E-mobility and electrification

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E-mobility and electrification

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1 Vehicle Electrification

- From simple engine start/stop to full battery electric – how they operate
- Mild vs. full Hybrid – *Watt's* the difference?
- Transmissions and their fluids have a key role to play

2 E-fluid Formulation

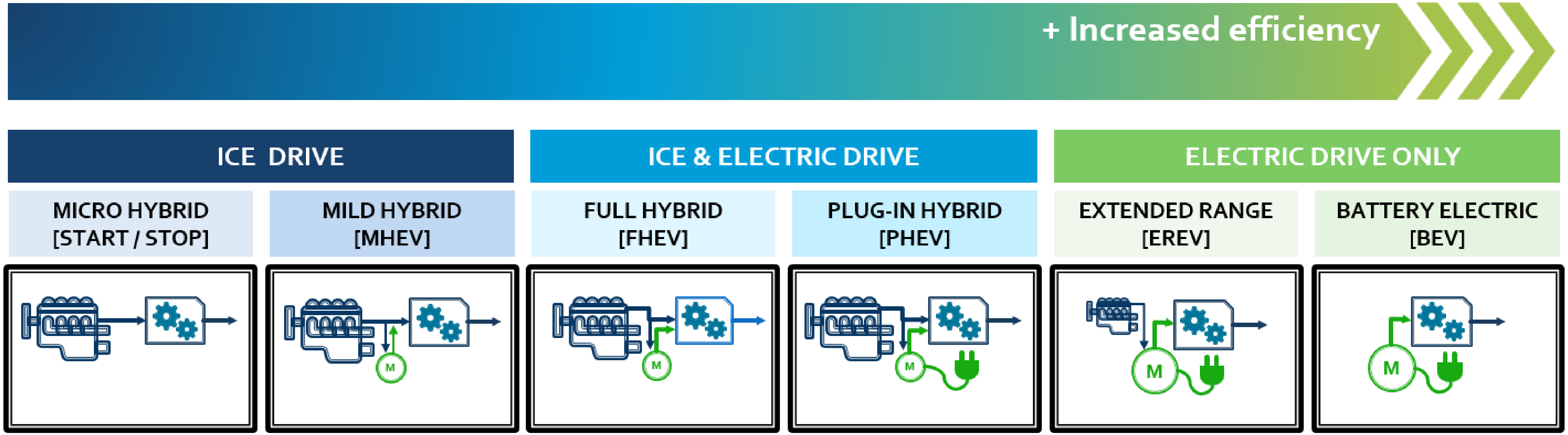
- New fluid requirements include motor cooling, compatibility and electrical insulation
- All must be balanced with transmission performance and durability

3 Electrification Outlook

- There will be a mix of technologies to meet climate goals depending on the application and region, including hybrids, FHEV, BEV, alternative fuels and improved ICE
- Global passenger car vehicle parc exceeds 1.4 billion, with sustained demand for conventional PTF through the 2030s

1. Vehicle electrification

Electrification Trends



Electrification trends – design and PTF impact

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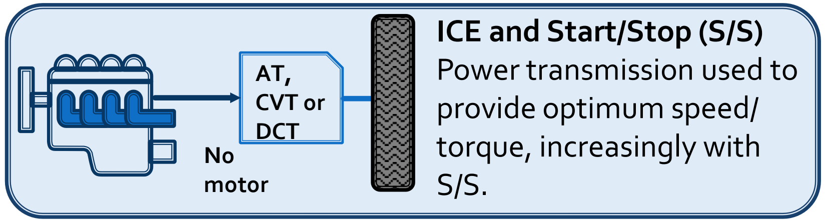
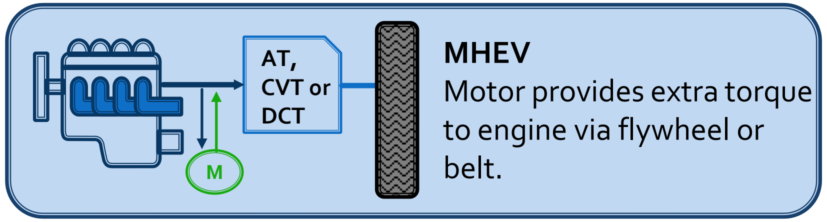
Mild Hybrid Electric Vehicles [MHEV]

Use conventional transmissions

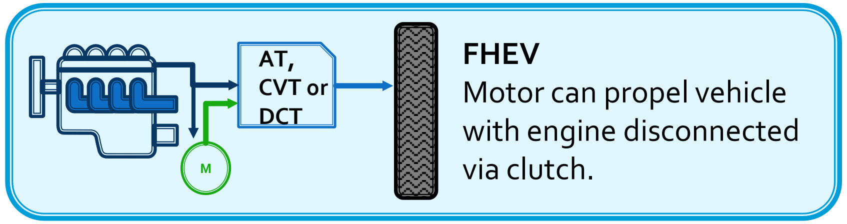




- Motor is placed either before [P0] or after [P1]
- **Standard ATF, CVTF or DCTF used, as transmission and motor are separate**

Full Hybrid Electric Vehicles [FHEV]

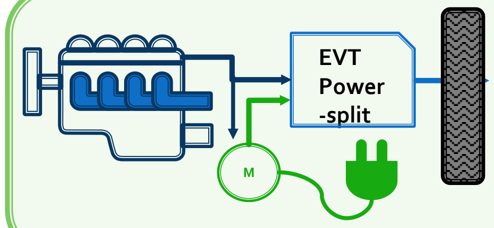
Typically house motor within transmission casing



- Referred to as "Wet motor", housed in the transmission in contact with the oil
- Motor can be placed before [P2], or after [P3]
- **ATF, CVTF or DCTF is used to cool and insulate motor, while providing friction performance and gear protection**

Electrification trends – design and PTF impact

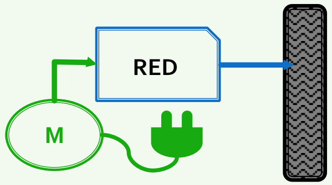
FHEVs may also use an
Electronic variable transmission [EVT] where a planetary gearset or set of clutches manage the power split [PS] between the engine and motor



EVT
Full hybrid electric vehicle with **electric variable transmission** split motor/engine power

- Shifting clutches are eliminated
- **Transmission fluid used to cool and insulate the motor, and protect the gears**

Battery Electric Vehicles [BEV] employ a **reduction [RED] gearbox**



RED
BEV with **reduction gearbox** used to convert motor speed to torque.

- Motor is connected to drive shaft, typically using a simple two-gear design
- **Motor and gears may be housed together, so transmission fluid may cool and insulates the motor, while protecting the gears**

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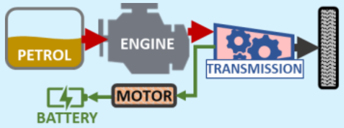
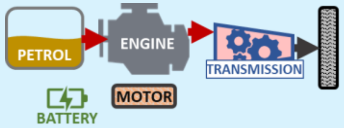
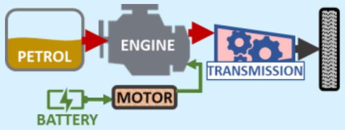
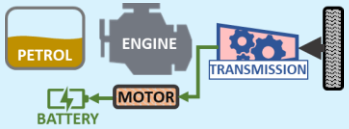
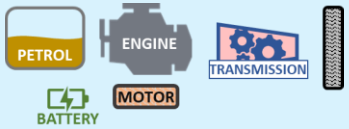
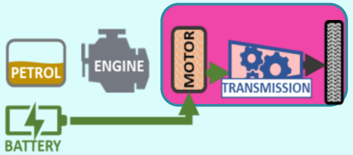
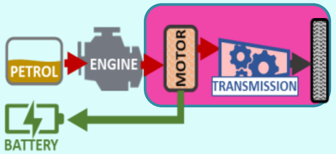
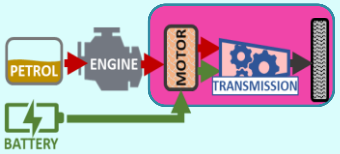
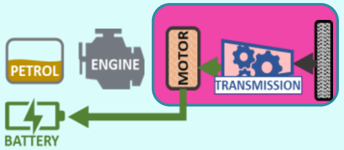
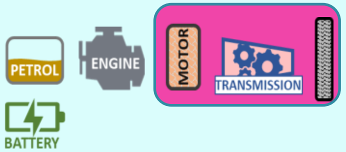
Vehicle electrification
operation of mild hybrid vs. full hybrid designs

GENTLE ACCELERATION	CRUISE	FULL ACCELERATION	DECELERATION	STOP
MILD HYBRID Engine drives vehicle. Motor captures any extra engine power to charge battery. 	**MILD HYBRID** Engine drives vehicle. Motor is on standby. 	**MILD HYBRID** Engine drives vehicle while **Motor only assists engine.** KEY DIFFERENCE 	**MILD HYBRID** Engine off. Motor regenerates braking energy to charge battery. 	**MILD HYBRID** Engine and Motor off. Battery provides energy to run accessories, such as A/C. 
FULL HYBRID **Motor drives vehicle** Engine is on standby. KEY DIFFERENCE 	**FULL HYBRID** Engine drives vehicle. Motor captures any extra engine power to charge battery. 	**FULL HYBRID** Engine and Motor both provide power to drive the vehicle. 	**FULL HYBRID** Engine off. Motor regenerates braking energy to charge battery. 	**FULL HYBRID** Engine and Motor off. Battery provides energy to run accessories, such as A/C. 

Battery electric vehicles (BEVs)

BEVs are 60~73% efficient (without regen)

Many approaches to gain more miles from a single charge

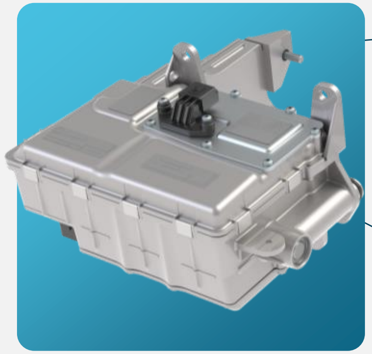
Increase power density

Reduce weight

Conventional

E-Machine

Power



Gearbox

Separate components widely used

Image: GKN Automotive CC0

Battery electric vehicles (BEVs)

Integrated approach

Reduced labor costs

Smaller lighter packaging

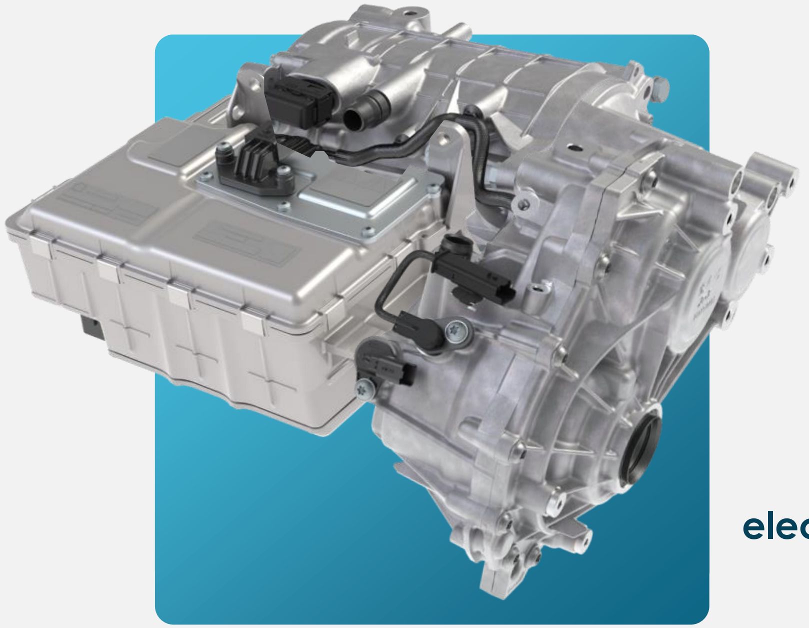
Reduced material costs

Integrated cooling

Increased design complexity

Higher working temperatures

Integrated electric drive unit



E-machine, gearbox and power electronics fully integrated

E-fluids increasingly required for cooling

Image: GKN Automotive CC0

Electric drive units and e-axles

Adoption rising

Nidec
5 models, 10 Million production by 2030

BluE Nexus
mass production for Toyota's bZ4X

Schaeffler AG
4 in 1 – includes thermal management

ZF Friedrichshafen AG
new generation 'e-drive'

