The State of the Automotive Industry as it **Turns to Electrification**

Impacts to OEMs and Suppliers

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Executive Summary

The Automotive Industry Has Reached **a Tipping Point**

With an economic downturn looming, OEMs must choose where to invest finite funding and they are choosing in favor of electrification.

The burden of developing an expanding powertrain portfolio — in which conventional internal combustion engine (ICE) vehicles face ever more complex, stringent market-specific pollution regulations and city bans — is a major investment drag on established OEMs. Suppliers, balancing the demands from OEMs with their own strategic business priorities, are fighting for a slice of a smaller number of systems and components on new platforms. With the demand to drive down the cost of the vehicle, all components, including non-electrification parts, are under great pressure so there is a premium on innovative solutions that break existing cost structures.

The massive investment in electrification has produced attractive vehicles that will achieve cost parity within the next five years and can be readily sold in all markets.

To reduce CO2 emissions and comply with government policy and increasing social pressure, OEMs have turned their focus to electrification in the form of battery electric vehicles (BEVs) and improved hybrids. This is a triumph for government policy, particularly in Europe and China where strict CO2 targets have been enforced.

Governments worldwide are offering incentives to bridge the gap and support the electrification infrastructure. ICE development is scaling back, and OEMs are already limiting future powertrain investment.

Starting with a general market overview and how the OEMs are transitioning, Chapter 5 discusses how this impacts Suppliers trying to maximize their opportunity and manage the risk in a highly dynamic transitioning Automotive market.

COVID-19 arrived at a critical time and has impacted this change, forcing OEMs to look at further reprioritization of investments in new products, often resulting in rationalization of conventional powertrains in favor of Electrified options. With auto sales dramatically reduced for most of 2020, OEMs have lobbied hard for even greater market stimulus and in numerous cases direct financial support. Governments have responded but have chosen to focus on funding low carbon products and developments, further compelling OEMs to invest in electrification. As the rapidly changing environment continues to impact the industry, suppliers need to react quickly and change priorities and reanalyze business plans regularly to keep up.

Who should read this paper?

OEM and supplier leaders **who are focused on growth**, keeping abreast of disruption and market changes while **staying ahead of the competition** should read this paper.

Key questions addressed:

The automotive business landscape:

- What is the legislative framework for greenhouse gas (GHG) and local air quality?
- How is government policy impacting the direction of technology?

The near future:

- How will each technology develop and what are the implications?
- How will OEMs react?
- What is the impact of new market entrants, and how are they influencing the industry?
- How does this impact Tier 1 suppliers?

Changing for market resiliency:

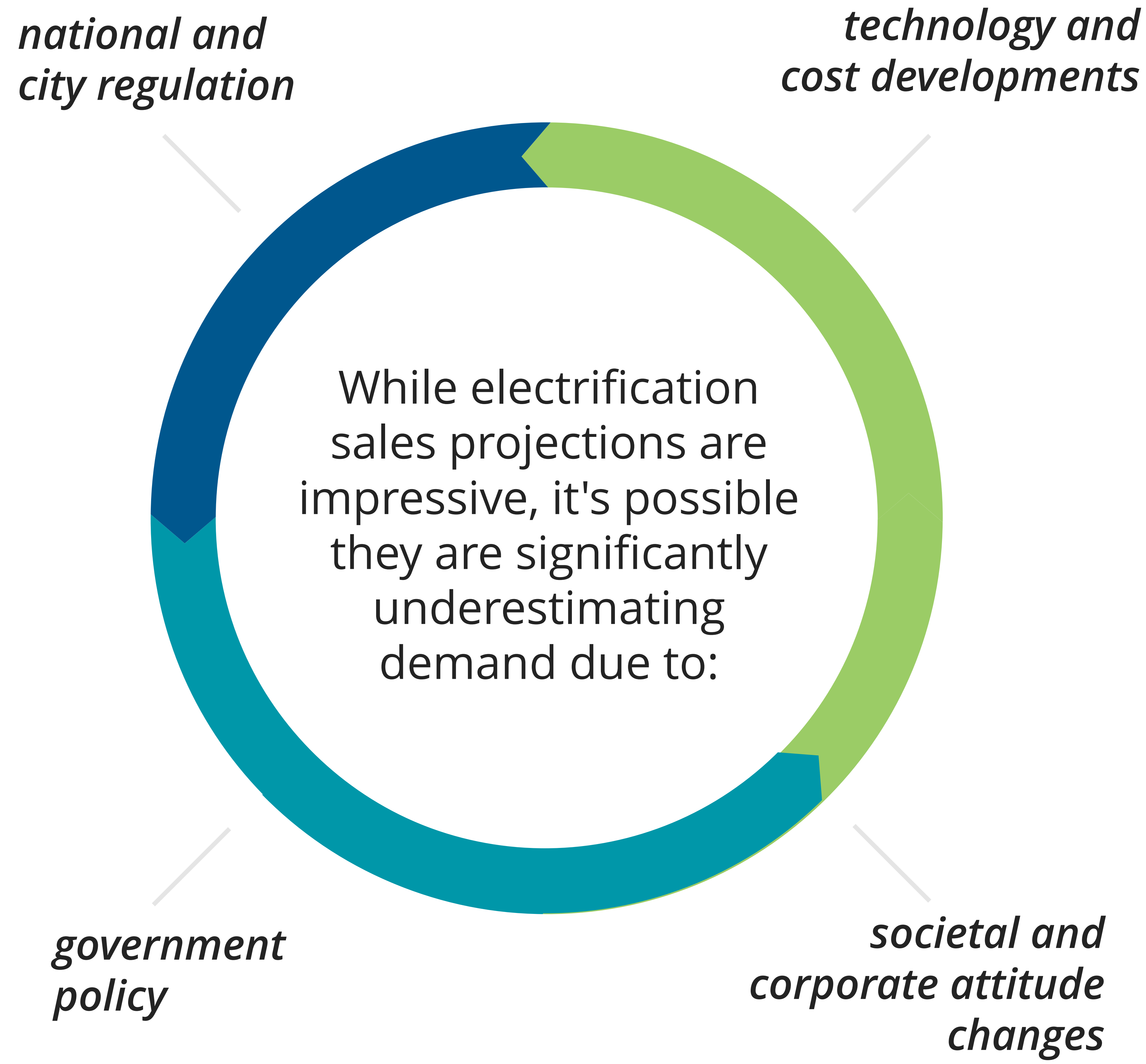
- Description of sample solution to help OEMs and suppliers address current challenges

Table of Contents

Chapter 1

INTRODUCTION

In a Decade of Disruption, Will Electrification Dominate the Automotive Market by 2030?



There's no doubt that automotive electrification is accelerating. In 2019, total plug-in electric car sales were 2.2m units and captured 2.5% of the global car market; that's a 400% increase from 2015, when just 550k units were sold. Battery electric vehicles (BEVs) accounted for 74% of the 2019 sales (1.63m units) and by 2025 it is expected there will be more than 400 electric vehicle models available globally.[1] Projections for future sales vary. Two recent studies range 2025 BEV sales from 6 to 11m units and for 2030, between 11 and 19m units PA. China and Europe are forecasted to lead with 48 and 32% of sales being electrified vehicles respectively, followed by the U.S. and Korea.[1, 2] 2020 sales figures are in and some countries have seen electrification sales increase to 10% of total sales.

Electrification is having an equally profound effect on other areas of the transport market, with a potentially faster transition in light commercial vehicles, buses and two-wheel vehicles.

This is creating a structural shift in the automotive industry.

OEMs struggling under the pressure of maintaining multiple propulsion options will change and realign their structure. They will drop conventional development at the earliest opportunity to maintain a focused approach to electrification, as it is the lowest cost route to global emissions and CO2 compliance. This may include increased vertical integration and partnerships to share investment.

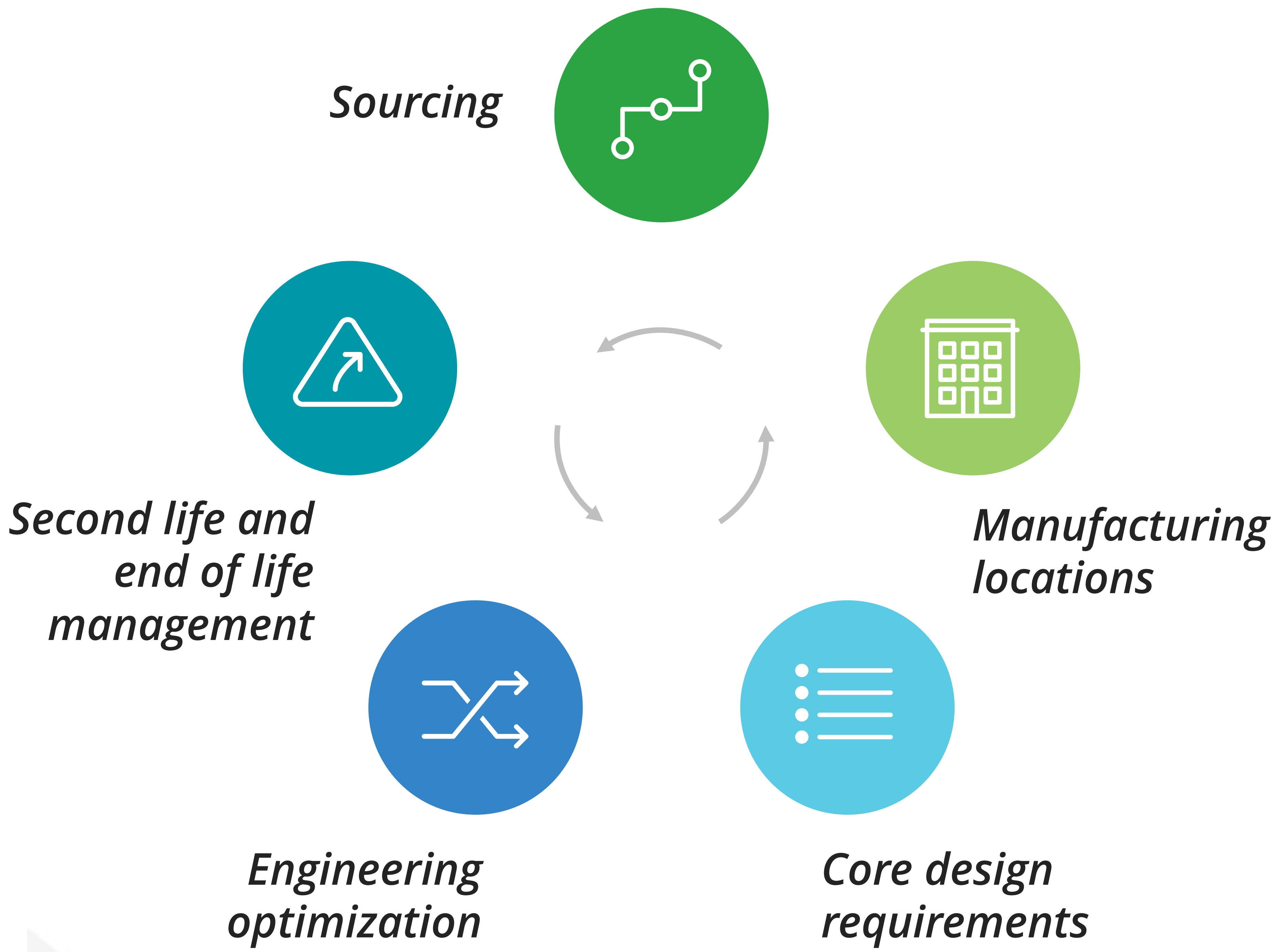
New entrants can flourish without the drag of conventional propulsion development on their business. However, they lack the scale to drive costs down to the levels of established OEMs and may be targets for takeover and consolidation.

Existing suppliers need to secure a share of the simplified electric platforms and manage the uncertainty of the rate of growth.

New suppliers will emerge, particularly in the production of batteries, and will grow dramatically through the next ten years, linking to new sources of raw materials. This growth will enjoy a high level of incentivization as governments battle to secure large scale, high paying employment.

We will discuss the potential impact on suppliers, and the range of responses, in Chapter 5.

All of these changes will take place through the lens of reassessing greenhouse gas (GHG) consumption throughout the **full product lifecycle** as the drive to a zero-carbon transport system accelerates:



Global Pandemic **Impact**

COVID-19 has added extra impetus to this situation. Many OEMs are reassessing and cutting cycle plans to reduce spend. Governments are being asked for bail out funding and adding additional stimulus packages that focus heavily on "green agendas" and low CO_2 technology adoption.

This will likely accelerate the demise of technologies that are already in slow decline and accelerate the electric transport agenda.

Chapter 2

LEGISLATION

Legislation: Public Opinion Increasingly Supports National Governments to Act and Curb Global Warming

Governments have grappled with developing plans to decarbonize and meet the commitments of the 2015 Paris Climate Agreement.

National action plans are progressing, backed by shifting opinions within civil society – particularly amongst the younger generations – along with scientific evidence, technology developments and signs that financial markets are reforming to reflect the impacts and risks associated with climate change and pollution.

Of the 195 signatories to the Paris Climate Agreement, the EU and 58 countries' actions and plans are assessed annually in the Climate Change Performance Index (CCPI) report.[3]

2015 Paris Climate Agreement – A Landmark Commitment by 195 Countries & Organizations

A commitment to reduce carbon emissions to levels that limit global temperature rise to well below 2 degrees Celsius, aiming to limit to 1.5 degrees Celsius.

The EU and 58 countries' plans are assessed annually in the CCPI Report

- Ranked by climate policy, GHG, renewable energy, energy use
- Top 5: Sweden, Denmark, Morocco, UK, Lithuania
- Bottom 5: Iran, Korea, Chinese Taipei, Saudi Arabia, US

2019 25th UN Climate Change Conference (COP 25) – Madrid

- Concluded with no new agreement despite extending the conference by two days
- Highlights include protests by many young people, including a speech by Greta Thunberg

2020 26th UN Climate Change Conference (COP 26) – Glasgow

- Postponed until Nov 2021 due to COVID-19
- Expected to force new agreements and add extra impetus to climate change actions

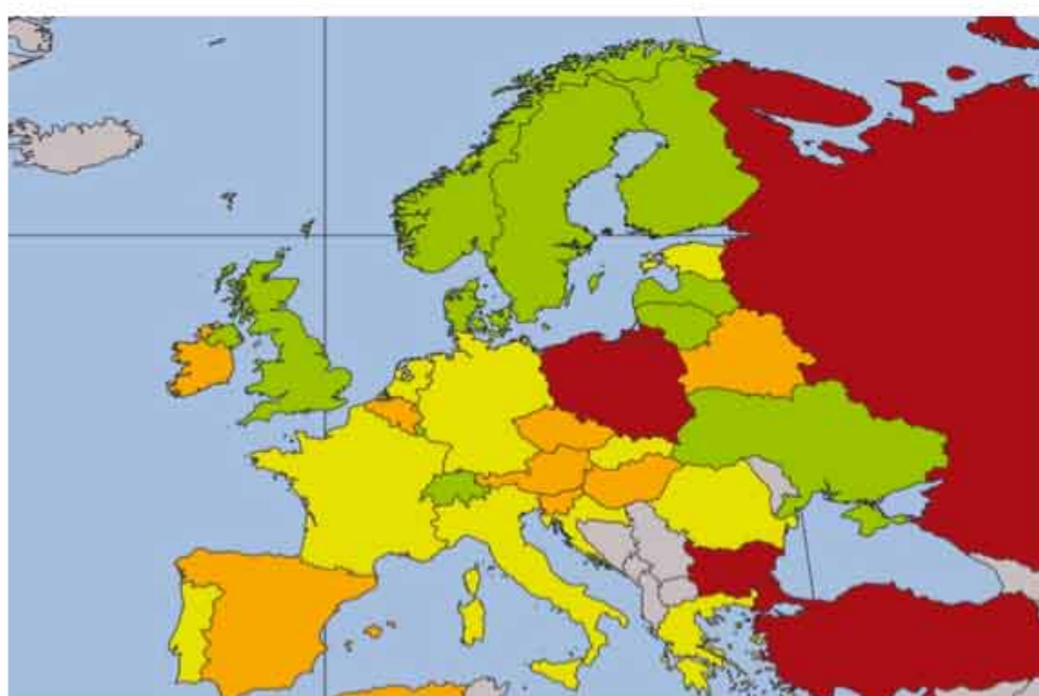
Source: Paris Climate Agreement status (CCPI Assessment 2020)

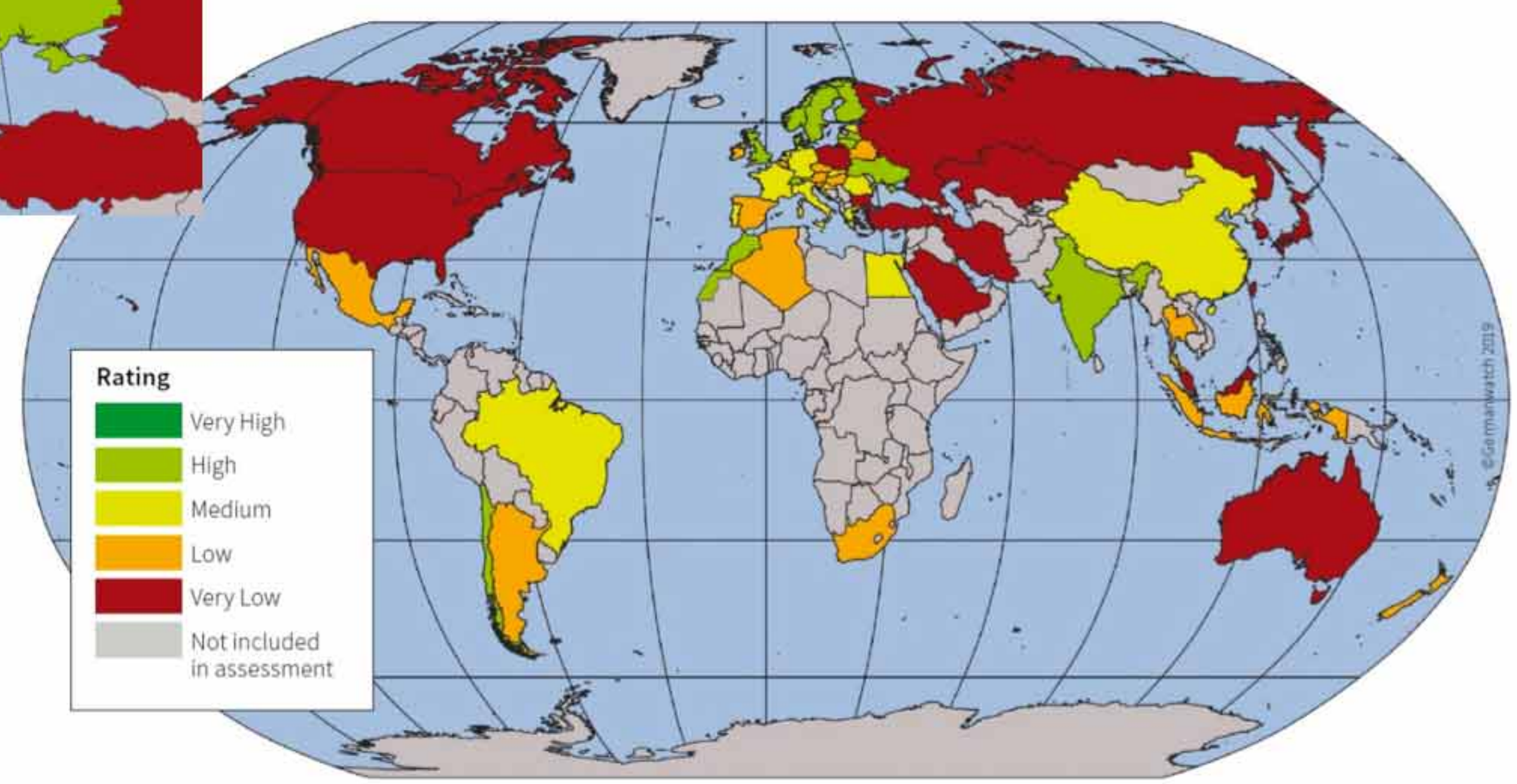
Today, Sweden and Denmark have the most comprehensive plans while Saudi Arabia and the U.S. have the least developed plans. **Most recently President Xi Jinping announced at the 75th UN General Assembly that China will be carbon neutral by 2060 and will aim to reach its peak in CO2 emissions before 2030.** This will provide massive impetus to the Global effort and is likely to provide extra incentives for other countries to announce their plans at or before COP 26.[4]

As part of their policy, many countries have set vehicle fleet CO2 targets. As of today, Europe has declared the most comprehensive and severe legislation for transport CO2 emissions *(see Figure 2A),* requiring manufacturers to reduce their fleet CO2 emissions by 15% by 2025 and 37.5% by 2030 from a nominal 95 g/km base set for 2021. Manufacturers will be fined annually for every 1gm miss to their targets from 2021.

