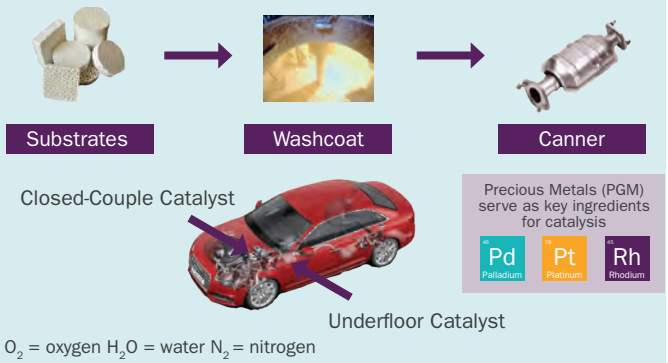
The following is a truncated version of the speech which Dr Josey delivered at the 2018 LBMA/LPPM Conference in Boston. It focuses on world emission standards, and what this means for the future demand for PGMs. This article complements the one by Rahul Mital on page 26.

BASF CORPORATION

BASF is the world's leading automotive supplier in the chemical industry, helping automakers address global automotive trends such as e-mobility, lightweighting, heat management, passenger experience, fuel efficiency and emissions reduction. We have the most extensive product portfolio in the automotive industry from engineering plastics, coatings and fuel additives to catalysts, battery materials and brake fluids to chemicals for leather and textiles. With a strong presence in Europe, Africa, North and South America, as well as Asia, BASF has a truly global network.

I am part of the Mobile Emissions business within the Catalysts division of BASF Corporation. BASF Catalysts division supports several areas across the automotive industry: precious & base metals services, mobile emissions catalysts and battery materials.

FIGURE 1: CONVERTING TOXIC EMISSIONS TO CO_2 + H_2O + N_2
Substrates are coated with a PGM washcoat and canned to produce emissions system



O_2 = oxygen H_2O = water N_2 = nitrogen

FIGURE 2: BENEFITS OF PGMS TO REDUCE EMISSIONS
PGMs are not fully interchangeable; typically more than one PGM needed per catalyst component

	Platinum	Palladium	Rhodium
Hydrocarbon Oxidation	+	+	+
CO Oxidation	+	+	+
NOx Reduction	+/–	+	++
Thermal Durability	–	+	–/+
SOx Poison Tolerance	+	–	–

++ best performance + good performance – poor performance

Performance can be different under lean conditions/stoichiometric conditions

CATALYTIC CONVERSION

A catalytic converter is produced using a ceramic or metal substrate, coated with a wash coat containing active ingredients such as platinum group metals (PGM) and canned in a metal housing. Catalytic conversion aims to convert all toxic emissions into atmospheric products, for example, carbon dioxide, water and nitrogen. PGM placement and use in our catalytic converters is key for BASF to have the best-performing product (see Figure 1).

The catalytic converter can be located in various spaces underneath the vehicle. The placement, determined by the OEMs, impacts the performance needs of the emissions system. Close-coupled catalysts are closer to the engine, with high temperature outgas and higher pollutants, since it is the first catalyst after the engine. The catalyst can also be placed underfloor in the system, along the trace underneath the vehicle. Underfloor catalysts need to perform at lower temperatures and clean up remaining pollutants

CHEMISTRY

What happens if one type of PGM, for example palladium, becomes prohibitively expensive? Can an alternative (e.g. platinum) be substituted? The metal choices depend on the performance of different chemical reactions that happen on the surface of the catalyst. Remember, the goal is to convert pollutants into products that would be found in the atmosphere. The main chemical reactions happening are (1) hydrocarbon oxidation, converting hydrocarbons into carbon dioxide and water, (2) CO oxidation, converting CO into carbon dioxide, and (3) NOx reduction, converting NOx into water and nitrogen.

OXIDATION

Figure 2 shows a performance comparison, contrasting the different types of PGM, to give an impression whether one PGM is easily replaceable by another. For hydrocarbon and CO oxidation, all three precious metals are good performers. Some would argue that palladium offers a little better performance overall, but at BASF, we can create a PGM for oxidation that meets customer performance requirements at the best cost using any of the three.

