PLATINUM ESSENTIALS

Automotive drivetrain outlook and the implications for sustained long term platinum demand

Trevor Raymond
Director of Research
+44 203 696 8772
traymond@platinuminvestment.com

Edward Sterck
Analyst
+44 203 696 8786
esterck@platinuminvestment.com

Brendan Clifford
Head of Institutional Distribution
+44 203 696 8778
bclifford@platinuminvestment.com

World Platinum Investment Council
www.platinuminvestment.com
Foxglove House, 166 Piccadilly
London W1J 9EF

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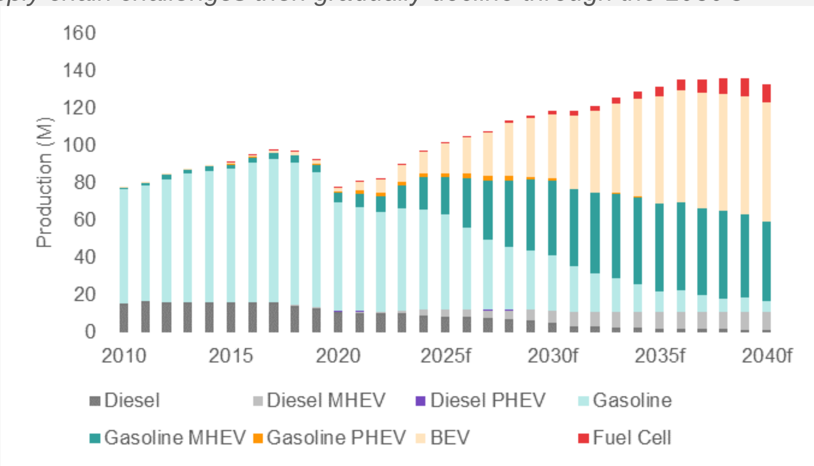
We forecast automotive demand for platinum from ICE vehicles alone to peak in 2028, but with sustained growth thereafter due to FCEVs.

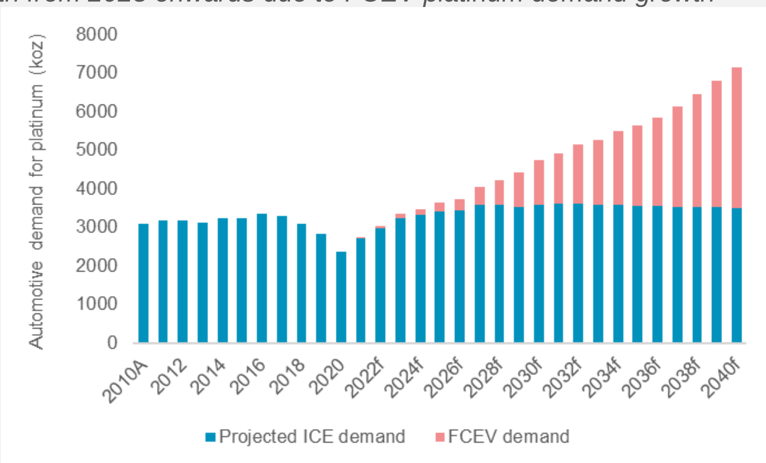
This report contains the results of WPIC analysis, based on public data, which presents our automotive drivetrain projections out to 2040 and the associated automotive platinum demand. Our key conclusion is that although long-term growth in vehicle production comes only from BEV and FCEV, ICE is expected to remain a core part of the automotive landscape for some considerable time. ICE will feature in roles and regions that are unsuited to battery electrification. In combination with the latest emission standards which raise loadings, and especially increased platinum for palladium substitution in gasoline vehicles, this results in ICE-related automotive demand for platinum peaking in 2028, with further platinum demand growth thereafter due to FCEVs. We plan to examine the potential near-term impacts of our automotive outlook on platinum supply and demand in upcoming reports.

Figure 1. We expect growth in global vehicle production to be dominated by growth in BEV and FCEV with ICE to recover somewhat from current supply chain challenges then gradually decline through the 2030's



Source: OICA, ACEA, Bloomberg, WPIC Research

Figure 2. Higher loadings and platinum substitution in gasoline vehicles result in ICE-related automotive demand for platinum recovering to pre-COVID levels, peaking in 2028 then gradually declining, with overall growth from 2028 onwards due to FCEV platinum demand growth



Source: Metals Focus, SFA (Oxford), Johnson Matthey, WPIC Research

- ***Internal combustion engines (ICE) to remain a major albeit declining component of the drivetrain mix through the 2030's***
- ***Growth in vehicle production driven by battery electric vehicles (BEV) and fuel cell electric vehicles (FCEV)***
- ***The sustained ICE tail, including plug-in hybrid electric vehicles (PHEV) and mild hybrid electric vehicles (MHEV), in combination with tighter emissions standards supporting higher platinum loadings, will sustain automotive demand for platinum at historic levels out to 2040***
- ***FCEVs drive platinum demand growth from late 2020s (see standalone FCEV report here)***

WPIC's ***Platinum Essentials*** is a publication which explores topics affecting platinum as an asset class. This is different to ***Platinum Perspectives***, which is a concise monthly publication which looks at a specific topic affecting supply demand dynamics for platinum.