JATCO
aim to produce **5 million** by 2030

Bosch mobility solutions
e-axle central to success

Hitachi Astemo
e-axles for Honda from 2026

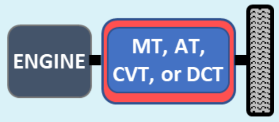
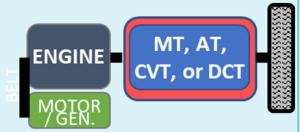
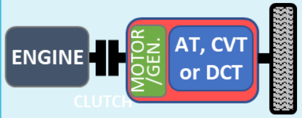
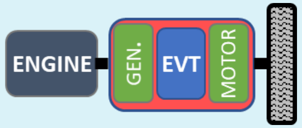
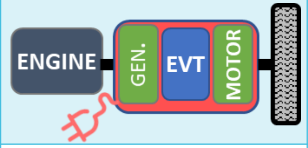
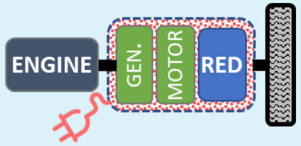
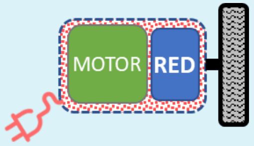
GKN-automotive
>2 million e-drives delivered

Schaeffler 4-in-1

Image Courtesy of Schaeffler

As e-axle sales ramp up manufacturers continue to improve current components and sell them individually or combined

Vehicle electrification
varying degrees and transmission impact

Electrification Type	Start/Stop [S/S]	Mild Hybrid [MHEV]	Full Hybrid [FHEV]		Plug-In Hybrid [PHEV]	Extended Range [EREV]	Battery Electric [BEV]
Basic Schematic							
Approx. Energy Efficiency	+2% to 4%	+8% to 11%	+20% to 35%	+30% to 50%	+50% to 60%	+60% to 70%	+70% to 80%
Energy Saving Operations	**Engine can shut-off when stopped**						
		Engine assisted by motor for extra torque					
		Braking energy recovered					
			Motor can propel vehicle with engine off				
					Plug-in recharge		
						Motor only propulsion [no engine]	
Motor Placement	n/a	Before **Engine** [**P0**] or After [**P1**]	Before [**P2**] or After [**P3**] **Transmission**	Before & After **Trans.**[**P13** or **P23**]	[**P2**],[**P3**], [**P13**] or [**P23**]	[**P4**] on **Axle**[s]	
Transmission Type	Standard **MT**, **AT**, **CVT** or **DCT**		Modified **AT**, **CVT** or **DCT**	Electronically Variable [**EVT**]	Modified **AT**, **CVT** or **DCT**; or **EVT**	Reduction Gear Box [**RED**]	
Transmission Fluid	**ATF**, **CVTF**, **DCTF** or **MTF**	**ATF**, **CVTF**, **DCTF** or **MTF**	**ATF**, **CVTF** or **DCTF**	**ATF**	**ATF**, **CVTF** or **DCTF**	**GEAR OIL** or **ATF**	
Motor Contact	n/a	no	typical	yes	typical	possible, with motor cooling	

2. e-fluid formulation

E-fluid formulation - conventional fluids, up to now…

Conventional transmission fluids are commonly used for FHEVs and BEVs

- Due to limited production
- Providing adequate motor protection

Tailored e-fluids are currently being developed

- Designs are becoming more demanding on fluid
- Increasing installations justify a bespoke fluid

Transmission		Manufacturer	FHEV / BEV (Placement)	Total Sales* (millions)	Top Models	Fluid Type (brand name)
EVT		Toyota	FHEV (P23)	17.2	Toyota Prius	**ATF** (Toyota WS)
		Honda	FHEV (P13)	1.2	Honda Accord	**ATF** (Honda DW-1)
AT		Hyundai	FHEV (P2)	0.6	Hyundai Sonata	**ATF** (Hyundai SP-IV)
		ZF Group	FHEV (P2)	0.5	BMW 5-Series	**ATF** (ZF Lifeguard 8)
CVT		Subaru	FHEV (P2)	0.1	Subaru Forester	**CVTF** (Subaru CVTF)
		Jatco	FHEV (P2)	0.1	Nissan X-Trail	**CVTF** (Nissan NS-3)
DCT	Dry	Honda	FHEV (P2)	1.2	Honda Fit	**ATF** (Honda DW-1)
	Wet	VW	FHEV (P2)	0.4	VW Passat	**DCTF** (EG 52529)
RED		Nissan	BEV (P4)	1.6	Nissan Leaf	**ATF** (Nissan Matic-S)
		Tesla Motors	BEV (P4)	1.3	Tesla Model 3	**ATF** (Tesla High Perf.)
		GM	BEV (P4)	0.2	Chevy Bolt	**ATF** (DEXRON® HP)

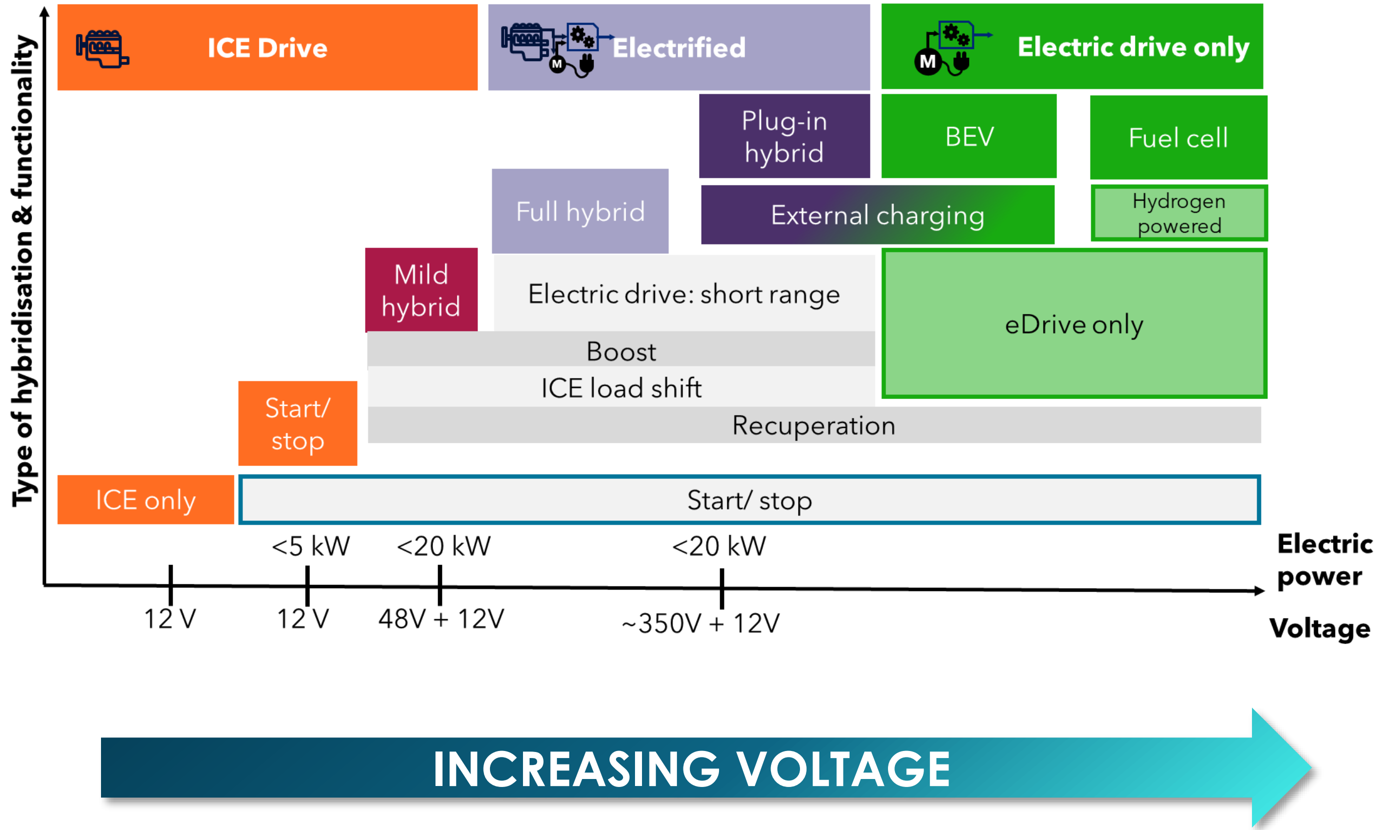
* Cumulative sales of all vehicle models through model year 2020

E-fluid formulation – electrification platform development

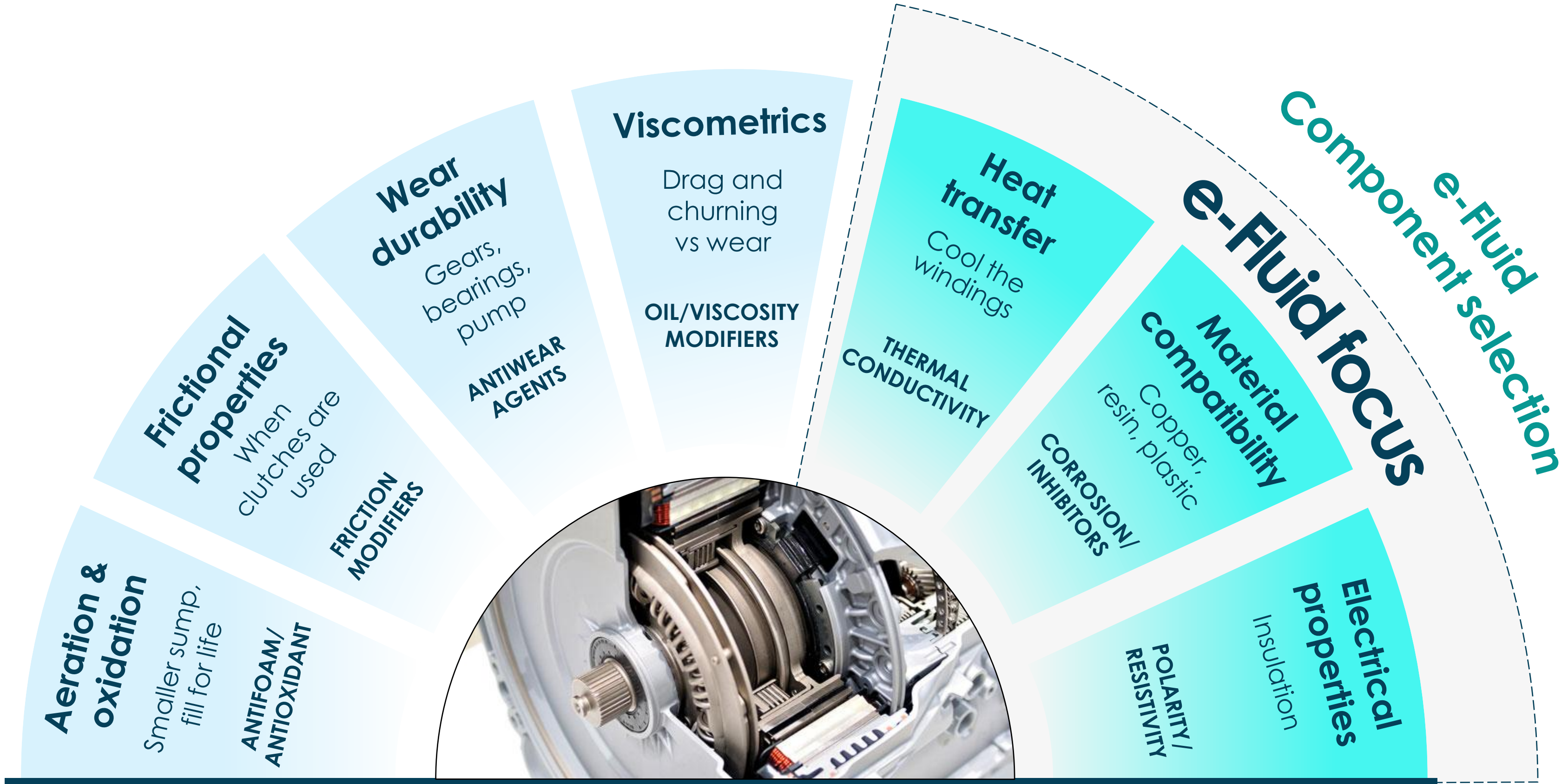
OEM optimized e-motor designs will result in new fluid requirements:

Increased power density to meet stricter packaging and performance requirements

- **Motor cooling via direct oil contact optimal**
  - More efficient than water jacket
  - Reduces complexity and casing size
- **Direct oil cooling drives other critical E-Fluid requirements**
  - Insulating current via volume resistivity
  - Specialized material compatibility



E-fluid formulation - added electrification requirements

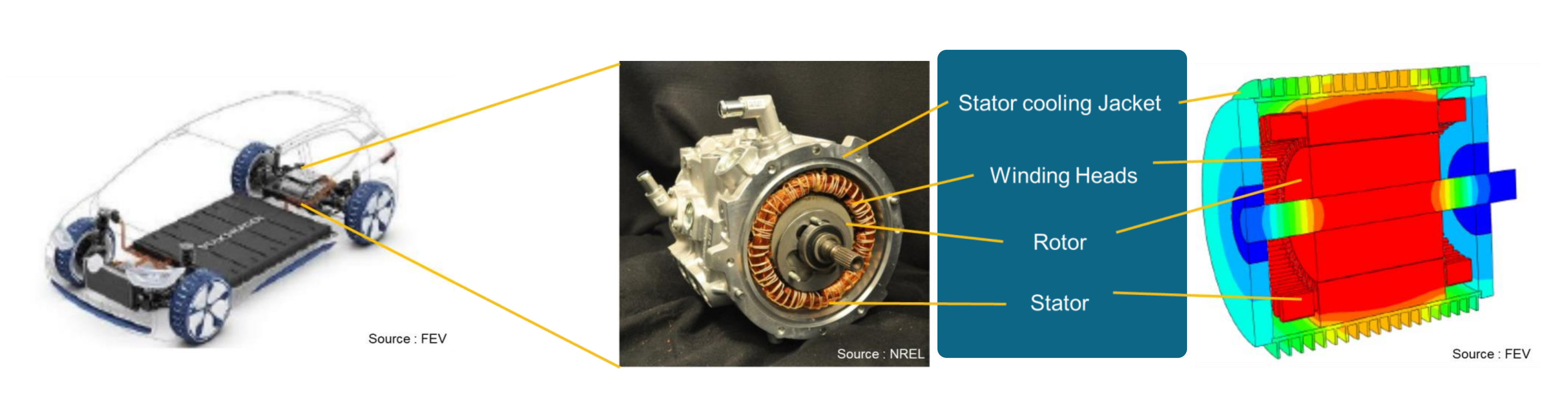


e-Fluid electrical properties must be considered, along with transmission performance and protection

E-fluid formulation – heat transfer requirements

High temperature can lead to motor performance loss and demagnetization.

