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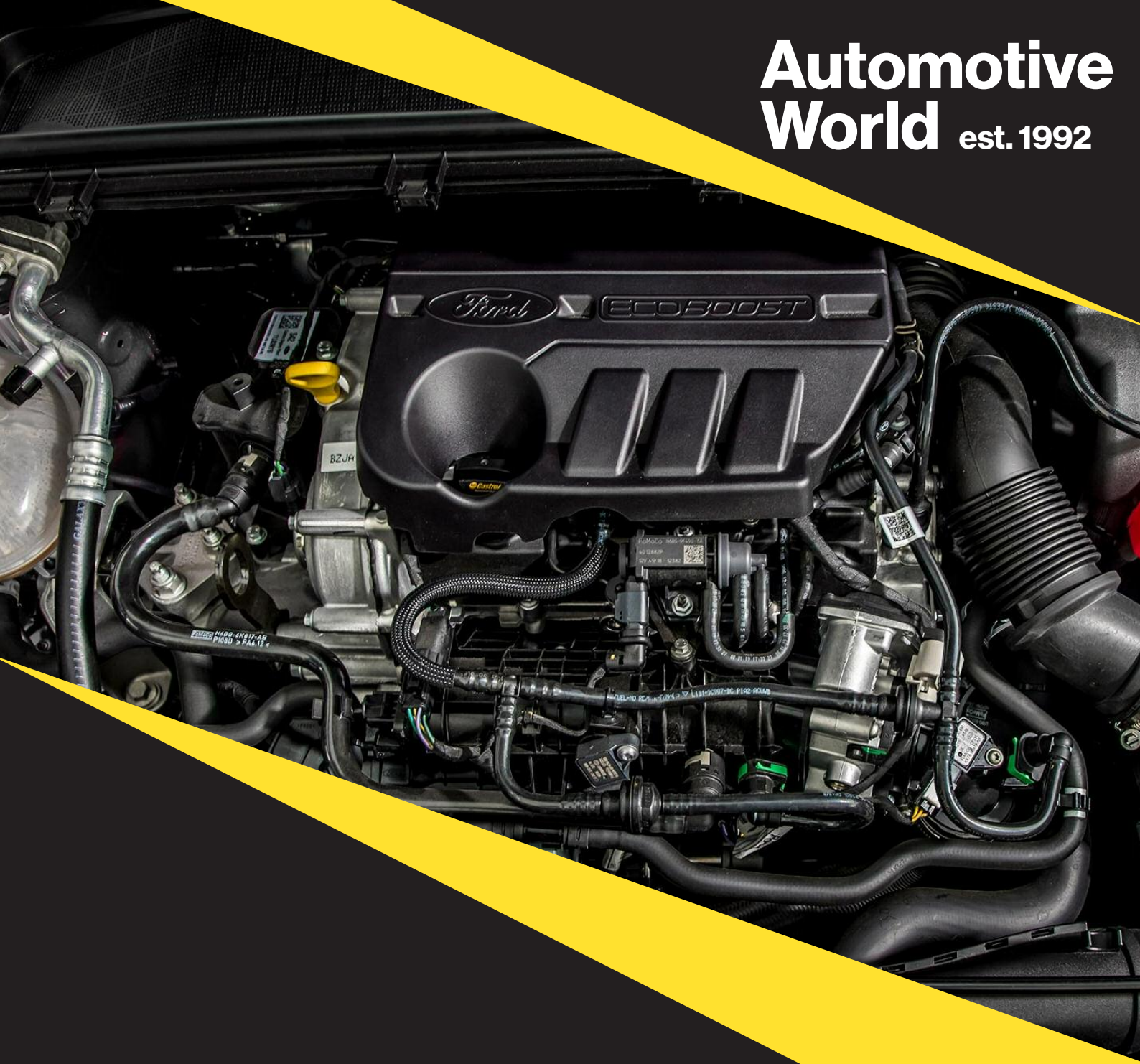

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Automotive World
1-3 Washington Buildings
Stanwell Road, Penarth,
CF64 2AD, UK

www.automotiveworld.com
T: +44 (0) 2920 707 021
support@automotiveworld.com

Registered number: 04242884
VAT number: GB 815 220 173

CEO & Managing Director:
Gareth Davies

Editor-in-Chief:
Martin Kahl

Contributors:

Sean O'Flynn
Freddie Holmes
Xavier Boucherat
Jack Hunsley

Production:
Anmol Mothy

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Executive summary

- Ever tighter emissions rules are increasing the pressure on automakers to abandon the fossil fuel-powered internal combustion engine (ICE) in favour of low and zero emission alternatives

- Future model ranges will include a growing proportion of electrified powertrains, from hybrid electric vehicles (HEVs) and plug-in hybrids (PHEVs) to pure battery electric vehicles (BEVs)

- Yet, while hybrids and BEVs make up a growing proportion of automakers' longer-term sales strategies, all hybrid and plug-in hybrid powertrains will contain an ICE of some kind

- According to AlixPartners, even by 2030, four in every five new light vehicle sales will rely on some form of ICE, meaning developments in combustion engine technology will be pivotal

- Automakers are actively preparing for the electrification; for example, every new Volvo car launched since 2019 will have an electric motor, and over the next five years, it will launch a fully electric car every year with a target of 50% all-electric sales globally by 2025. BMW has set itself a target of one million electrified vehicle sales by 2021

- Long-term, automakers are pouring resources into full electrification. BMW will offer at least 13 will be fully electric vehicles by 2023. In Europe, Honda will offer only electric and hybrid vehicles from 2022. GM has 20 full EVs planned for launch by 2023
- The ICE is likely to survive in the commercial vehicle space for many years. However, reliance on pure ICEs will fade quickly. Expect this decade to see increasing truck hybridisation, alongside a growing reliance on bio- and synthetic-fuels

- Suppliers face the challenge of continued development of the ICE, whilst also investing in expensive alternative propulsion systems with no clear early return-on-investment

- Suppliers that specialise in ICE components and systems could see orders cut in future as battery electric powertrains become more popular. In 2019, Continental said it would reduce investment in ICE development in response to the automakers' focus on EVs

- Even as the major markets ditch the ICE, it is likely to live on in other smaller markets. While Europe, China and North America may have the capital and regulatory interest to cut combustion from their diets, continued reliance on the ICE to enable performance at a reasonable cost will continue elsewhere

- Engine downsizing has likely reached its end–any smaller and automakers run the risk of adversely affecting the driving experience, emissions and fuel economy

- Biofuel compatibility with ICEs could provide a cleaner means of keeping traditional engines on the road. But only the development and rollout of second-generation biofuels (those that use waste products instead of edible foodstuffs) will ensure environmental benefits

- The mainstream ICE of the future will feature direct fuel injection, forced induction, lean combustion and electric motors

- Electrification is inevitable, and there is no viable future for mainstream vehicles powered by pure ICEs. However, according to AlixPartners, from being yesterday's technology, the ICE will play an integral role in helping automakers secure the return on investment they require to prosper in an ultimately all-electric future

An ICE-y road to an electric future

Everyone agrees the future is electric, but the medium-term strategic and commercial importance of the internal combustion engine must not be overlooked writes Sean O'Flynn

It is not news that electrified vehicles are in the ascendancy. By 2030, AlixPartners projects that battery electric vehicles (BEVs), plug-in hybrid electric vehicles (PHEVs) and hybrid electric vehicles (HEVs) together will comprise 44% of the overall global light vehicle market, up from only 5% in 2018.

This growth in electrified sales is vital. Major markets such as Europe have committed to strict average CO2 reductions from newly registered vehicles, with penalties for those who fail to meet them. In Europe, starting 2020, a range-wide average CO2 target of 95g/km comes into effect. Automakers who exceed this face fines of €95 per gram of CO2 over target, per car sold. The annual fines for some large brands could run into several billions.