President Joe Biden has re-energized the push for CO2 reduction with multiple executive orders*. This and likely future policy shifts will move the goalposts for the U.S.*

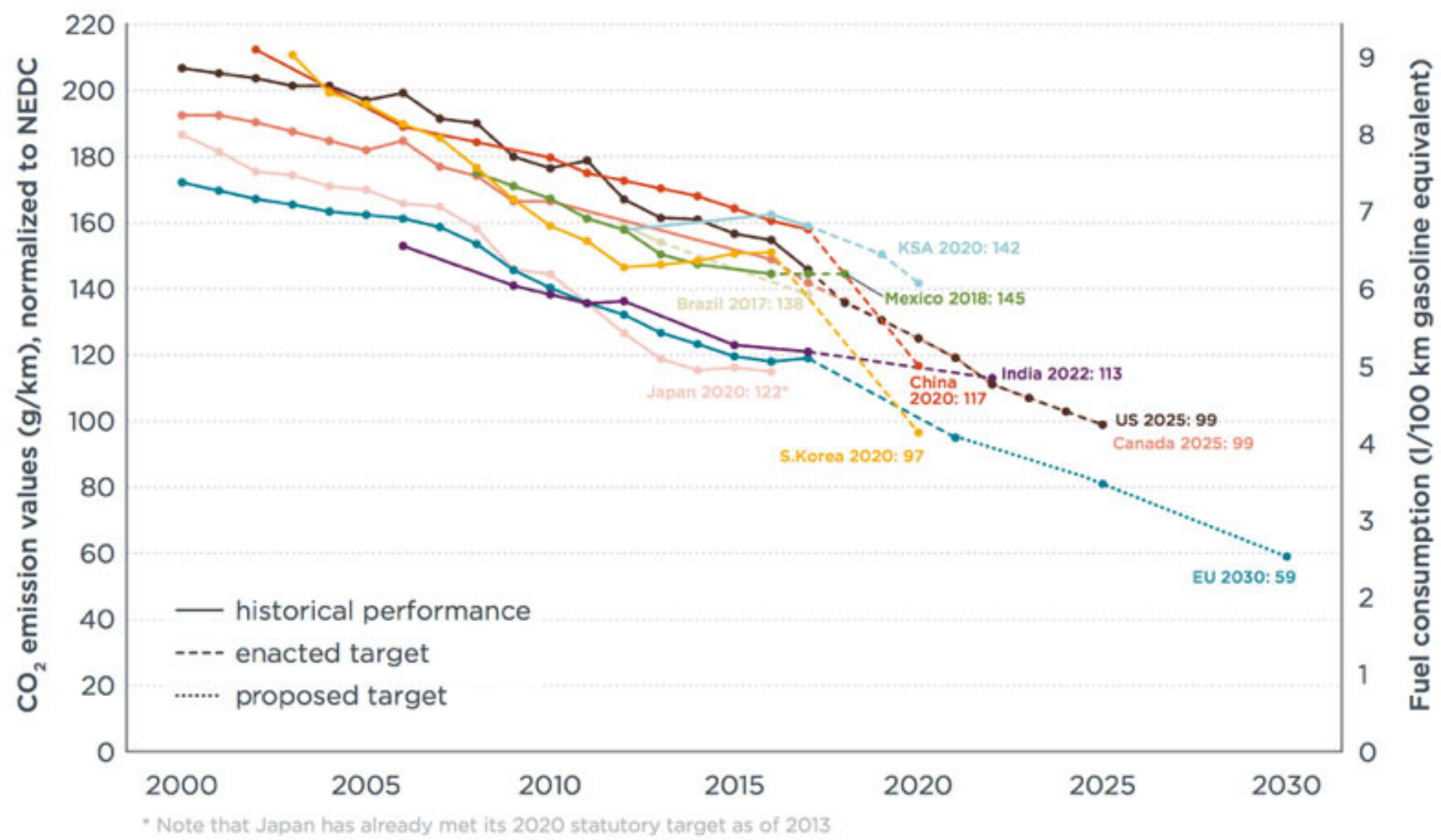
Progress towards established 2015 Climate Goals
Note: as of 2020 no country has received a Very High Rating
Figure source: CCPI Climate Change Performance Index 2020





Top 5	Bottom 5
Sweden	Iran
Denmark	Korea
Morocco	Chinese Taipei
UK	Saudi Arabia
Lithuania	US

Figure 1: Assessment of National Carbon Dioxide Reduction plans

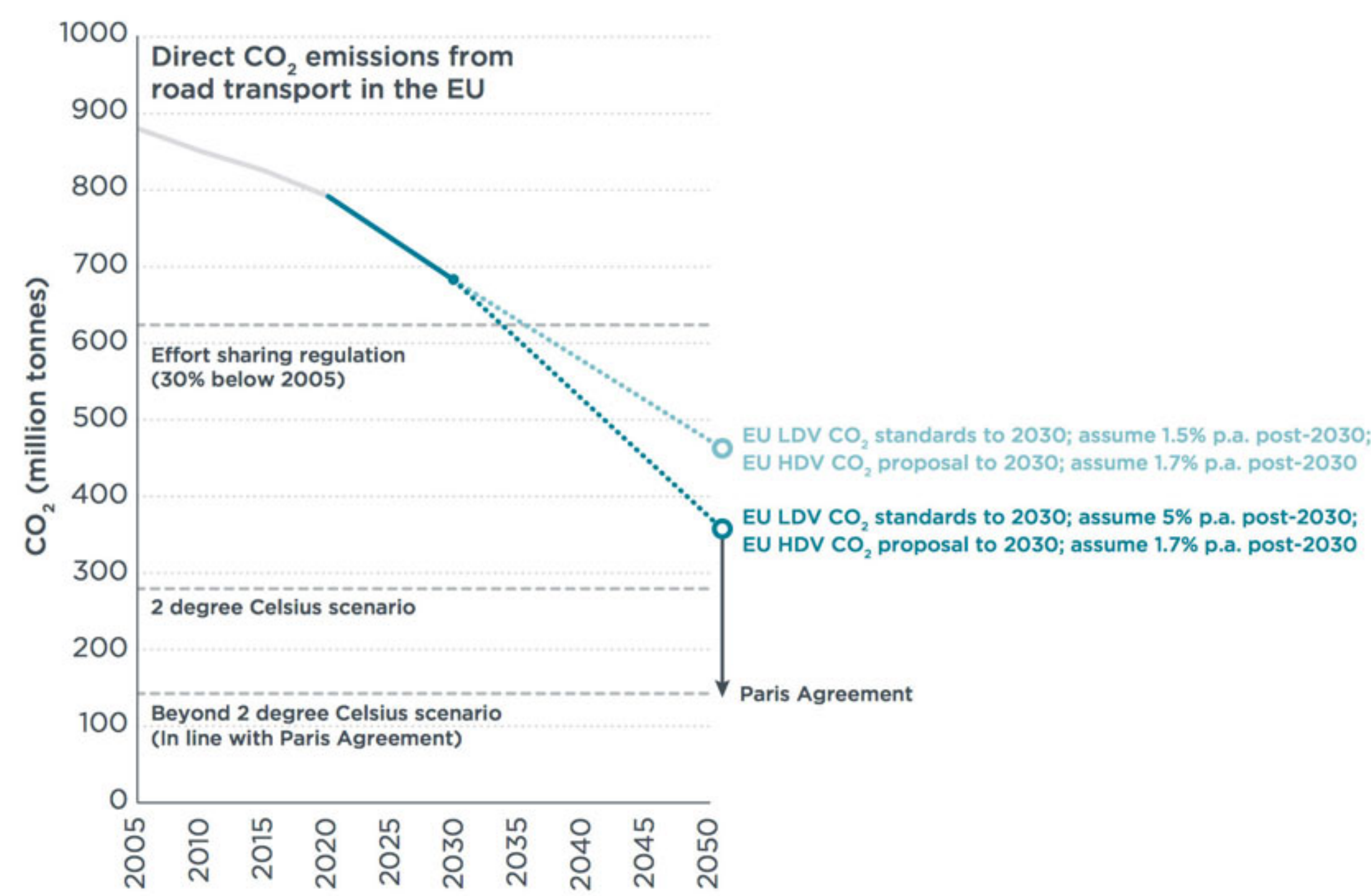


CO2 Emissions Reduction Target Setting by many countries.

- EU targets remain the most aggressive and reach the furthest ahead in time
- However, current estimates suggest that the targets will still fall short of the reductions required to meet Paris Climate Goals

Figure 2A: CO2 emission standards for passenger cars and light-commercial vehicles in the European Union.

Figure 2B: Reduction scenarios for CO2 emissions from the transport sector.



EU CO2 emissions standards and current roadmap status project to achieve carbon neutrality by 2050. Agreements will continue to evolve and become more stringent to meet targets.

Figure 2A & 2B source: ICCT. Jan 2019

In Europe and the U.S., manufacturers **are incentivized to promote sales of electric vehicles** (EVs) using zero emissions vehicle (ZEV) certification.

In Europe, if manufacturers' sales of zero or low emission vehicles (ZLEV) are above 15% in 2025 and 35% in 2030, a less stringent CO2 target will be set. However, it is arguable that a manufacturer that achieves such high levels of electrified car sales will need a less stringent target. Given the success that manufacturers have had in achieving the CO2 targets in 2020, it is now likely that the EU Commission will move to set more stringent targets for 2025 and 2030.

China is currently reviewing its targets and future legislation; this is expected to follow a similar format, housed within the new energy framework (NEV) that has provided the driving force behind China's growth in electrified vehicles.

All current CO2 legislation operates on a "tank to wheel" basis. However, **it's clear that if a sustainable, zero carbon economy is to be achieved, then the full lifecycle CO2 footprint will need to be established, incorporating the energy for fuel and vehicle and battery production, in service and end-of-life** *(see Figure 2B).*

The EU is currently assessing the feasibility of framing legislation for such a system and is due to report before 2023.

All manufacturers are increasingly incorporating this into their long-term strategies, taking steps to ensure they have sustainable and compliant component strategies in place.

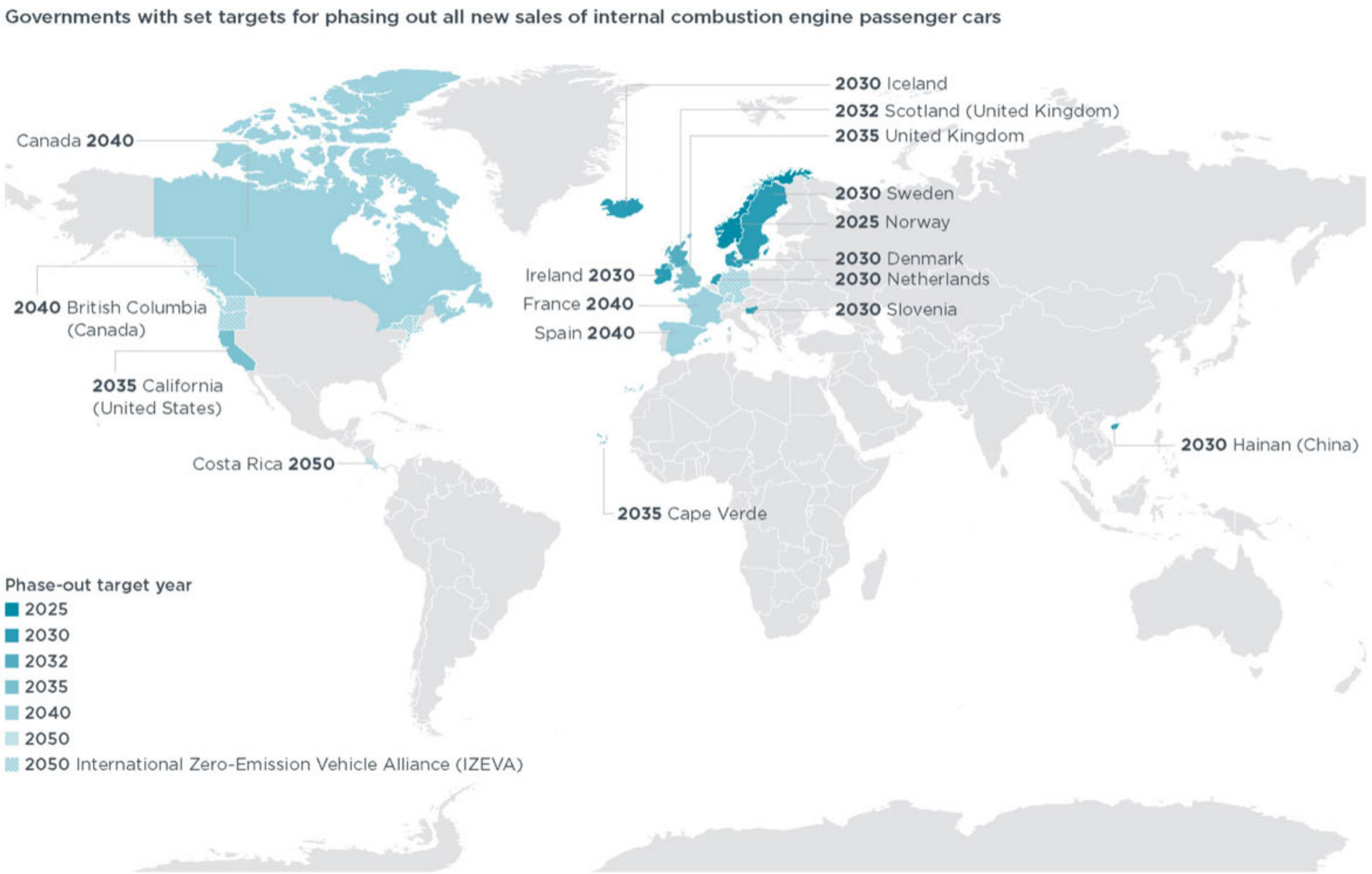
As part of national strategies, 12 countries have declared dates by which sales of new vehicles using conventional internal combustion engines will be banned *(see Figure 3).*

Most aggressive amongst these is Norway, which plans to implement a CO2 ban from 2025. Recent sales figures for Norway show that 70% of new vehicles sold are electric, which suggests it's on-target to achieve this goal. It is possible that beyond the current sales position, the shift to 100% may accelerate as customers consider the limited residual value of conventional vehicles bought in the next few years.

Read more on actions – or lack thereof – to develop a Net Zero carbon plan by 2050 in Appendix 1.

Local Air Quality and its Health Impact Creates Widespread Concern

Alongside national actions, cities worldwide have declared that they plan to ban some or all internal combustion engine vehicles to reduce local emissions pollution and improve air quality.



Source: ICCT 2020

A number of cities have made ICE phase-out announcements, including these European cities:

- Amsterdam, the Netherlands
- Bergen, Norway
- Brussels Capital Region, Belgium
- London, U.K.
- Milan, Italy
- Oslo, Norway
- Paris, France
- Rome, Italy
- Strasbourg, France

Source: ICCT 2020

Figure 3: Countries and cities that have dates to phase out fossil fuel vehicles.

It's estimated 3.5m people died in 2017 due to respiratory problems and strokes caused by particulate and Nitrogen Oxide (NOx) pollution, emitted by vehicles

A study comparing the situation in 2010 and 2015 showed that the attributable deaths had largely remained constant globally because improvements in emissions control had been offset by increased miles travelled. However, regionally the figures have quite significant differences. In Europe and the U.S., deaths declined by 14 and 16% respectively but increased by 26% in China and India as mileage has increased.[4]

When we look at the cities with the highest death rate as a percentage of the population, the top ten in 2015 were all in Europe: Milan, Turin, Stuttgart, Kiev, Cologne, Haarlem, Berlin, Rotterdam, London, and Leeds. This is due to the high prevalence of diesel cars in Europe.

The introduction of EU6 emissions standards and testing in real world conditions, known as Real Driving Emissions (RDE), has reduced new vehicle emissions in all environments. This, combined with local actions such as lower speed limits and traffic restrictions, has shown improvements in some cities. However, the rate of improvement is too slow as the vehicle fleet takes up to 17 years for all older cars to be replaced. So, it is highly likely that city center bans for internal combustion engines (ICE), particularly diesel vehicles, will be enforced and a further round of tighter legislation will be instituted in EU7.