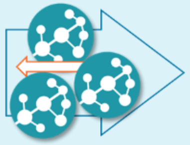
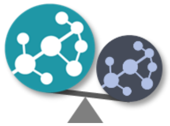
- Winding heads and magnetic rotors may be subject to localized hot spots at peak loads



Direct oil cooling is more efficient and less complex than water cooling jackets.

- Oil cooling can improve motor efficiency and enable smaller higher voltage motors.

E-fluid formulation – fluid heat transfer properties

Fluid property	Measurement	Impact on heat transfer
Thermal Conductivity (k) 	Molecular ability to conduct heat [W/m·K]	Fluids with higher k have molecules that are better at transferring heat away from hot surfaces and between each other.
Specific Heat Capacity (c_p) 	Molecular amount of heat per unit mass required to raise the temperature by 1°C [kJ/(kg·K)]	Fluids with higher c_p have molecules that are better at absorbing heat with a lower rise in temperature
Dynamic Viscosity (μ) 	Molecular resistance to flow [cP]	Fluids with lower μ have molecules with less internal resistance to flow to hot surfaces and away with the heat
Density (ρ) 	Molecular compactness [kg/m^3]	Fluids with higher ρ have more molecules per given volume that can conduct heat between each other

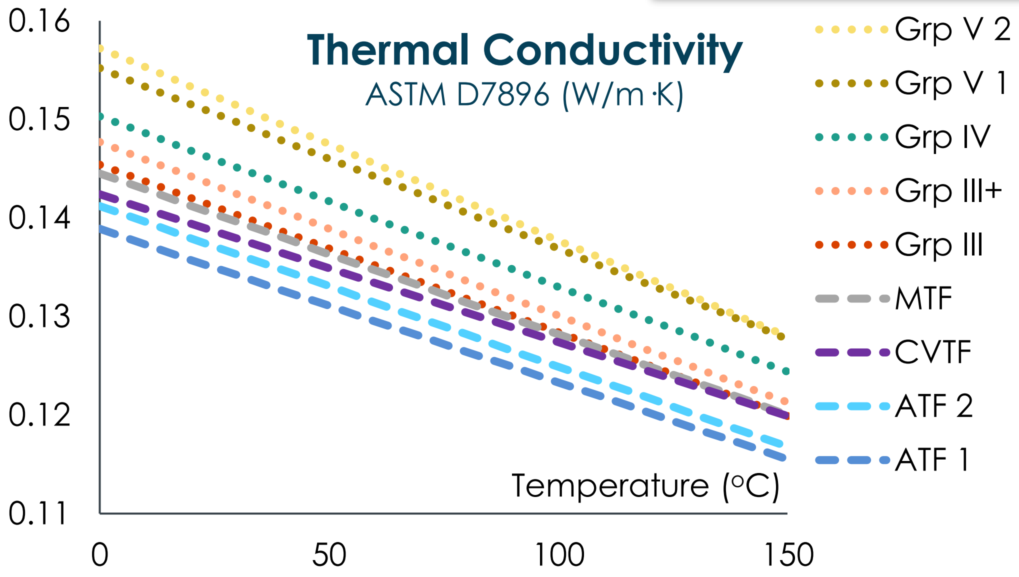
E-fluid formulation - measuring heat transfer properties

ASTM D7896:
Standard test method for thermal conductivity, thermal diffusivity and volumetric heat capacity of fluids

- Uses a transient hot wire liquid thermal conductivity method

The thermal conductivity of transmission fluids is largely a function of the base oil used.

- ⬆ base oil quality → ⬆ ***k***



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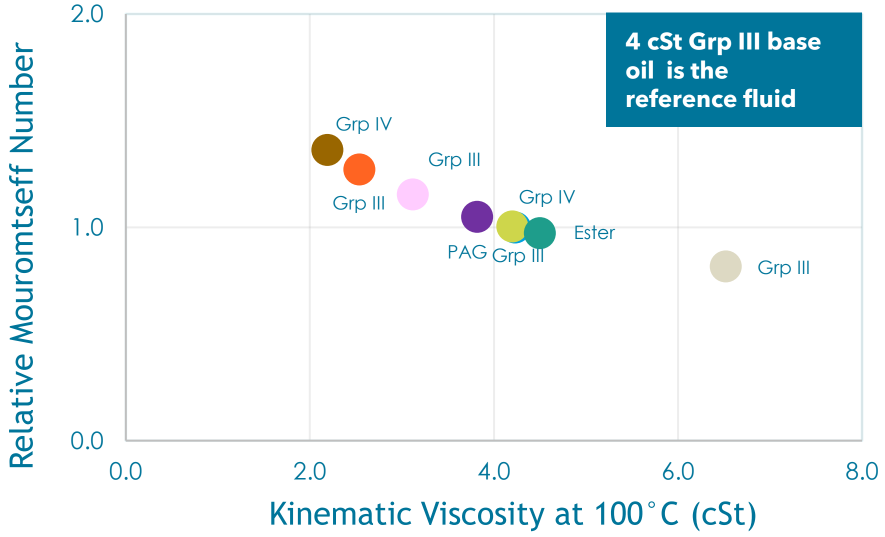
E-fluid formulation - formulating for heat transfer



The *Mouromtseff* number [M_0] is used to compare the heat transfer capability of turbulent fluids

e-Fluids are subject to turbulent flow

Mouromtseff Number for turbulent fluids:

Fluid properties:

ρ = Density [kg/m³]
k = Thermal conductivity [W/(m·K)]
C_p = Specific heat capacity [kJ/(kg·K)]
μ = Dynamic viscosity [cP]

$$M_0 = \frac{\rho^{0.8} k^{0.67} c_p^{0.33}}{\mu^{0.47}}$$

Provides formulation guidance, largely on base oil selection

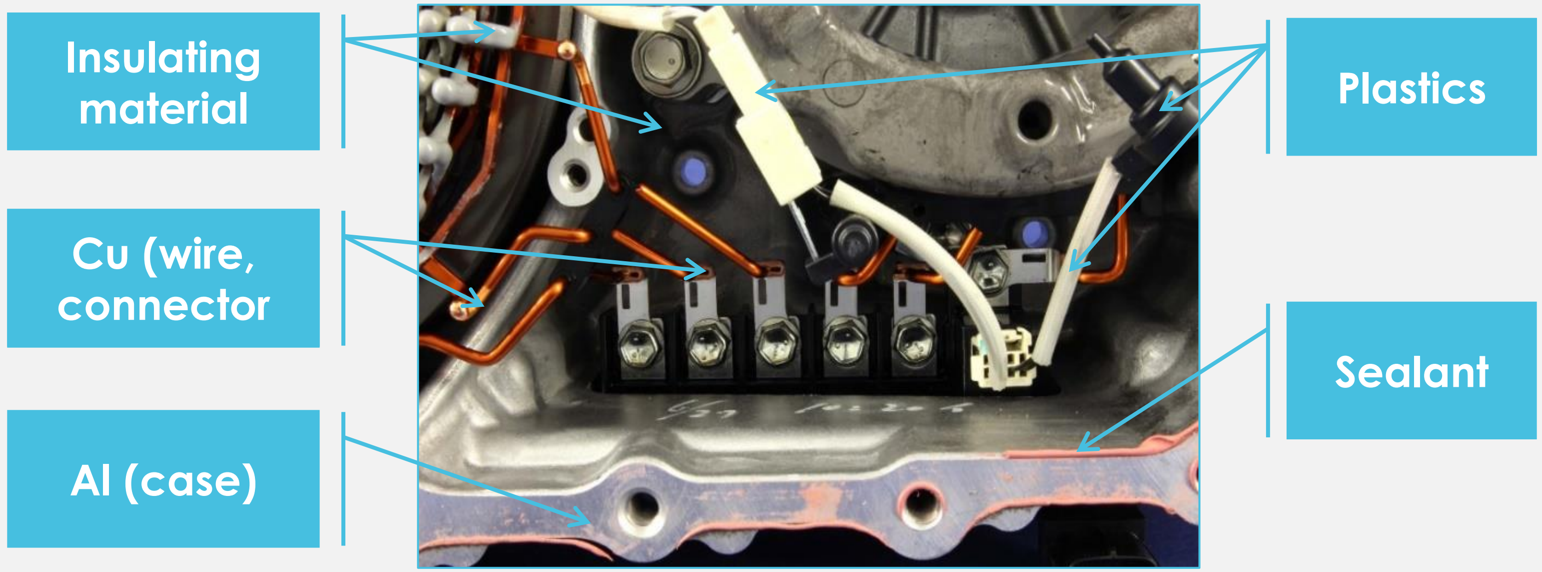
Increase fluid thermal conductivity
Function of base oil purity [Grp IV > Grp III] – small effect on M_0

Reduce fluid dynamic viscosity
Lower viscosity oil – major effect on M_0 [balance vs. wear]

E-fluid formulation - material compatibility requirement

Motors introduce new materials to the transmission

- Copper wire and connections, along with insulating materials, plastics, sealants, etc.



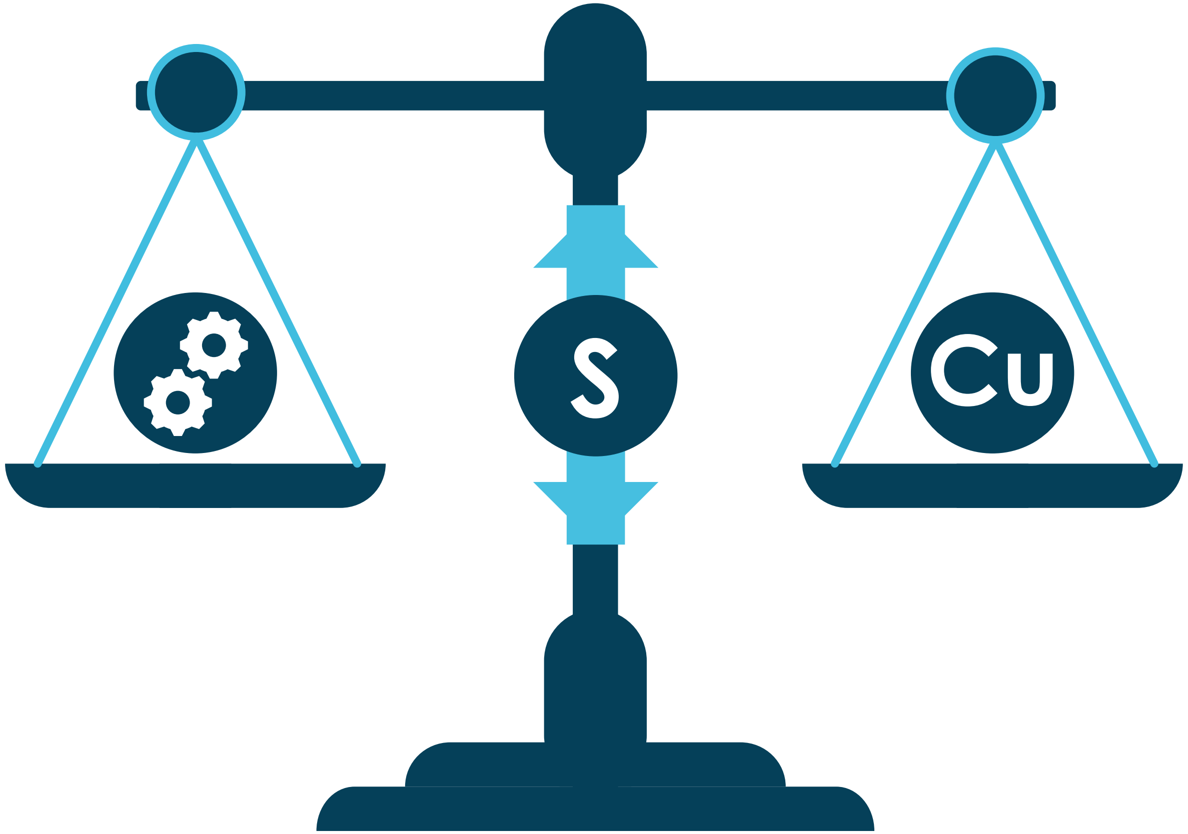
Material compatibility with transmission fluid is critical for e-fluids

- Insulation failure can lead to shortages, corrosion can erode connections and circuits

E-Fluid Formulation -

Formulating for Material Compatibility

- **Gear scuffing protection** is usually obtained through the **addition of sulphur** containing compounds
- However, **increased sulphur** can lead to **corrosion of copper** components
- Conversely, **decreased sulphur** for copper performance can lead to a **reduction in scuffing performance**
- **e-fluids require a balance** between scuffing performance and copper compatibility



E-fluid formulation - formulating for material compatibility

Material compatibility must be considered for additive selection, e.g.

