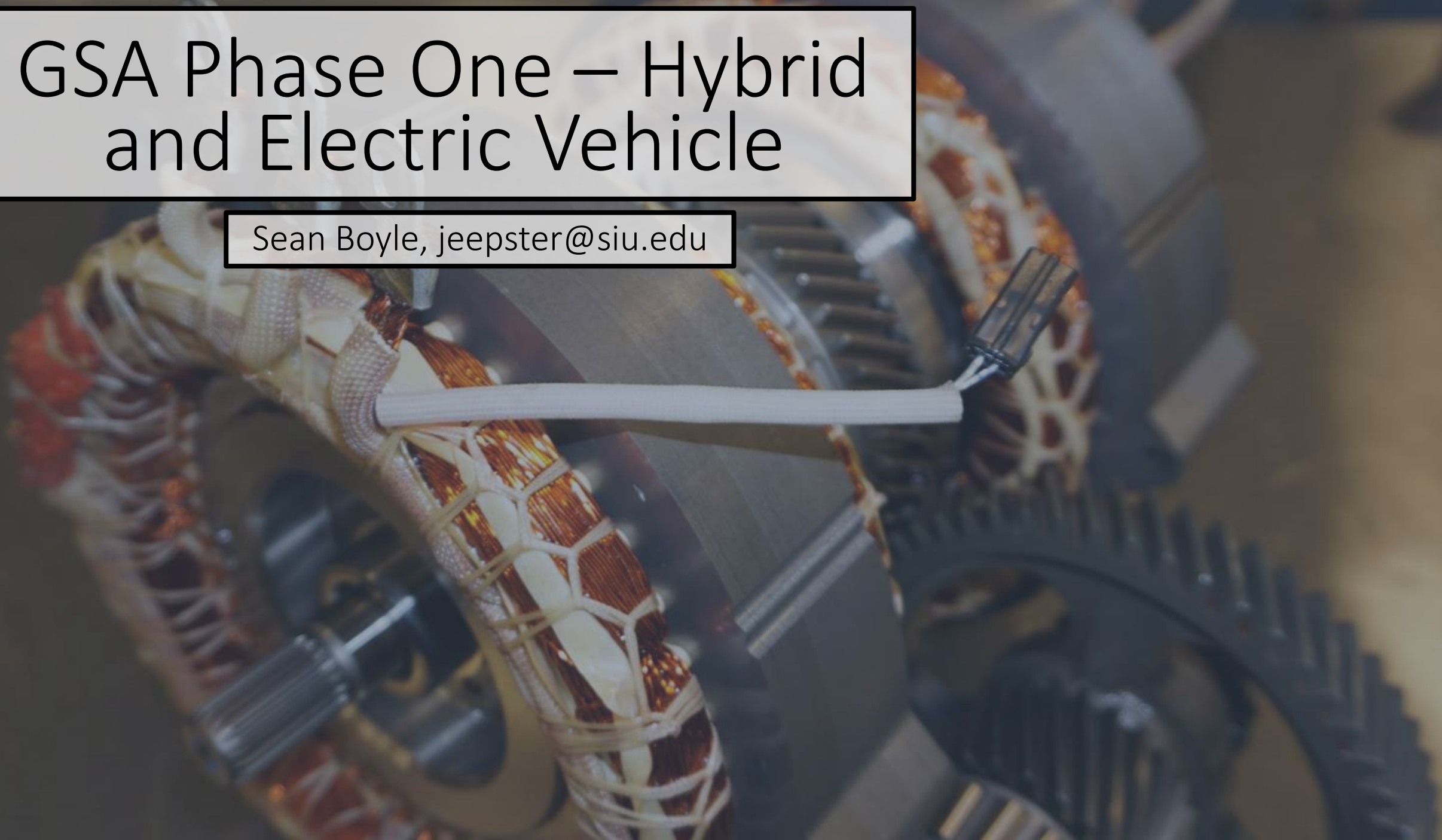


GSA Phase One – Hybrid and Electric Vehicle

Sean Boyle, jeepster@siu.edu



Questions to answer:

- What's the benefit of a hybrid or an EV?
- How are xEVs configured?
 - Hybrid
 - Parallel
 - Series
 - Series/Parallel
 - Full hybrid vs. mild hybrid
 - Plug-in Hybrid
 - EV
- What makes them different?
 - Engine
 - Electric motor
 - Inverter Technology
 - Cooling system
 - Battery
 - High voltage
 - Low voltage
 - Charging
 - Braking System
 - Regenerative Braking
 - AC/Heating System

Questions to answer:

- What are some service considerations?
 - Hybrids engines are similar to conventional vehicles
 - Oil changes
 - Spark plugs
 - Air filter
 - Cooling system
 - Brake systems
 - Tire rotation/Balancing
 - Cooling system maintenance
- What are some usage considerations?
 - Towing requirements
 - Charging requirements
- Practicality
- Management
- Recycling

Introduction

- xEV
 - 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



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



General xEV Characteristics

- BEV
 - Driver needs to charge to maintain range
 - Home charging preferred
 - Range issues
 - Long drives
 - Cold weather

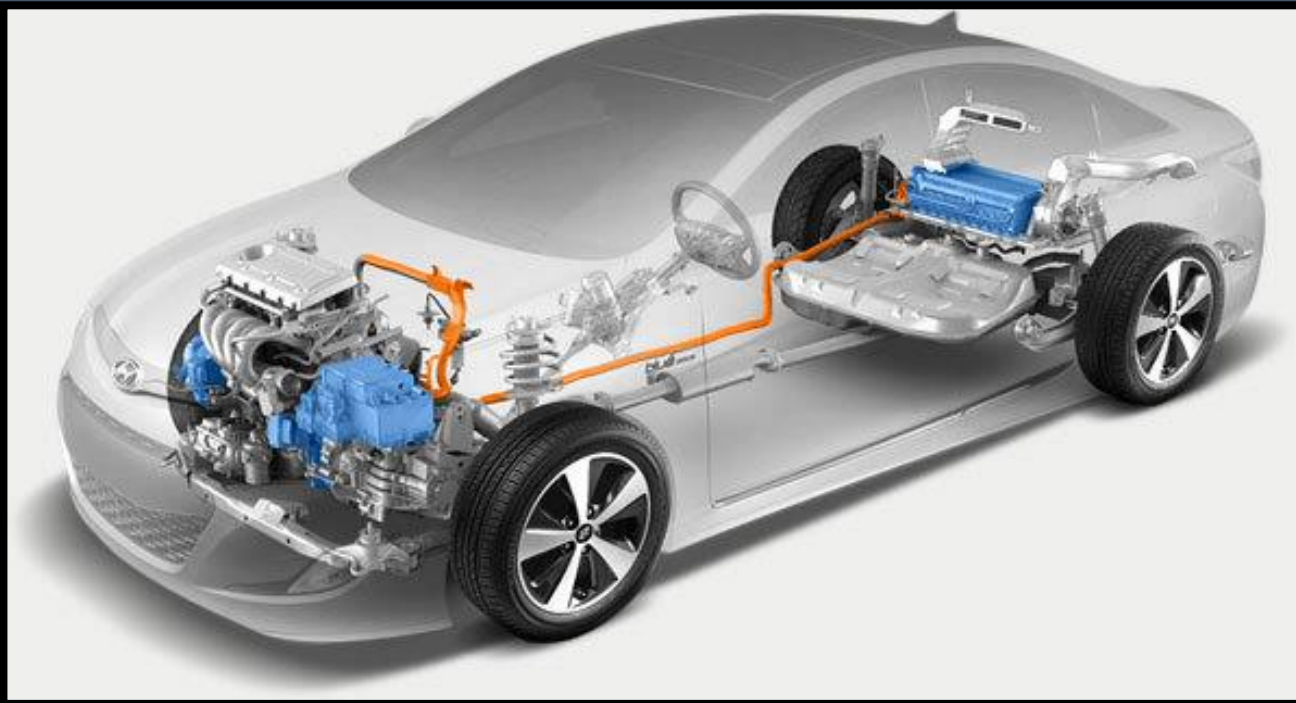


xEV – what makes them different from a traditional ICE vehicle?

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

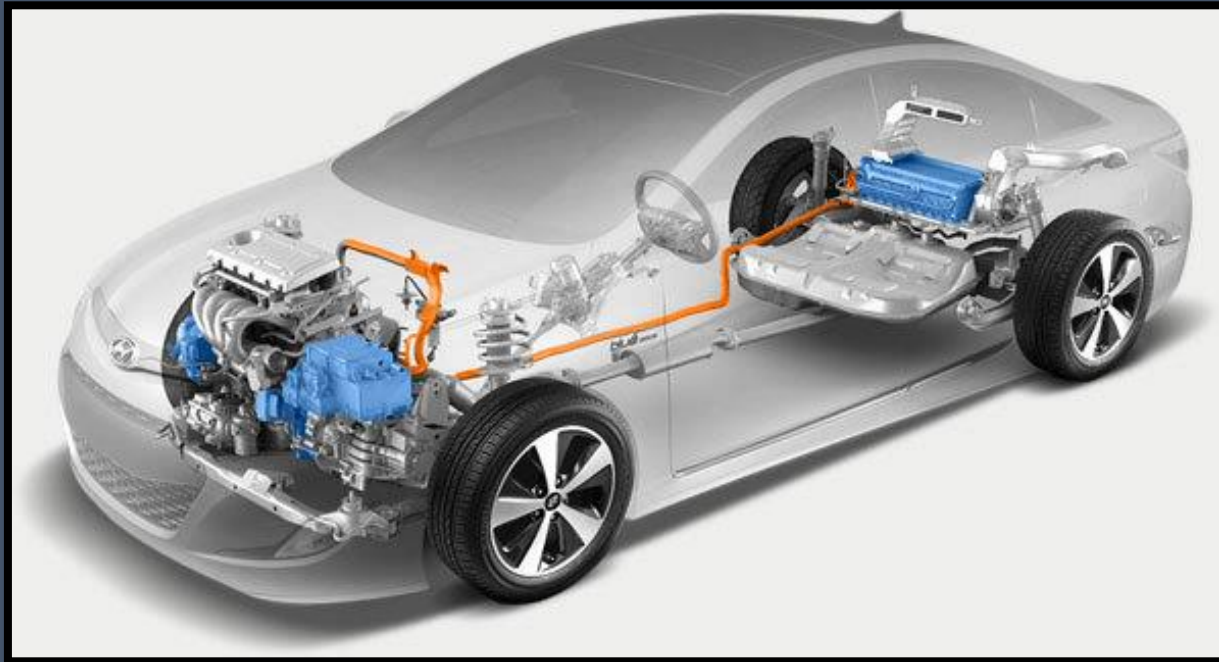
xEV – Regeneration

- 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



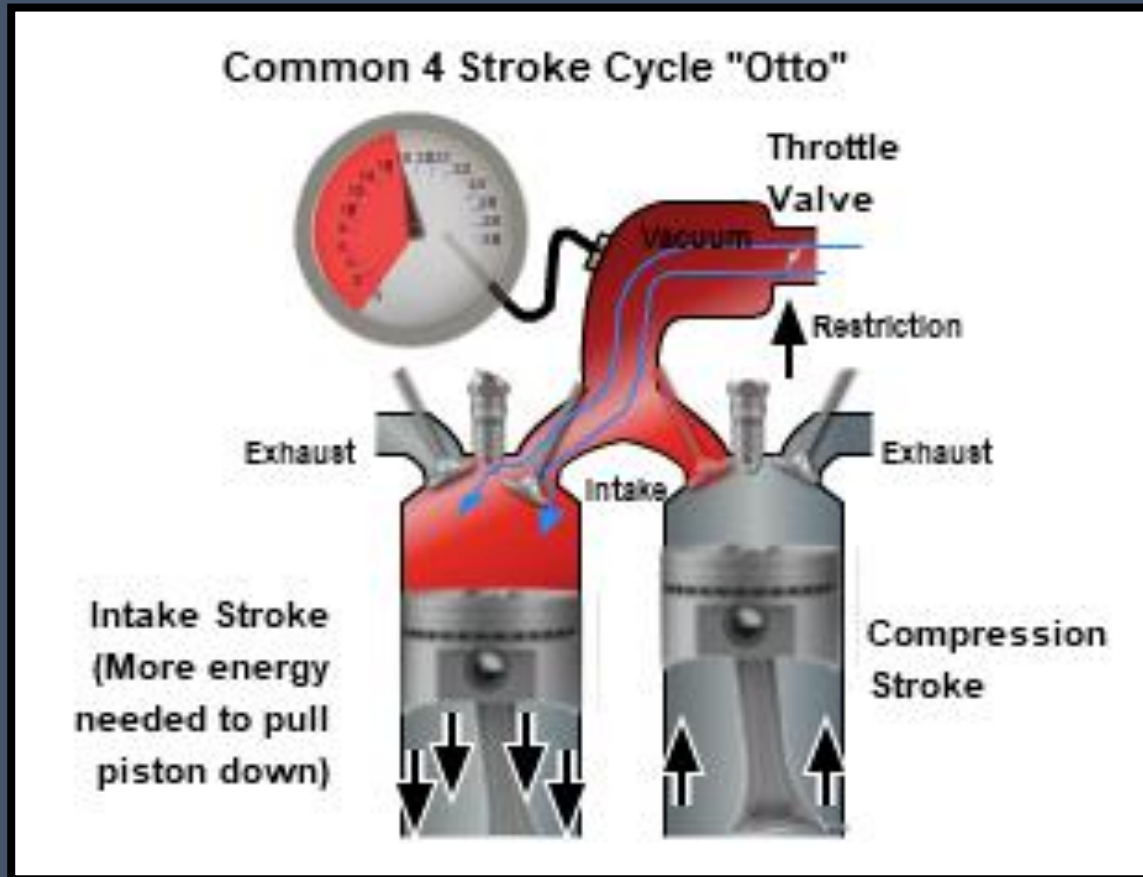
xEV – Efficient Engine (HEV/PHEV)

- Belt driving vs. full electric accessories
 - On some, no belt driven alternator
 - On some, no belt driven water pump
 - On some, no belt driven air conditioner
- Electric power steering



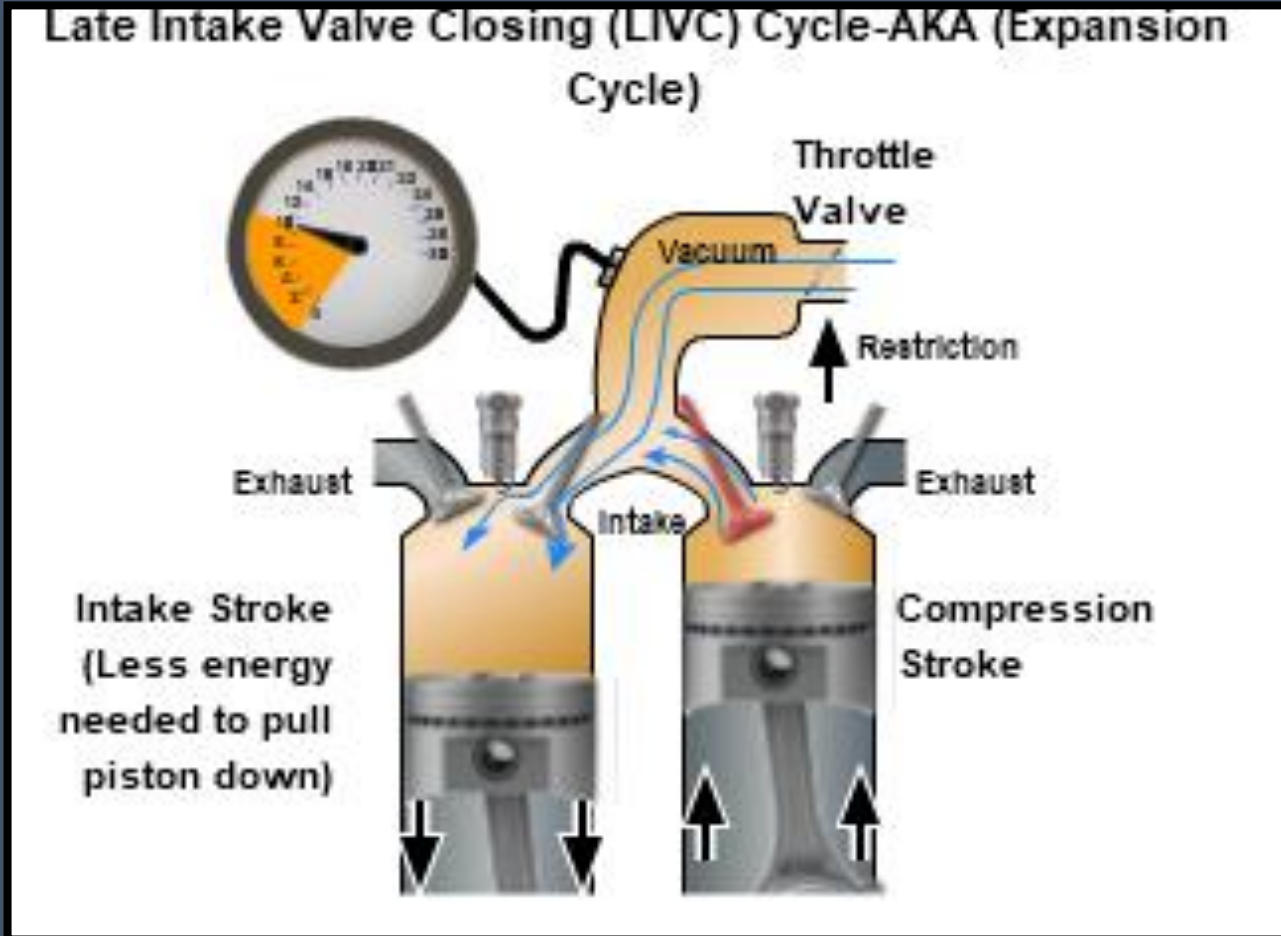
xEV – Efficient Engine (HEV/PHEV)