Lab Testing WLTP Cycle

Real World Driving Emissions

- **EU7:** Focus emissions evaluation on RDE testing, emissions in control under all conditions and driving behavior. Same increased for all engines and fuels. Extended test requirements, increased cold testing, new emissions requirement, On Board Monitoring.
- **EU6e:** Possible additional target change, extend test cycle operating window, reduce conformity factors and add new emissions requirements.
- **Eu6c:** Introduced a new test cycle and more realistic testing cycle, emissions checking in a real world driving conditions. Calibration work increased by a factor of 3 and testing by a factor of 8-10.

Air quality emissions standards projections for Europe are driving technology, workload and cost

	Today			Possible 2023-2025		Possible 2025-2028	
	Euro 6d Type 1 test WLTP Cycle			Possible Euro 6e WLTP Cycle		Possible Euro 7 WLTP Cycle	
Pollutant	**Petrol**	**Diesel**	**RDE Conf. Factor**	**Petrol & Diesel**	**RDE Conf. Factor**		**RDE Conf. Factor**
Carbon Monoxide (CO) mg/km	1000	500		1000	M&R	250-500	<1.2
Total Hydrocarbons (THC) mg/km	100			100	<1.43	50	<1.2
Non Methane Hydrocarbons (NMHC) mg/km	68			68	<1.43	35	<1.2
Oxides of Nitrogen (NOx) mg/km	60	80	1.43	60	<1.2	30-40	<1.2
Combined Hydrocarbons + Oxides of Nitrogen (THC+Nox)		170				90	<1.2
Particulate Matter (PM) mg/km	4.5	4.5		4.5		2.5	
Number of Particulates (PN) particles per km	6X10.11 @23nm	6X10.11 @23nm	1.5	6X10.11 @10nm	<1.5	6X10.11 @10nm	<1.2
New Requirements							
Nitrogen Dioxide (NO2)				20	<1.43	20	<1.2
Ammonia (NH3)				Monitor and record (M&R)		10	<1.2
New Requirements							
Methane (CH4) mg/km						15 or CO2 equ	
Nitrous Oxide (N2O) mg/km						10 or CO2 equ	
Formaldehyde (CH2O) mg/km						2.5	
Total Aldehydes mg/km						5	

Figure 4: EU6 standards, EU6e (interim standards), and EU7 projected standards

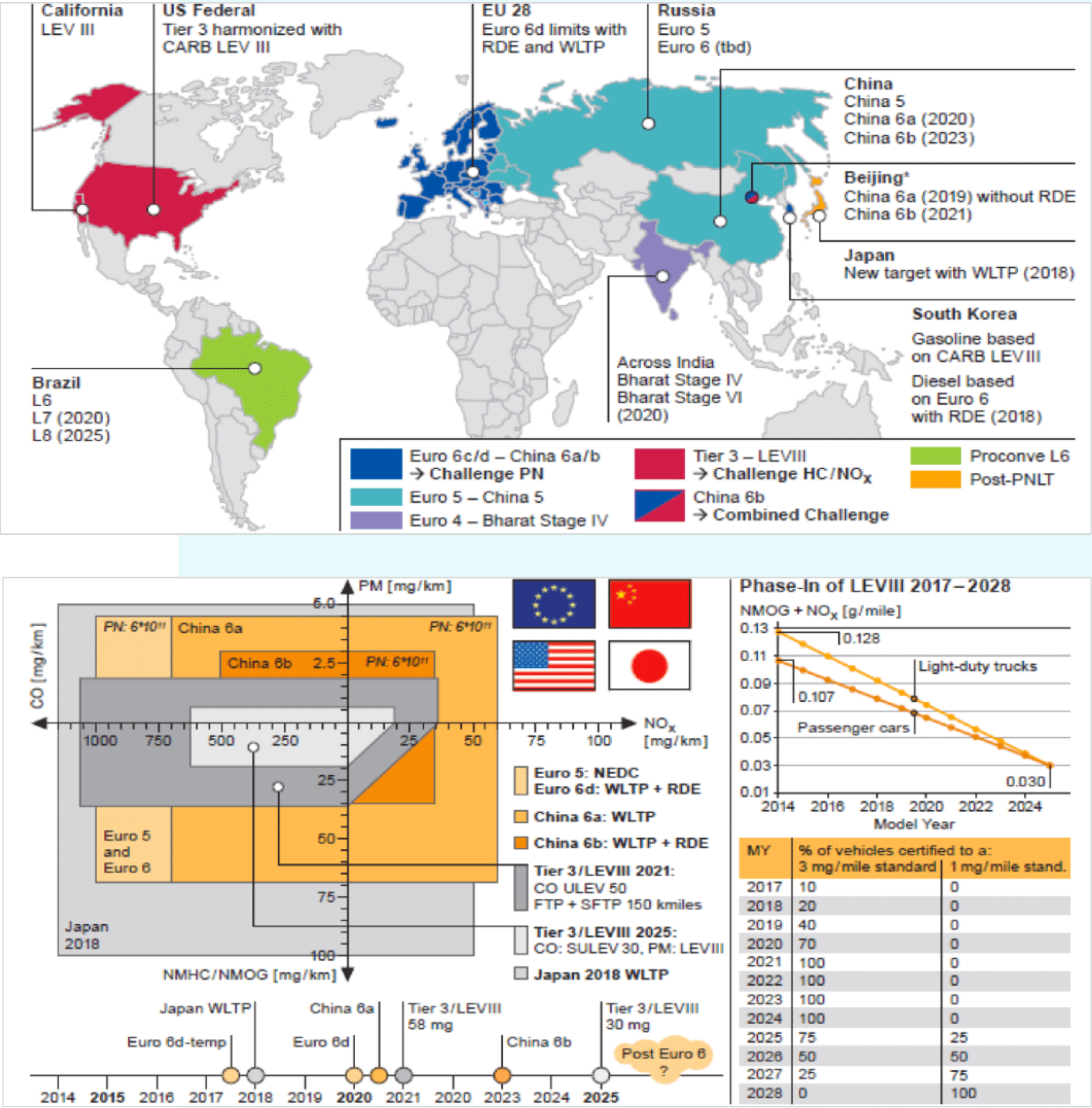
Particulate matter from vehicles is not limited to exhaust emissions, with brake dust, tire wear and road abrasion all contributing to pollution. It is expected that future legislation will be developed to address this.

The recent large-scale reduction in vehicle activity due to COVID-19 has graphically shown residents in high-pollution areas just how poor their air quality was before the pandemic. This new awareness is likely to add further impetus for anti-pollution measures to be introduced.

It is possible that governments – both national and local – could act quickly and respond to this pressure with rapid changes in legislation, particularly when technology exists to meet tighter legislative standards in other markets. This has happened before in the industry's long history and is highly disruptive to vehicle supply lines.

Meeting Global Air Quality Standards Costs Huge Resources for Existing OEMs

Air quality legislation and emissions standards have been a technology driver in the auto industry since they were first enacted by California in 1966 to combat ozone and smog pollution. They remain one of the most technically challenging and resource intensive activities within OEMs that are producing petrol, diesel and hybrid vehicles. These standards are a central consideration during product lifecycle planning.



Source: Continental 2019

Figure 5: Many OEM and supplier difficulties stem from seven of the major markets having different test procedures, emissions standards and timelines.

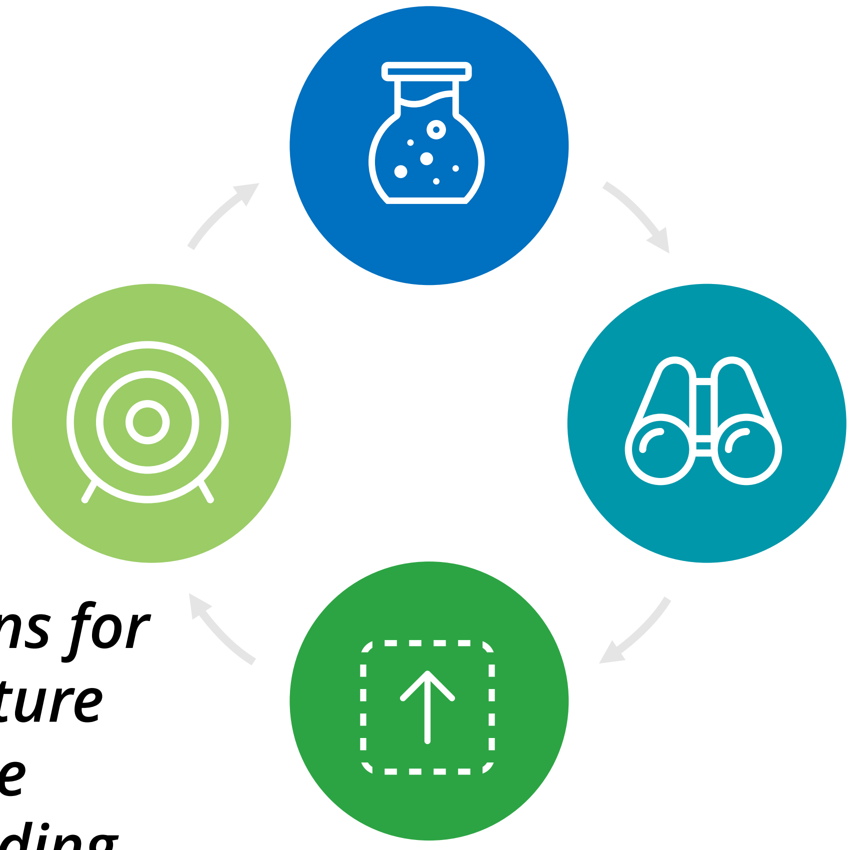
All markets have air quality standards, with most small markets using standards from larger markets. However, the seven largest markets all have different standards, some using different testing cycles and methods. The specifications are progressively made more difficult by setting new targets or by changing the test boundary conditions, such as changing test temperatures or test durations.

EU7 legislation is also considering adding an on-board monitoring requirement for exhaust emissions to continually check emissions compliance. This would require a new suite of sensors and measuring technologies to be developed and implemented.

All of these changes drive significant investment in new vehicle hardware and software, extensive calibration programs, investment in new and highly specialist test facilities and commitments to large certification programs.

The proposed EU7 standards demonstrate this:

emission levels are anticipated to be cut by approximately 50%



new pollutants will be measured and controlled

test conditions for low temperature testing will be more demanding

test operating windows for Real World Testing will increase

Maintaining a portfolio of ICE and hybrid powertrains to meet the many different standards and customer demands there are globally is technically demanding and comes with significant compliance and reputation risk, along with a high workload and investment in product and test facilities. Compare that to developing BEVS, which avoid many aspects of this workload and where a single BEV can be compliant in all markets. As OEMs and suppliers look forward, the benefits of investing in BEVs versus ICE and hybrid vehicles will continue to become more apparent.

"Here we are setting new standards ..."

Panagiota Dilara (European Commission)

Euro 7 Challenge

Vehicles shall be as clean as possible under 'all' EU driving conditions <u>over the entire useful life</u>, with a focus on <u>near zero emissions in cities</u>

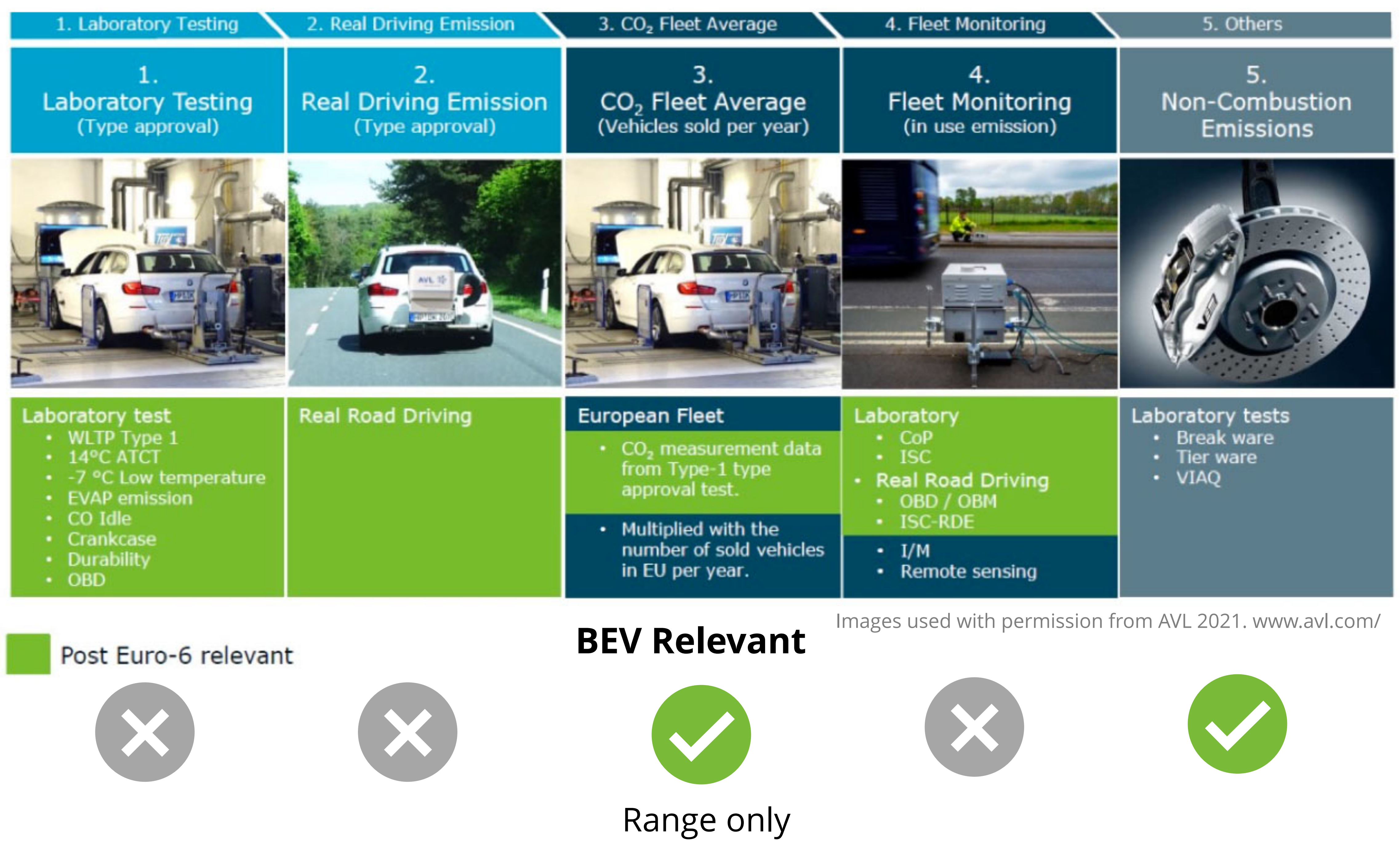


Figure 6: Emissions legislation demands meeting extensive requirements

- Established manufacturers are developing conventional ICE powertrains, hybrids and BEV's to meet multiple emissions and CO2 standards.
- The standards regularly increase in severity by:-
    - Lowering targets
    - Adding in new pollutants to be measured
    - Changing boundary conditions
    - Adding technical requirements such as on-board monitoring
- The investment in technology innovation, engineering capacity, test facilities, Certification and Compliance monitoring is a major sustained cost
- Many of the tests do not apply to BEV vehicles and the same calibration can be sold in multiple markets

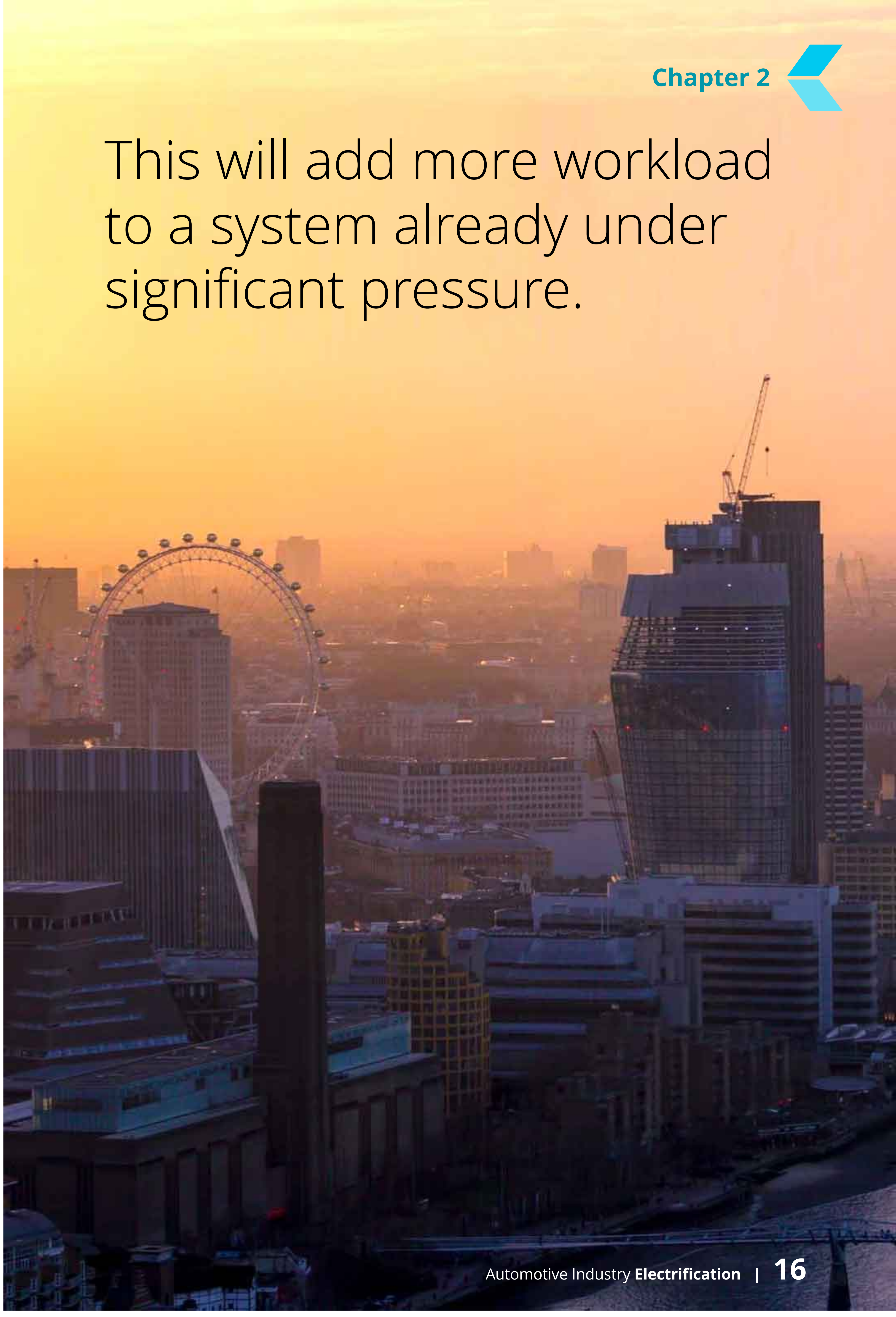
This situation is further compounded by different fuel specifications and different driving patterns in major markets, which often means that multiple after treatment systems and calibrations are required for each vehicle derivative in each market.

