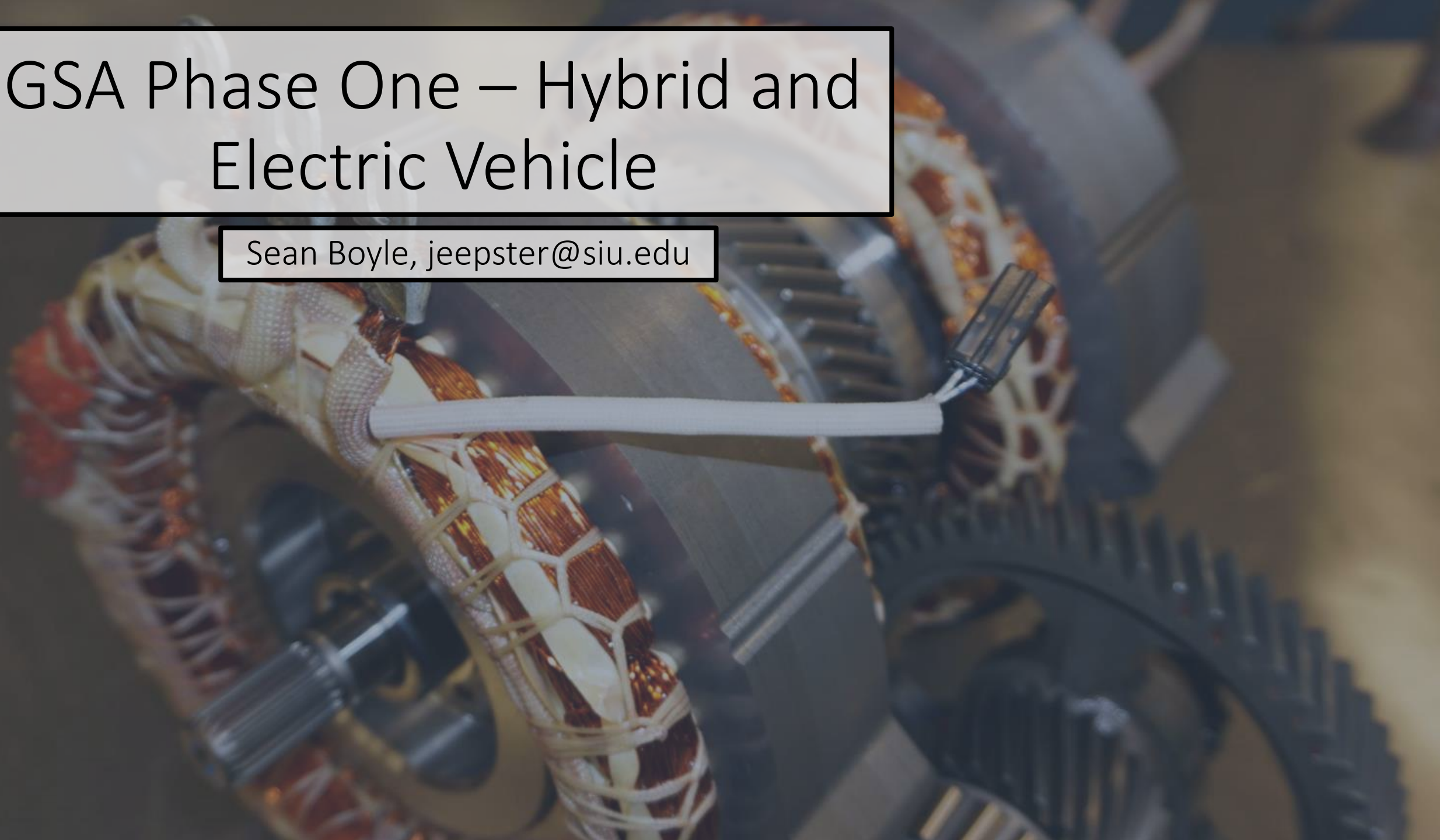


GSA Phase One – Hybrid and Electric Vehicle

Sean Boyle, jeepster@siu.edu



Introduction

- xEV
 - Now viable because:
 - Lithium Ion Battery (Li-ion)
 - Nickel Metal Hydride (NiMH)
 - Advanced Power Electronics



General xEV Characteristics

- HEV
 - No change for the driver
 - Start Stop feature – smooth
 - Small HV and LV battery
 - No range issues
 - Slight price increase
- Perfect for customers who:
 - Have long work commutes
 - Sole vehicle
 - Stop and go traffic



General xEV Characteristics

- PHEV

- Driver can opt to do nothing different opt to plug-in their vehicle for electric only
- Start Stop feature – smooth
- Medium sized HV and small LV battery
- No range issues
- 5 – 10k upcharge

- Perfect for customers who:

- Have ~ 30-mile commute or less
- Sole vehicle
- Live where electricity is relatively inexpensive
- Can charge at work for free



Volt test drive



General xEV Characteristics

- BEV
 - Driver needs to charge to maintain range
 - Home charging preferred
 - Range issues
 - Long drives
 - Cold weather
- Perfect for customers who:
 - Have multiple vehicles in household
 - Have access to home charging
 - Live where electricity is relatively inexpensive
 - Can charge at work for free

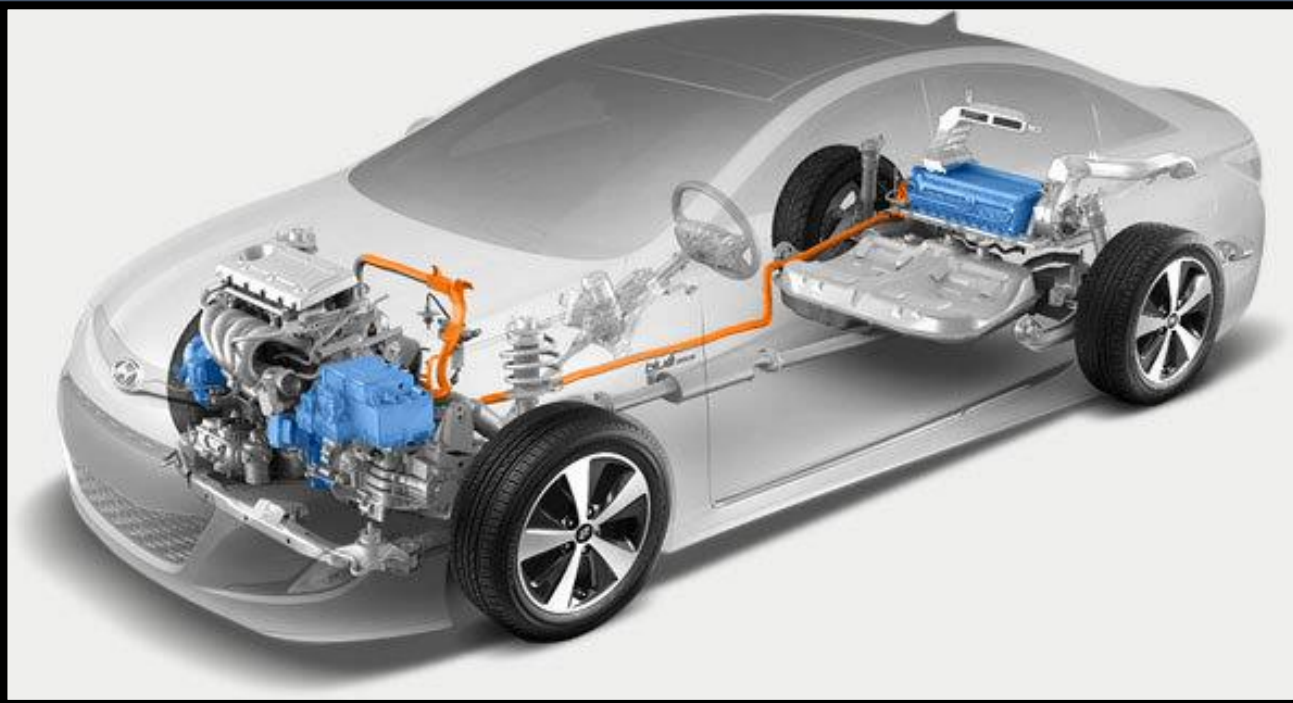


xEV – what makes them different from a traditional ICE vehicle?

- Regeneration
 - Advanced Braking
- Efficient Engine (HEV/PHEV)
- Electric Accessories
- Heating and Cooling
- Parts Reduction

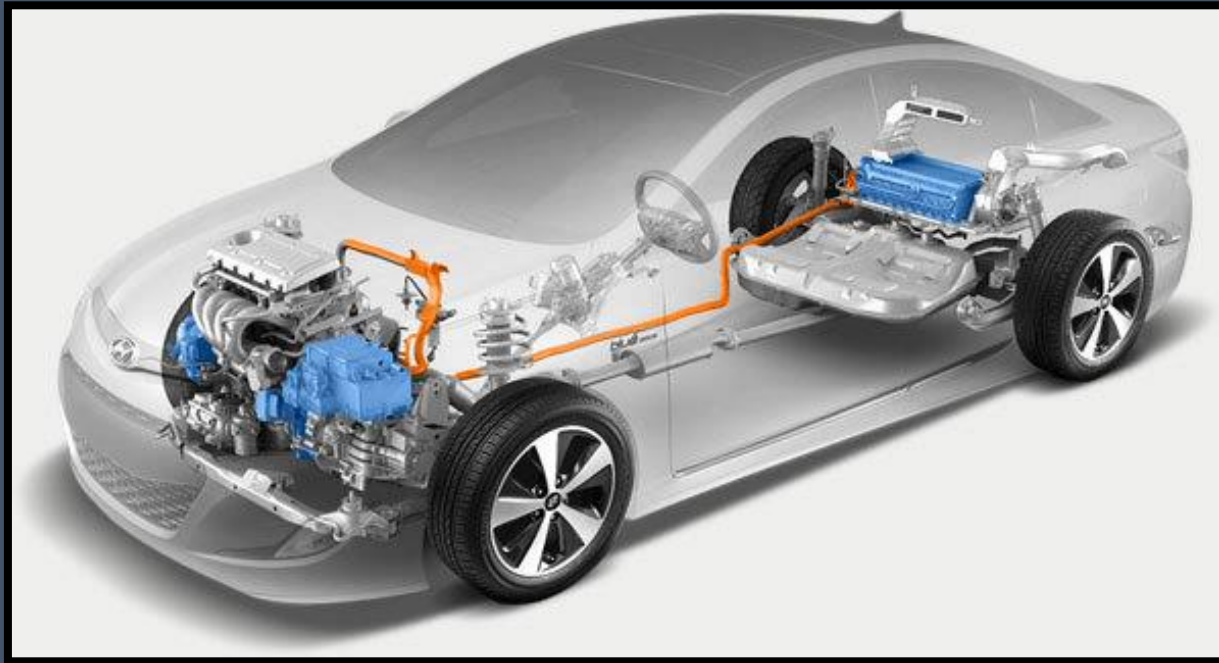
xEV – Regeneration

- Recover energy lost through friction (heat)
 - Generate electricity during braking and deceleration
 - Use that electricity during acceleration



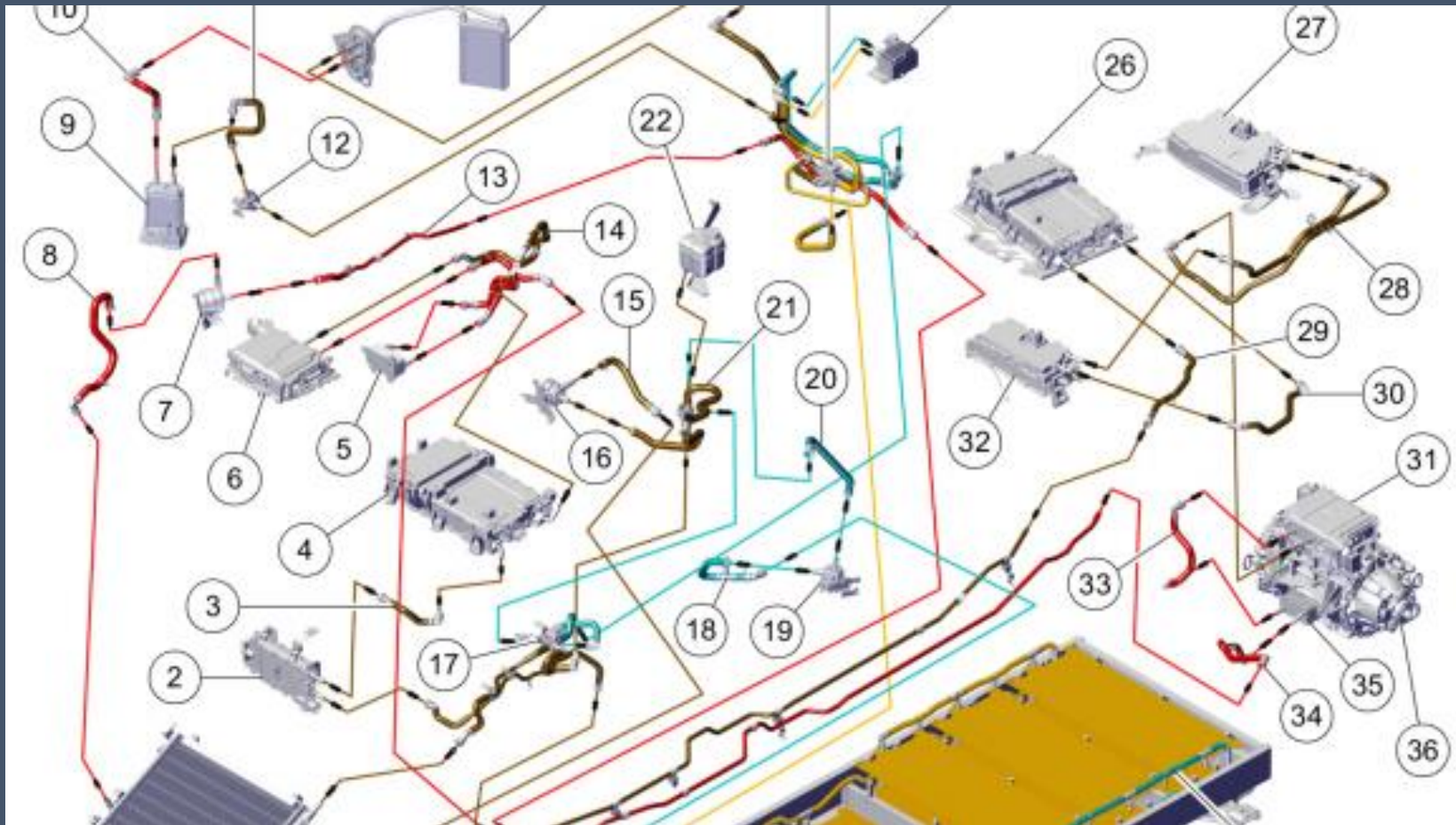
xEV – Efficient Engine (HEV/PHEV)

- Combination engine and electric drive
 - Efficient engines provide mid range RPM torque
 - Electric motors provide excellent low RPM torque
 - Good combination



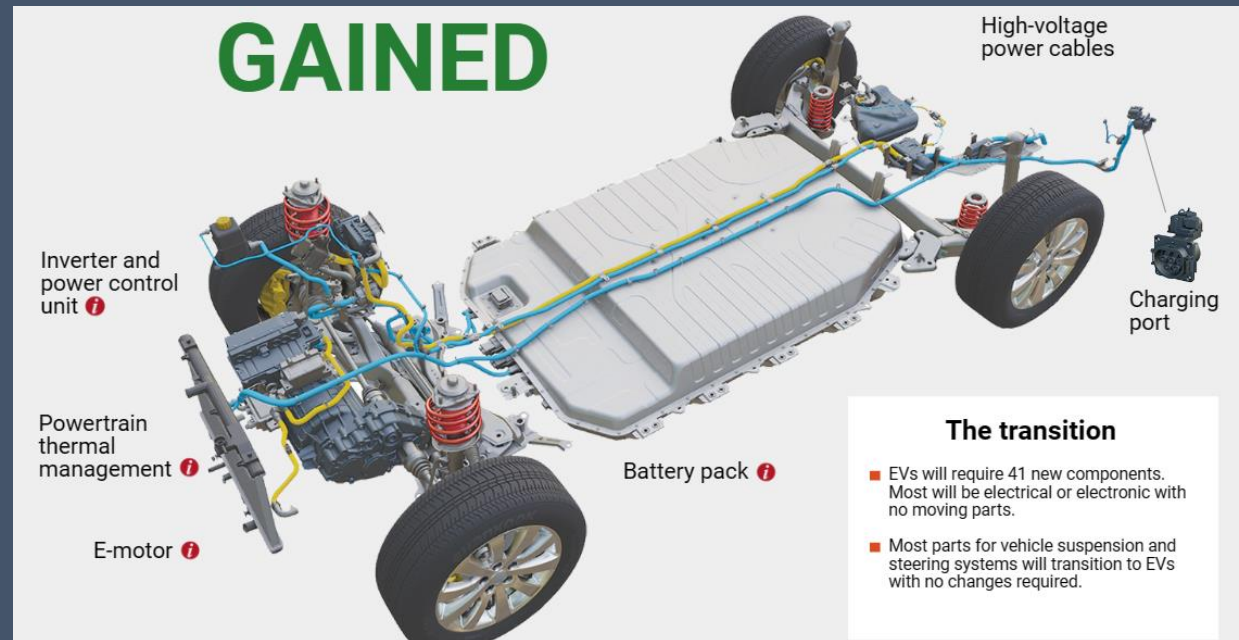
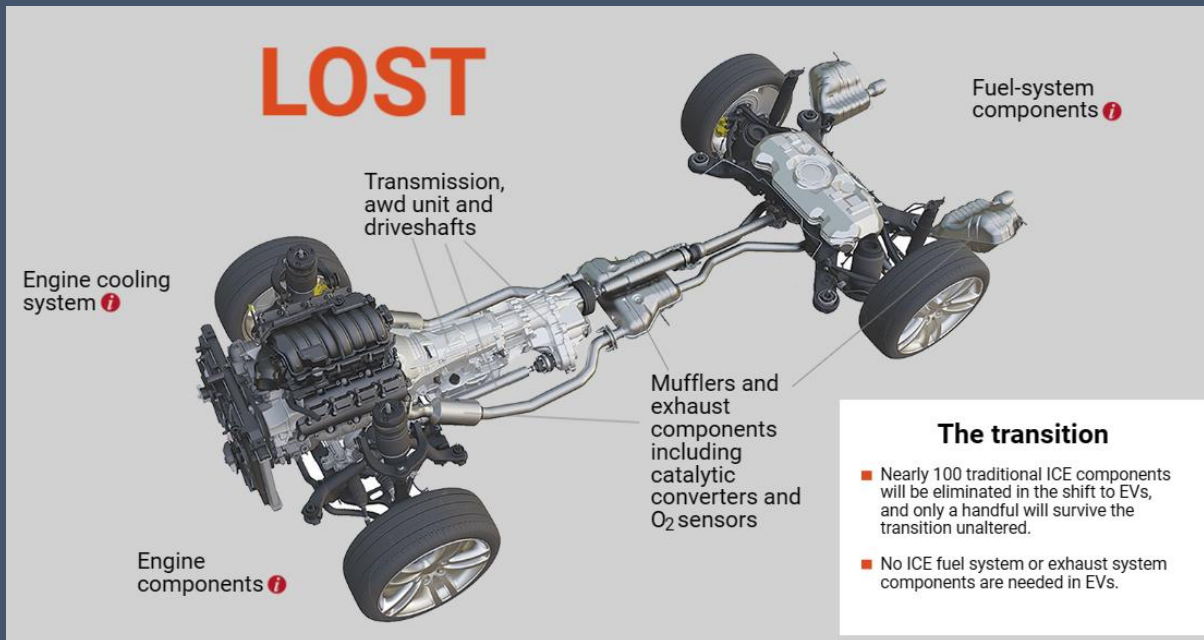
xEV – Heating and cooling

- Heating and cooling is much more complex in an xEV

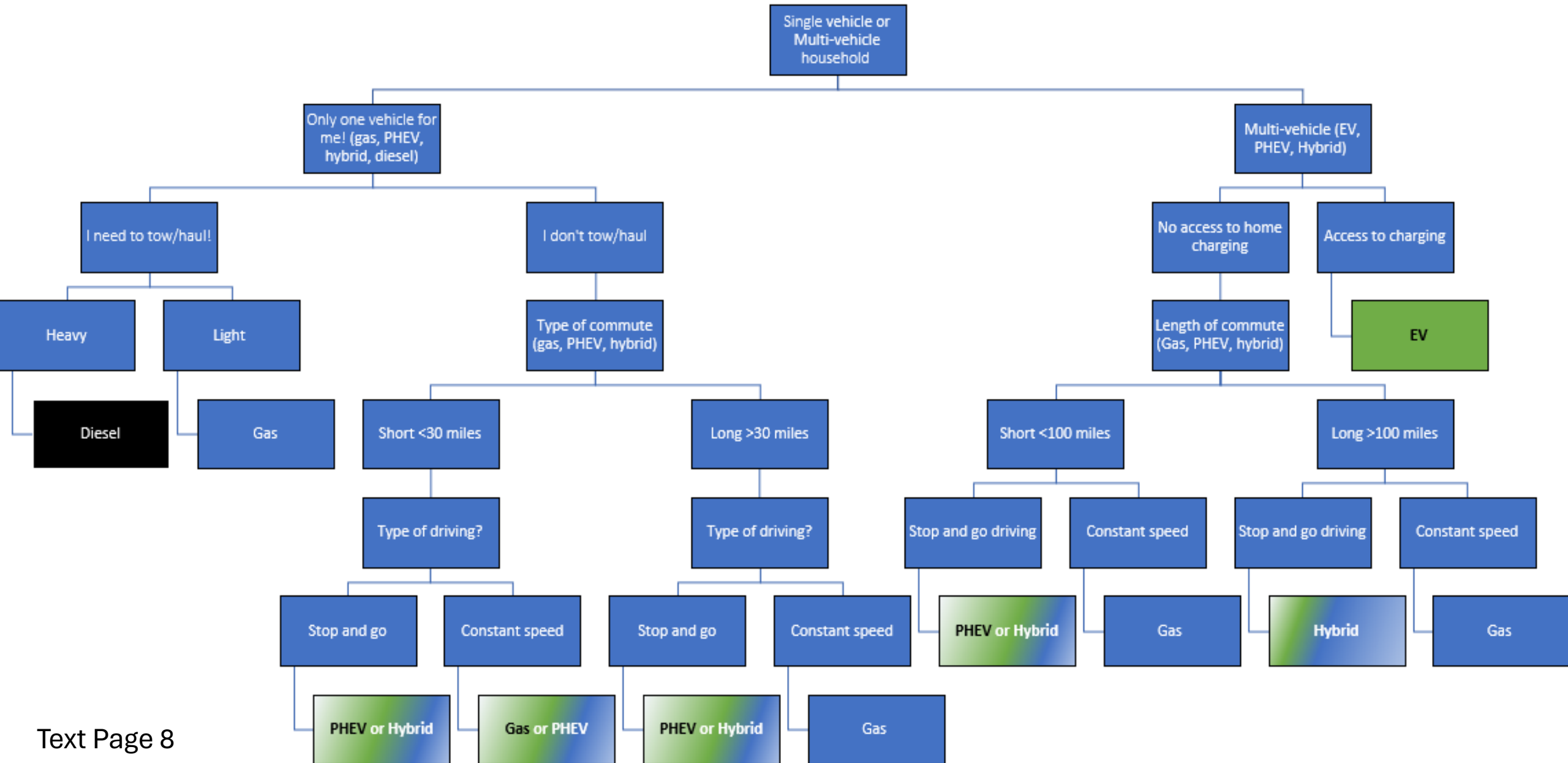


xEV – Parts reduction

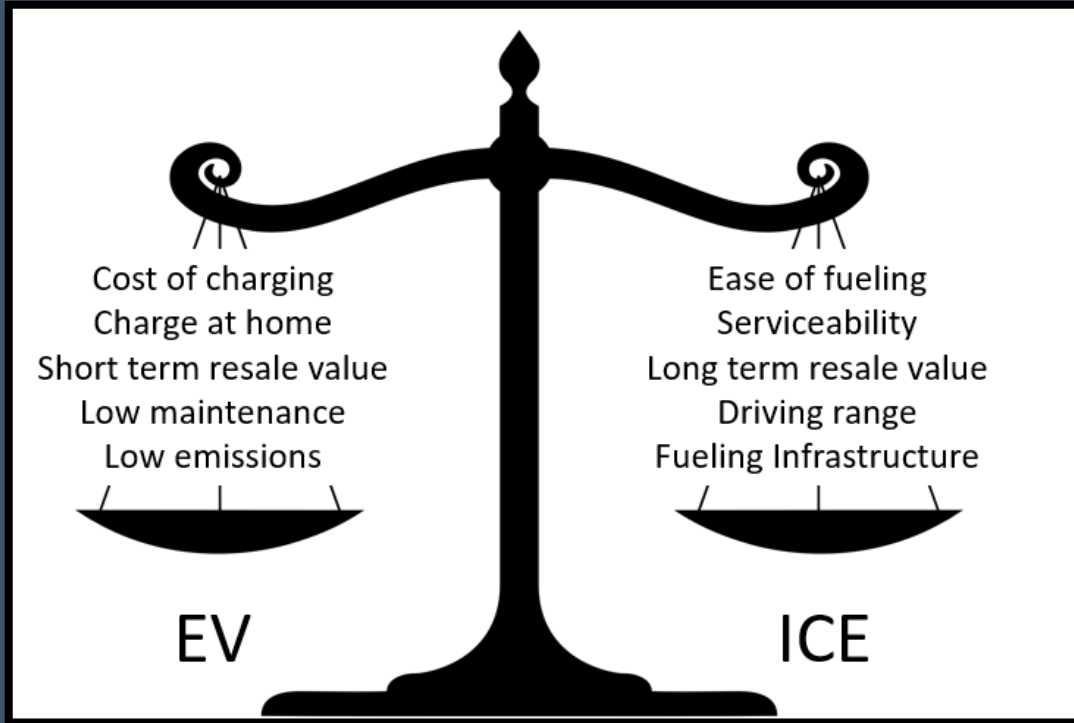
- Estimated about 15k fewer parts!



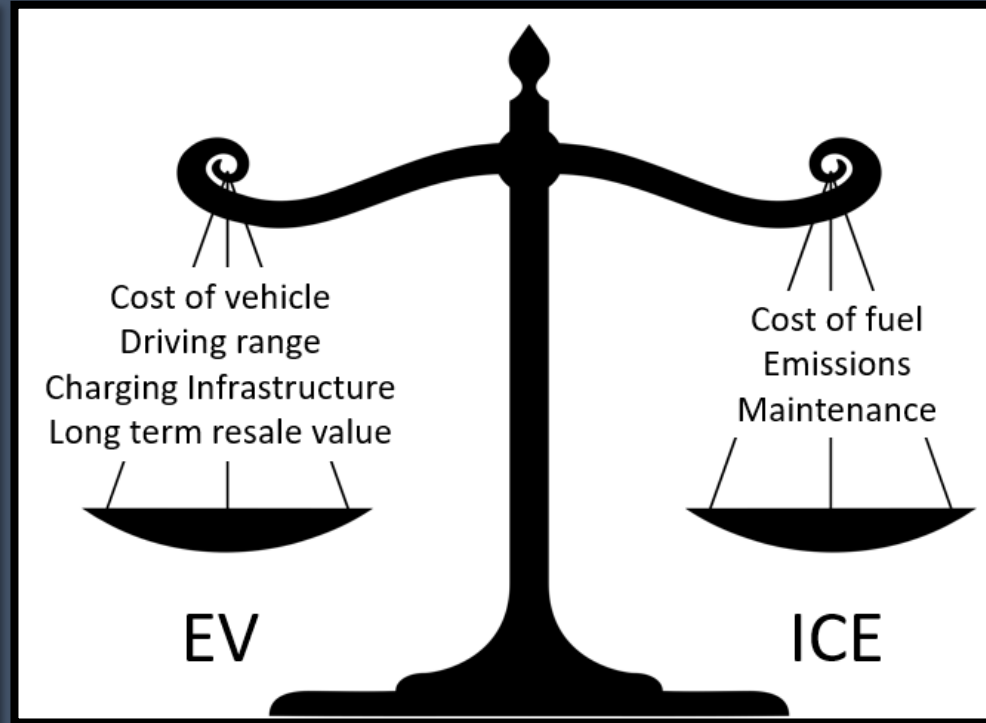
What's best for me?



What's best for me?