Contents

The drive for electrification

Before discussing expected changes in the full drivetrain mix, it is worth focussing on the main trend that is expected to dominate the automotive industry over the coming two decades – namely electrification to reduce tailpipe emissions (although not necessarily total emissions).

There are four main vehicle types for achieving electrification:

1. **Battery electric vehicle (BEV)** – A plug-in vehicle with a large battery that is plugged in to an electric power source to charge.
2. **Plug-in hybrid electric vehicle (PHEV)** – A vehicle that combines an internal combustion engine with a mid-sized battery that can be plugged in to charge to run as a BEV for a limited distance as well as run on petrol or diesel alone.
3. **Mild hybrid electric vehicle (MHEV)** – A vehicle with an internal combustion engine plus a small battery, that has the ability to harvest and store energy from braking, which is used to improve fuel- and CO2-efficiency.
4. **Fuel cell electric vehicle (FCEV)** – An electric vehicle that uses a fuel cell to produce electricity (by passing hydrogen and oxygen over a platinum catalyst). Thus they drive an electric motor/s consuming hydrogen fuel, which is quickly refillable, similar to gasoline or diesel (see FCEV report here).

All technologies are needed to decarbonise transport; FCEVs are complimentary to BEVs and are key to decarbonising areas unsuited to battery electrification

We assume that the pivot towards BEV already underway will continue, led by Europe and China. We make no reductions in uptake for the likely possibility of significant battery raw material supply constraints, particularly in class 1 nickel, or for the impact that material cost inflation could have on the affordability of BEVs. However, we are of the view that there will be a natural saturation point for BEV penetration in each major market, which results in a tapering of the BEV growth rate over time. This will happen once saturation of the vehicle and vehicle roles suitable for BEV electrification is reached. Growth will taper also based on likely infrastructure shortfalls in different geographies.

Electrification trend to continue, although we have assumed no battery commodity raw material supply constraints

We don't see PHEVs as a long-term technology as it combines the worst aspects of ICE and BEVs, namely the heavy battery which negatively impacts the ICE fuel efficiency and emissions once it is depleted; which happens relatively quickly.

Expect PHEVs to be phased out and essentially all ICE to be hybridised

We expect MHEV to be the principal transition technology for vehicle roles unsuited to BEV electrification, with smaller batteries helping to improve ICE efficiency and reduce emissions. Although the emissions reduction efforts are being led by the economically developed countries and China, it seems probable that pretty much all ICE vehicles will transition to be MHEVs globally given the relatively low cost of the technology once the production lines are set-up. There are also demonstrable benefits for the environment and an attractive improvement in the total cost of consumer ownership due to improved fuel efficiency.

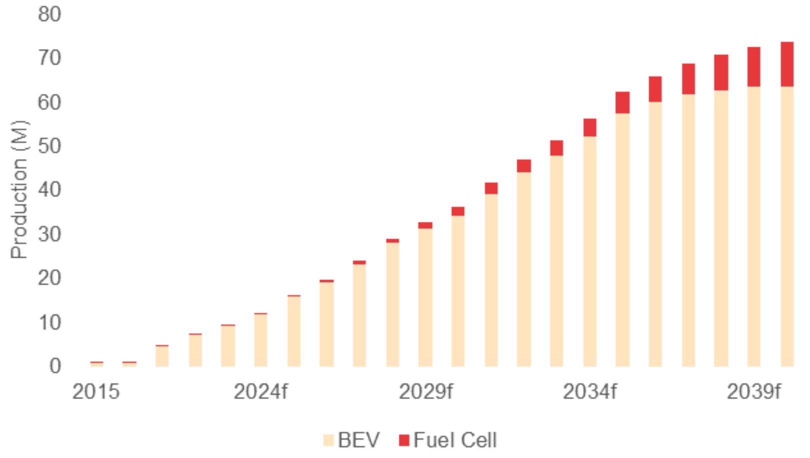
FCEV to be the technology of choice for the vehicle roles unsuited to battery electrification

Ultimately, we expect FCEV to be the technology of choice for the vehicle roles unsuited to battery electrification. For the purpose of the projections put forward in this report we focus on the policy-driven FCEV outlook as presented in our recent FCEV report, although plans to substantially expand hydrogen production, particularly in Europe, are highly supportive of the broad-based commercial adoption presented in the same report and which would accelerate the uptake of FCEV. Please see our standalone FCEV report for more details.