The introduction and timing of new emissions legislation is a significant factor in cycle planning.

In the U.S. new legislation is phased in over a number of years, providing OEMs flexibility to align emissions compliance with model year changeovers and new car introductions.

In Europe and China, however, the introduction date of new legislation applies to all vehicles being sold; it is an effective guillotine. The practical impact of this is that OEMs must develop and deploy new emission technology two or three years ahead of an introduction date. This often takes the form of a low volume prove-out program, followed by a phased introduction leading up to the compliance date. Delays in the introduction of EU7 run the risk of authorities introducing a further intermediate legislation change, some already referring to these likely requirements as EU6e.

This will add more workload to a system already under significant pressure.



Chapter 3

INTERCONNECTED

Interconnected: Planning for the Future

External factors such as government policy changes, new emissions legislation, local city decisions and rapid technology developments disrupt OEM and supplier development plans. Here's an example of a roadmap, showcasing just how entwined technology development plans are with external factors.

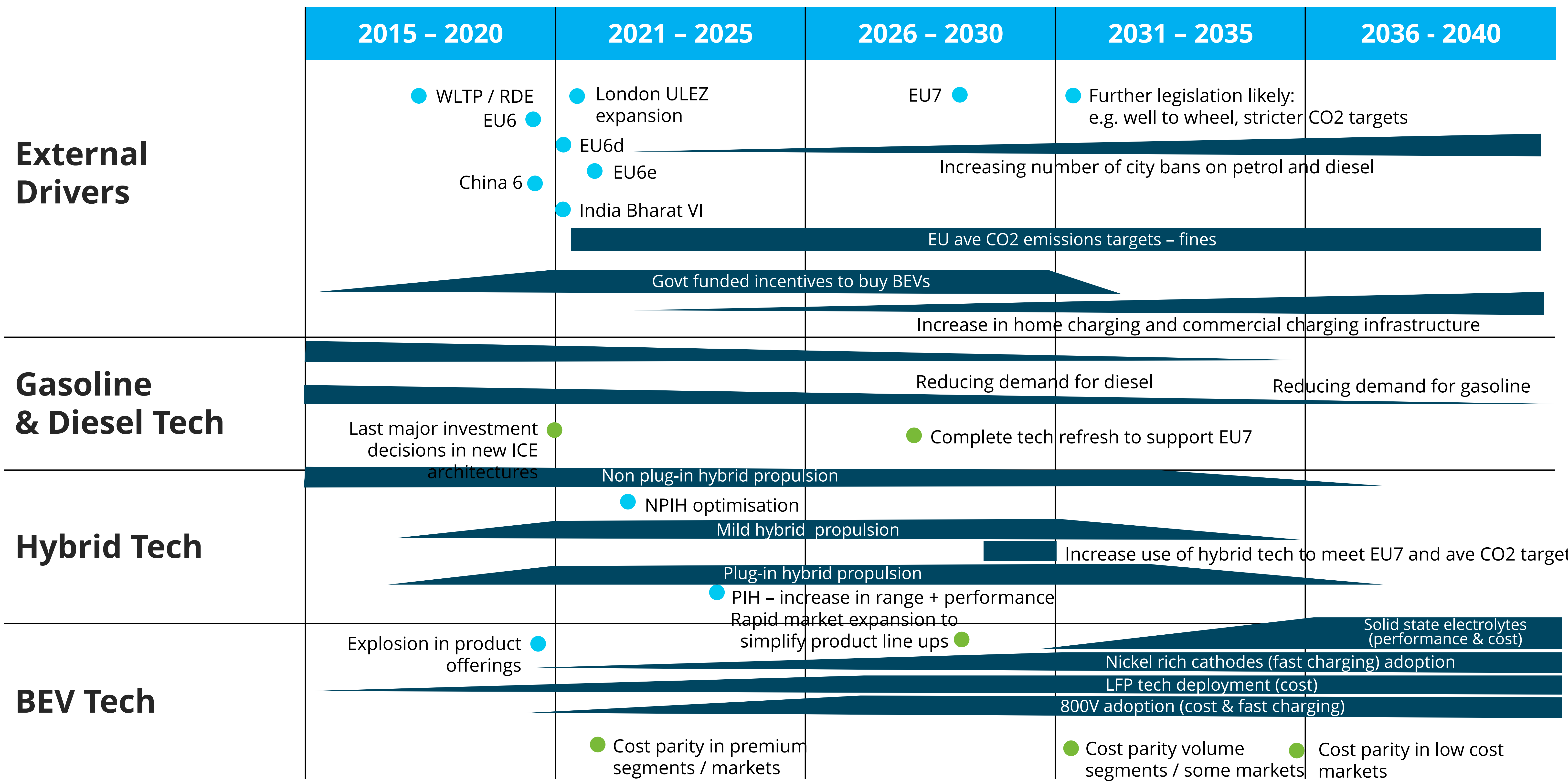


Figure 7: Example Roadmap

Technology Options: Reducing CO2 and Emissions

Vehicle fuel economy will continue to improve through a combination of vehicle design changes, propulsion technology and advanced control systems. In most cases the vehicle-level improvements can be applied to all vehicles. As vehicle-level technologies improve efficiencies, ICE-powered vehicles will reduce CO2 emissions and BEVs will improve range and performance.

Drag Reduction

Aerodynamics continue to improve despite a general increase in the size of vehicles. This is a testament to the advanced analysis techniques, extensive complex test facilities and new manufacturing techniques that facilitate panel designs that were not economically feasible ten years ago.

Tire manufacturers continue to develop new designs that reduce rolling resistance while maintaining grip levels and extending operational life. Both tire and brake manufacturers are also heavily focused on reducing particulate emissions.

Vehicle Weight

Weight reduction remains a challenge as vehicle size continues to drift upwards despite huge efforts by manufacturers. The use of aluminum and plastic are widespread in all aspects of the vehicle and this will continue to expand, however more fundamental changes are driving the next set of weight opportunities.

Two major themes have emerged in recent years:

- functional integration
- distributed electrical architecture

Functional Integration

To contain and drive weight down, manufacturers are looking at complex assemblies and redesigning large modules to integrate more functionality. For many years, OEMs have outsourced large module assemblies to Tier 1 suppliers who designed and consolidated the assembly to control cost.

However, to go beyond this and fully optimize lightweight designs often cuts across traditional supplier capabilities. This requires changing skills and relationships from both the OEMs and suppliers.

Another way to save weight is by electronically integrating multiple functions into displays and switchgear, reducing both switches and the wiring harness behind them. Tesla has been a prime exponent of this technology.

Distributed Electrical Architecture

Wiring harnesses have grown dramatically in vehicles with multiple networks for voltage distribution, high and very high-speed communication, video and internet. Alongside this, sensors have grown massively, and many systems have their own control modules.

It's not unusual for a premium vehicle to carry the weight and cost of more than 100 dedicated control modules. As more vehicle connectivity and autonomous features are introduced, sensor and processing demand continues to increase.

Replacing this traditional design with an integrated system that uses sensors with basic processing intelligence, fewer large central processing units and offloading tasks to the Cloud have all had a dramatic impact on both the cost and weight of the electrical system.

CEO and Chairman of German carmaker Volkswagen addresses the media during the annual news conference at the Volkswagen plant in Wolfsburg, Germany March 12, 2019

"Software will account for 90 percent of future innovations in the car."

- Herbert Diess

Advanced Control

Behind this is a significant shift in the business structure that supports vehicle and service development. Increasingly, OEMs have recognized the strategic importance of owning the whole software stack in the vehicle. Not only does this save weight and cost while improving quality and security, it also opens the door to many of the new business opportunities that OEMs expect to capture in the future.

Traditionally, OEMs have cascaded the development of software and hardware to Tier 1 suppliers and have focused on integrating many, often hundreds of separate solutions. This has led to the suboptimal, heavy, costly and low-quality solutions seen in many vehicles today. While many OEMs have recognized the shortfalls of this situation for a long time, the investment and logistics of changing has proven a significant barrier. New entrants, such as Tesla, unencumbered by legacy platforms have started with integrated solutions and have demonstrated the true value of such a solution. These entrants have justified the accelerated development to traditional OEMs.

Now hardware and software can be engineered and purchased separately and can be decoupled from the vehicle development process. With the advent of SOTA (Software of the Air) vehicles can be updated for features and problem fixes without going to the dealers.

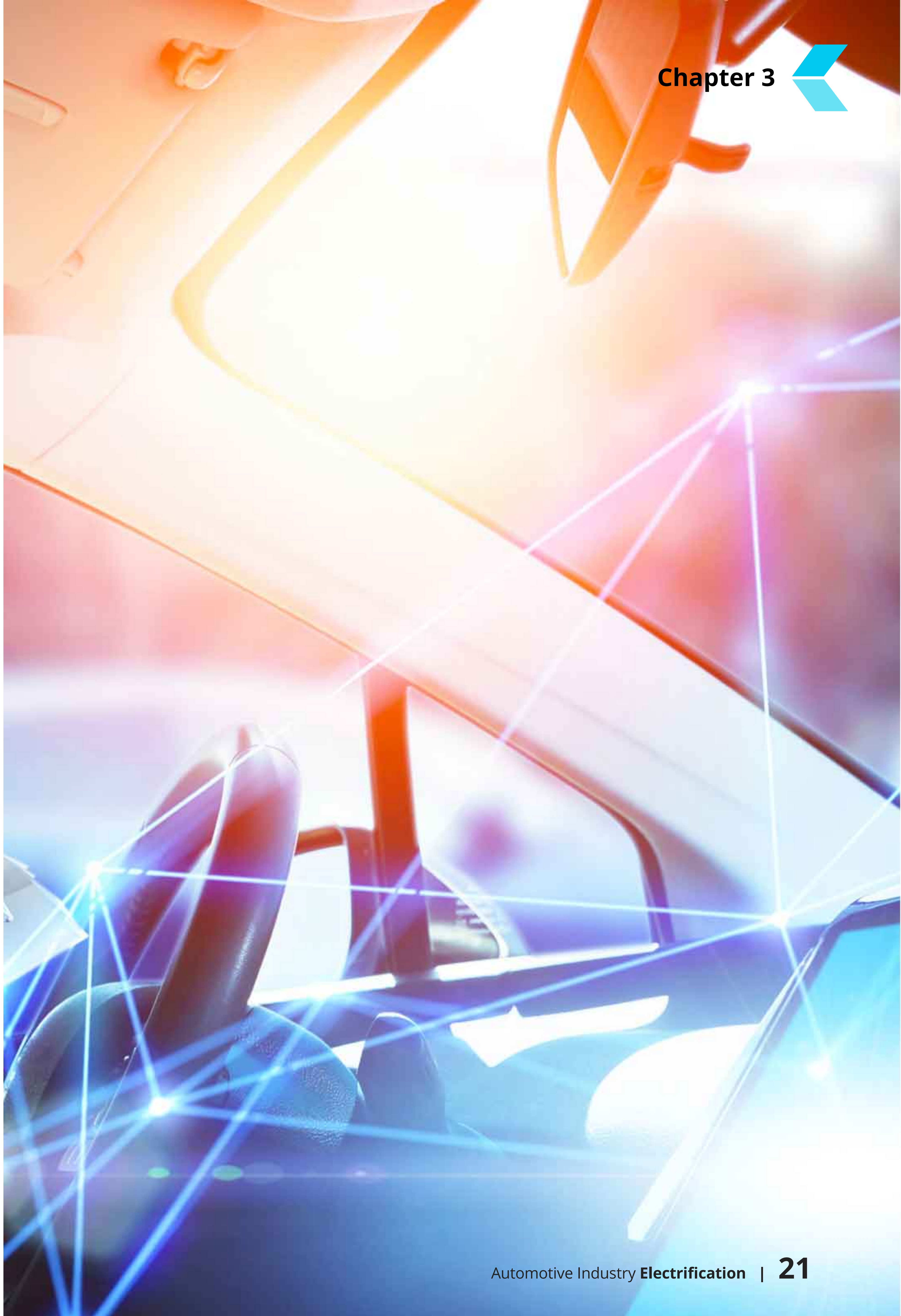
Connectivity and Autonomy Drive Further Vehicle **Efficiency Improvements**

As vehicles increase their connectivity and autonomous capability they offer the potential for further vehicle efficiency improvements.

The ability to use long-range route planning, combined with short-range dynamic traffic, weather and surrounding vehicle information enables optimized energy usage for vehicles. In electric vehicles, the same systems can be used to optimize the battery condition as the vehicle approaches charging stations, helping the battery to charge at the fastest rate possible.

As autonomous capability increases, features such as highway platoon driving can be introduced to save fuel.

In the long term, the widespread deployment of autonomous capability there is the intriguing possibility that vehicle accidents will reduce significantly. This offers the potential to remove some of the structure in the vehicle and precipitate a virtuous circle of weight reduction.



Powertrains Require Technology Upgrades, Further Creating Opportunity for Electrification to Dominate the Market

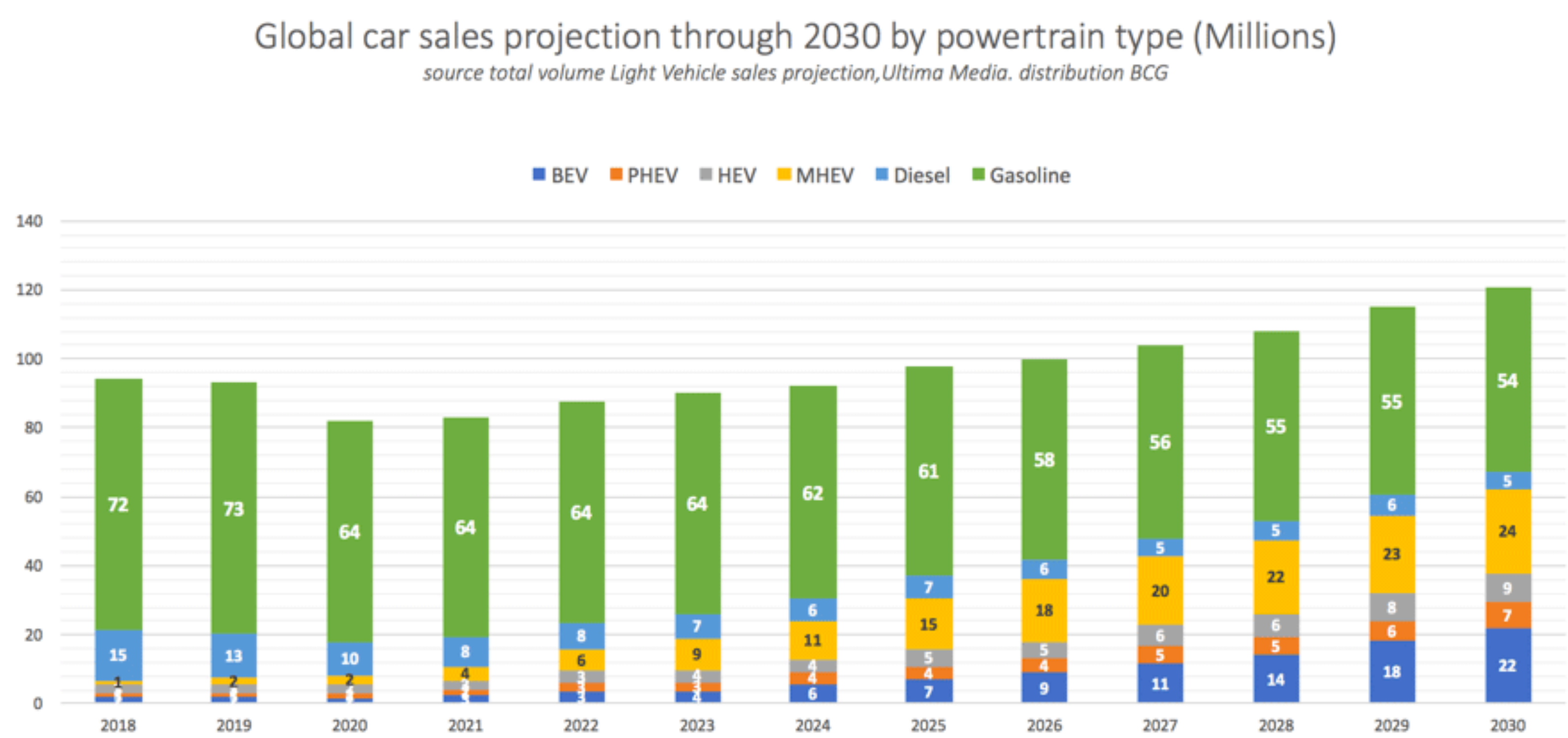


Figure 8: Global projection of propulsion system choice through to 2030

While the vehicle and sub-systems discussed above can help to significantly improve the CO2 levels of the vehicle – and in some cases the local air quality – it is the choice of powertrain that has the greatest influence on both.

For established OEMs there has been an increase in the number of different powertrains being developed simultaneously in the last decade, petrol and diesel engines have been joined by hybrid, plug-in hybrid and fully electric powertrains.

Differences in fuel specifications, driving styles and certification test requirements across major markets adds a further level of complexity below the headline power unit complexity, requiring different hardware and control systems (most notably for exhaust after treatment) and calibrations, sign off and certification activity.

This has added large costs into development cycles for OEMs. A further round of technical upgrades is being undertaken to meet future requirements as described in the technical panels.

This creates a dilemma for suppliers who are continuing to undertake research and the development of upgraded and new commodities, knowing that the annual and lifetime volume demand is far more uncertain.

This uncertainty impacts the traditional development relationships and models of sharing development costs between the suppliers and OEMs. Internally, it places a strain on resources, particularly the number of skilled staff that can be deployed on new areas of business development.

Diesel Engine Technology Development

In 2011, diesel engines owned 56% of the car market in Europe and in the premium auto manufacturers were the backbone of CO2 compliance strategies. After the infamous “Dieselgate” fallout, market share declined to 32% in 2019. In many small cars and volume manufacturers, diesel options have dropped out of the range altogether. However, in SUVs, and particularly premium SUVs, the market share remains around 70% of sales (77-89% market share in 2011).[5]

Read more about the Dieselgate emissions scandal in Appendix 2.

Euro 6 emissions standards and the introduction of real-world emissions testing (RDE) drove technology updates and resulted in dramatic improvements in emissions performance.