But even an aggressive roll-out of BEVs will not be the complete answer to hitting these targets, which will quickly become even more aggressive. By 2025, a 15% reduction on the 2021 figure must be achieved. By 2030, this grows to a 37.5% reduction. This is an average target figure of less than 60g/km. Electric cars are important–but so too are lower CO2 versions of conventional ICEs.

The importance of ice

The strategic role, and inherent value, of the internal combustion engine (ICE) can be easily overlooked in the electric excitement. However, even by 2030, four in every five new light vehicle sales will still rely on an ICE in some form meaning developments in combustion engine technology will be pivotal in the decarbonisation strategy of automakers.

Yet to maintain an exciting, balanced and commercially viable portfolio of pure ICE and hybrid models, automakers must meet the challenge of recouping the rising costs of emissions-compliant ICE development. Compounding the challenge is the fact that they must balance this against a backdrop of shrinking model lifecycles that continue to be shortened by fast paced change in regulations and consumer preferences.

Sharing newly developed ICE technology across multiple vehicle platforms–and, most importantly, across hybrid platforms as well–helps to achieve this. By sharing ICE technology across both pure ICE and hybrid powertrains, automakers can achieve the higher volumes of sales needed to generate the necessary returns on engine investments and avoid scenarios of "stranded" powertrain investments. Automakers simply cannot keep producing ICEs without hybrids, and vice-versa.

We therefore expect hybridisation of ICE vehicles to accelerate, particularly with regular and 48V mild hybrid solutions. Hybrid electric is more affordable and more accessible than pure BEV or plug-in hybrid, and increasingly efficient.

> Between 2019 and 2023, the cost of electrification alone may be US$225bn, equal to the amount automakers already commit on capital expenditure and R&D in total

Nowhere is this more poignant than for mass market smaller vehicles such as B-sector superminis and C-sector family-sized hatchbacks, where hybrid is a more effective mainstream strategy to expensive BEV drivetrains. We hold the view that, from 2023, battery pack manufacturing costs are likely to hit the US$100/kWh level indicating the likely point of production cost parity with ICEs. However, this holds only for all light vehicles on average—it does not apply to smaller B and C segment vehicles where battery pack costs will need to drop further to reach a point of parity.

Due to this cost and accessibility gap, the ICE and hybrid will also remain the answer for years to come in the markets that automakers are relying on for future growth—major emerging markets across Asia, Middle East, Latin America and, eventually, Africa. Cost will remain king in these lower per capita income markets, keeping the ICE firmly in its dominant position.

At the other end of the value scale - and building heavily on technologies increasingly honed in motorsport - premium and high-performance manufacturers recognise the combined merits of hybrid technology to deliver not just efficiency and pace but crucially the mechanical engagement and driving attributes intrinsic to their brand values.

Hybridisation is not the only trend making a future involving ICEs seem more possible and palpable despite tightening emissions regulations. Developments in terms of catalysis and sustainable drop-in fuels have also shown promise for bringing the industry closer to a "net-zero" emissions reality. When these are combined with hybrid powertrains, it is clear the industry surrounding the ICE still has a few more tricks up its sleeve.

Batteries: threats and anxieties

The hurdles for mass adoption of electric vehicles are, however, arguably more involved and fundamental. Automakers face considerable challenges in the supply of raw materials for batteries. For example, with approximately 50% of the world's cobalt supply coming from a single country (Democratic Republic of Congo), the risks of supply chain bottlenecks and price fluctuations are significant. New reserves urgently need to be unearthed, given that there are also capacity constraints on nickel, another rare earth material used increasingly in today's batteries, to ease the strain on the cobalt supply chain.

Consumers have more real-world concerns. Despite rising BEV real-world ranges, consumer 'range anxiety' persists, driven by weak charging infrastructure development. New EV models are being rolled out faster than charging points can be installed and before viable business models and the correct mix of fast and ultra-fast chargers can be established in all major markets. Until this develops further, consumers will remain reluctant to commit to a BEV at the final point of purchase despite many claiming good intentions when surveyed about their propensity to buy BEVs.

Carrot and stick

Bans on the sale of new ICE vehicles are coming, but not yet. England and Wales have a goal of 2040 for the ban on sales of new ICE petrol and diesel vehicles. France is also targeting 2040.

> Far from being yesterday's technology, the ICE still has an integral role to play in helping automakers secure the ROI they require to prosper in an ultimately all-electric future

Other countries are more ambitious. Scotland is targeting 2032; Sweden and Denmark say 2030; and Norway, where electric vehicles are already approaching 50% of the new car market, has set its target as 2025.

Ahead of that, cities are proposing their own regional ban on fossil fuel vehicles. Others are focusing on ultra-low emissions zones, in which all but the cleanest gasoline and diesel cars are charged to travel within them. Consumers face a stick; where is the carrot?

Heavy-duty haven

For heavy-duty (HD) vehicles, the ICE will continue to dominate for at least the medium term (today, over 98% of European new trucks are diesel), as fitting so many batteries to effectively serve the required range would restrict both carrying capacity and payload.

Recharging would be inconvenient and the up-front cost of purchasing an electric heavy-duty vehicle would be prohibitive for many businesses, due to the raw battery cost. The immaturity of a second-hand marketplace for electric HD trucks also means the potential repair costs and effective management of depreciation and resale values represent uncharted territory for fleet operators and lessors.

A 'hub and spoke' solution for logistics companies is the most likely scenario. ICE heavy-duty vehicles will run long distances between hubs, where they are at their most efficient, with smaller electric commercial vehicles transporting loads from these hubs into those cities which place restrictions on ICE vehicles.

Bridging the profit desert

Electrification requires enormous investment by the automotive industry. This is in addition to investment in other technology, known as CASE: Connected, Autonomous, Shared, Electric. AlixPartners research has previously stated the automotive industry is likely to enter a 'profit desert' due to the massive investment required.

Between 2019 and 2023, the cost of electrification alone may be US$225bn, equal to the amount automakers already commit on capital expenditure and R&D in total. The need for such considerable investment may last for an extended period of time, potentially placing hundreds of thousands of jobs at risk.

Electric is the future, but the careful and deliberate evolution of the ICE is how automakers will get there. Progressive investment in transferable platform technology that can be shared across both regular ICE models and hybrids will help spread risk and generate faster returns as model life cycles shrink further. Far from being yesterday's technology, the ICE still has an integral role to play in helping automakers secure the ROI they require to prosper in an ultimately all-electric future.

About the author: Sean O'Flynn is a Managing Director in the Automotive practice at consultants AlixPartners

Kia sees ICE playing a key role in future mobility

Freddie Holmes speaks to Kia's Michael Winkler about the changing face of the internal combustion engine, and why it is far from extinction

With governments cracking down on harmful tailpipe emissions and global regulators enforcing strict CO2 reduction targets, the future of the internal combustion engine (ICE) has come into question. It is a conversation that has rolled on for years now, but the industry has recognised that the transition to zero emissions propulsion needs to pick up a notch.

In terms of next-generation propulsion technology, almost every major automaker today has placed its bets in one camp or another. Toyota has largely followed the hybridisation and fuel cell path; Renault has favoured battery electric vehicles (BEVs), while the Hyundai-Kia Automotive Group has spread its investments across a range of alternative powertrains. From pure ICEs, mild-hybrids and plug-in hybrids (PHEVs) to hydrogen fuel cell and BEVs, the South Korean conglomerate is flying the flag for going green. With all this in mind, is the death of the ICE just hearsay, or is now the moment to seriously consider its long-term position in the automotive industry?

"It is certainly the right time to talk about future mobility," says Michael Winkler, Head of Powertrain at Kia Europe. "The changes taking place in the industry are tremendous; BEVs are quite popular at the moment, and we have already industrialised fuel cell technology. But the subject of whether the ICE will be the powertrain of the future is not a question we are asking ourselves today–we asked this question years ago."