Dramatic improvements in battery technology broadens the roles suited to battery electrification but does not solve grid charging capacity issues

One key point to highlight is that we have not attempted to predict any currently unenvisioned step-change in battery technology that improves energy density or decreases the charging time without degrading the battery. Similarly, we are not including any volume effects from the constant upcoming improvements in ICE technology, efficiency and cleanliness. Dramatic improvements in battery technology would expand the vehicle roles that could be suitable for battery electrification, although they would not address the challenges around the ability of local electricity grids to support the demand for rapidly charging BEVs, particularly in the larger vehicle sizes.

Figure 3. Production of pure BEV and FCEV – BEV demand expected to taper in late 2030's due to saturation of vehicles that are suitable for pure battery electrification



Source: OICA, ACEA, Bloomberg, WPIC Research

Light passenger vehicle outlook

Light passenger vehicles (LVs) are probably the area of the automotive industry that engenders the greatest controversies and loudest discussions around the pace of electrification and peak vehicle ownership. This reflects:

1) The fact that there are significantly more LVs on the road than other vehicle types and
2) That we as individuals are typically more likely to be car owners than fleet operators, and thereby more directly impacted by fuel and vehicles costs, which in turn are influenced by emission reduction policies and supply chain inputs – i.e. we have more of a vested interest in the regulations for LVs

Key to the outlook for platinum is the overall sentiment towards the internal combustion engine (ICE), with increasing public comments that the technology is destined to become extinct with ever more aggressive estimates of the pace and reach of electrification. The consequent potential loss of platinum demand associated with those predictions would equate to a third of platinum demand.

Not all vehicle roles are suited to battery electrification

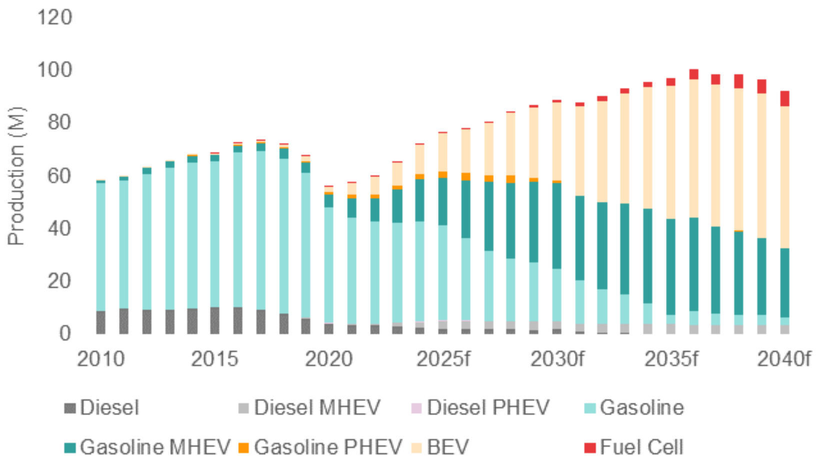
As already mentioned, it is clear to us that not all vehicle roles are suitable for battery electrification and so we expect ICE to remain a core, albeit declining, part of the drivetrain mix into the 2040's. Furthermore, currently produced vehicles have been significantly improved in order to meet ever more stringent emissions legislation. Since the 2015 Dieselgate scandal, the focus on vehicle emissions has been the reduction of emissions impacting mainly urban air quality and tailpipe emissions of combustion gases (mainly oxides of nitrogen or NO_x). These regulations may tighten further and require, for example, pre-heated catalytic converters to reduce emissions at cold start. However, if the transition from ICE to electric vehicles takes longer than envisaged, the focus will be on ensuring production of the most CO_2-efficient ICE vehicles, to support the transition which is to ultimately achieve net zero globally. Continued improvements in ICE engine efficiencies are likely to most easily be delivered, in part, by almost all ICE vehicles becoming MHEVs by the mid-2030's. This is also likely to be enhanced by the use of biofuels, potentially derived from household waste to limit impacts on food production. Current geopolitical developments may also see increasing ICE-supportive policies from countries such as Germany, France and Italy balancing the impacts on ICE production with constrained BEV and FCEV uptake. Several major automakers continue to develop new internal combustion engines, even though they officially plan to phase them out later in the 2020s or early 2030s.

We expect continued improvements in ICE efficiencies with reduced emissions, particularly increased mild hybridisation

It is worth discussing how vehicle ownership might change in the future. Many commentators assume that the model of car ownership will change from outright ownership to a subscription-based model with automated vehicles turning up on demand when needed. It seems probable that there will be a move towards this, particularly in the urbanised West. But how this model works for commuters, rural populations, and anyone with children (imagine wrestling child seats in and out of vehicles for every journey!), remains unclear to us. Thus, we have allowed for only a small element of shared car ownership, which has the effect of suppressing production numbers in the 2030's and keeping annual output below the oft-vaunted 100 Mpa level.