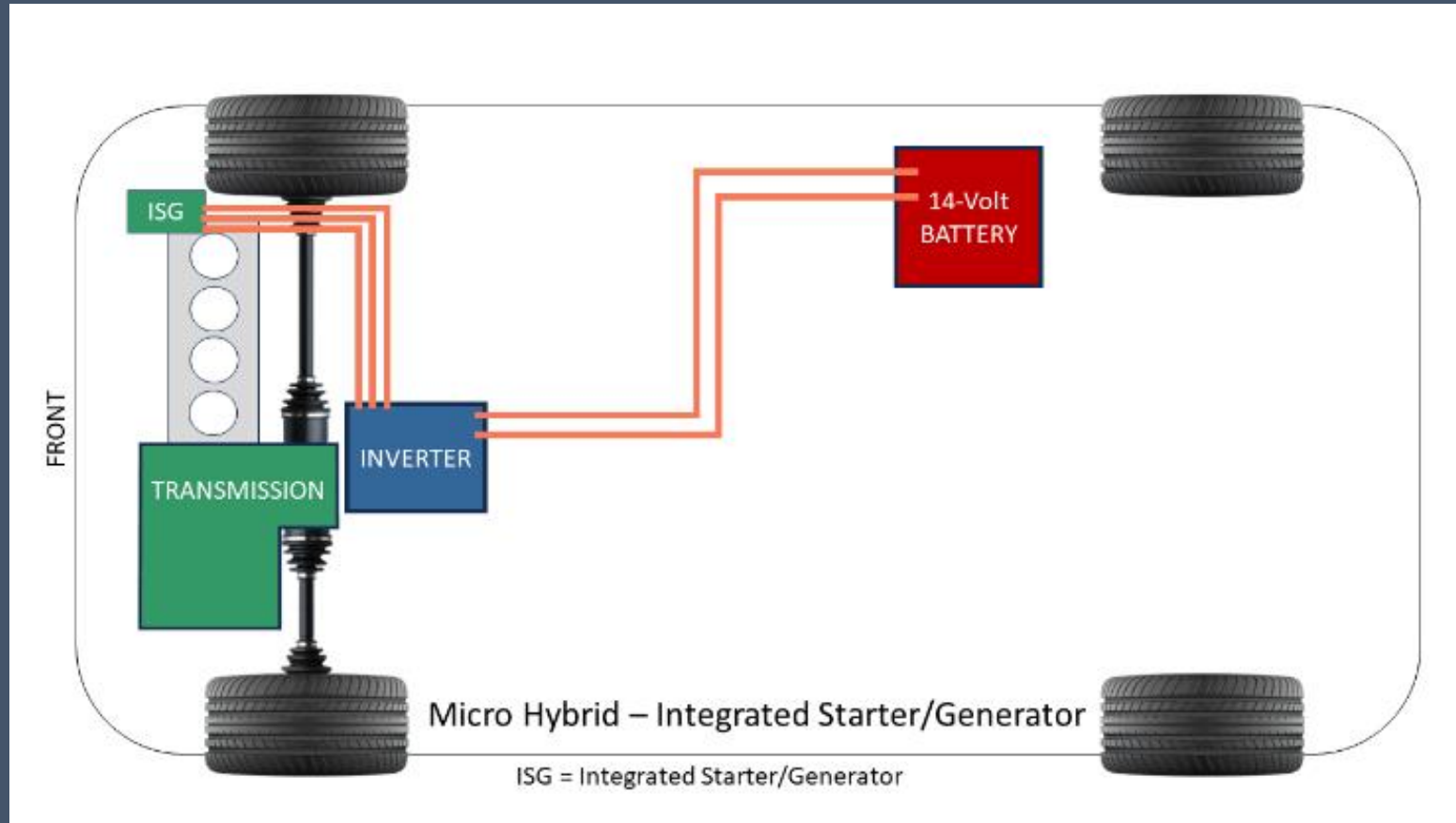
EV Advantages



EV Disadvantages

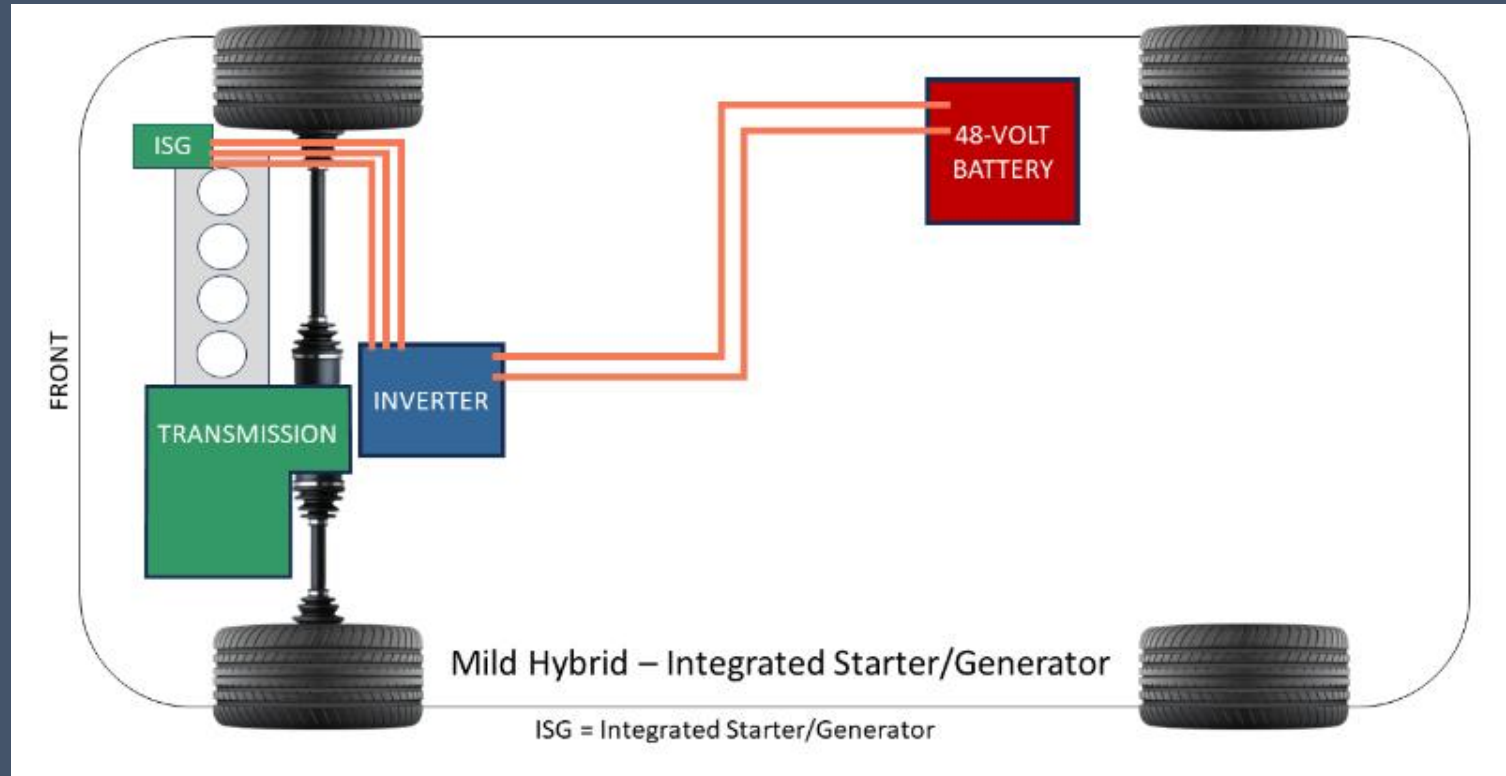
HEV Classifications

- **Micro**
- Mild
- Medium
- Full



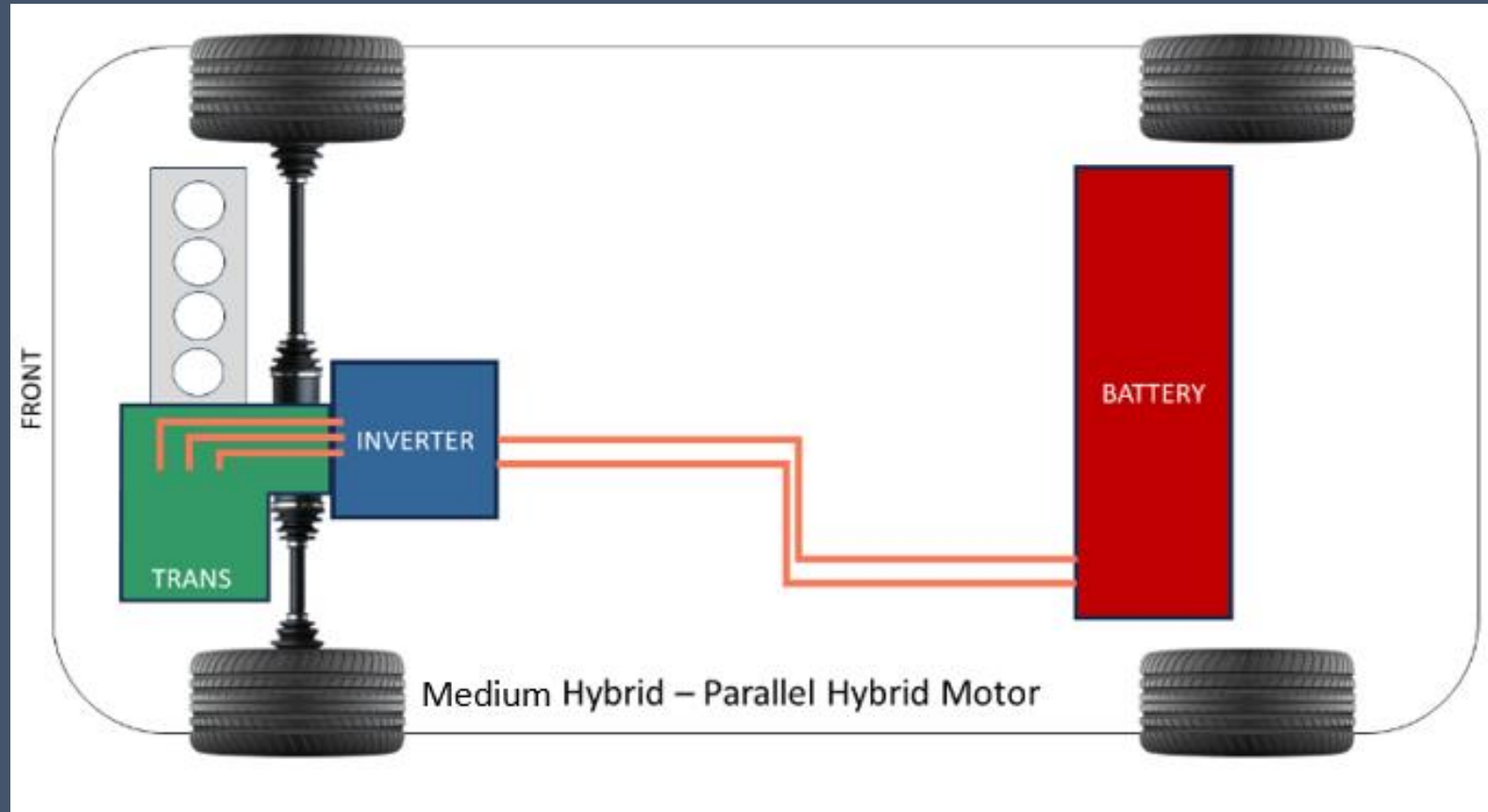
HEV Classifications

- Micro
- **Mild**
- Medium
- Full



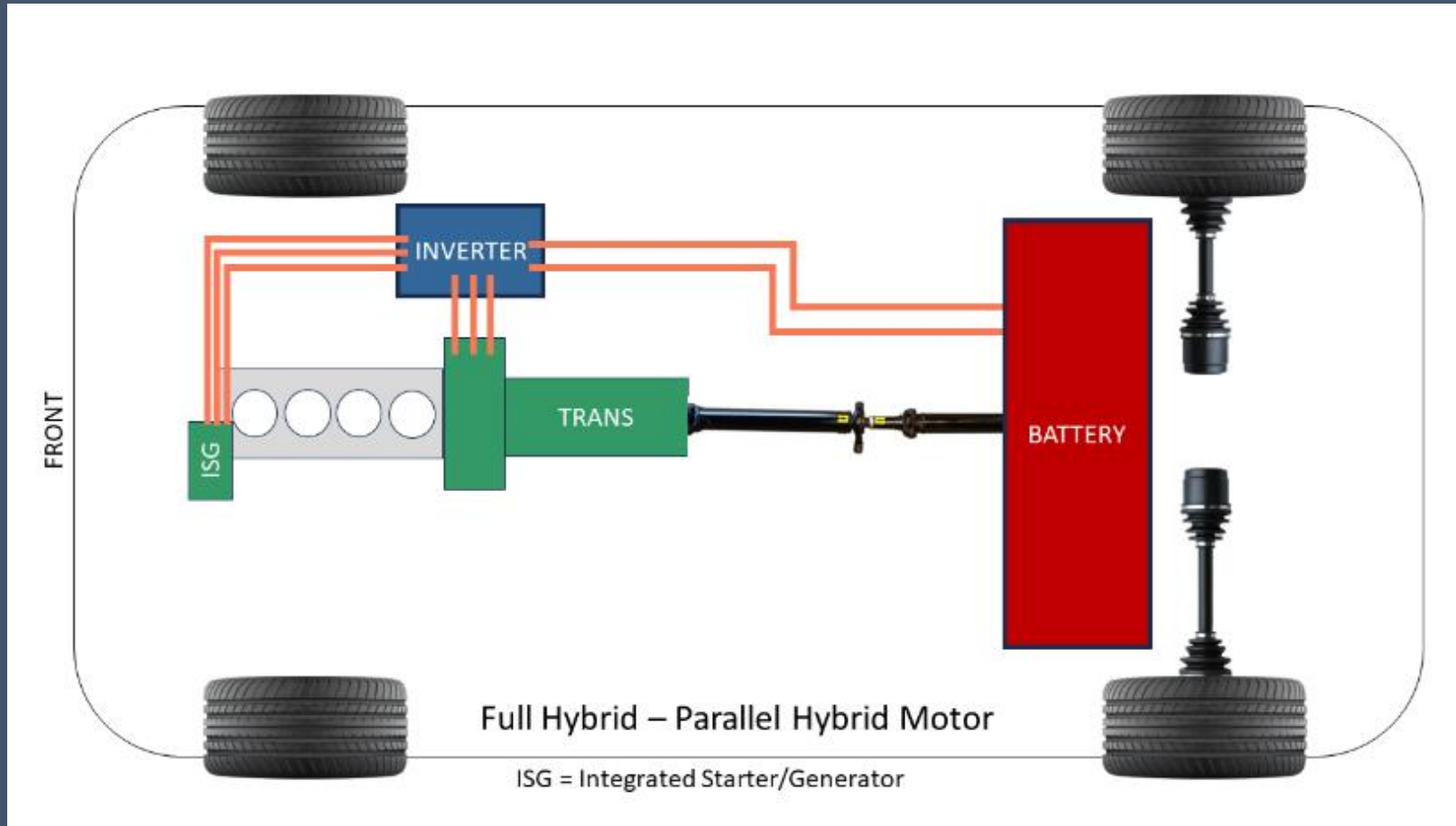
HEV Classifications

- Micro
- Mild
- **Medium**
- Full



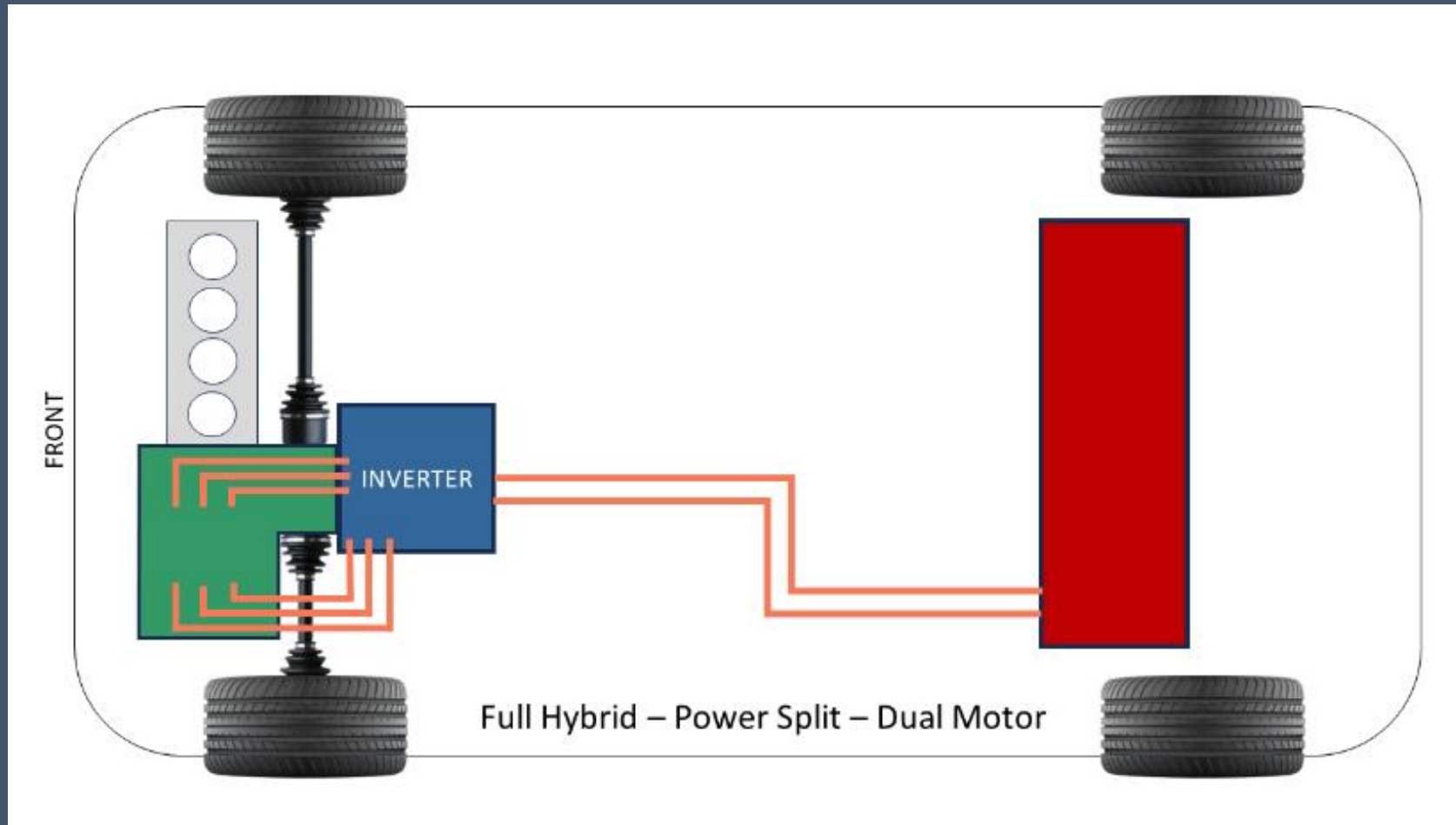
HEV Classifications

- Micro
- Mild
- Medium
- **Full**



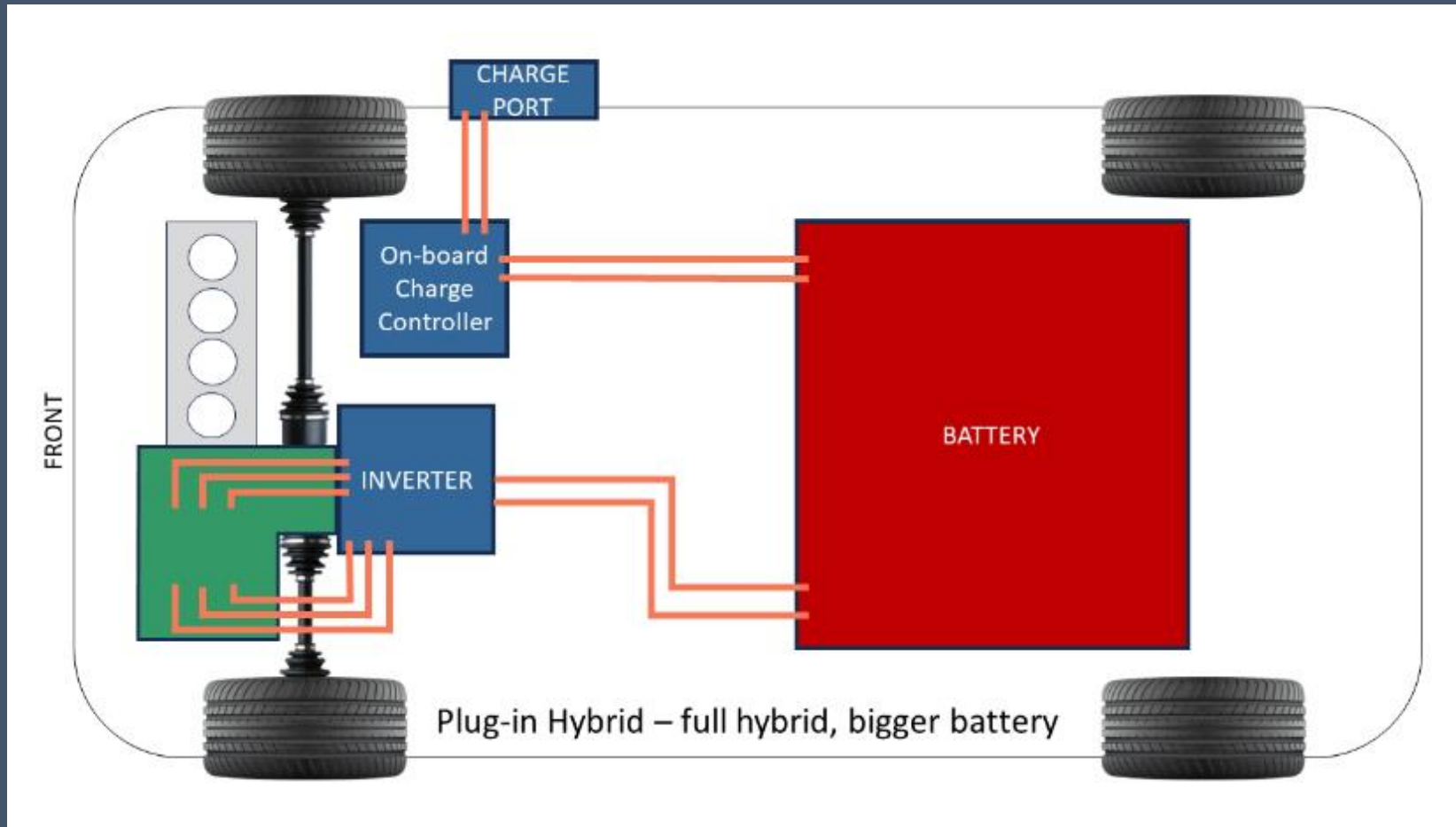
HEV Classifications

- Micro
- Mild
- Medium
- **Full**



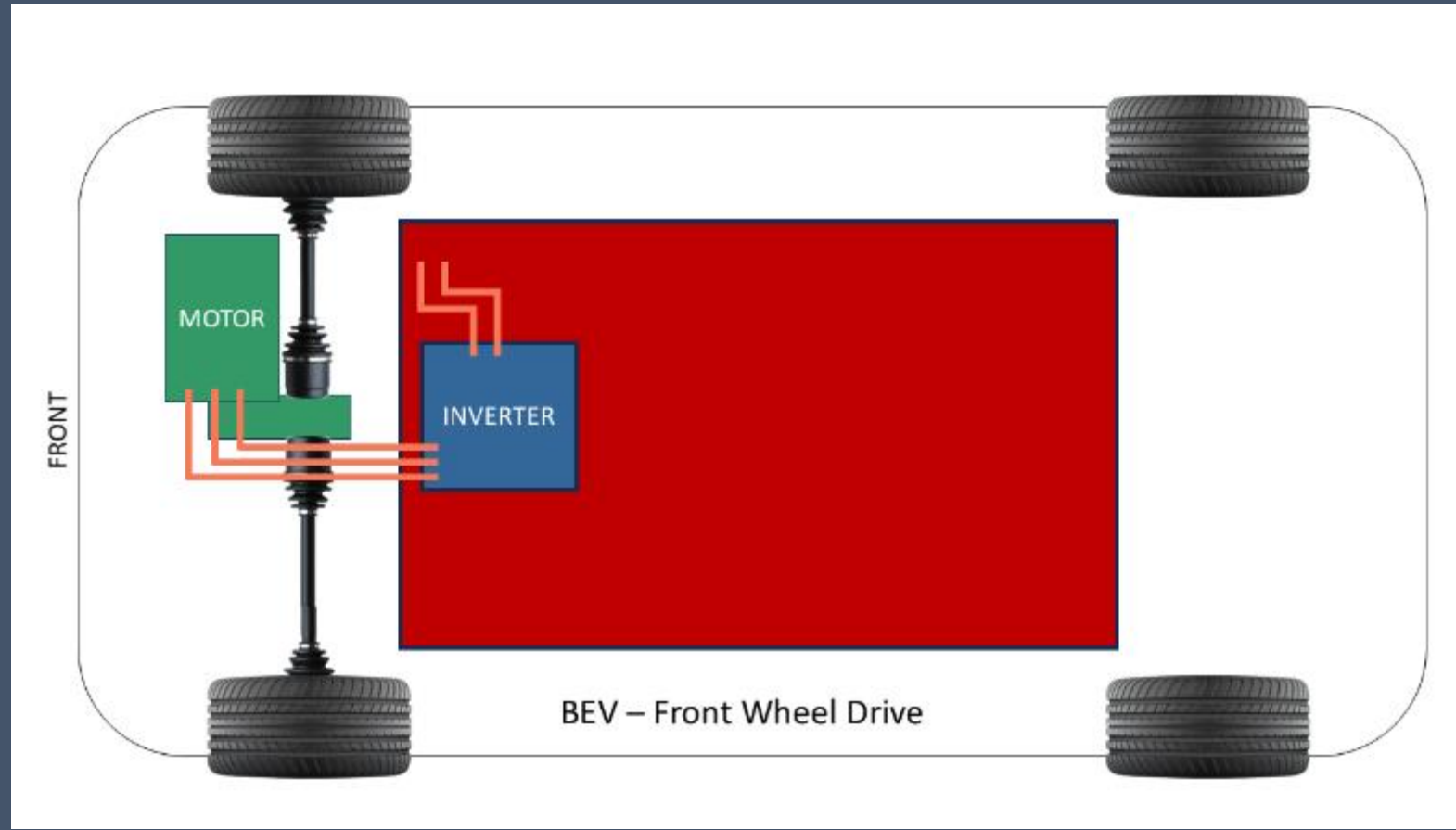
PHEV Classifications

- PHEV



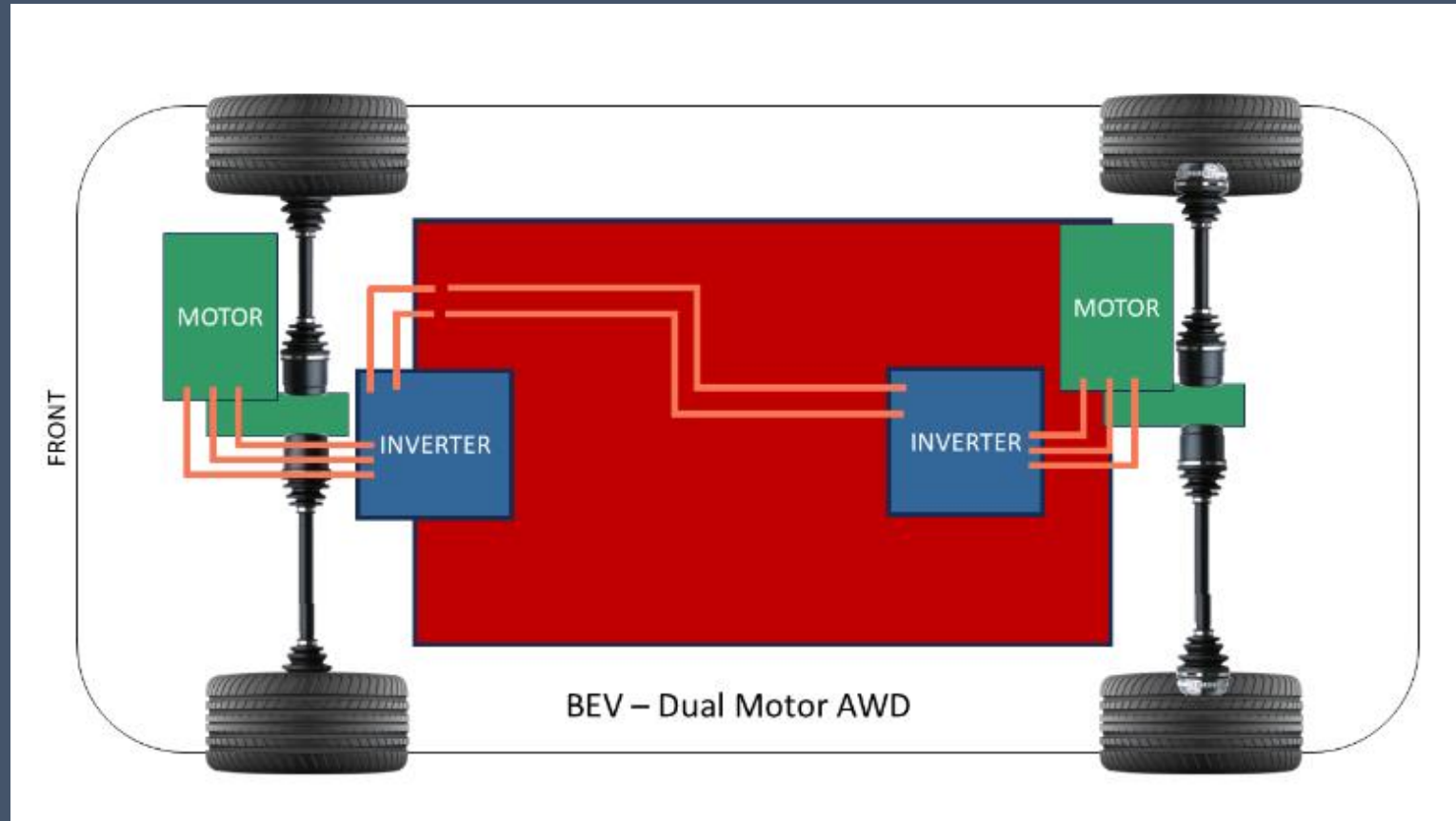
BEV Classifications

- BEV



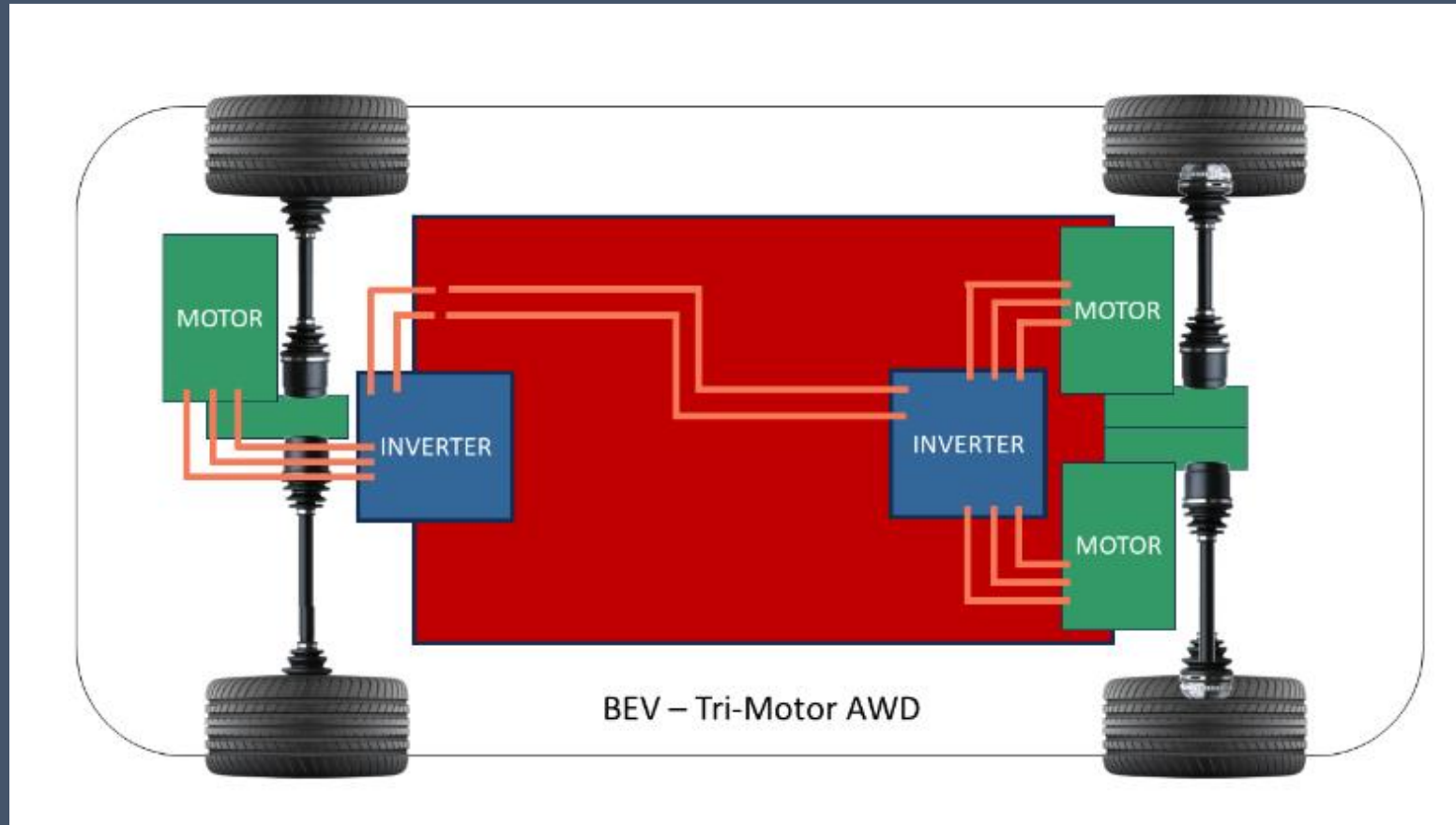
BEV Classifications

- BEV



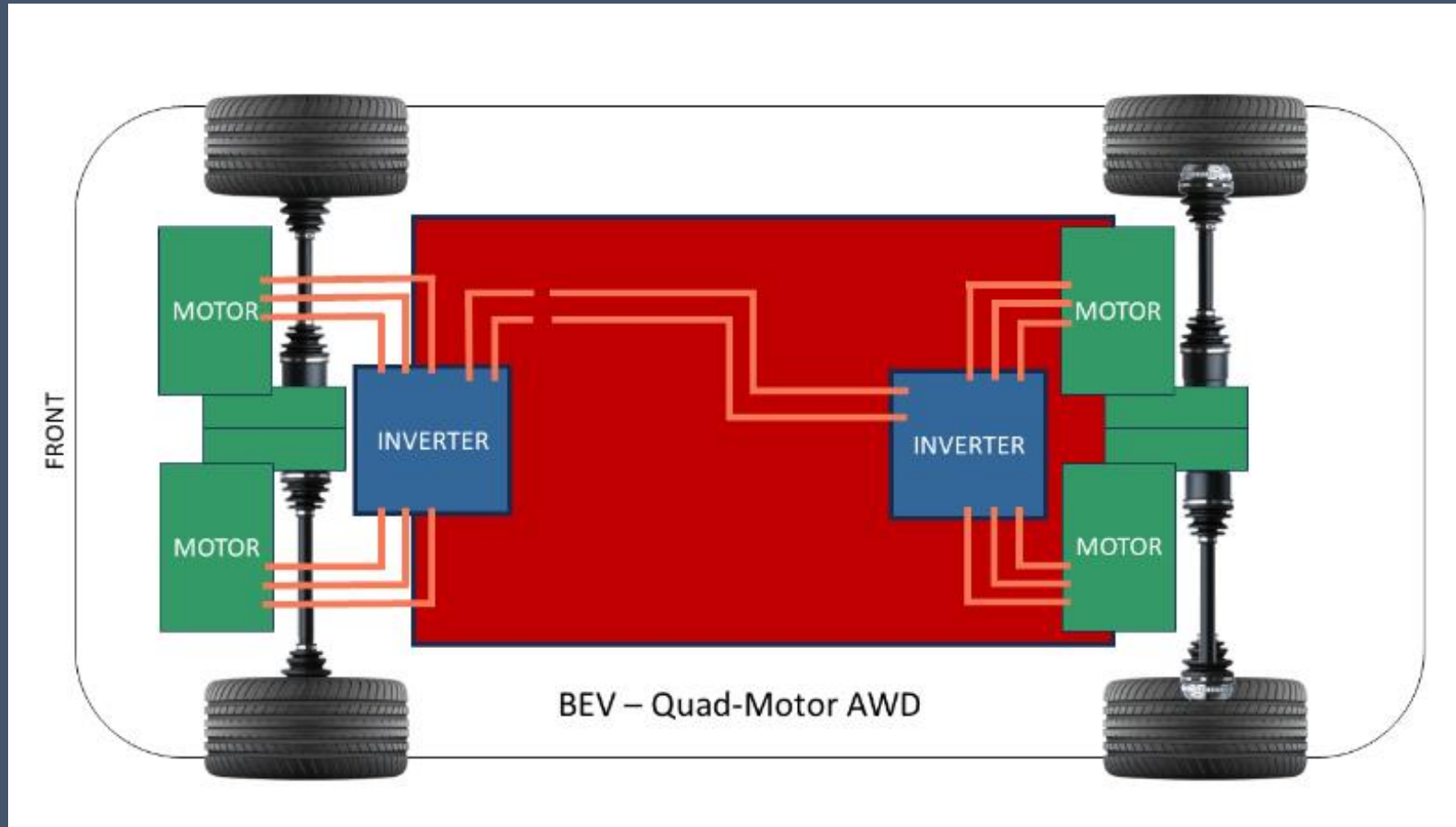
BEV Classifications

- BEV



BEV Classifications

- BEV



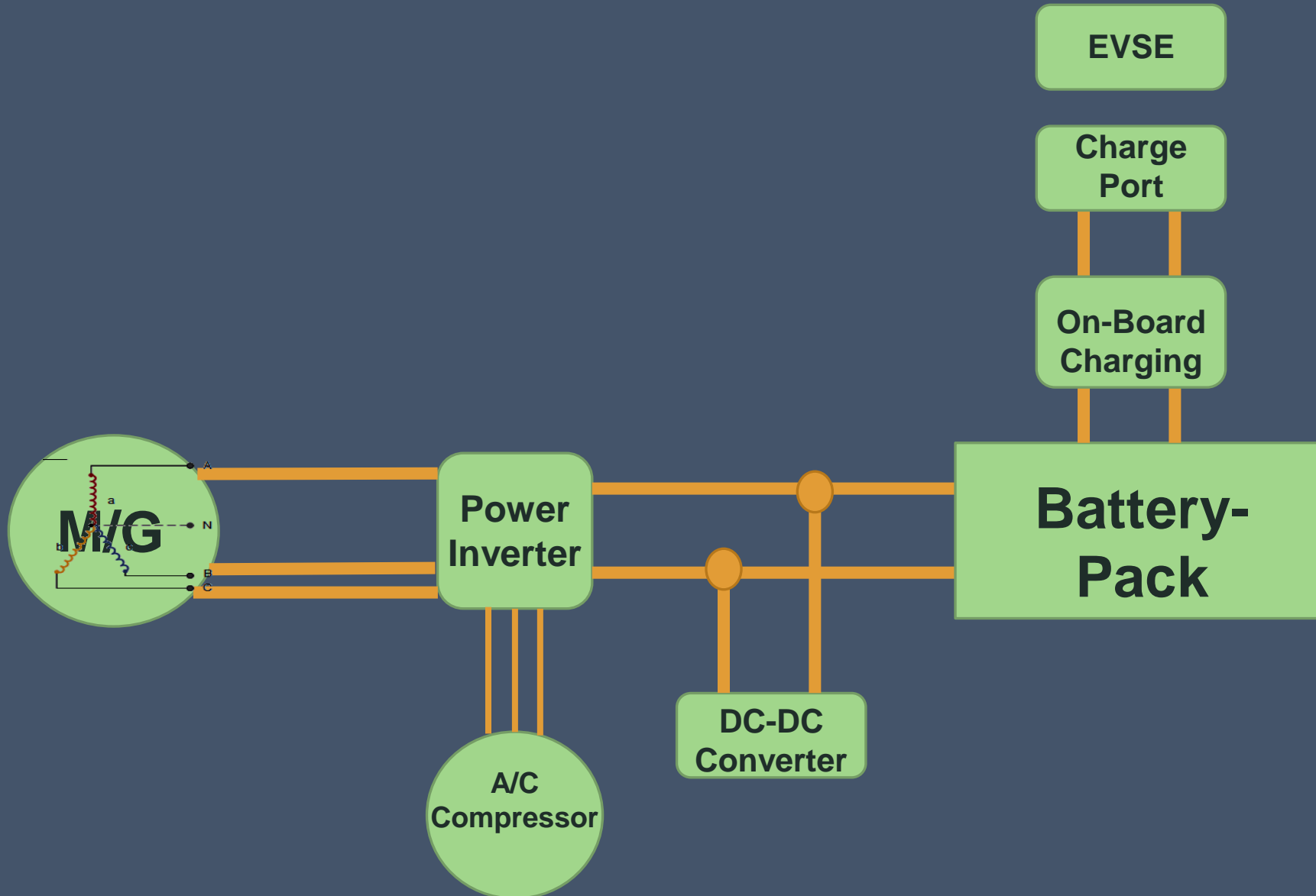
A detailed close-up photograph of a multi-pin electrical connector. The connector features numerous silver-colored pins arranged in a grid pattern. A prominent black plastic component with a cross-shaped cutout is positioned in the center. The background shows the intricate details of the connector's housing and the metallic surfaces of the pins.

xEV High-level Overview

High level overview

Components	ICE	HEV	PHEV	BEV
Engine	X	X	X	
Emissions components	X	X	X	
Fuel tank	X	X	X	
HV Battery		X	X	X
Transmission	X	X*	X*	
Electric Motors		X*	X*	X
Inverter		X	X	X
DC-DC Converter		X	X	X
Elect AC		X	X	X
Charge controller			X	X
Charge port			X	X

High level overview of HV components

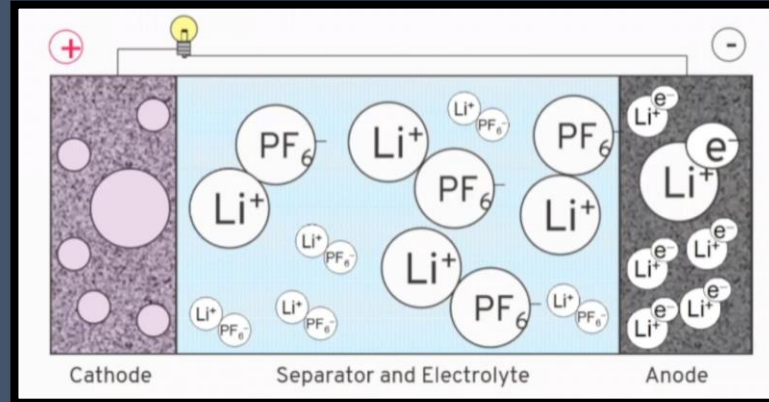


xEV Batteries

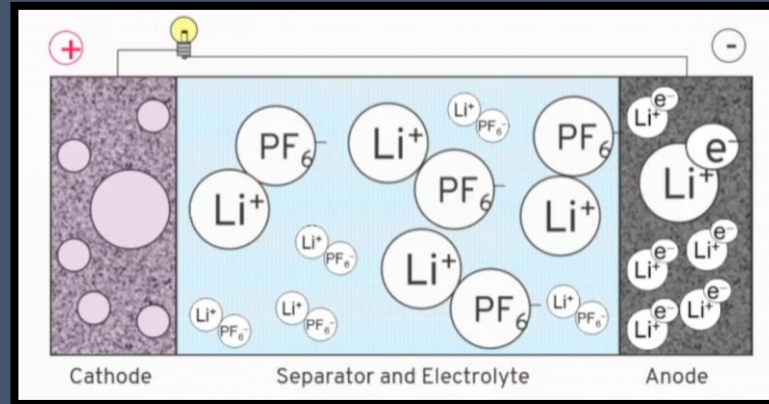
A detailed view of an electric vehicle's battery pack. The image shows a complex arrangement of orange high-voltage cables and connectors. A Panasonic battery module is visible, with a label that includes the part number AEV3000A and a date code 201301020427. The battery pack is housed in a metal frame, and the overall design is compact and efficient.

High voltage battery

- Charging

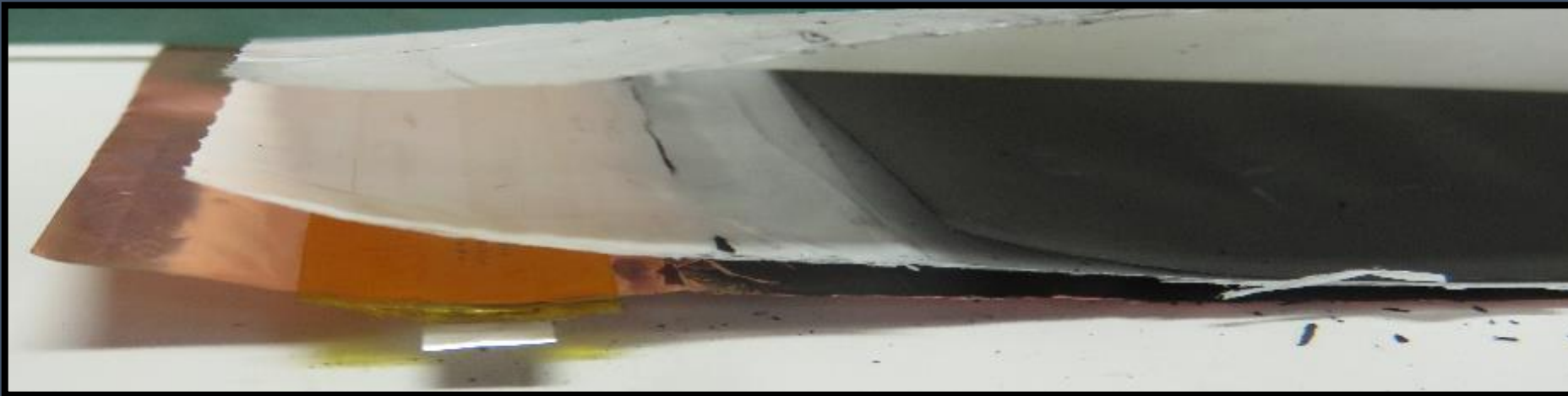


- Discharging



High voltage battery

- Rated voltage
- Specific Power
- Specific Energy
- Energy Density
- Cycle live
- C-rate
- Thermal stability
- Safety
- Cost



High voltage battery

Manufacturer	Standard Warranty	% degraded
Tesla	8 year, 150K (S and X), 120K (M3 LR, MY LR and Perf), 100K M3 and MY standard range)	70
Ford	8 years, 100K miles	70
Rivian	8 years, 175K miles	70
GM	8 years, 100K	60
Hyundai, Kia	10 years, 100K	70

Ford F150 Lightning Battery Costs

ED MORSE FORD

Select Dealer

2022 Ford F-150

Selected Attributes

High Voltage Battery And Mounting

Attach Illustration

Print

10A687A

10A687B

10D672B

10D672A

10A687A

10A687B

Selected Parts

Show Other Parts In Illustration

Array Assembly - Traction Battery

From: 03/14/2022 ; Less Engine, Traction Battery #1 * Array Kit

Callout: 10D672B – Add To Selected

10D672B

10D672A

Price:

\$4,196.47

Qty Req:

1

Add To Cart

Cover

From: 03/14/2022 ; Less Engine, Traction Battery #1 * Array Kit

Callout: 10A687A – Add To Selected

10A687A

10A687B

Price:

\$0.00

Qty Req:

1

Add To Cart

Cover

From: 03/14/2022 ; Less Engine, Traction Battery #1 * Array Kit

Callout: 10A687B – Add To Selected

10A687A

10A687B

Price:

\$0.00

Qty Req:

1

Add To Cart

10D672B

10D672A

10A687A

10A687B

ED MORSE FORD

Select Dealer

2022 Ford F-150

Selected Attributes

High Voltage Battery And Mounting

Attach Illustration

Print

10B759

10C699

5F161

10B759

10C699

5F161

Selected Parts

Show Other Parts In Illustration

Battery

From: 03/14/2022 ; Less Engine, Traction Battery #1 * Traction Battery

Callout: 10B759

10B759

10C699

5F161

Price:

\$34,393.48

Qty Req:

1

Add To Cart

Cover

From: 03/14/2022 ; Less Engine, Traction Battery #1 * Traction Battery

Callout: 10B759

10B759

10C699

5F161

Price:

\$46,907.06

Qty Req:

1

Add To Cart

10B759

10C699

5F161

10B759

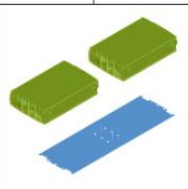
10C699

5F161

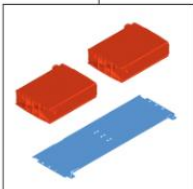
Text Page 26

2022 Ford Mach-e

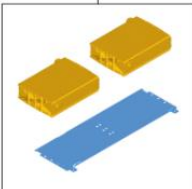
10D672A



10D672B



10D672C



4140305C
11-2020-45
GW
K 0395109 01

©Copyright, 2020, Ford Motor Company Limited

Show Other Parts In Illustration

Array Assembly - Traction Battery

List Price: \$4,341.18

Available: Available

From: 05/05/2021 ; Traction Battery #2 *

Array Kit

Callout: 10D672C – Add To Selected



Price: \$4,341.18

Qty Req: 1

Add To Cart

Array Assembly - Traction Battery

List Price: \$5,967.06

Available: Available

From: 05/05/2021 ; Traction Battery #2 *

Array Kit

Callout: 10D672B – Add To Selected



Price: \$5,967.06

Qty Req: 1

Add To Cart

Array Assembly - Traction Battery

List Price: \$4,960.99

Available: Available

From: 05/05/2021 ; Traction Battery #2 *

Array Kit

Callout: 10D672A – Add To Selected