Meet the alternatives

Broadly speaking, battery electric appears to be the favoured zero-emissions approach. In November, the European Automobile Manufacturers' Association (ACEA) reported that third quarter BEV sales in the European Union had grown 126.3% year-over-year, while demand for PHEVs fell by 7.6%.

Albeit several years behind the Nissan Leaf, Kia was one of the first early-movers to introduce a mass-market EV. The Kia Soul EV launched in its home market back in 2014, and sales have since expanded across Europe and the US. Its flagship EV is now the e-Niro, which sits as a slightly more affordable alternative to the Tesla Model 3 with a real-world range of anywhere between 230 and 280 miles (370-450km). Sharing the same platform as the Hyundai Kona, both models have seen soaring demand; in the UK, for example, customers after the e-Niro will need to join a lengthy waiting list. "One clear direction for us is BEVs," said Winkler. "That is clearly a strong pillar of our future powertrain offering, but fuel cell and hybrids are other dominating elements."

The XCeed PHEV will join Kia's electrified range in 2020

Indeed, Hyundai-Kia has also made serious investments in hydrogen fuel cell technology. Its first fuel cell SUV was unveiled two decades ago in California, and the Kia Borrego concept was revealed at the LA Auto Show back in 2008, but did not make it to production. A handful of other models have followed since. The Nexo is Hyundai's latest fuel cell vehicle on offer, and replaces the ix35 FCEV. The manufacturer is targeting 10,000 Nexo sales in 2020–more than double 2019's total. Japan and South Korea appear to be the leading markets for hydrogen fuel cell adoption, although California is also something of a hydrogen hub in the US.

In January 2020, Hyundai-Kia invested €100m (US$111.6m) in UK-based EV firm Arrival to tap into the commercial vehicle market. Hyundai is already working in this space through the H2 initiative in Europe; 50 of its H2 XCIENT heavy-duty fuel cell trucks are due to be delivered in Switzerland this year.

The future of the ICE

These are all exciting developments, but the ICE will ultimately remain the powertrain of choice for most cars, and most drivers, for at least the next decade. With hybridisation such a core tenet of the brand's portfolio, and a welcome stepping-stone for customers yet to go fully electric, those ICEs are not going anywhere soon. "For the next ten years, maybe even longer, the combustion engine will still have a relevant role," affirmed Winkler.

Kia's current range of gasoline direct injection (GDI) engines underpin the vast majority of its portfolio today. While the company is promoting its eco-credentials, it has also taken steps to become more than just another mass-market brand; the Stinger sports saloon launched in 2017 as Kia's most powerful model yet, with gasoline and diesel engines ranging from 2.0 to 3.3 litres in size.

The 1.6-litre gasoline direct injection (GDI) engine too is seeing increased use as the automaker expands its plug-in hybrid range. Most recently, PHEV variants of the new XCeed and Ceed Sportswagon were launched. A mild hybrid version of the Sportage SUV, as well as hybrid and PHEV versions of the Niro, are also available. "The powertrain of the future is electrified, with a wide range of technologies in the market from 48-volt to high voltage hybrids and plug-ins, along with BEVs and fuel cells," noted Winkler. "Electrification will be the key topic for the next few years."

Size matters

At the other end of the market, its three-cylinder 1.0-litre GDI unit has been implemented across the portfolio, from the Picanto supermini to the new XCeed crossover. It is an example of how engine downsizing has enabled automakers to reach a point where even larger vehicles can become fuel efficient and low emission without sacrificing too much drivability. "Across the automotive industry, 1.0-litre and 1.2-litre engines have entered the C-segment quite well," noted Winkler.

However, he suggests that the trend of downsizing may have reached its conclusion. "I do not believe that the displacement volume can get any smaller in the future," he explained. "There is not a reasonable next step down from a three-cylinder 1.0-litre engine. I would say the direction of downsizing has achieved its base level."

From a technical perspective, a 1.0-litre engine typically has three cylinders. To downsize further would mean going to a two-cylinder engine, which makes things difficult for engineers from an NVH perspective and creating a 'smooth' drive. In addition, the specific load in the cylinder itself will be higher, which hurts fuel consumption when travelling at higher speeds.

"It makes sense at the moment to review the displacement volumes, and I think the right level of downsizing has at least been achieved," said Winkler. "In some cases, it may even make sense to 'rightsize' and consider a slight increase in the displacement volume."

On to a winner

Kia's strategy to cover such a broad spectrum of powertrain options means it is well placed to reap the rewards of growth in any of those

The 3.3 T-GDi engine found in the Stinger is Kia's most powerful car engine ever

The 1.0 T-GDi engine can even be found in the Stonic compact SUV

areas. Hedging its bets across hybrids, EVs and fuel cell means that the company is not blindly supporting what it hopes may be a winning solution.

> The combustion engine ultimately has a strong future, but in combination with electrification

Winkler is keen to underline that this is not a new strategy for Kia, as investments have been spread across the last couple of decades and more. Moving forward, he believes the company is in a good position to capitalise on any powertrain trends, regardless of the solution in question.

"We have not only developed them as part of a study, but have in fact industrialised the technologies for the market," he concluded. "That is why we believe we have a good starting position for the next few years–which remain uncertain–in order to react to customer needs. The combustion engine ultimately has a strong future, but in combination with electrification."

In January, the automaker unveiled 'Plan S', its new long-term strategy that will spearhead the move toward EVs. By the end of 2025, the plan is to have 11 BEVs in the model line up, and 500,000 annual EV sales by 2026.

How will the death of the ICE impact suppliers?

The end of the combustion engine may be decades away, but with such a large industry at stake what can be done to secure suppliers' futures? By Freddie Holmes

The automotive industry is entering one of the most significant periods of change in its history, as it slowly transitions away from diesel and gasoline internal combustion engines (ICE). It is not only automakers at threat, but also the diverse network of global suppliers that support them.

There is growing concern that businesses which specialise in ICE components and systems could see orders cut or cancelled entirely in future, with those contracts instead going to specialists in electrified powertrains. Such concerns would not have been soothed by suggestions that, with fewer components, battery electric powertrains could put workers out of a job. In December, *Bloomberg* found that automakers may need to cut around 80,000 jobs as EV production ramps up.

Waning demand for diesel cars has already impacted some plants involved in the production of diesel engines, with Bosch, ZF and Continental all warning of job cuts recently. "It will have an impact on employees, especially in the diesel plants," Bosch Chief Executive Volkmar Denner told German newspaper *Süddeutsche Zeitung* in August. According to the National Platform for the Future of Mobility (NPM), the transition toward e-mobility will not only affect the number of jobs available, but also the nature of that work. The trend is having "a larger and larger impact on employment structures," said Jörg Hofmann, Head of NPM's Working Group 4 and Chair of the German Industrial Union of Metalworkers.