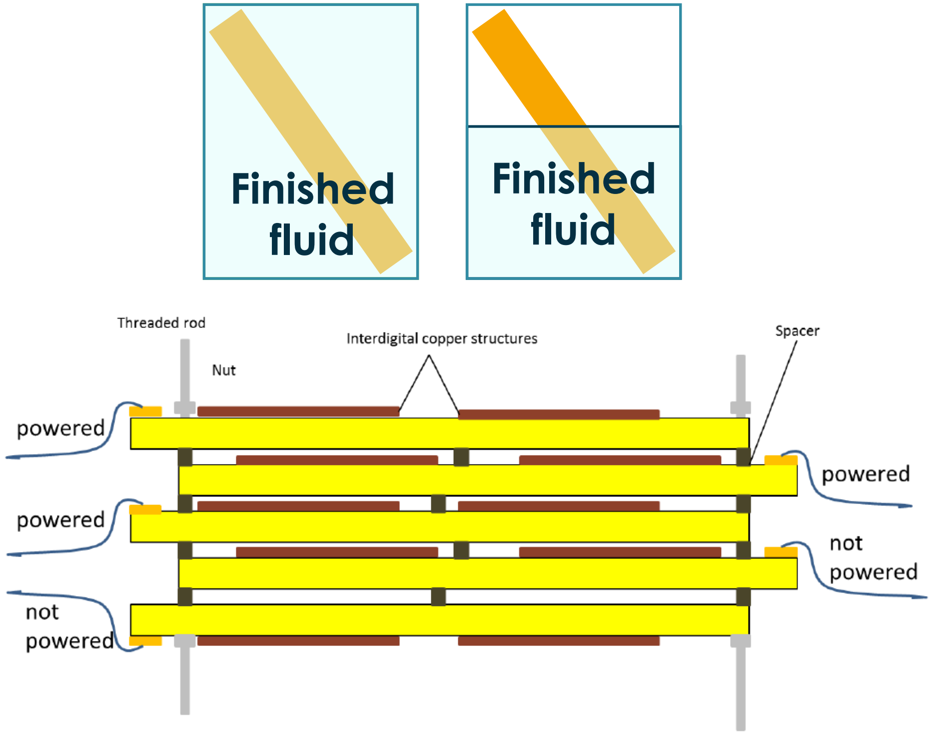
- Extreme pressure additives used in typical gear oils will corrode copper
- Corrosion inhibitors may help mitigate

Additive components used in e-fluids must be screened for compatibility:

- Soak tests, at elevated temperature
- Energized circuit board tests
- Conductive wire testing

Test methods are still being developed

ASTM D130 modified testing
(solution and vapor phase)

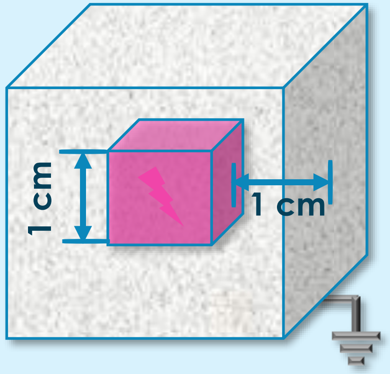


Energized Circuit Board testing

E-fluid formulation - electrical property requirement

Motors rely on insulating material to isolate high voltage components

- When oil cooled, the e-fluid's resistance to current flow must be considered



Volume Resistivity [VR] is the oil resistivity [1/conductivity] multiplied by the separation and divided by the area

EXAMPLE:
Consider a 1 cm^2 conductor immersed in oil and separated from ground by 1 cm

- *Oil with conductivity 1x10-9 S/cm at 100 °C would present 1 GΩ resistance*
- *If driven by 500 V, a 0.5 μA leakage current would occur*

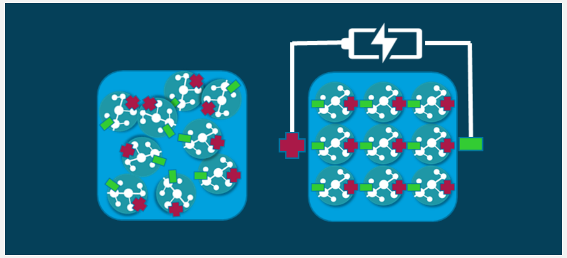
The optimum e-fluid VR to electric current is being investigated

- Higher VR can allow for increased motor voltage and smaller casing but can lead to static build-up and arcing

E-fluid formulation - fluid volume resistivity properties

Relationship between molecular electronic properties and measured resistivity

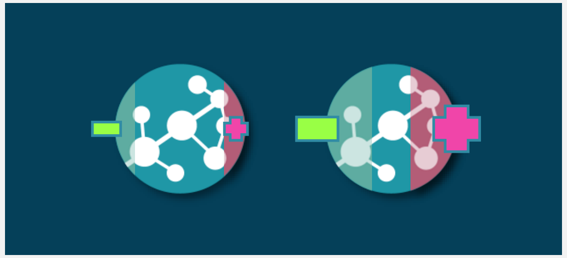
Dipole Moment (Debye):



Difference in electrical charge between a positive end and a negative end of a molecule

- More polar molecules are less resistive
- **Detergents**

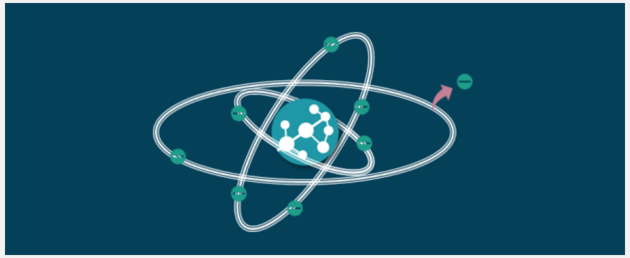
Polar Surface Area (PSA):



Polarity based on the surface area (Å2) of oxygen and nitrogen atoms including attached hydrogen atoms

- Molecules with higher *PSA* are less resistive
- **Friction modifiers**

Band Gap (eV):



Energy required to move an electron from the valence band to the conduction band in the outermost orbit of a molecule

- Molecules with lower eV are less resistive
- **Zinc phosphide [eV ~ 1.5] < Zinc oxide [eV ~ 3.4]**

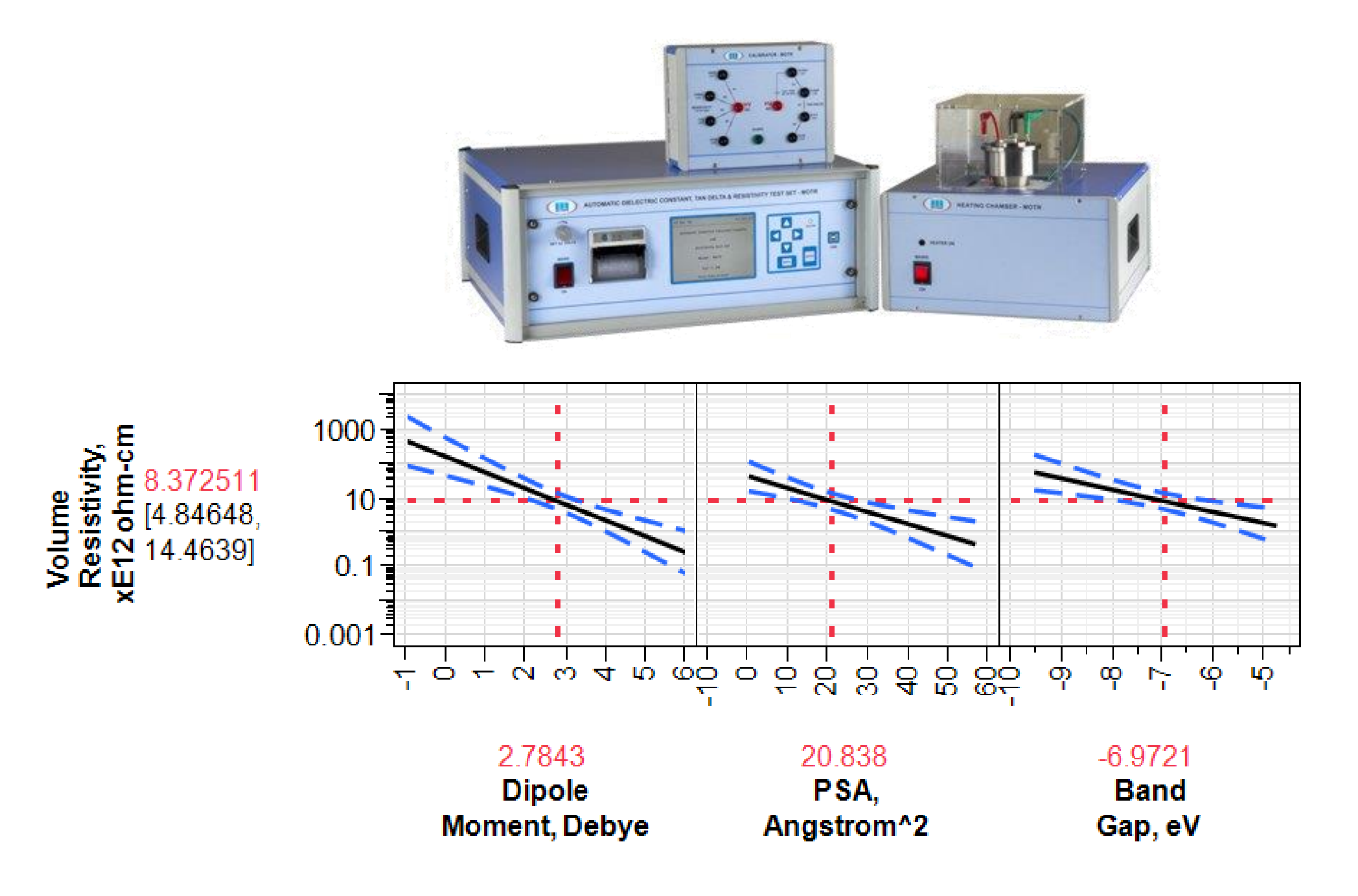
E-fluid formulation - measuring volume resistivity

ASTM D1169 –
Covers the determination of specific resistance (resistivity)

- Applied to new, in-service, or used fluids in electrical apparatus
- Used fluids tend to have poorer resistivity than new

VR decreases as molecular polarity increases:

- ⇧Debye → ⇩VR
- ⇧PSA → ⇩VR
- ⇩eV → ⇩VR

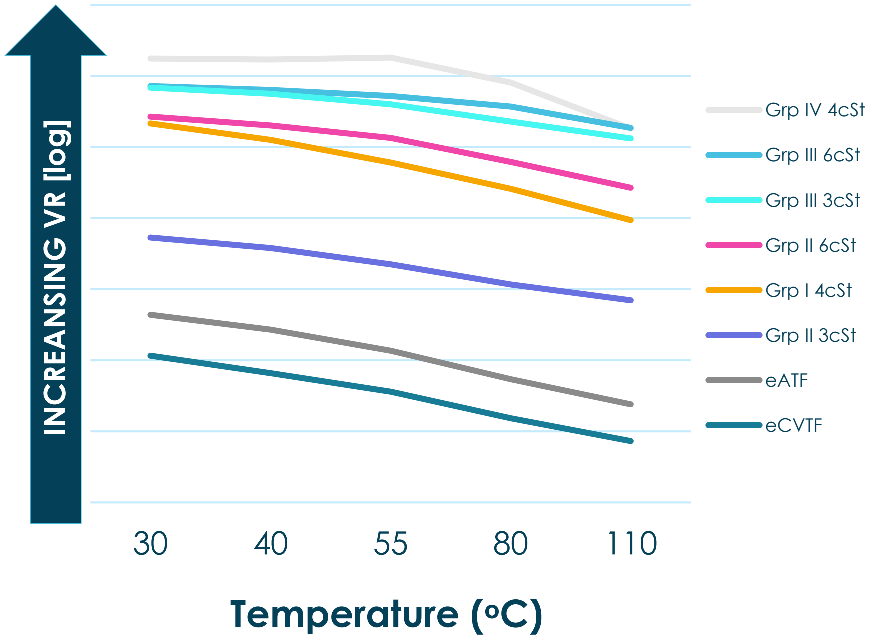


E-fluid formulation - formulating for volume resistivity

Maximum e-fluid VR is dictated by base oil:

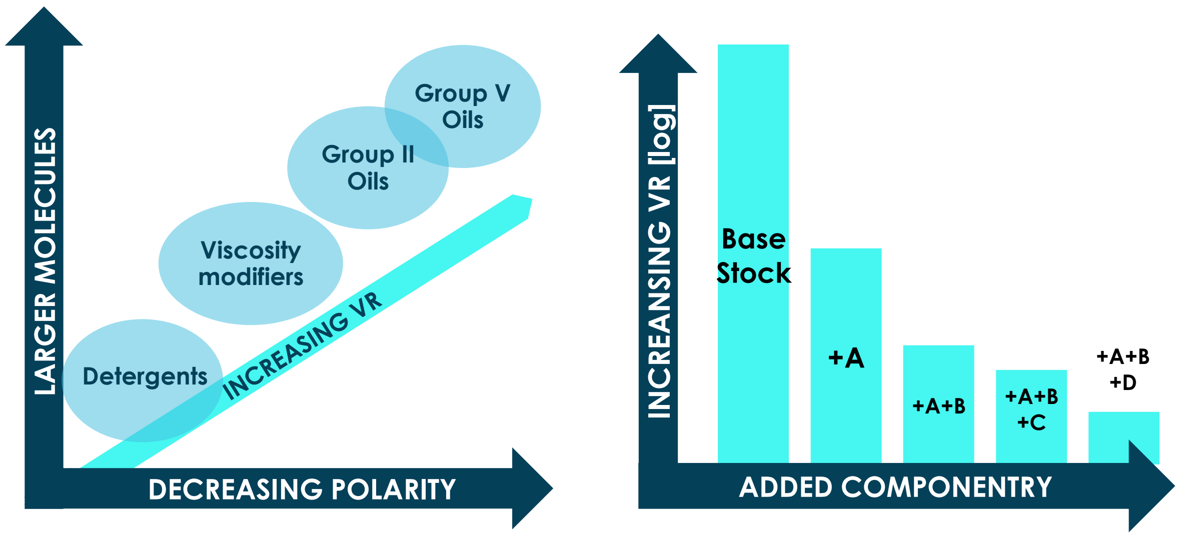
- Higher quality reduces polarity and increases VR
- Higher viscosity increases molecule size and VR

Volume Resistivity: ASTM D1169 (Mohm-m)



Additives lower VR as:

- Molecular polarity increases
- Molecules are smaller
- Molecules increase in number e.g. higher treat rate



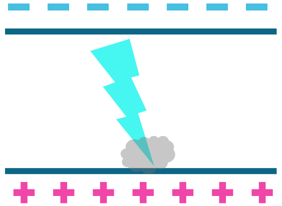
E-fluid formulation - Volume resistivity considerations

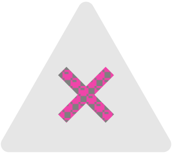
What may define the upper and lower limits for volume resistivity?

SAFETY:

ISO6469-3 Part 3:
Protection of persons against electric hazards

- (DC) Isolation resistance minimum value 100 ohm/volt (10mA)
- (AC) Isolation resistance minimum value 500 ohm/volt (2mA)





OTHER PARAMETERS TO CONSIDER:

- Electrical arcing with high VR?
- Potential current leakage with low VR?
- Electrically induced corrosion with low VR?

E-fluid formulation – aeration requirements

Aeration is a critical performance parameter for **ultra-low viscosity e-fluids** (e-motor speeds >10,000 rpm)

Entrained air can lead to:

- Cavitation → wear due to irregular oil film
- Loss of hydraulic performance

Standard ASTM foam tests only measure foam generated via air inlet, which may not represent the actual air entrainment running at high speeds under shear in spinning parts e.g. gears, bearings

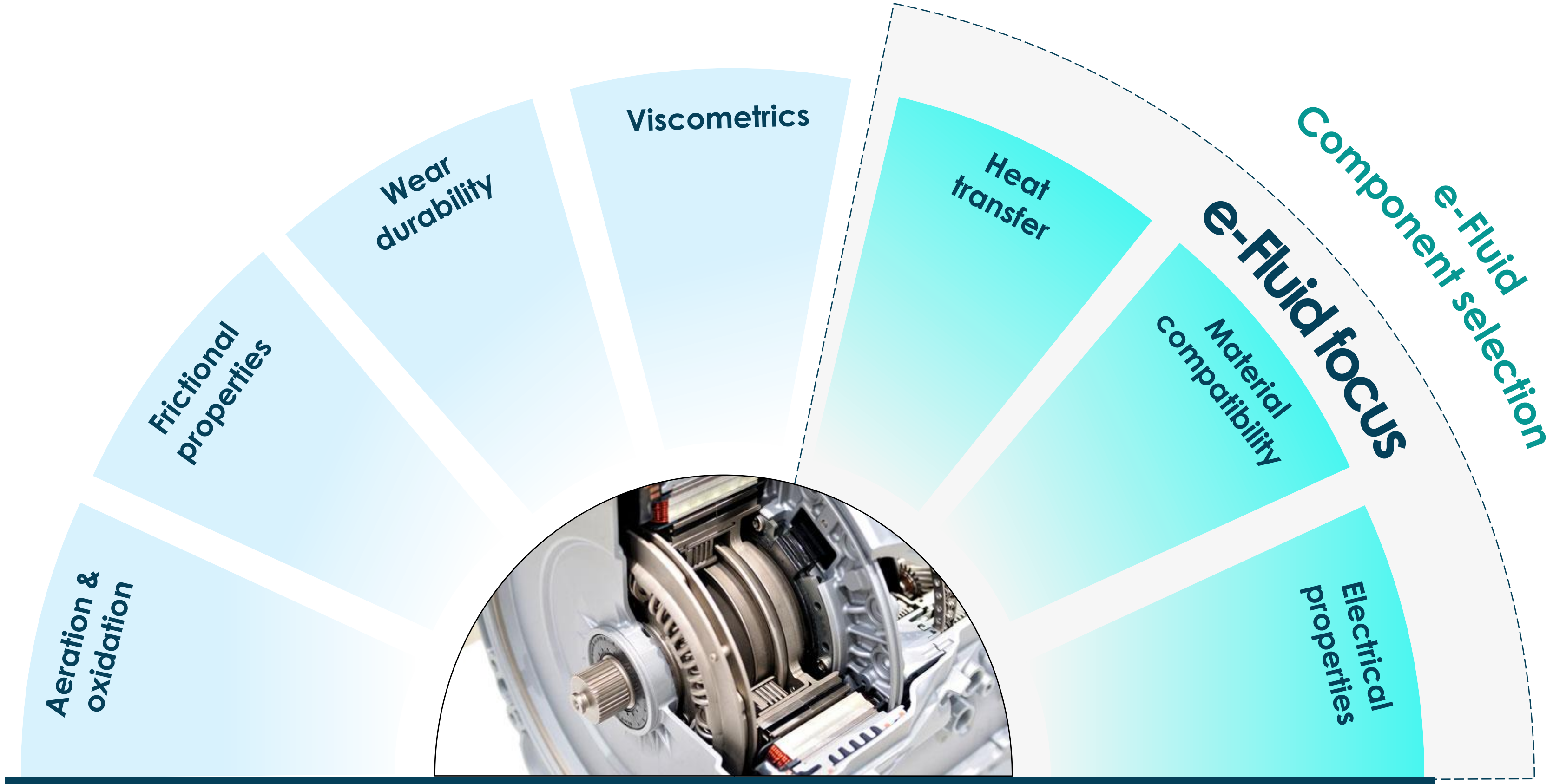
This is leading the industry to develop new test methods that will better simulate what happens in an e-motor

Fluid After Mixing

Fluid After 5s mixing off

E-fluid formulation -
added electrification requirements

Careful balance is necessary to meet all the requirements for a specific hardware



**e-Fluid electrical properties must be considered,
along with transmission performance and protection**

Transmission fluid vs. e-fluid

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Additive Package

	Vol %
Performance package	**5-10%**
Seal swell agent	**0-3%**
Pour point depressant	**0-0.5%**
Viscosity modifier	**3-10%**
Total Additive treat:	**8-24%**

Base oil (Group II,III)

Red dye

Additive Package

	Vol %
Performance package	**4-8%**
Seal swell agent	**0-1%**
Pour point depressant	**0-0.5%**
Total Additive treat:	**5-10%**
Viscosity modifier	**0-2%**

Base oil (Group I,II,III, IV)

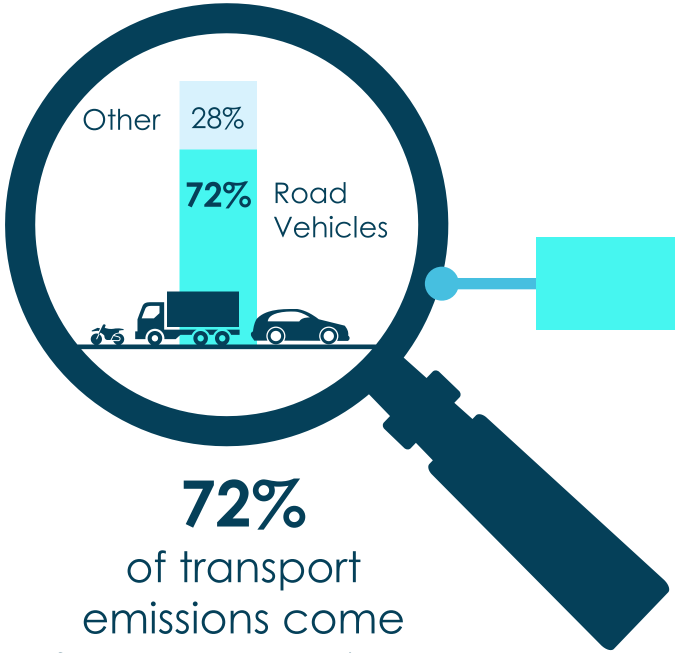
Red dye (optional)

3. Electrification outlook

The transportation industry

Shift to sustainable mobility

The **transportation industry** represents a **large portion** of Green House Gases (GHG) emitted

