

# Electric Vehicles

Industry Trends, Hardware and Fluid Requirements

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# Agenda

- **Industry Drivers & Trends**
  - Industry Drivers
  - Zero Emission Challenge- Automotive Industry Approach
  - Global Market Share & Trends
  - BEV Adoption Challenges
- **Vehicles Electrification Level and Types**
  - Light Duty and Heavy Duty Vehicles
- **Full Electric Vehicle - Fluid Needs**
- **Full Electric Vehicle Hardware Overview**
  - E-motor (dry and wet system), gears, bearings
- **E-motor Cooling Modes (dry and wet systems)**
- **E-Drivetrain Fluids for Dry and Wet Systems**
- **E-Drivetrain Fluids Design Challenges**
- **Summary**

# Industry Drivers – Climate Change and Mitigation Efforts

- **2015 Paris Agreement**

- limit global temp. rise to 1.5°C for the 21<sup>st</sup> century

- **COP26 (UK 2021)**

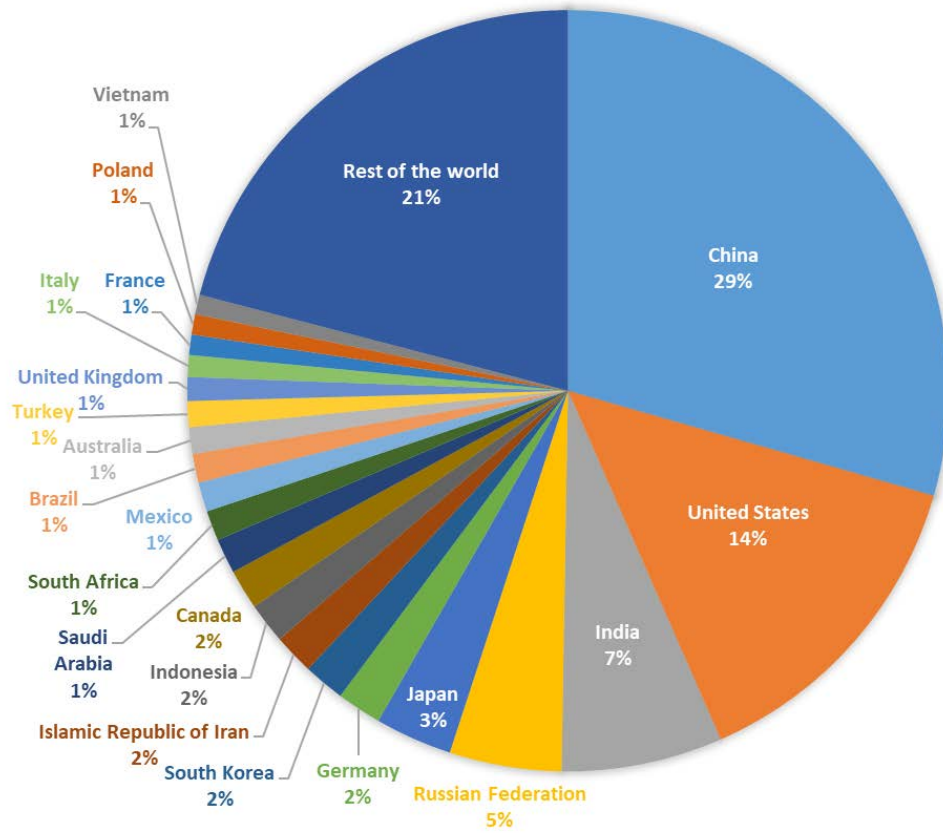
- net zero emissions by 2050
- commitments to move away from coal power, halt and reverse deforestation, reduce methane emissions and **speed up the switch to electric vehicles**
- **Coal Power:** stopping the building of new coal power plants, scaling up clean power and retiring existing coal fleets: in advanced economies by 2030 and globally by **2040**

**Global CO2 emissions rebound by nearly 5% in 2021, approaching the 2018-2019 peak**

<https://www.iea.org/reports/global-energy-review-2021/co2-emissions>

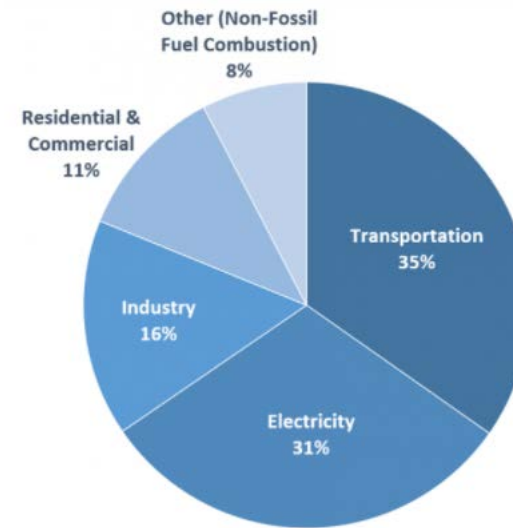
# Industry Drivers – Emissions and Regulations

GLOBAL CO<sub>2</sub> EMISSIONS IN 2019  
TOTAL: 33.62GT



<http://energyatlas.iea.org/>

2019 U.S. Carbon Dioxide Emissions, By Source



Note: All emission estimates from the [Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2019](#) (excludes land sector).