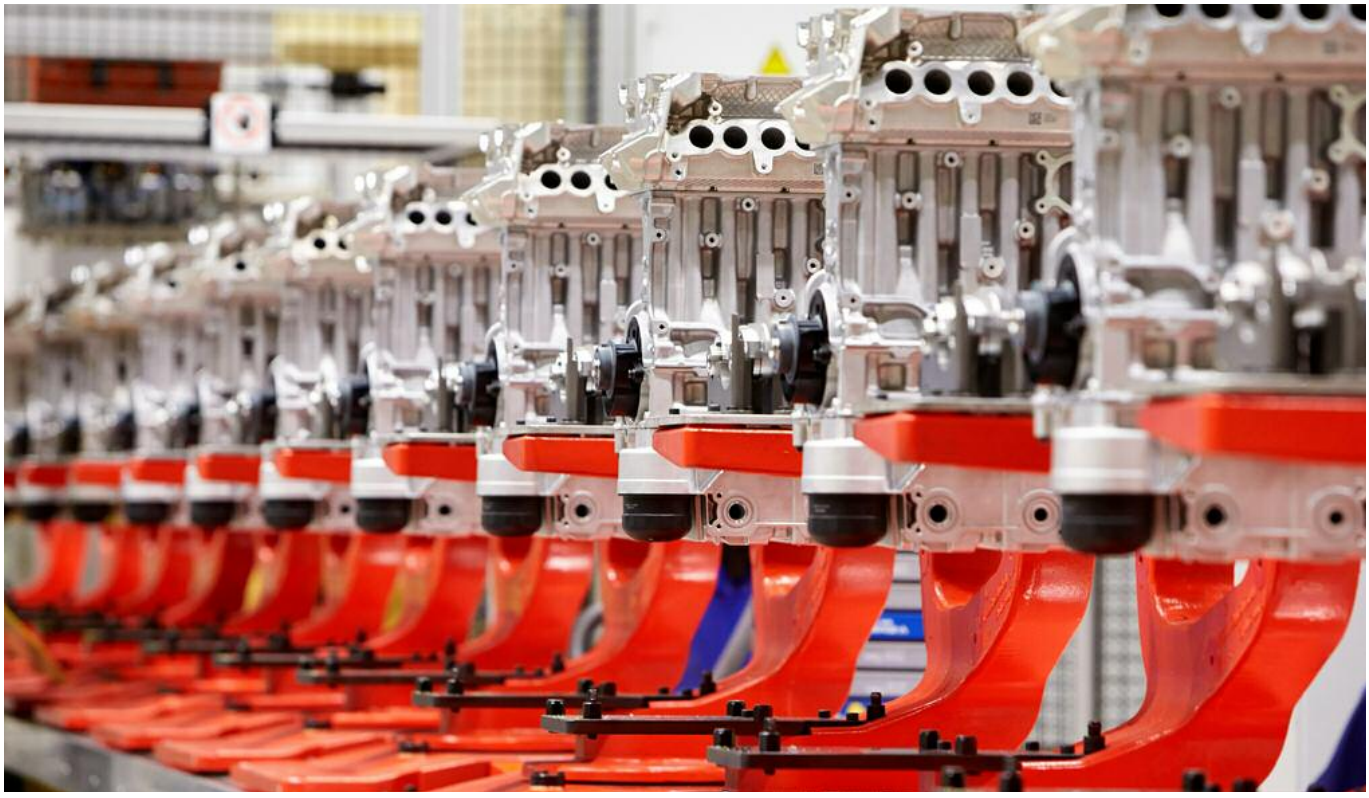
It begs the question: how will the death of the ICE impact today's suppliers?

Finding the right balance

This is a question that most of the major Tier 1s have already addressed, and have gradually reshaped their portfolios over the last decade at least. Nevertheless, the long-term challenge should not be understated; today's suppliers must continue developing a technology that will eventually be phased out, whilst also investing in expensive alternatives for which demand currently pales in comparison.

"Electrification requires high investments from all market players," said a spokesperson from Continental. "At the same time, regulations require advanced combustion engines with high efficiency and low emissions which meet real-drive-emission regulations. The challenge for all companies is to find the right balance."

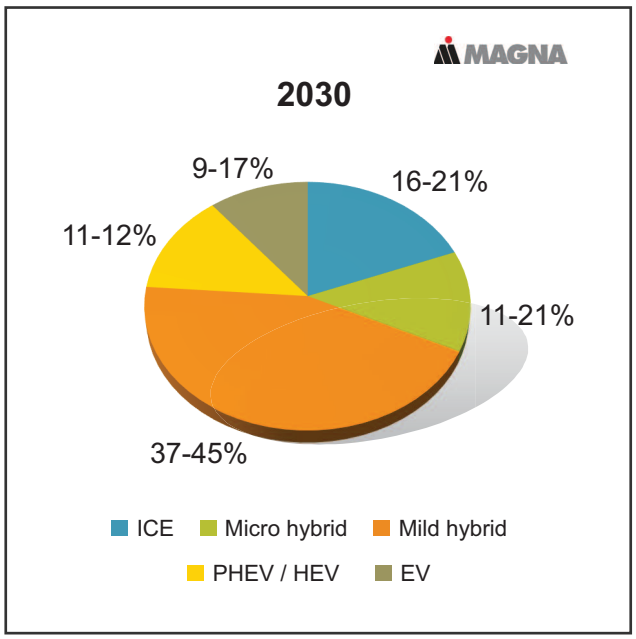
Sigrid de Vries, Secretary General of the European Association of Automotive Suppliers (CLEPA), suggested that the automotive industry is "undergoing the biggest



With fewer components, could battery electric powertrains put some workers out of a job?

transformation in over 100 years," with e-mobility "both an opportunity and a challenge for ICE suppliers, with competition getting tougher overall."

Despite the challenge, hybrid powertrains look set as the next big thing in the long run.



Tier 1 supplier Magna, which is heavily invested in the electrified powertrain, currently predicts that pure ICEs will account for just 16-21% of all powertrains by 2030. By comparison, mild hybrids are expected to take a 37-45% share of the market, with PHEVs and HEVs accounting for 11-12%. By the end of the decade, it predicts EVs will hold a 9-17% share of passenger car powertrains.

Clearly, this will influence how both technology and manufacturing investments are directed. New hybrid architecture, thermal management and power electronics will become key elements to the portfolio, and plants will need to be outfitted with the necessary tooling, robotics and workforce. "Manufacturers and suppliers are undertaking enormous efforts to bring advanced alternative drivetrain solutions to market," said de Vries. "In this context, it is expected that business revolving around combustion engines will decline, and this impacts investment decisions too."

Importantly, all of those hybrid powertrains still rely on an ICE; suppliers will not sit on

> Where it makes sense in terms of fuel efficiency, clean air and market volumes, further development of ICE technology will continue—but other parts of the business will be managed to shrink

their hands and let such a pivotal technology become outdated. "While electromobility is gaining traction, ZF estimates that at least 70% of all new passenger cars in 2030 will still have an internal combustion engine," said Stephan von Schuckmann, Head of ZF's Car Powertrain Technology Division.

"Where it makes sense in terms of fuel efficiency, clean air and market volumes, further development of ICE technology will continue–but other parts of the business will be managed to shrink," de Vries explained.

Sought-after specialists

But does powertrain electrification pose a threat to certain areas of the existing supply chain, or is it an opportunity for all involved to find new growth? Daniel Pokorny, Head of Corporate Communications, Future Trends at Schaeffler, pointed out that suppliers now play a greater role in the production of a new vehicle than ever.

"Automakers are increasingly expecting their suppliers to perform as system suppliers and are demanding complete systems of an ever-greater scope and complexity," he told *Automotive World*. "For suppliers with strong drivetrain expertise–suppliers like Schaeffler, which in recent years has made the transition from component to system supplier–this is an opportunity to offer a broader range of products and services."

Suppliers that have a broad and deep understanding of the complete drivetrain are in "high demand," he added. "Where once the demand was for clutches, torsion dampers and bearings for transmission systems, now it's for entire transmission units or drivetrains in all-electric vehicles."

As things stand, European suppliers are "well prepared" to handle increased demand for hybrid-electric powertrains, said de Vries. "The strong systems know-how in drivetrains makes them well positioned to deliver innovative solutions for e-mobility, as illustrated by uptake by major OEMs in this field," she explained. "Europeans are capitalising on essential competence in tooling, production, process insights–all needed to produce high-quality vehicles for mass-market use."

Highly advanced ICEs

Electrification may steal the headlines, but hybrid powertrains capture a negligible portion of the new car market today. The switch to zero emissions will not happen overnight and that means continued refinements to the ICE must continue where possible.