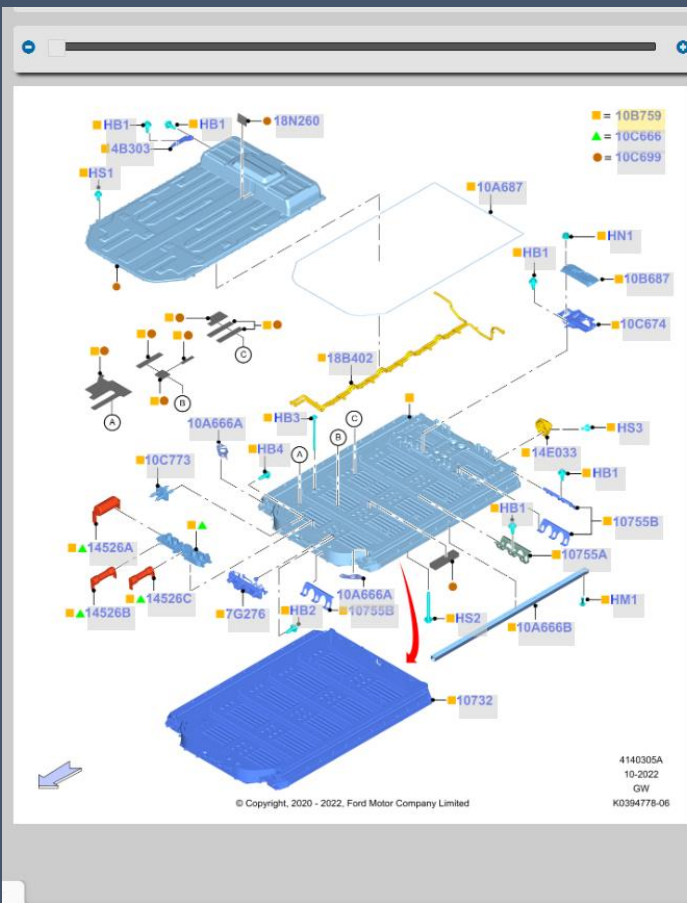


Price: \$4,960.99

Qty Req: 1

Add To Cart


2022 Mach-e



Battery

From: 08/30/2021 ; LHD RWD, Traction
Battery #2 *

[ATT]FORD_ORDER_FORM_FOR_HVT_BATTERIES_final_31_01_20222_v2_0.pdf,
FITINS, en, 30, [ATT],
[ATT]GSB_20_january_2022.pdf, FITINS,
en, 30, [ATT], Traction Battery
Callout: 10B759




Price: **\$33,409.41**
Qty Req: [Add To Cart](#)

Battery

From: 09/22/2021 ; LHD 4WD (Part Time Drive), GT Version - Feature Car *

[ATT]FORD_ORDER_FORM_FOR_HVT_BATTERIES_final_31_01_20222_v2_0.pdf,
FITINS, en, 30, [ATT],
[ATT]GSB_20_january_2022.pdf, FITINS,
en, 30, [ATT], Traction Battery
Callout: 10B759




Price: **\$6,638.82**
Qty Req: [Add To Cart](#)

Battery

From: 08/30/2021 ; LHD 4WD (FTD),
Traction Battery #2 *

[ATT]FORD_ORDER_FORM_FOR_HVT_BATTERIES_final_31_01_20222_v2_0.pdf,
FITINS, en, 30, [ATT],
[ATT]GSB_20_january_2022.pdf, FITINS,
en, 30, [ATT], Traction Battery
Callout: 10B759




Price: **\$33,667.06**
Qty Req: [Add To Cart](#)

Battery

From: 08/30/2021 ; LHD RWD, Traction
Battery #1 *


[ATT]FORD_ORDER_FORM_FOR_HVT_BATTERIES_final_31_01_20222_v2_0.pdf,
FITINS, en, 30, [ATT],
[ATT]GSB_20_january_2022.pdf, FITINS,
en, 30, [ATT], Traction Battery
Callout: 10B759



Price: **\$41,060.00**
Qty Req: [Add To Cart](#)

Battery

From: 08/30/2021 ; LHD 4WD (FTD),
Traction Battery #1 * Traction Battery
From: 08/30/2021 ; RHD 4WD (FTD),
Traction Battery #1 * Traction Battery
Callout: 10B759



Price: **\$37,383.53**
Qty Req: [Add To Cart](#)

2022 Chevrolet Bolt

ED MORSE AUTOMOTIVE GRP-WEIR
[Call Dealer](#)

2022 Chevrolet Bolt EV

Parts List [Return to Catalog](#)

 [Print](#)

Add Parts to List

Add Parts to List

Add Part

Upload File

CSV or text format

Choose File


and

Upload File



<input type="checkbox"/>	Part Number	Part Description	Brand	Promotion	Pricing	Req Qty	Availability	Delivery option	Net Price
<input type="checkbox"/>	24052286	BATTERY,HIGH VOLTAGE	General Motors		List Price: Call Price: \$15,547.14	1		Standard ▾	\$15,547.14 Delete

2022 VW ID.4



Suntrup Nissan, Volkswagen

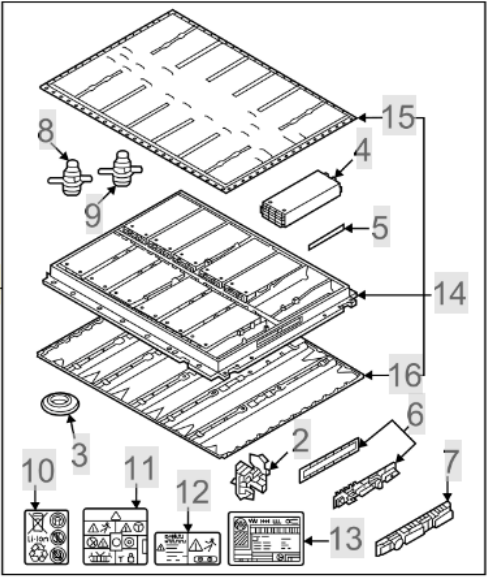
Select Dealer

2022 Volkswagen ID.4

ELECTRICAL - BATTERY

Back

Attach Illustration Print



+

Selected Parts

Drive Motor Battery Pack

List Price: \$27,000.00

Available:

Volkswagen

Usage: Volkswagen - ID.4 (2022) *

BATTERY & COMPONENTS HIGH

VOLTAGE * from 03/01/2021

Callout: 1

Price:

\$17,679.96

Qty Req:


1

Add To Cart

+

Show Other Parts In Illustration

Text Page 26



MORLAN NISSAN

Call Dealer

2020 Nissan Leaf

Parts List [Return to Catalog](#) [Print](#)

Add Parts to List

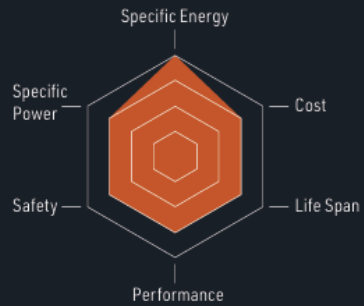
CSV or text format and ⚠️

<input type="checkbox"/>	Part Number	Part Description	Brand	Promotion	Pricing	Req Qty	Availability	Delivery option	Net Price
<input type="checkbox"/>	295B95SF9D	BATTERY MODULE-LITHIUM ION	Nissan		List Price: \$2,734.16 Price: \$1,913.91	<input type="text" value="4"/>		Standard ▾	\$7,655.64 Delete
<input type="checkbox"/>	295B95SF9C	BATTERY MODULE-LITHIUM ION	Nissan		List Price: \$1,290.59 Price: \$903.41	<input type="text" value="8"/>		Standard ▾	\$7,227.28 Delete
<input type="checkbox"/>	295B95SF9E	BATTERY MODULE-LITHIUM ION	Nissan		List Price: \$2,185.21 Price: \$1,529.65	<input type="text" value="4"/>		Standard ▾	\$6,118.60 Delete

Battery Chemistries

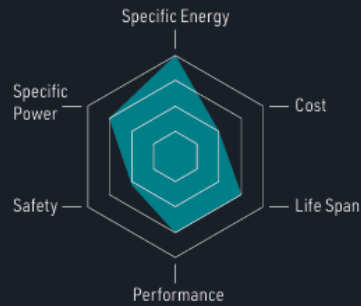
NMC LITHIUM NICKEL MANGANESE COBALT OXIDE

NMC batteries are named after different ratios of minerals in the cathode. For example, the **NMC811** cathode comprises **80% nickel, 10% manganese, and 10% cobalt**, along with lithium.



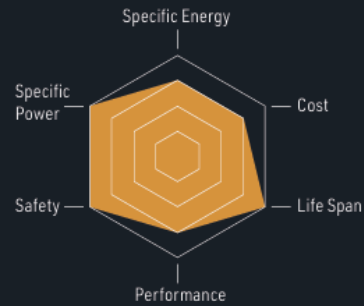
NCA LITHIUM NICKEL COBALT ALUMINUM OXIDE

Nickel based cathodes like NMC and NCA offer **high specific energy**.



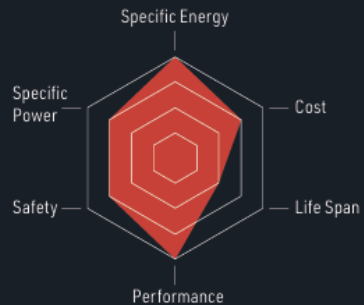
LFP LITHIUM IRON PHOSPHATE

LFP batteries are used in **energy storage systems** and are unmatched for **safety and lifespan**.

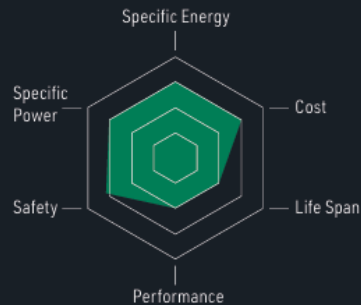


LCO LITHIUM COBALT OXIDE

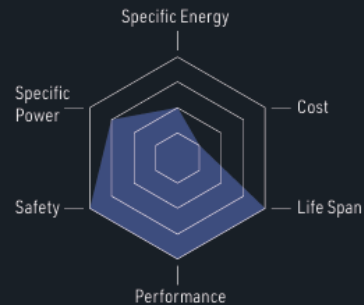
Lithium Cobalt Oxide cathodes are a popular choice for **laptops, smartphones, and digital cameras**.



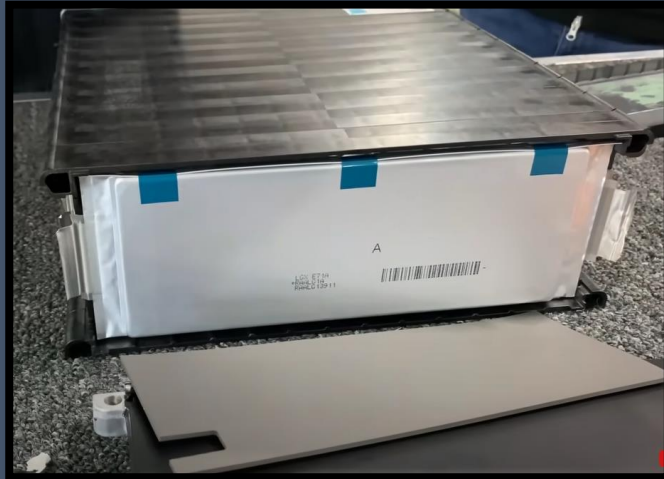
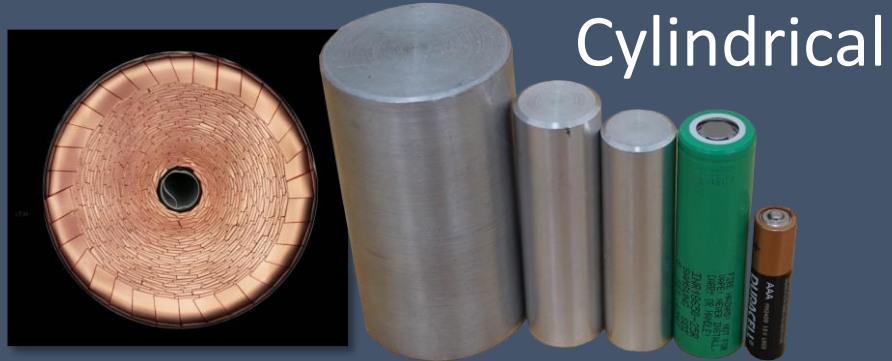
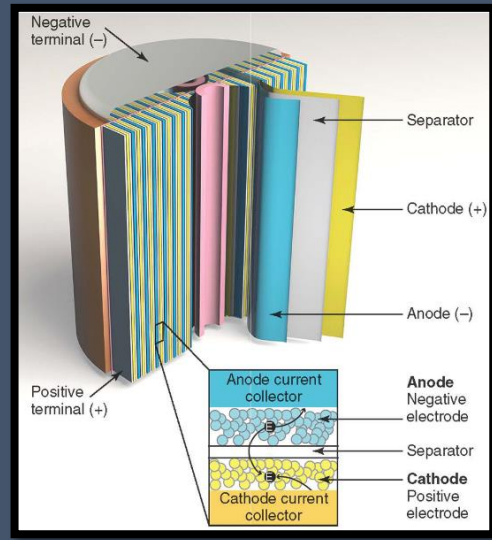
LMO LITHIUM MANGANESE OXIDE



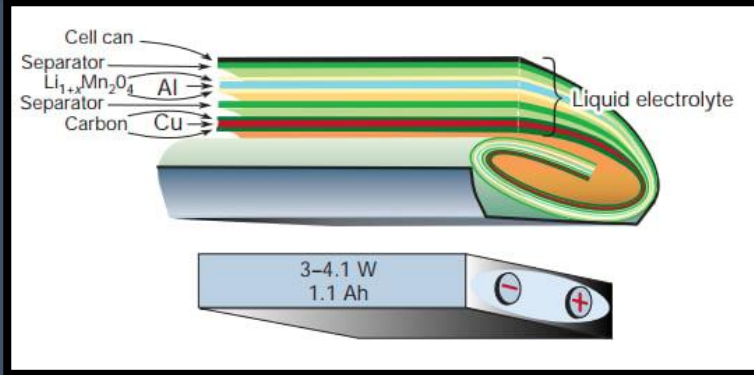
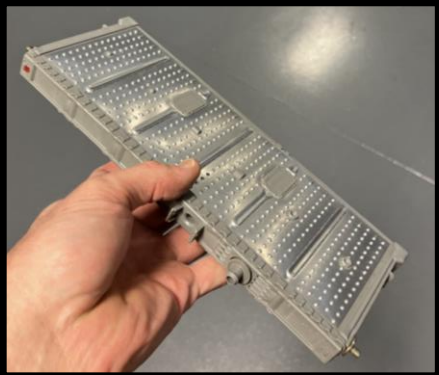
LTO LITHIUM TITANIUM OXIDE



Battery Form Factor

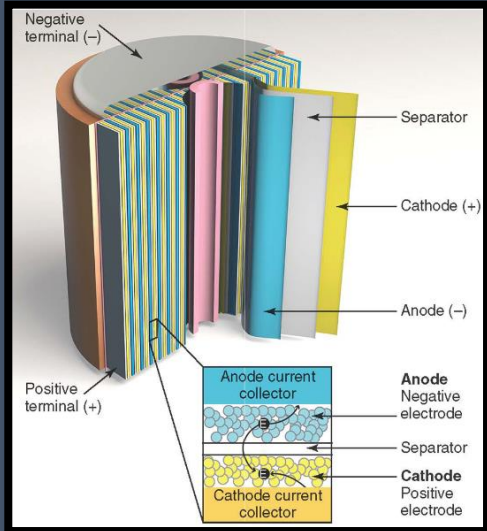


Pouch



Prismatic

Battery Form Factor - Cylindrical

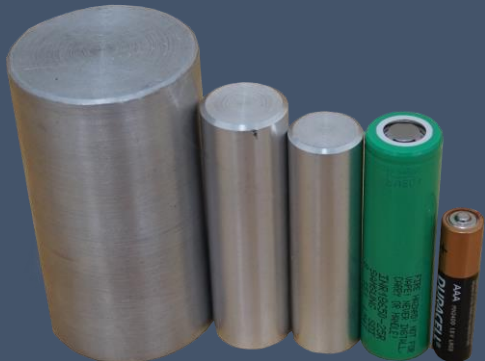


Advantages

- Structural
- Stable cell size
- Ease of manufacturing
- Cell cooling

Disadvantages

- Packaging
- Round cells
- Smaller cells



Battery Form Factor - Pouch

Advantages:

- Shapes and sizes
- Packaging
- Large pouches = high capacity

Disadvantages:

- non-structural
- Pouches swell
- Contacts need to be welded
- Failure affects capacity