- Atkinson style engine leaves the intake open further into the compression stroke
- Low low-rpm torque, but high efficiency



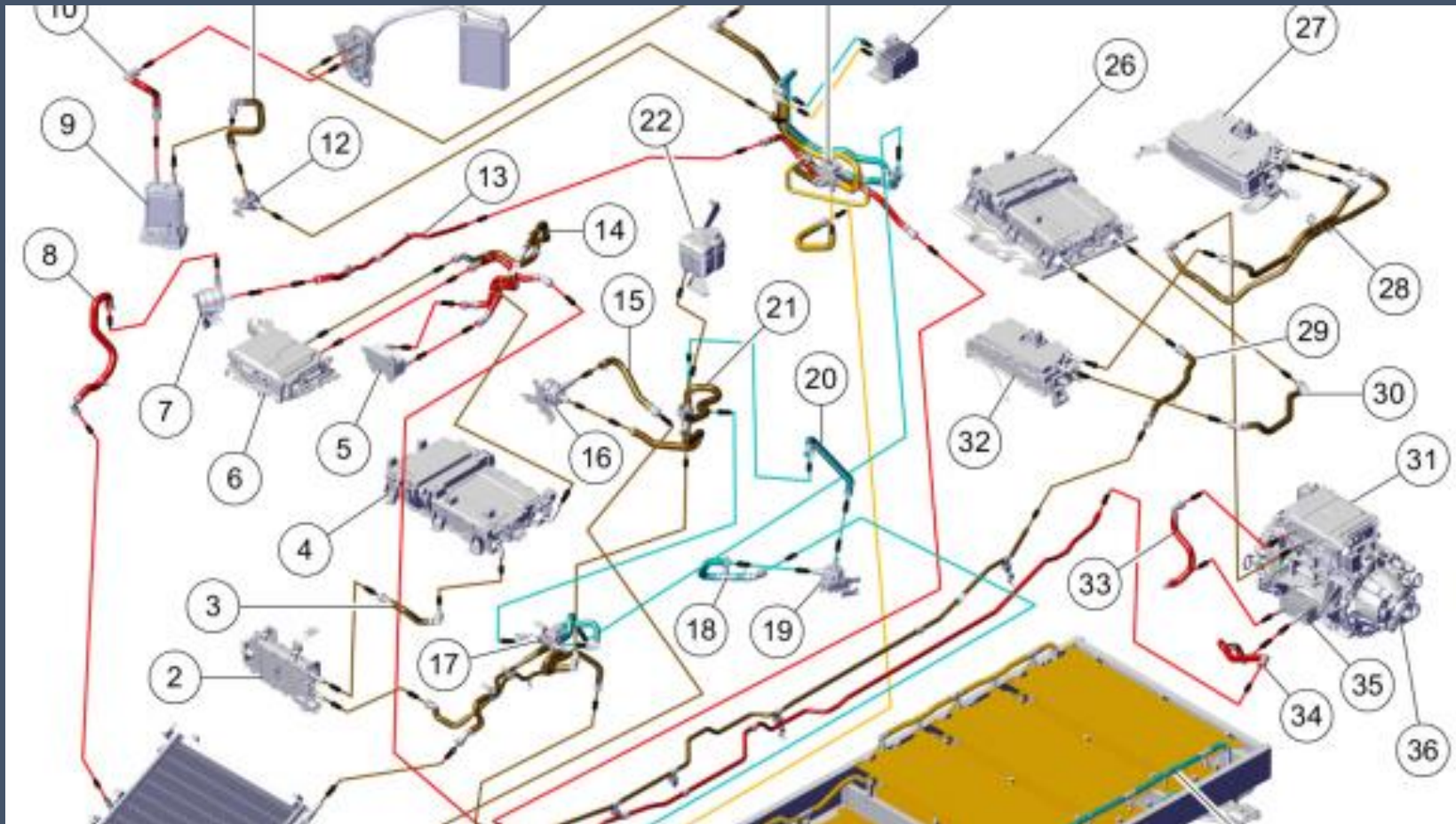
xEV – Efficient Engine (HEV/PHEV)

- Atkinson engine will have less intake vacuum



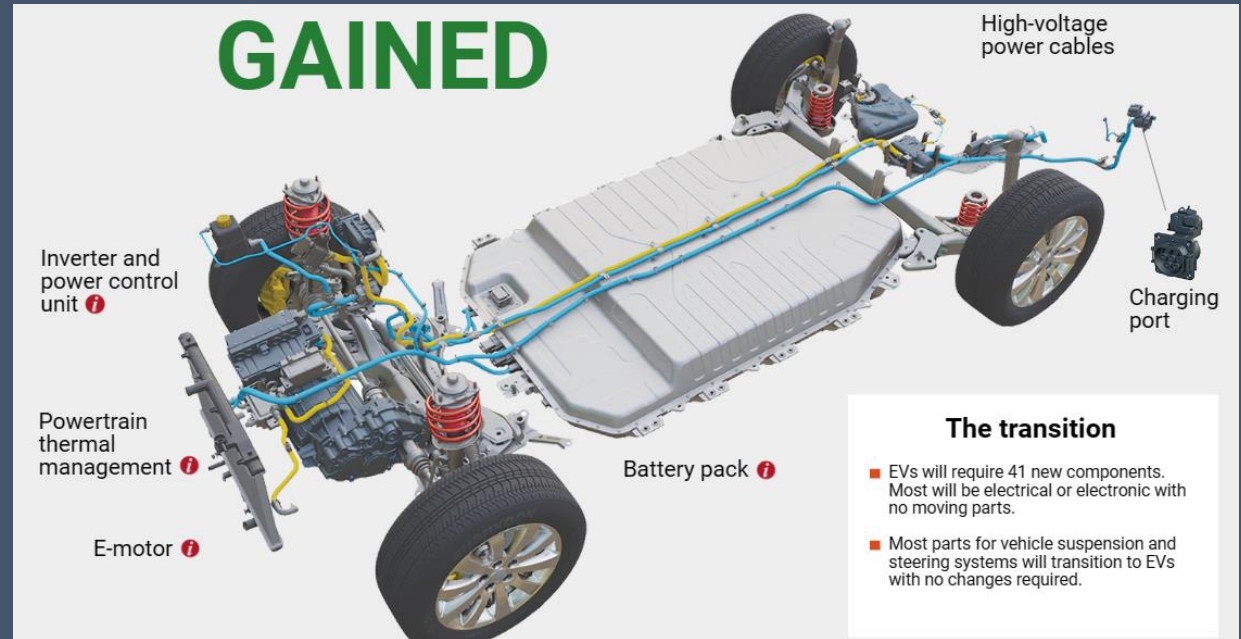
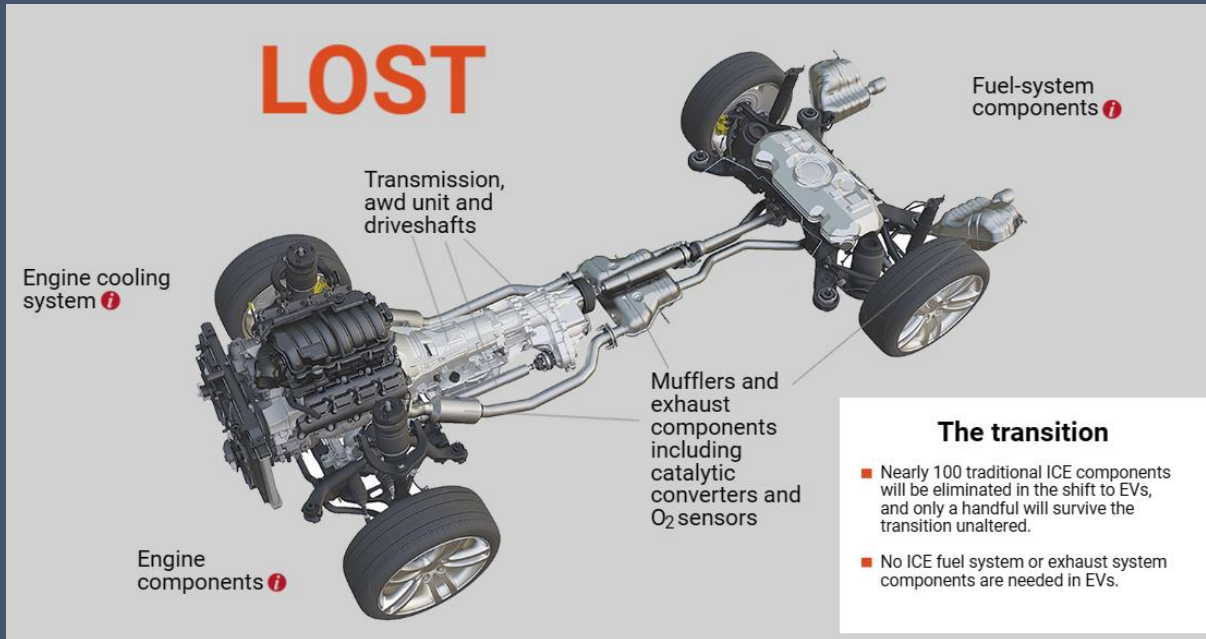
xEV – Heating and cooling

- Heating and cooling is much more complex in an xEV

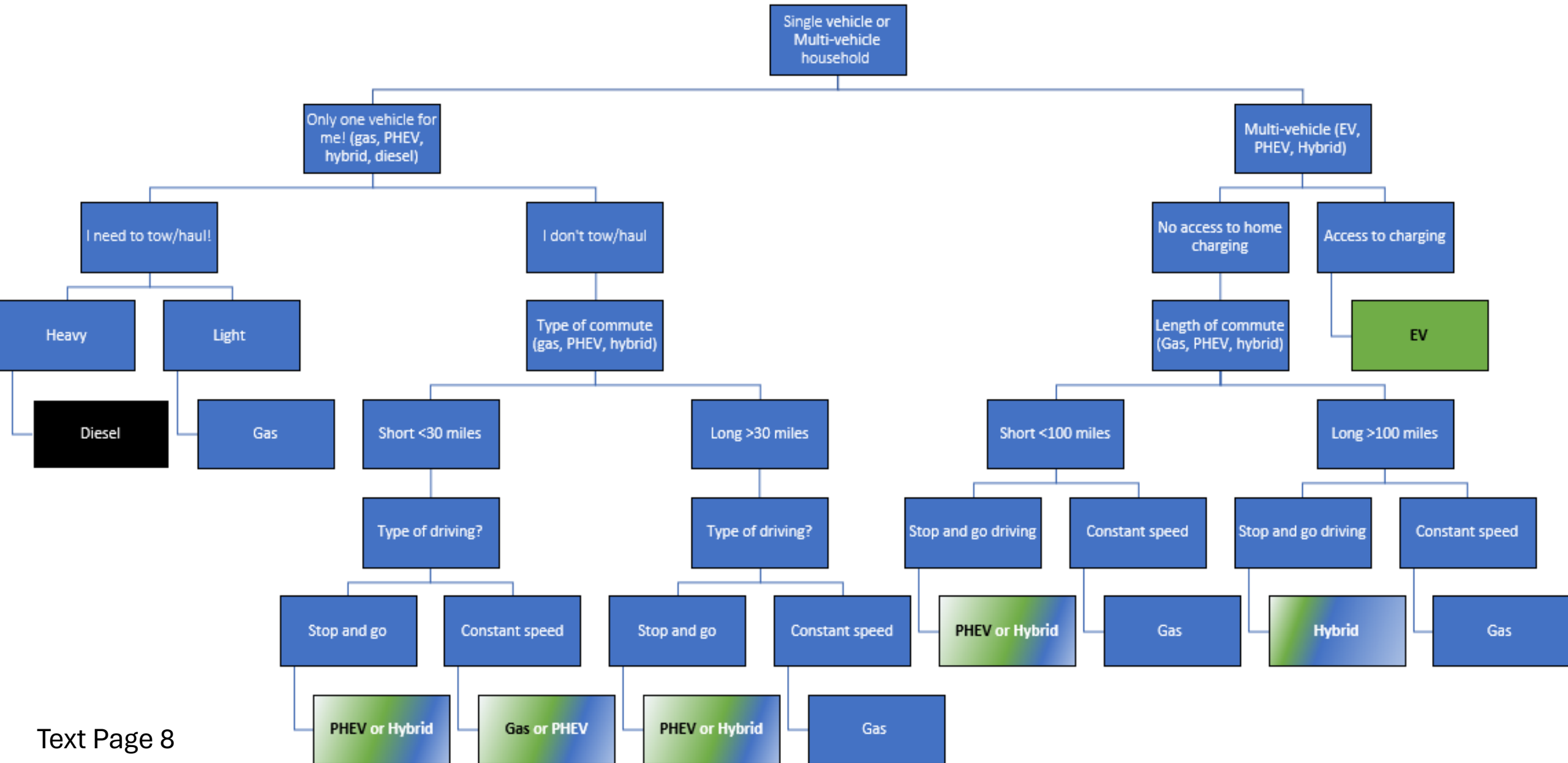


xEV – Parts reduction

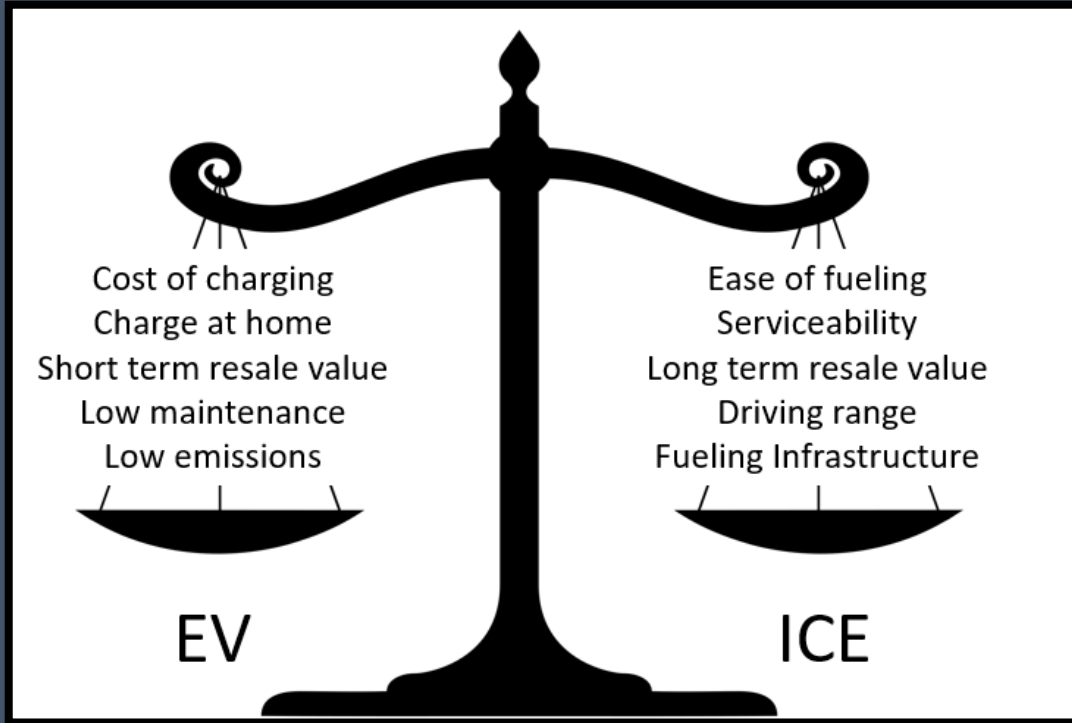
- Estimated about 15k fewer parts!