<https://www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions>

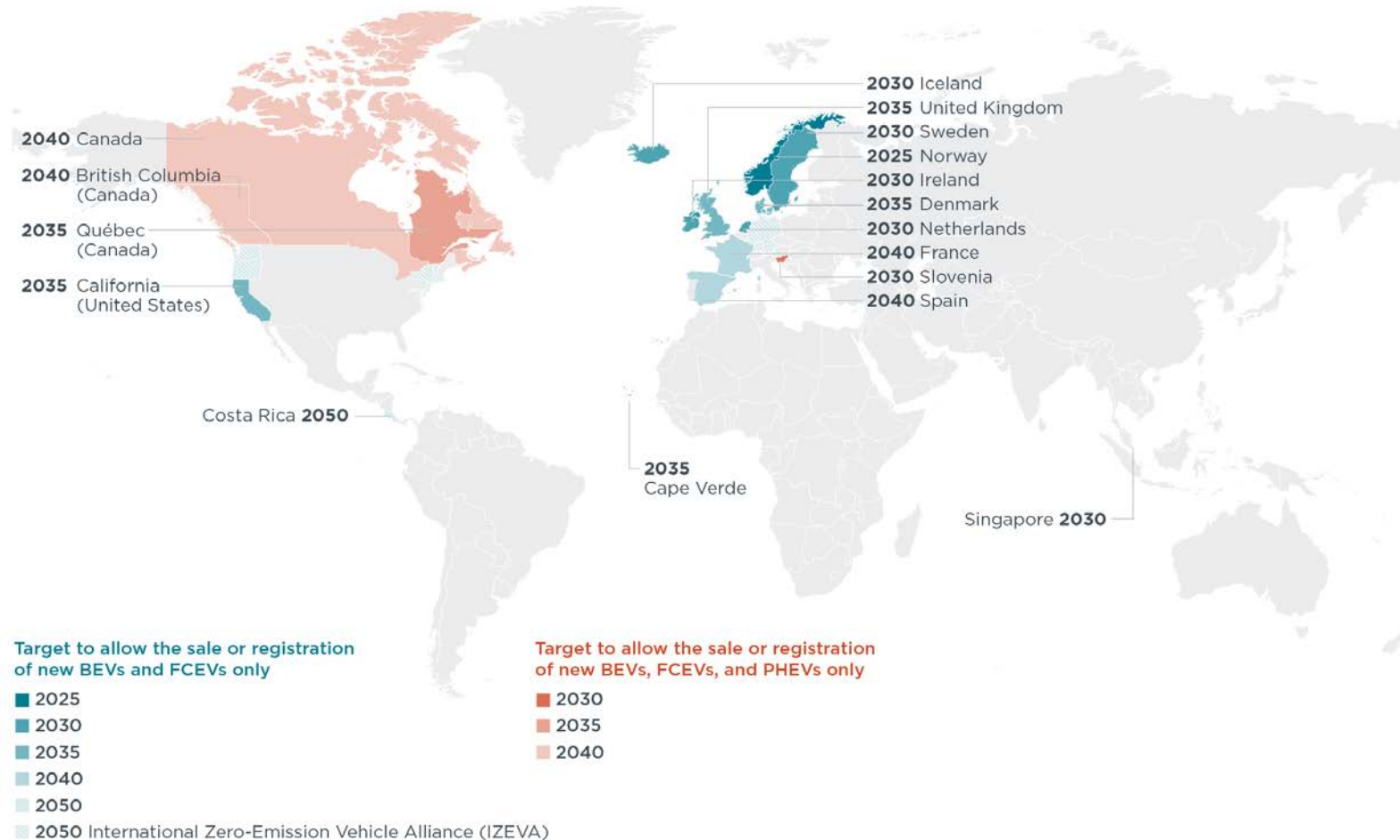
**Transportation is the major contributing sector (US)**

**China & US major contributors to CO<sub>2</sub> emissions globally**

# Industry Drivers –

## Governments Commitment on Zero-Emission Vehicles

Governments with official targets to 100% phase out sales or registrations of new internal combustion engine cars by a certain date\*  
(Status: June 2021)