Euro 7 further tightens emissions standards and will be mandated in 2025-2028 (the exact date has yet to be confirmed). A key feature of the intention of this legislation will be adopting the same standards for both petrol and diesel engines. *(See Figure 4).*

These standards can be met but will require technology developments, extending EU6 solutions and inventing new sensor systems.[6]

Read more about diesel technology developments from 2020-2028 in Appendix 3.

Diesel hybrids are an option. However, the cost and complexity of this type of powertrain are prohibitive and will not likely be a widespread trend.

Diesel Engine Outlook

Automotive diesel engines remain an option for mid-size and large SUVs (both growth sectors) for the time being.

However, lack of support from national governments (namely Germany, a long-time supporter of diesel technology which appears to have shifted its position), the threat of city bans, the increasing cost of emissions compliance and the improved capability of plug-in hybrid vehicles are all pressures that are likely to continue to push down the overall volume of diesel engines, projections suggest this could be as low as 4% by 2030. *(See Figure 8).*

Under these circumstances few OEMs will continue to invest in diesel technology; key suppliers have already scaled back development. If EU7 legislation drifts back to 2027-28 it is possible that many diesel engines will stop production at this point.

Gasoline Engines

Petrol engines have been the primary beneficiaries of the decline in diesel demand and are the primary choice for hybrid vehicles.

Air pollution issues with modern petrol engines – EU6-compliant (Europe and China) and super ultra-low emission vehicle (SULEV) emissions compliant (U.S.) – are largely confined to the period when the engine is started and the catalyst system has not reached its operating temperature (the first 30 seconds of operation).

To meet the more demanding targets of EU7 emissions, a further round of technical upgrades will be required.[6]

Read more about petrol engine technology developments from 2020-2028 in Appendix 3.

Hybrids

Hybrids in various forms will grow quickly throughout the next decade.

Mild Hybrid

Mild hybrids take the form of a small electric motor/generator (10-30KW) combined with a small Li-Ion battery. Early roll out has been accompanied with a 48V electrical network.

The system provides the ability to both harvest electrical energy during deceleration and then add torque under acceleration.

This is a cost effective means of achieving a 7-10% reduction in CO2 and is expected to significantly roll out in the next five years. Versions of this technology (12 or 48V) are likely to be incorporated in all but the most basic vehicles in the future.

By increasing the power of the motor and the size of the battery, mild hybrids can extend their operating window providing further small CO2 improvements.

Several premium manufacturers have incorporated the 48V motor into the gearbox; this offers greater fuel savings potential and provides the further added feature of low speed electric drive. The downside to this technology is that it requires a significantly larger battery.

Full Hybrids: Non Plug-in or Self-charging

Full hybrid powertrains have been on the market for nearly 20 years. Most notably is the Toyota Prius, which launched in 1997 and has sold 16m units thus far.

The CO2 emissions from full hybrid vehicles represents an improvement of 10-20% beyond a conventional gasoline engine in test and real-world conditions, often being used where no diesel options existed.

The systems utilize high voltage electric motors that have similar performance levels to the IC engine. Full hybrids use the electric drive element to boost torque and operate in electric-only mode. The relatively small batteries control cost but limit the range of electric-only drive.

As discussed in the gasoline engine section, as OEMs and suppliers further develop engines, transmissions and batteries, **it is likely that non plug-in, self-charging hybrids can improve their CO2 emissions to meet <u>current</u> 2030 European targets.**

Plug-in Hybrid

Plug-in hybrid electric vehicles (PHEVs) are charged at an electric charging point and have larger batteries that enable the vehicle to drive in electric-only mode for a significant distance. They are particularly attractive to customers who have a drive profile that includes a significant portion of both high mileage highway travel and regular towing.

The first wave of plug-in hybrid vehicles were sized and optimized to achieve ZEV classification, meaning the vehicle can complete the entire CO2 certification drive cycle in electric-only operation and receives a CO2 certification below 50 g/km. In practical terms, this resulted in electric operation range of typically 30km.

A second wave of PHEVs are now rolling out and generally have larger batteries and higher torque electric motors; **this significantly increased the electric range to between 60km and 100km and increased acceleration and speed capability.**

The increased capability responds to a customer desire to operate the vehicle as an electric vehicle for most short journeys and exploit the technology to drive in electric-only mode in cities that ban internal combustion engine vehicles.

The Future Outlook of Hybrids

All hybrid types are projected to grow through 2030. The types of hybrid offered within each market are intrinsically linked to the government incentives that are in-place.

Mild Hybrids are expected to grow quickly in the first half of the decade, being able to deliver a significant cost effective CO2 reduction. The technology can be applied in all markets and is projected to grow from 3% in 2020 to 15% in 2025 and 20% by 2030. It is unlikely that MHEV vehicles will have sufficient capability to meet CO2 targets in the most stringent markets such as Europe and China by 2030.

As air quality standards tighten, catalyst preheating becomes a requirement and whole vehicle electrical demand increases (example: for autonomous features). Adopting mild hybrid electric vehicle (MHEV) technology and switching to 48V electrical systems is likely to increase and this may push the adoption further than current projections.

The choice between full hybrids and plug-in hybrids will vary by market.

Japan is a unique market; it has invested in full hybrid vehicles for many years and already has a 30% penetration of hybrid vehicles. They particularly suit the high-level of urban usage and low-speed nature of the market.

The US, Europe and China allow ZEV vehicles with combined test cycles of less than 50 g/km. These markets favor plug-in hybrids and will be developed alongside electric vehicles through the next decade. It is likely PHEVs will decline post-2030 as the range capability and charge speed of BEVs improves and the charging infrastructure grows.

Full hybrids will continue to grow in markets where ZEV incentives do not apply, where home charging is not feasible for many customers and particularly in low-speed markets, such as Asia.

Battery Electric Cars

Battery Electric Cars (BEVs) reached 2M annual sales in 2019 and are projected to grow rapidly through the next decade, achieving a market share of 7% (6m cars) in 2025 and 18-20% (19m cars) in 2030.[7]

The more customers experience BEVs the more they find them attractive. They have great functionality with excellent performance and high levels of refinement. Customers quickly adapt to the different fueling processes and in many markets the increased vehicle cost is partly offset through tax rebates.

Driven by government policies and growing customer demand, OEMs are investing huge amounts (an estimated $300bn in the next 10 years) to create better vehicles and aim for cost parity with conventional powertrains. The point at which parity is achieved will differ by markets with Europe, China and the U.S., achieving this ahead of low-cost markets such as India.

Cost reduction will be achieved through a combination of vehicle platform opportunities, scale capabilities and technological developments – particularly battery innovations.

Dedicated BEV platforms offer significant potential for reduced costs, although some manufacturers have developed dedicated platforms (examples: BMW i3, IPace, Tesla). These have not been designed for high-volume manufacturing on the same scale as conventional platforms. Volkswagen Group seems to be furthest down the road in developing a high-volume dedicated platform, and as such, seem highly confident in achieving cost parity in the next decade.

At a manufacturing level, EV platforms require fewer components to assemble and modules have fewer assembly points compared to traditional platforms.

Dedicated platforms can take advantage of the unique features of electric vehicles. This includes:

- More simple controls
- Fully integrated drive units that house their power electronics
- Reduced noise, vibration, and harshness (NVH) and high temperature protection materials
- An optimized package for the battery
- A structure designed to take advantage of the geometry of the battery and drive units

Increasing scale is taking place on many levels. Sharing platforms and major modules across OEMs is accelerating. Volkswagen Group have offered to share some or all of their platform with other manufacturers. Ford and Volkswagen Group have recently signed an agreement to share the modular electric drive (MEB) platform, adding significant volume.

Similarly, companies such as BMW and JLR have started co-developing key modules like drive units to reduce engineering and part costs.

Battery capacity is expanding dramatically. In Europe, battery production is increasing from less than 10 GWh today to more than 500 GWh before 2025. This is accompanied by a corresponding increase in demand for raw materials. In the short term, this may increase material costs. But as new sources are discovered, the prices are likely to reduce.

OEMs have understood the criticality of driving down the cost of the battery and in many cases have drawn this expertise in house.

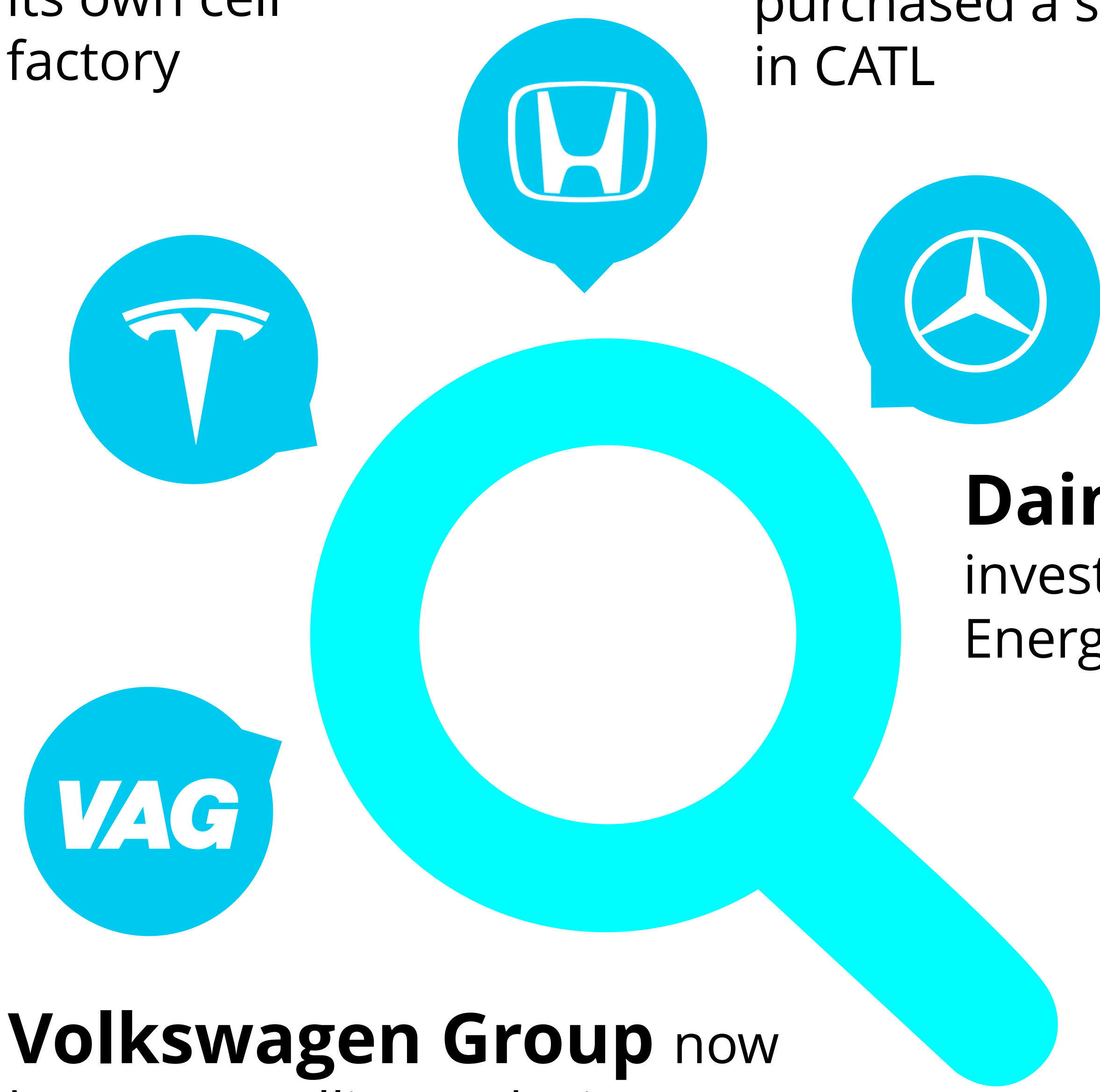
Examples of this include BMW's recently announced Battery Competency Centre, this builds on an already strong internal capability built over 30 years. BMW has stated they expect their i3 battery vehicle to reach profitability in 2021 and are predicting they will double the energy density of the battery by 2030.

They have established strong, long-term strategic relationships with several cell suppliers to speed up the implementation of new developments.

Other manufacturers are moving further down the supply chain:

Tesla is building its own cell factory

Honda has recently purchased a stake in CATL



Daimler is invested in Farasis Energy

Volkswagen Group now has a controlling stake in Guoxuan High Tech Co., a Chinese cell manufacturer, and has also supported a battery cell factory in Germany with Northvolt, a Norway-based battery manufacturer.

These moves further down the supply chain mean Volkswagen Group and other OEMs have global access to the full value chain of the battery from the raw materials to the finished pack.

Under these circumstances, it's understandable that Volkswagen Group are confident in driving the battery costs ever lower.

In addition to OEMs and battery manufacturers, many governments see the strategic importance of securing a place in the science of battery technology and are supporting core research. For example, the UK's Faraday Institute supports over 500 scientists in universities and industry in core battery research.

Given all this investment and effort, it seems inevitable that Lithium-Ion battery costs will reduce to a level that electric cars will have propulsion cost parity with conventional powertrains within the 2020s.

Different types of battery technologies continue to be developed, the most prominent of these being solid state batteries. It is often quoted that a new breakthrough technology will appear. However, given the scale of production investment in Li-Ion batteries, the rate of cost reduction and performance improvement, and the time to prove out a new technology, it is far more likely that evolutionary developments will prevail and any new technology will not gain widespread acceptance until post 2030.

Read more about batter technology development in Appendix 4.

The Future Outlook of BEVs

Government policies in China and Europe have strongly underpinned the growth in the electric car market. These two regions account for 72% of the global market by 2030 and will continue to dominate for the foreseeable future.

Removing favorable tax policy results in decreased sales, as evidenced in Holland and China, suggesting the market is not yet mature enough to self-sustain. It is however likely that direct subsidies to offset the cost gap will decrease significantly in the next few years. Challenging CO2 targets and zero emission mandates will drive OEM's and ultimately demand as subsidies diminish.

Governments are supporting charging infrastructure development. The roll out rate of charging infrastructure has accelerated rapidly in the last few years, both in low-power charging and networks of high-power fast chargers.

As a result of the COVID-19 pandemic, a number of governments in Europe have announced large stimulus programs and bail out packages for auto companies, providing the opportunity for governments to push a "green" agenda, stimulating electrified transport development.

In addition to banning ICE vehicles, major city governors can create further demand for electric vehicles through their own fleet purchases and requiring taxi, utility and delivery service fleets to adopt zero carbon transport solutions. London as an example has a license hire and taxi fleet of 126k vehicles.

Beyond government incentives, as the cost of electric cars reduces to parity, there is evidence that there is significant additional demand. A recent study of Millennial attitudes to purchasing cars showed that 85% of respondents still see a car as necessary, 75% planned to buy a new car in the next five years, and of the population living in cities 88% are expected to buy or lease a second car.[7] Second cars can be seen as a significant opportunity for electric cars as they do not suffer the range criticality of single car ownership.

All established manufacturers have an extensive cycle plan of electric cars that will roll out through the next decade. The damaging impacts of the COVID-19 pandemic will have major implications on many of the established OEMs, forcing them to cut investments in new products.

In Europe and China, this is likely to result in manufacturers maintaining electrified programs at the expense of medium-term conventional programs.

For new, electric-only manufacturers the situation is not the same. For Tesla the market leader, the drop in revenue is disruptive; however, with a large order book to fulfill and a narrower range of technologies to support it is likely they will be resilient and can recover quickly.

For manufacturers who are not yet in production, such as Lucid, Arrival, Volta and Rivian, the disruption has been an opportunity to find more engineering capacity to deliver their first products. What these manufacturers lack is production scale. As established OEMs focus on electric vehicles, it is possible that the new entrants will be the target for alliance or acquisition providing purchase capacity to lower costs and technology acquisition, market share and CO2 credits. Both Rivian and Arrival have links to large OEMs.

Hydrogen

Hydrogen as a fuel additive or within a fuel cells is being developed as a low emission technology and will find a place in the transport sector. However, development is at the same stage electrification was a decade ago and is likely to follow a similar trajectory. Existing manufacturers have active development programs and are operating small fleet tests. New entrants such as Nikola are aggressively developing and marketing the technology and finding market opportunities that will help shape the market position through the decade. Most recently several governments have backed Hydrogen fuel developments.[8][9][10]

Hydrogen has the advantage of higher energy density than electricity and faster refueling times. It requires the development of a fuel infrastructure and lends itself to long distance fleet operation.

Environmentally, Hydrogen production is a relatively inefficient use of energy. One opportunity is to utilize excess renewable energy where it can provide an effective buffer for the periods where electricity production is higher than demand, an issue that is increasing with the increase of renewable energy sources.

Chapter 4

OEM RESPONSES:

CONDITIONS EXIST TO
FURTHER ACCELERATE THE
RAPID DRIVE TO ELECTRIFICATION

Electrification Accelerates **in Europe and China**

In Europe and China, national and local governments support vehicle electrification and are increasingly negative to conventional powertrains. EU7 legislation requires lower tailpipe emissions and further technology investment that will add to the cost of ICE powered vehicles. As this legislation moves later into the second half of the 2020s, it will add costs at a time when BEV technology approaches parity.

In the U.S., sales of electrified vehicles have stagnated since 2018 and with sustained low oil prices it is expected that sales will continue to grow at a slower rate than Europe and China. The recent change in U.S. presidency will likely signal a renewed drive to lower CO2 emissions and will provide more impetus to accelerate the switch to electrified vehicles.

Societal attitudes have also shifted: awareness of both local air pollution impact and climate change is supporting strong government action and is increasing the pressure on major companies to realign themselves with a low carbon agenda.

Many businesses have looked at their transport requirements and have or are planning to shift to electric vehicles. In combination with government fleets, this is driving a rapid transition in bus, light duty commercial and ride hailing markets to electric vehicles. New businesses such as Arrival® and Volta Trucks® have set up to service this market and all existing manufacturers are offering electric options of their existing commercial vehicles.

Customers are increasingly positive about BEVs because they offer great user experience. Incentives to bridge the cost gap, leasing opportunities and new and innovative business models like battery rental lower the cost barrier. Rapid improvement in charging infrastructure and charging speed are reducing concerns with range and charging availability. There is little disincentive for choosing a battery vehicle. Further work needs to be done to make charging services more seamless, but this is a good commercial opportunity and will be resolved in many markets soon.

The huge investment in electrification technology and all aspects of the value chain is driving technology and cost advances that will bring cost parity and improved user experience in the 2020s.

For manufacturers to take full advantage of this will require high volume, dedicated BEV platforms that cannot accommodate IC engines. In all major OEMs, the designs for such platforms exist and are constantly being refined as new developments take place. It is simply a matter of when to fully commit.