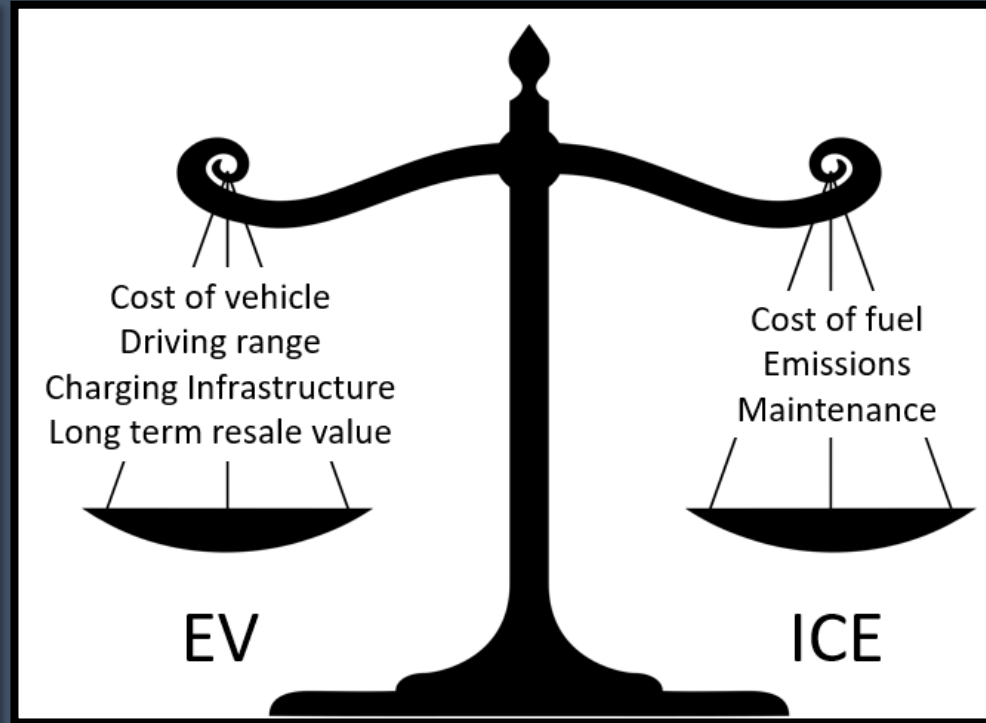
What's best for me?



What's best for me?