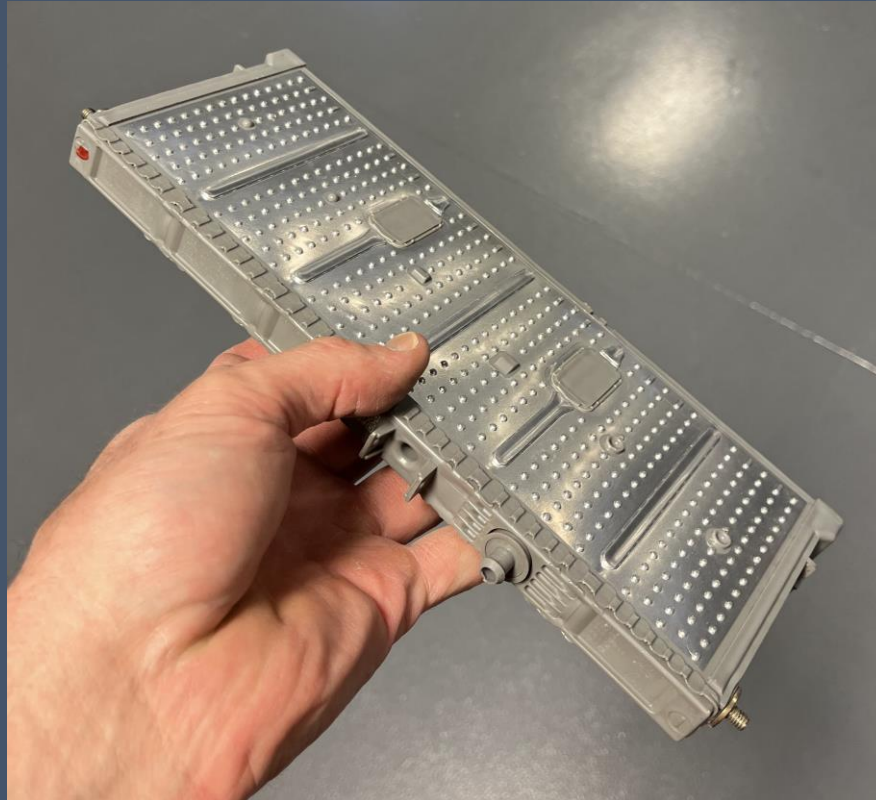
Battery Form Factor - Pouch

Advantages:

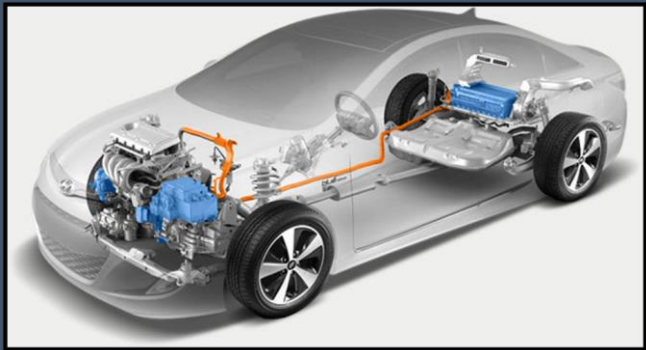
- One container holds a lot of cell material
- Packaging options
- Ease of construction

Disadvantages:

- Thermal control of the cell – uneven cooling



Battery Layout Examples



- Hybrid vehicle
 - Smaller battery
 - Needs to store energy recovered from braking



- Plug-in hybrid vehicle
 - Medium battery
 - Store energy from braking
 - Store enough to drive EV only for 20 – 50 miles or so

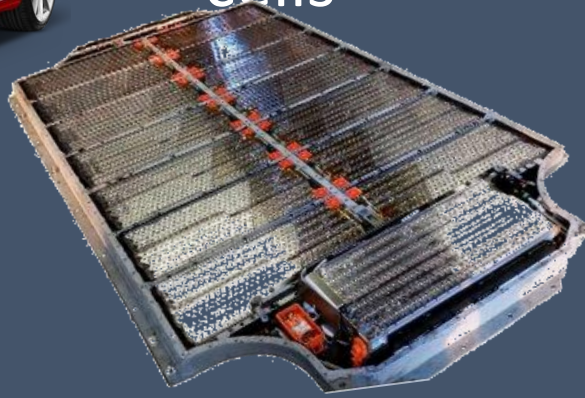


- EV
 - Large battery
 - Range vs cost vs weight

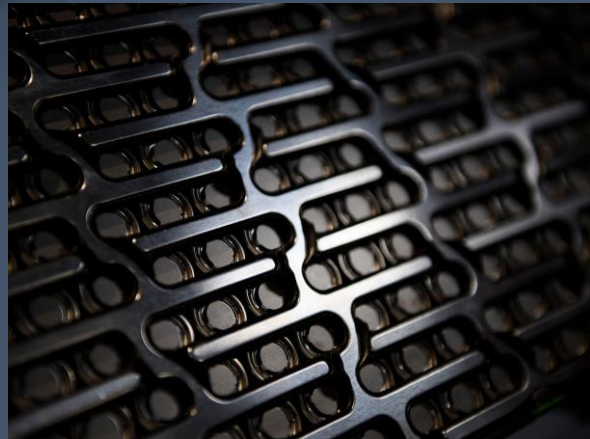
Battery Layout Examples



- Tesla Model S – 7104 “1865” cells



- Lucid Air – 6600 “2170” cells



Battery Layout Examples

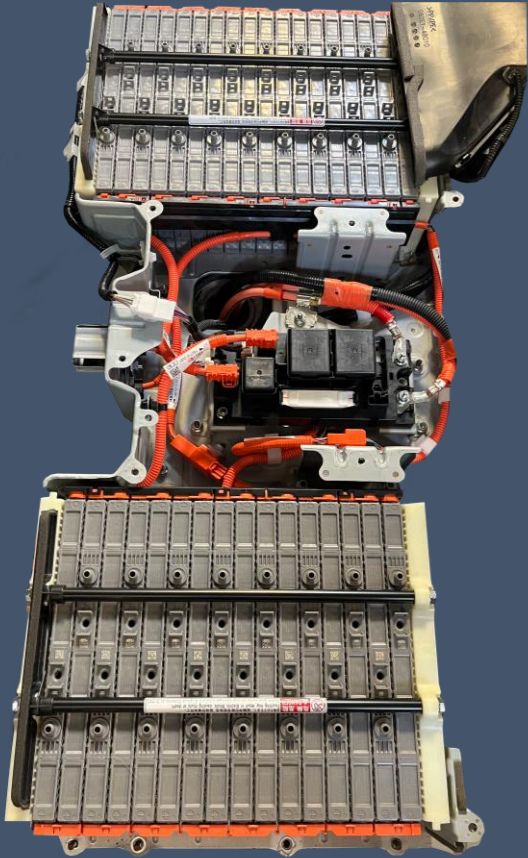
- Rivian R1T – 7776 “2170” cells



- Tesla MY – 828 “4680” cells



Battery Layout Examples



Toyota Rav 4 Hybrid



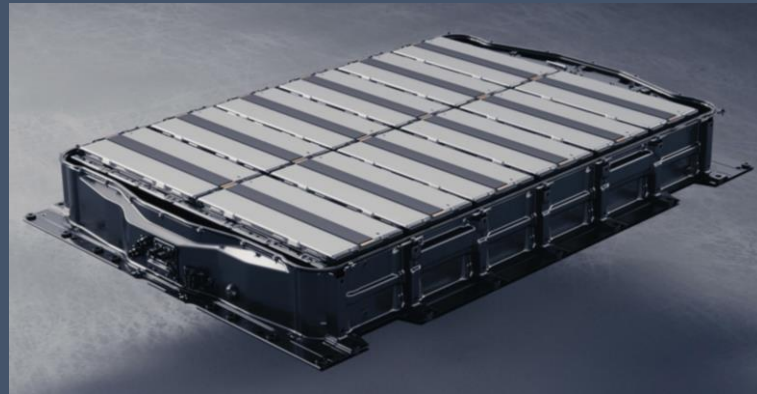
Jeep 4xE

Arrays and Modules

- Hyundai electric global module platform

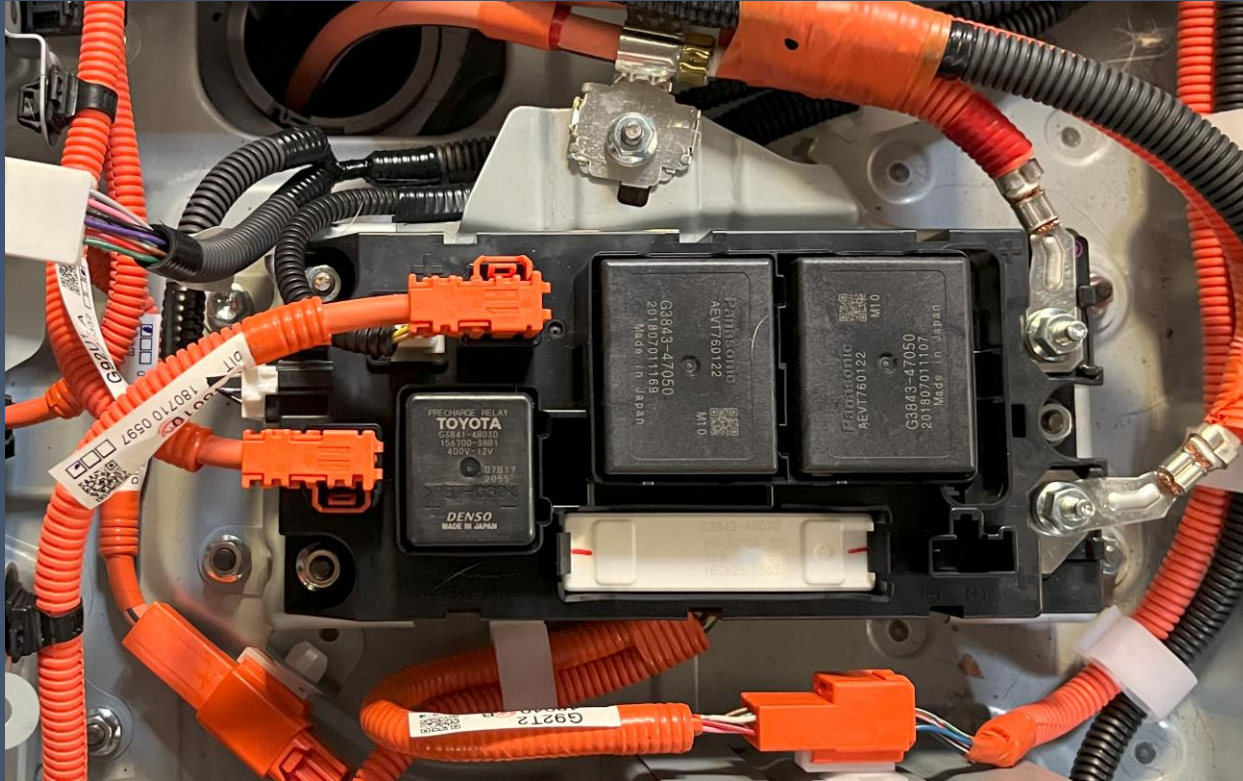


- GM Ultium battery pack



High Voltage Contactors – Delivering the power

Contactors (relays) control the power and ground from the HV battery



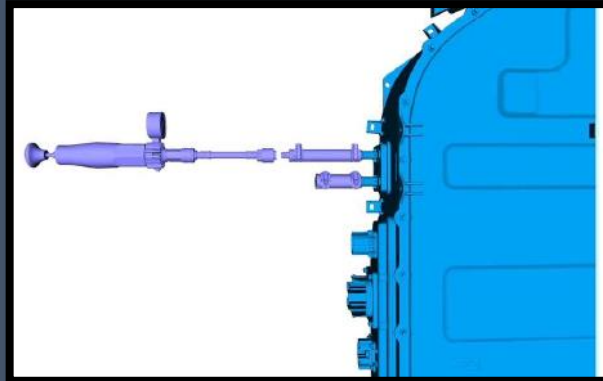
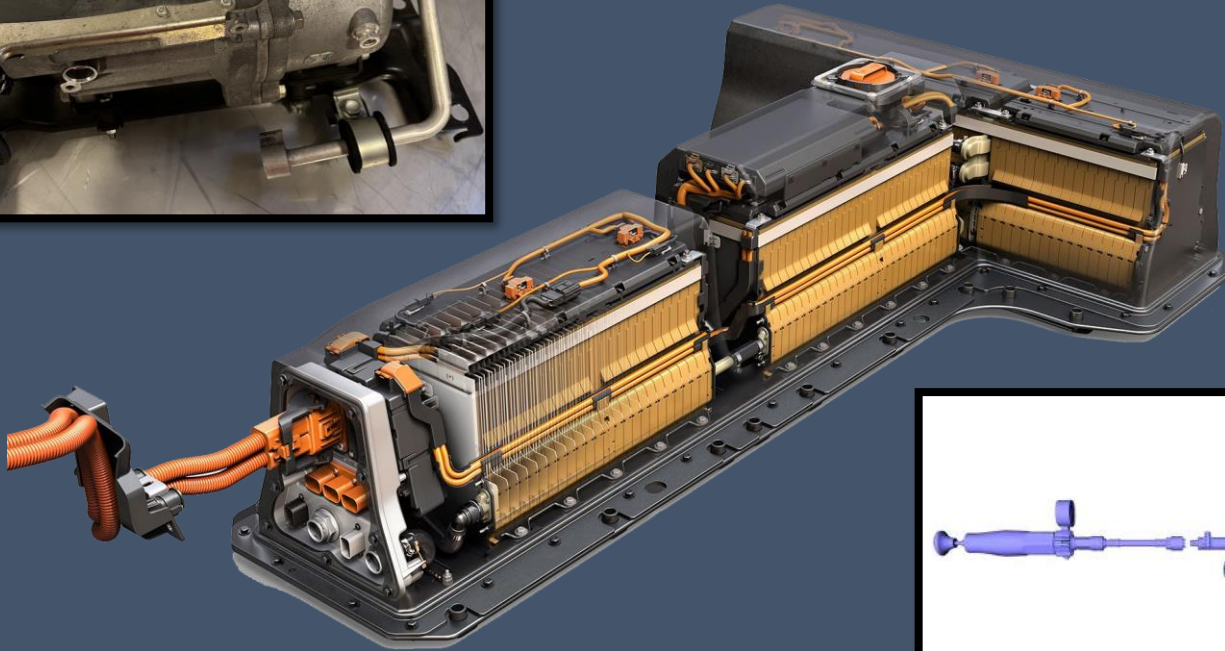
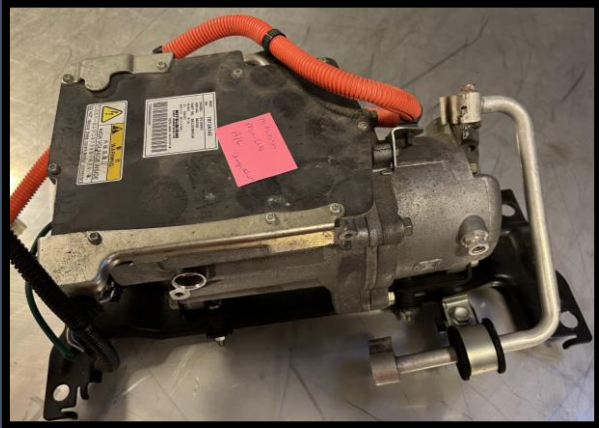
High voltage battery temperature

- Li Ion doesn't perform as well in cold temperature
 - Battery heater
 - PTC – electric resistance heater
 - Heat Pump
 - Uses refrigerant to heat coolant to heat the battery



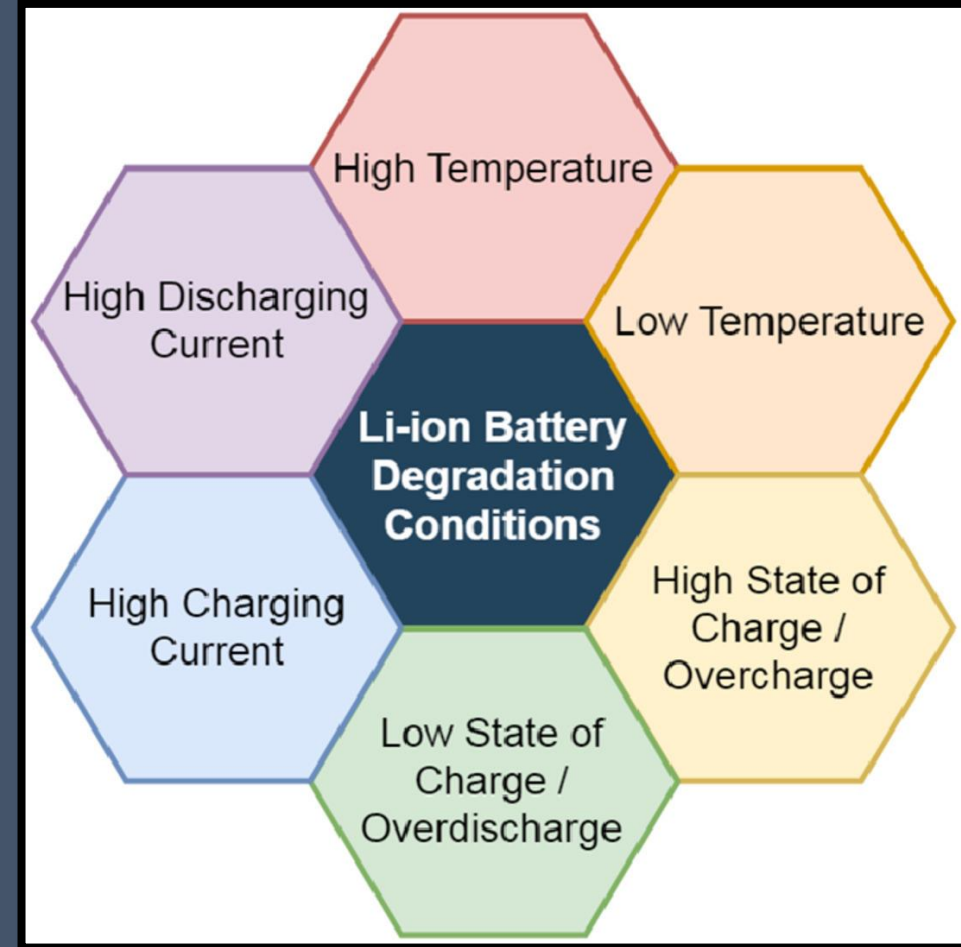
High voltage battery temperature

- Li Ion needs to be cooled in high temperatures



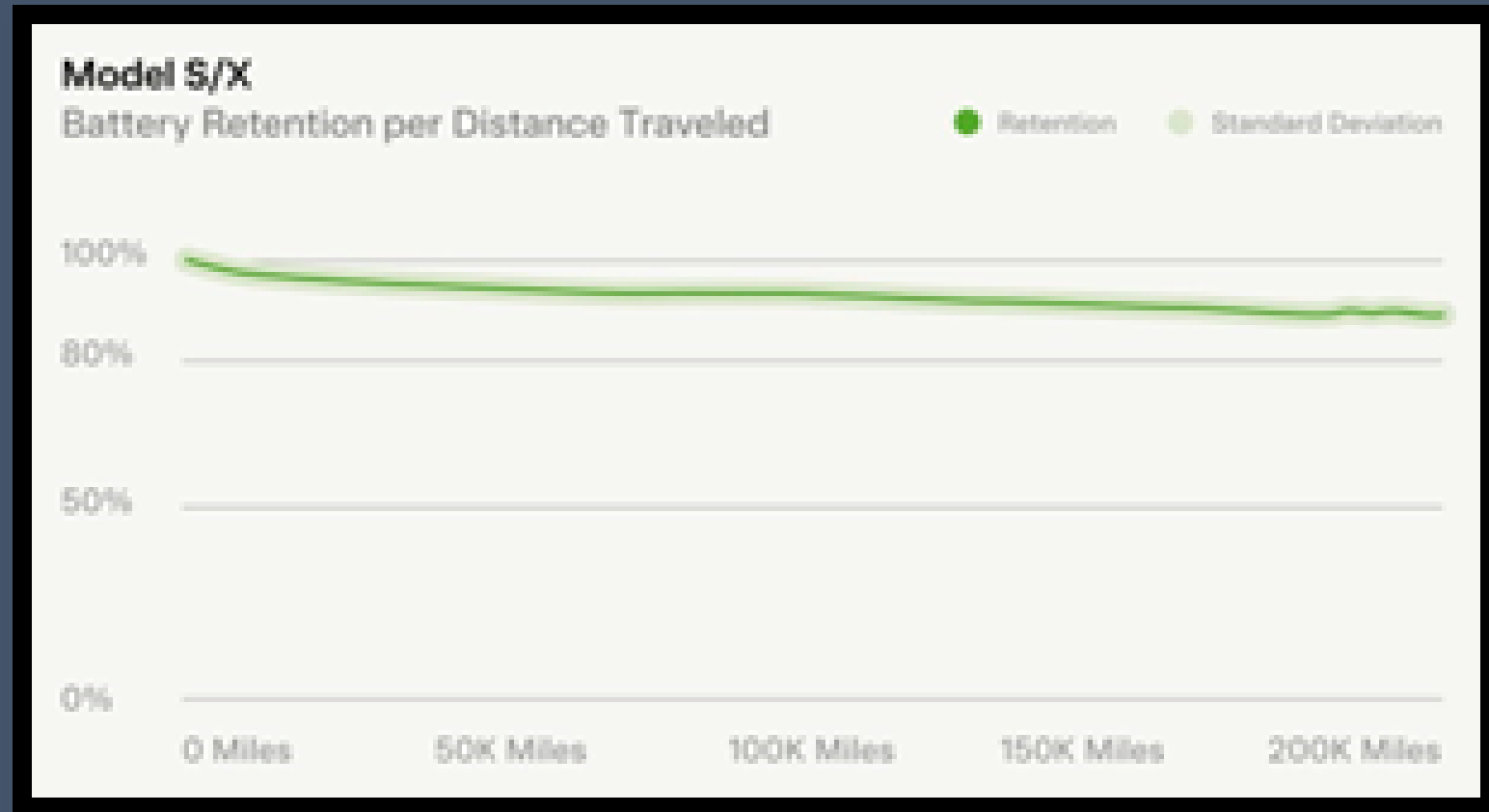
Why do batteries degrade?

- Temperature
- State of Charge (SOC)
- Depth of Discharge (DoD)
- Charge rate
- Discharge rate
- Cycling

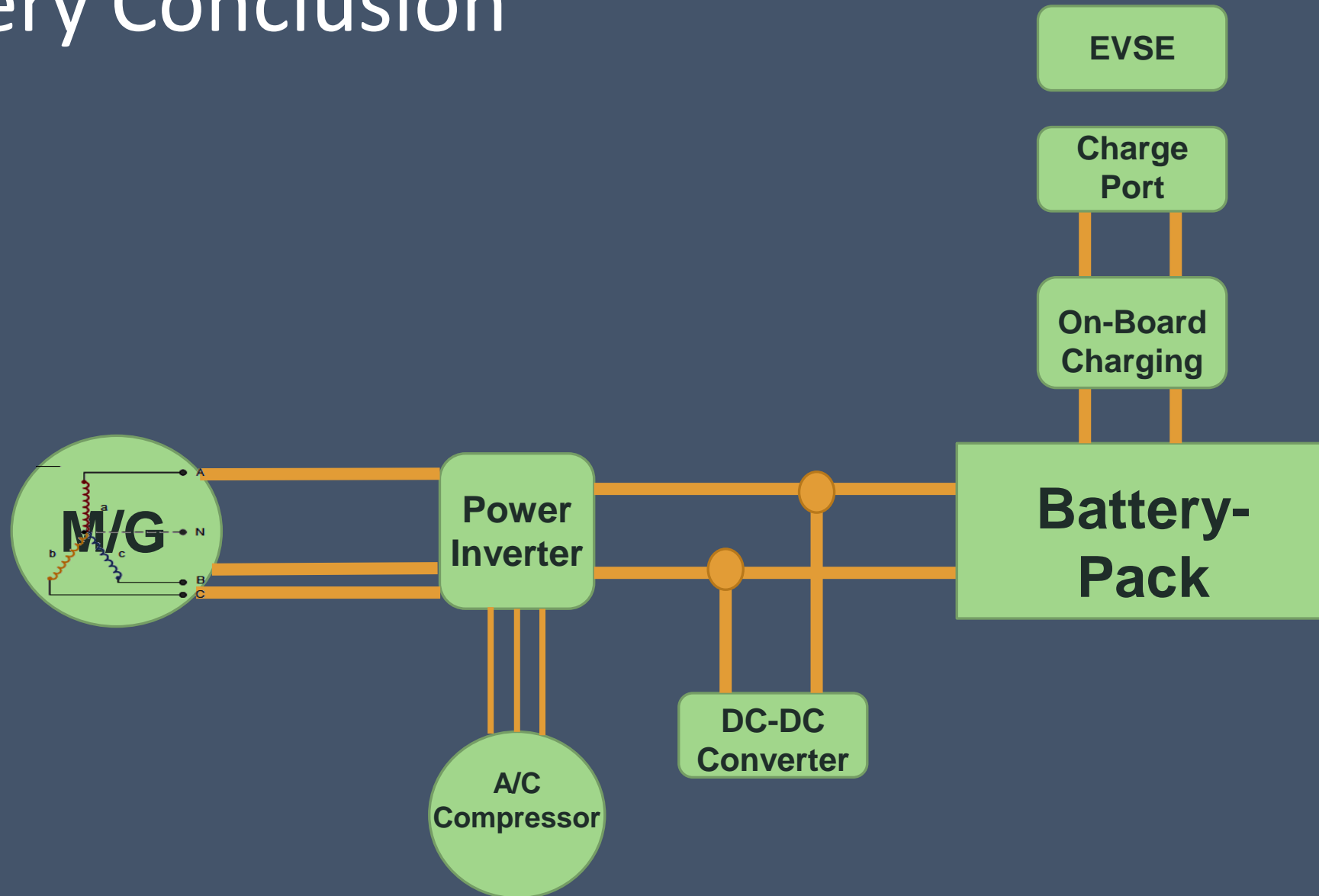


Why do batteries degrade?

- Tesla Self Report
 - Most S and X batteries still had about 90% of capacity after 200k miles



Battery Conclusion

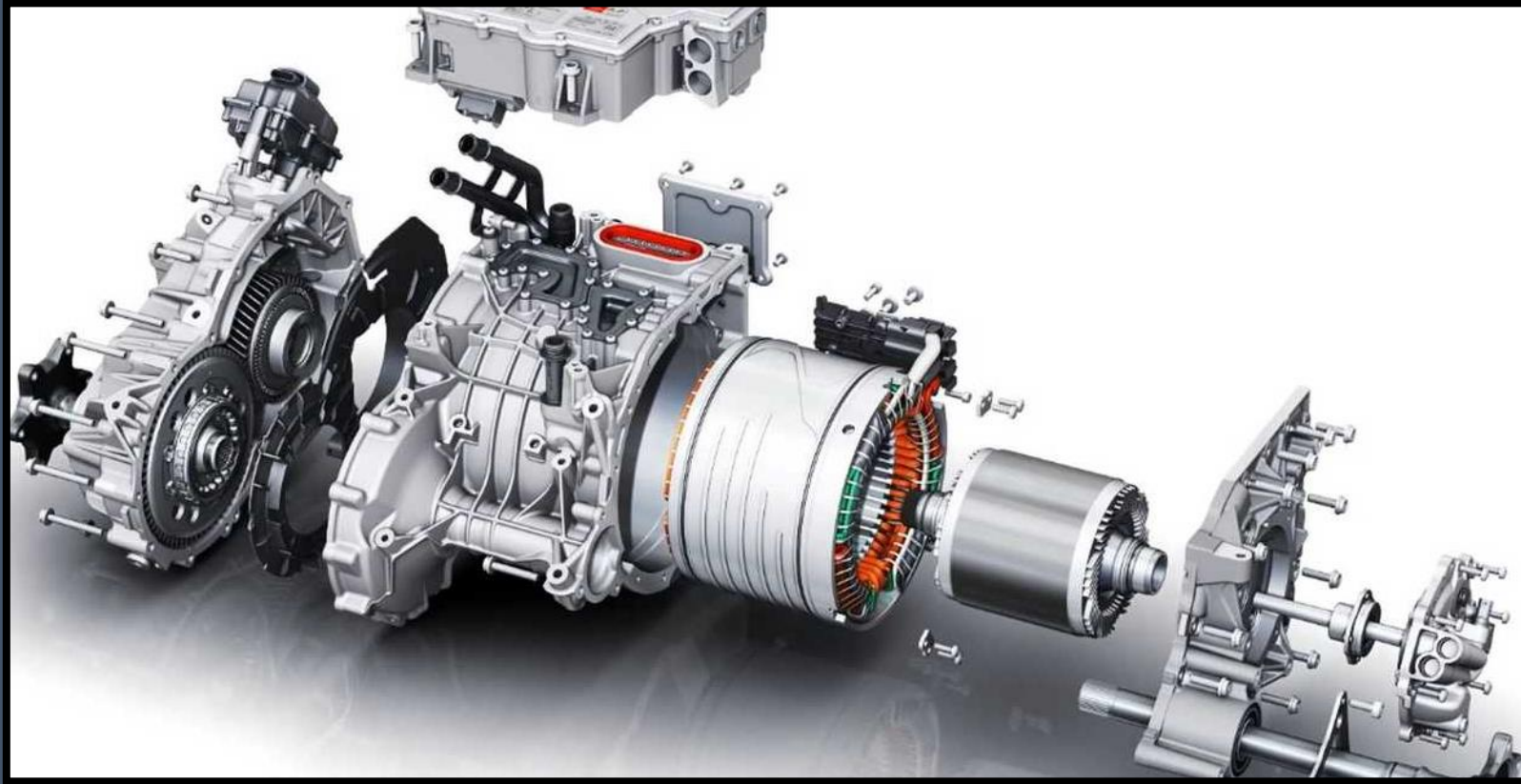


A detailed close-up photograph of an electric motor's internal components. The image shows the stator, which consists of numerous dark, rectangular magnetic poles arranged in a circular pattern. Interspersed among these poles are copper-colored windings. In the foreground, the rotor is visible, featuring a series of black, trapezoidal permanent magnets mounted on a metal core. The central shaft of the rotor is also visible, surrounded by a metal housing. The overall image is a high-resolution, industrial-style photograph.