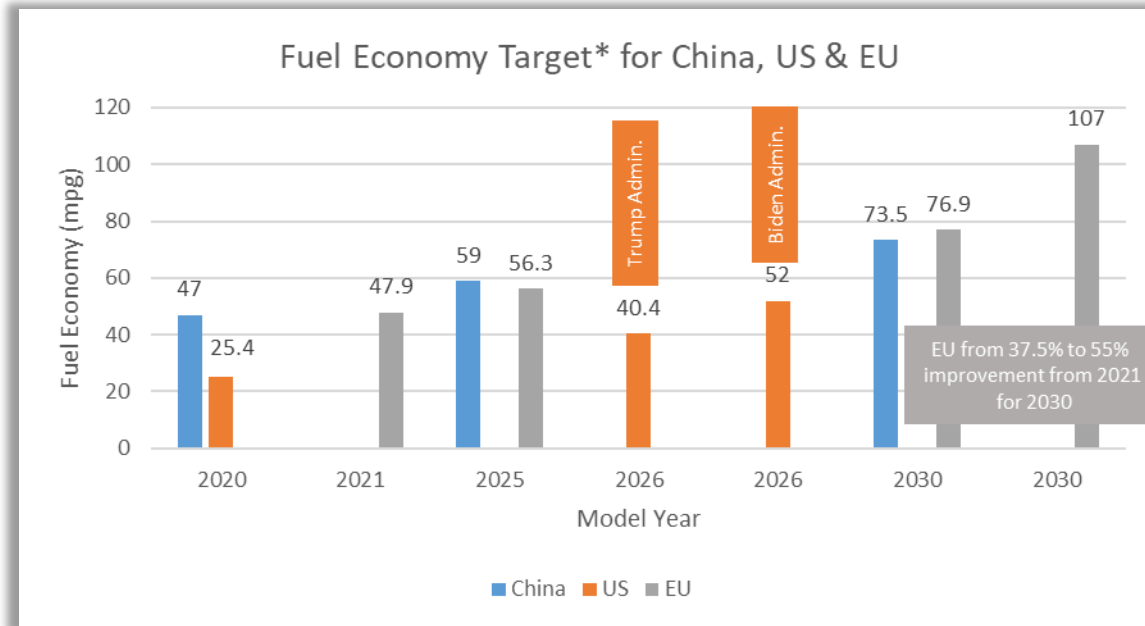
\* Includes countries, states, and provinces that have set targets to only allow the sale or registration of new battery electric vehicles (BEVs), fuel cell electric vehicles (FCEVs), and plug-in hybrid electric vehicles (PHEVs). Countries such as Japan with pledges that include hybrid electric vehicles (HEVs) and mild hybrid electric vehicles (MHEVs) are excluded as these vehicles are non plug-in hybrids.

PHEV: plug-in battery electric vehicle

BEV: battery electric vehicle

FCEV: fuel cell electric vehicle

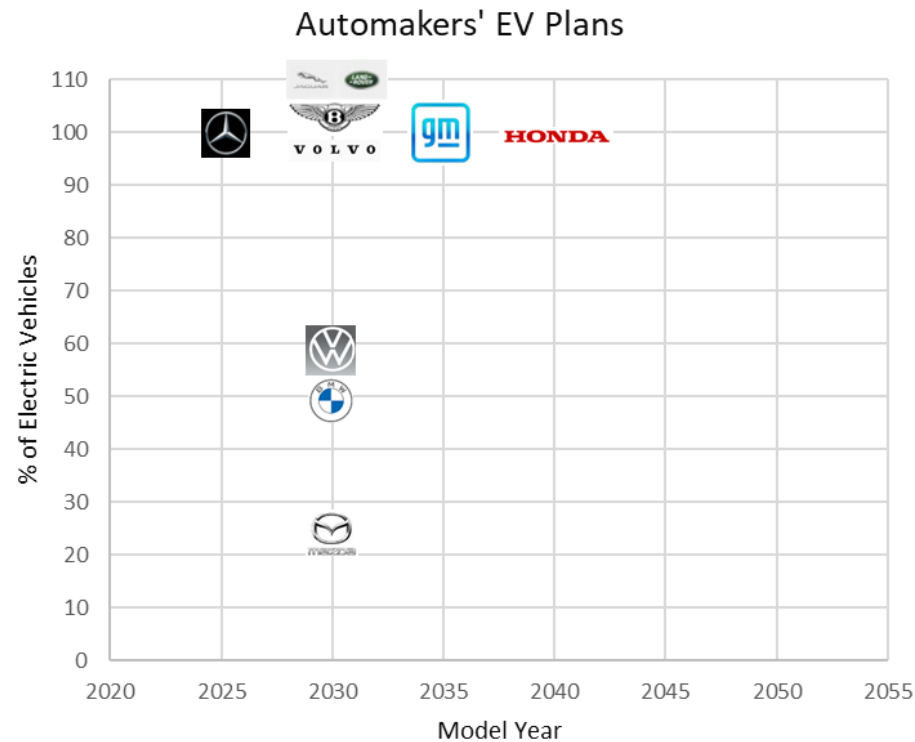
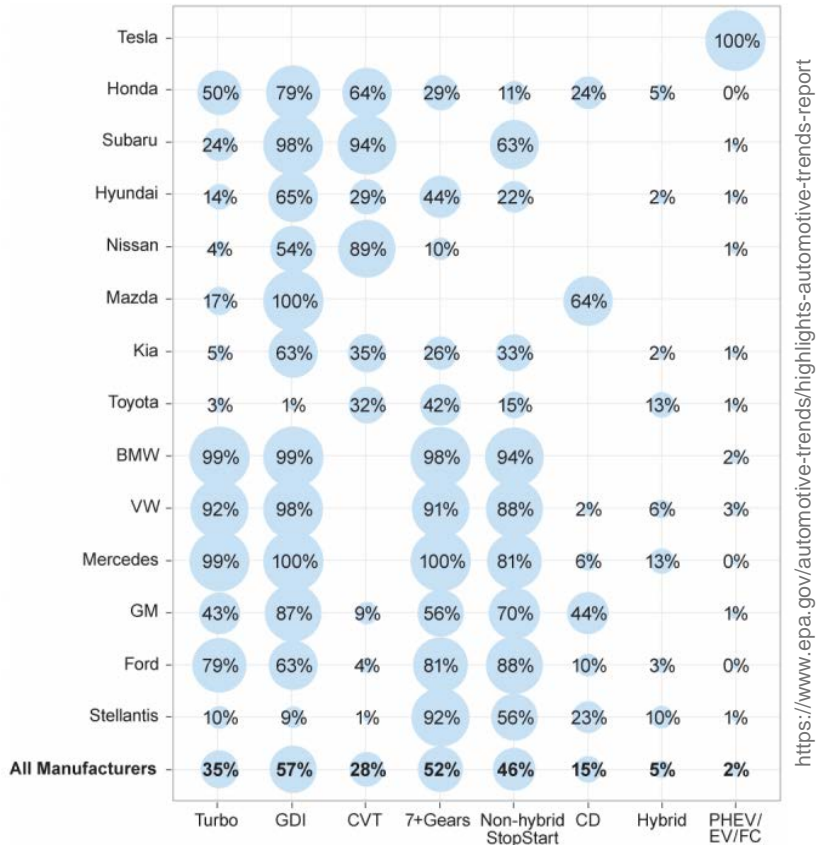
# Industry Drivers – Emissions and Regulations