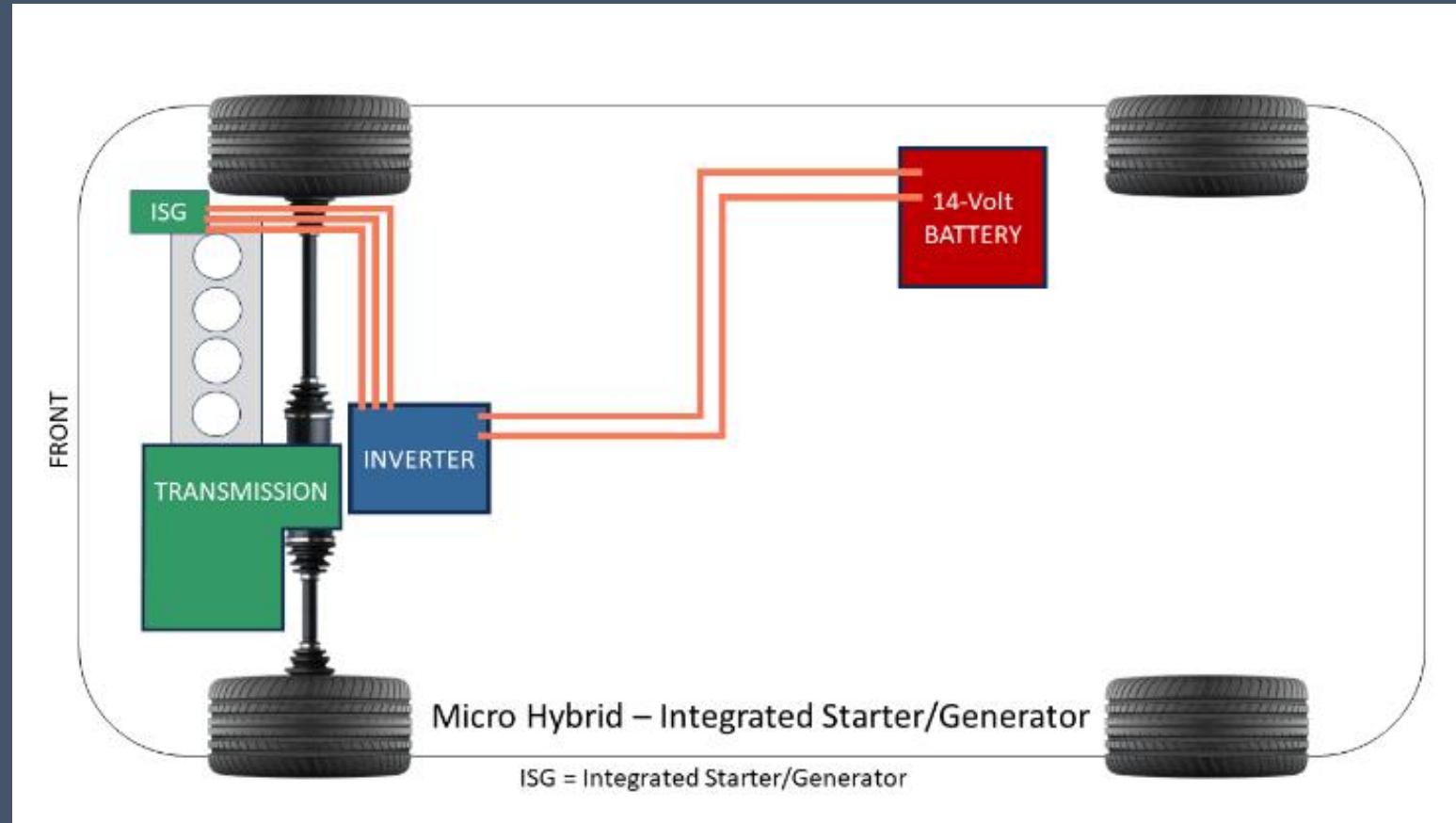
EV Advantages



EV Disadvantages

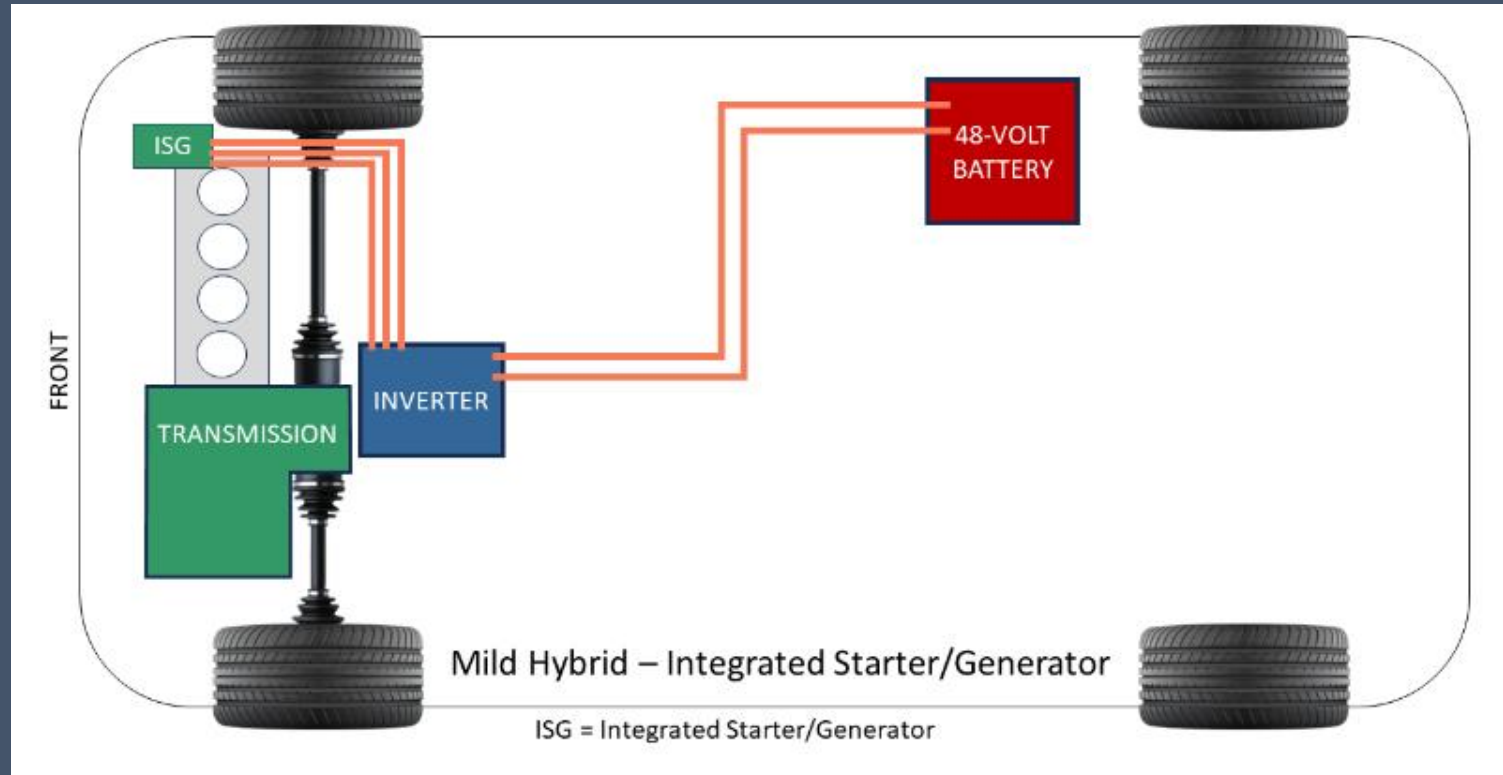
HEV Classifications

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



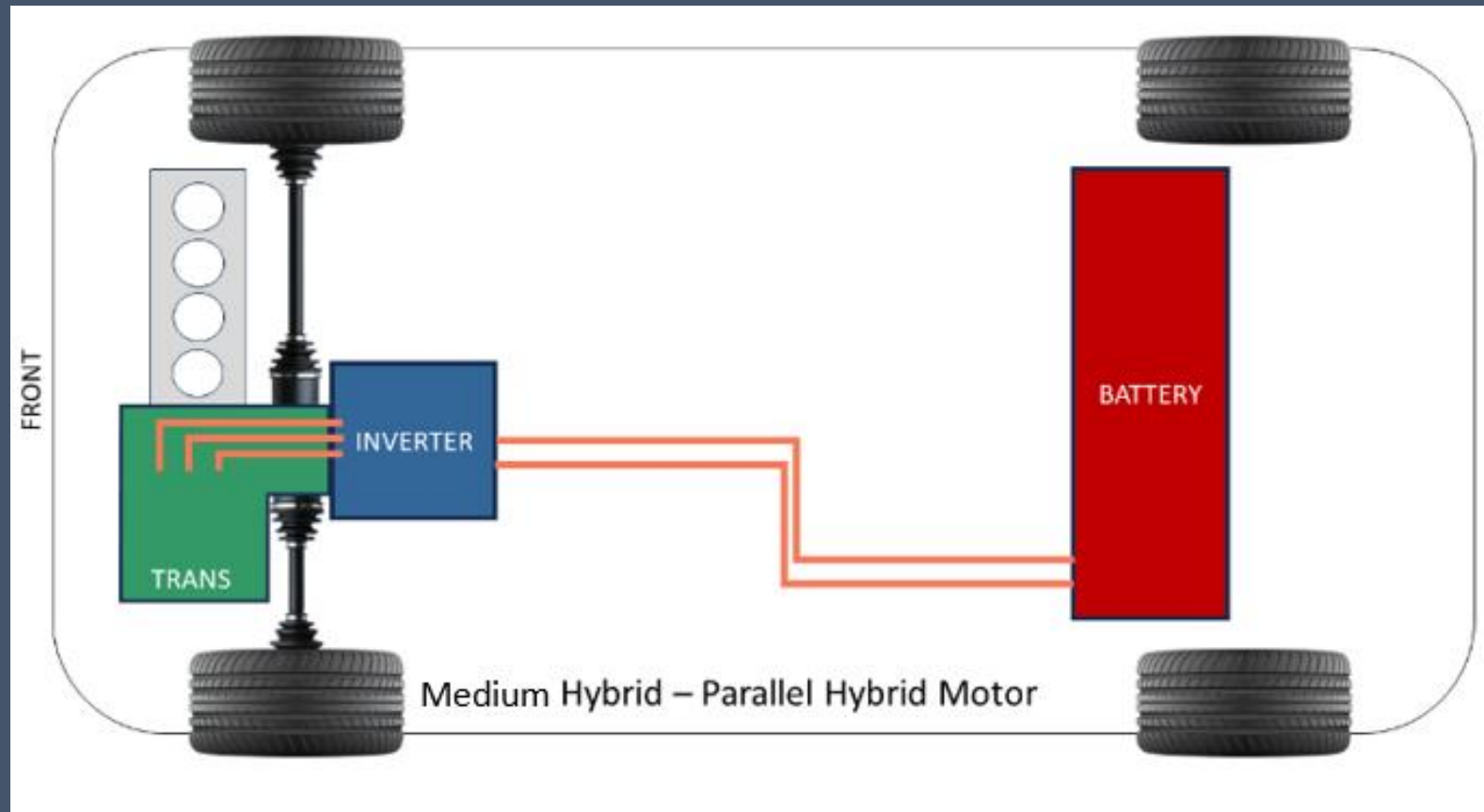
HEV Classifications

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



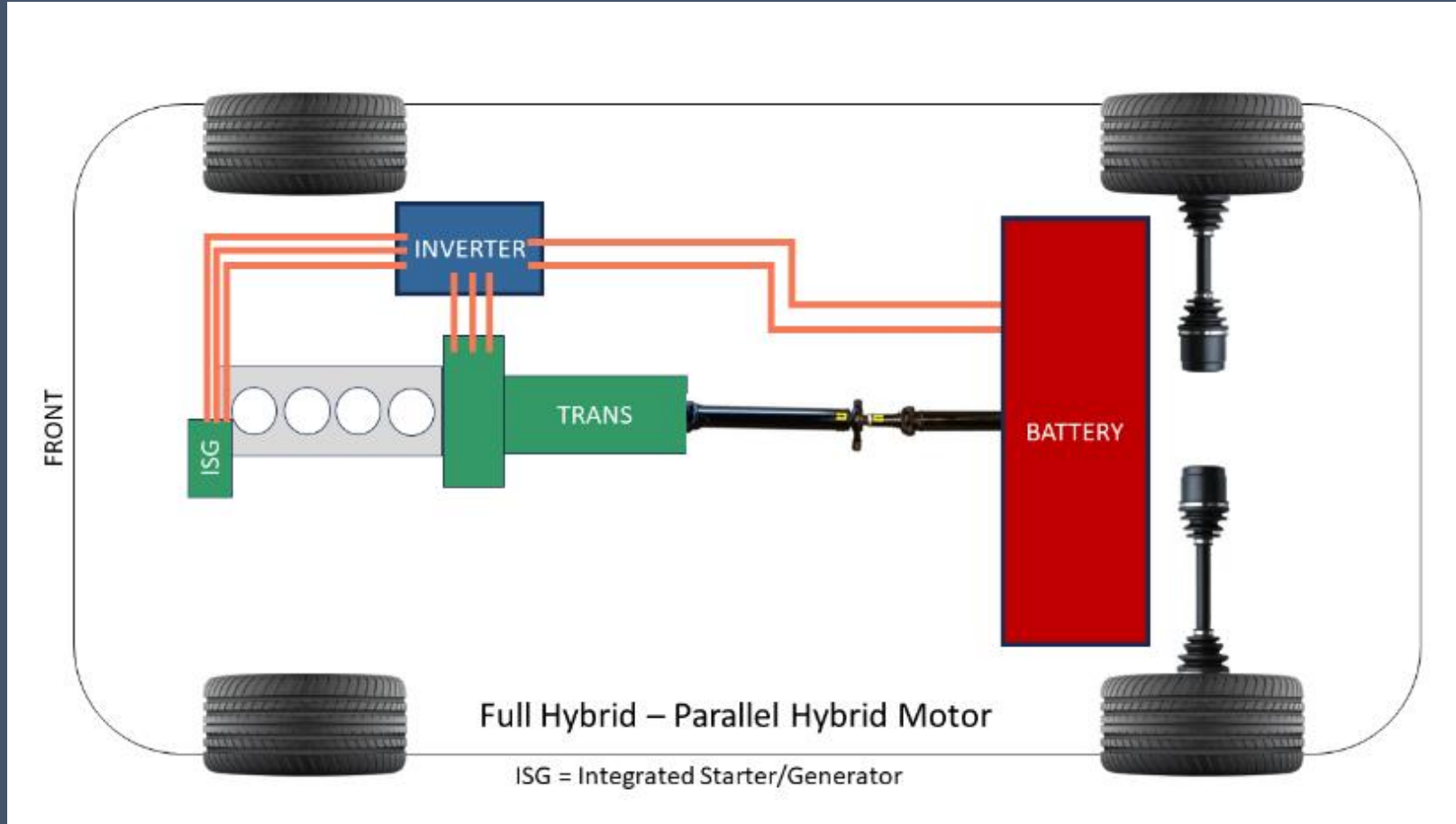
HEV Classifications

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



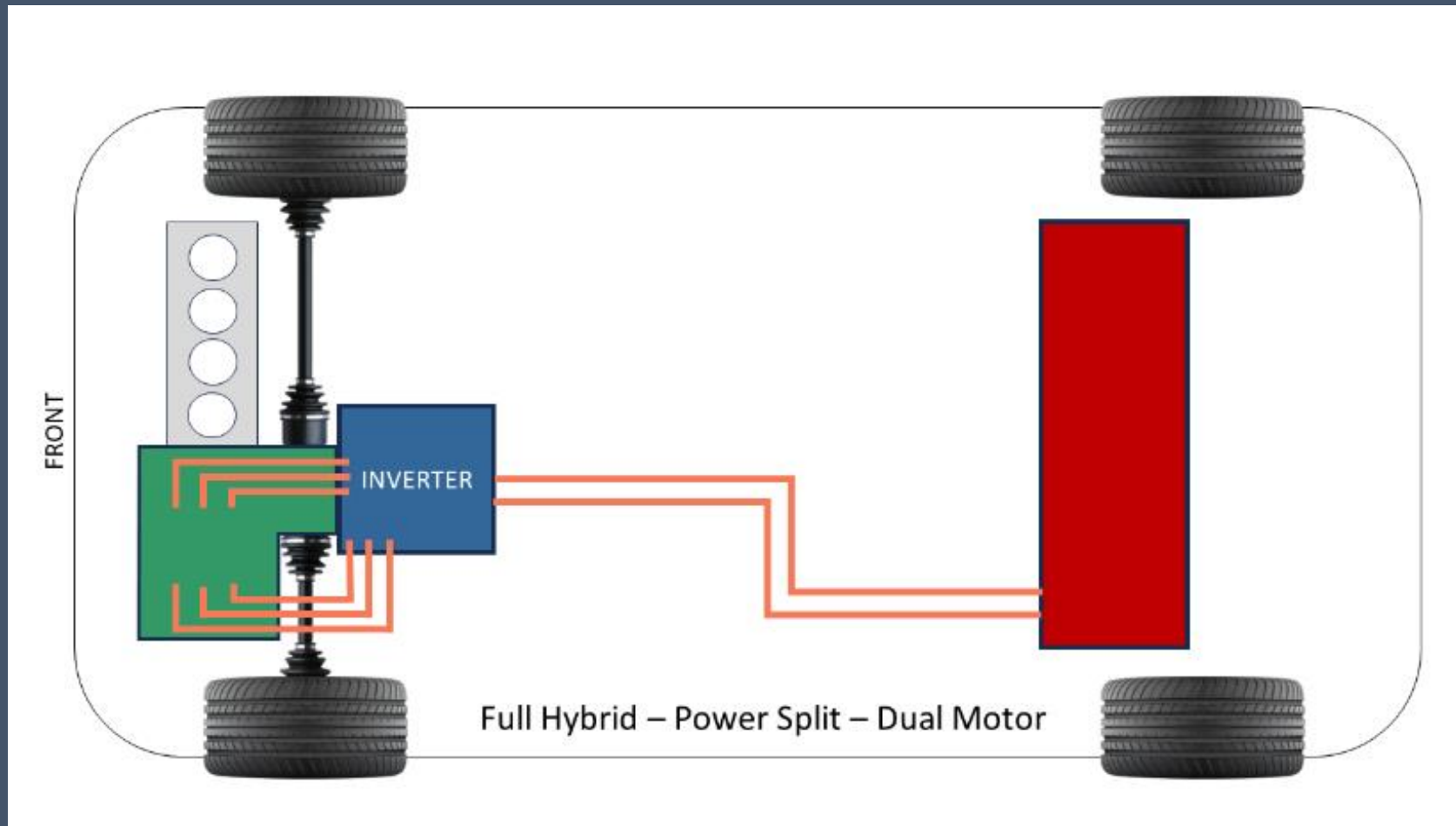
HEV Classifications

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



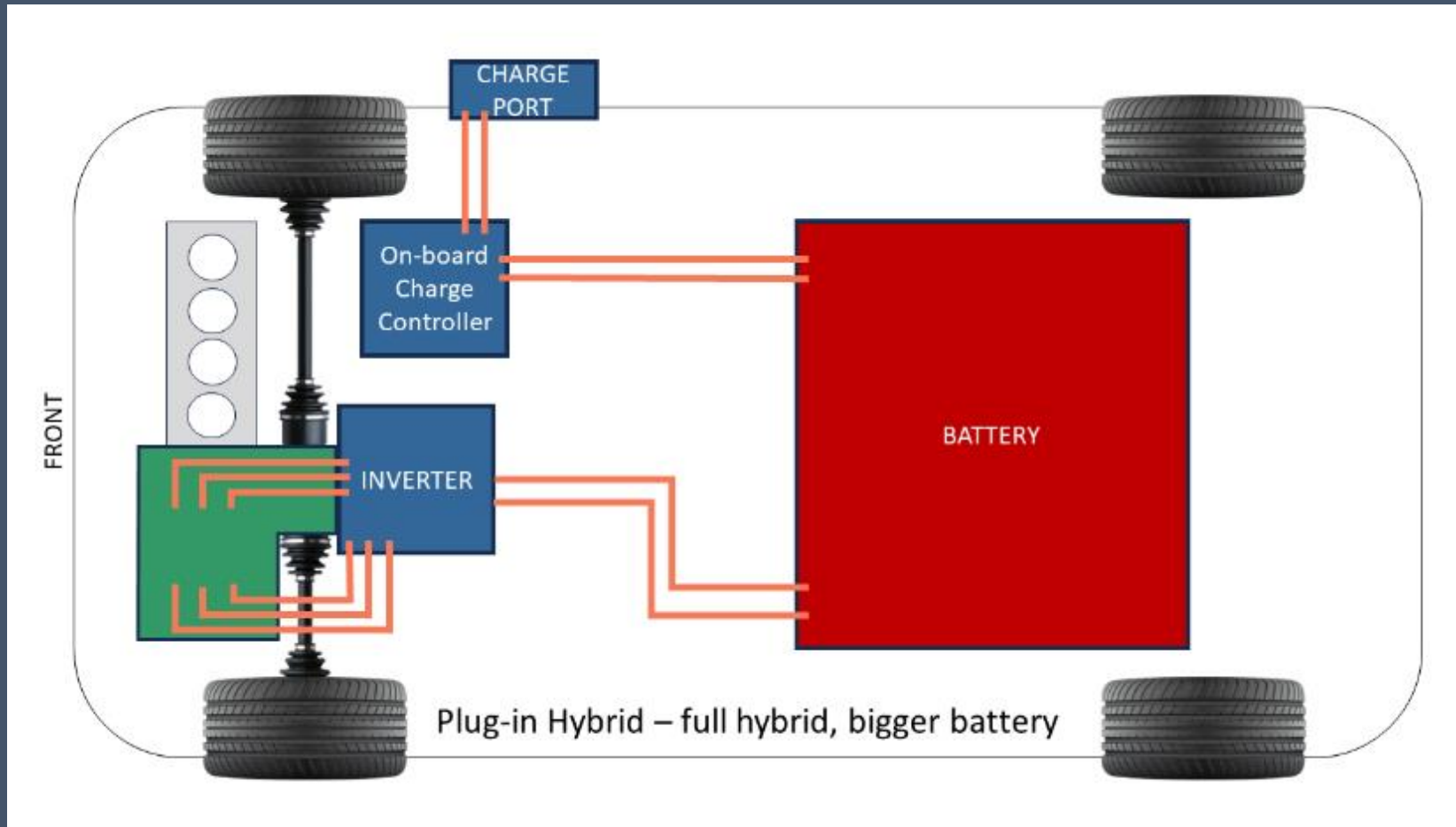
HEV Classifications

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



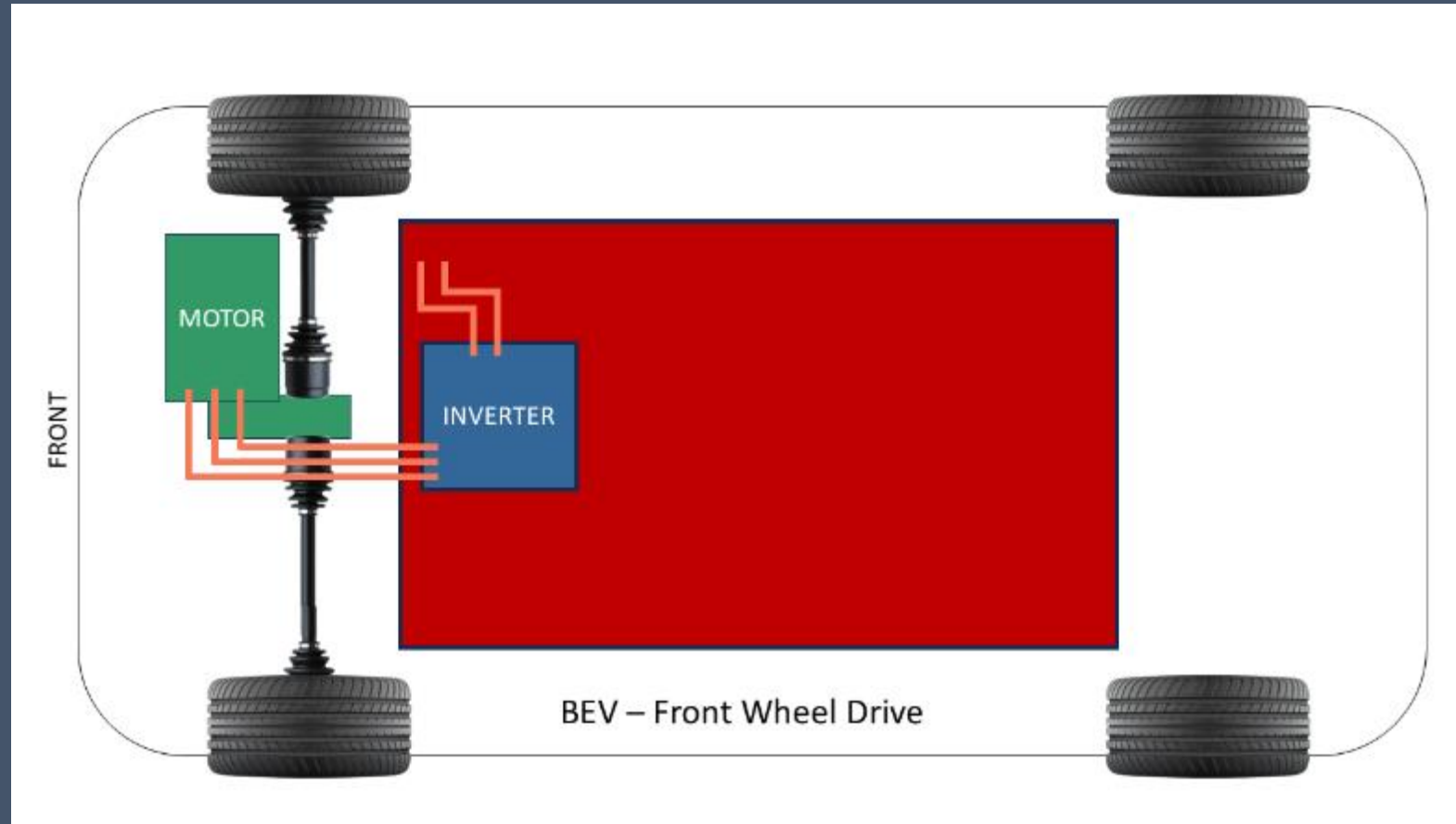
PHEV Classifications

- PHEV



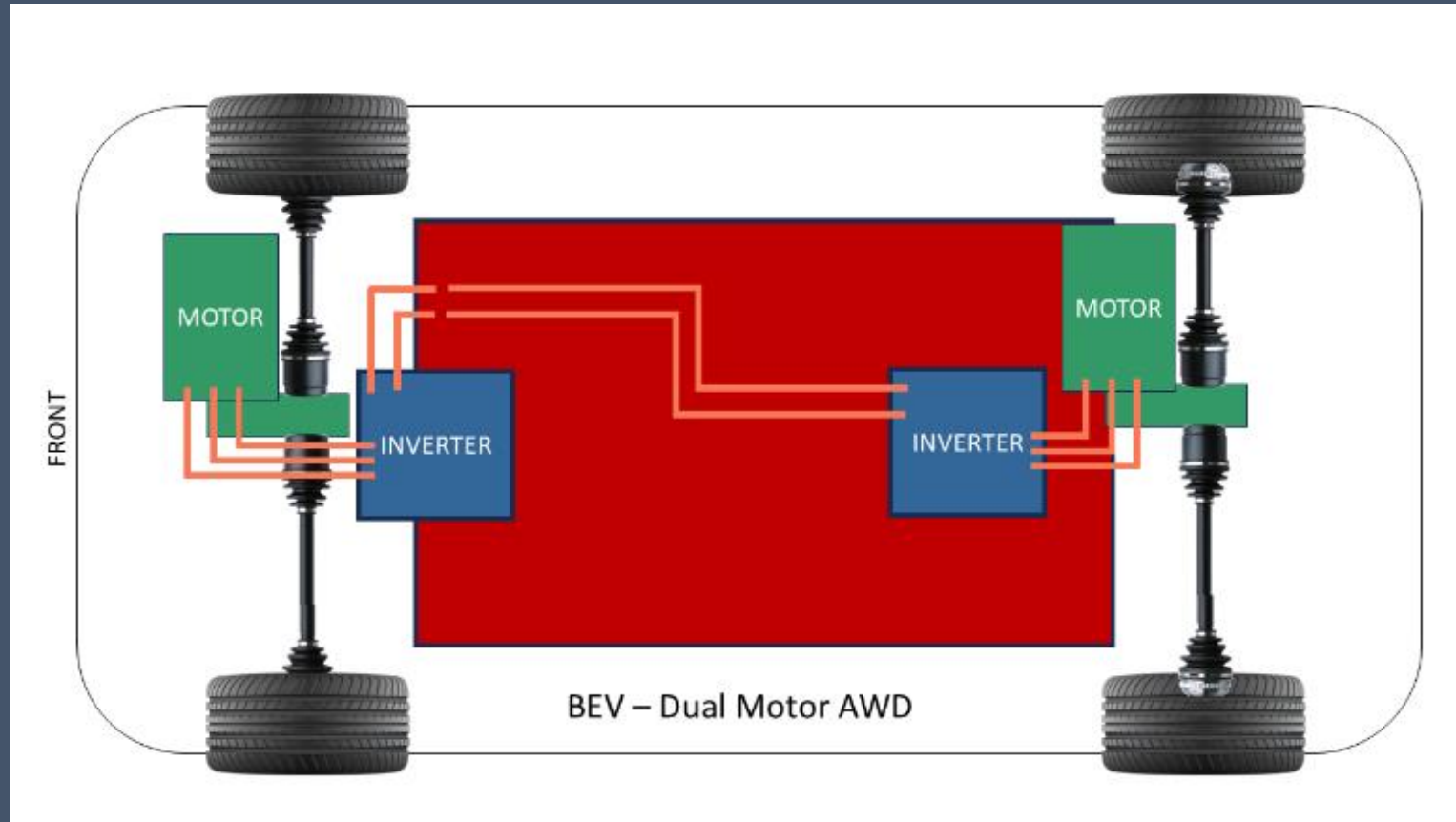
BEV Classifications

- BEV



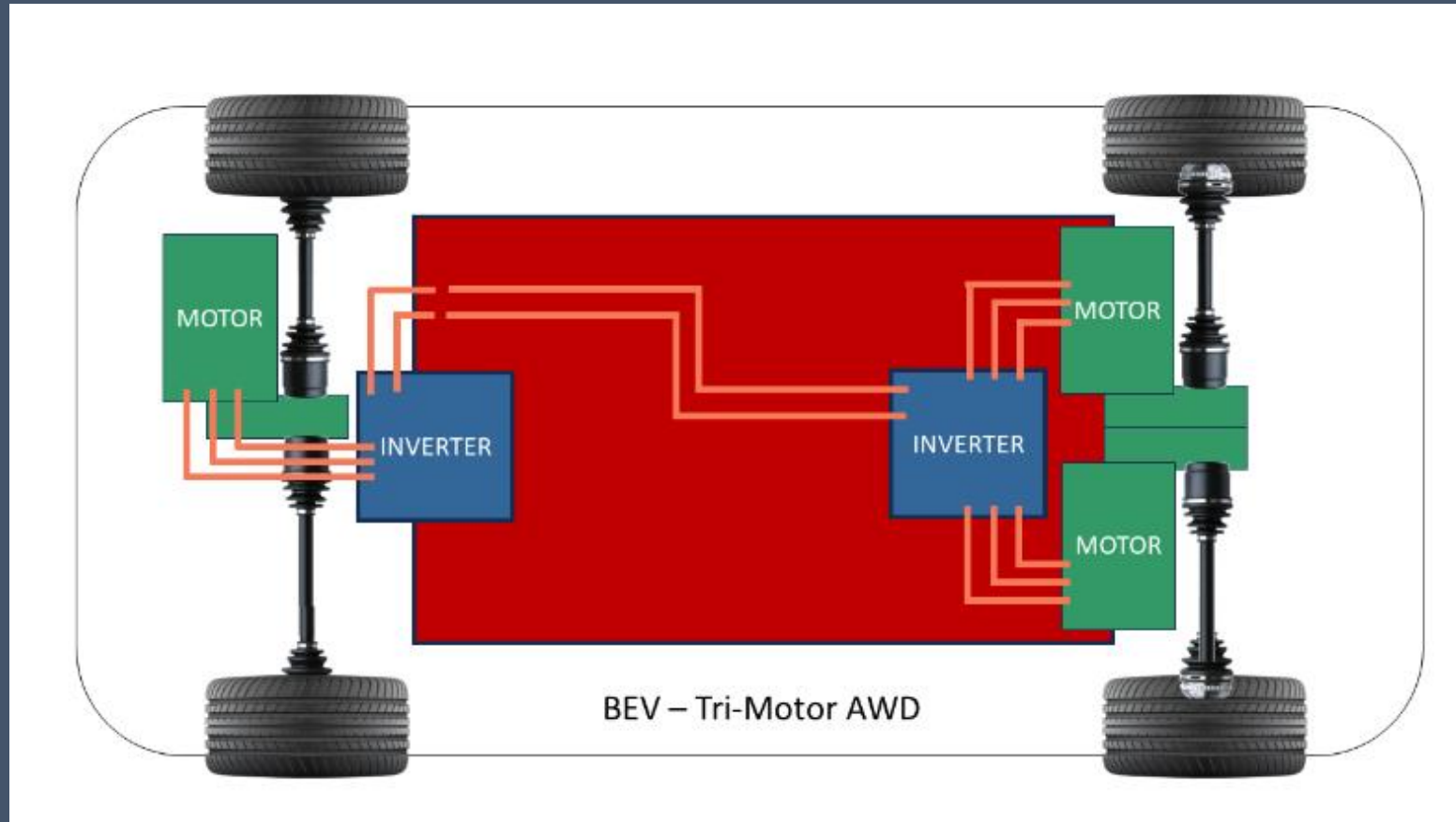
BEV Classifications

- BEV



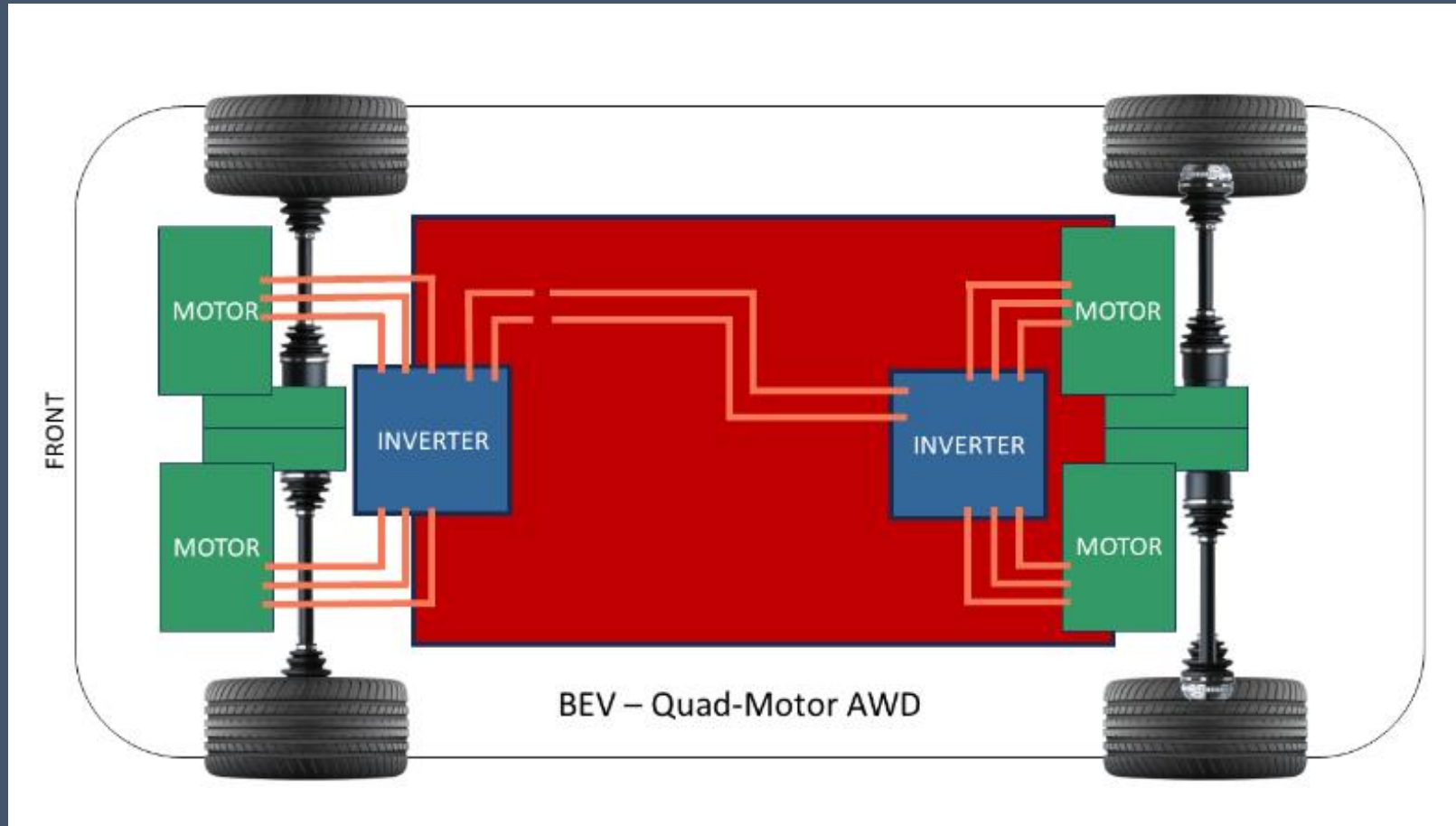
BEV Classifications

- BEV



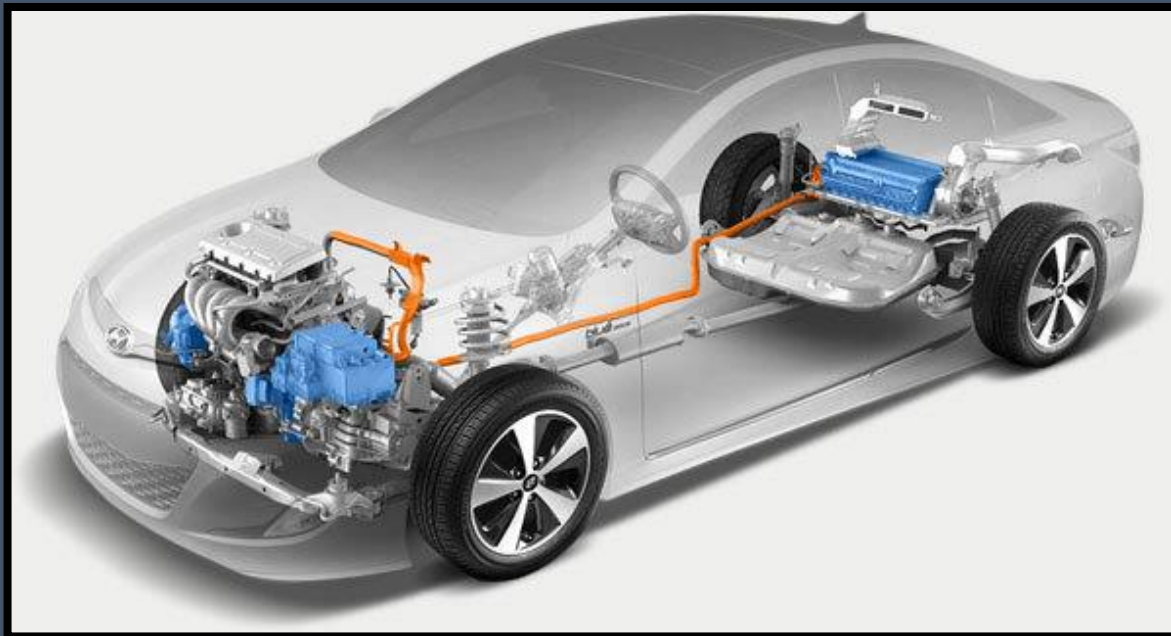