"By 2030, the ICE will still play a major role in the mobility sector because the majority of cars will be hybrids in all lead markets such as the EU, China and the US," noted Continental's spokesperson. The supplier envisions a highly advanced ICE by this point, which will draw on numerous means of reducing fuel consumption and emissions: direct injection, turbocharging, lean combustion and an increasing number of sensors, for example.

Particular emphasis will be placed on improving 'cold starts', where aftertreatment systems need to reach their optimum operating temperature to keep emissions low. With the engine in a hybrid vehicle frequently engaged and disengaged during a journey–perhaps even after a drive of 30 miles or more

in full electric mode–it is important to optimise those 'engine off' phases. "Adapted combustion methods will be implemented," said the Continental spokesperson. "The availability of recuperated electric energy allows for smart solutions like the electrically heated catalyst."

ZF's von Schuckmann noted that automakers are primarily concerned with being able to flexibly adapt hybrid versions to the "shifting sands" of changing market requirements. "To comply with stringent CO2 thresholds in the future, a substantial number of these vehicles will likely have an electric motor alongside the internal combustion engine," he told *Automotive World*. "By the end of the next decade, the hybrid drive is predicted to be a fixture in modern cityscapes, either as a modest electrically driven model with 48 volts or as a high-volt model with electric ranges of up to 100km."

Too big, too small, or just right?

Over the last couple of decades, automakers have also taken steps to reduce the size of their engines–even for models that are geared toward performance and driving experience. The industry is at a point where even 1.0-litre engines can be found in SUVs. Can the trend continue–and if not, what is next?

> "Where once the demand was for clutches, torsion dampers and bearings for transmission systems, now it's for entire transmission units or drivetrains in all-electric vehicles

> "The combustion engine is not old tech and it has an important contribution to make for the transition, globally

By 2030, Continental expects that combustion engines will remain downsized, with losses in power and dynamics 'compensated' by the high torque of electric motors. Others in the industry suggest engine size may increase slightly in relation to the size of the vehicle in question. "Both downsizing and 'rightsizing' will continue in response to the ever stricter CO2 targets, as well as the ever-increasing performance that innovation and new technologies offer," said CLEPA's de Vries. "Downsizing can be seen as a 'flexible rightsizing', which means a smaller engine but with the same power and torque–in case it is required–without carrying around a large engine unnecessarily."

Echoing other views held by industry stakeholders, CLEPA is also advocating for synthetic fuels, which "deserve a place in the decarbonisation mix"–along with hydrogen fuel cell powertrains. "Mobility and transportation needs are highly diverse and this is not likely to change any time soon. The combustion engine is not old tech and it has an important contribution to make for the transition, globally," de Vries concluded. "The BEV is a great solution, but not the only one."

Automotive suppliers are businesses first and foremost, and must support the needs of their automaker customers as they evolve. How rapidly the ICE evolution will become apparent over the coming years, but suppliers reliant on diesel and gasoline alone must consider diversifying sooner rather than later.

Biofuel could give new life to the ICE, but scale is a challenge

Alternative fuels have long promised greener transportation, yet remain dogged by controversy. Shell believes change is on the way, potentially adding several years of life to the ICE. By Xavier Boucherat

The automotive industry has spent the better part of a century refining internal combustion engine (ICE) technology: it is difficult to overstate just how advanced the modern powertrain is. When one considers the millions of man-hours and the billions of dollars that have been poured into propelling cars via controlled explosions, along with the worldwide network of supporting infrastructure, it's easy to understand why the industry has proven unenthusiastic about moving on.

In an ideal world, cleaning up transport would not involve consigning gasoline and diesel ICEs to history, and through the years, the biofuel and synthetic fuel sectors have attempted to uncover ways to leverage the same, long-established technologies used today. Proponents argue that through blending biofuel and synthetic fuel with traditional fuels, or through direct replacement, automakers can achieve lower emissions at the pipe and contribute to reducing emissions in production.

Biofuel refers to any fuel produced using biomass or organic matter, including foodstuffs and agricultural waste. Such fuels emit less carbon dioxide, and Shell estimates that they now represent 3% of road transport fuels in use. Over the last ten years, biofuel development has focused on moving away from use of edible crops such as sugarcane, maize and wheat–used to produce ethanol–to inedible foodstuffs and products including waste oils and municipal solid waste. This improves sustainability by addressing the 'food versus fuel' debate often associated with biofuels, at a time when populations are growing.

Whether biofuels really deliver on their green credentials has come under fire on multiple occasions through the years. A 2016 study by the University of Michigan, for example, found that the corn ethanol production in the US was resulting in more greenhouse gas emissions than the fuels they are meant to replace. Meanwhile, biodiesel remains highly controversial for its extensive use of palm oil, requiring mass deforestation: January 2020 saw Italian oil company Eni fined €5m (US$5.5m) by regulators for claiming its Eni Diesel+ product has a positive impact on the environment, failing to mention the indirect emissions associated with palm oil use.

> Proponents argue that through blending biofuel and synthetic fuel with traditional fuels, or through direct replacement, automakers can achieve lower emissions at the pipe and contribute to reduce emissions in production

The European Federation for Transport and Environment welcomed this move, having previously expressed concerns that biofuels have created 'greenwashing' opportunities for the fossil fuel industry. Yet policy still rests in favour of biofuel use. In the US, the Environmental Protection Agency (EPA) announced in October 2019 that it would require 15 billion gallons of ethanol to be blended into the country's fuel supply. Meanwhile, a collation of vehicle manufacturers and alternative fuel producers in Europe has called on the EU for consistency on what constitutes fuels that will play a role in the Green Deal transition to clean energy. A technology-neutral approach, says the group, is essential.

> Whether biofuels really deliver on their green credentials has come under fire on multiple occasions through the years

Keeping the forecourts open

Scott Bailey, Chief Executive of ICE technology company Tula, agrees that whilst the picture is complicated, there is surely a future for alternative fuel use. "The objective must be to effectively eliminate all harmful emissions associated with transportation," he says, "and continuing to use fossil fuels in any part of the energy generation or conversion process is at odds with that goal. Methods that eliminate the total life-cycle production of CO2 emissions at the tailpipe, at the refinery, or even the fertiliser plant, are key."

Crucially, he says, compatibility with ICEs is a step that can be taken today, ahead of the mainstream roll-out of electric vehicles (EVs) which remains some time out. "Conventional energy companies as well as start-ups are putting tremendous effort into developing clean, alternative fuels," he points out. "It's difficult to predict what advances will shape the future 50 or 100 years from now, but certainly in 20 to 30 years, our future will still have clean, efficient ICEs, especially if alternative fuels can be produced cost-effectively at scale. And given the timeframes required to fully transition to electric propulsion, there is ample lead time for significant progress on alternative fuels."

Beyond the hype, he suggests, the benefits are manifold: use of existing fuel distribution infrastructure is one, but on the vehicle manufacturing side, increased biofuel use could help answer some of the big questions

> Over the last ten years, biofuel development has focused on moving away from use of edible crops such as sugarcane, maize and wheat—used to produce ethanol—to inedible foodstuffs and products including waste oils and municipal solid waste

posed by the limitations of today's batteries. These include the packaging and complexity challenges posed by hybrid vehicles, as well as the environmental concerns currently related to mining materials for use in batteries and end-of-life recycling.

The big time

Bailey is correct to point out the interest from the traditional oil-giants. Shell, for example, is adamant that fossil-fuel dependency will lessen in the years ahead, and that over time, its main revenue sources will change. Charging for EVs, and hydrogen fuel for fuel-cell vehicles, will become major pillars, but a role for biofuels is also guaranteed, says the company.

Wolfgang Warnecke, Chief Mobility Scientist at Shell, believes change could be on the way for alternative fuel use. Currently in the EU, biofuels can be blended up to a limit of 7%, to prevent engine damage and to stop food prices going up. This could change with second-generation biofuels, which, as Warnecke notes, can be produced in greater quantities. But the production process is yet to be perfected, and abundant, green fuel via existing infrastructure remains a pipedream.