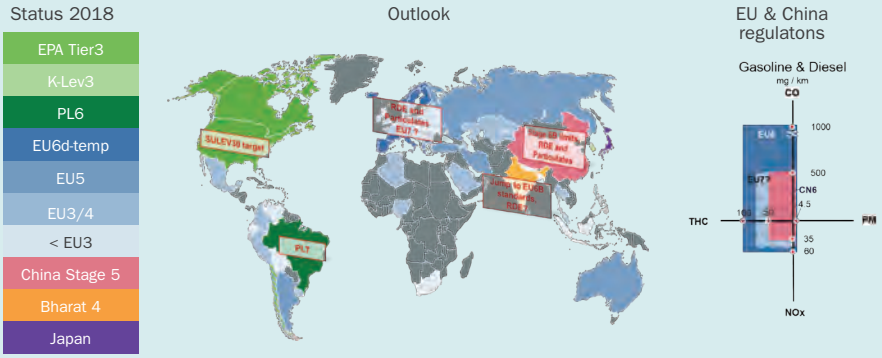
NOX REDUCTION

NOx reduction is becoming increasingly important with upcoming world regulations. For that reaction, there is both a plus and a minus for platinum which is related to whether the vehicle is running lean burn, with a higher oxygen/fuel ratio in the outgas (diesel engines), versus stoichiometric burn, which we have in a typical gasoline engine. While in a diesel engine, platinum supports NOx reduction and is a key component, a gasoline engine running under stoichiometric conditions does not favour the use of platinum alone. Rhodium is by far the best performer in NOx reduction, which is why it will be a critical precious metal going forward.

METAL PERFORMANCE – OTHER CRITICAL INDICATORS

In addition to supporting key chemical reactions, thermal durability and sulphur tolerance are critical performance parameters for PGM. Platinum has a poorer thermal durability, so placing that metal in the close-coupled position in gasoline engines can be challenging without another metal to support it. For rhodium, performance also depends on whether you are running gasoline or diesel (stoichiometric or lean burn). Finally, sometimes our fuels contain sulphur, so some of the precious metals can have their activity poisoned by sulphur. However, platinum has a good record in limiting sulphur poisoning.

FIGURE 3: EMISSION STANDARDS AND CHALLENGES
Current status and outlook for light duty → need significant performance improvements



Main challenges are particulate matter (PM), CO_2, and NO_x control

THC = total hydrocarbon CO = carbon monoxide NOx = nitrogen oxides CO_2 = carbon dioxide
Emission regulation Light duty vehicles; Source: UNEP

EMISSIONS REGULATIONS

EUROPE

Europe has real-driving emissions (RDE) regulations coming on line in the next couple of months, with Euro 6d Full.

This will also require the control of particulate matter (PM) using filters in the after-treatment system. The hypothetical regulation beyond that is Euro 7. It is not known exactly where requirements will be set for Euro 7, but many of the OEMs are already working on performance needs based on hypotheses (see Figure 3).

CHINA

China will be implementing the world's strongest regulations – China 6. Some of the major cities in China will probably move to China 6-type regulations by 2020, but the whole country will comply by 2023. Figure 3 is a representation of the requirements for emissions and a comparison between China and Europe.

2027

AUTOMOTIVE DEMAND WILL BE THE MAIN DRIVER FOR INCREASES IN PGM NEEDS THROUGH 2027

When it comes to CO and hydrocarbon oxidation, these two parameters are fairly easy to control, based on expected regulations. The main challenges going forward are more on the particulate matter (PM), CO2 level and NOx control. This again points towards an increasing need for rhodium to control the NOx.

PGM USAGE

MARKET PROJECTIONS

BASF's market model until 2027 shows a projected 3% increase in PGM demand driven by regulation. A 1.5% increase in PGM supply is expected, with the recyclers offering support. Vehicle production has a 1.5% expected CAGR, and the key point here is that 48% of this growth will come from China, so it is the biggest growth region by far. The emission regulations are the main driver (see Figure 4).