BEV Classifications

- BEV



HEV

- Perfect for customers who:
 - Have long work commutes
 - Sole vehicle
 - Stop and go traffic



Plug-in Hybrid (PHEV)

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

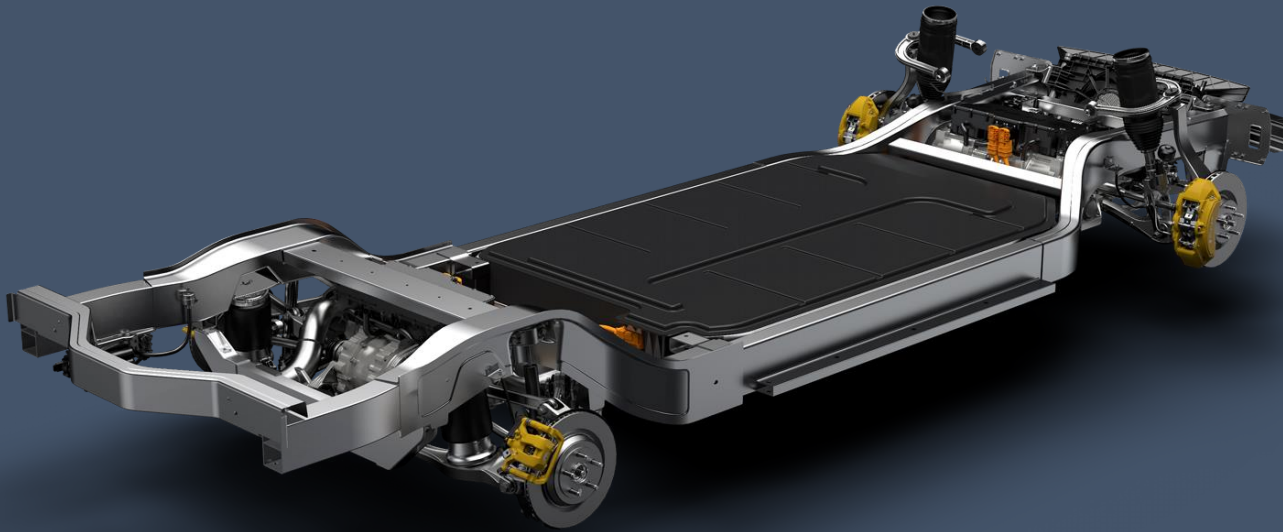


Volt test drive



Full Electric

- 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

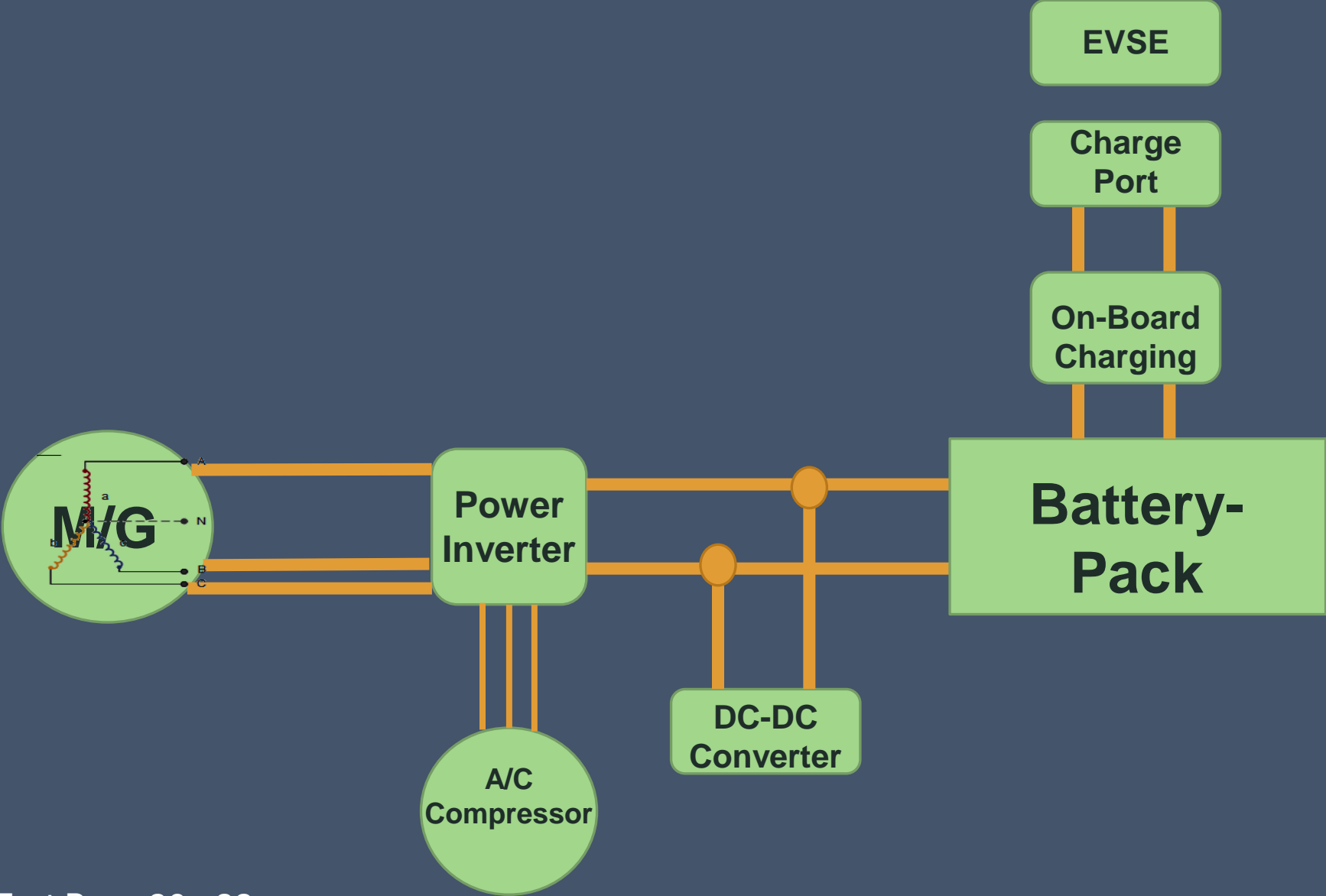


xEV High-level Overview

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

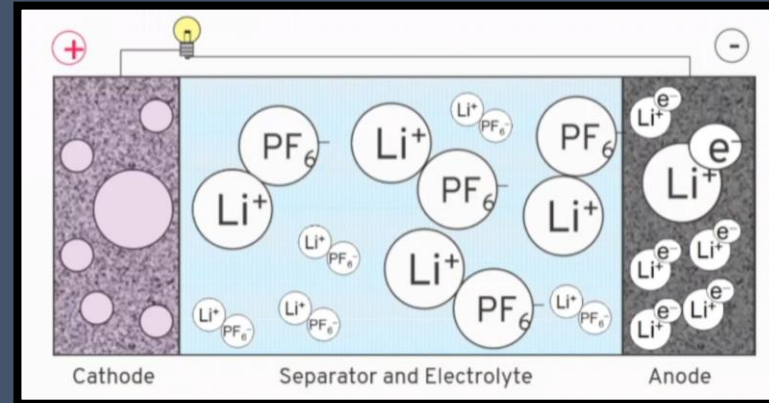


xEV Batteries

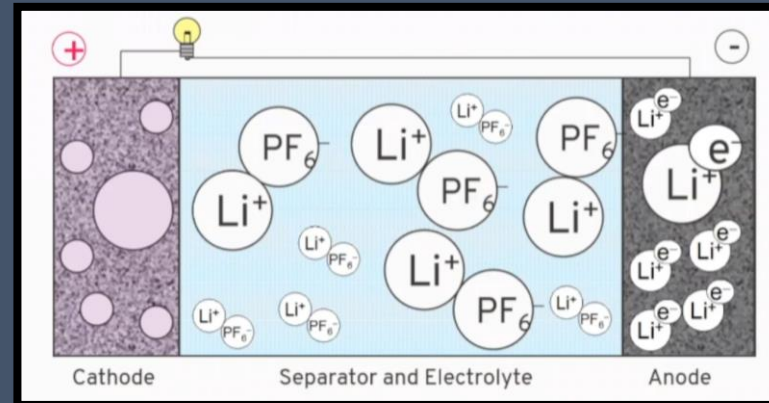
The image shows the internal components of an xEV battery pack. On the right, there are several battery modules housed in a metal frame, with red insulation visible. A network of bright orange high-voltage cables is routed across the top and middle of the pack. A central Panasonic battery cell is visible, with a label that includes the model number AEV3056A and a date of 2013/10/10. The entire assembly is mounted within a grey metal chassis.