- China:** government's official target is for electric cars to reach a market share of 20% for the full year in 2025  
 government extended electric car subsidies for 2021 (10% reduced) and 2022 (30% reduced)
- US:** 50% electrification target for new cars by 2030 ("non-binding")  
 installation of 500,000 charging points
- EU:** net-zero greenhouse gas emissions by 2050 with targeted 90% reduction of emissions from transport by 2050
- Canada:** all new light duty vehicles to be zero-emissions by 2035  
 5-year \$280 (CAD) million program to increase the availability of charging and hydrogen refueling stations

# Zero Emission Challenge- Automotive Industry Approach

## Technology Share for Large Manufacturers, Model Year 2020



## 17 New EV models in 2022

- Rivian R1S SUV
- Kia EV6
- BMW i4
- BMW iX SUV
- Ford F-150 Lightning
- Cadillac Lyriq
- Mercedes-Benz EQB
- Mercedes-Benz EQE
- Toyota bZ4X
- Subaru Solterra
- Genesis GV60
- Nissan Ariya
- Polestar 3
- Lexus RZ 450e
- Canoo Lifestyle Vehicle
- Vinfast VF 8 and VF 9
- Fisker Ocean

[https://www.greencarreports.com/news/1134789\\_here\\_are\\_all\\_the\\_evs\\_arriving\\_in\\_2022](https://www.greencarreports.com/news/1134789_here_are_all_the_evs_arriving_in_2022)

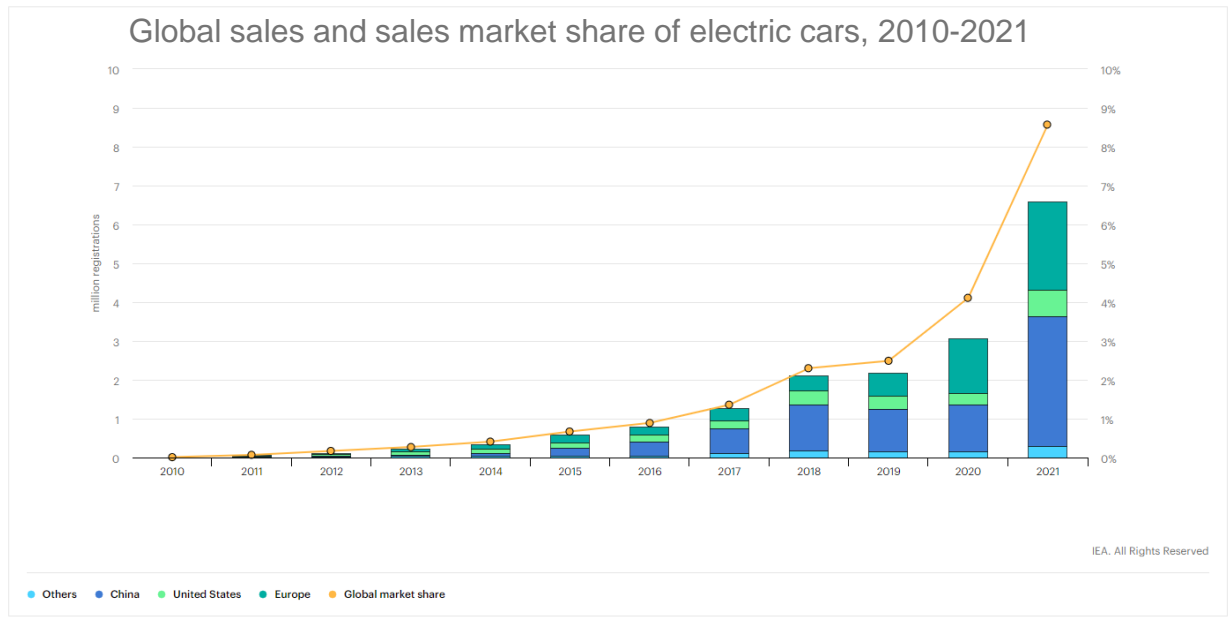
Cost range: \$34,000 to \$84,000 USD

Some OEMs have almost 100% adoption of ICE fuel efficient technologies and moving faster to PHEV/BEV