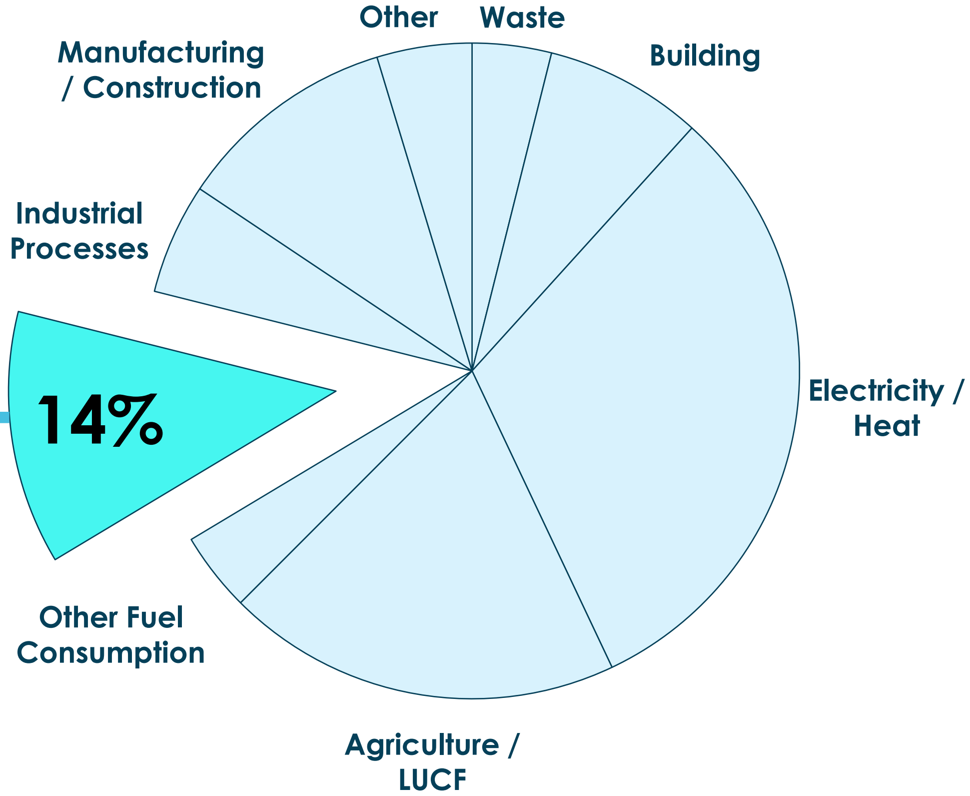


72%
of transport emissions come from road vehicles

TRANSPORTATION

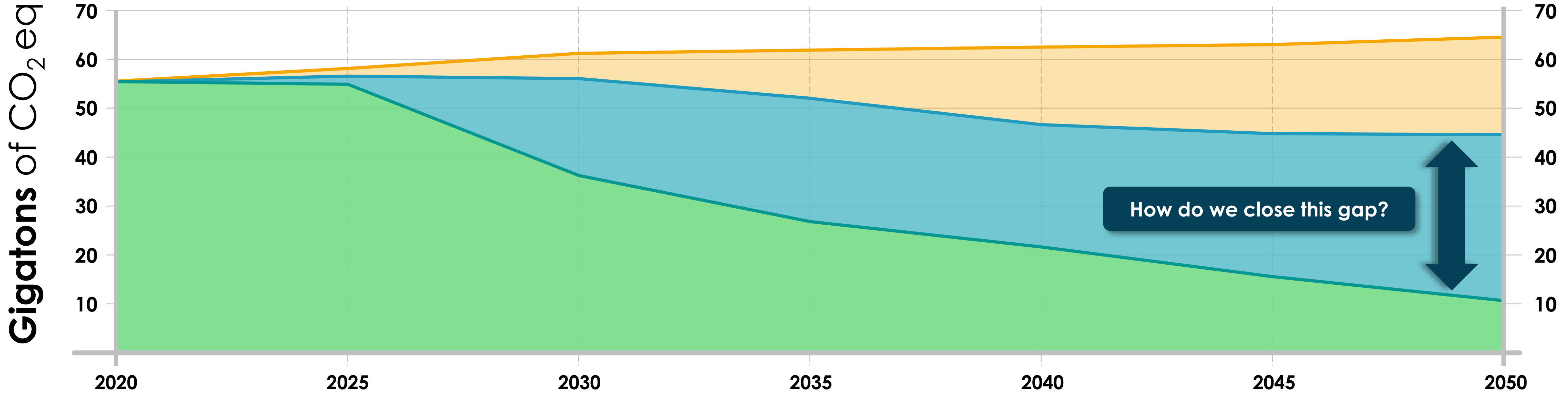
Accounts for **14%** of all Global GHG emissions

Global GHG emissions



Source: IEA

We are a long way from achieving our goal

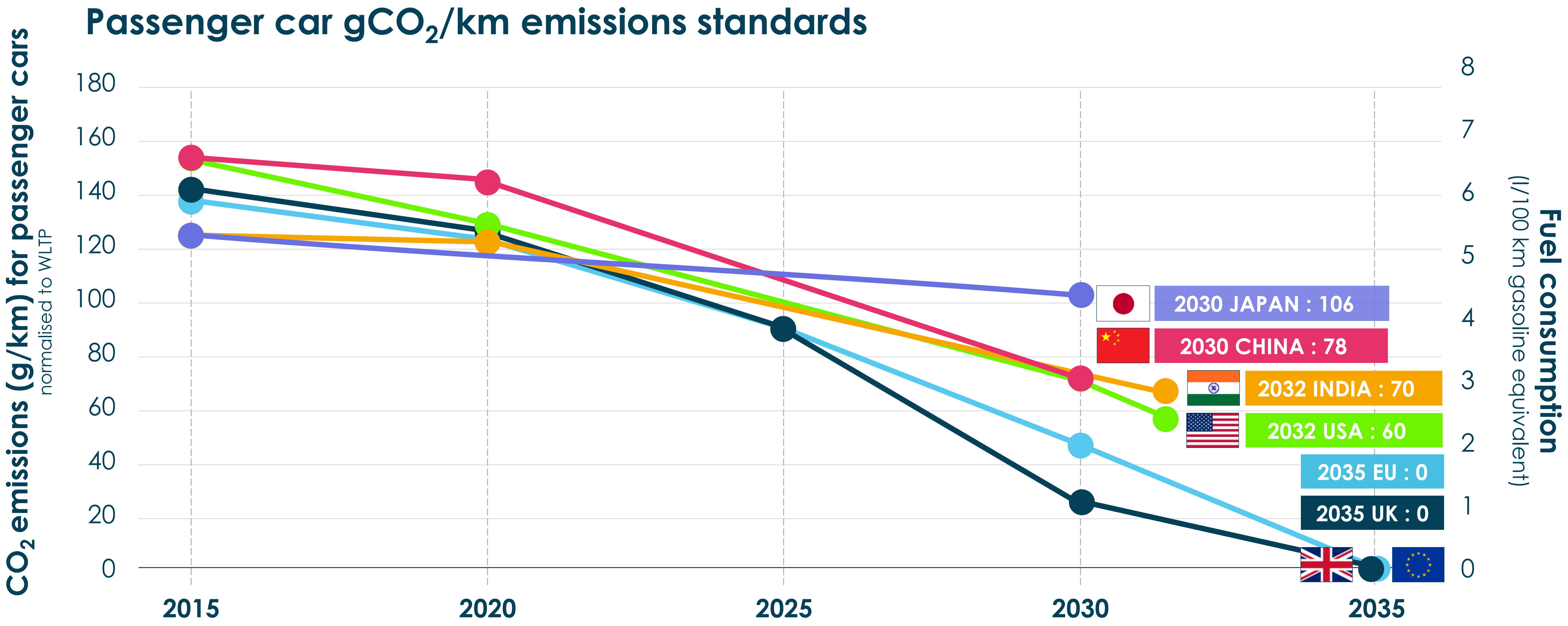


World GHG emissions projections – **'Business as usual'** scenario
'Do as promised' scenario
'Achieve our goal' scenario

Data source: World emissions clock - worldemissions.io

Transition to net zero accelerating

Infineum



Data source: The ICCT Licensed under a Creative Commons Attribution 4.0 International license https://creativecommons.org/licenses/by-sa/4.0/

HONDA

Vision to realize carbon neutrality for all products and corporate activities by **2050**

HYUNDAI

In progress to achieve carbon neutrality by **2045**

GM

Vision to become carbon neutral in global products and operations by **2040**

STELLANTIS

Strategic plan to out CO_2 emissions in half by 2030, and achieve carbon net zero by **2038**

MITSUI

Goal to achieve net zero emissions as our Vision for **2050**

RENAULT GROUP

Our challenge is to reach zero CO_2 impact by **2050** in Europe

DAIMLER TRUCK

By **2039**, aim to achieve CO_2 neutral production at plants and business units worldwide

GE

Ambition is to be a net zero company by **2050**

TOYOTA

By **2050**, we aim to eliminate CO_2 emissions from our value chain

TATA

Specific goal to achieve net zero greenhouse gas emissions by **2045**

YAMAHA

Our goal is carbon neutrality by **2050**

ISUZU

Aim for zero greenhouse gas emissions across the life-cycle of the Group's products by **2050**.

WÄRTSILÄ

Carbon neutral in our operations, and provide a product portfolio ready for zero carbon fuels.

FORD

Working to achieve carbon neutrality globally no later than **2050**

MAZDA

Achieve carbon neutrality over the entire life cycle of vehicles and supply chain by **2050**

NISSAN

Pledged to achieve carbon neutrality across its operations and life cycle of products by **2050**.

MAN-ES

By **2030**, sustainable technologies and solutions will account for 70% of our business.

BMW

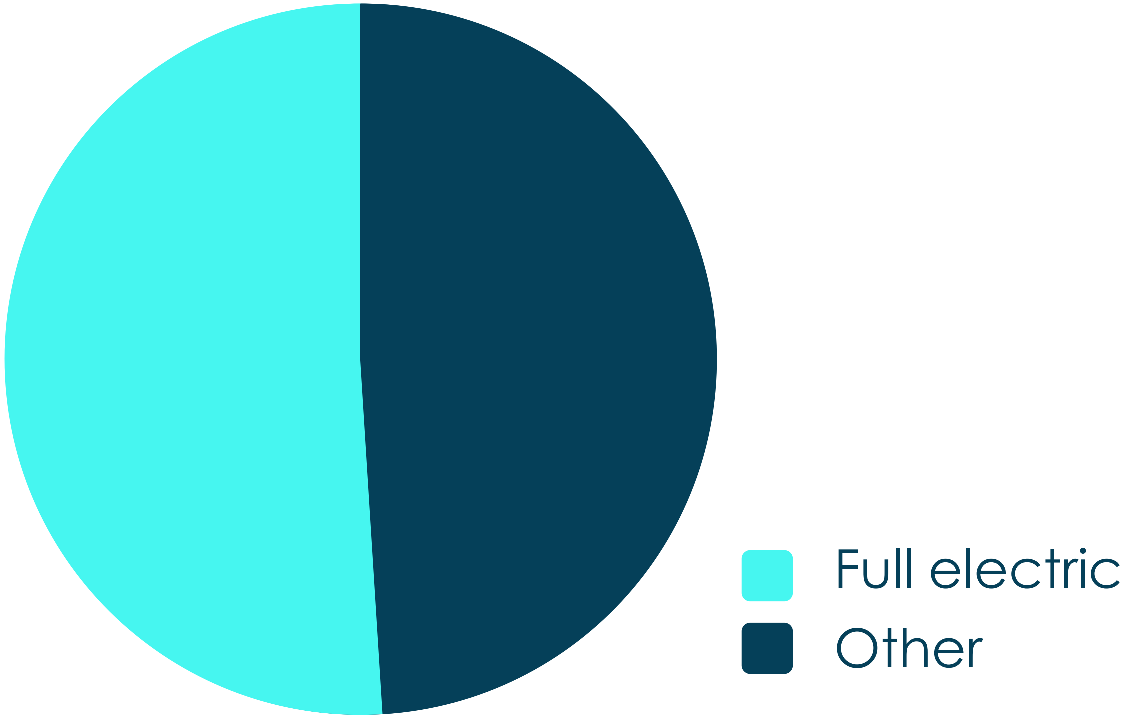
Electric vehicle market growth

Infineum

Vehicle production

2024
15%
of vehicle production is full electric

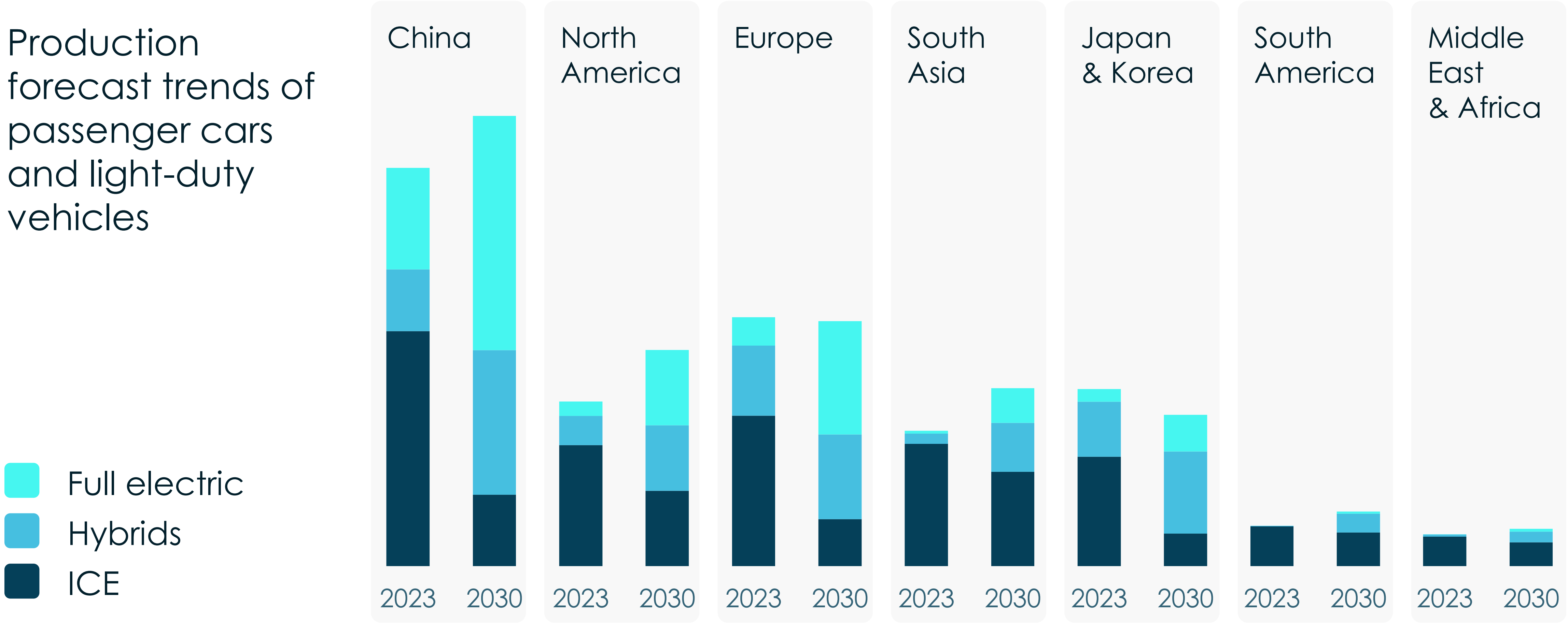
2035
51%
of vehicle production is full electric