Behind this, OEMs are building up internal technical and commercial knowledge, shifting their business models, and developing battery, drive unit and high voltage electronics as core capability.

There will likely be many co-operations and partnerships between OEMs as they strive to build up capacity in new technology while minimizing the investment in existing products.

OEMs are extending their reach through the electrification value chain to secure capacity and costs, building strong strategic alliances with the biggest battery producers such as CATL, while also supporting new entrants.

OEMs are also very aware of the implications of a change from 'tank to wheel' assessments of CO2 to a full lifecycle assessment and are building this into their strategic plans.

This has significant long-term implications across the whole value chain and business model.

Suppliers must understand and manage the complex processes of extending sustainability, from raw material sourcing through the renewable energy for the processing facilities, the reusability and repairability of the design and the logistics of supply.

Similarly, battery recycling will become an important industry and source of high value materials. Today, this is a small industry based off of a relatively small number of batteries and requires technology development. But by 2030, this will be a major industry in key markets.

By contrast, virtually all OEMs have more engines than they need. They have fully developed engine families that range in size and technology and are often manufactured in central plants that have limited flexibility.

As discussed, technical upgrades will be required to meet EU7 emissions and electrification offers straightforward improvements.

Other more fundamental improvements in efficiency require substantial design changes and extensive development in the base units and control systems. Given the cost and lifetime value of these upgrades, it seems likely that only a limited range of engines will be upgraded at EU7 and many of the fundamental improvements will not be implemented.

Even at a vehicle level there is a question as to the value of upgrading conventional powered platforms with significant efficiency improvements versus spending the money on dedicated platforms, unless the parts carry forward into the BEV platforms. OEMs can't afford to do both, and the impact of COVID-19 has come at a critical time in the decision-making process in many OEMs.

Using a workload index, we have estimated that existing OEMs are expending 5-7 times the amount of effort on powertrains compared to a business that is just focused on electric vehicles. Every time emissions legislation is ratcheted up, this difference increases.

The cost of maintaining a globally competitive range of powertrains while developing new hybrid and battery electric systems is a major investment drag on established OEMs and traps a large talent pool of staff; this is true even after OEMs have heavily cut back on most major commodity developments such as new engines and transmissions.

While this cost is tolerated today, as the price of maintaining volume production continues to gouge OEMs, it will become much harder to justify as BEVs achieve cost parity and the same specification of vehicle can be deployed in all markets.

Within these OEMs the drain of resources used for maintaining existing powertrain technology creates a conflict with the desire to put more resource into electrification and other future technologies such as autonomous driving. This will cause OEMs to focus on streamlining powertrain development and also outsourcing this work to others.

Largely, the new entrant BEV-only OEMs are focused on the high-end highest margin vehicles. This is also where established OEMs have developed their initial BEV products, making for an increasingly competitive sector.

Following this are a range of smaller vehicles that have upper price ceilings. This will drive design differences (reduced range, different battery technology) and different sales models, such as battery renting or models where the battery cost and lower operational costs are blended, opening the market.

The highest volume manufacturers and manufacturers that have strong technology links with China will have clear advantages in this sector.

OEMs have developed several business models supporting the rapid expansion of charging networks, from home installations and energy management through to the trans-national high-speed charging networks. This has generated new revenue streams and gives the OEMs access to more customer information. In the past two years the charging sector has accelerated, and many businesses and governments are active in this sector. Charging availability is unlikely to be a market constraint soon and ease of access, which is an annoyance today, will get fixed.

With all these conditions in place, it seems plausible that the market for BEVs in 2030 could be significantly underestimated in both China and Europe. The outlook for the U.S. is less clear but will likely change quickly with the change in administration.

As the vehicle costs change, many smaller markets that have strong environmental intentions could start to legislate for BEVs. One study (IEA Global EV Outlook 2019) analyzed a scenario that reflects a wider adoption of electric vehicles (EV30@30) and is based on a campaign launched at the Eighth Clean Air Ministerial in 2017.

This projection results in nearly twice as many BEVs by 2030 (148m BEV and 27m LCVs) with annual sales of 38M BEVs. The study concluded that this size of market was feasibly within the range of product programs announced by OEMs.

Chapter 5

IMPACT ON SUPPLIERS:

GLOBAL CHALLENGES
REQUIRE LONG-TERM,
DYNAMIC GLOBAL RESPONSES

Impact on Suppliers

The environmental challenge and the technology responses are global, meaning that centralized planning must draw information from many dispersed sources to create and maintain a global long-term holistic view. Many OEMs are strategizing and scenario planning with a 20 to 30-year timeframe, supporting development of their business and informing their lobbying positions with governments around the world. Governments are striving to set policy beyond the 30-year timeframe. Suppliers need to understand what megatrends OEMs are tracking while cultivating relationships with the OEM teams responsible for planning. Given the array of challenges faced by the OEMs, their focus has already shifted.

The impact of COVID-19 has changed electrification growth rate assumptions, particularly in Europe where the government incentives that have been so influential in this transition will be instrumental in accelerating the change. For strong manufacturers, this is a challenge but with effective strategies they are reacting quickly. For weaker and smaller OEMs, this is an existential threat and has created circumstances that some will not survive. The situation creates both risks and opportunities and Figure 9 outlines some of the possible responses for both the OEMs and suppliers.

The OEMs that will succeed best will be the ones who can minimize the cost of maintaining their conventional propulsion systems (including hybrids) while creating affordable BEVs, the volume of which can build up dynamically as different markets allow exploitation.

How OEMs will respond to key Propulsion challenges and potential responses

Challenge	OEM	Supplier
Expanding workload & Cost to meet new air quality standards globally	Globally rationalize a currently expanding powertrain line-up, act dynamically in all markets - Will BEV only deliver in particular market	Understand the value and lifecycle of existing product portfolio, Rationalization
	Drive down the cost of emissions development and outsource development to focus internally on future technologies	Extend capability vs new product design, simulation and advanced rig testing,
	Divest non strategic business - Engine development & manufacture	Expand business scope, dealing with Tier1 vs OEM
Accelerate the drive to cost parity and better for Electric Vehicles	Vertical integration of battery and drive unit production	Value chain owned and understood by the OEM's, where do suppliers fit and add value, new customers
	Increase sources of battery cells, secure supply, add cost competition and back multiple technologies	New Suppliers Emerging - Start up, Buy in, Invest in technology
	Battery technology development, lower cost, longer life, fast charge acceptance, energy density	Acquisition of IP and expert resource, License,
	Introduce high volume dedicated BEV platforms, multiple range and power options	Design optimized systems for BEV, Balance secured business and high volume potential vs unpredictable and regional growth
	Full digital engineering process, Product life cycle management, Agile Development	Reduce development cycle time and cost, Robust digital capability, ability to manage product lifecycle, minimal prototypes and rapid and dynamic development
	Internal software stack expertise and ownership	Develop Software as a stand alone product, development expertise and product pipeline, collaboration model changes
	New business models, battery rental, software add on's	New business opportunities to support OEM's
New market entrants taking profitable market share of the electric market	Move to dedicated BEV platforms, Use size to make better cars, offer a better service, Collaborate and Invest	More Challenging due to pace and performance targets. Cost and product robustness, greater innovation in non electrification systems
Overcome customer concerns with charging availability	OEM's broker home charger installation, Single point access to multiple charger networks, intelligent trip management	New supplier base emerging
Lifecycle management of electrification commodities, Full digital engineering	Source sustainably, Design for repair, reuse and recycling	Understand Sustainability of supply base, use of renewable energy. Increased engineering capability, greater requirements, more standards, responsibility and opportunity for second life use participation

Figure 9: OEM and supplier responses to the key powertrain challenges of the next decade.

What are the Implications for Suppliers?

It has never been more important for suppliers to hold a clear view of the environment in every market and be able to plan both business and technical innovation within a clear framework. Suppliers must have the ability to operate in what will be a dynamic and uncertain decade.

External Framework Development and Scenario Planning

Given the influence of national and local policy in legislation that will influence the viability of particular technologies in both the short- and long-term, and the significant levels of public funding that can be committed to different technology developments, it is important that suppliers create a global external reference framework. Understanding the external factors that can cause the OEMs (customers) to change direction or accelerate decisions enables suppliers to develop multiple scenarios and position themselves to react most positively.

Drawing the information for this from the broadest set of markets has great advantages. While the largest markets are now much more dynamic, smaller but highly profitable changes may come from smaller markets realigning with larger markets.

Portfolio Lifecycle Planning and Value Analysis

For many suppliers, understanding the value and lifecycle of their portfolio will be critical.

How long to invest in existing areas of expertise, consolidating manufacturing and when to sell products are all key decisions surrounding product lines that may become obsolete when electrification becomes dominant. Many far East suppliers have been able to consolidate components that European and U.S. manufacturers no longer see as strategic and developing profitable business.

The new technology behind electrification has grown as quickly in China as it has in Europe, and the U.S. on the back of the large local market and local OEMs. This means that European/U.S. suppliers need a strong awareness of the Chinese supply base and be open to the use of Chinese suppliers as technology partners

As electrification moves into high volume production, platform engineering and material costs come under great pressure. It is likely that the level of product standardization will increase, enabling volume leveraging to drive costs down. However, the upgrade cycle for sub-systems will likely remain shorter than conventional powertrains as the technology evolves faster. Maintaining a high-level of efficient technical innovation will be a key asset for suppliers to grow.

Roadmapping

Actively roadmapping future technologies has great potential in identifying new product opportunities. The key steps required to bring a technology to a commercial opportunity can identify the key enablers such as new skills and facilities that are required to execute.

A comprehensive cross-business roadmapping process enables suppliers to examine an opportunity from multiple perspectives such as engineering, manufacturing and marketing. This provides a more comprehensive analysis, can help avoid missing key delivery factors and can also show where greater market opportunities may exist.

Impact Analysis

Electrification today is at a position where there are significant and rapid developments and skills shortages. How IP and skills are acquired are critical decisions. This can be through internal development and hiring or acquisition in a market where today there are many small specialist businesses that have developed products and IP. Much of the fundamental research is occurring in universities; sponsoring research programs can provide valuable access to information and specialist skills. Following a structured approach to analyzing the full implications of executing a decision to exploit new technology can speed up implementation time and improve the chances of successful execution.

De-Risking Long-Term Strategic Decisions

For electric vehicles, suppliers are fighting for a slice of a small number of systems and components on the new platforms. With the demand to drive down the cost of the vehicle all components, including non-electrification parts, are under great pressure so there is a premium on innovative solutions that break existing cost structures.

Leveraging volume in this situation remains critical but it's likely that demand will remain dynamic for some time. Suppliers will need to effectively manage manufacturing capacity investment while coping with rapid changes in demand and deliver a pipeline of cost reductions and technical upgrades efficiently.

Given the scale of investment and the cross-system requirements of many of the new systems in electrification, consolidation, collaboration and joint ventures have increased as suppliers look to exploit complementary capabilities.

Government funding programs in electrification have extended to innovation and advanced product development. This is an opportunity to de-risk new technology development and demonstration. For suppliers, this can be a challenge as much emphasis is often placed on OEM (end user) participation and the funding comes with significant procedural workload. Suppliers with geographically dispersed development teams are at an advantage as governments expect the funded work to be undertaken predominantly locally.

New Business Opportunities

Services will provide more opportunities as OEMs extend themselves beyond their conventional range of products and services and act as a customer portal. Areas such as on-board monitoring, battery life assessment, repair, recycling and second life usage all create new business opportunities that may have cross-OEM value and do not exist today. Similarly, taking on production of existing products that OEMs decide they wish to vacate can provide valuable opportunities.

Incorporating Lifecycle Analysis into Business Operations

Understanding the sustainability cost throughout the full value stream of products (lifecycle methodologies) will become a necessary cost of doing business with all major OEMs.

Developing a long-term strategy that supports a zero carbon product is a crucial consideration in future manufacturing investment. The two key considerations in this being access to carbon free electricity and low cost logistics.

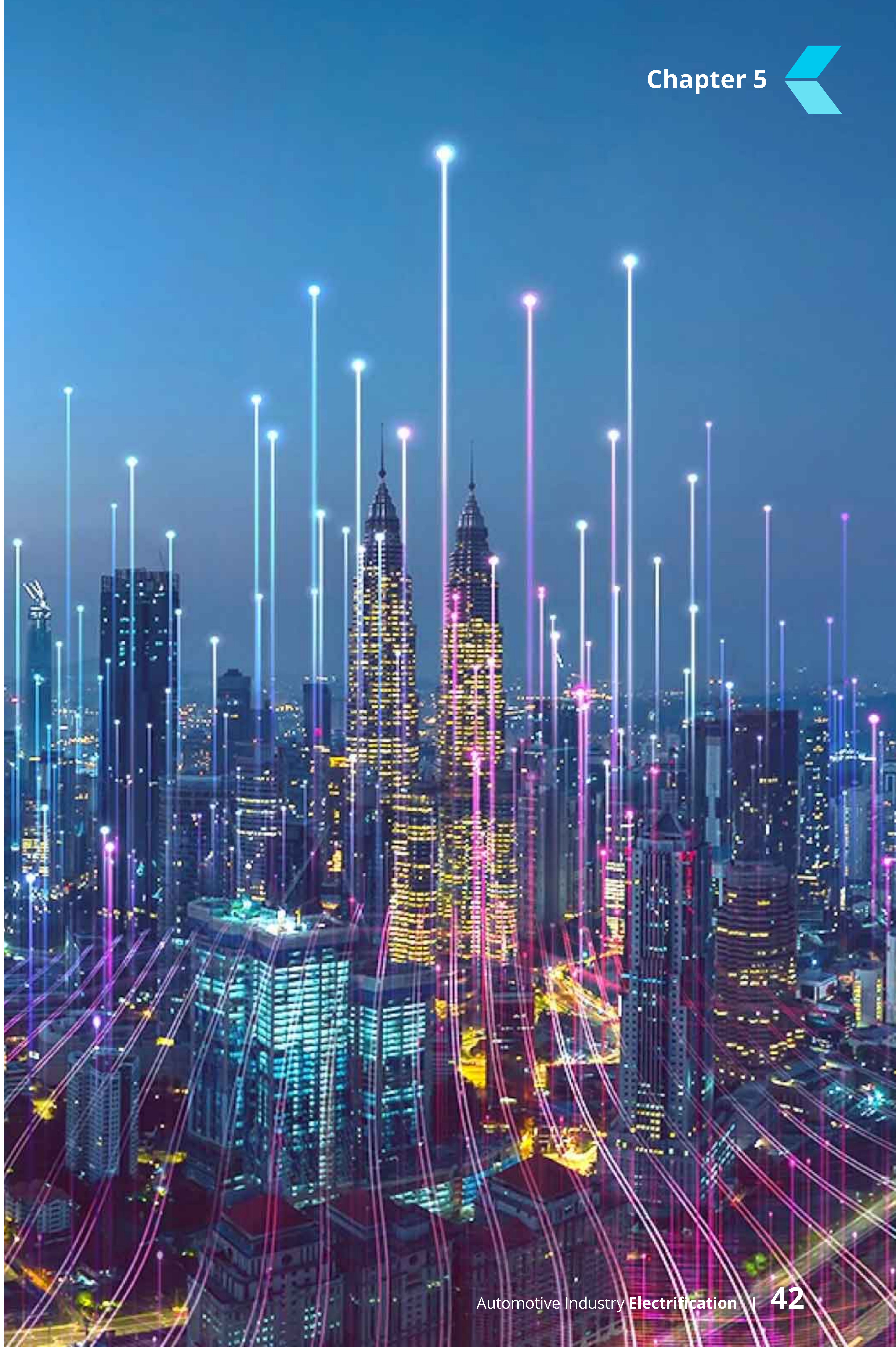
As this type of analysis becomes a requirement from the OEMs and through national legislation, the scope will inevitably expand and encompass other aspects of a sustainable economy. This will include more sustainable land and water use and improved labor relations. Building this effectively into planning processes and decisions will require new frameworks and data collection.

As explained in chapter 2, over the next 20 years far more severe carbon reduction measures will be required to meet the 2050 zero carbon target. This will drive product innovation. Moving beyond low carbon production and recycling, new products will need to have greatly extended lifecycles, be easily repaired, upgraded and reused. OEMs will look to move in this direction and its likely legislation will develop in this direction through the next decade.

Institutionalizing Full Digital Capability Speeds Up Development Cycle

The entrance of new electric-only OEMs is accelerating the digital engineering revolution within OEMs. Unencumbered by legacy systems and background material, new OEMs use the latest digital platforms and engineering thinking, enabling them to operate more efficiently throughout the product development cycle, effectively reducing the time and cost to market. Established OEMs already on this track are embedding the processes into their development cycles.

This impacts every aspect of the development cycle to speed up the process, including systems engineering, structures, technical simulation of products and manufacturing systems, digital component life management, restructured and agile software development, fewer prototypes and complex automated testing systems. All of which drives a much higher level of cooperation between suppliers and OEMs and suppliers with each other. Suppliers will have to invest in the same digital capability to have compatible systems and qualify for work on new OEM programs and be able to meet the expected quality, cost effectiveness and speed of delivery.



About the **Author**

Ron Lee,
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Before Consulting, Ron had a 35-year career in the Automotive Powertrain Business, he reported to the JLR Board for 17 years as Global Director of Powertrain Engineering and five years as Chief Engineer and Programme Chief for Engine Engineering at Jaguar. After a successful career in product innovation and launch for numerous OEMs and with many Suppliers, Ron, a Fellow of the IMechE, now advises companies on the strategy, key decisions, technical structures and methods that get products into production and operating at scale robustly.