Biofuels could prove particularly suitable for the commercial vehicle sector. "For commercial road transport, we expect ICEs to retain a dominant position in certain regions for some time, simply because of how transport infrastructure, roads and filling stations have been designed to support them," experts from Shell Rimula told *Automotive World*.

Diversification of fleet powertrains has already begun, and companies are investing and experimenting accordingly. Shell is already one of the largest biofuel blenders, having started large-scale production in 2011 in Brazil. Here, research into advanced biofuels using sugar-cane residues continues. Meanwhile, at the Shell Technology Centre in Bangalore, the IH2 demonstration plant can turn non-food waste like wood and municipal waste into transport fuel.

In March 2019, it began a pilot program with Maxim's, a restaurant group in Hong Kong, to power its fleet of 100 trucks, which consumes some 396,000 litres of fuel a year. Waste cooking oil is used to produce a biodiesel product. Shell also operates three biodiesel fuelling stations in the region. More recently, the company invested in Indian biomass-energy company Punjab Renewable Energy Systems, which is hoping to position itself as a key biomass supply chain manager.

All this said, the technology is yet to be demonstrated at scale, and moving forward, Shell Rimula stressed that the ongoing development of diesel engine efficiency, along with low-sulphur and low-viscosity oils, will be essential for meeting short term targets.

"The adoption of greener powertrain technologies can only be accelerated if we are equipped with sufficient infrastructure to support them," says the company. For biofuels, this will mean improved distribution networks, higher blend rates and more sustainable sources of production that do not impede on land usage or food availability. All of this suggests an extended life for the ICE, which will run regardless of biofuel content.

Hybrids will keep combustion engines relevant 'for the foreseeable future'

Confidence in hybrid demand is high. Automakers offering a growing range of hybrid options assures a place for the ICE, although not the dominant spot it's always had.
By Xavier Boucherat

The automotive industry's public-facing message is clear: the future is electric. It would appear consumers agree. A 2019 study from Volvo found that 74% of Americans polled believe the upfront cost of battery-electric vehicles (EV) could be outweighed by savings at the pump, and 59% believe that they could deliver a positive environmental impact.

> "I'm confident that our latest generation of PHEVs show the great potential of this technology, and a valid proofpoint that this is much more than just a short-term bridging technology, sometimes called a 'compromise'

Yet the fact remains that in terms of efficiency and convenience, battery technology lags behind that of internal combustion engine (ICE) counterparts. Range anxiety remains a major concern, and the same study from Volvo showed that EVs are still associated with inconvenience. More than one-third of those polled said that the experience of using a public charging station was time-consuming.

As such, there is no sudden jump to battery-electric on the horizon, and hybrids remain an essential part of most automakers' strategies. Indeed, some remain a little sceptical of the pure EV agenda. Honda Chief Executive Takahiro Hachigo recently publicly questioned whether demand for full EVs would experience a dramatic increase any time soon, with infrastructure and technology limitations restricting true potential for growth. R&D on full EVs will continue, he added, but hybrids will play a critical role moving forward.

Whilst the imposition of stricter emissions regulations in markets worldwide means that time is limited for pure ICEs, this by no means sounds the death knell for engines. Indeed, the years to come could prove an exciting and transformative time for the technology, as automakers and other industry stakeholders innovate to optimise ICE use in hybrid variations.

State of play

Hybrids and their production may not grab the same headlines as their pure electric counterparts, but developments continue apace. One of the most recent announcements came from Ford, which in January 2020 unveiled plans to invest €42m (US$46.6m) in its Valencia, Spain facility. Along with tooling for the S-MAX Hybrid and Galaxy Hybrid models, a new, two-line battery assembly facility will be built to supply the vehicles. Ford of Europe President Stuart Rowley said that by the end of 2022, the manufacturer expects most passenger vehicle sales to be electrified.

> “The Golf remains the best-selling vehicle in Europe, with over 427,000 units sold in 2019. The shift to mild hybrid comes ahead of the launch of the all-electric ID 3 which, whilst important, will almost certainly lag behind in sales

Elsewhere on the continent, Volkswagen Group is gearing up for a 2020 launch schedule that will include eight full EVs and hybrids across all brands. Critically, this will include the eighth-generation Golf, which features the mild hybrid e-TSI engine. The Golf remains the best-selling vehicle in Europe, with over 427,000 units sold in 2019. The shift comes ahead of the launch of the all-electric ID 3 which, whilst important, will almost certainly lag behind in sales. Interestingly, however, plans to put the e-TSI in the 2020 Golf GTI have been reversed, and the popular variant will continue to rely on ICE technology alone. Long-term, the company has plans for 60 hybrids, along with 75 full EVs, by the end of 2029.

Automaker focus in the US continues to shift from sedans and compacts to SUVs and trucks, yet hybridisation remains an equally prevalent trend. Toyota’s ongoing success in the market is such that last year, despite a year-on-year drop in overall numbers for 2019, it sold over 274,000 hybrids–more than the total number of full EVs sold by all manufacturers combined–including 92,500 RAV4 SUVs, the latter representing year-on-year growth of over 92%. Meanwhile, FCA continues to shy away from the type of commitment to pure EVs seen from GM by pouring investment into hybrid production. By the end of 2021, plug-in hybrid electric (PHEV) versions of the Jeep Grand Cherokee, Wrangler and Wagoneer are all slated to have gone into production.

Ford, too, has expressed commitments to PHEVs, whilst General Motors has outed itself as the dissenting voice among the big three. Speaking in August 2019, President Mark Reuss told the Wall Street Journal that hybrids only represented a temporary solution when, in the long run, zero-emission would become the requirement. Investments, he added, must be spent on developing the real solution quicker and better than anyone else could.

So whilst hybrid portfolios are healthy, there are already some differences of opinion. Just how much time do they buy the ICE? And how do automakers square continued ICE use at a time of climate crisis, when greener transport has never been so strongly pushed for by both regulators and society?

In the family

Dr Torsten Eder is Vice President Product Group Drivetrain at Mercedes-Benz. As he explains, hybrids are going to play a big role in helping the company achieve its ambitions for sustainability. “It is obvious that CO2 emission limits worldwide can only be met with

electrification," he says. "It means that electrified alternatives will be available in every segment, from smart cars to large SUVs.

"By 2039, our ambition is to be a complete CO2-neutral new passenger car fleet," he continues. This will involve a future for the ICE, specifically the automaker's Family of Modular Engines (FAME), the latest iterations of which are being rolled out through the portfolio. Modularity will enable scaling for solutions like EQ Boost, a 48V option, and EQ Power, a PHEV option. The latter is gaining momentum, with plans to offer PHEV choices for more than 20 model variants by the end of 2020.

Battery-powered ranges on PHEV models like the GLE, says Eder, can reach up to 100 kilometres (62 miles), more than adequate for many commutes. For this reason, he suggests, hybrids will have better staying power than some might suspect: "I'm confident that our latest generation of PHEVs shows the great potential of this technology, and a valid proofpoint that this is much more than just a short-term bridging technology, sometimes called a 'compromise'."

The brand wants to electrify its entire range by 2022, joining the likes of Volvo in phasing out pure ICEs. "We are convinced that with this mix of driver systems, we can offer customers worldwide the right vehicle, meeting a variety of needs," affirms Eder. Uniquely, he points out, Mercedes-Benz is the only premium manufacturer currently offering a diesel-based PHEV. But what does the evolution of hybrids mean for the ICE itself, and how might it change?