Source: S&P Global, Global Production based Powertrain Forecast, March 2025

Post-election US policy shifts expected to slow global growth; underlying momentum softening

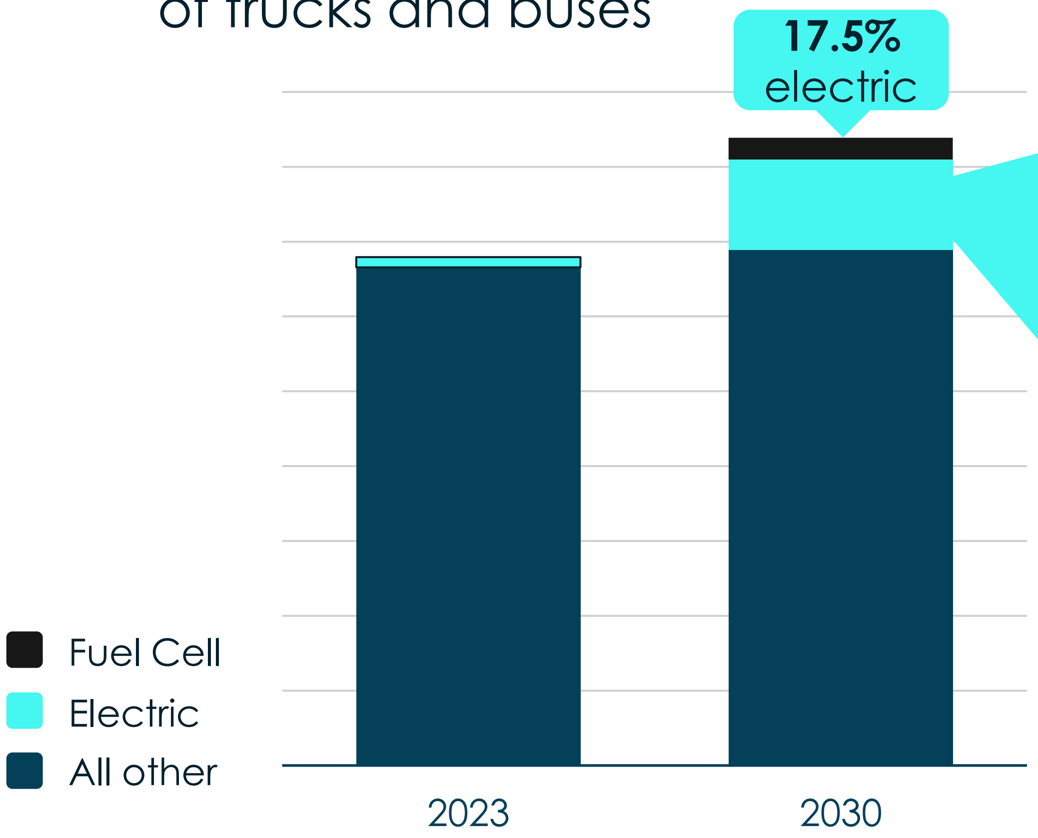
Mixed regional picture ahead for full electric vehicles



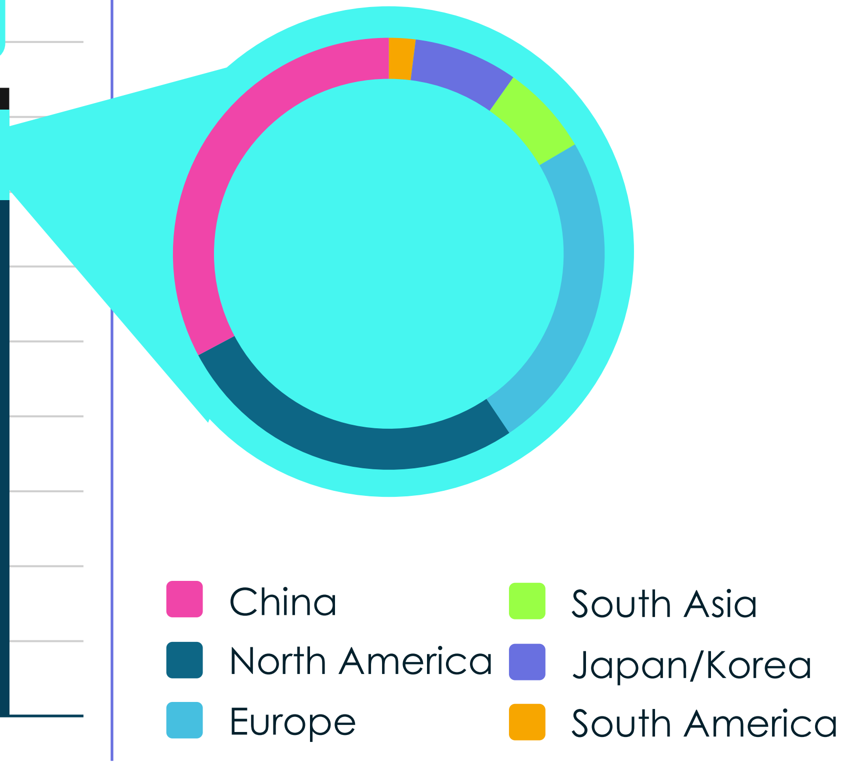
Source: S&P Global, Light Vehicle Powertrain + Alternative Propulsion Forecast, March 2025

Limited BEV growth in commercial vehicles

Global production trends of trucks and buses



Truck and bus electric production 2030



Source: kgpauto.com/products, Jan 2024

2021 Global fleet

4% global buses and 0.1% heavy-duty trucks are electric

Full electrification barriers and drivers

Infineum

	Drivers	Current barriers
END-USER	Take personal action on emissions	Range anxiety
	Lower running costs	High vehicle cost
	Less maintenance	Long charge time
	Great acceleration	Lack of infrastructure
	Charge at home	Battery weight/space
OUR WORLD	Zero in-use exhaust emissions	Raw material sustainability
	Efficient conversion of power to wheels	Mining practices
	Electricity source could be renewable	Electricity source
		Battery disposal
		Human health
		Full life-cycle needed

Taking action today:
The transition to net-zero

Full electrification is just one technology approach – issues with LCA and end user acceptance

Affordability

Range anxiety

Charging infrastructure

The future is a multitude of **technologies**

Paris Climate Agreement

Accelerating decarbonization of all transportation modes

Infineum

Improve ICE

Expand hybrid production

Develop new fuels and infrastructure

Multi-fuel

Multi-hardware

Multi-technology

Accelerating decarbonization of all transportation modes

Improve ICE

There is room for improvement, today

Diesel engine
50% efficient

Gasoline engine
~40% efficient

Expand hybrid production

Develop new fuels and infrastructure

Multi-fuel

Multi-hardware

Multi-technology

Accelerating decarbonization of all transportation modes

Infineum

Improve ICE

Expand hybrid production

Smaller **batteries** in more cars

Develop new fuels and infrastructure

Multi-fuel

Multi-hardware

Multi-technology

Accelerating decarbonization of all transportation modes

Improve ICE

Expand hybrid production

Develop new fuels and infrastructure

- Green hydrogen
- Green ammonia
- E-Fuels

Multi-fuel

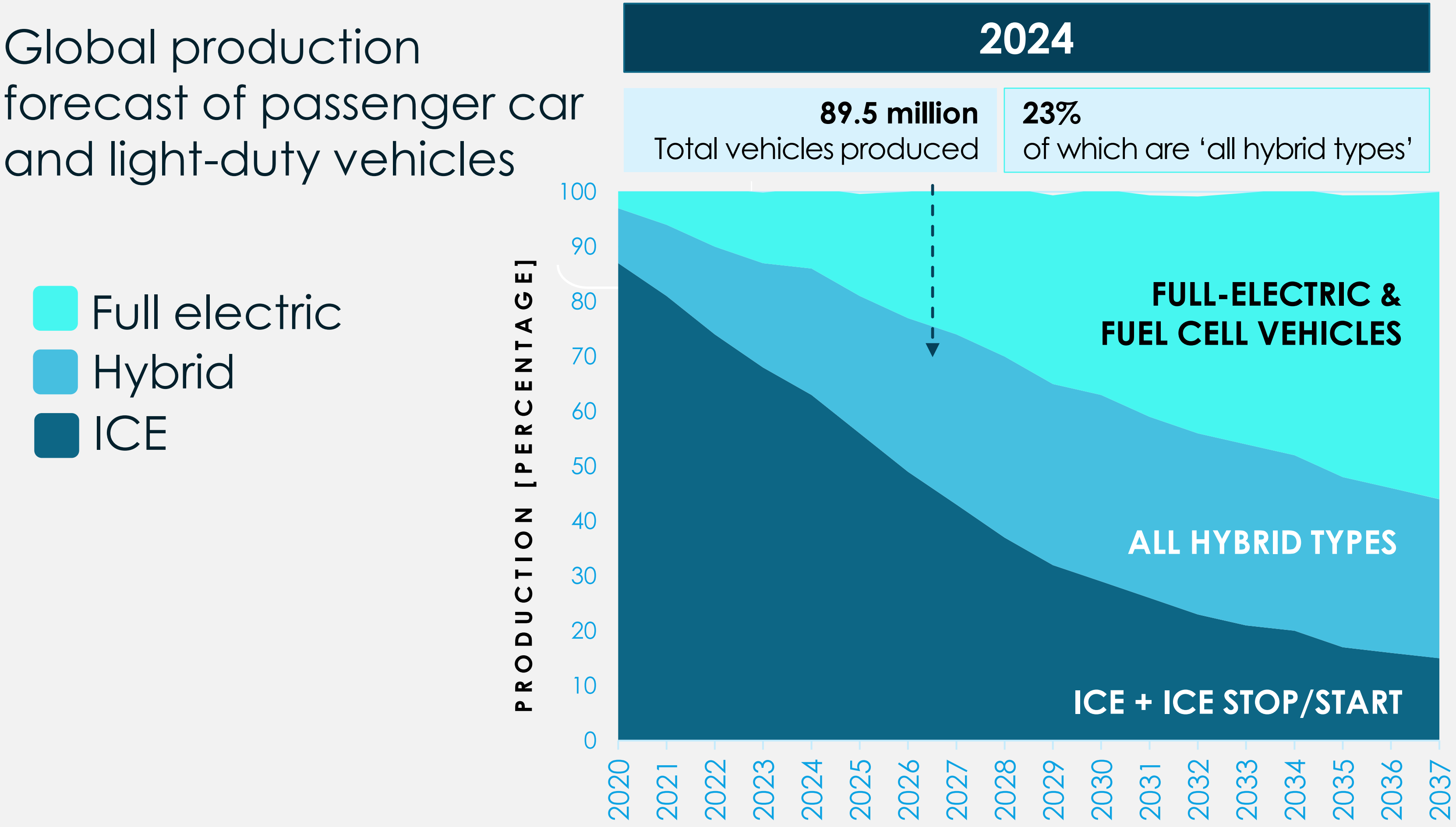
Multi-hardware

Multi-technology

Production trends

Infineum

Global production forecast of passenger car and light-duty vehicles



Hybrids are expected to be a large component of the light-duty market for many years to come

By 2030

> 34% hybrid

>63% of vehicles produced contain an ICE

Source: S&P Global, Light Vehicle Powertrain + Alternative Propulsion Forecast, March 2024