High voltage battery

- Charging

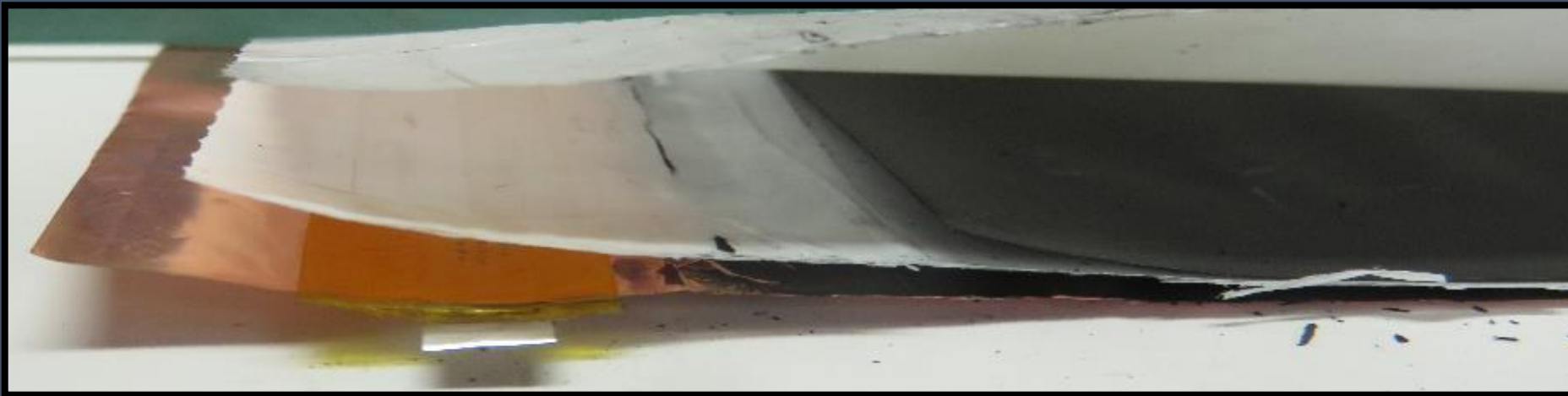


- Discharging



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

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 2022 Ford F-150 Selected Attributes

Select Dealer

High Voltage Battery And Mounting

Attach Illustration Print

Selected Parts

Show Other Parts In Illustration

Array Assembly - Traction Battery
 List Price: \$4,196.47
 Available: 0
 From: 03/14/2022 ; Less Engine, Traction Battery #1 * Array Kit
 Callout: 10D672B - Add To Selected
 CALL WHOLESALE PARTS FOR COMPETITIVE PRICING ON ENGINES, TRANSMISSIONS AND TRANSFER CASES!

Cover
 List Price: \$0.00
 Available: --
 From: 03/14/2022 ; Less Engine, Traction Battery #1 * Array Kit
 Callout: 10A687A - Add To Selected

Cover
 List Price: \$0.00
 Available: --
 From: 03/14/2022 ; Less Engine, Traction Battery #1 * Array Kit
 Callout: 10A687B - Add To Selected

Price: \$4,316.07
 Qty Req: 1 Add To Cart

ED MORSE FORD 2022 Ford F-150 Selected Attributes

Select Dealer

High Voltage Battery And Mounting

Attach Illustration Print

Selected Parts

Battery
 List Price: \$34,393.48
 Available: 0
 From: 03/14/2022 ; Less Engine, Traction Battery #1 * Traction Battery
 Callout: 10B759
 CALL WHOLESALE PARTS FOR COMPETITIVE PRICING ON ENGINES, TRANSMISSIONS AND TRANSFER CASES!

Price: \$38,286.82
 Qty Req: 1 Add To Cart

Battery
 List Price: \$46,907.06
 Available: 0
 From: 03/14/2022 ; Less Engine, Traction Battery #2 * Traction Battery
 Callout: 10B759
 CALL WHOLESALE PARTS FOR COMPETITIVE PRICING ON ENGINES, TRANSMISSIONS AND TRANSFER CASES!

Price: \$48,243.91
 Qty Req: 1 Add To Cart

Show Other Parts In Illustration

2022 Ford Mach-e

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: Add To Cart

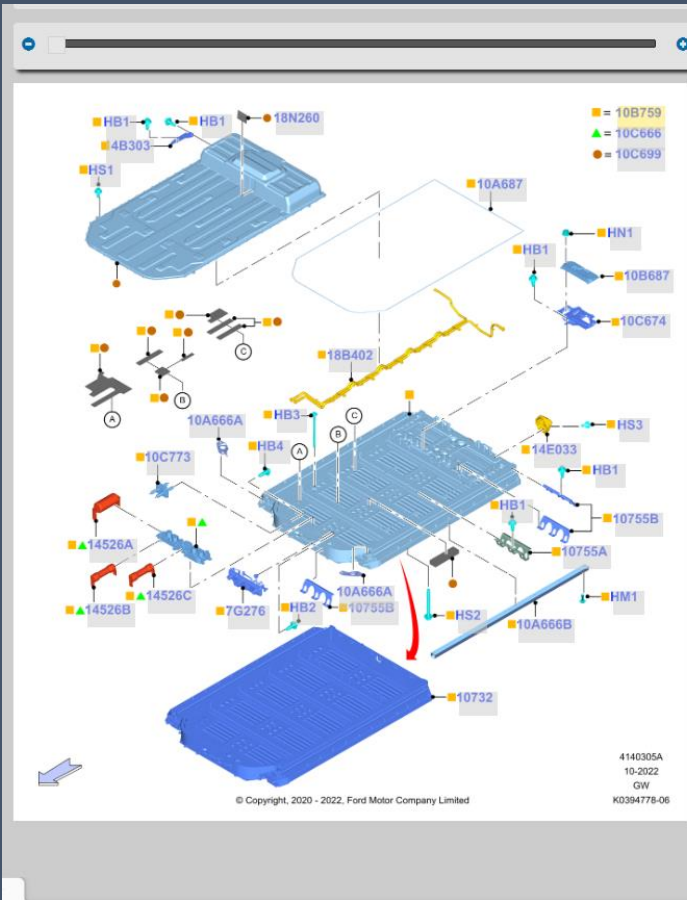
Array Assembly - Traction Battery List Price: \$5,967.06 Available: Available
From: 05/05/2021 ; Traction Battery #2 *
Array Kit
Callout: 10D672B – Add To Selected

Price: **\$5,967.06**
Qty Req: 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: Add To Cart

2022 Mach-e



Battery List Price: \$33,409.41
Available: Available

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 List Price: \$6,638.82
Available: Available

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 List Price: \$33,667.06
Available: Available

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 List Price: \$41,060.00
Available: Available

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 List Price: \$37,383.53
Available: Available

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: Add To Cart

Show Other Parts In Illustration

2020 Nissan Leaf 62kw

MORLAN NISSAN 2020 Nissan Leaf

Select Dealer

ELECTRIC VEHICLE BATTERY [Back](#)

[Attach Illustration](#) [Print](#)

Selected Parts

OE BATTERY MODULE-LITHIUM ION List Price: \$2,185.21 Available:

Nissan
Usage: 201901-202205
HB 62KWH * BATTERY SUB-ASSY FRONT
Callout: 295B9+B

Price: **\$1,529.65** Qty Req: [Add To Cart](#)

OE BATTERY MODULE-LITHIUM ION List Price: \$1,290.59 Available:

Nissan
Usage: 201901-202205
HB 62KWH * BATTERY SUB-ASSY CENTER
Callout: 295B9+C

Price: **\$903.41** Qty Req: [Add To Cart](#)

MORLAN NISSAN 2020 Nissan Leaf

[Call Dealer](#)

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

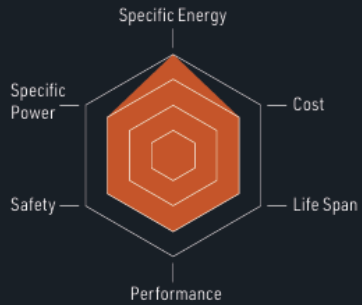
Add Parts to List [Add Part](#) Upload File CSV or text format [Choose File](#) and [Upload File](#) ⚠

<input type="checkbox"/>	Part Number	Part Description	Brand	Promotion	Pricing	Req Qty	Availability	Delivery option	Net Price	
<input type="checkbox"/>	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

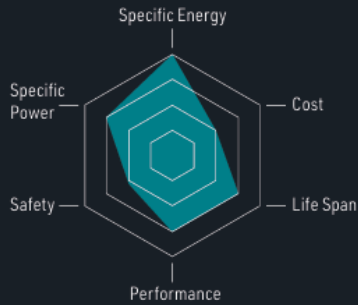
NMC LITHIUM NICKEL MANGANESE COBALT OXIDE

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.



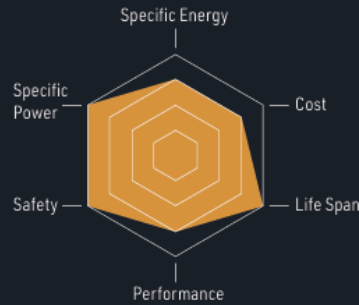
NCA LITHIUM NICKEL COBALT ALUMINUM OXIDE

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



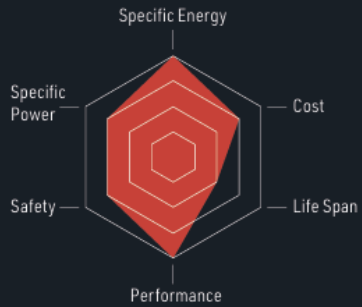
LFP LITHIUM IRON PHOSPHATE

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

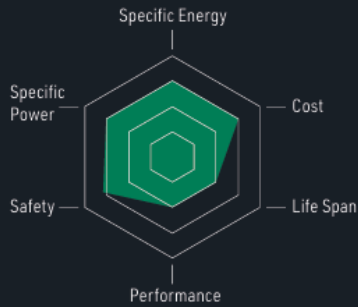


LCO LITHIUM COBALT OXIDE

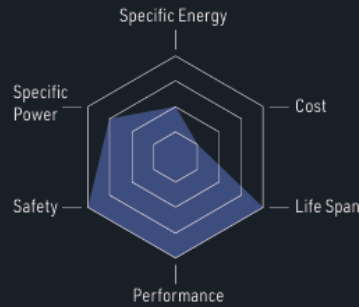
Lithium Cobalt Oxide cathodes are a popular choice for laptops, smartphones, and digital cameras.



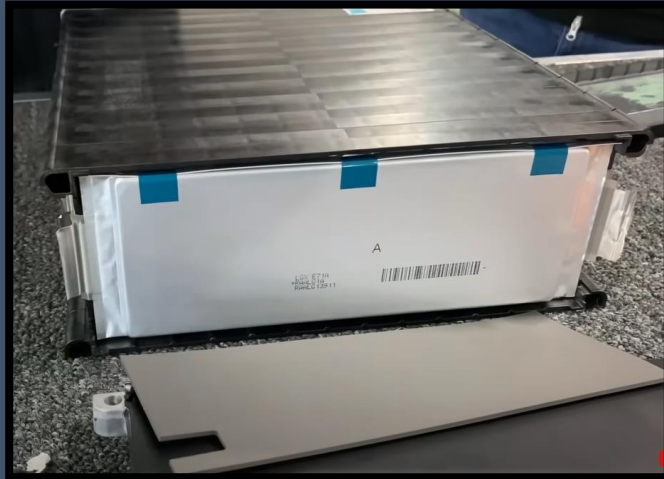
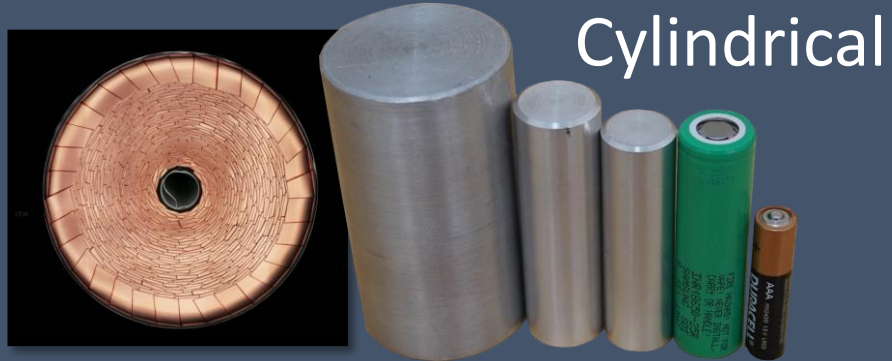
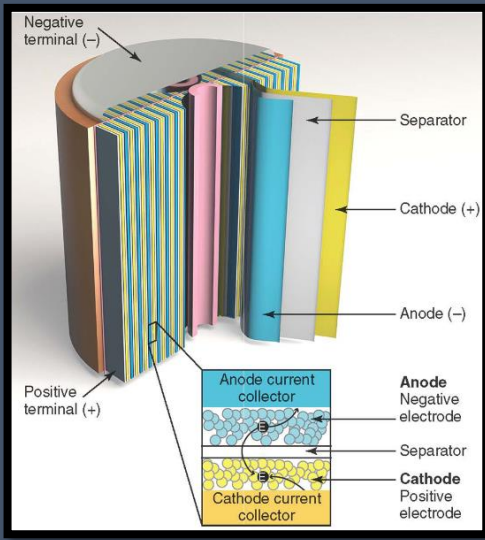
LMO LITHIUM MANGANESE OXIDE



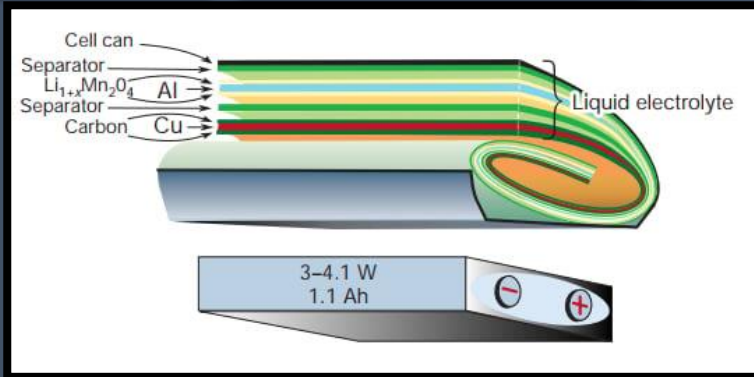
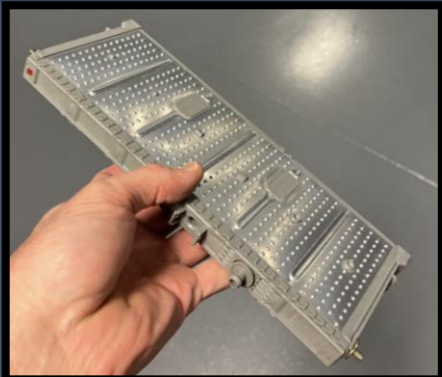
LTO LITHIUM TITANIUM OXIDE