Current Roles

- Executive in Residence at Sopheon
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- Technical Advisory Panel, Tokamak Nuclear Fusion
- Board Member I Mech Eng. Powertrain Systems and Fuels Board

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Response

SOPHEON'S RESPONSE:

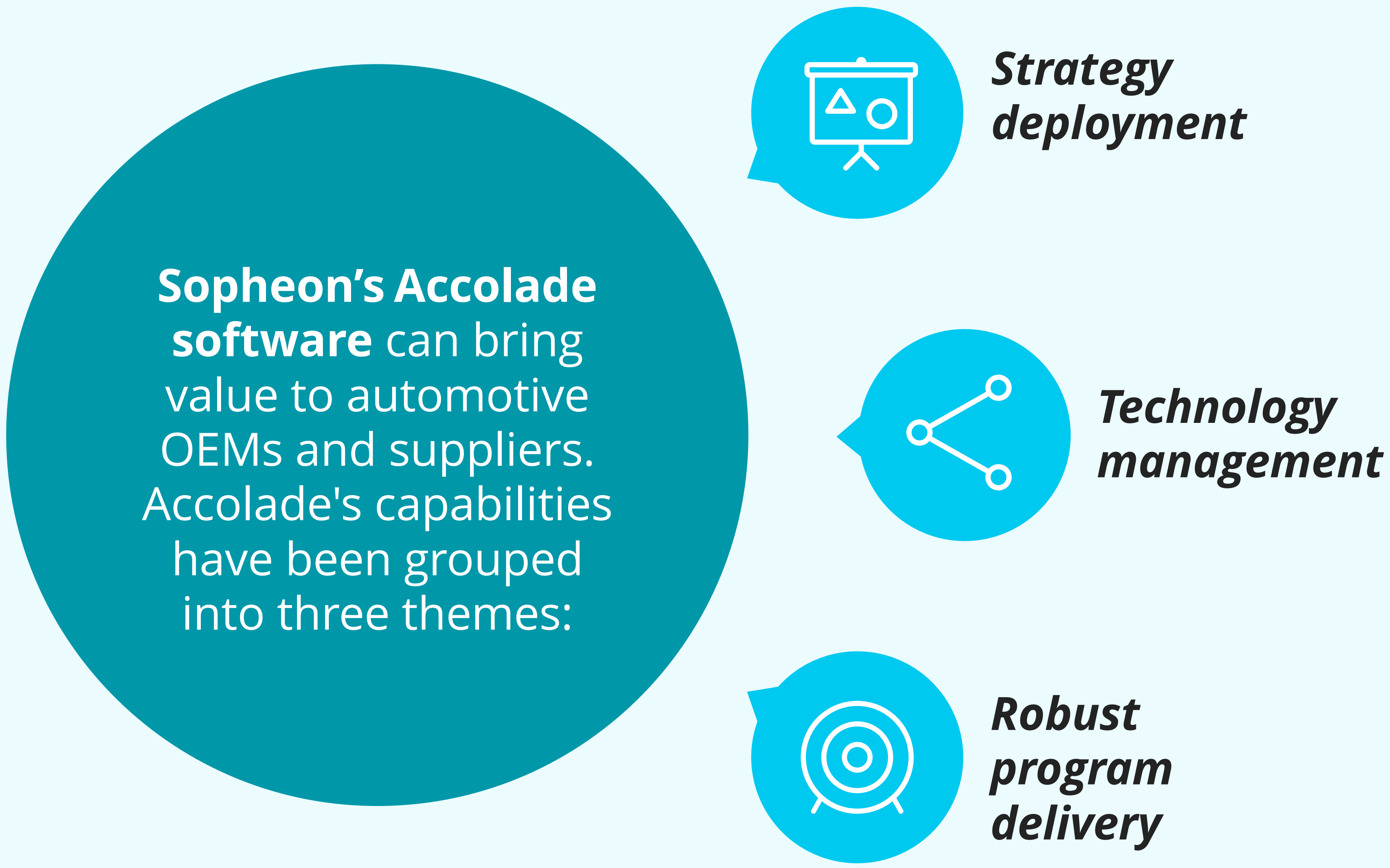
HOW ACCOLADE SOFTWARE CAN HELP

Sopheon's Response
How our Accolade Software can Help Address the Challenges Outlined in This Paper

In this paper, author ***Ron Lee*** – the globally experienced industrial leader with a depth of management, technology and transformation expertise in the road transport sector – has identified a range of responses that suppliers to the automotive industry need to consider and set out some approaches they could take.

As a company that supports a wide variety of customers in their innovation efforts, we at ***Sopheon*** feel we are well-placed to support the automotive OEMs and suppliers that are facing the challenges outlined in this paper and formulating a response to plan for the future. Innovation is now applied not only to the product, but to all aspects of the value chain and business model, which is especially true for this industry at this time.

Our enterprise innovation management solution, ***Accolade®***, combined with our experienced consultants, helps our customers simplify and automate innovation and NPD processes while boosting intellectual productivity. It gives business leaders visibility so they can make informed decisions based on trusted, cross-functional data generated by the daily work of project, program and portfolio teams.

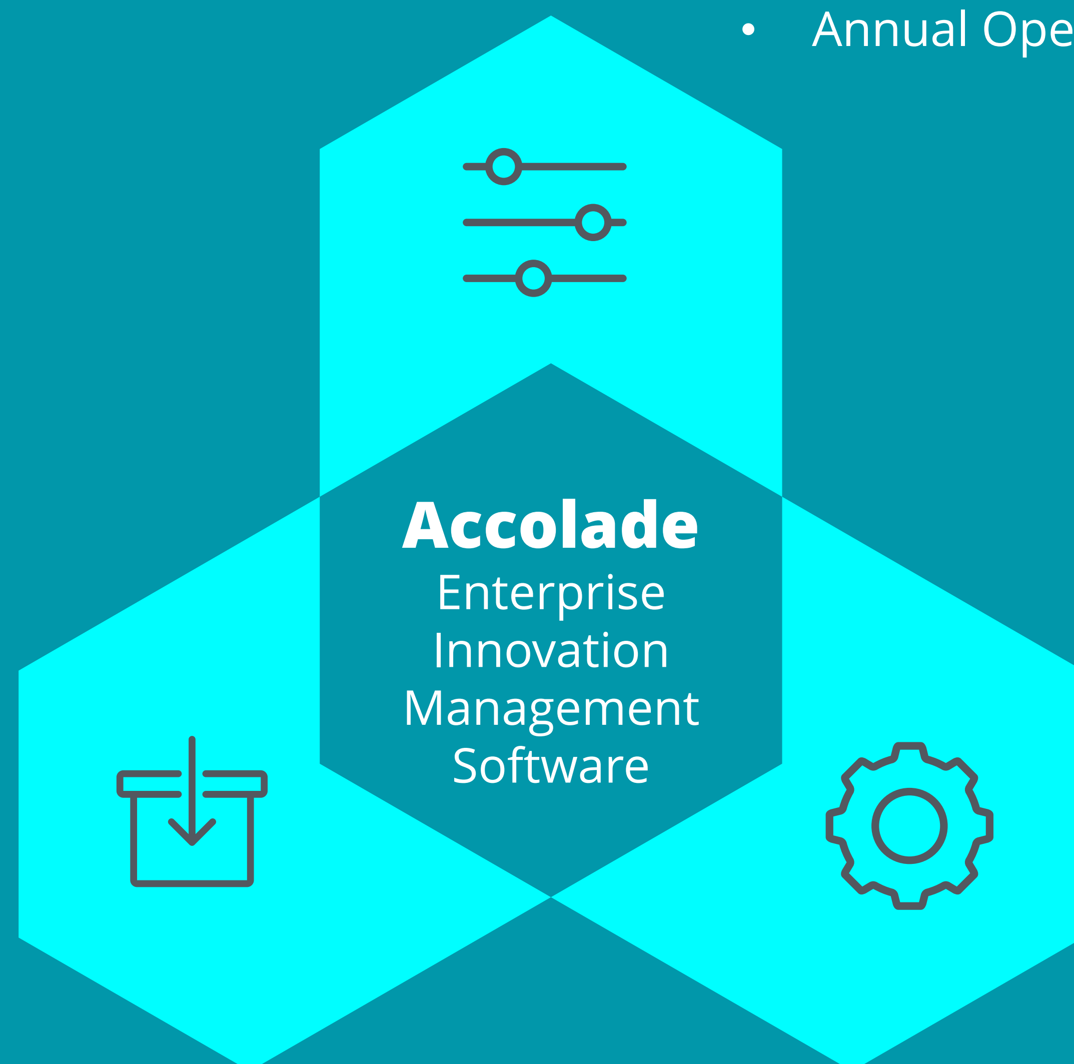


For each theme, ***Craig Bangham*** – Sopheon Senior Managing Consultant and our lead consultant for the road transport sector – analyzes the supplier responses set out in the The State of the Automotive Industry as it Turns to Electrification paper. He then summarizes the value and benefits to OEM and supplier businesses in leveraging Accolade enterprise innovation management software.

Business **Cycle**

Strategic Decision Making

- Business Strategy and Targets
- Product Strategy and Targets
- Product Portfolio and Cycle Plan
- Annual Operating Plan



Robust Program Delivery

- Product Pre-Development Projects
- Product Development Projects
- Product Improvement Projects
- Capability Projects
- Infrastructure Projects

Technology Management

- Technology Development Portfolio
- Product Technology Roadmaps
- Idea Development
- Research and Technology Projects

Typical challenges we see:

- Strong functional expertise, but operating in silos
- Information held in different systems or files
- Customer insight limited and fragmented
- Resources: loaded until they break or projects slip
- Decisions take a long time, much effort to prepare for, and are still based on wrong information

Desired characteristics:

- Highly cross-functional, globally networked teams
- Single source of truth for business -level strategy, planning and program information
- Global understanding of all customer requirements
- Standardized processes for product planning and program delivery
- Top down resource planning and visibility of bottlenecks
- Rapid and effectively connected, two way communication to support agile data gathering and decision making

Strategy Deployment

With the status quo not being an option, the number and significance of strategic decisions made in today's environment are on the rise. Examples include decisions to:

Consolidate manu-facturing sites

Invest in expertise or build capability

Acquire or divest businesses

Develop new technologies

Due to the dynamic environment, these decisions need to be revisited frequently and any course correction needs to be cascaded throughout the organization in an effective manner.

Often, companies determine strategic initiatives to execute on these decisions. For example, a strategic initiative to improve the CO_2 footprint throughout the full product lifecycle and value chain may be established. As this initiative uncovers new findings, projects are mobilized, and smaller decisions are made that need to be implemented across multiple functions and programs.

To support strategy deployment, Accolade can:

- Bring together intelligence about the external environment into one place to provide business context (for example: regulatory, competitors and customers)
- Enable the analysis of multiple "what-if" scenarios to understand potential outcomes of different decision choices (for example: multiple versions of the product cycle plan)
- Support the annual operating planning (AOP) process by capturing the key outputs of each step, visualizing plans and allowing for a more dynamic AOP
- Validate the effectiveness of previous decisions by comparing the expected outcome at the time with the actuals in a next cycle of the AOP. Subsequently finding root cause(s) and adjusting process to continuously improve
- Support the capture, cascade and monitoring of targets throughout the business
- Enable the planning and execution of the strategic initiatives and deliver the strategy
- Ensure that both pre-development and product development activities are aligned with customer needs, strategic priorities and financial targets

Typical benefits achieved when deploying Accolade to support strategic decision making include:

- Improving alignment of product cycle plan with strategy, customer, regulations and resource availability
- Improving business agility through access to high quality, timely decision-support information
- Maximizing the return on investment of available resources by analyzing multiple portfolio scenarios
- Providing suppliers with the ability to compete for an increased share of the market, via increased visibility of customer needs and timing
- Improving "intellectual productivity" by removing the dependency on manual methods of managing data (typically in MS Office documents)

Technology Management

As highlighted in the paper, the race to develop and optimize new technologies is as furious as ever: **there is great pressure to not only improve performance (be it range, efficiency or other attributes), but also reduce cost.**

Understanding customer needs and the environment is imperative to laying the foundations of a product technology roadmap that will deliver on strategic goals. As the technology landscape becomes more dynamic, decisions and plans need to be re-visited more often, so having up-to-date status information becomes a critical business capability.

Viewing roadmaps through multiple lenses helps ensure that all delivery factors are considered. Ensuring that solutions are re-used and re-applied, rather than re-invented across a large, geographically dispersed organization, is another common challenge. Deciding what to invest resources in and consistently executing technology development projects with multi-disciplinary teams is another challenge.

To support technology management, Accolade enables the:

- Active management of technology roadmaps, with multiple views of the same roadmaps to allow analysis through different lenses
- Mapping of solutions to customer needs
- Evaluation of investment opportunities using qualitative and quantitative methods
- Generation of ideas to support gaps in current and future product quality, cost, weight and functional roadmaps
- Planning and execution of technology research and development projects with a repeatable process
- Collaboration with external parties in the above in a digitized way
- Tracking of your IP

Typical benefits achieved when deploying Accolade to support technology management include:

- Improving visibility across research and product planning teams' work
- Identifying opportunities and dependencies early on
- Enhancing the speed and quality of decision making for technology investments
- Better alignment of the technology investment portfolio to business and product strategy
- Increasing technology adoption and re-use across more customers and applications, maximizing return on investment
- Reducing effort to maintain data, with improved information quality
- Reusing knowledge, ideas and concepts for different products and use cases

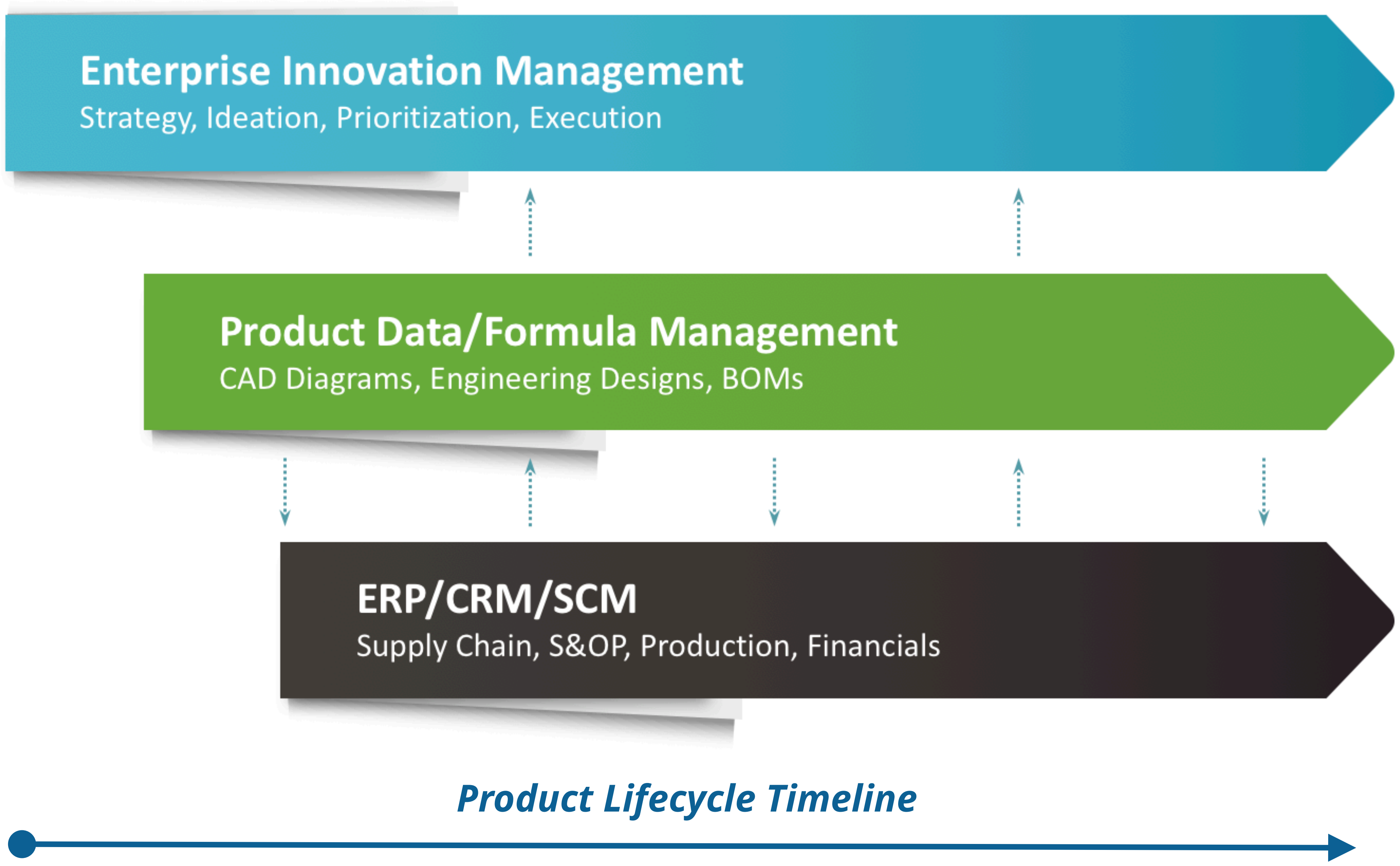
As technical innovation becomes more of a business-wide activity, then these benefits can also be applied to innovations outside of the core R&D-led product technology development. Examples include innovation of the manufacturing process, business model, service, channel and customer engagement.

Robust Program Delivery

Most OEMs and suppliers have already invested significantly in the digitization of their product development activities at the technical-execution level, for example with CAD, CAE and PLM solutions, and at the transactional-level with ERP solutions. As Ron highlights, the new entrants have found this easier due to the lack of legacy systems and data which make it more challenging for established organizations to transition into a seamless digital environment.

However, the benefits of these investments are often not fully realized as the "business layer" is managed using a combination of manual solutions that cannot adequately support the business decisions and process collaboration required to successfully develop complex products.

Sopheon's Accolade is the Business Layer of the Product Lifecycle



Sopheon

Business layer

- Strategic Innovation Planning
- Roadmapping
- Portfolio and Resource Planning
- Idea and Concept Development
- Process and Project Management

Engineering Technical layer

infor DASSAULT SYSTEMES SIEMENS PTC ORACLE PLM

Transactional layer

SAP ORACLE infor

The need to share a common source of program-level information is even more critical when collaborating across organizations, for example, with a customer or partner.

With resources dispersed around the world and demand for skills evolving faster than ever, understanding where you will have gaps or opportunities now and in the future can make the difference between being first or second to market with a new innovation.

With reduced system upgrade cycles, the pressure to diminish and stick to delivery timescales is immense. Having a solution that allows you to manage these programs while bringing in key data from the technical and transactional layers helps increase efficiencies and meet deadlines.

To support robust program delivery, Accolade can:

- Automate NPD processes like Stage-Gate® to support different types of projects and programs
- Collate program team inputs across functions and systems engineering teams
- Provide standardized deliverable templates to improve quality and consistency
- Present configurable analytics to support gate decision making
- Support top-down planning based on project types to streamline development and investment efforts
- Manage product target setting and status
- Capture lessons learned
- Support the planning of resource demand and capacity across the portfolio in a proactive manner to support decisions in investment, recruitment and outsourcing

Typical benefits achieved when deploying Accolade to support program delivery include:

- Enhancing the speed and quality of decision making (for example at program gates)
- Improving team collaboration and efficiency, by assuring all cross-functional team members have access to the latest information and are involved at the right time for the right type of program, and in reporting
- Reducing program delays by providing a more timely and robust view of program health, thus avoiding the additional costs and loss of revenue that delays incur
- Improve speed to market and capture the advantages related to earlier market entry, by, for example, inclusion of latest process thinking and lead time reduction practices within the Accolade representation of this process
- Improving risk visibility so that they can be addressed appropriately
- Reducing the cost of poor quality in the delivery of projects, through the standardization of work and gate governance
- Increase success rate, with success defined as capturing the full potential of the program's business case at the time it was expected
- Leveraging organisational information and knowledge reuse across teams, products and initiatives
- Improving visibility of resources and capabilities across the enterprise

Sopheon has a track record of working with its customers to solve complex problems across many industries. We do this through teamwork, the application of our knowledge and experience, and leveraging the capabilities and flexibility of Accolade. We can bring an experienced team of people to help you address the challenges set out in this white paper and enable you to be better positions for the challenges of the future. With so much riding on every decision made, the sooner you act, the better.