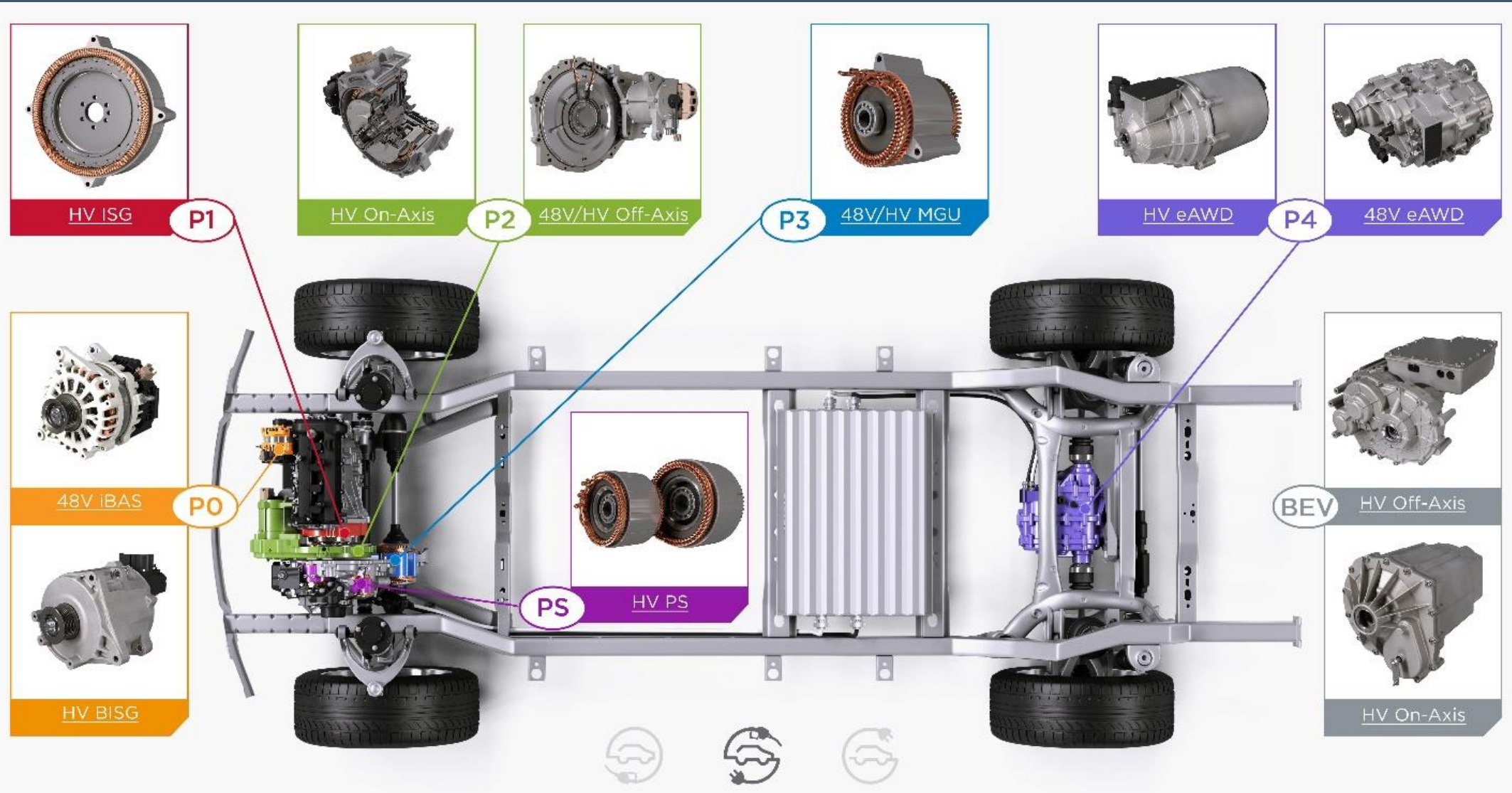
xEV Motors

Electric Motors

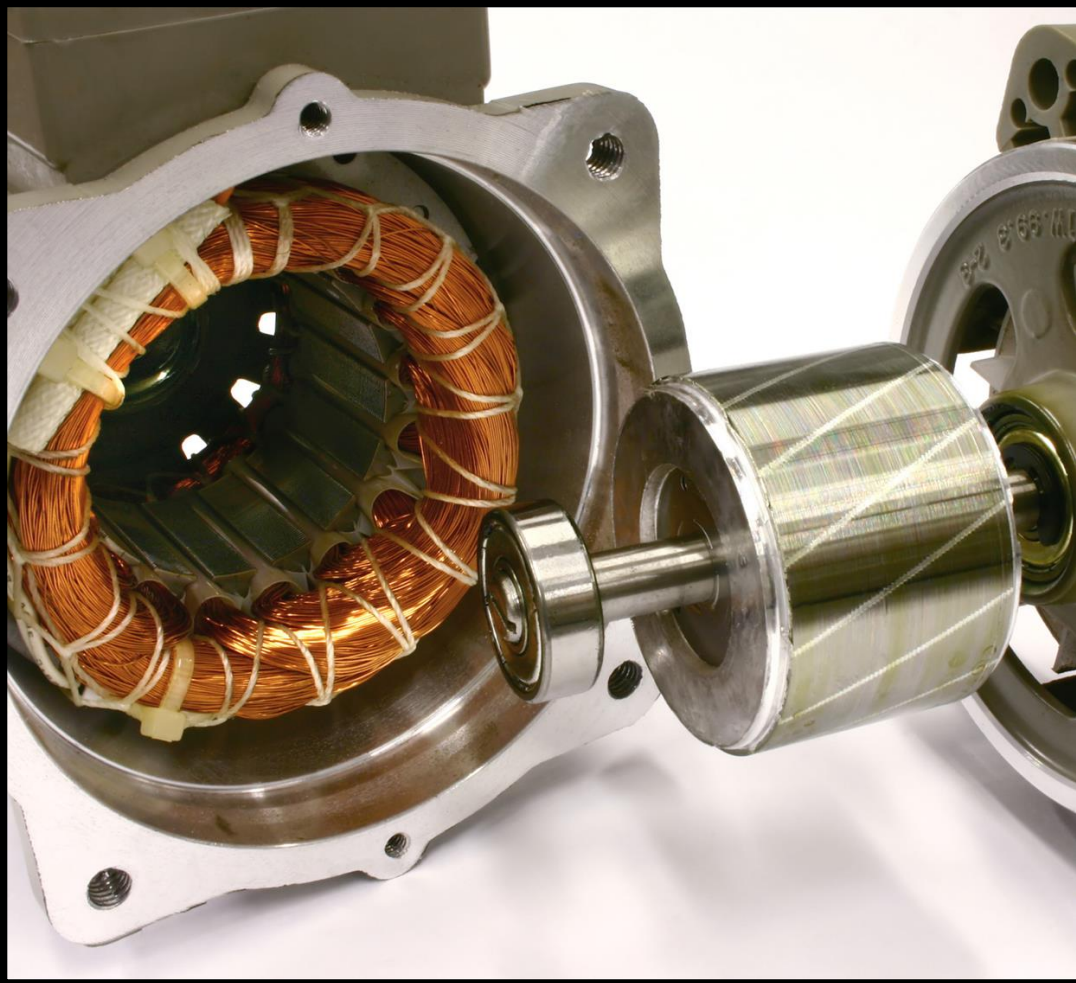
- The muscle for the BEV
- The helper for the HEV



Motor designations



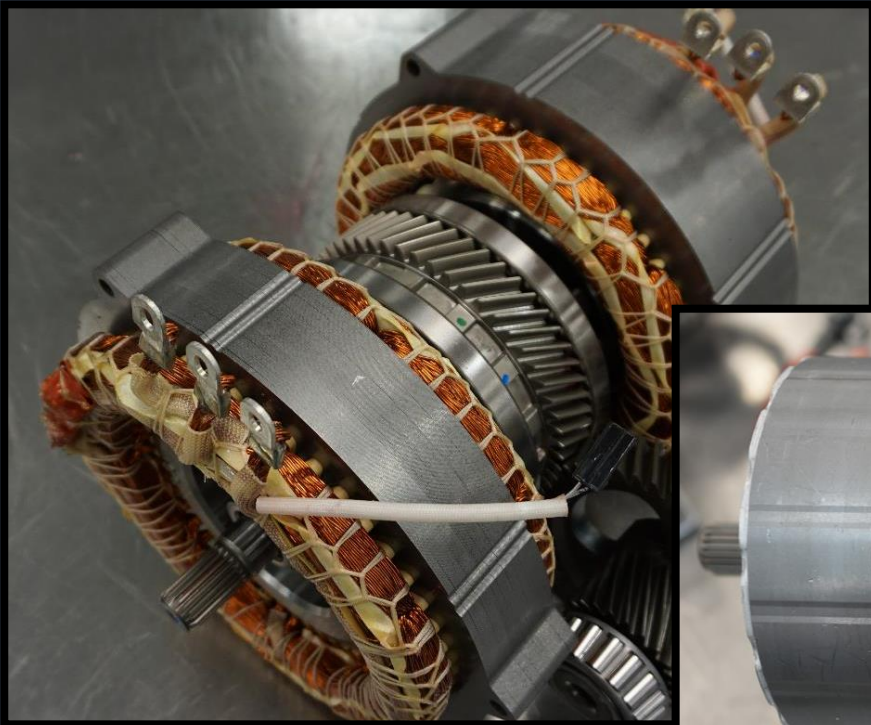
Basic Motor Operation



- Main components
 - Stator
 - Windings to create a “rotating magnetic field”
 - Rotor
 - Most common - Permanent magnet to chase that rotating magnetic field

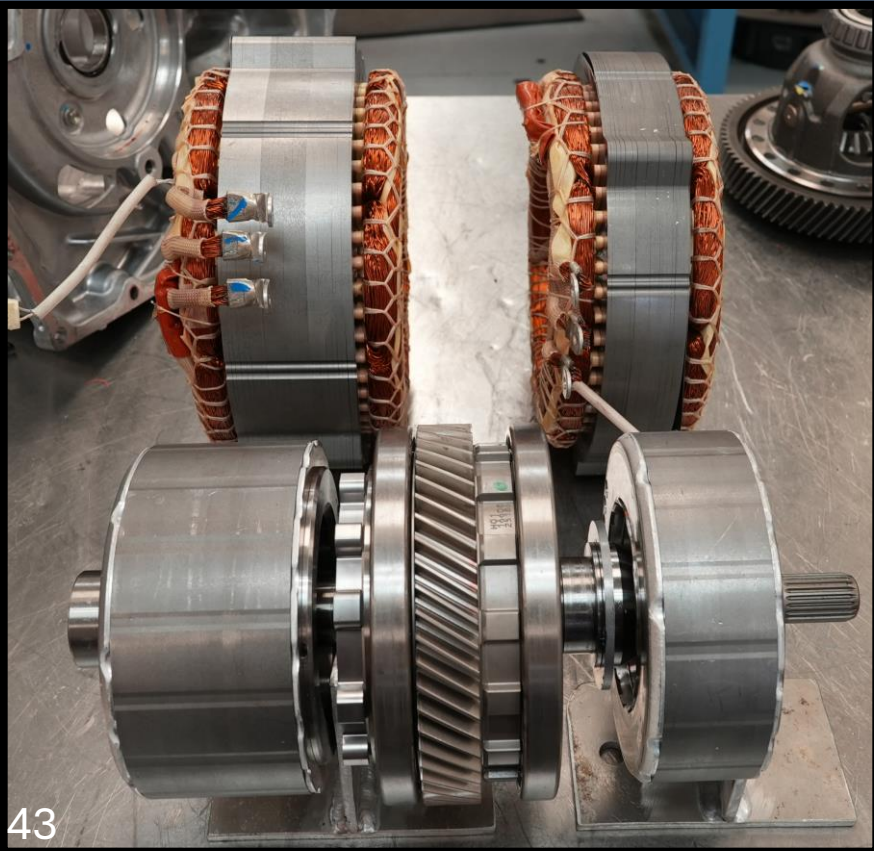
Transaxles – Toyota/Nissan/Ford/Hyundai

- Two Electric Motors (in one transaxle housing)
 - Permanent magnets in rotors
 - 3-phase stator windings



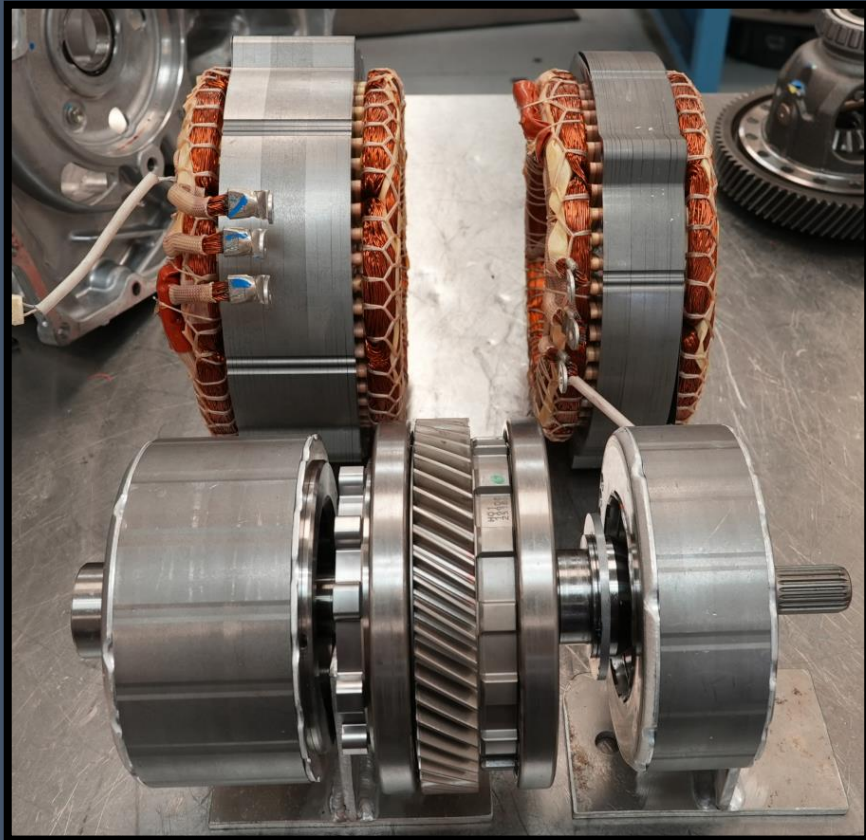
Transaxles – Toyota/Nissan/Ford/Hyundai

- MG 1 (smaller)
 - Works as a generator
 - Works as an engine starter
 - Provides resistance to a planetary gear to allow the engine to vary RPM



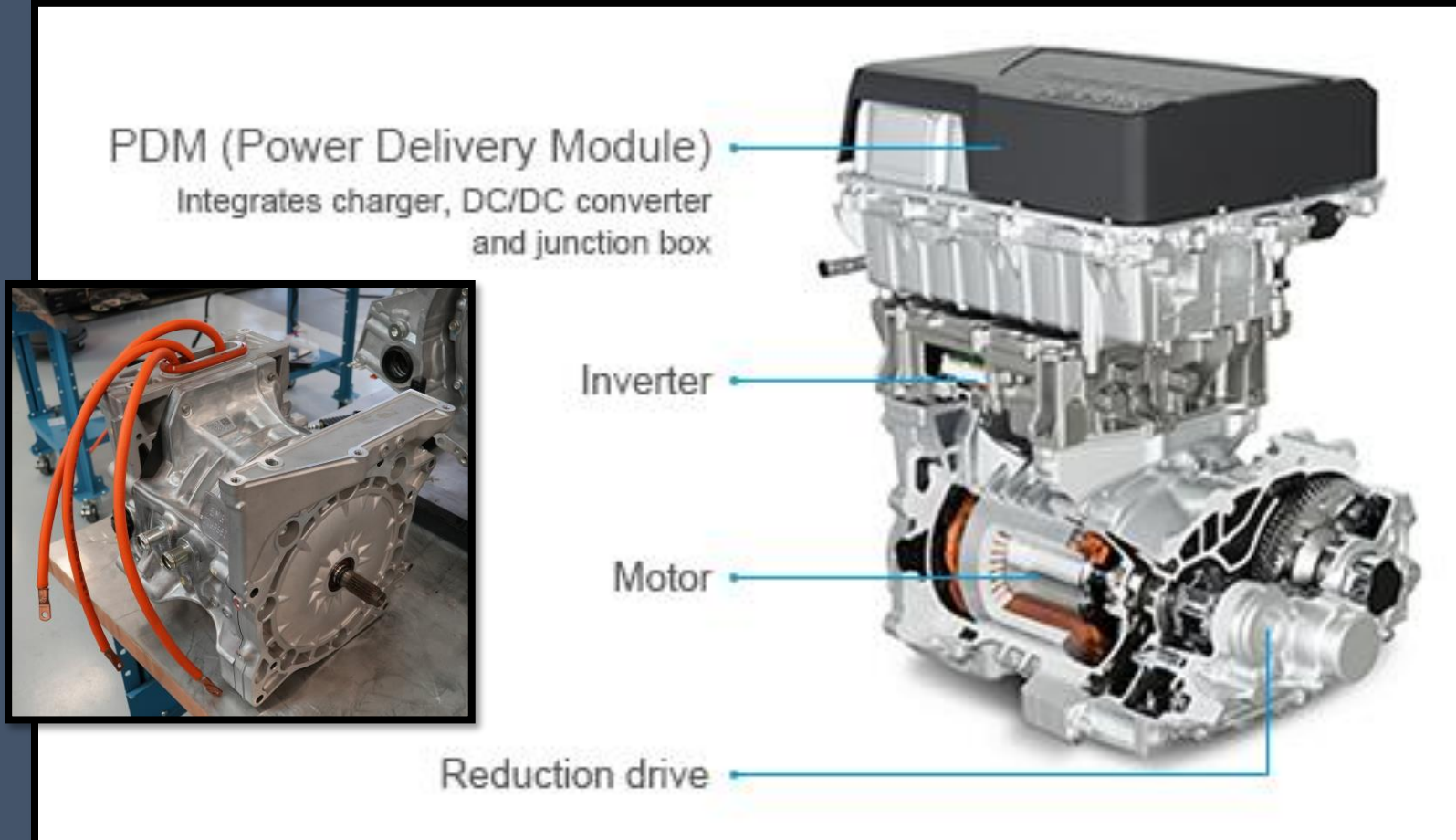
Transaxles – Toyota/Nissan/Ford/Hyundai

- MG 2 (larger)
 - Drives the wheels
 - Generates electricity during braking (regen)

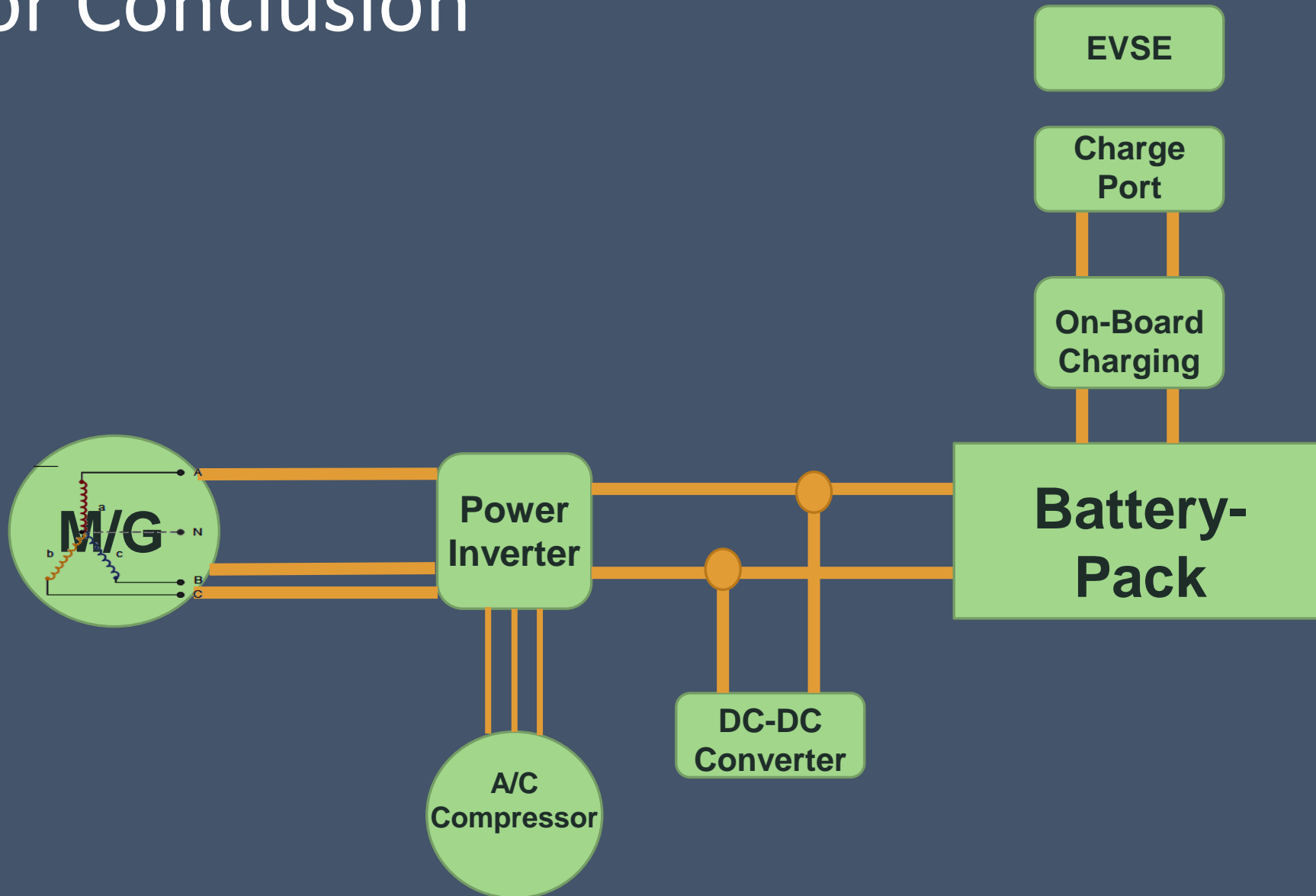


Nissan Leaf Motor

- 80-110kW motor



Motor Conclusion



xEV Inverters

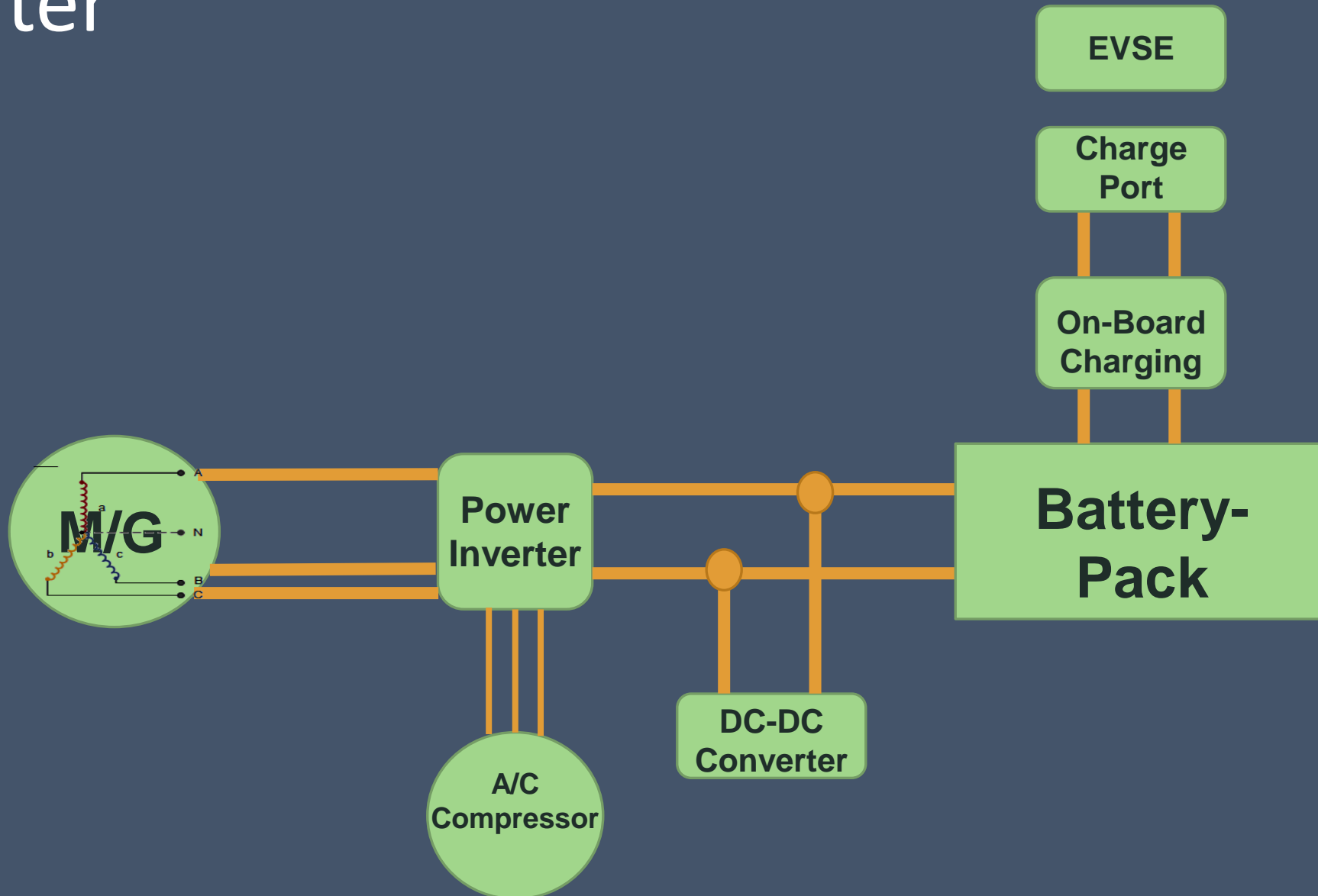


Inverter Technology

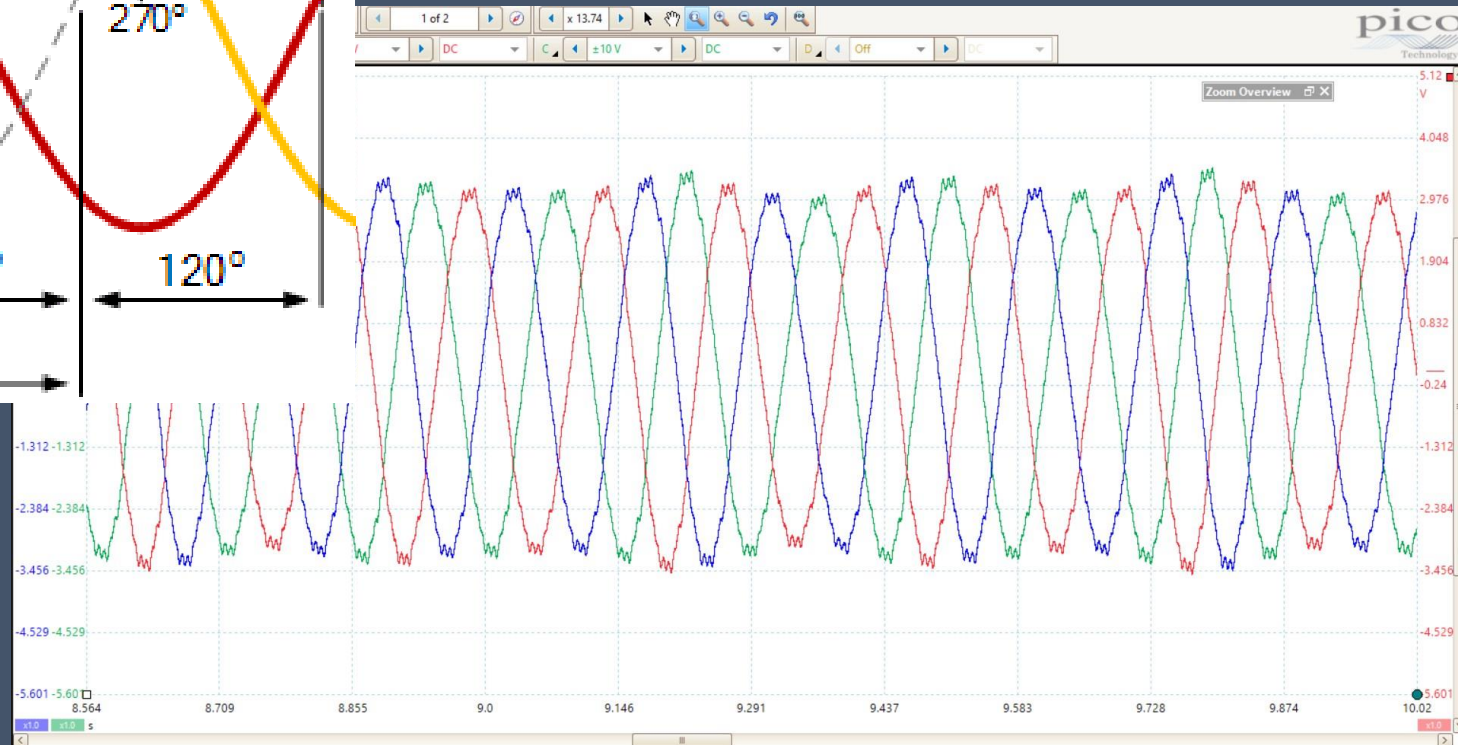
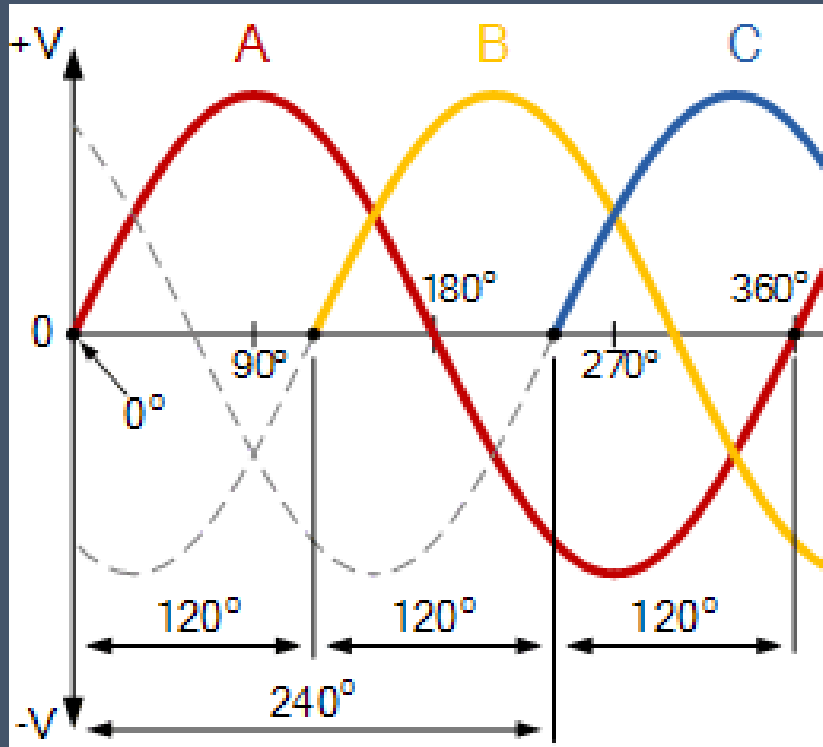
- The inverter will take DC battery voltage and convert it to AC voltage to operate the electric motors
- It will also convert AC voltage created during regeneration to DC voltage to store in the battery
- The transistors will get hot from controlling the current