GEOGRAPHICAL DIFFERENCES

In Europe and the US, overall internal combustion engine development is expected to be flat or decreasing; however, an increase in the number of catalysts per vehicle is

FIGURE 4: GLOBAL TRENDS IN PGM USAGE FOR AUTOMOTIVE CATALYSIS
Tightening regulations drive increased catalysts on vehicles and PGM growth overall

3.0% PGM demand

Increasing demand driven largely by tightening in automotive emissions regulation.

Jewellery and chemical catalyst remain relatively flat.

1.5% PGM supply

Autocat recycling continues to represent a higher percentage of overall supply (function of rising scrap steel price & PGM loadings).

Partially offset by reduced mine output from South Africa.

1.5% Vehicle production

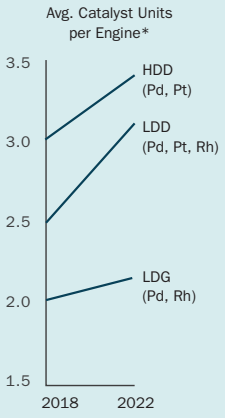
Catalyzed engine production (both light and heavy duty) expected to grow by 1.5%.

China accounts for over 48% of this growth.

EMISSIONS REGULATION

Euro 6d final, China NS 6a, India BS 6 expected in 2020.

Level of regulation enforcement remains uncertain in China and India.



Percentages represent CAGR through 2027
**based on LCMA engine data (June 2018) and OEM program data.*
HDD: heavy duty Diesel; LDD: light duty Diesel; LDG: light duty gasoline

still expected and therefore catalyst units in the market are growing. In our projections until 2022, in all segments (heavy-duty and light-duty), an increase in the number of catalysts per vehicle is expected.

METAL DEMAND

BASF market insights projects that automotive demand will be the main driver for increases in PGM needs through 2027. As a percentage share of the total annual market demand palladium is expected to increase from 69% to 88%, platinum from 38% to 48% and rhodium from 78% to 91% (see Figure 6).

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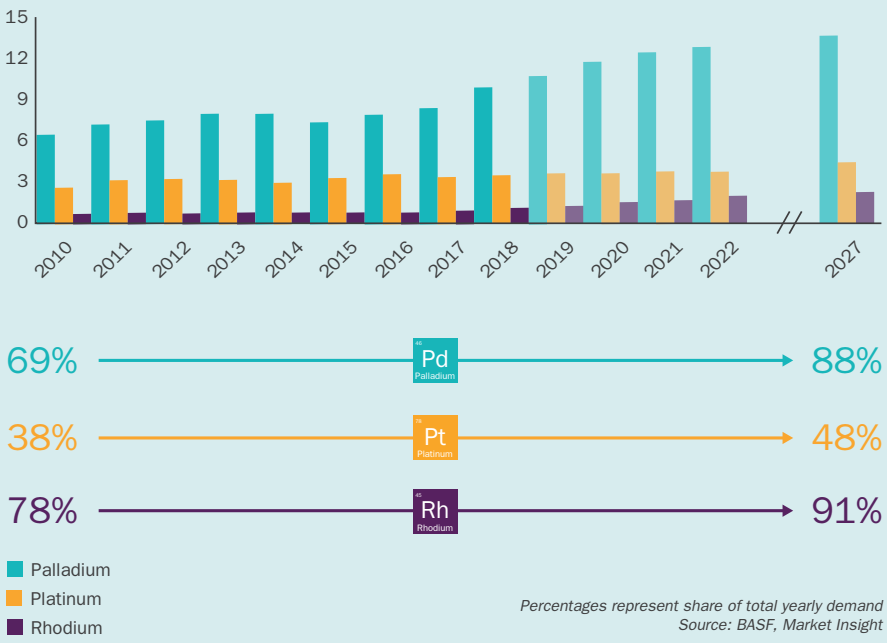
FIGURE 5: AUTOMOTIVE PGM DEMAND (IN MILLION TOZ)