Want to **know more?**

Contact Sopheon and we will connect you with an industry specialist to begin discussing the challenges you are facing and how to **bridge the gap** and accomplish strategic goals.

START THE CONVERSATION

About the **Author**

Craig Bangham,
Senior Managing Consultant

Craig has over 11 years' experience as a consultant and 15 years' experience in industry, including 7 years in the automotive industry.

Craig's automotive career was primarily at Jaguar Land Rover, where he held several roles within Powertrain Engineering, covering the full product lifecycle from concept development, through to launch and plant vehicle team support.

Craig has been a consultant with Deloitte prior to joining Sopheon, where he led the UK Product Development practice. As a Managing Consultant, Craig draws upon his considerable business and consulting experience to ensure our clients can derive value from the Accolade solution.

Craig is based in the UK, has an Engineering Degree from Cambridge University and is a Chartered Engineer.

Connect with Craig on LinkedIn.

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Appendix

Appendix 1:
Further Actions Required to Develop a Net Zero CarbonPlan

Currently, all carbon reduction plans fail to meet Net Zero commitments by 2050. Several countries have made commitments to achieve carbon neutrality by 2050. However, no one has produced a plan that can achieve this. A number of significant obstacles exist and these are likely to form frameworks for future government policies.

The cost of producing sustainable electricity has dropped significantly to the point where new wind and solar plant can be delivered and operated cheaper than all fossil fuel sources. However, the growth rate for building and commissioning is unlikely to keep up with the huge demand increase from all sources, a recent analysis in the UK suggests that only 50-60% of anticipated demand (based on today's consumption demand projected) can be built. The implication of this is that transport will need to operate within this "zero CO2 budget allocation" constraint.

This will have a profound effect on the whole product lifecycle and will go well beyond the popular view of lifecycle analysis, where the energy consumption for producing the vehicle, its operation (fuel) and end-of-life are accounted for.

To meet this budget allocation, several strategic and technical strategies will need to be developed and many OEMs are now developing their own thinking to align their long-term strategies to this situation.

At a strategic level, extending the life of vehicles and their systems will have a significant effect on manufacturing energy use, with greater focus on refurbishment, repair, reuse and a significant (50%) reduction in manufacturing scrap.

Large scale mass reduction (1000 kg), reductions in drag (5%) and continued focus on vehicle efficiency (average to the best available technology) will all be required. This requires a reversal in current industry direction and customer preference for large and bulky SUVs.

Appendix 2:
Dieselgate Emissions Scandal

In September 2015, Volkswagen admitted to the U.S. authorities that its diesel vehicles were fit with control strategies that defeated emissions tests and allowed the vehicles to pollute in real world operation. This scandal – which became known as "Dieselgate" – rocked the automotive industry and triggered the mass exodus of customers from the diesel market. While the scandal effectively lost consumer trust and pushed buyers over the edge, the key elements of government policy against diesel cars had already been set into motion.

Dieselgate precipitated a wave of investigations into all vehicle manufacturers by authorities in many markets, rippling consequences for manufacturers as some of these investigations are still on-going today. As of 2020 the total cost to Volkswagen is estimated at over €31 billion. While the investigation revealed no other manufacturers cheating in the same way, the investigations highlighted the extent to which manufacturers were manipulating their designs and calibrations to achieve low emissions results on the test cycle and then optimizing for fuel economy, refinement and component durability in the real world operation (off cycle). This in turn brought the inadequacies of the certification processes and test requirements into the spotlight.

In technical circles, this was a known problem and the new Worldwide Harmonized Light Vehicle Test Procedure (WLTP) test cycle and the requirement for real world testing standards (RDE) were being developed to address this shortfall. However, Dieselgate strengthened the position of the environmentalists and legislators and greatly weakened OEMs' arguments for less stringent standards. It resulted in a rapid set of ever stronger emissions requirements introduced in Europe and China. Examples include EU6c, enacted for all vehicle registrations in September 2018, and EU6d mandated in September 2020 for new homologations and September 2021 for all registrations.

Importantly, the legislation now requires OEMs to use the best available technology, which has generally translated to OEMs employing one base technology solution. The legislation also leaves compliance responsibility with the OEMs by stating that the vehicle is compliant in all circumstances rather than specifying a test cycle. This has led to a massive increase in testing by the manufacturers, effectively adding costs for both test facilities and development work.

The net result of Dieselgate and the legislation changes that accompanied it is that the latest diesel cars are very clean in virtually any circumstances. Unfortunately, the cost of the vehicles has increased and many manufacturers have chosen to stop developing the technology. Governments have also hardened their views that electric vehicles are the future, bringing on the seemingly inevitable steady decline in diesel car volumes.

Appendix 3: **Engine Technology Development 2020-2028**

Modern engines are the result of compliance to ever more stringent emissions legislation and a drive for maximum efficiency (minimum CO2 emissions). However, within the engine these dual objectives are not always mutually achievable and in recent years the need to produce ever cleaner cars has taken priority over the drive for efficiency.

Improving efficiency is focusing more and more on increasing the electrification application within the engine. For both petrol and diesel engines, the key systems that are the focus of upgrades are largely the same.

Petrol Engines

Reducing Emissions

For petrol engines the key focus is reducing particulates and cold start hydrocarbon emissions:

- Reduce particulate emissions by up to 65% by increasing fuel injection pressures from 200 bar to between 350 and 500 bar
- Upgrade exhaust after treatment, including gasoline particulate filters (GPFs), close coupled three-way catalyst (TWC) and additional underfloor catalysts, controlled by fast-acting lambda sensors
- Enable catalysts to rise to operating temperature with only a 2-3 second delay before the car can drive by incorporating additional catalyst heater burners

Improving Efficiency and CO2 emissions

There is potential for further improvements in engine efficiency and hence CO2 emissions, both through changes in engine technology features and through increasing levels of hybridization. For vehicles in Europe to meet the stringent CO2 targets by 2030, it is unlikely that any non-hybridized powertrain will be sold.

Engine efficiency improvement level between 10-15% are feasible. This can be achieved by adopting modified operational cycles such as the Miller or Atkinson cycle, and augmenting these with advanced turbocharging solutions and further increases in fuel injection pressures. Several manufacturers have made developments in this direction.

Further gains can be made by adopting higher compression ratios with pre-chamber combustion systems, however this requires significant changes to the base engine design and while the concept is proven and demonstrated, a great deal of work is required before high volume exploitation; given the drive for electrification it is arguable that complex features such as this and variable compression ratio systems will now see volume production.

As levels of hybridization increase, further efficiency gains can be achieved by creating dedicated hybrid engines that are optimized to work in-concert with the electrical power. This can reduce weight, package and unit cost. How far this trend will progress is uncertain. Stripping engines of the accessory drive and replacing mechanical pumps with electric units improves engine efficiency at relatively low investment.

However, actions that progress beyond this create significant effort and complexity in the base engines — because engines are generally produced for a global market and non-hybrid options will remain for many markets — and significant work in control and calibration development. When this is compared to modest simplification of the engine and the use of a plug-in hybrid system, it is not clear if the effort will be warranted.

Diesel Engines

Reducing Emissions

The key focus for diesel engines is reducing NOx across the whole operational envelope particularly due to highly dynamic driving:

- Reduce particulate formation through improved fuel injection control features (digital rate shaping), increased fuel injection rail pressure (2700-3000 bar) and temperature control strategies
- Optimize catalyst temperature through reduced thermal mass, highly dynamic turbochargers
- Reduce NOx by 50-80% in high load operation via updated after treatment systems featuring two-injection-point urea selective catalytic reduction (SCR)

The deployment of ultra-low emissions diesel technology in countries that do not mandate such strict emission targets is limited by the sulfur content in the fuel, the technology is susceptible to poisoning at fuel sulfur levels above 50ppm, in many countries legislation has been enacted to bring fuels into compliance.

Improving Efficiency and Reducing CO2 Emissions

It is doubtful that significant improvements in diesel engine efficiency will be delivered with this round of technology updates, with the additional energy demands of increased fuel pressure and after treatment heating offsetting any improvements in efficiency.

It is possible to improve the engine efficiency by changing from aluminum to steel pistons as this improves heat loss and hence boosts efficiency; several manufacturers have moved to deploy this technology. Additionally, low friction coatings have been developed.

As with petrol engines the addition of electrification also benefits diesel engines.

Appendix 4:
Battery Technology Development

Energy storage and battery demand will grow massively through to 2050 as society de-carbonizes in all sectors. To support this, many governments and businesses are investing heavily in technology development, and the automotive industry represents an important subset of this development.

Lithium-Ion batteries are the technology of choice for plug in hybrids (PHEVs) and Battery Electric Vehicles (BEVs) due to the high energy density and relatively low weight. The capability of the batteries has improved dramatically over the past decade and its expected that the functionality and cost will improve significantly further by 2030 as shown in the charts below.

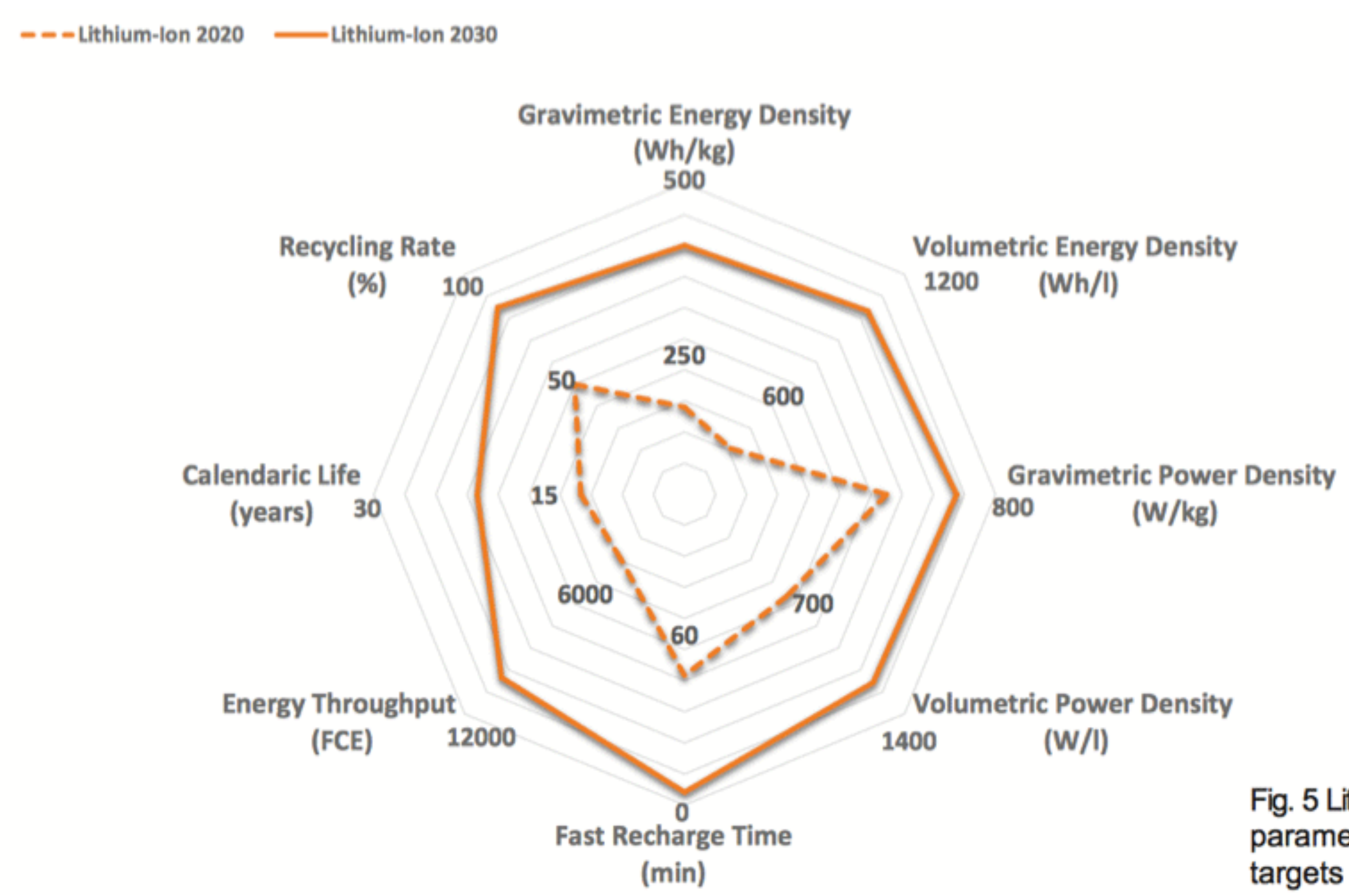
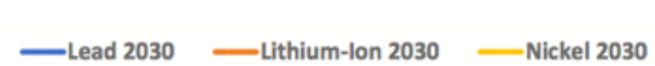


Fig. 5 Lithium based technologies: key performance parameter data – state-of-the-art 2020 and targets for 2030

Overview of the targeted key performance indicators by 2030 for each battery technology, demonstrating the continuation of the complementarity of the technologies in the market



EUROBAT Battery Innovation Roadmap 2030

		Lithium-ion	
		Lithium ion 2020	**Lithium-ion 2030**
Electromechanical-System	**Cathode**	NCM 111 (Gen.2a); NCM 523-622 (Gen.2b), LFP, LMO, LCO, NCA	NCM 622 – NCM811 (Gen.3a); NCM 811, HE-NCM, HVS (Gen.3b); Solid State
	Anode	LTO, C (Gen2a. 2b)	C+ Si (5-10%) (Gen.3a.); Si/C (Gen.3b)
Energy Density (Wh/kg)	**Cell**	60 - 250	300 - 450
	System	20 - 140	80 - 400
Energy Density (Wh/l)	**Cell**	140 - 580	650 - 1100
	System	20 -250	100 - 1000
Power Density (W/kg)	**Cell**	210 - 1800	450 - 1100
	System	170 - 520	250 - 700
Power Density (W/l)	**Cell**	470 - 2200	800 - 2500
	System	180 - 650	600 - 1200
Lifetime	**FCE (Full Cycle Equivalent)**	>3500	>10.000
	Calendaric Lifetime [a]	10	15 - 25
Operation Temperature range [*]		0 … +45 °C charge -20 … +60 °C discharge -30 … +55 (LTO)	-30 … +60
Energy efficiency [%]		>90	95
Recycling	Efficiency (% of average weight)	50	8 - -85

Table of performance parameters for each battery technology – state-of-the-art in 2020 and targets for 2030

Source: EUROBAT Battery Innovation Roadmap 2030

- **Generation 2a.** NMC 111 / 100% C
- **Generation 2b:** NMC 523 -622 /100% C
- **Generation 3a:** NMC 622 / C+ Si (5-10%)
- **Generation 3b:** NMC 811 / Si/C composite

Due to the variety of possible combinations of cathode and anode materials, the resulting Li-ion batteries show specific and individual performance characteristics suitable for different kinds of applications. The development of Li-ion technologies suitable for industrial and automotive applications is still a challenge in terms of material research, process, production, development, recycling, safety and transportation.

Source: EUROBAT Battery Innovation Roadmap 2030

The charts compare state-of-the-art 2020 battery cells with anticipated state-of-the-art batteries in 2030; this shows gravimetric energy density increasing by a factor of three and charging times reducing from tens of minutes to minutes while lifetime performance increases by a factor of three. This is enabled largely by higher nickel content in the cathode and a switch to solid electrolyte. This change also significantly increases the battery safety as it is the liquid electrolyte that tends to burn in today's batteries.

Battery cells with even higher charging efficiency at high current densities can be achieved by using Lithium metal as the anode. However, more work is required to overcome the growth of Lithium dendrites that quickly deteriorate performance. Several solutions to this, including polymer solid state electrolyte have been demonstrated but require further development to industrialize.

Nickel-rich batteries are already in production and will continue to develop throughout the decade, with solid state electrolyte being production ready towards the end of the decade.

Such high performance batteries come at the expense of cost, where OEMs are focused on range, package and charging speed, as is the case with many European OEMs, Nickel Manganese Cobalt (NCM) and Nickel Cobalt Aluminum (NCA) cells are favored.

When cost and high reliability are the primary consideration for applications then Lithium Iron Phosphate (LFP) batteries are used. Typically, LFP cells have lower energy density and lower voltage than high performance cells leading to larger packs with lower range.

The Chinese market has continued to use and develop this cell chemistry and it is used in the home auto market and commercial applications such as busses. CATL and BYD (China based battery manufacturers) have continued to invest and improve the performance. Tesla recently sourced LFP cells for the China localized Tesla 3. It is projected that up to 25% of the auto cell market will be LFP cells. This is also the basis for the recently announced one-million-mile battery.

Beyond the chemistry of the cells, improved cell performance and safety is driving developments in cell sensing, including the development of embedded sensors in the cells that are potentially using wireless broadcasting to communicate with the battery management system.

Further safety mitigation systems are being continually improved both to sense thermal runaway events at the earliest point and to suppress and delay the event for as long as possible.

At a pack level, moving from a nominal 400V operating Voltage to 800V has several advantages. It enables higher charging rates (reducing charging times to circa 15 minutes on a 350KW charger). It is also possible to reduce the weight and cost of the pack by reducing the weight of the current carrying cables for equivalent performance to a 400V system. Today the Volkswagen Group, through Porsche, have deployed 800V systems, along with Hyundai which has also introduced such a system.

It is likely that other manufacturers will move in this direction and this will require Suppliers to redevelop the power electronics systems to operate at the higher voltage.

Battery pack management systems (BMS) will continue to develop to optimize the efficiency of the pack under all its operating conditions (calendar Life – standing, charging and discharging – running operation), all OEMs are linking the battery to off vehicle information and services and this is used to monitor the batteries performance and to optimize the battery condition ahead of charging.

With the high cost of batteries, the importance of second life usage and recycling of the materials, a great deal of research is being invested in new designs of battery module and pack to improve assembly, repair and disassembly.

Thank you

Interested in learning more?
Contact us.

CONTACT US

For more information, visit **www.sopheon.com/automotive-innovation**

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