We assume that the current model of direct vehicle ownership is sustained, particularly outside of the urbanised West

Figure 4. Light vehicle production outlook by drivetrain



Source: OICA, ACEA, Bloomberg, WPIC Research

Note that this outlook for LV vehicle production volume as well as the drivetrain mix and pace of electrification is broadly similar to the projections that we have seen from other market commentators.

Europe – For better or worse, the epicentre of policy setting

We think that the importance of Europe to global light vehicle production is considerable. Outside of China it leads the emissions reduction agenda which makes it a key influence on the global drivetrain mix. The key unknowns in Europe are the implementation of Euro 7 emission standards, and the possibility of an ICE ban in or around 2035.

Europe is a key decision-making centre for automotive emissions reduction targets

It is clear that the Euro 7 proposals, as they stand, are considered unworkable by the automotive industry; meeting them would make vehicles prohibitively expensive for only marginal improvements in noxious tailpipe emissions. One potential outcome is that automakers are forced to drop all ICE sales in Europe (but continued production for export is possible), but we think it more probable that the potential negative impact to GDP of forcing unenthusiastic consumers to BEVs will result in sense prevailing and an adjustment to the proposals that keep ICE as part of the drivetrain mix. If this occurs, then we could see a rebound in (now clean) diesel production due to the significant 20% benefit in lower CO_2 emissions versus gasoline.

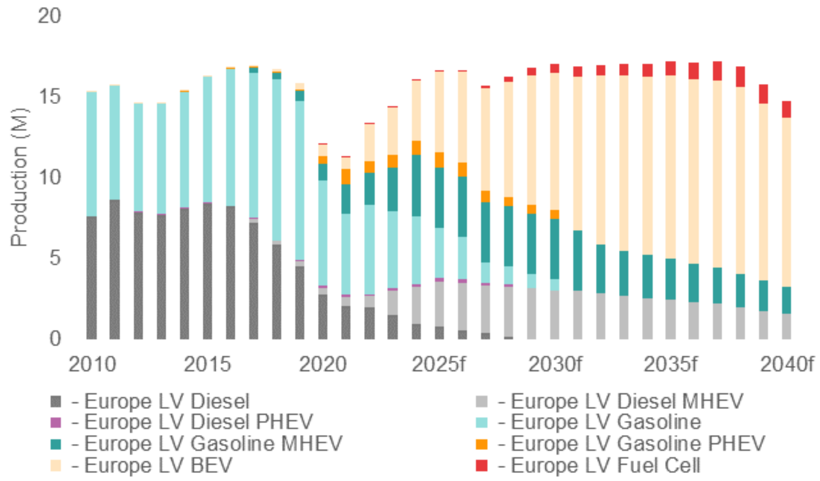
Euro 7 as currently envisioned seems to be unworkable

We are of the view that banning ICE by 2035 is impractical, and that previous city bans, which were to reduce urban NO_x concentrations (London and Paris in particular), are far less likely as CO_2 is a national rather than urban issue. However, even though BEV ownership in urban areas is partly driven by air quality considerations, the charging challenges are a deterrent to adoption. We think the impact of both effects are captured in our BEV estimates.

We expect Europe to allow for ICE exemptions beyond 2035

Following the Russian invasion of Ukraine, Europe has taken steps to reduce the reliance on Russian oil and gas. In addition to the increased use of green hydrogen, increased demands for electricity and consequently demands on national grids may also reduce BEV penetration. This will be due to charging infrastructure and battery charging cost considerations. We have not attempted to capture these dynamics in our base case outlook.

Figure 5. European policy remains unclear – we think that for practical reasons ICE remains an integral part of the outlook past 2035



Source: OICA, ACEA, Bloomberg, WPIC Research

We foresee a possible resurgence in diesel in Europe due to 20% lower CO_2 emissions versus petrol

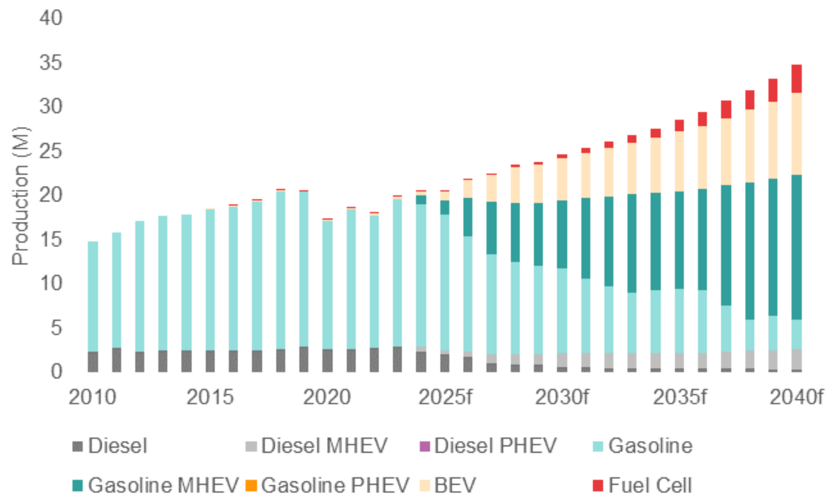
Automakers are developing new diesel engines, but consumer marketing remains coy as to the fuel type in the wake of 'Dieselgate'