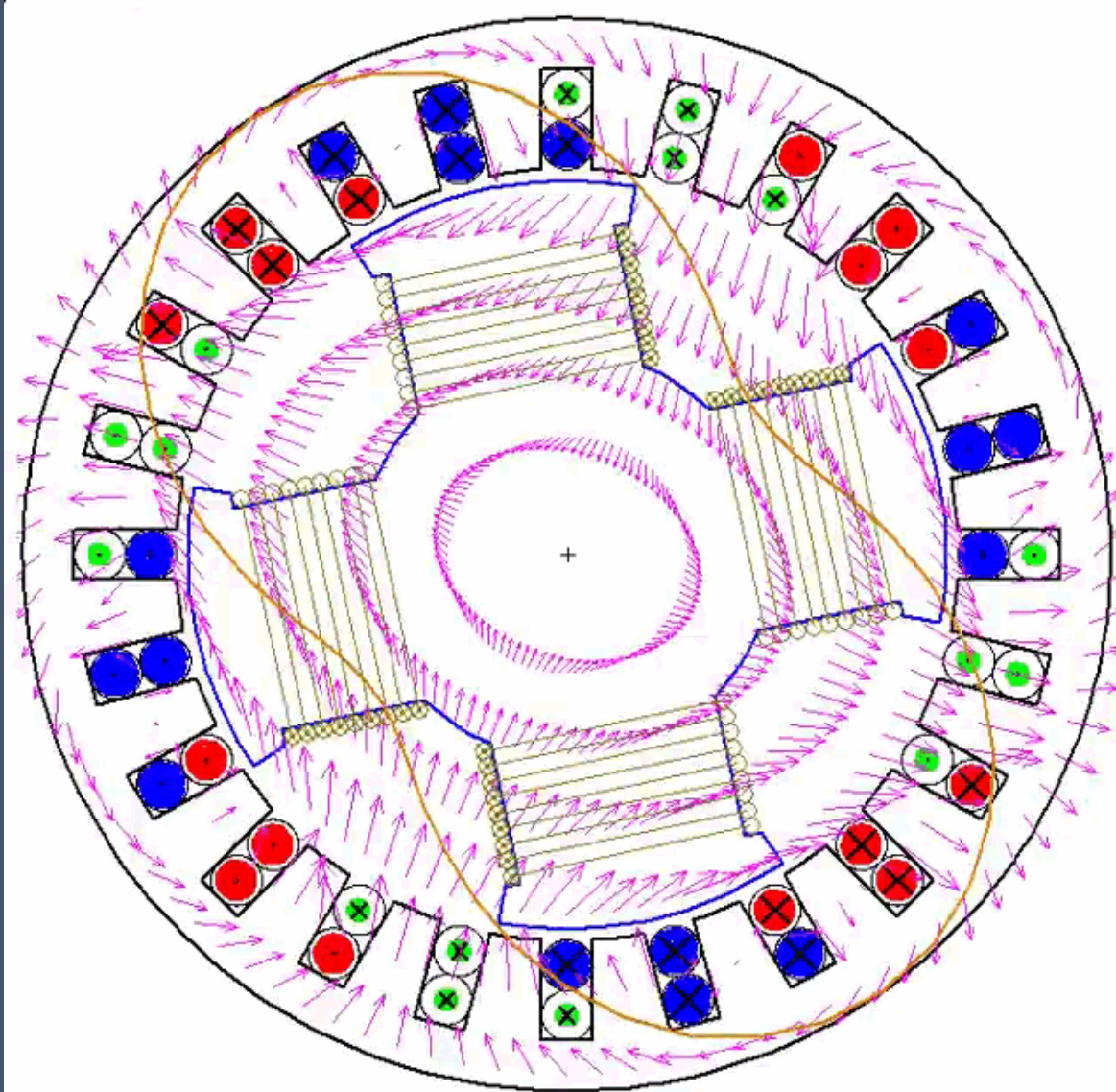
Inverter



Inverter



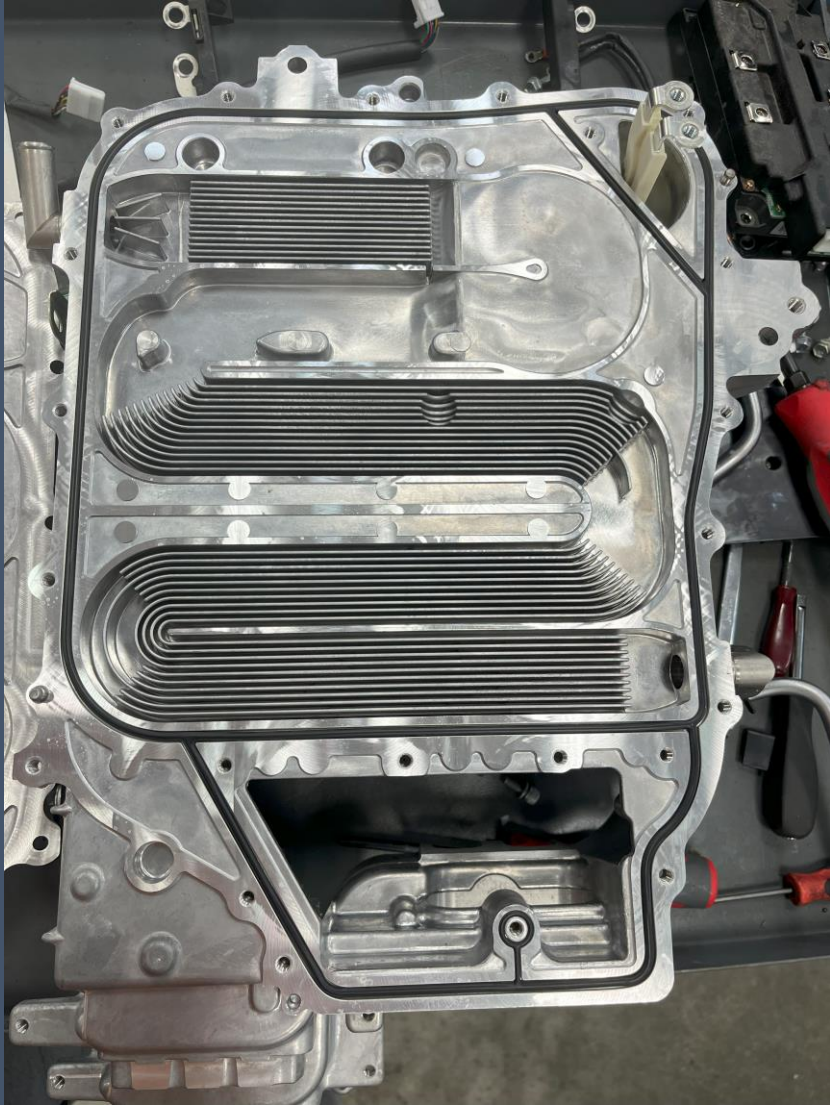
Inverter Technology



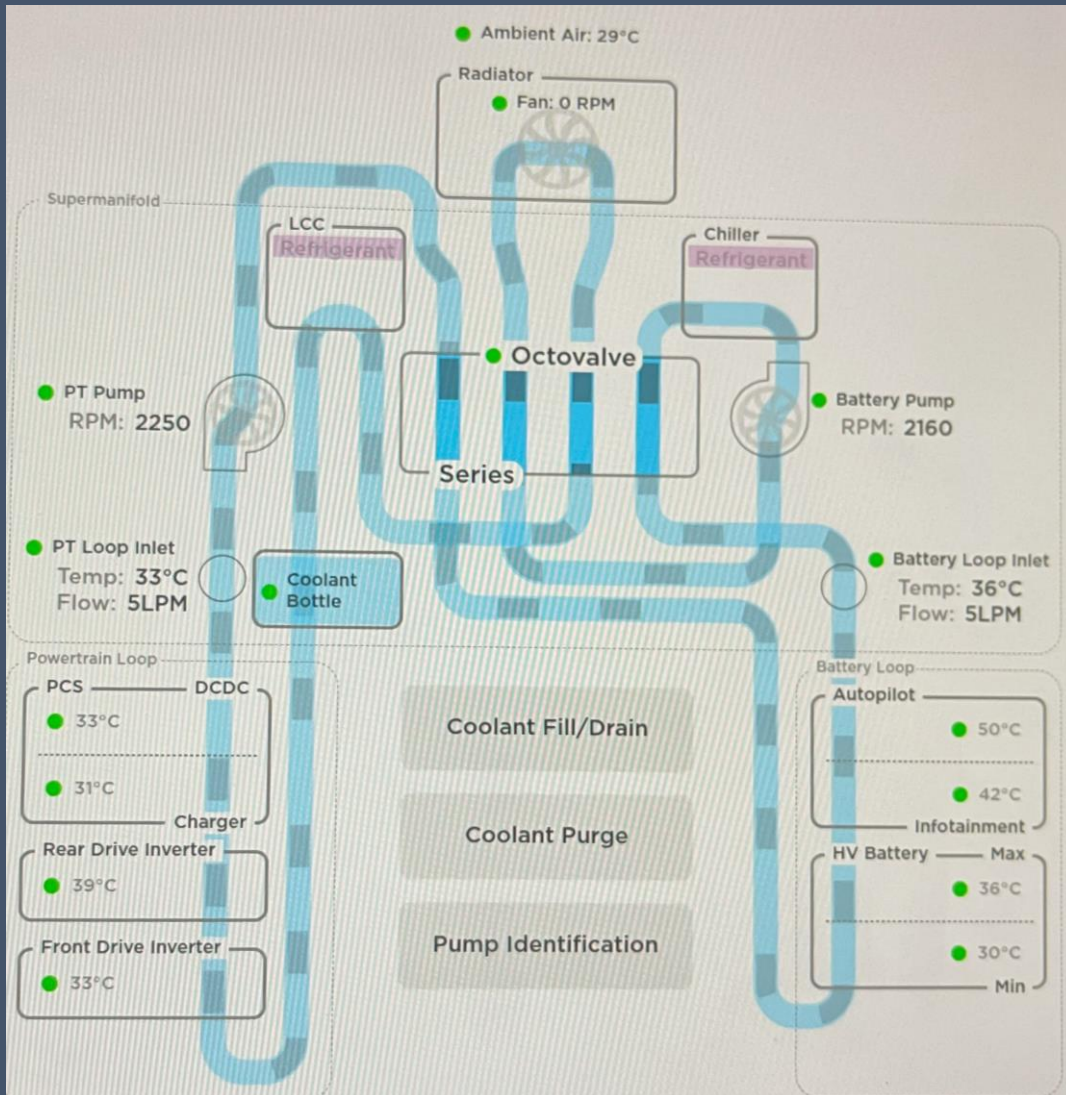
Kia EV6 Front Motor Inverter



Inverter



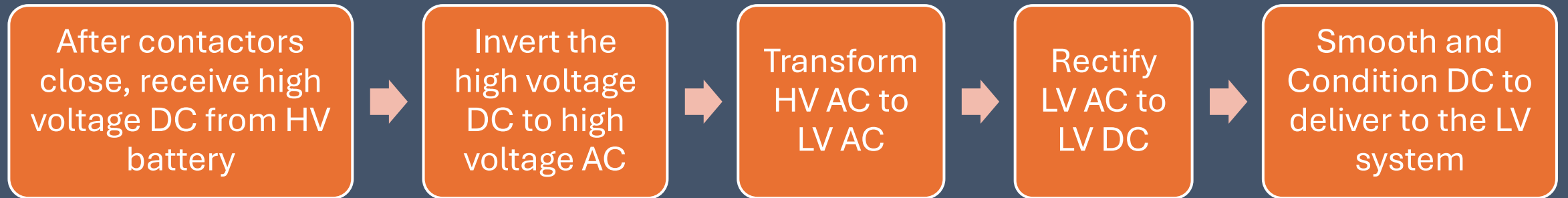
Inverter











xEV DC-DC



DC – DC Conversion Process



Converter diagnostics

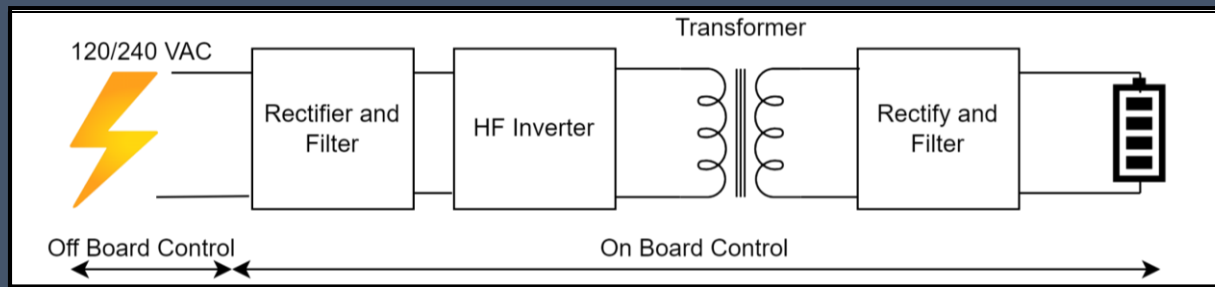
 Exit	 Hide	 Reset	 1	 2	 4	 4	 6
Complete List	Custom List						
Name	Value						
Hybrid Electric Vehicle High Voltage Bus - Measured (V)	274						
DC / DC Converter High Voltage HV Current - Measured (A)	20						
Control Module Voltage (V)	15						
DC / DC Converter Low Voltage LV Current (A)	31						
Module Supply Voltage (V)	15						
Total Time ECU Has Been Active	37570:11:21						
Active Diagnostic Session	Operational						
Airflow Drawn By Hybrid/EV Battery - Estimated (l/min)	0.28						
DC / DC Voltage Converter Status	Enable						
DC / DC Converter Internal Temperature - Measured (°F)	68						
DC / DC Low Voltage Setpoint (V)	40.5						
ECU Status	ON						
Hybrid / EV Battery Coolant Inlet Temperature (°F)	59						
In Car Temperature (°F)	89						
Number Of Trouble Codes Set Due To Diagnostic Test	0						
Switched Ignition Voltage (V)	14.8						
Total Distance (mi)	48348						
Variable Voltage Controller Input Voltage (V)	280						

xEV Charging

A detailed close-up photograph of the internal components of an xEV (extended-range electric vehicle) charging system. The image shows a green printed circuit board (PCB) populated with various electronic components. Two large, prominent copper wire coils are visible on the left side of the board. A central component is a white cylindrical transformer with copper windings. Other components include several electrolytic capacitors (some red, some blue), resistors, and integrated circuits. A black component with the text '224FK275V' is visible in the lower-left. A blue component with 'STE T9AS1D14-12 Potter & Brumfield' is in the lower-center. The PCB is populated with numerous surface-mount components and through-hole components. The entire assembly is mounted on a metal chassis, with various screws and mounting brackets visible. The text 'xEV Charging' is overlaid in a large, white, sans-serif font within a semi-transparent grey rectangular box in the upper-middle portion of the image.

Charging configurations

- Level one and two chargers
- Household or commercial AC delivered to vehicle
 - Level one – 120V (up to 16 amps)
 - Level two – 240V (up to 80 amps, 32 or 50 typical)
- On board control
 - AC to DC rectification
 - DC back to AC for voltage control
 - AC Transformer to isolate the charger from the vehicle's HV
 - Rectify and filter to DC for the HV battery





NOTE: Acceptance Rates were obtained using Wikipedia and/or manufacturer websites.
Miles per hour of charge are only an estimate and the range shown on the vehicle's dash will vary, as the vehicle's computer will calculate the mileage based on many variables.

ELECTRIC VEHICLE RANGE PER HOUR OF CHARGING

VEHICLE	ACCEPTANCE RATE (kW)	ACS-15 (kW) (15 min. charge) starting at \$379	AmazingE (kW) (2 hrs. charge) starting at \$529	LCS-25 (kW) (2 hrs. charge) starting at \$449	LCS-30 (kW) (2 hrs. charge) starting at \$499	AmazingE FAST (kW) (2 hrs. charge) starting at \$449	HCS-50 (kW) (4 hrs. charge) starting at \$635	HCS-60 (kW) (4 hrs. charge) starting at \$699	HCS-80 (kW) (4 hrs. charge) starting at \$949
Audi A3 E-Tron Cadillac ELR Chevy Volt Ford C Max Energi Ford Escape 2020 Ford Fusion Energi Hyundai Ioniq Plug-In Hyundai Santa Fe Plug-In Hybrid Hyundai Sonata Kia Niro PHEV Kia Optima Kia Sorento PHEV Mercedes C350 Hybrid Mercedes GLE 550e Mercedes S550 Hybrid MINI Cooper SE Countryman ALL4 Mitsubishi Outlander Nissan LEAF 2013-16 S (3.3 onboard charger) Nissan LEAF 2017 (3.3kW onboard charger S Model) Nissan LEAF 2018 (3.3kW onboard charger S Model) Smart Car Subaru Crosstrek Toyota Prius Toyota Prius Prime Toyota RAV4 Prime SE, XSE Volvo V60 Volvo XC90 T8	3.3	5.5	13*	13	13	13	13	13	13
BMW 330e BMW 530e BMW 740e BMW 745e BMW i8 BMW X3 xDrive30e BMW X5 xDrive40e BMW X5 xDrive45e Cadillac CT6 Chevy Volt 2016-2018 Chevy Volt LT 2019 Lincoln Aviator Grand Touring AWD Porsche Cayenne S E-Hybrid Porsche Panamera S E-Hybrid Porsche Panamera 4 E-Hybrid Porsche 918 Spyder Volvo S90 T8 Volvo XC60 T8 VW e-Golf (3.6kW onboard charger)	3.6	5.5	14*	14	14	14	14	14	14
Chrysler Pacifica Fiat 500e Ford Focus EV Ford Focus EV 2017 Honda Clarity EV Honda Clarity Plug-In Hyundai Ioniq Karma Revero Kia Soul	6.6	5.5	15	18.5	22.5	25.5*	25.5	25.5	25.5

* RECOMMENDED EVSE
If you have an older model and don't see it listed here, check out the EVSE Selector tool on our website at clippercreek.com/charging-station-selector-tool/

Miles per hour of charging

Miles per hour of charging

VEHICLE	ACCEPTANCE RATE (kW)	ACS-15 LEVEL 1 (12A, 1.4kW) starting at \$379	AmazingE LEVEL 2 (16A, 3.8kW) starting at \$329	LCS-25 LEVEL 2 (20A, 4.8kW) starting at \$469	LCS-30 LEVEL 2 (24A, 5.8kW) starting at \$499	AmazingE FAST LEVEL 2 (32A, 7.7kW) starting at \$469	HCS-50 LEVEL 2 (40A, 9.6kW) starting at \$635	HCS-60 LEVEL 2 (48A, 11.5kW) starting at \$899	HCS-80 LEVEL 2 (64A, 15.4kW) starting at \$969
BMW 330e BMW 530e BMW 740e BMW 745e BMW i8 BMW X3 xDrive30e BMW X5 xDrive40e BMW X5 XDrive45e Cadillac CT6 Chevy Volt 2016-2018 Chevy Volt LT 2019 Lincoln Aviator Grand Touring AWD Porsche Cayenne S E-Hybrid Porsche Panamera S E-Hybrid Porsche Panamera 4 E-Hybrid Porsche 918 Spyder Volvo S90 T8 Volvo XC60 T8 VW e-Golf (3.6kW onboard charger)	3.6	5.5	14*	14	14	14	14	14	14
Chrysler Pacifica Fiat 500E Ford Focus EV Ford Focus EV 2017 Honda Clarity EV Honda Clarity Plug-In Hyundai Ioniq Karma Revero Kia Soul	6.6	5.5	15	18.5	22.5	25.5*	25.5	25.5	25.5

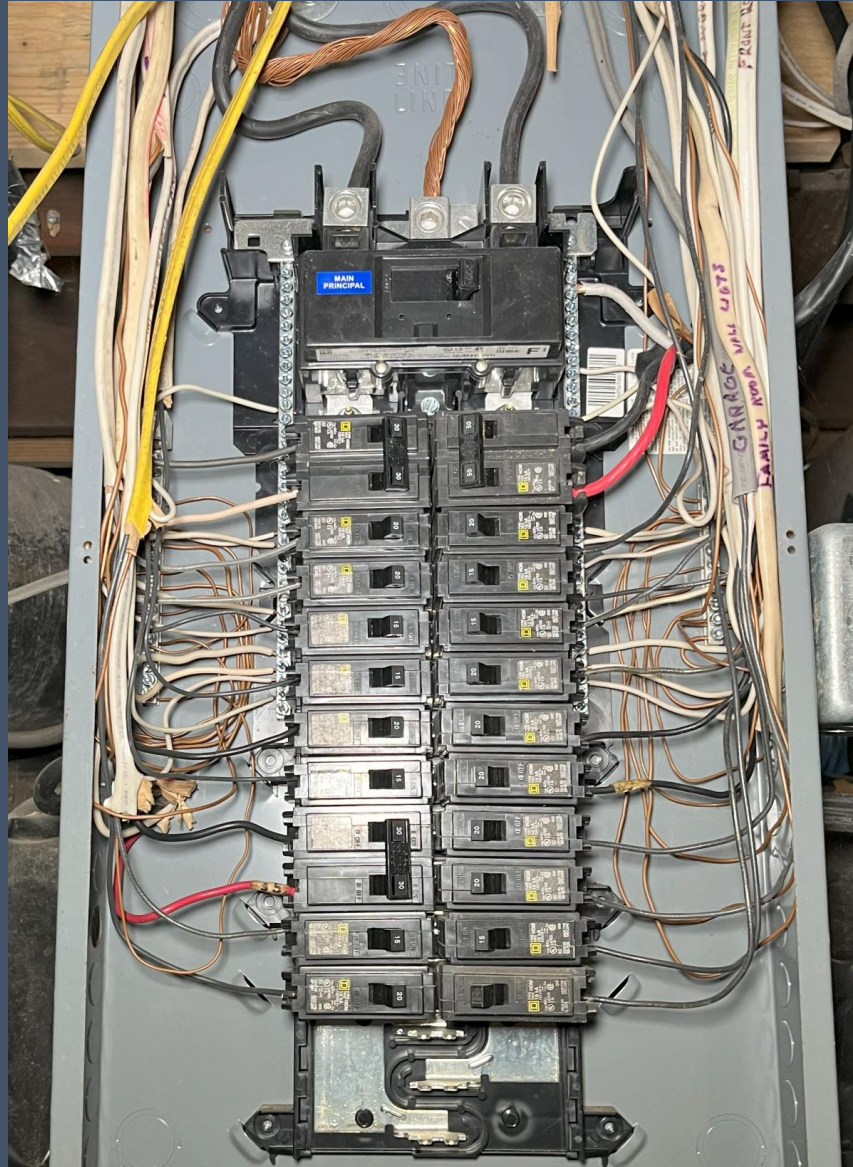
Miles per hour of charging

VEHICLE	ACCEPTANCE RATE (kW)	ACS-15 LEVEL 1 (12A, 1.4kW) starting at \$379	AmazingE LEVEL 2 (16A, 3.8kW) starting at \$329	LCS-25 LEVEL 2 (20A, 4.8kW) starting at \$469	LCS-30 LEVEL 2 (24A, 5.8kW) starting at \$499	AmazingE FAST LEVEL 2 (32A, 7.7kW) starting at \$469	HCS-50 LEVEL 2 (40A, 9.6kW) starting at \$635	HCS-60 LEVEL 2 (48A, 11.5kW) starting at \$899	HCS-80 LEVEL 2 (64A, 15.4kW) starting at \$969
Nissan LEAF S 2016 (6.6kW onboard charger, S Upgrade) Nissan LEAF S 2016 (6.6kw onboard charger SL & SV Model) Nissan LEAF 2017 (6.6kW onboard, S Upgrade, SL & SV Model) Nissan LEAF 2018 (6.6kW onboard, S Upgrade, SL & SV Model) Nissan LEAF Plus (S, SL, SV Models) Nissan LEAF 2022 (All Models) Toyota RAV4 Prime XSE Premium	6.6	5.5	15	18.5	22.5	25.5*	25.5	25.5	25.5
BMW ActiveE Jaguar I-Pace Range Rover P400e	7	5.5	15	18.5	22.5	27.5	27.5	27.5	27.5
Chevy Bolt Chevy Volt LT 2019 Upgrade, Premier 2019 Hyundai Ioniq 2020 Hyundai Kona Jeep Wrangler 4xe Kia Niro EV Kia Soul 2019-2020 Porsche Cayenne S E-Hybrid Upgrade Porsche Panamera 4 E-Hybrid Upgrade Porsche Panamera S E-Hybrid Upgrade Smart Fortwo ED VW e-Golf (7.2kW onboard charger) VW e-Golf 2017-2019 (7.2kW onboard charger)	7.2	5.5	15	18.5	22.5	28*	28	28	28
BMW i3 2017 (60 Ah battery) BMW i3 2017-2018 (90 Ah battery) Mercedes GLC 350e 2020 MINI Cooper SE Polestar 2	7.4	5.5	15	18.5	22.5	29*	29	29	29

VEHICLE	ACCEPTANCE RATE (kW)	ACS-15 LEVEL 1 (12A,1.4kW) starting at \$379	AmazingE LEVEL 2 (16A, 3.8kW) starting at \$329	LCS-25 LEVEL 2 (20A, 4.8kW) starting at \$469	LCS-30 LEVEL 2 (24A, 5.8kW) starting at \$499	AmazingE FAST LEVEL 2 (32A, 7.7kW) starting at \$469	HCS-50 LEVEL 2 (40A, 9.6kW) starting at \$635	HCS-60 LEVEL 2 (48A, 11.5kW) starting at \$899	HCS-80 LEVEL 2 (64A,15.4kW) starting at \$969
BMW i3 2017 (60 Ah battery) BMW i3 2017-2018 (90 Ah battery) Mercedes GLC 350e 2020 MINI Cooper SE Polestar 2	7.4	5.5	15	18.5	22.5	29*	29	29	29
Audi Q5 Plug In Hybrid Tesla Model 3 Standard	7.7	2 5.5	5.5 15	6.5 18.5	8 22.5	11 30	11 30	11 30	11 30
Audi e-tron SUV Mercedes B Class B250e Porsche Taycan Tesla Model S 60 Single Tesla Model S 70 Single Tesla Model S 85 Single Tesla Model S 90 Single Toyota RAV4	9.6	5.5	15	18.5	22.5	30	37.5*	37.5	37.5
Ford Mustang Mach E	10.5	5.5	15	18.5	22.5	30	37.5	41	41
Chevy Bolt/Bolt EUV Hyundai Ioniq 5 VW ID.4	11	5.5	15	18.5	22.5	30	37.5	43	43
Tesla Model 3 Long Range Tesla Model S Performance, Long Range Tesla Model X Performance, Long Range Tesla Model Y Performance, Long Range Volvo XC40 Recharge	11.5	5.5	15	18.5	22.5	30	37.5	45*	45
Tesla Model S 100D & P100D Tesla Model X 60 Dual, 75 Dual, 90 Dual Tesla Model X 100D & P100D Tesla Roadster	17.2	5.5	15	18.5	22.5	30	37.5	45	60*
Cadillac Lyriq Lucid Air (all models: Dream Edition & Touring) Tesla Model S (60, 70, 85 and 90 Dual models)	19.2	5.5	15	18.5	22.5	30	37.5	45	60*

Wiring a level two charger

- Do you have enough service?
- Do you have open breaker spots?
- Do you have to remove drywall or major demo?
- Romex or Conduit
- What size charger?



Electric Vehicle Charging Station Locations

Find electric vehicle charging stations in the United States and Canada. For Canadian stations in French, see [Natural Resources Canada](#).

Public Stations

Advanced Filters

Fuel Corridors

4,176 results in U.S. and Canada

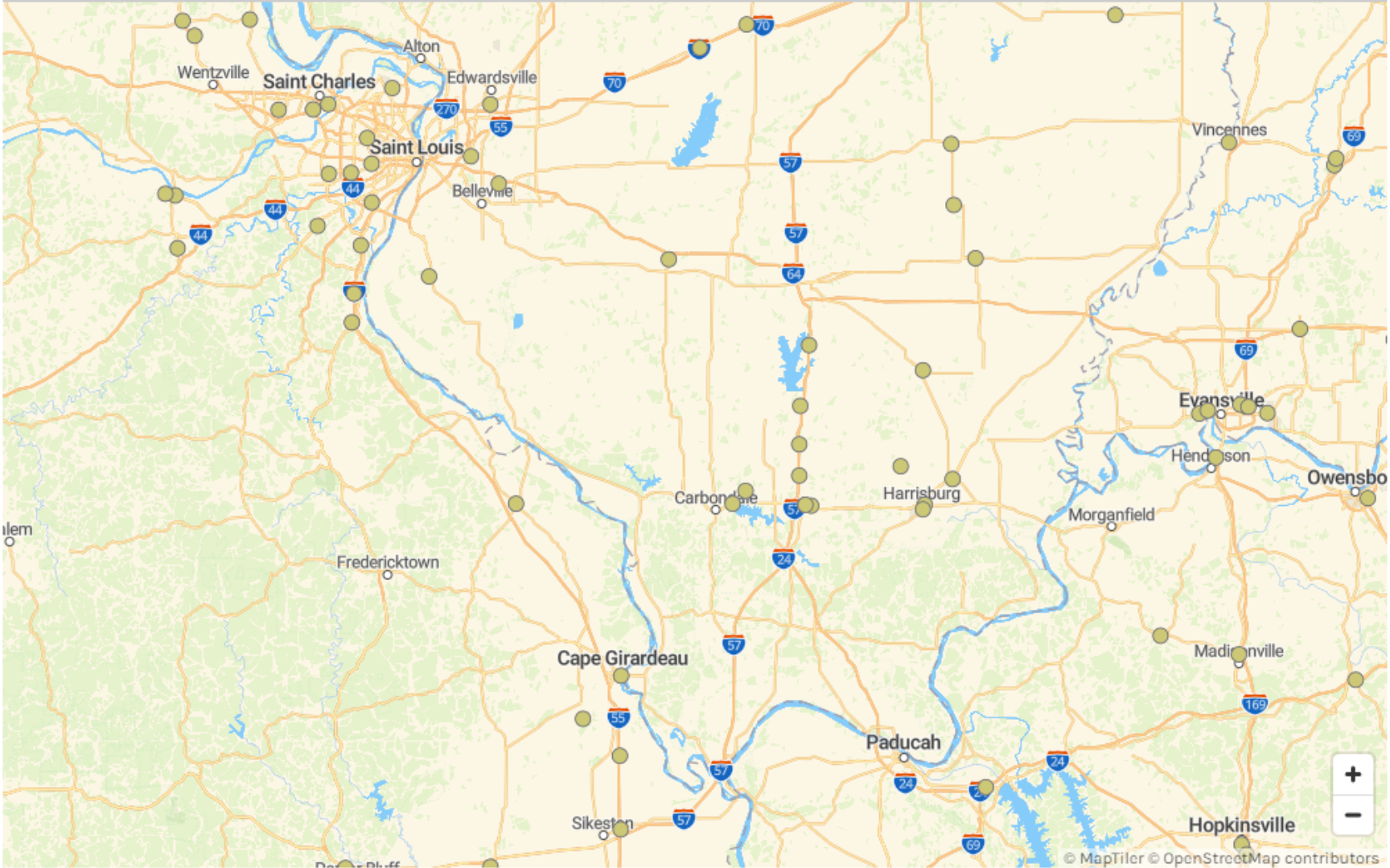
Enter location

Q

Ethanol (E85)

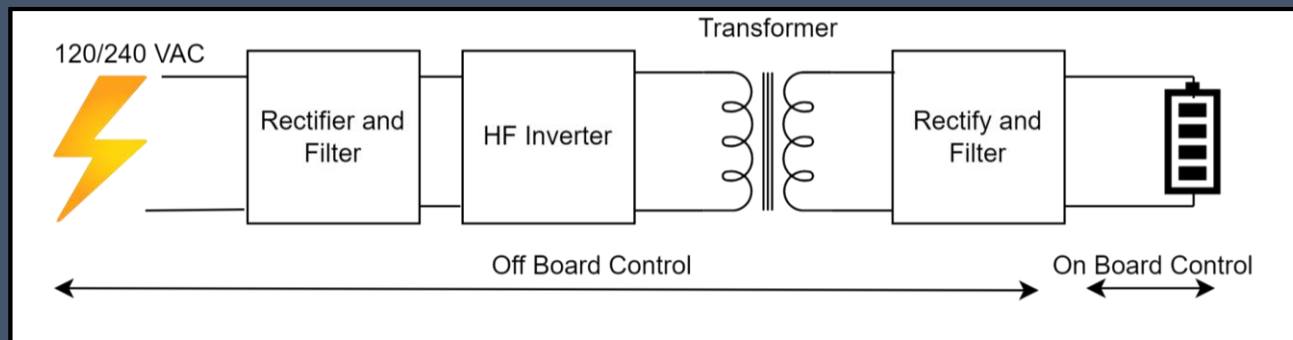
⌵

Map a Route



Charging Configurations

- Level 3 chargers
- Commercial DC delivered to vehicle
 - Class three – High voltage DC ready for the battery
- Off board control
 - AC to DC rectification
 - DC back to AC for voltage control
 - High frequency AC transformer for efficiency
 - Rectify and filter for the vehicle's HV battery



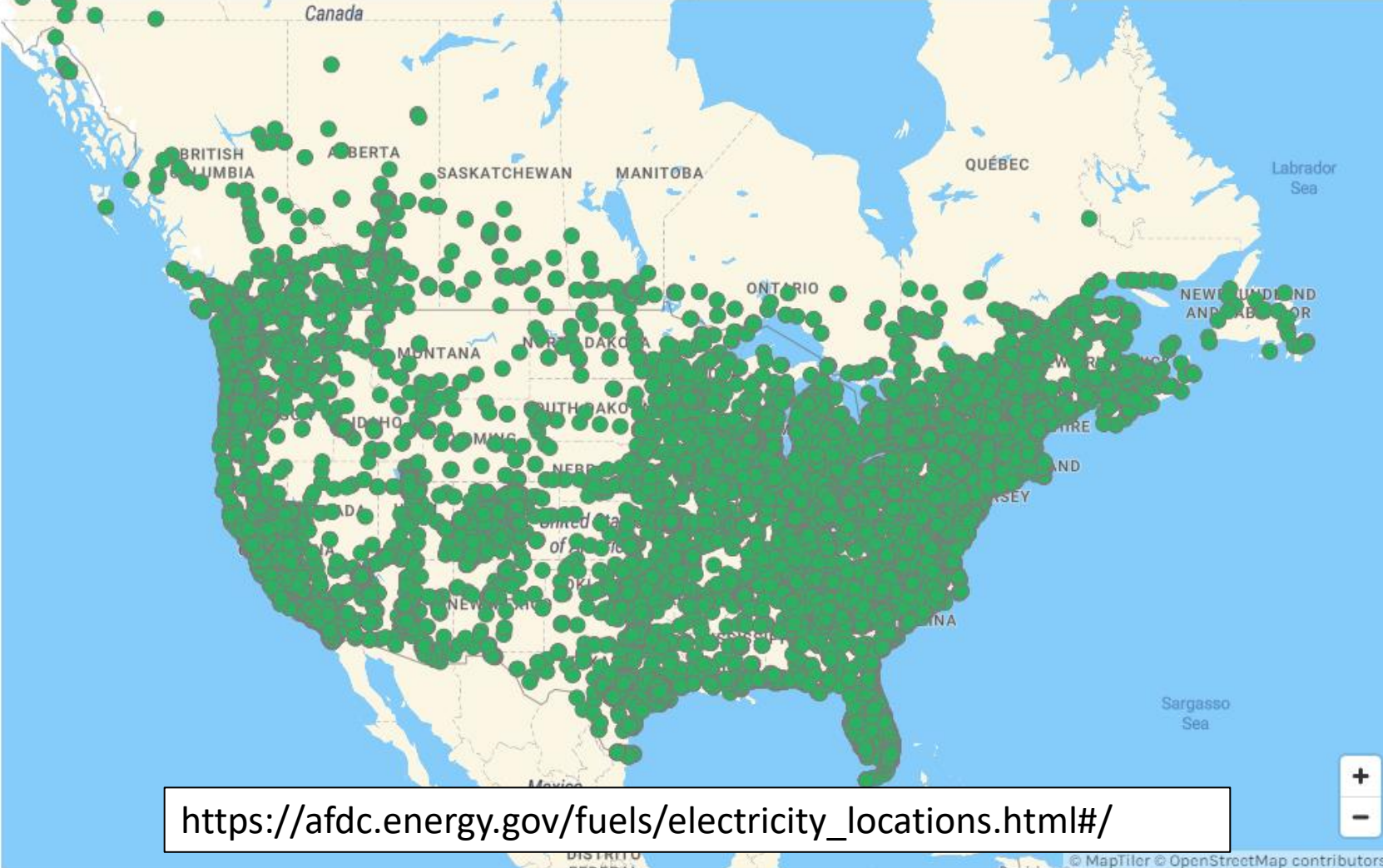
Electric Vehicle Charging Station Locations

Find electric vehicle charging stations in the United States and Canada. For Canadian stations in French, see [Natural Resources Canada](#).