Percentages represent share of total yearly demand
Source: BASF, Market Insight

REAL-WORLD TESTING

CERTIFICATION METHODS

One of the biggest changes to emissions requirements is certification with real-driving conditions. OEMs want to ensure their vehicles will meet the requirements under all conditions and will sometimes require additional PGMs to support this as new technologies are being developed. This may cause demand increases in the short-to-mid-term; however, it is fully expected that after launching new systems to meet RDE, the OEMs will require the catalyst developers to continue work on improvements to maintain the performance of these systems, while using less PGMs.

RDE certification requires that OEMs develop a testing cycle where the vehicle runs through an urban, suburban and rural loop and on-board testing is performed. One challenge arising from the need to meet RDE versus previous certification requirements is instead of a steady-state temperature in a controlled testing environment, OEMs need to show performance at temperatures from below freezing to very warm in an on-the-road environment. When it is really cold, it takes longer for the catalyst to warm up and be effective, and lower temperature performance becomes critical.

FUTURE CO_2 EMISSIONS REQUIREMENTS ARE A MAJOR FACTOR INFLUENCING THE NEED FOR ELECTRIFICATION AND ALTERNATIVE POWERTRAINS, SUCH AS HYBRID VEHICLES.

Lab certification provides a direction in terms of which technologies are best, but may not conclusively indicate which technology should be used until RDE testing is performed. This requires more discussion, work and time to achieve the right requirements for RDE testing, and could also impact the use of additional PGM if there is not enough time to make overall changes to the catalyst.

ELECTRIFICATION

Future CO2 emissions requirements are a major factor influencing the need for electrification and alternative powertrains, such as hybrid vehicles, mainly because CO2 can be reduced by improving fuel economy. Europe will have the most challenging CO2 emissions requirements in the future. However, many consumers in Europe are switching from diesel to gasoline vehicles due to the 'Dieselgate' scandal. This has had a negative impact on fleet average fuel economy and therefore is driving OEMs to promote alternative powertrains and electrification. Additionally, controlling emissions on hybrid vehicles can be even more challenging, because as the vehicles switch from electric to gasoline (or diesel), the engine needs to warm up again for the catalyst to perform. This is partially being solved through additional PGM or heating strategies in the vehicle.

The catalyst manufacturers are also working on low temperature solutions to alleviate the need for more PGM and/or heating.

ALTERNATIVE PROPULSION SYSTEMS

Compressed natural gas is another propulsion system being investigated by the OEMs. It is not believed to be a solution in the US in the future, but for regions such as China and maybe within Europe, where they have natural gas stations, it could be an option. There are other alternative vehicles such as lean GDI, which is a gasoline vehicle running lean similar to diesel, and hybrid vehicles, which present different challenges as well. Most of these alternative systems require more PGM to have the best performance.

CONCLUSIONS

PGM demand is expected to increase, especially with world regulation updates in the mid-term. This is driven by more catalysts per unit, challenges with hybrid vehicles and making sure we have sufficient performance when the engine is colder. We expect to achieve CO2 reduction through fuel economy improvement, which is driving the need for electrification. However, it is still expected in the next decade that a majority of the engines will continue to be internal combustion engines. Finally, while many of these requirements coming from world emissions support a strong increased demand for PGM, it is expected that once OEMs are able to meet the targets, they will challenge the catalyst manufacturer to improve costs while maintaining performance.

Dr. Amanda Josey has a passion for bringing science and business together. Dr. Josey earned her Ph.D. in inorganic chemistry from North Carolina State University in 2008. She started her career at BASF the same year doing research & development in Catalysis and has moved through the company in the last 10 years in innovation, business development, and marketing roles. Dr. Josey is currently responsible for the global portfolio management of BASF's Mobile Emissions business. In her talk, she shared her ideas on the risks and opportunities that her customers face with the upcoming world regulations and the very important role precious metals, like rhodium, must play in the success to meet those regulations.