Light commercial vehicle outlook

Although the global population is projected to continue growing until at least 2050, and the aspiration for car ownership is expected to continue, the reality is that per capita car ownership, particularly in the West, is probably going to decline. While this suppresses the LV vehicle production forecasts, a side effect of this trend is continued growth in online shopping and home deliveries, which is expected to be extremely positive for light commercial vehicle (LCV) demand.

Online shopping deliveries likely to continue to support the demand for LCVs

Figure 6. Light commercial vehicle production expected to grow to meet the sustained post-pandemic high demand for home deliveries



Source: OICA, ACEA, Bloomberg, WPIC Research

Heavy-duty vehicle outlook

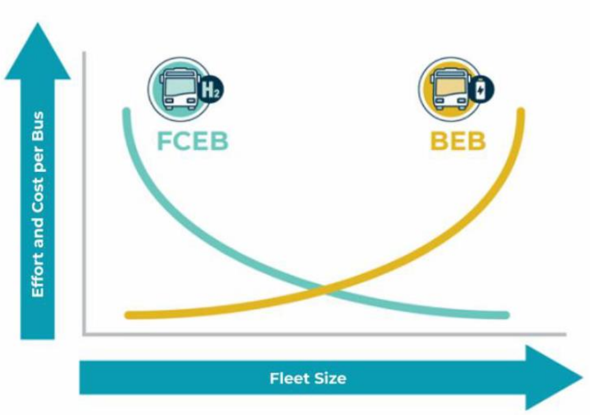
Heavy-duty (HD) vehicles are arguably the most challenging to electrify. Battery electrification adds significant weight and reduces load carrying capacity. Battery electrification also lowers capacity utilisation due to long recharging times and can require significant local grid infrastructure upgrades. Nonetheless, most truck manufacturers now offer BEV options for rigid trucks up to about 19 tonnes GVW with some BEV articulated tractors also being launched. However, battery electrification is currently only really suitable for journeys of 250 miles or less and are therefore likely to be restricted to urban or suburban roles. We expect a pretty rapid saturation of HD vehicle roles suitable for battery electrification.

HD vehicles the most challenging to electrify due to weight, range, capacity utilisation and grid recharging challenges

An alternative to battery electrification is fuel cell technology, which is particularly well-suited to HD roles and allows for longer range, faster refuelling times, higher capacity utilisation and lighter vehicle weight. While charging BEV LVs is unlikely to overly tax the primary electrical power grid now, it will require significant grid upgrades at certain mass adoption thresholds. This is particularly true for HD vehicles operating from depot environments where charging multiple vehicles overnight or on an opportunity basis can require significant grid upgrades, especially as the fleet grows larger. On the other hand, the per vehicle cost of installing hydrogen refuelling infrastructure falls at larger fleet sizes as the quicker refuelling times mean that it can service a greater number of vehicles, as illustrated in the following schematic for bus operators.

Fuel cells best suited to electrifying the HD segment

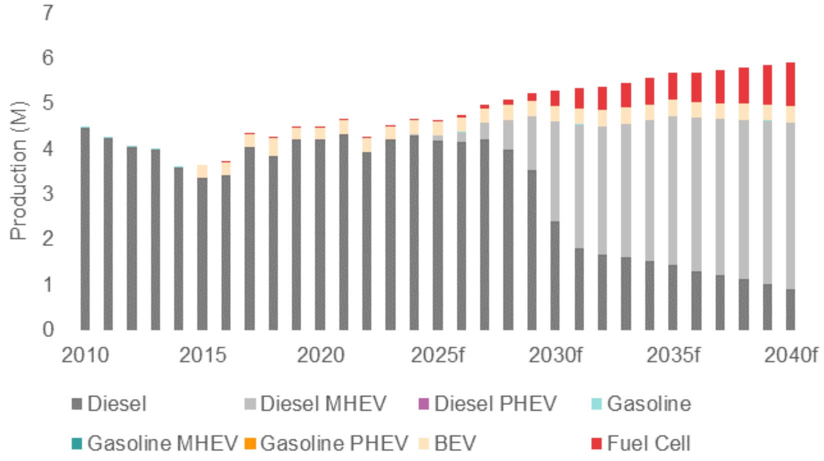
Figure 7. Per vehicle refuelling costs for FCEVs fall with increasing fleet size, whereas the additional grid upgrade costs for BEVs continue to grow with the fleet. City bus fleet example in chart.