Complex animals

Scott Bailey is Chief Executive at Tula, a Silicon Valley-based company specialising in ICE optimisation through cylinder deactivation technology called Dynamic Skip Fire (DSF). The company works with the likes of GM and Delphi, and claims its technology can boost fuel efficiency by between 7% and 15%. Bailey believes there is every reason to expect continued growth in hybrid propulsion systems; however, they do create challenges for automakers.

Cost is the most obvious: two powertrains are more expensive than one. "Whilst a simpler, and therefore cheaper ICE, can potentially be used, there are still electric motors, batteries and inverters that need to be added and packaged," he says. In addition, added system complexity brings bigger reliability issues and bigger challenges around system optimisation and calibration. "This consumes engineering resources and capital at a time when automakers are already increasing electrification across their platforms, implementing ADAS and converting their product portfolios to more crossovers and SUVs.

"From a functional standpoint," he continues, "it is a challenge for automakers to design and calibrate hybrid vehicles to simultaneously operate continuously at optimal efficiency, while maintaining the ability to transition immediately to significant changes in the driver's demand for torque and power." One solution is to boost battery capacity and enable greater electric-only ranges, but efficiency improvements for the ICE remain to be explored, he insists. DSF is one example, he adds, allowing displacement of 40 to 200 times every second. More broadly however, he believes that an out-of-the-box mindset could birth further innovations for ICEs, both gasoline and diesel. Machine learning strategies and e-machine controls could yield further optimisation, he says.

Whilst few are now questioning the EV's place in the transport mix, he concludes, the major markets will remain dependent on the ICE. It is not just a question of technology: regulations, fuel prices, population densities and range requirements all play equally important roles in deciding which powertrains are acceptable, and which are not. "Hybrids are expected to have the broadest applicability across global markets and a wide variety of use cases," he says, "and therefore should dominate for the foreseeable future." The ICE stays, but whether or not it will be recognisable in 20 or 30 years is a different question.

Synthetic fuel and hybridisation key to extended ICE lifespan

Electric may be the future, but the ICE can still yield significant emissions gains through synthetic fuels and electrification. By Jack Hunsley

The consensus might be that the long-term future for mobility is electric, but getting to this future will be no easy feat. Electric vehicle (EV) sales may, on paper, be exploding–Statista figures show that in the UK around 230,000 ultra low emission vehicles were licensed by the end of 2019 compared to just 1,481 in 2010–but these sales are still dwarfed by traditional fossil fuel vehicles.

In fact, also in the UK in 2019, according to the SMMT (Society of Motor Manufacturers and Traders), the average CO2 emissions of cars sold rose for the third year in succession. With an average CO2 measurement of 127.9g per kilometre, the figure marked a 2.7% year-on-year increase that also flouted the European Union's newly introduced target of 95g per kilometre. With wide-scale EV adoption still years away, there remains huge potential in continued internal combustion engine (ICE) improvements.

Where are the gains?

Several areas in the ICE could yield gains the industry needs, particularly in reducing friction, pumping and heat efficiency losses. As Richard Osborne, Ricardo's Global Technical Expert in Gasoline Combustion explained, of these three categories the biggest potential lies in the latter.

> "One way in which the ICE lifespan should be extended is looking at more renewable and sustainable fuels

"Heat loss is the one area where we still have many opportunities to tackle," said Osborne. "That includes the dilution technologies such as EGR (exhaust gas recirculation) and lean-burn operation, but it also includes the more subtle aspects of engine development: compression ratio, bore-to-stroke ratio, insulation of different parts of the engine and so on. Tackling the thermodynamic efficiency, as we would call it, is the biggest opportunity."

How quickly these improvements can be implemented varies. Chasing reductions in friction, for example, is a continuous process

> Tackling the thermodynamic efficiency, as we would call it, is the biggest opportunity

that can be driven largely by using different coatings, materials and designs. Larger step changes, such as those surrounding EGR improvements, for example, have a much longer timescale–three to four years, according to Osborne.

Differences also crop up when contrasting passenger vehicle and commercial vehicle development. As Osborne detailed, while Ricardo is looking at passenger car ICE brake thermal efficiency improvements from around 40% today to 45% or even as high as 50% across the next decade, "for larger engines further improvements in thermal efficiency are possible."

"As we progress ICEs past 50% efficiency towards 60%, which is perhaps slightly easier for larger engines, then these sort of engines are also much more competitive against EVs and fuel cells on an efficiency basis," added Phillip Hopwood, Head of Engine and Emissions Control Products at Ricardo. "We need to continue to focus on efficiency achieved at a low cost to keep the ICE's current benefits against some of the battery and EV competition; that's true for all engine segments."

A move to hybrids

Potential may still lie in pure ICE development, but it is becoming increasingly difficult to ignore the potential for electrification, particularly with hybrids, to accelerate efficiency progress even more quickly. This also applies to the proposed thermodynamic gains. "Hybrid powertrains allow us to potentially reduce the operating range of our engines, and that allows us to improve," added Osborne. "A typical ICE runs over a very wide speed range, and also a very wide load range. If we narrow those ranges, then we can focus on improving thermal efficiency quite fundamentally. We can also potentially take some cost out of the engine, because some of these variable systems that we use are not needed as much."

For the European passenger car market in particular, developing a hybrid future is becoming increasingly attractive. Countries such as Norway, which will ban the registration of pure ICE vehicles in 2025, will be looking to forcibly phase out ICE vehicles across the next ten to 20 years. Even if there remain theoretical ICE gains to be made, soon the business model for pure ICE development is likely to fade.

"For Europe, hybridisation–including micro and mild hybrids–will probably be nearly universal by the end of this decade. That is a European focus," said Osborne. "In other markets, the answer is probably slightly different, but for Europeans, the future is hybrids in a range of forms."

Getting synthetic to work

Another route to prolonging the ICE's lifespan is to change the fuel it burns. As efforts continue to reduce the harmful emissions of gasoline and diesel engines, the industry is also hard at work exploring cleaner alternative fuels that could be added to the current fuel mix.

"One way in which the ICE lifespan should be extended is looking at more renewable and sustainable fuels–defossilised liquid fuels, whether that's from biosources, fully synthetic electro fuels or e-fuels," said Osborne. "The important point about those is that they apply to all of the vehicles that are already out there."

Indeed, as Audi detailed to *Automotive World* in August 2019, the automaker expects "a considerable part of the fuel pumped at a station" to be made up by synthetic fuels by 2029. As Otten Reinhard, Consultant Strategy Sustainable Product Development at the automaker detailed, this will be prefaced by a rapid production scale-up. "We will need five to ten years to push this big industrialisation effort and then the curve will go up very rapidly around 2027," he said. "It will not be a 50% fossil fuel-synthetic fuel mixture by 2030, maybe around 20%. But I think it is possible to have a complete substitution of fossil fuels after 2040."

The potential might be clear and the industry may have begun dabbling in this field already, but exactly why these fuels have not yet made it to the mainstream is more difficult to pin down. "I think it is partly a policy question," said Osborne. "The policymakers have been very focused on one solution, which is battery electric vehicles (BEVs). Regulatory approaches are also very focused on tailpipe CO2 emissions so that they heavily favour EV or plug in hybrid electric vehicles (PHEVs). Everyone knows that we need to move to address well-to-wheel carbon emissions and life cycle assessment, but it's easier said than done in policy terms."

As Osborne continued, there are also technical challenges to overcome. While these fuels may have been successful in small scale trials, ramping up production and distribution is another challenge entirely. "At the moment the energy requirements are quite high, so there are process improvements needed there. But a mix of biosources and liquid e-fuels is what we need," he added. "We need the kind of policy approaches that encourage those, as well as EVs."

Market outlook

Continued efficiency improvements may paint a better picture for the ICE but with more city ICE bans and low emission zones likely to be put into place over the next decade, exactly how well the pure ICE can compete with PHEVs and BEVs going forward is up for debate. It might still be able to retain market share outside of city centres, but there is no clear indication as to exactly how long it can maintain its position as the leading powertrain technology.