Public Stations Advanced Filters Fuel Corridors 53,133 results in U.S. and Canada

Charger Types Connectors Map a Route

Level 2, DC Fa... All



https://afdc.energy.gov/fuels/electricity_locations.html#/

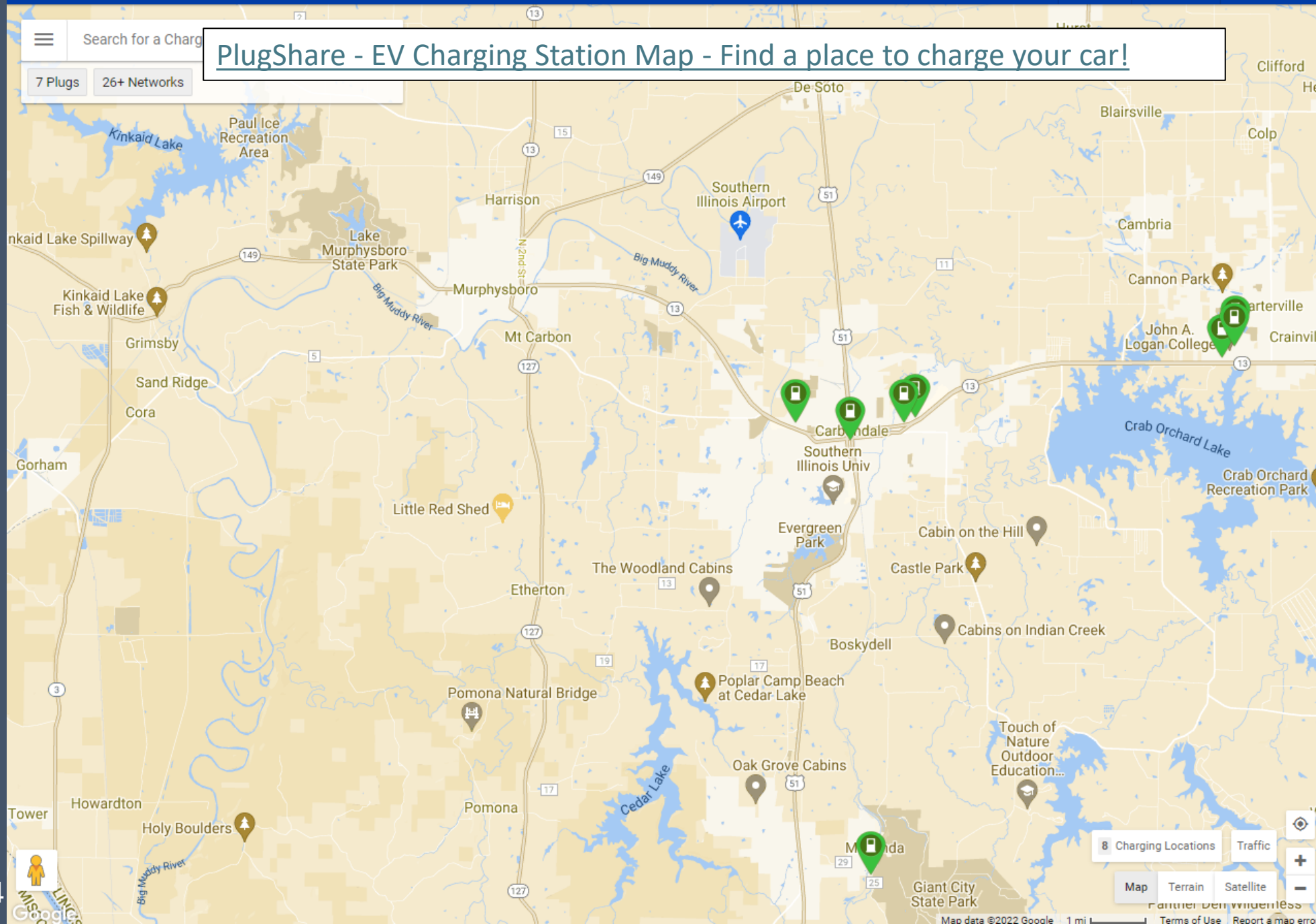


Search for a Charge

PlugShare - EV Charging Station Map - Find a place to charge your car!

7 Plugs

26+ Networks



Google

8 Charging Locations

Traffic

Map

Terrain

Satellite

Plug Configurations

- North America was using the SAE J1772 standard for AC charging
- CHAdeMo was common Japanese standard
- North American Charging Standard (NACS) SAE J3400 is the Tesla adapter which almost everybody has adopted



Type-1 Connector (1-ph AC)



Type-2 Connector (3-ph AC)



Combo Charging System (AC/DC)



CHAdeMO Connector (DC)



NACS

Plug Configurations

- Some plug sizes are out of control!



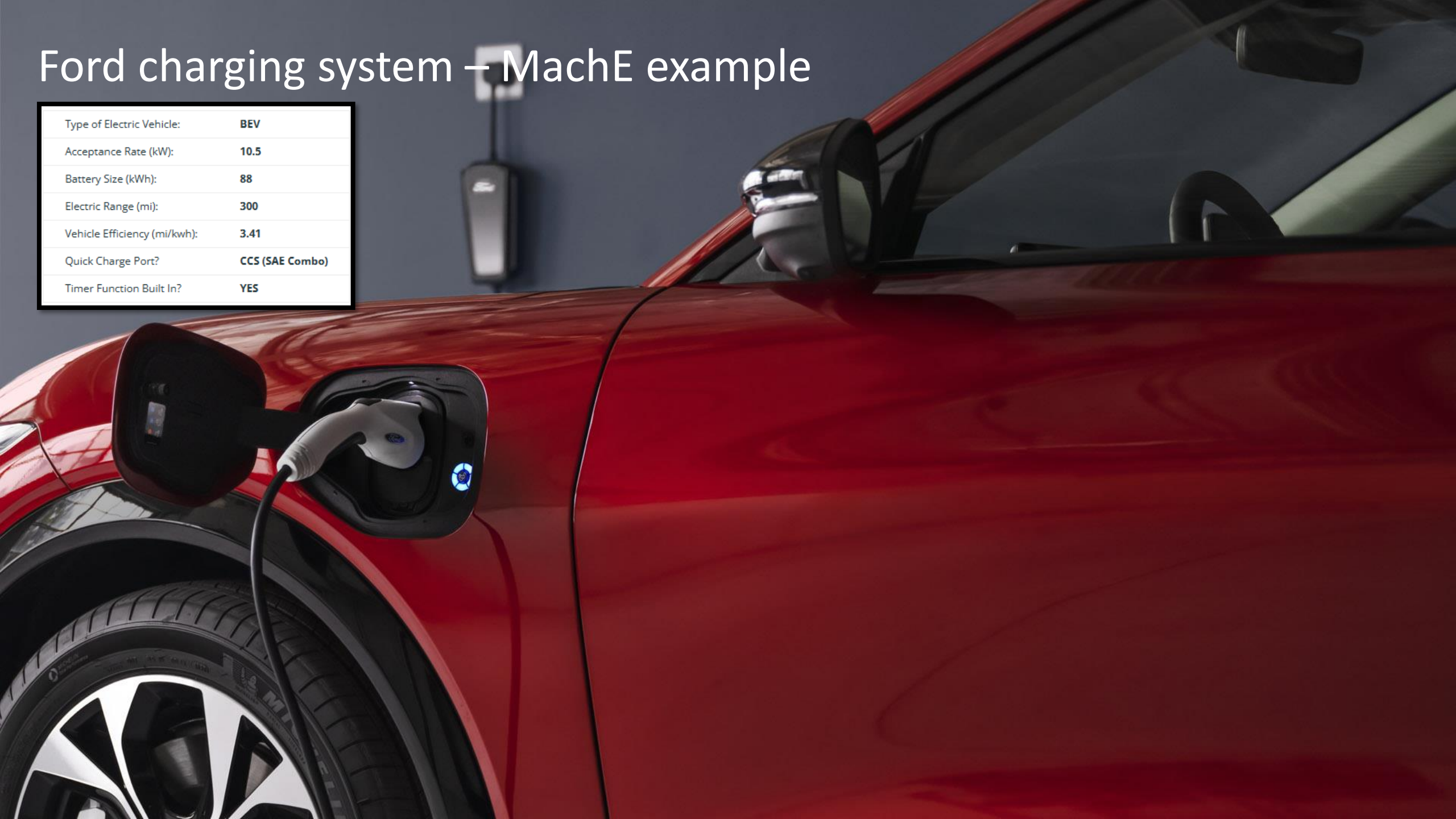
Plug Configurations

- NACS vs. CCS1



Ford charging system – MachE example

Type of Electric Vehicle:	BEV
Acceptance Rate (kW):	10.5
Battery Size (kWh):	88
Electric Range (mi):	300
Vehicle Efficiency (mi/kwh):	3.41
Quick Charge Port?	CCS (SAE Combo)
Timer Function Built In?	YES



Ford charging system

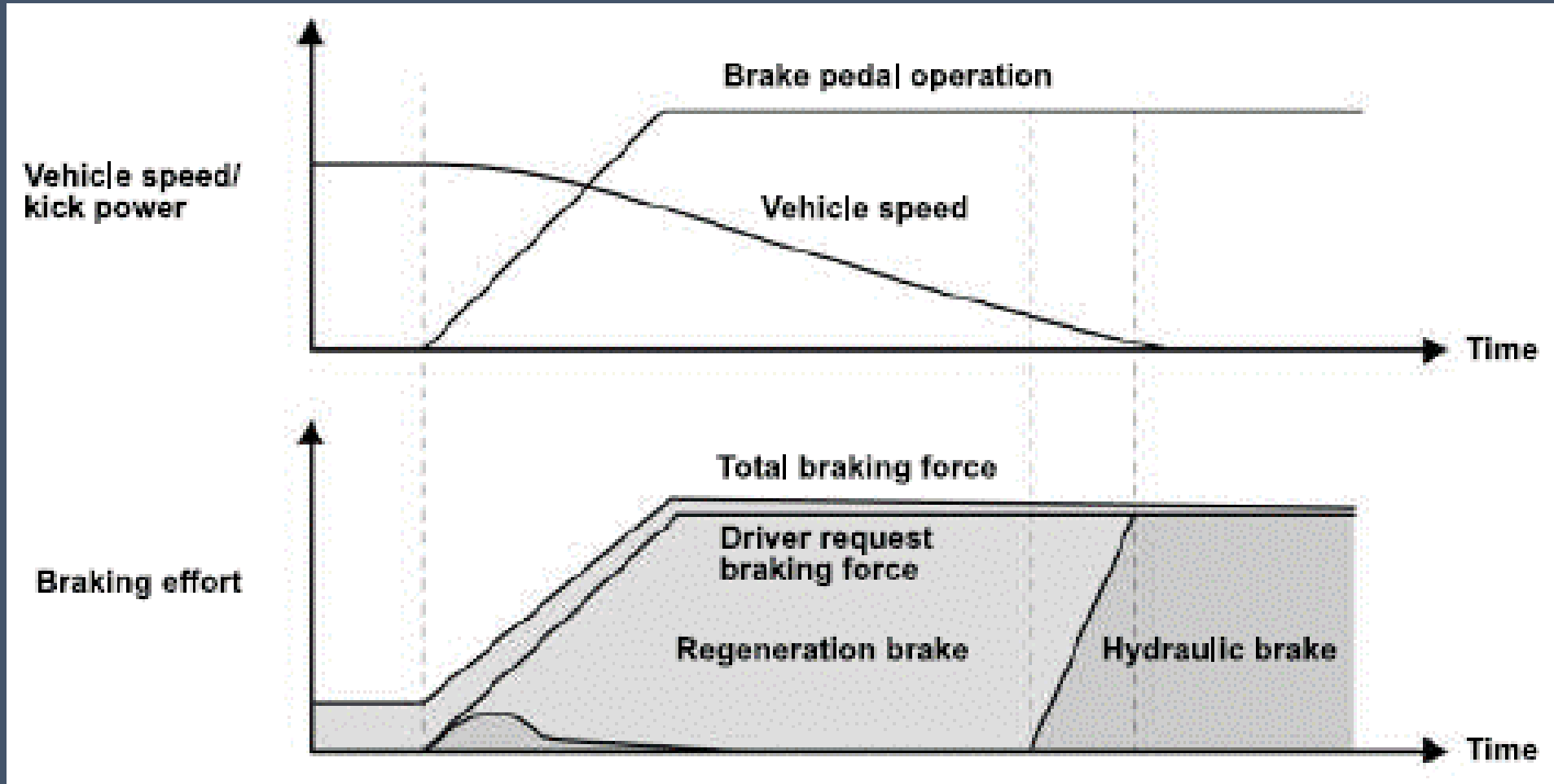
- Charging port light ring (CPLR)
 - Current SOC
 - Light ring
 - Charging, faults, status
 - 25%, 50%, 75%, and full charge



A close-up photograph of a vehicle's brake master cylinder. The master cylinder is a white plastic reservoir with a black cap. It is connected to various metal hydraulic lines and components. A black cap with a yellow label is visible on the left. A metal bracket with a bolt is on the right. A small white label with a QR code and the number 88211336 is at the top. The text "xEV Brakes" is overlaid in a white box with a black border.

xEV Brakes

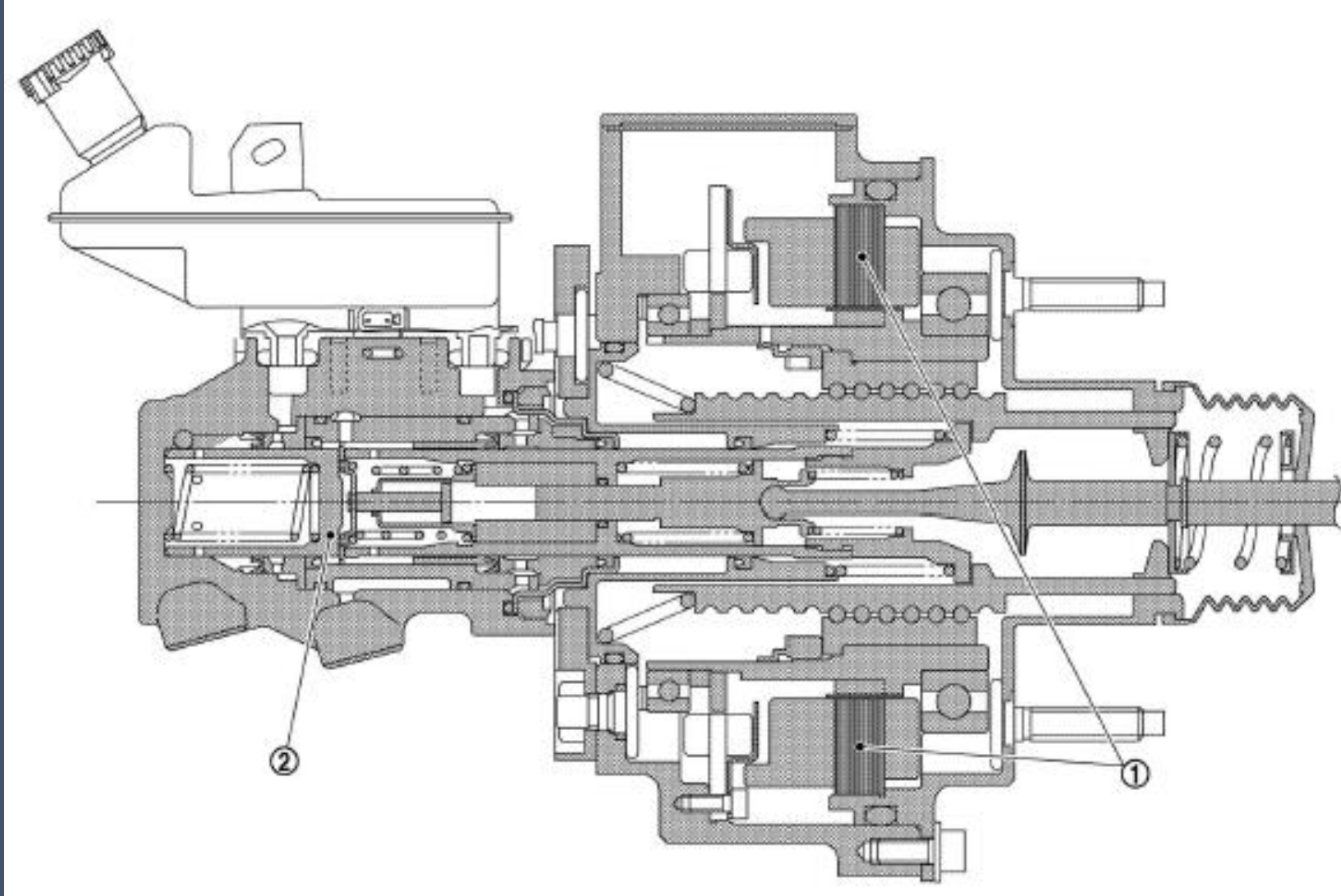
Regen vs. Hydraulic vs. Blended



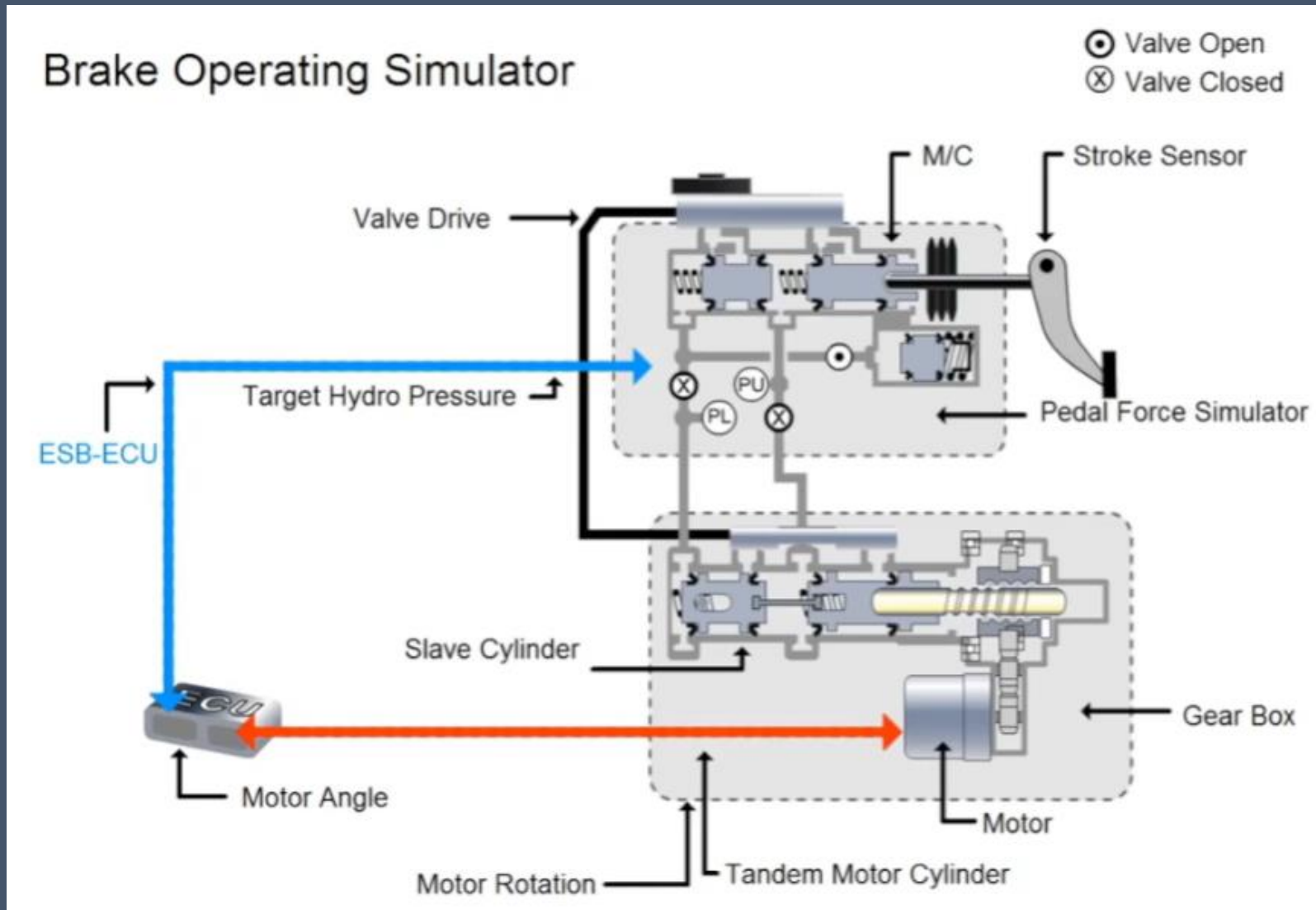
Variations of Electronic Braking

- Accumulator stored pressure (Toyota hybrid, Ford hybrid, and early Honda hybrid are examples)
- Motor and piston-generated pressure (Hyundai Sonata Hybrid/Ionic 6, Ford Gen 4 vehicles with electronic brake booster)
- Motor-actuated master cylinder (Nissan Leaf, Honda Accord Hybrid, Tesla)
- Vacuum booster controlled through solenoid modulation (Ford Gen 2 and 3 hybrids)

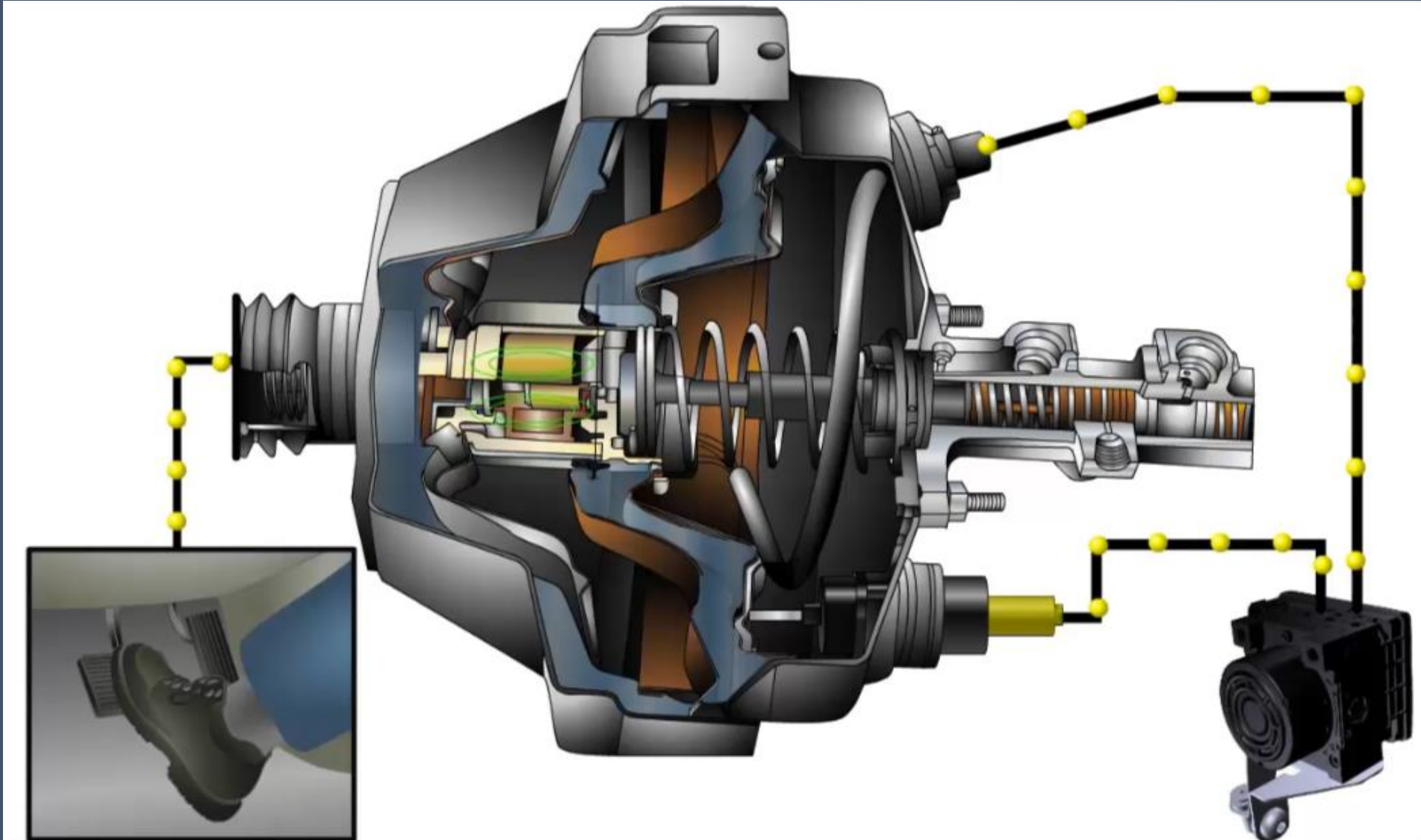
Leaf and Ariya Intelligent Brake Unit




2023 Honda Accord Hybrid



Ford 2nd and 3rd Generation Electronic Braking

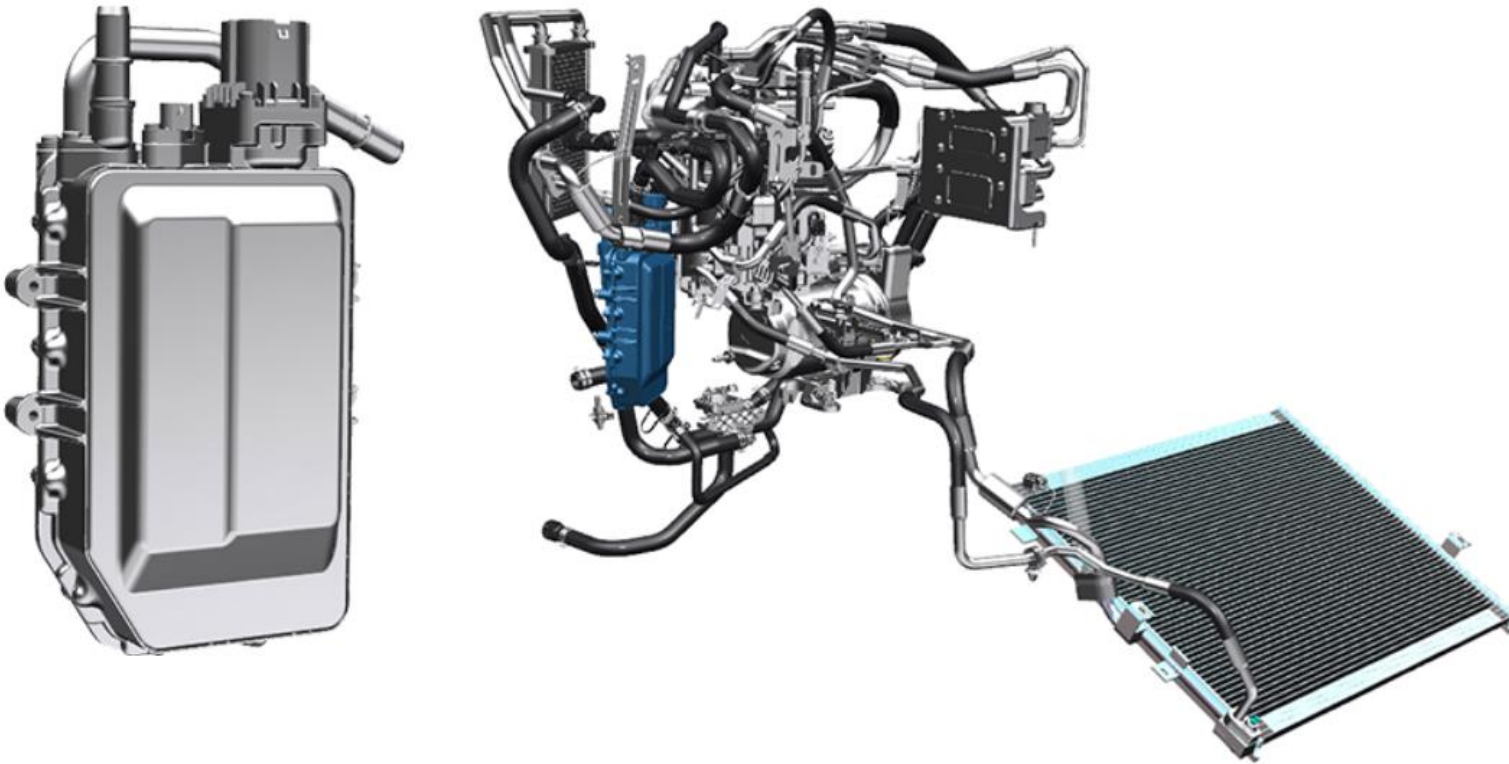


A close-up photograph of a car's front end, focusing on the grille and hood. The grille features vertical slats on the left and a more complex, curved slat pattern on the right. A semi-transparent grey rectangular box with a thin black border is positioned in the upper center of the image, containing the text 'xEV HVAC' in white, bold, sans-serif font.