Source: Center for Transportation and the Environment (CTE), IDTechEx

Pending FCEV and hydrogen refuelling infrastructure becoming more broadly available, we assume that diesel will remain the primary fuel for HD vehicles, particularly in the high volume, long-distance intra-urban roles. However, as with LV and LCV, we expect hybridisation to come to dominate the production mix.

Figure 8.HD is the most difficult segment to electrify with battery technology, remaining dominated by diesel and diesel MHEV, although fuel cells are likely to be the longer-term electrification solution



Source: OICA, ACEA, Bloomberg, WPIC Research

Combined drivetrain outlook

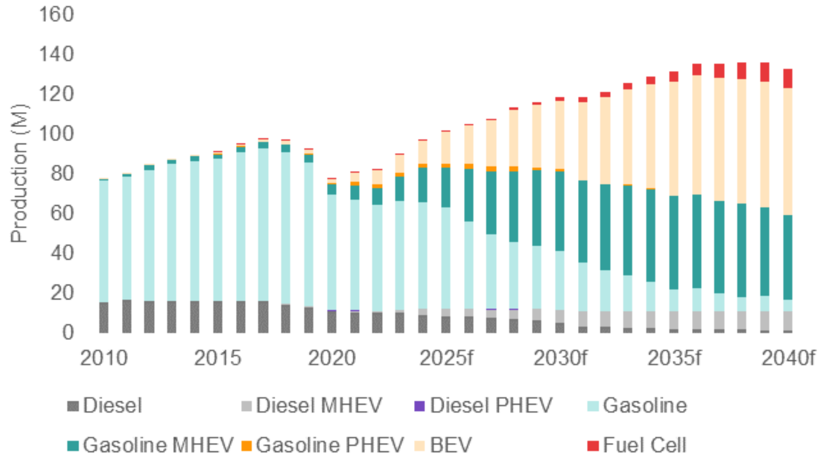
On a combined basis, any growth in total global vehicle production will be due to growth in BEVs, supplemented by FCEVs. We do not expect total ICE production numbers to ever return to pre-COVID levels, but we do expect ICEs to continue to be a major, albeit slowly declining, part of the drivetrain mix, with almost all ICE production transitioning to MHEV. In terms of ICE, the picture continues to be dominated by gasoline, although diesel remains an important fuel, for HD in particular. While the fall-out from 'Dieselgate' continues to stack sentiment against diesel, there is potential that a rational review of the relative pros and cons of petrol versus diesel could see a swing back towards diesel due to its 20% lower CO2 emissions, and because the NOX issue for new diesel vehicles has been solved by modern catalytic converters combined with on-road tailpipe emissions testing.

Global growth in vehicle production driven by BEVs and FCEVs

ICE to bounce-back from supply chain challenges but not to pre-COVID levels

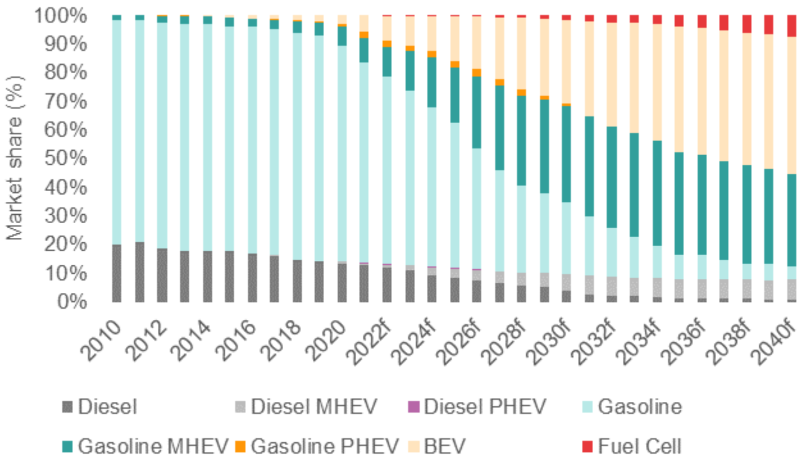
Potential for diesel to benefit over petrol due to 20% lower CO_2 emissions

Figure 9. Combined LV+LCV+HD production outlook by drivetrain



Source: OICA, ACEA, Bloomberg, WPIC Research

Figure 10. Combined LV+LCV+HD market share outlook by drivetrain



Source: OICA, ACEA, Bloomberg, WPIC Research

Platinum loadings per vehicle

Building a platinum demand outlook from our vehicle production and drivetrain outlook requires taking a view on platinum loadings. We have included the most recent standards introduced in 2021, but looking ahead have only included Euro 7/VII (+10% platinum loadings) and assumed the rest of the world stays broadly unchanged.