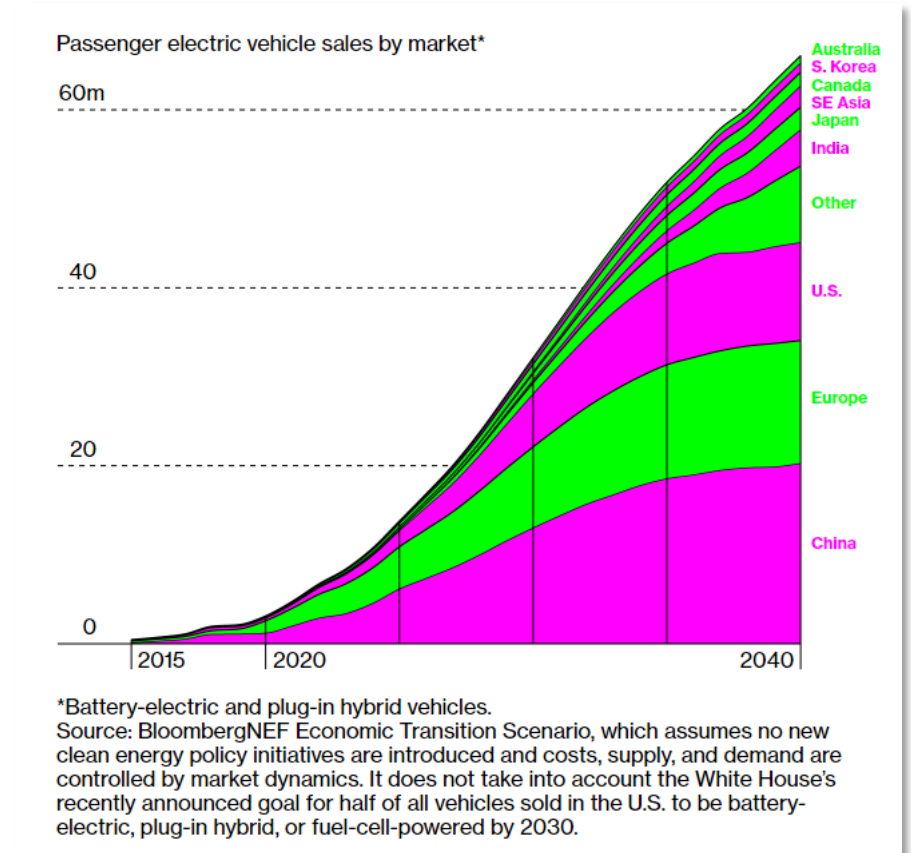
Canoo Lifestyle Vehicle

# Electric Vehicles- Global Market Share & Trends



**Sales of electric cars hit 6.6 million in 2021, more than tripling their market share from two years earlier**

[www.iea.org](http://www.iea.org)





Source: Bloomberg Markets; "At Least Two-Thirds of Global Car Sales Will Be Electric by 2040"- Aug 2021



# BEV Adoption Challenges

## ▪ Battery cell supply and cost

-  Parity to ICE vehicles for total cost of ownership for consumers, excluding subsidies is reached by 2025
-  To hit net-zero *globally* by 2050, would require six times more mineral inputs in 2040 than today

## ▪ Driving Range

-  Electric vehicles can now go 200+ miles on a charge
-  Cold temp. can reduce an unplugged EV's range by 20%

## ▪ Charging network and clean energy source

-  Governments subsidies and private companies (e.g.:Tesla) increasing public charging stations
-  COP26 governments commitments to reduce coal as energy source and increase green energy sources (solar, wind)

## ▪ Regulations and Incentives

-  Incentives for BEV still in place but decreasing over time and in some cases linked to specific OEMs

## ▪ Fuel Price

-  BEV payback achieved in about 3-6 years

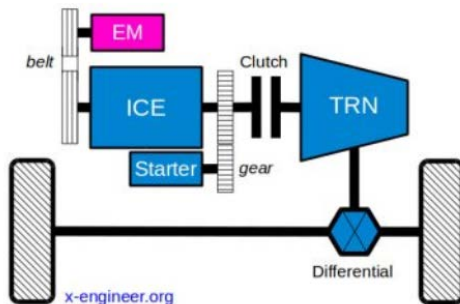
# Vehicles Electrification Levels and Types

## Comparison of Hybridization Levels

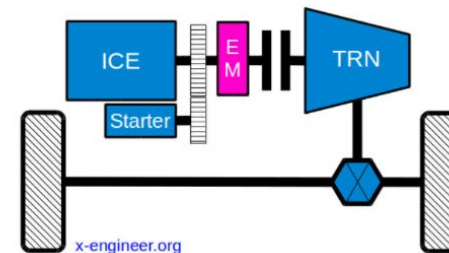
Hybrids	Micro Hybrid		Mild Hybrid	Full Hybrid	Plug-in Hybrid
	ISG Start/Stop	ISG Hybrid			
Engine	Conventional	Conventional	Downsized	Downsized	Downsized
Electric Motor	Belt drive	Belt/Crankshaft	Belt/Crankshaft	Crankshaft	Crankshaft
Electric Power	2-5Kw	3-10kW	10-20kW	15-100kW	15-100kW
Operating Voltage	12V	12-42V	60-200V	200V-600V	200V-600V
Charging off the grid	No	No	No	No	Yes
Fuel Economy Improvement*	3-5%	5-10%	15-20%	20-30%	20-30%
Vehicle Examples	Ford Focus		Chevy Malibu eAssist Honda Civic Hybrid	Toyota Prius	Toyota Prius Plug-in