xEV HVAC

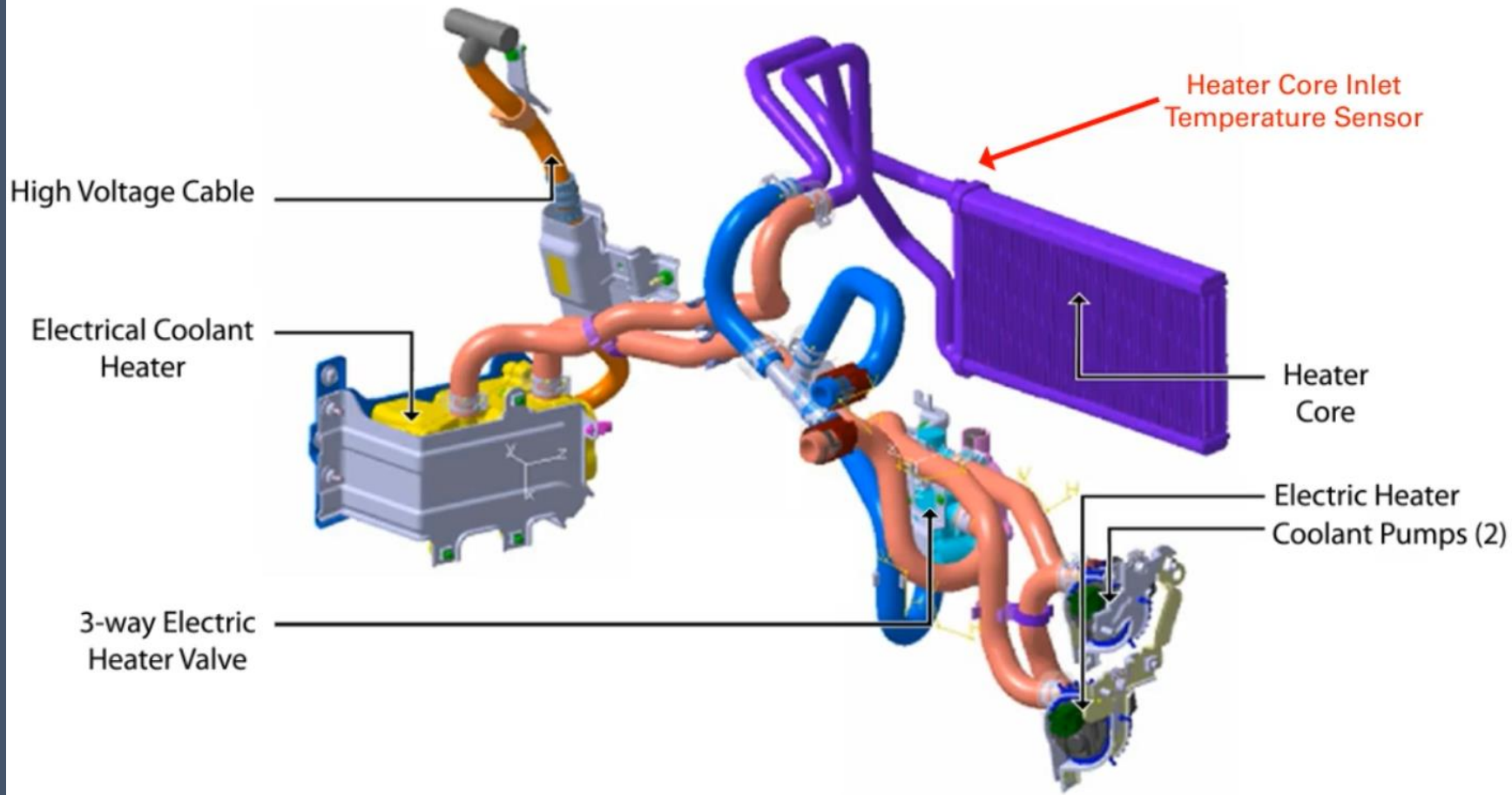
Electric Heating Elements

Positive Temperature Coefficient (PTC) heater

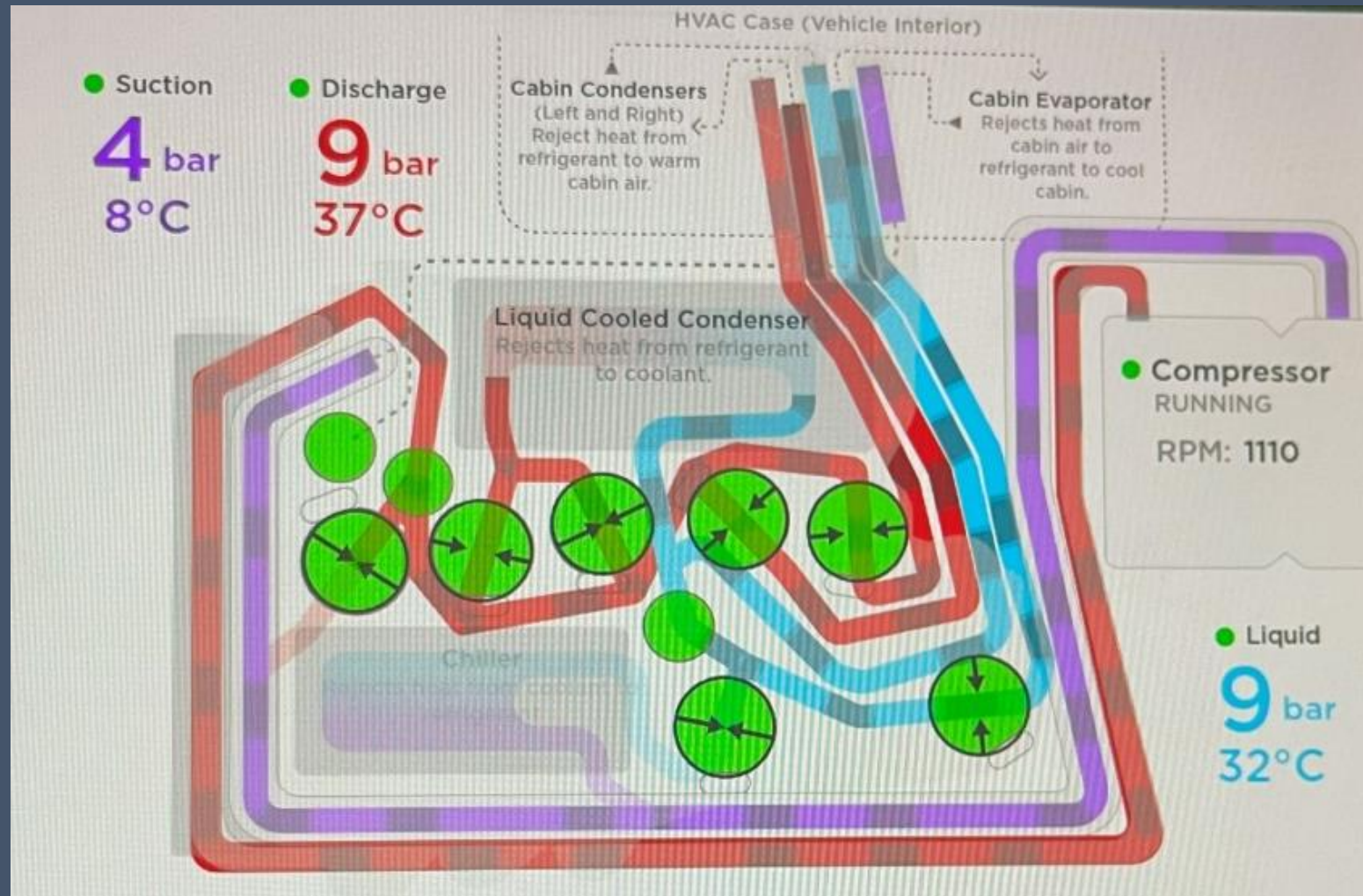


Electric Heating Elements

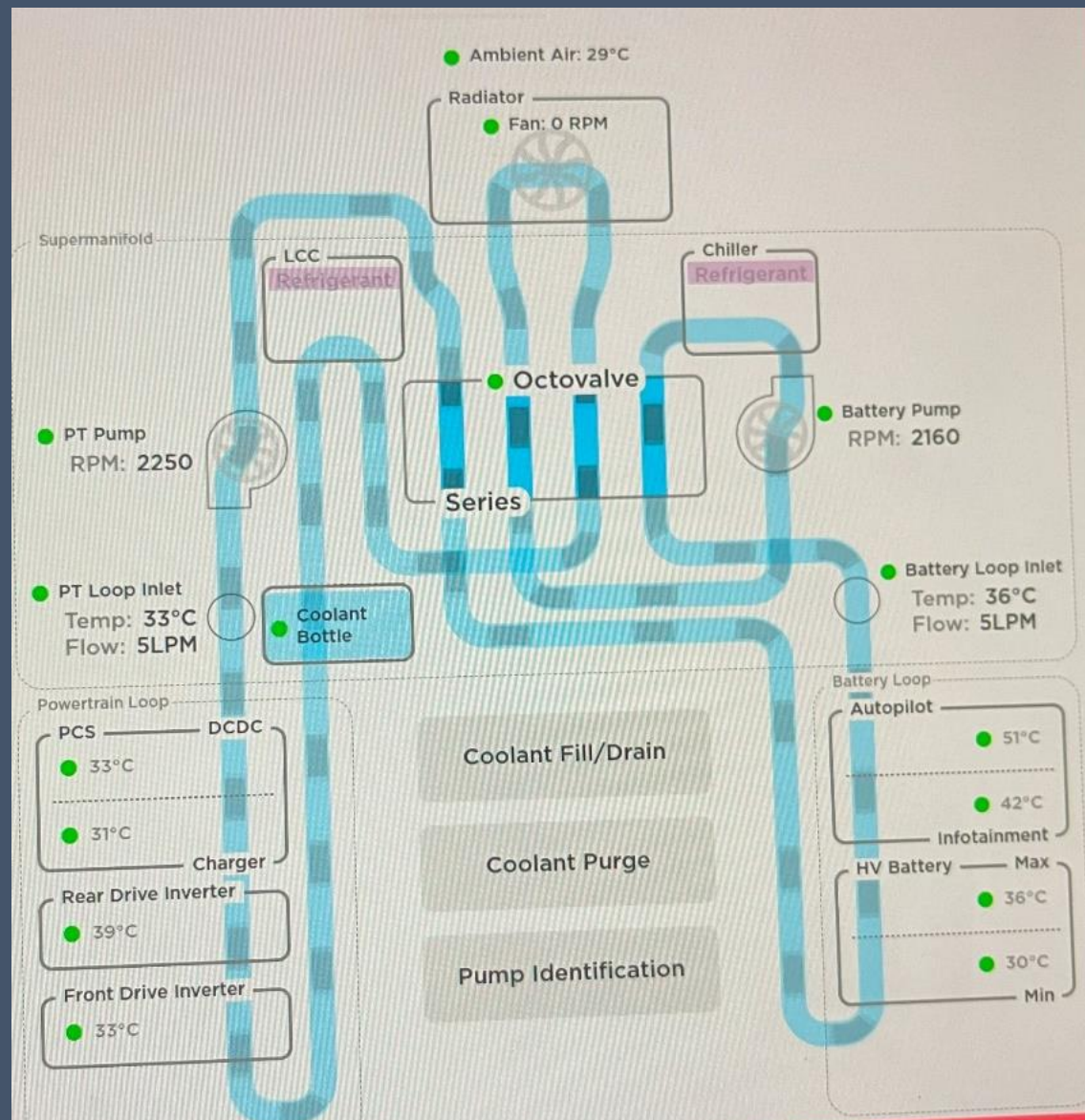
Heater System Components



Heat Pump



Heat Pump

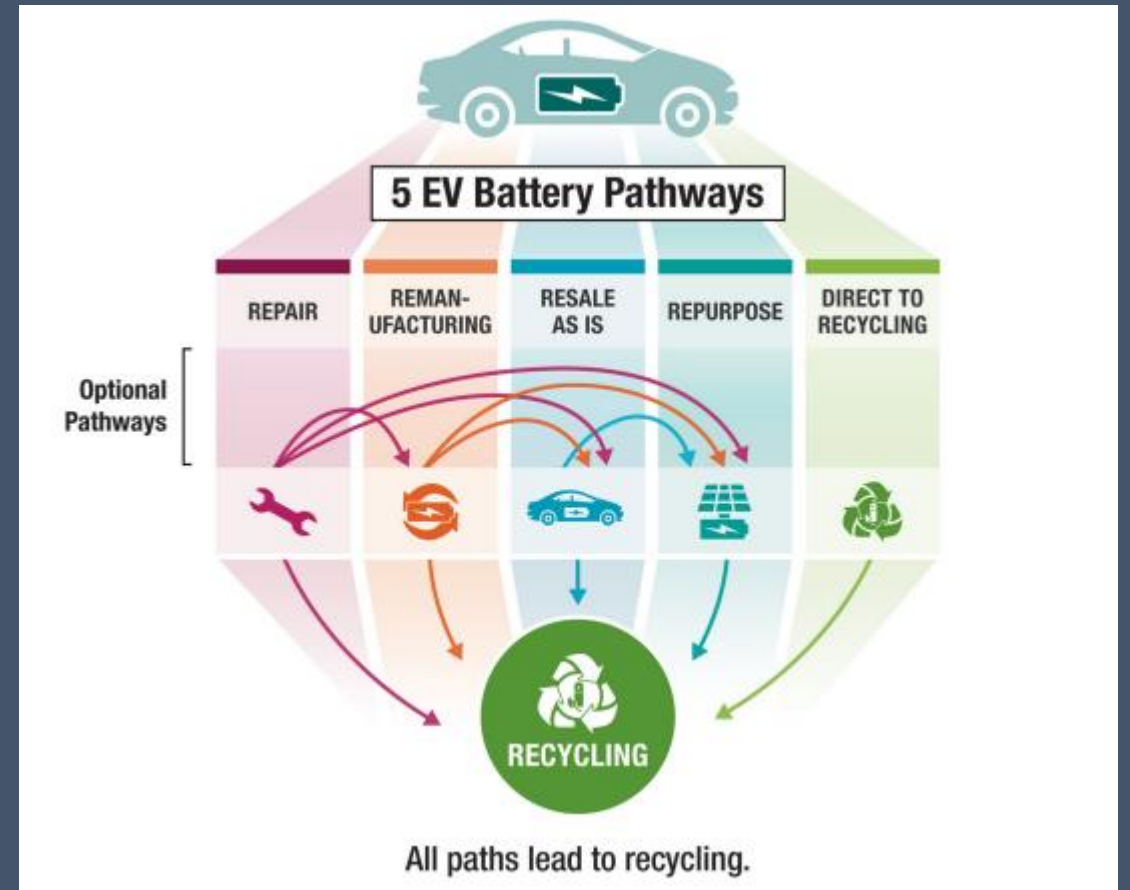


Environmental Impact

An aerial photograph of a vast, rectangular agricultural or industrial landscape. The area is divided into a grid of numerous small, rectangular plots. The plots are filled with various substances, giving them different colors: bright green, yellow, brown, and white. Some plots appear to be water-filled, while others look like dry earth or covered in a substance. The overall pattern is a complex, colorful mosaic. In the background, there are some larger, more irregular structures and what might be roads or canals.

Environmental Concerns: Recycling

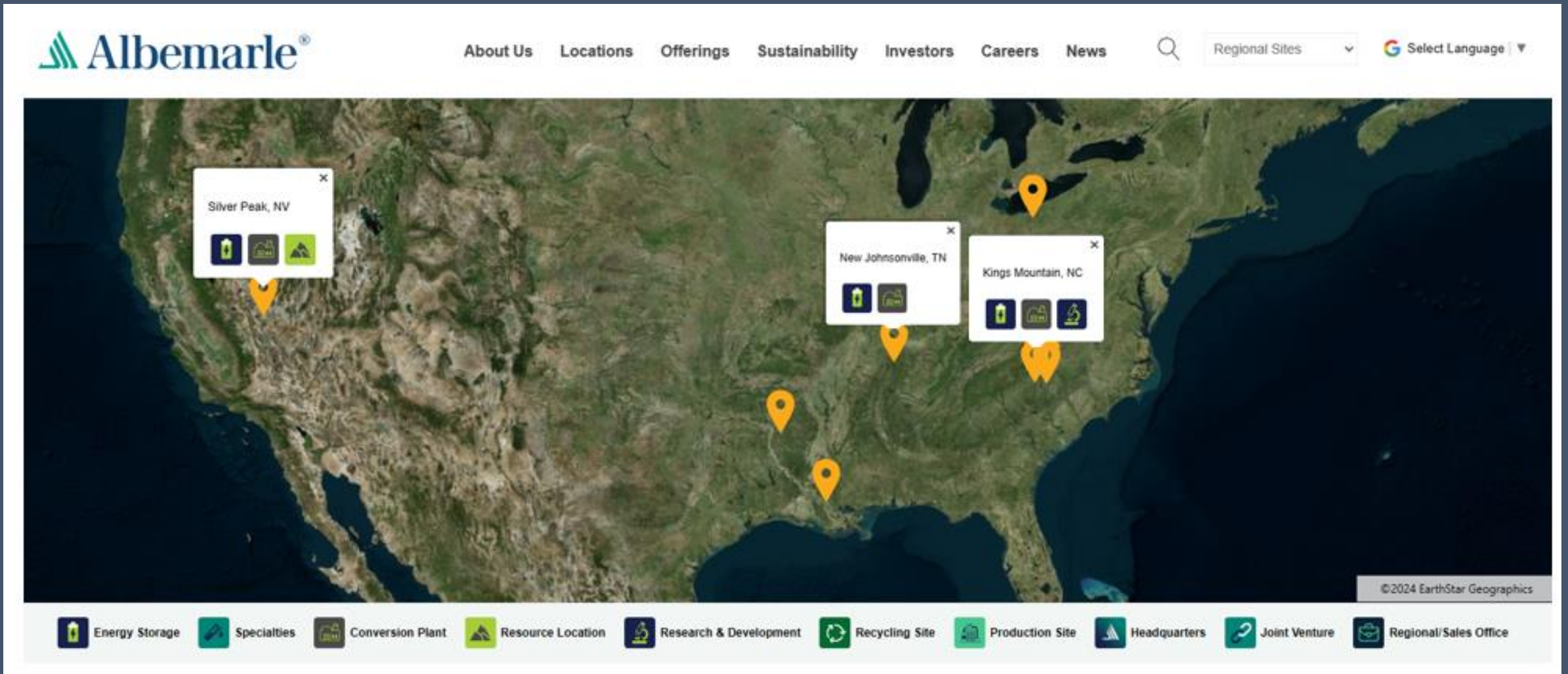
- <https://www.lithiontechnologies.com>
- <https://www.cirbasolutions.com>
- <https://www.call2recycle.org>
- <https://www.globaltechenvironmental.com>
- <https://www.redwoodmaterials.com>



Battery recycling – Can these batteries be recycled?



Mining – Are we running out of minerals?



Mining – Are we running out of minerals?

THE MINING LIFECYCLE

CURRENT STAGES



EARLY EXPLORATION

- Prospecting
- Geological Mapping
- Airborne Survey



ADVANCED EXPLORATION

- Exploratory Drilling
- Preliminary Economic Evaluations



DEVELOPMENT

- Environmental & Social Baseline
- Prefeasibility Studies
- Feasibility Studies
- Detailed Economic Evaluation
- Socio-Economics
- Environmental Impacts
- Permitting



CONSTRUCTION

- Final Engineering
- Plant Construction
- Site Development



OPERATION

- Ore Extraction
- Milling
- Processing
- Product Sales
- Environmental Management
- Progressive Reclamation



CLOSURE

- Mine Closure
- Demolition
- Repurposing
- Reclamation
- Post-Closure
- Environmental Monitoring & Maintenance

Emissions – Are EVs really better?

The US generates:

- 60% of its electricity from fossil fuels:
- 19% (828 TWh) from coal
- 39% (1,695 TWh) from gas
- 0.9% (40 TWh) from other fossil fuels
- Wind and solar 15% (644 TWh)
- Nuclear 18% (772 TWh)
- Hydro 5.9% (251 TWh)
- Bioenergy 1.2% (52 TWh)

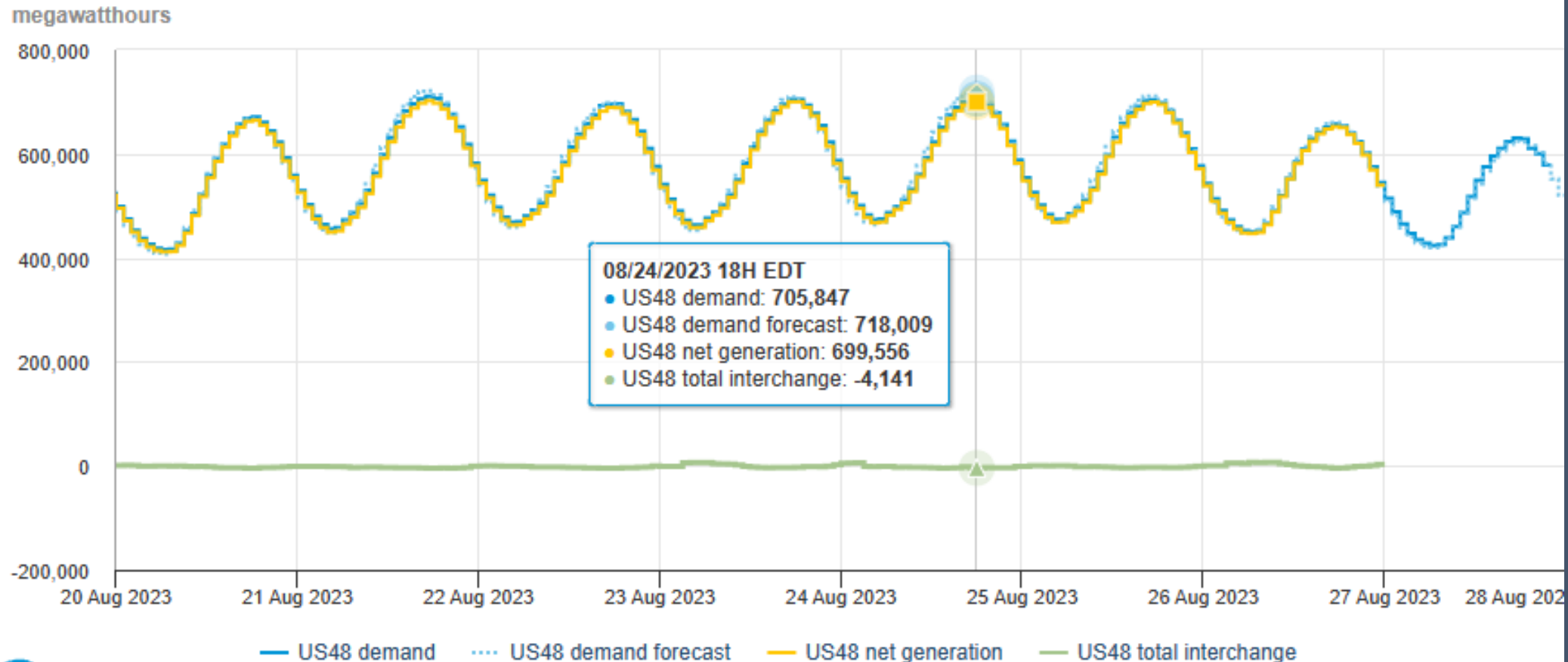
355 grams CO₂/mile (gas) or 407 grams CO₂/mile (diesel)

Vs

118 grams CO₂/mile

Power Grid – can it handle it?

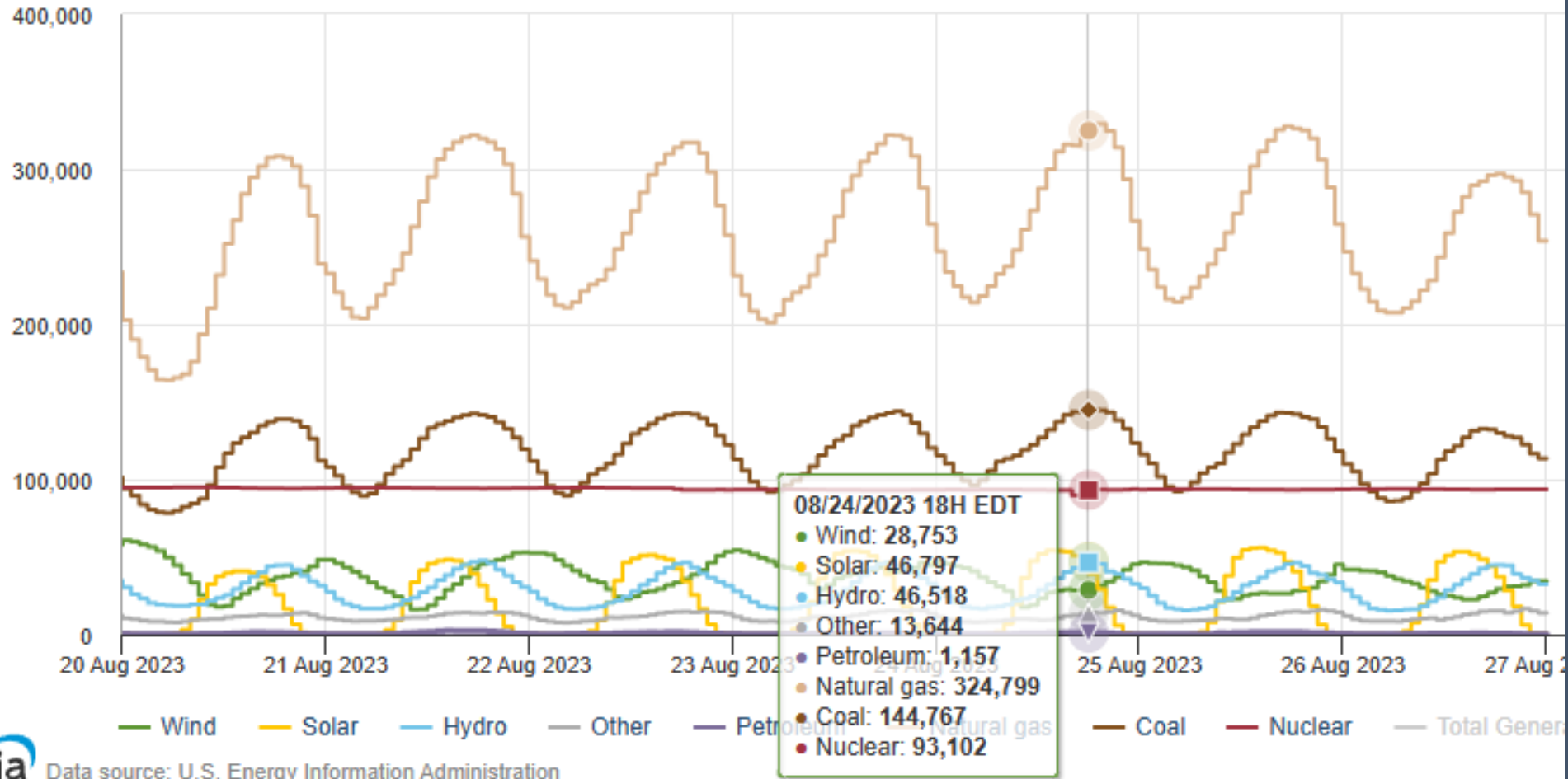
U.S. electricity overview (demand, forecast demand, net generation, and total interchange) 8/20/2023 – 8/27/2023, Eastern Time



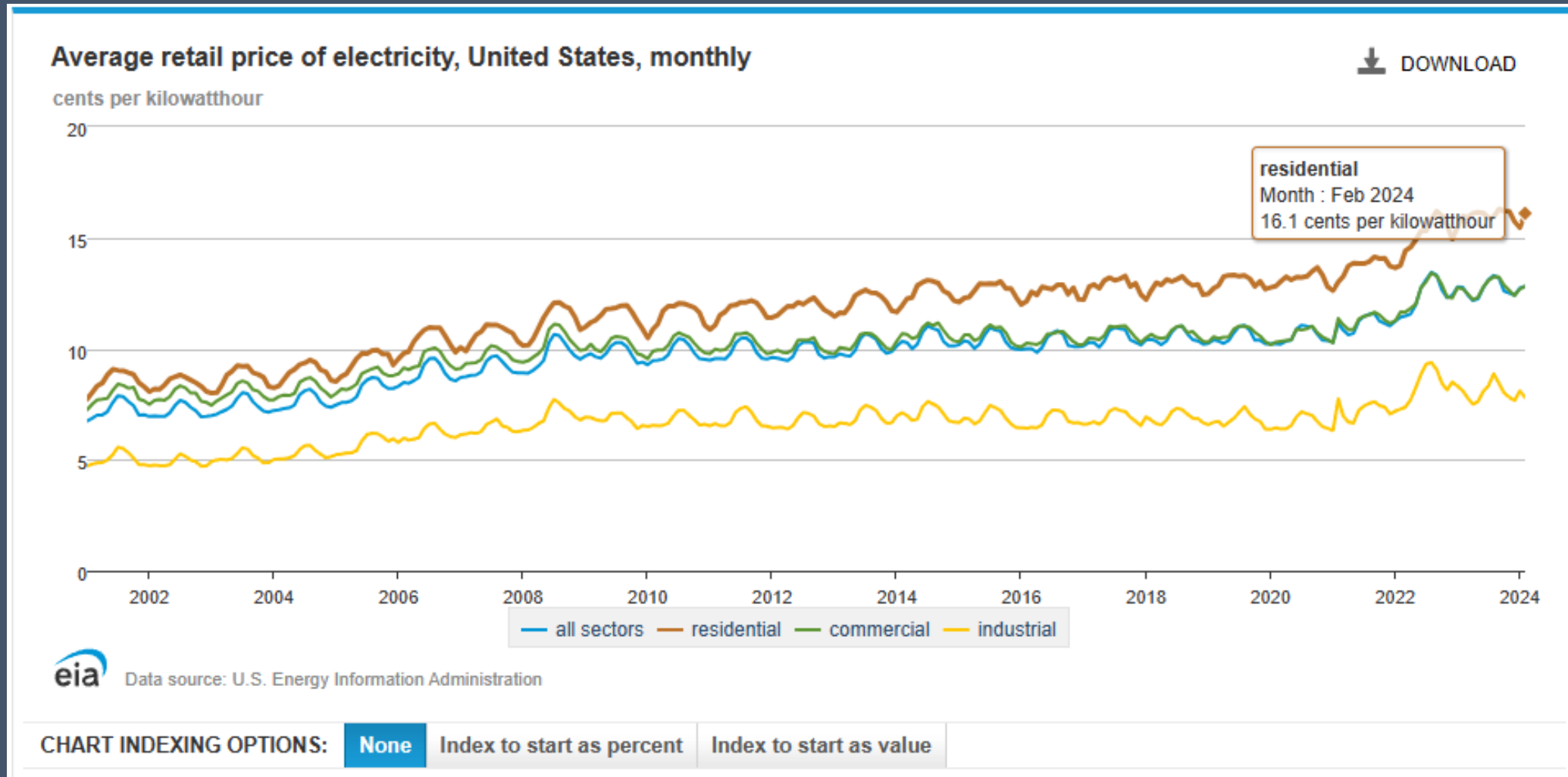
Power Grid

U.S. electricity generation by energy source 8/20/2023 – 8/27/2023, Eastern Time

megawatthours



Power Grid



electrek

Exclusives

Autos

Alt. Transport

Autonomy

Energy

Tesla Shop

TODAY

Hyundai confirms plans for a new electric car factory in the US

Fred Lambert · May, 11th 2022 12:17 pm PT

@FredericLambert

HYUNDAI

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Amid rumors of a new EV factory in Georgia, Hyundai confirms plans for the US, but it's not clear where yet.

EXPAND FULL STORY +

EVs are here. Try to keep up.

CHARGED

ELECTRIC VEHICLES MAGAZINE

HERNUL

MATERIAL SOLUTIONS FOR RELIABLE, POWERFUL CHARGE

2022 Ford F-150 Lightning First Drive: Ford's most valued model is now electric

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THE INFRASTRUCTURE

Roush Industries to assemble electric platforms for Bollinger Motors

Designing DC fast charging stations for next-gen EVs

ABB to supply AC and DC charging stations to Shell

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Basics You Should Know

The Battery and You

Batteries as Power Source

Great Resources

- [Ev-database.org](https://ev-database.org)
- Chargedevs.com
- Electrek.co
- Batteryuniversity.com
- Greencarreports.com
- Insideevs.com
- evspecifications.com