On a forward looking basis we assume loadings are unchanged from current estimated levels, increasing by 10% for Euro 7/VII

Diesel vehicle catalytic converters remain the largest component of platinum automotive demand and near-term platinum demand growth. However, despite the limited historic public data on substitution to date, our forward-looking inclusion of platinum substitution for palladium in gasoline vehicles further boosts medium-term platinum demand growth. This growth in platinum for palladium substitution in gasoline vehicles is directly linked to the use of the tri-metal catalysts first developed by BASF, in partnership with Impala Platinum and Sibanye-Stillwater, and now also offered by other catalyst manufacturers. Platinum substitution for palladium in 2022, included in our published 2022 forecast (Platinum Quarterly Q1, 2022), is estimated at 340 koz platinum. Using our forecast powertrain mix and conservative levels of substitution (when compared to public disclosures) we project that the portion of automotive platinum demand due to substitution will increase from 340 koz in 2022 to 739 koz in 2024 and 960 koz in 2026. Sibanye Stillwater expects substitution to reach 1.5 Moz per annum by 2024, more than twice the level of our more conservative forecast in that year.

We expect continued substitution of platinum for palladium in gasoline vehicles due to cost advantages as well as reducing Western reliance on Russian palladium

Using our forecast powertrain mix and conservative levels of substitution, when compared to public disclosures, we project that the portion of automotive platinum demand due to substitution will increase from 340 koz in 2022 to 739 koz in 2024 and 960 koz in 2026

Our model also incorporates variations in loadings by geography to account for different emission standards as well as variations in average engine capacities. Typically, we expect smaller engines in China and emerging markets, with larger engines and therefore higher platinum loadings in Western markets.

We include regional variations in engine size and loadings

We are not detailing our loadings here, but we are very happy to discuss the rationale behind our assumptions with anyone looking for additional information in this area.

Automotive demand for platinum

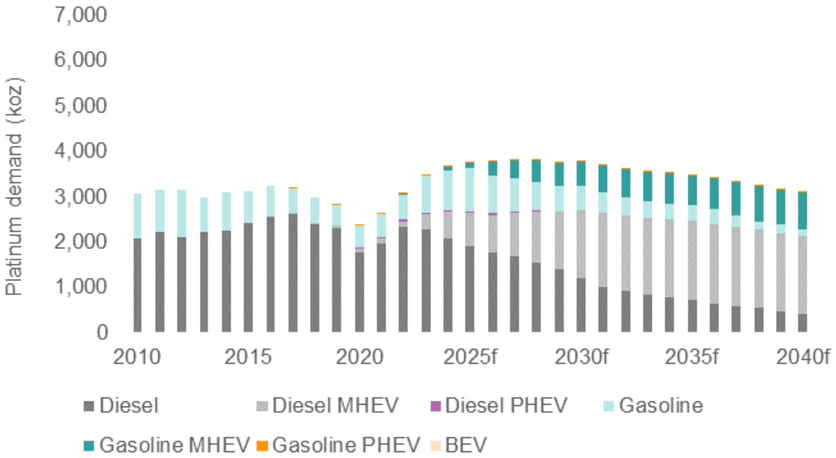
While our forecasts are for ICE production volumes to decline, in terms of automotive demand for platinum, we expect this to be more than offset in particular by platinum for palladium substitution in gasoline vehicles, as well as higher loadings due to tighter emissions standards.

Substitution and higher loadings to offset declining ICE production numbers

The net impact to automotive demand for platinum is that it increases from current levels (2022 3,055 koz), peaking in 2028 at 3,819 koz before declining thereafter. While the outlook is for a gradual erosion of automotive ICE platinum demand, we think that it will be much more sustained than most investors would expect without careful analysis given the current BEV zeitgeist.

The net impact to automotive demand for platinum is that it increases from current levels (2022 3,055 koz), peaking in 2028 at 3,819 koz before declining thereafter

Figure 11. ICE demand for platinum peaks in 2028

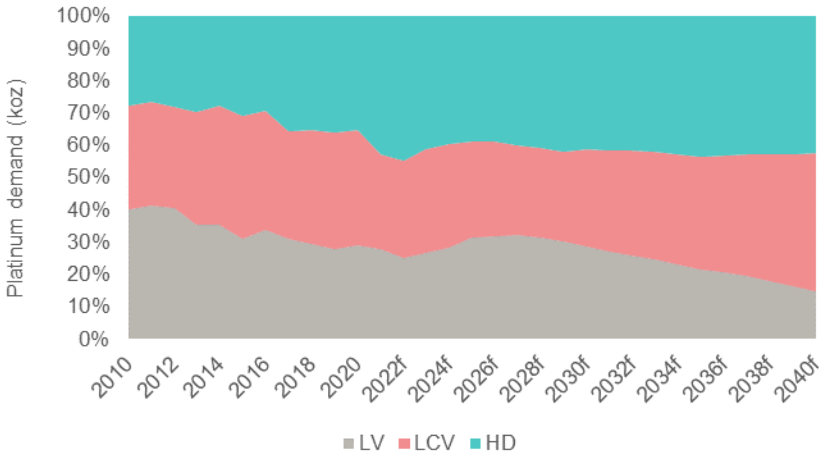


Source: OICA, ACEA, Bloomberg, WPIC Research

When considering the risks to this outlook, we note that 70% growing to 85% of automotive demand for platinum comes from the LCV and HD segments, which are comparably harder to electrify with battery technology and therefore less likely to see a rapid move away from ICE.