\* from Non-Hybrid option

<http://autocaat.org/>



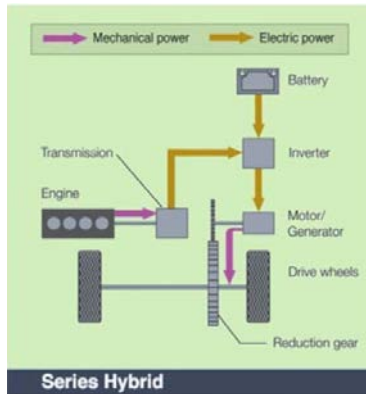
**Belt** Integrated Starter Generator



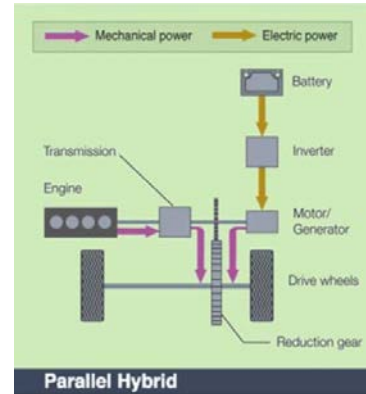
**Crankshaft** Integrated Starter Generator

# Vehicles Electrification Levels and Types

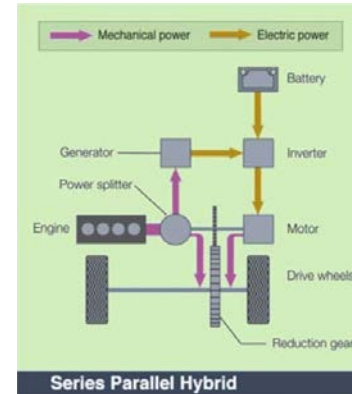
## Hybrid Types – What is driving the wheels?



E-motor driven  
Chevrolet Volt (mild)

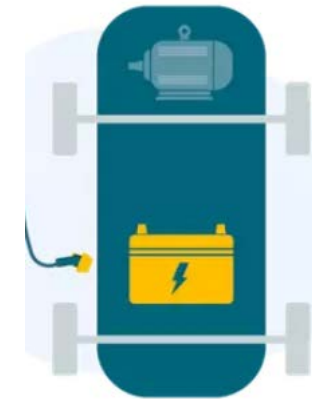


E-motor & ICE driven  
No pure electric mode  
Honda Civic Hybrid (mild)



E-motor & ICE driven  
Pure electric mode capable  
Toyota Prius (full)

## BEV or Full Electric



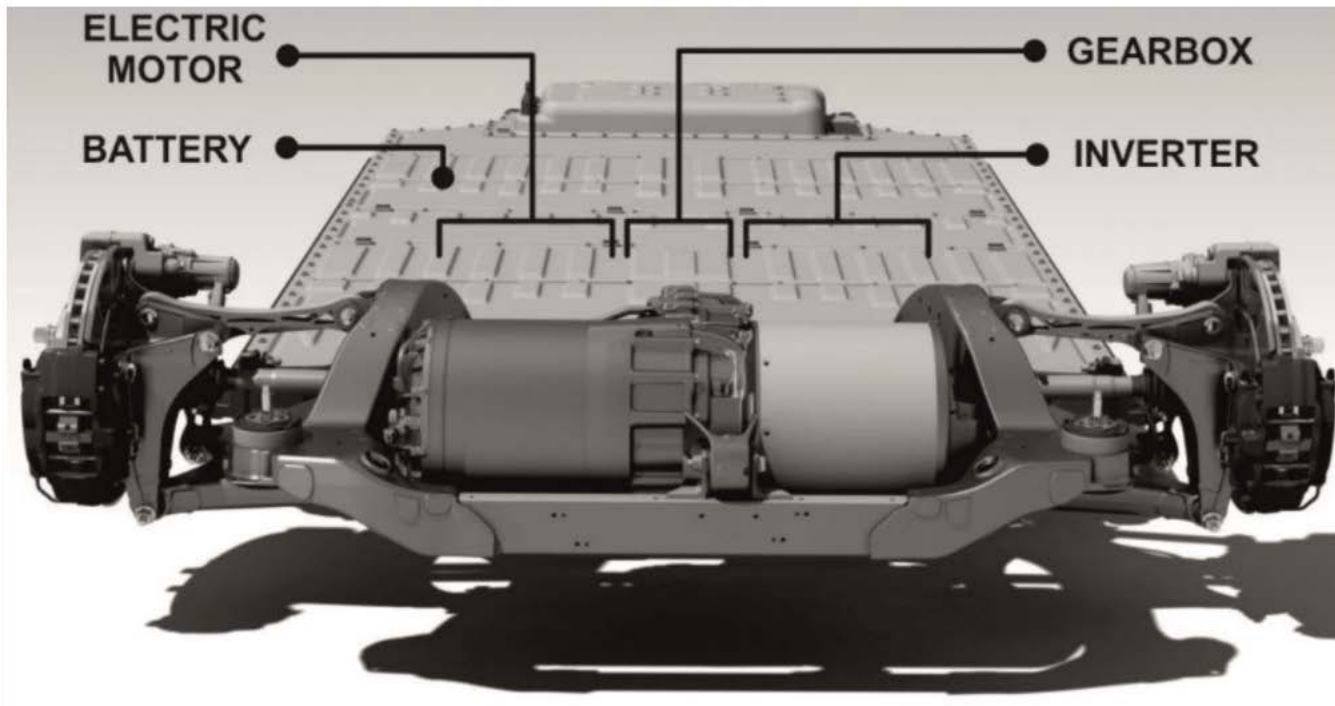
93 to 95% efficient  
from 1 to 4 e-motors