The rise of the hybrid

Volkswagen

Anyone who believes that the e-car alone will take us into the future is mistaken – we are investing 18 billion euros in e-mobility, hybridization and digitalization by 2026

Hyundai

Not all customers are ready to make the switch to EVs – we will offer a range of powertrains, including ICE, HEV, PHEV, EVs and FCEV

Honda

Making steady progress in the **development of new hybrid-electric vehicles** to meet high demand

Suzuki

Expanding and and diversifying our product lineup while **strengthening hybrid vehicle offerings** to meet demand

Stellantis

Electrification is not a one-size-fits-all proposition, we're developing vehicle platforms, propulsion & energy storage systems to enhance our 14 brands

Toyota

We need to address the needs of customers in each region with a **multi-pathway approach** that includes FCEV, BEV, HEV, and PHEV

Ford

Adjusting vehicle roadmap to offer a range of electrification options and plans to **leverage hybrid technologies** for its next three-row SUVs

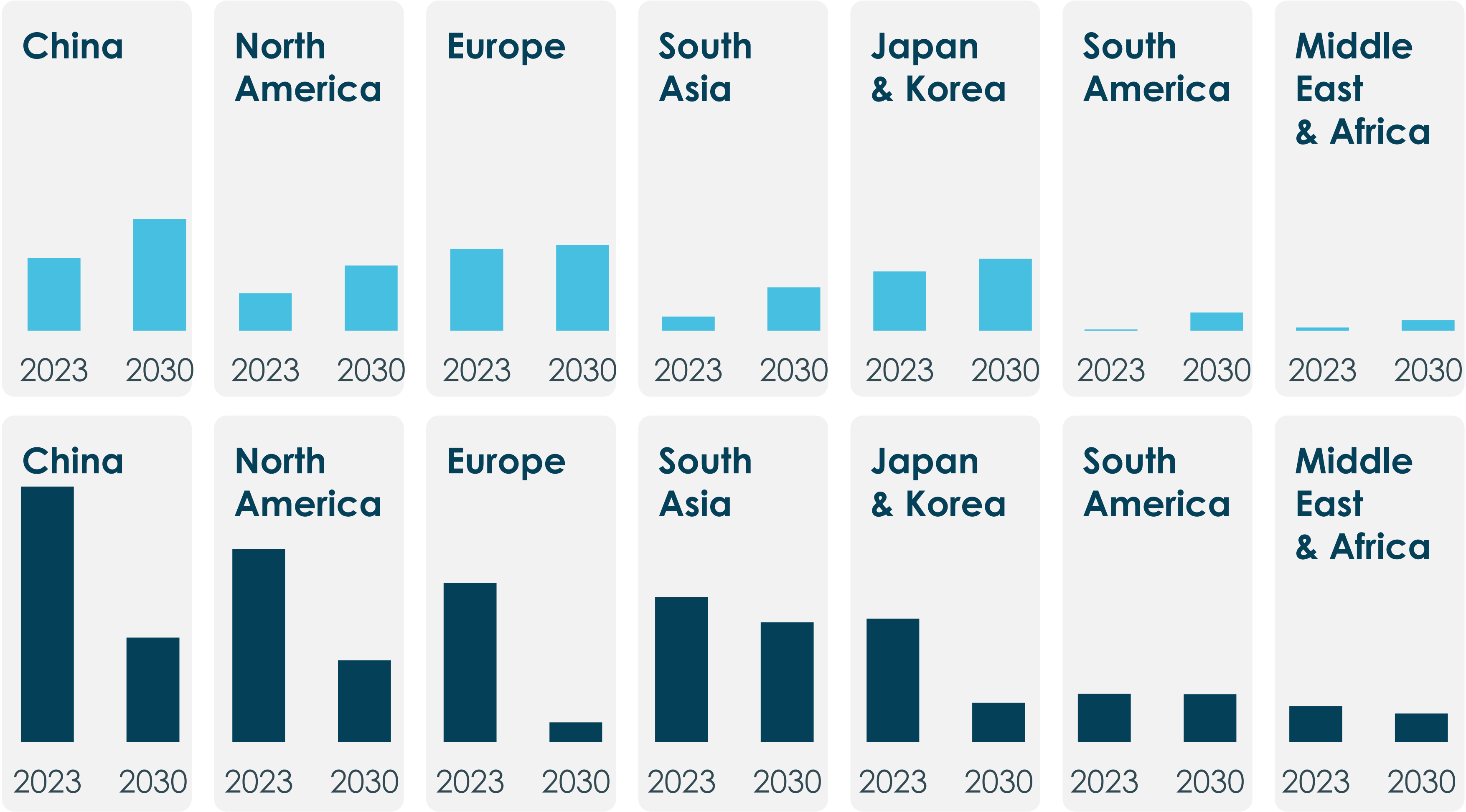
Hybrid growth in all regions

Infineum

Production forecast trends of passenger cars and light-duty vehicles

Hybrid

ICE + ICE start/stop



Source: S&P Global, Light Vehicle Powertrain + Alternative Propulsion Forecast, May 2023

Hybrids in other transport applications

Kawasaki

Hybrid in **2024** product range

Other OEMs

Yamaha & others plan to launch hybrid models

Yutong

11,966 new energy vehicle sales in 2022

Mercedes

Citaro hybrid up to **8.5%** fuel saving vs Euro VI diesel

Volvo

Hybrid running on biofuel can **cut** $\mathbf{CO_2}$ by **~60%** vs. a diesel bus

MAN ES

Hybrid delivers **10%** savings on fuel oil

Wärtsilä

Marine industry's largest **11.5 MWh** hybrid vessels

Lower emissions, longer range and well understood hardware

Multi-solution future gaining wide support

Leveraging technology options is the key

No single technology is capable of achieving carbon neutrality across the global automotive industry

International Organization of Motor Vehicle Manufacturers

Every technological solution that has the potential to contribute to decarbonising road transport **needs to be considered**

International Road Transport Union

Requires various vehicle & fuel solutions and **must consider full life-cycle emissions**

Biden's U.S. National Blueprint for Transportation Decarbonization

Europe should aim for a **pragmatic, progressive and technology-neutral approach** that ensures scalable solutions

ACEA

We need to take a **multi-faceted and multi-dimensional** approach

Honda

We need **diverse powertrain technologies** that offer more performance in combination with reduced consumption

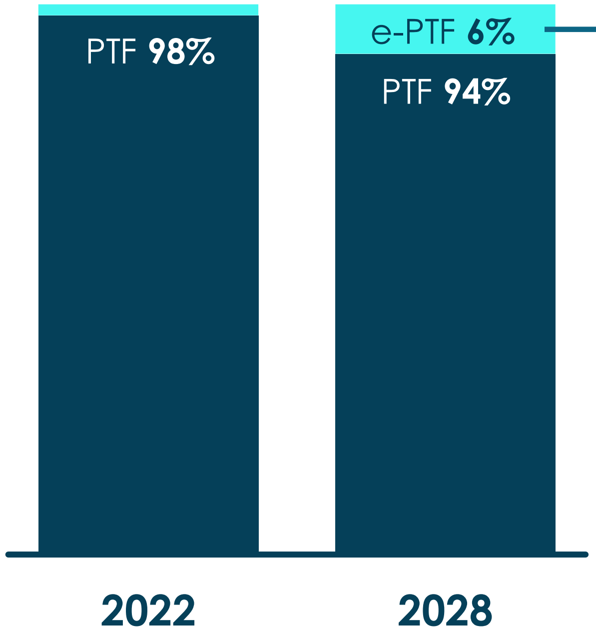
VW

EVs are not a panacea for the energy, transport, and climate crises we face

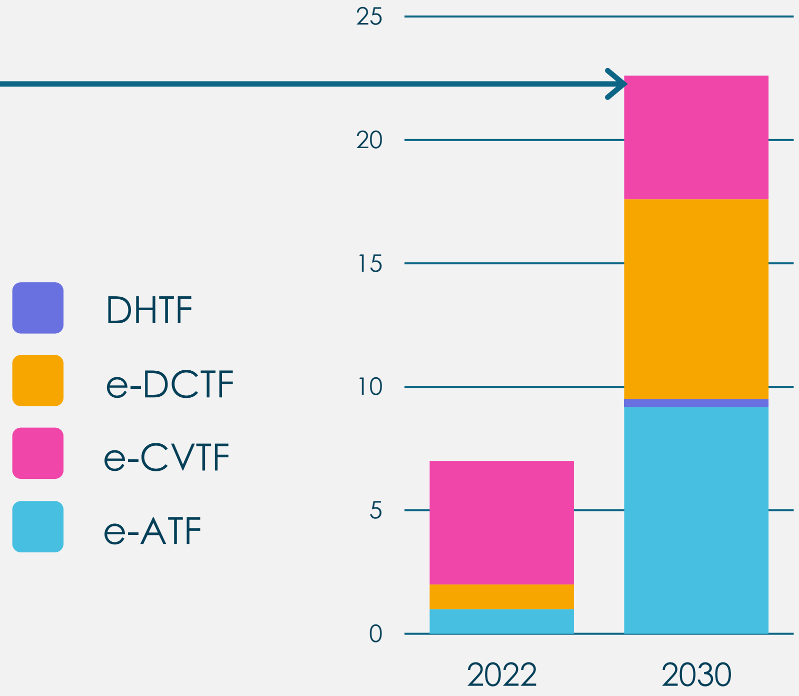
Greenpeace

E-PTF service fill market will grow but remains small

Global light-duty e-ptf service fill **market** split



Global e-PTF service fill, kMT



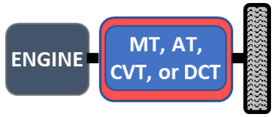
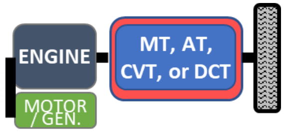
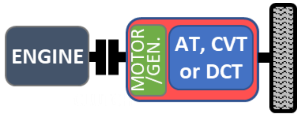
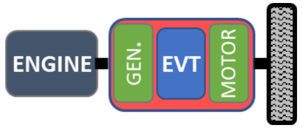
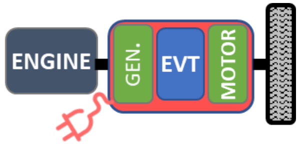
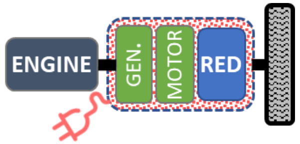
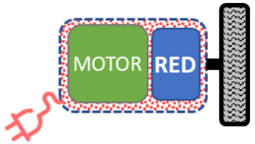
OEM Fill for life (150,000+ miles) fluid targets will slow e-fluid market growth

e-PTF service fill market **~23 kMT/yr** **2030**

PTF – power transmission fluid

Summary/ recap

Vehicle electrification
varying degrees and fluid development

Electrification Type	Start/Stop [S/S]	Mild Hybrid [MHEV]	Full Hybrid [FHEV]		Plug-In Hybrid [PHEV]	Extended Range [EREV]	Battery Electric [BEV]
Basic Schematic							
Approx. Energy Efficiency	+2% to 4%	+8% to 11%	+20% to 35%	+30% to 50%	+50% to 60%	+60% to 70%	+70% to 80%
Fluid Requirements	No additional requirements beyond appropriate power transmission fluid (PTF)	No additional requirements beyond appropriate PTF	PTF with additional requirements for motor cooling, electrical properties and compatibility	Gear protection for EVT, no clutches, possibly eliminating need for some FMs, but with additional requirements for motor cooling, electrical properties and compatibility	Same as FHEV, depending on FHEV configuration, modified transmission or EVT	Gear protection with additional requirements for motor cooling, electrical properties and compatibility	Gear protection (potential for high load) with additional requirements for motor cooling, electrical properties and compatibility

E-mobility and electrification

1 Vehicle Electrification

- Electrification efficiency varies from simple engine start/stop [~2-4%] to full battery electric [~70-80%]
- Motors only assist the engine in mild hybrids, but Full Hybrid motors propel the vehicle without the engine
- In hybrids, transmissions still have an important role to play
- BEVs require only motor and reduction gear box for torque multiplication

2 E-fluid Formulation

- FHEV and BEV transmissions currently use conventional PTF and gear oil but are now being improved
- New fluid requirements include motor cooling, compatibility and electrical insulation
- These new requirements must be balanced with transmission performance and durability
- The right combination of base oils and additive componentry is required

3 Electrification Outlook

- There will be a mix of technologies to meet climate goals, depending on the application and region, including hybrids, FHEV, BEV, alternative fuels, improved ICE
- Global passenger car vehicle parc exceeds 1.4 billion and there will be continued demand for conventional PTF through the 2030s
- E-PTF service fill market continues to grow but remains small ~6% due to long ODI and small sump sizes

Thank you

Infineum

Formulating tomorrow together

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