Automotive demand for platinum increasingly dominated by the harder to electrify LCV and HD segments

Figure 12. Automotive demand for platinum is dominated by the harder to electrify LCV and HD segments

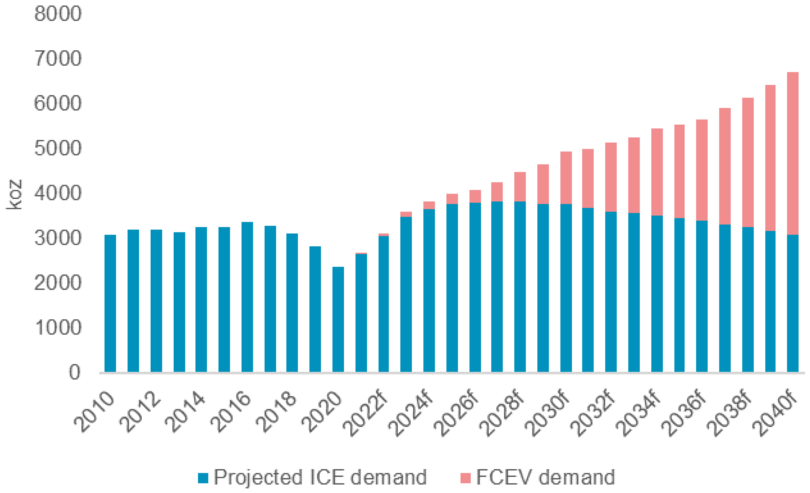


Source: OICA, ACEA, Bloomberg, WPIC Research

Added to the sustained platinum demand from ICE is the potential for FCEVs to become an important component of medium to longer-term electrification. Including FCEV demand for platinum results in sustained growth in demand to over 6 Moz by 2040. Note that this is only using the policy driven scenario put forward in our FCEV report, where government incentive programmes are the primary driver of FCEV uptake; including the broad-based commercial adoption scenario in the same report would boost this to over 6 Moz by 2033. We believe that Europe's plans to boost green hydrogen production are highly supportive of the commercial adoption scenario, at least in that geography. Please see our standalone FCEV report for more details.

FCEVs to play an important role in electrifying LCV and HD in particularly

Figure 13. Adding in FCEV results in sustained growth in automotive demand for platinum



Source: OICA, ACEA, Bloomberg, WPIC Research

Growth in automotive demand for platinum driven by FCEVs

Conclusions

While the electrification of the transport industry is undeniably essential to meet global emissions targets to minimise global temperature rise, our key conclusion is that not all vehicle roles or geographies are suitable for electrification with current technologies. Consequently, ICE vehicles will remain a material part of the drivetrain mix for the foreseeable future, albeit a gradually declining one and with increasing mild hybridisation. In combination with the latest emission standards which raise loadings, and in particular increased platinum for palladium substitution in gasoline vehicles, this results in ICE-related automotive demand for platinum peaking in 2028, with further platinum demand growth thereafter due to FCEVs. To put this into perspective, we project catalytic converter demand for platinum to peak at 3,819 koz in 2028, vs the 3,055 koz expected in 2022. When adding the platinum demand from the slowly growing FCEV volumes, we expect automotive demand for platinum to exceed 4,700 koz, in 2028, 60% higher than forecast automotive platinum demand in 2022.

Internal combustion engines (ICE) to remain a major albeit declining component of the drivetrain mix through the 2030's

Growth in vehicle production driven by battery electric vehicles (BEV) and fuel cell electric vehicles (FCEV)

Catalytic converter demand for platinum expected to peak at 3,819 koz in 2028, vs 3,055 koz expected in 2022

What does our outlook for automotive demand for platinum mean for the future platinum supply/demand balance beyond 2022? We intend to address this question in upcoming reports.

FCEVs drive platinum demand growth from late 2020s

WPIC aims to increase investment in platinum

World Platinum Investment Council (WPIC) was established by the leading South African PGM miners in 2014 to increase investment ownership in platinum. This is done through both actionable insights and targeted development within the platinum investment industry. We provide investors with the information to support informed decisions regarding platinum e.g. the *Platinum Quarterly* and monthly *Platinum Perspectives* and *Platinum Essentials*. We also analyse the platinum investment value chain by investor, product, channel and geography and work with partners to enhance market efficiency and increase the range of cost-effective products available to investors of all types.

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