# Heavy- Duty Electrified Options

- 48V **mild-hybrid** technology can be applied to medium-duty (MD) and HD trucks and buses (AVID 48 delivery truck in EU)
- **Full hybrid** (series, parallel, or power split)
- **Plug-in hybrid**
- **Full electric**



# Full Electric Vehicle - Fluid Needs



- *Battery coolant fluid: water/glycol mixture*
- *Electric motor: coolant or lubricant*
- *Gearbox: lubricating fluid*

# Full Electric Vehicle – Gears and Bearings

- **Gears:**

- helical gears
- Planetary gear box



**Helical Gear Set**



**Planetary Gear Set**

- **Bearings:**

- ball bearings (steel and ceramic)
- tapered roller bearings
- needle roller bearings



**Ball B**



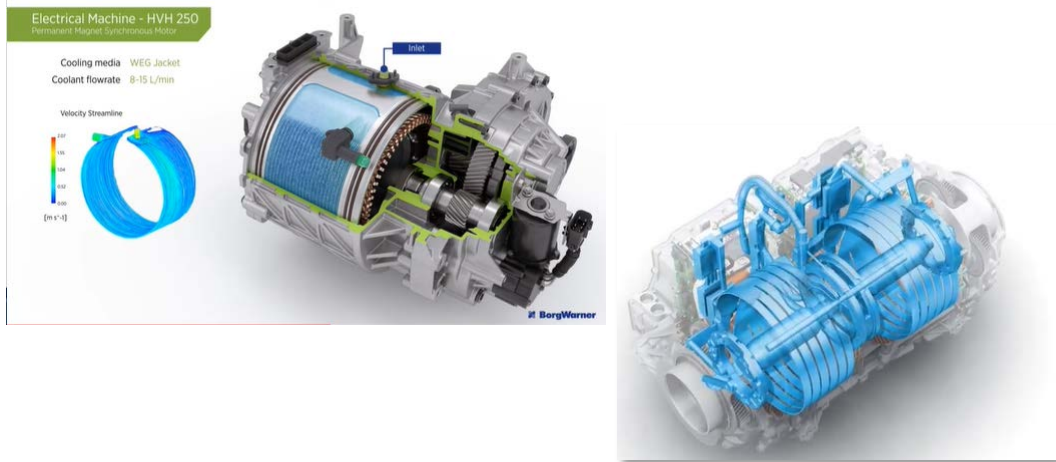
**Tapered B**



**Needle B**

# Full Electric Vehicle – System Design and Cooling

## “Dry” System



Audi e-tron Twin Motor Water Cooling System

## “Wet” System



Motor is cooled with cooling jacket/ WEG mixture  
Gear Set is lubricated with gear oil

Motor is cooled with cooling jacket/ WEG mixture  
AND with lubricant improving motor efficiency

**NO CLUTCHES!**

*“it’s easy to get peak power for a short period of time – it’s hard to have sustained peak power, because you overheat, and it’s hard to get high efficiency over a complicated drive cycle.”* Elon Musk

# Current E-Drivetrain Fluids for Full Electric Vehicles

- **Dry Systems**

- MTF or gear oils
- Limited contribution to motor cooling
- Viscosity grade: 70W (~ 6cSt @ 100°C)
- Fluid volume: ~1 to 4L
- More demanding low temperature properties for gear oils

- **Wet Systems**

- ATFs like DEXRON VI, DEXRON HP, MERCON ULV
- Most efficient motor cooling
- Viscosity grade: 4.2 to 6 cSt @ 100°C
- Fluid volume: ~1.4-3L
- Not specifically formulated for this application and there is no specific need for friction modifier additives as there are no clutches



# Specialized E-Drivetrain Fluids for Dry and Wet Systems

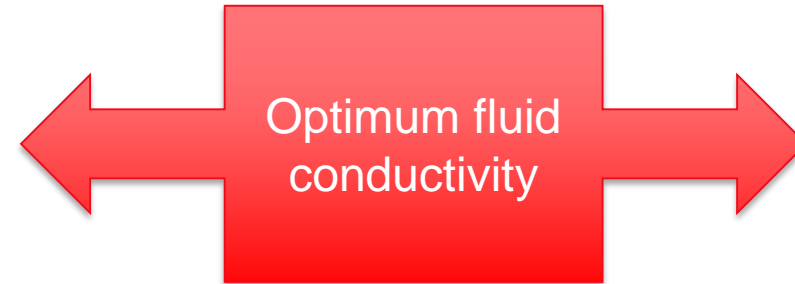
Dedicated fluids to address specific hardware requirements:

- ***Electrical Properties*** the right electrical properties in the fresh and used oil
- ***Compatibility*** with Cu and new polymers (nylon) and seals, e-motor is immersed in the oil
- ***Cooling Ability:*** balance between heat capacity and fluid viscosity
- ***Wear Protection:*** extreme speed bearing protection and tighter tolerances between e-motor rotor/stator
- ***Other important properties:*** Foaming Control, Aeration, Volatility

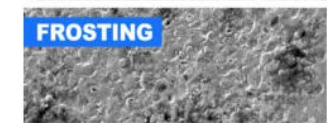
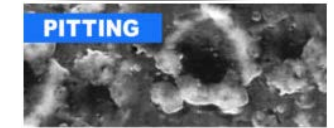
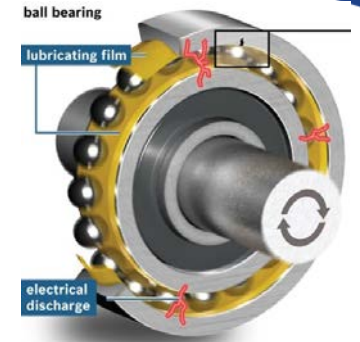
# E-Drivetrain Fluids Design Challenges

## – Electrical Conductivity

**Too high:** current leakage, loss of efficiency

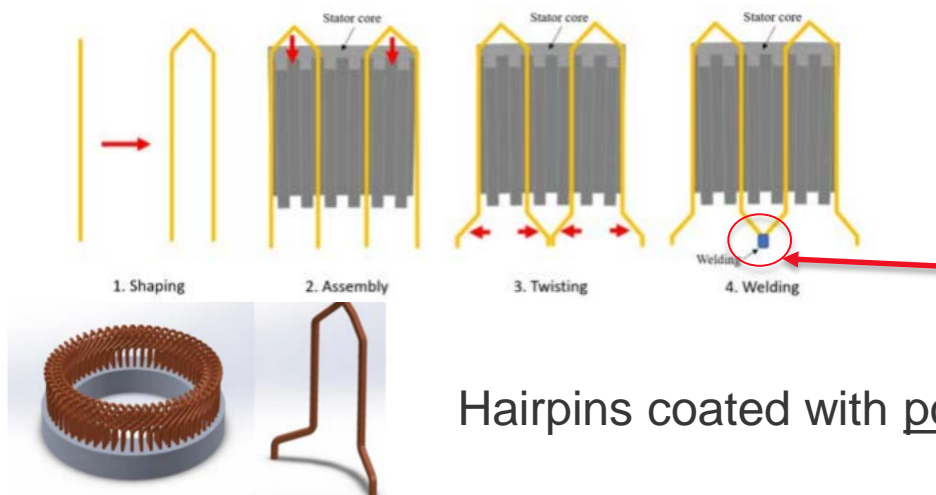


**Too low:** static charge build up



## – Compatibility with new materials

- Cu and Cu hairpin coatings



Welding coated polyimide or polyether ether ketone (PEEK)

Hairpins coated with polyester or epoxy varnish

# E-Drivetrain Fluids Design Challenges

- **Cu Corrosion Protection vs. Improved Load Carrying Capacity**
  - Requires different antiwear chemistry less reactive against Cu
- **Heat Transfer Capacity & System Efficiency vs. Gear Wear Protection**
  - How to improve heat capacity while maintaining the lubrication protection to the reduction gearbox
  - Lower viscosity fluids to improve system efficiency will require better gear wear protection
- **Aeration and Foaming**
  - High speed motor (up to 20,000 rpm) + high gear reduction ratios (10:1) + splash lubrication = entrained air and foaming = poor lubrication
- **Oxidation Stability**
  - Hot spots due to splash and spray e-motor cooling and gear lubrication
  - Oil exposed to higher temp  $\sim 150^{\circ}\text{C}$  will require fluids with high resistance to oxidation and volatility control
- **New test methods**
  - New fluid characteristics will require new testing methods representative of field conditions and capable of discriminating between fluids

# Collaboration

## SwRI AFEV Consortium for Advanced Fluids for Electrified Vehicles

*Goal:* The goal of the Advanced Fluids for Electrified Vehicles (AFEV) Consortium is to advance the industry's understanding of the unique stressors placed on electric vehicle (EV) and hybrid vehicle fluids. This will enable development and optimization of EV fluids and progress EV powertrain design.



Collaborative effort from  
Additive Suppliers  
OEMs  
Oil Marketers  
SwRI

# Summary

- Global trends indicate continued **and fast pace growth of electrified and full electric passenger vehicles and light-duty trucks and buses**
- Geography leaders on implementation: **China, Europe and US**
- **Electrification** level driven by emission **regulations, OEMs, consumer choice and infrastructure**
- Full electric vehicles' diverse architecture will require a **good understanding of hardware design for fluid selection/recommendation**
- **Current fluid requirements are at the FF/SF dealership level** projected to reach aftermarket penetration beyond 2040
- **Specialized fluids for full electric vehicles have been introduced in the market and new ones being developed** while also gaining new knowledge of new/different fluid characteristics



# THANK YOU

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