Battery Form Factor

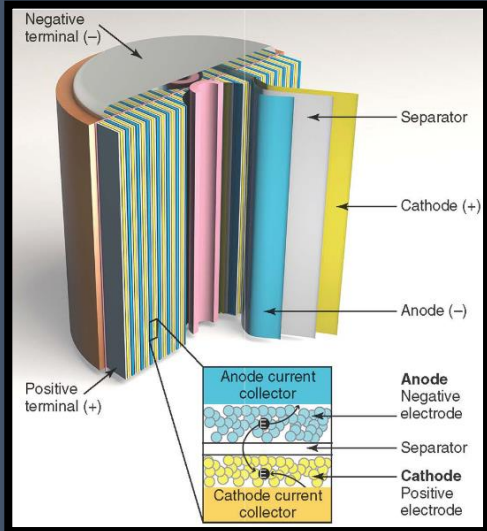


Pouch



Prismatic

Battery Form Factor - Cylindrical

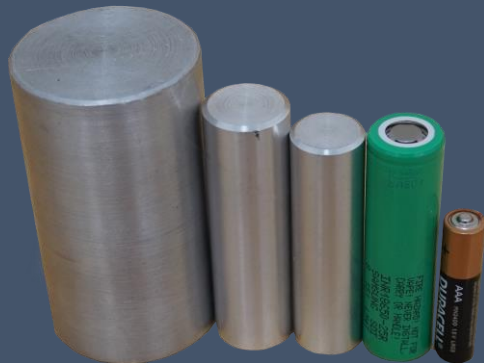


Advantages

- 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



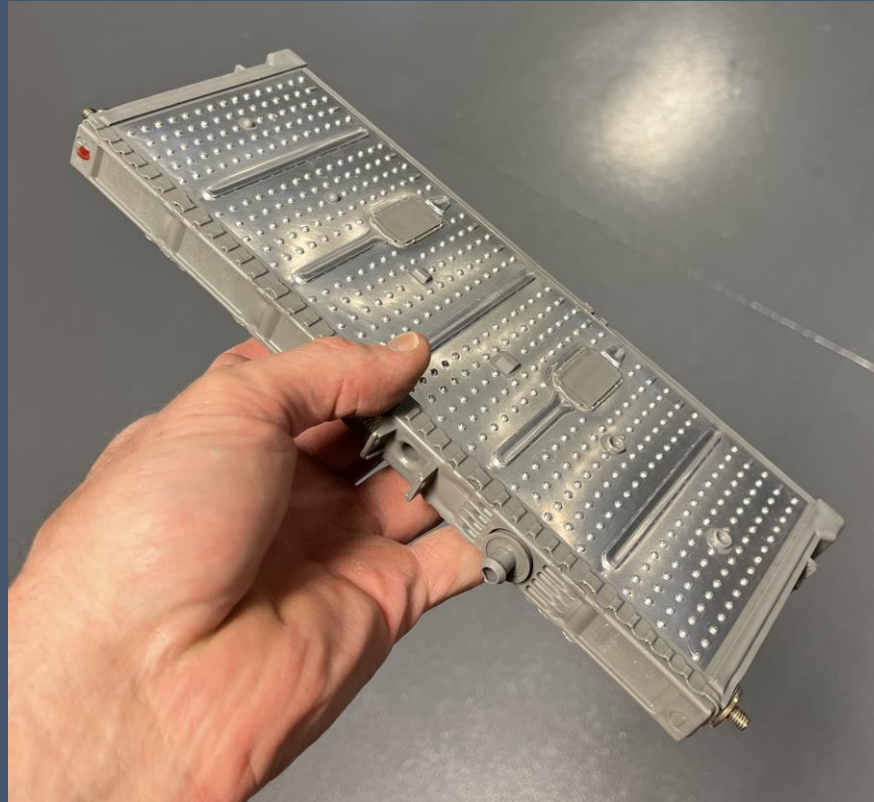
Battery Form Factor - Pouch

Advantages:

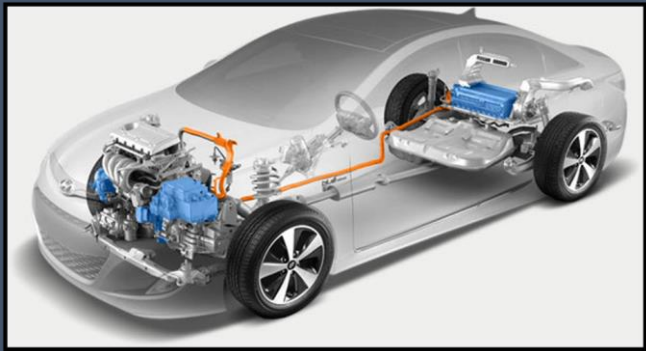
- One container holds a lot of cell material
- Packaging options
- Ease of construction

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

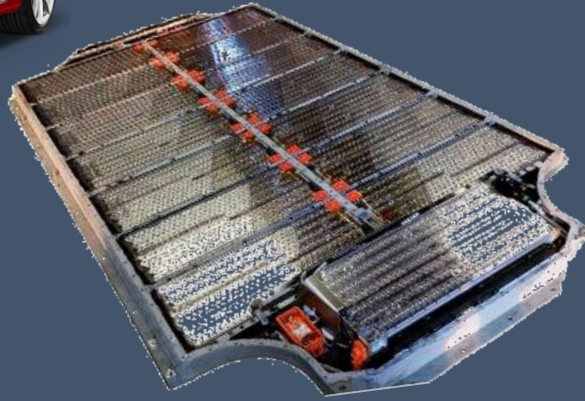


- EV
 - Large battery
 - Range vs cost vs weight

Battery Layout Examples



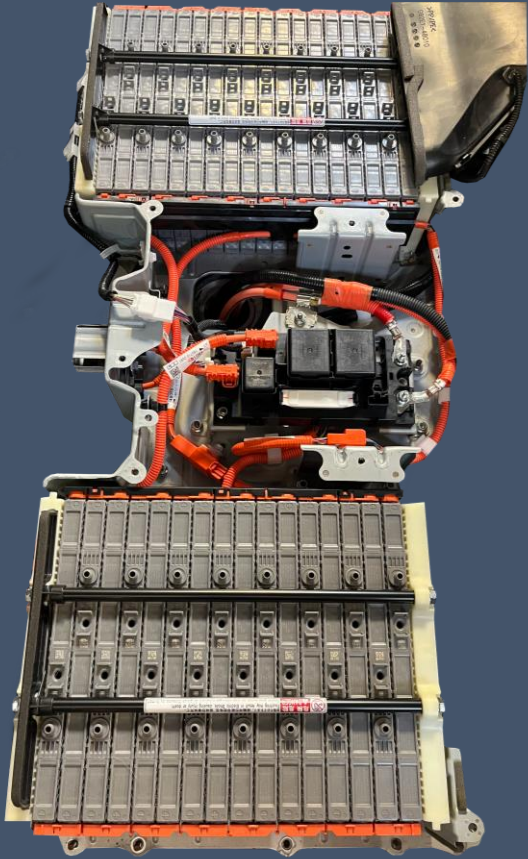
- Tesla Model S – 7104 cells



- Lucid Air – 6600 cells



Battery Layout Examples



Toyota Rav 4 Hybrid



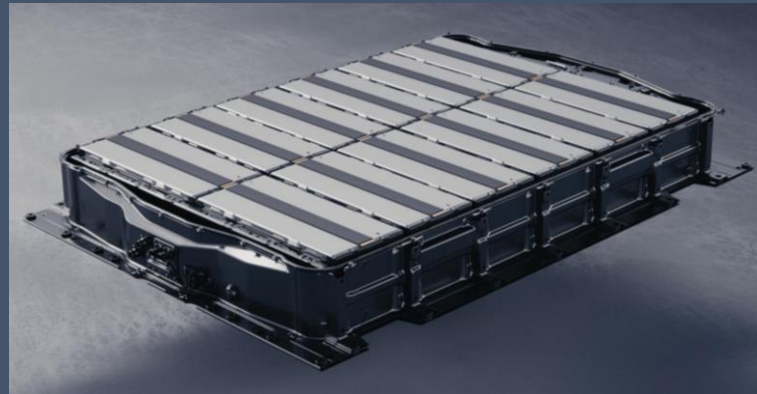
Jeep 4xE

Arrays and Modules

- Hyundai electric global module platform

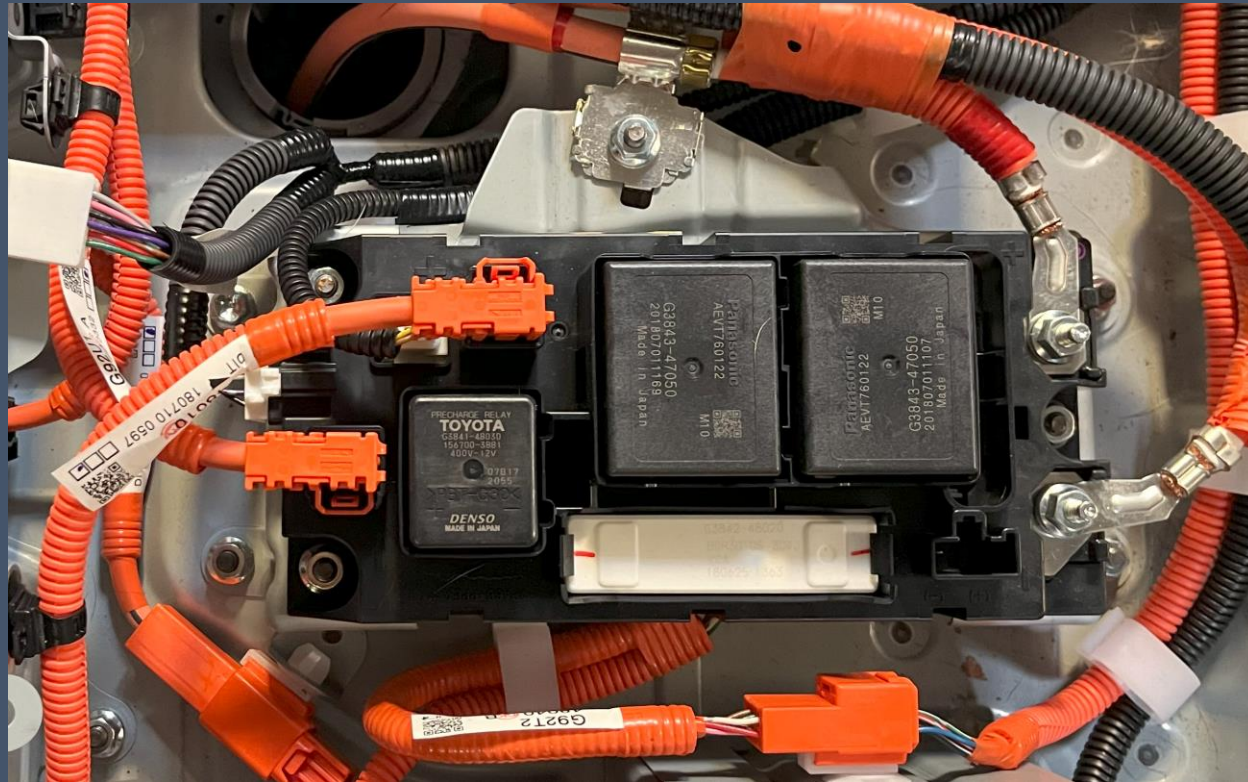


- GM Ultium battery pack



High Voltage Contactors – Delivering the power

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



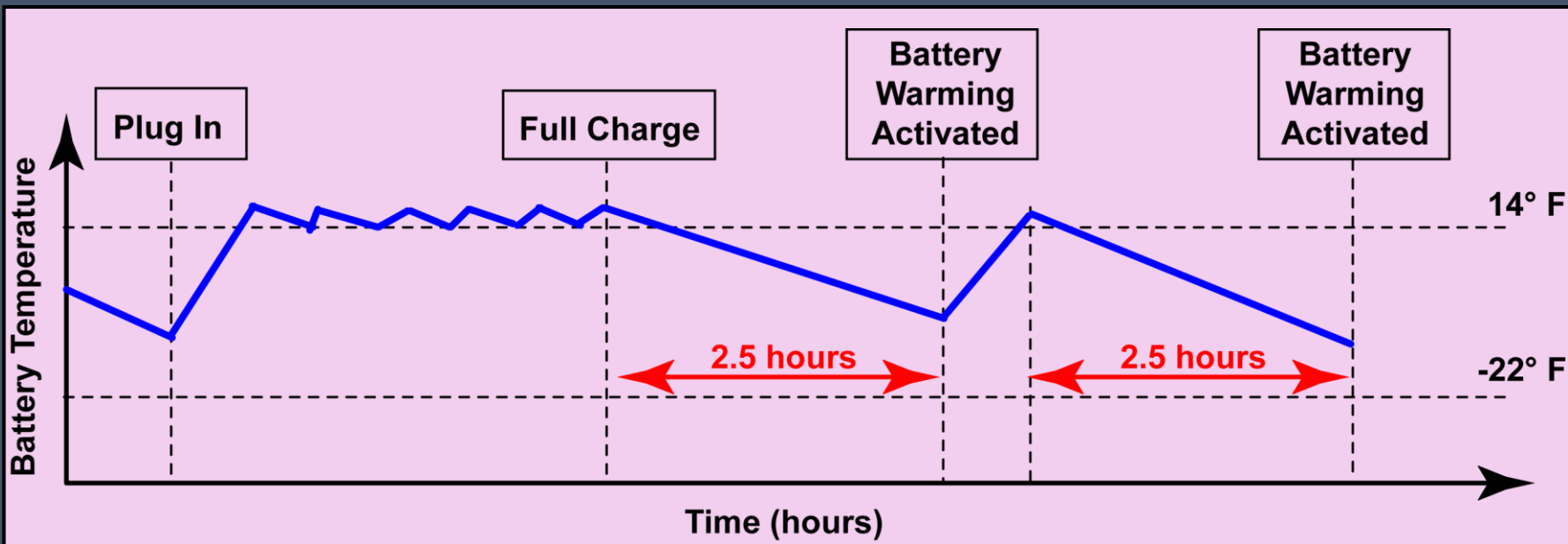
High voltage battery temperature

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



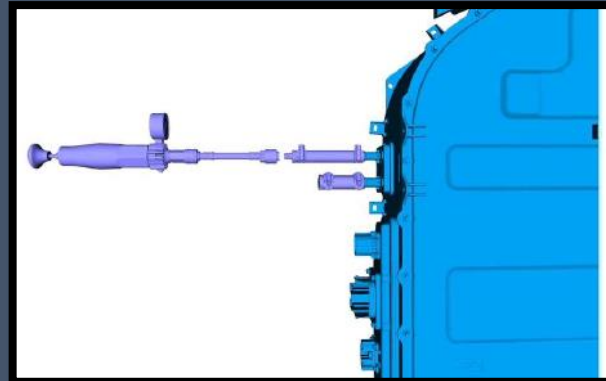
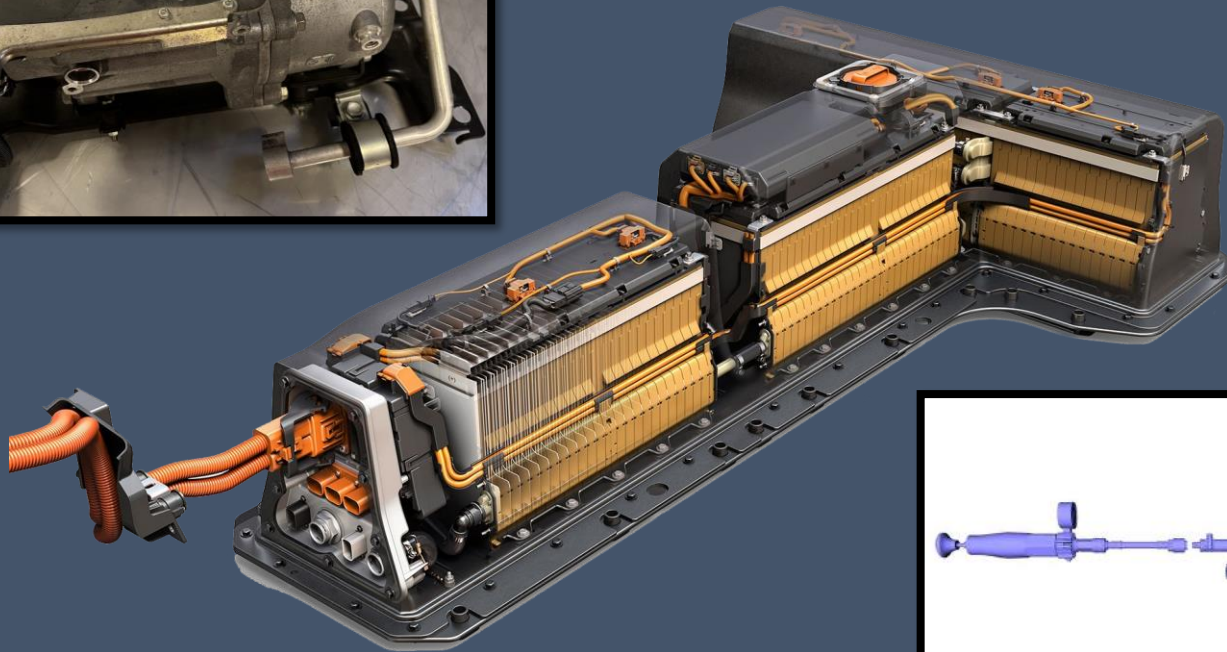
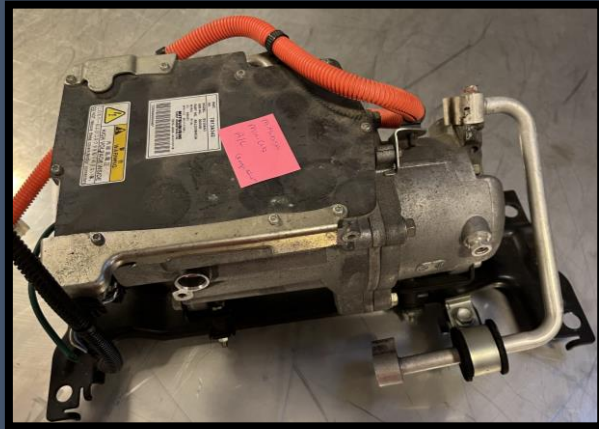
High voltage battery temperature