> "As we progress ICEs past 50% efficiency towards 60%, which is perhaps slightly easier on a larger engine scale, then these sort of engines are also much more competitive against EVs and fuel cells on an efficiency basis

"We're still expecting around 80% of vehicles to have an ICE of some sort by 2030, but a large proportion of those will be hybridised to various extents," said Osborne. "Certainly the lifespan is going to extend well beyond 2030, and that's the European market, so that proportion is likely to be even bigger as we look at the world markets and we look at different segments. There are around 900 million passenger cars currently circulating on the planet, and that's going to continue to increase."

"It will depend very much on the customer's vehicle usage, but ICEs certainly have some compelling attributes that customers are used to, which include usability, convenience and range," added Hopwood. "EVs have a different set of attributes, so it will be interesting to see how automakers work with customers to help them select the best vehicle for their usage. In many cases, they're not directly comparable."

Hybrids a lifeline for truck ICE as electrification accelerates

With stringent industry-wide and local emission regulations coming into force this decade, hybrids offer the internal combustion engine a chance to hold on. By Jack Hunsley

The internal combustion engine (ICE) has been a core tenet of the commercial vehicle sector for decades. With these bulky, heavy vehicles expected to drag sizeable loads over long distances, it has proven challenging for any other technology to compete effectively with the power density offered by the ICE. However, that might not be the case for much longer.

As calls to cut carbon emissions globally build momentum, and technologies such as battery electric vehicles (BEVs) and fuel cell mature, the question is no longer if, but when the ICE will be forced to abdicate. For passenger cars, that transition could happen sooner rather than later, but for larger commercial vehicles the challenge is much greater.

No one answer

The key caveat for the commercial vehicle sector is that the far broader range of vehicle types leaves more room for the ICE to survive. Light-duty commercial vehicles designed for inner-city streets may, through choice or force, soon opt for cleaner powertrain technology, but the difficulties in electrifying heavy-duty long haul trucks in both a cost and performance-effective manner is a much larger task.

Problems also arise from the lack of associated supporting infrastructure. “It will take time before we have other alternatives to combustion engines in all segments,” said Lars Mårtensson, Environment and Innovation Director at Volvo Trucks. “That is partially due to the profitability of certain technologies, but it is also influenced by societal factors.”

These factors can include anything from grid capacity to a lack of charging infrastructure. The major automotive markets may have already taken huge steps towards preparing grids for future mobility energy demand, but outside of these key locations the combustion engine and diesel fuel are likely to remain the dominant force for decades yet. “We are a little disappointed in most countries that the focus so far has been on supporting increasing infrastructure for light duty cars,” added Mårtensson. “It seems to have been forgotten that heavier vehicles need rapid growth in terms of charging infrastructure too.”

Chasing continued efficiency gains under the hood of these heavier vehicles, therefore, remains an attractive prospect. This applies both to pure ICE products, as well as efforts to electrify today’s engines with hybridisation. “As ICEs move past 50% efficiency and towards 60%, which is perhaps slightly easier on a

> We need to continue to focus on efficiency achieved at a low cost to keep the ICE's current benefits against some of the EV competition; that's true for all engine segments

larger engine, they will become much more competitive against electric vehicles (EVs) and fuel cells on an efficiency basis," said Phillip Hopwood, Head of Engine and Emissions Control Products at Ricardo. "We need to continue to focus on efficiency achieved at a low cost to keep the ICE's current benefits against some of the EV competition; that's true for all engine segments."

These efficiency gains are likely to come from limiting friction, pumping and heat losses in the ICE. However, there is also potential to gain percentage points through additional software and turbocharging. "The ICE is a very mature product, but you can tweak the combustion chambers or the turbocharging systems a little and you can improve the fuel economy through smart software and transition controls as well," added Björn Westman, Head of Engine Development at Scania. "There are also bigger gains when you are investing in larger components such as the engine block itself."

A future-proof solution

Continued ICE development may have value, but as this decade progresses the odds are that the tide will begin to turn. Here, city mobility could be a key driver, with the decision of whether to stick or twist on the ICE likely to be taken out of the hands of commercial vehicle fleet operators very soon in these locations. Private passenger vehicle owners may be able to opt for alternative transport methods to traverse inner-city streets. But for those companies with vital business to conduct in urban centres, the rise of congestion charges and low emissions zones stacks the deck in favour of electrification.

"There is an awareness that if you buy an ICE truck that is to be used in a city environment, there is a risk that, at some point, you will not be allowed to drive in that city. For some applications that is already the case today," said Mårtensson. "If you want to have a future-proof solution for cities you need to start looking at other alternatives to combustion engines."

This need has already been acted on at Volvo Trucks. In March 2019, for example, the truck maker delivered its first all-electric truck, the Volvo FL Electric, to customers in Gothenburg, Sweden. In the city, recycling company Renova has used it for refuse collection, while logistics company DB Schenker has deployed it within its city distribution network. With stringent CO2 deadlines to meet this decade–and increasing interest from cities to limit transport emissions–the place for the ICE in these locations will dwindle. The broader energy needs of the entire industry, however, should allow it to maintain its position elsewhere.

"When it comes to heavier and longer distance transport I'm convinced there is an area where the combustion engine will continue to play an important role," said Mårtensson. "The fact is that our customers are looking for something reliable and they want to make sure that it is to some degree future-proof so that second-hand value is there. From that perspective, we see the potential especially in long haul for combustion engines."

A role for hybrids

As electrification increases, this is likely to create significant market share for hybrids. Battery electric or fuel cell may be seen as the two core technologies of the future, but while

> Even if we see battery electric—the ICE's main competition—picking up speed in a couple of years, even ten years out, the majority of the vehicles sold in trucking will have a combustion engine

the industry waits for these to mature effectively, hybrids offer a chance to limit ICE emissions today while also complying with emissions regulations.

"Hybridisation is also clearly on the roadmap, but it is slightly behind the passenger car roadmap, primarily due to the duty cycles," said Hopwood. "Mild hybridisation will come, especially at the smaller vehicle sizes. For larger vehicles, which operate more at higher loads, we need to look at slightly different hybrid architectures. Only a subset of what's happening in the passenger car arena will move to heavy duty on road."

For those looking for future proof solutions, Westman suggests that hybrids could appeal to city fleet operators due to the flexibility they offer in being able to switch between electric or combustion power. "Hybrids will be mainly beneficial for the inner city, at least with full hybrids which can run in a 'silent' mode within the ICE," he said. "BEVs, however, have an interesting advantage in that in the long term the running costs of using electricity as the primary energy source is likely to be less costly than running on oil. The question is how quickly will we see the charging network that will give us those low-cost electricity outlets for our customers."

Overall, the current tech maturity and regulatory environment for ICE commercial vehicle alternatives do spell good news for those developing and marketing trucking combustion products. The greater energy demands of commercial vehicles, across a far broader range of vehicle sizes and types, means that while some fleets may be forced to go green earlier, there remains plenty of room for the ICE.

"It can definitely be said that at some point there will be no role for the combustion engine, but if that day is 30 or 50 years in the future it is difficult to say," said Mårtensson. "If the ICE will have an important role to play 50 years from now it has to be able to run on extremely good biofuels. When we look at this view from a global perspective, different parts of the world have different opportunities to take steps towards different alternatives."

> It will take time before we have other alternatives to combustion engines in all segments

"Even if we see battery electric–the ICE's main competition–picking up speed in a couple of years, even ten years out, the majority of the vehicles sold in trucking will have a combustion engine," added Westman. "CO2 is the focus now. We have fixed the problem on the harmful NOx and particulates so the focus is on CO2 reductions to aid sustainability. It is important to chase combustion engine fuel economy improvements, work with alternative fuels with ICEs and develop BEVs to make them as attractive as possible so we can get volume in the future."