- When plugged in, the battery can maintain a minimum temperature



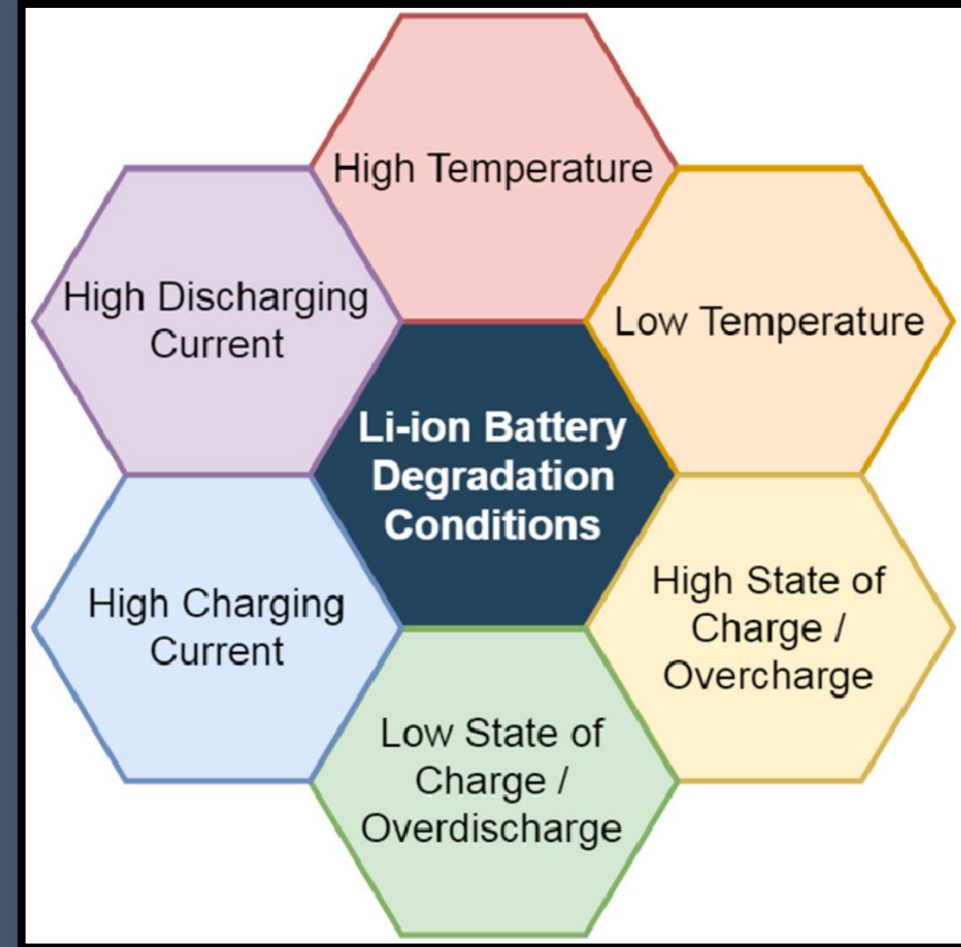
High voltage battery temperature

- Li Ion needs to be cooled in high temperatures



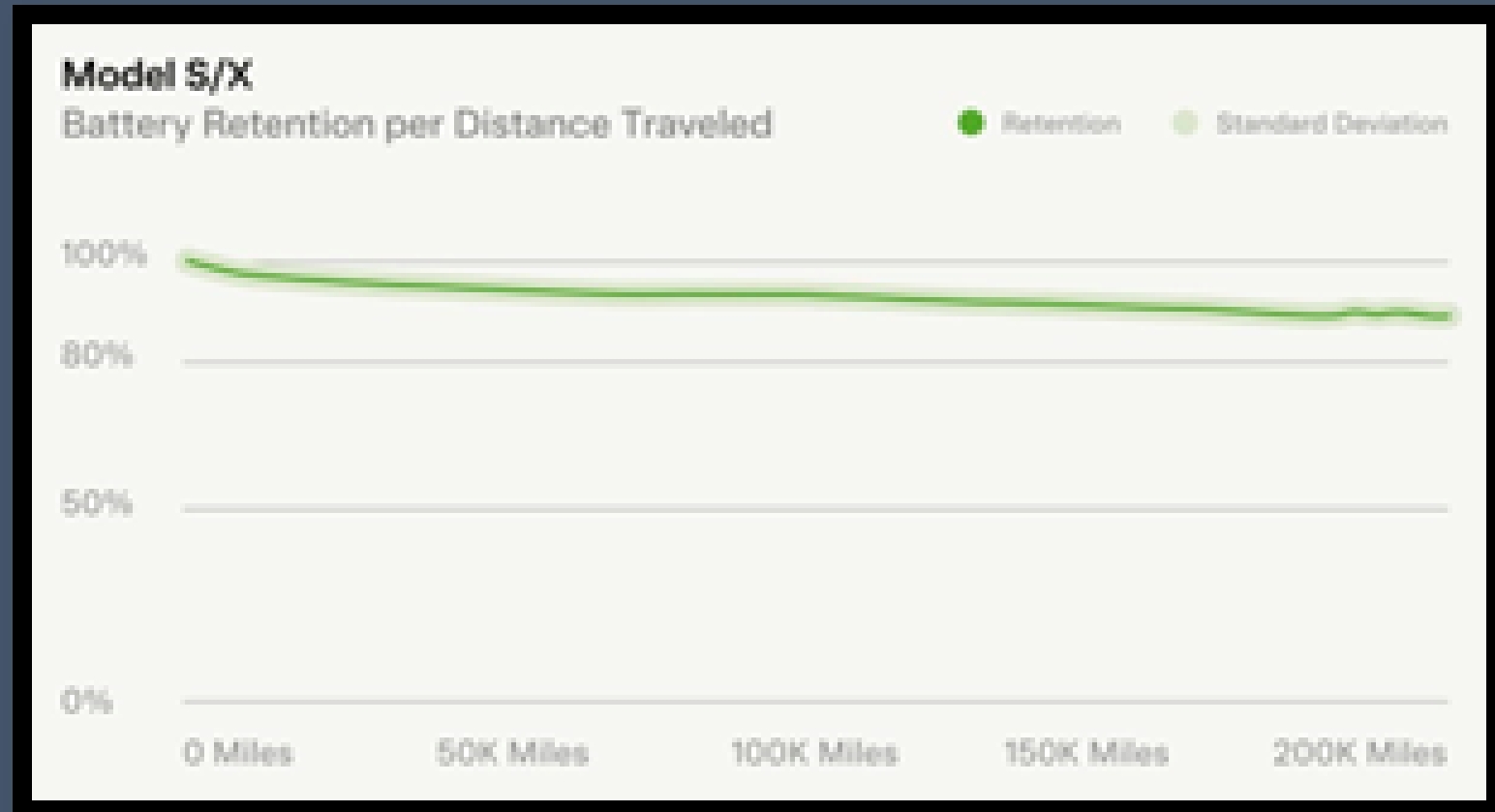
Why do batteries degrade?

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

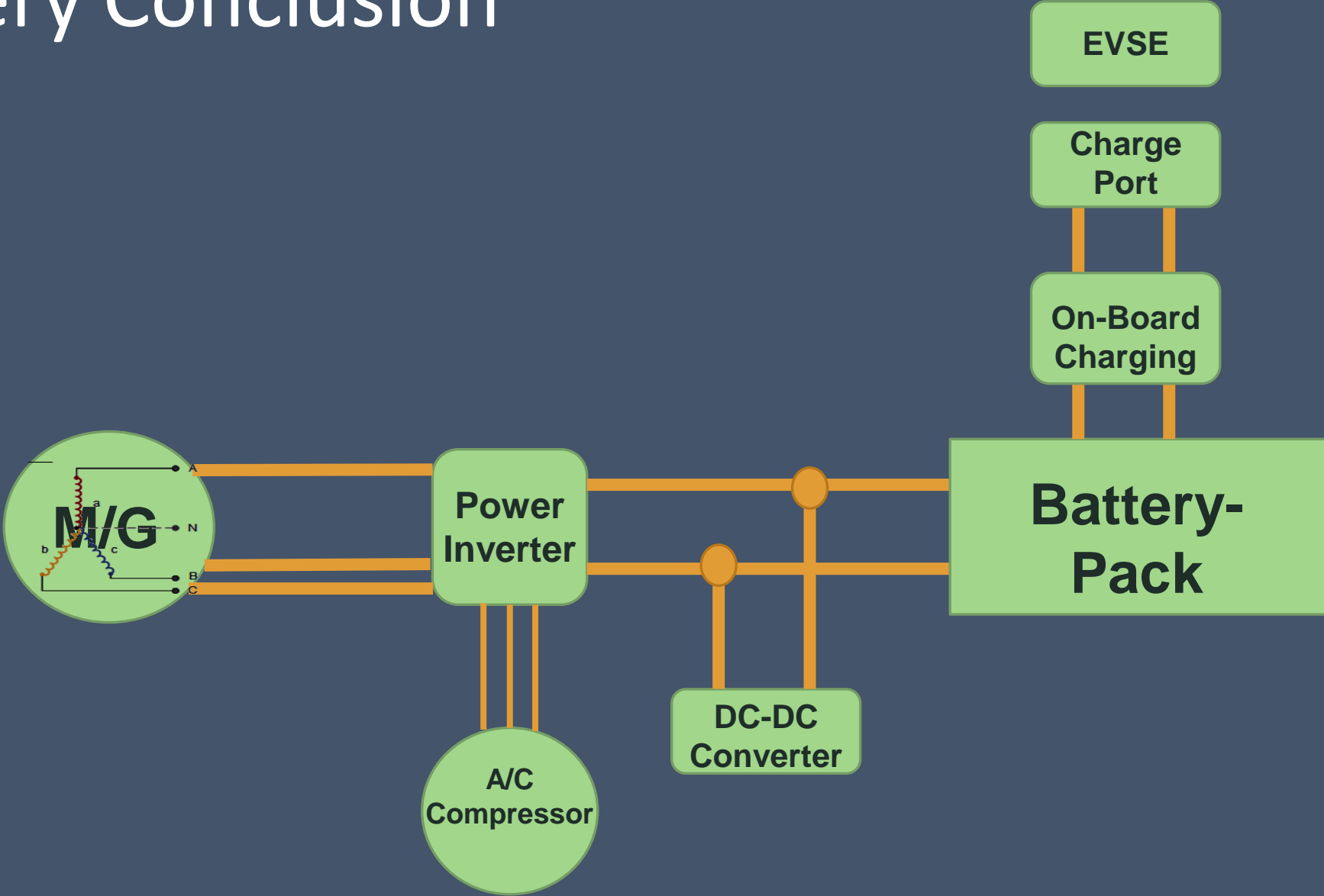


Why do batteries degrade?

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



Battery Conclusion

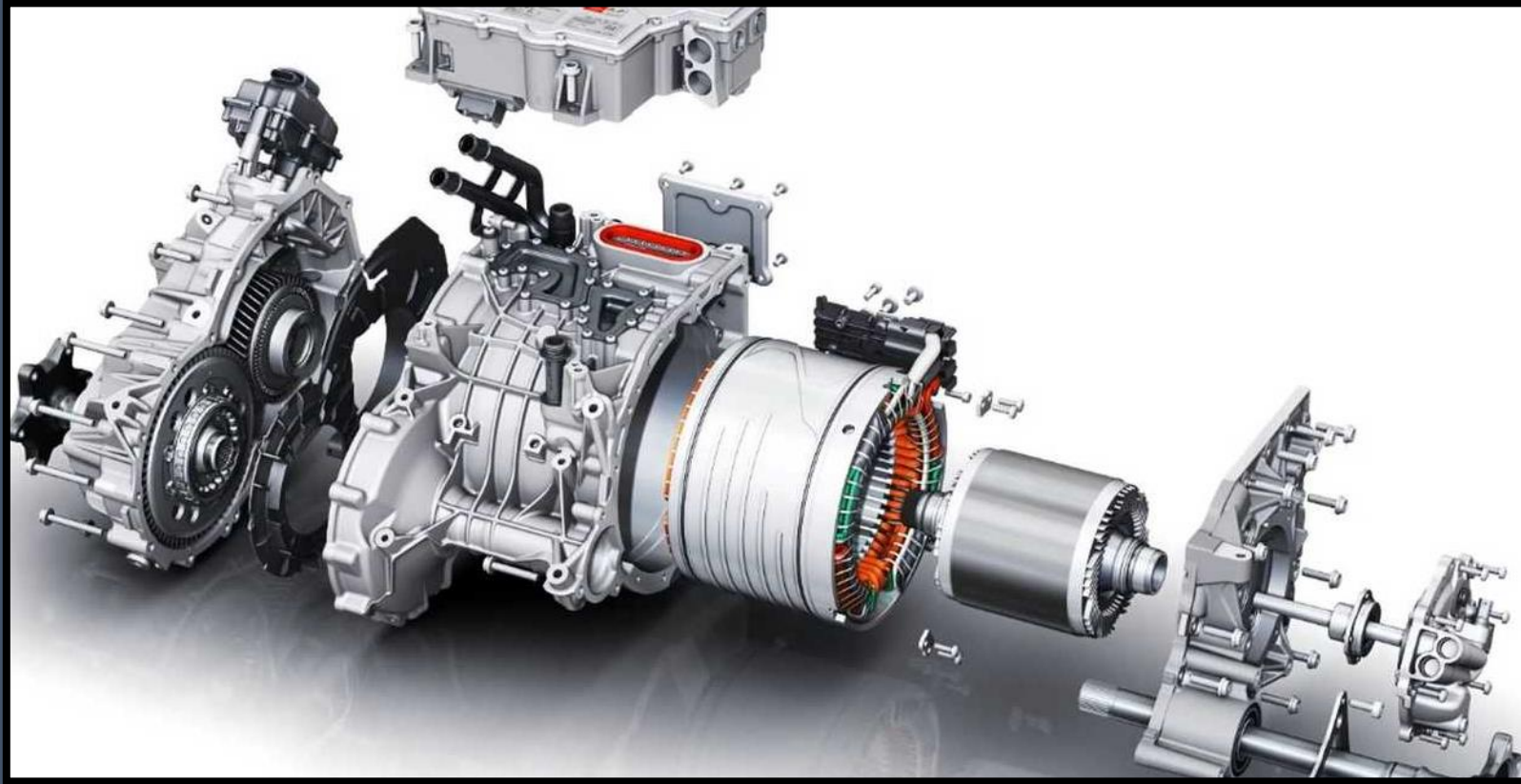


A detailed close-up photograph of an electric motor's internal components. The image shows the stator (stationary part) on the left, characterized by numerous dark, rectangular stator slots arranged in a circular pattern. The rotor (rotating part) is visible on the right, featuring a series of protruding teeth or segments. The central shaft and other internal mechanical parts are also visible, showing a polished, metallic finish. The overall scene is brightly lit, highlighting the intricate details and textures of the motor's construction.

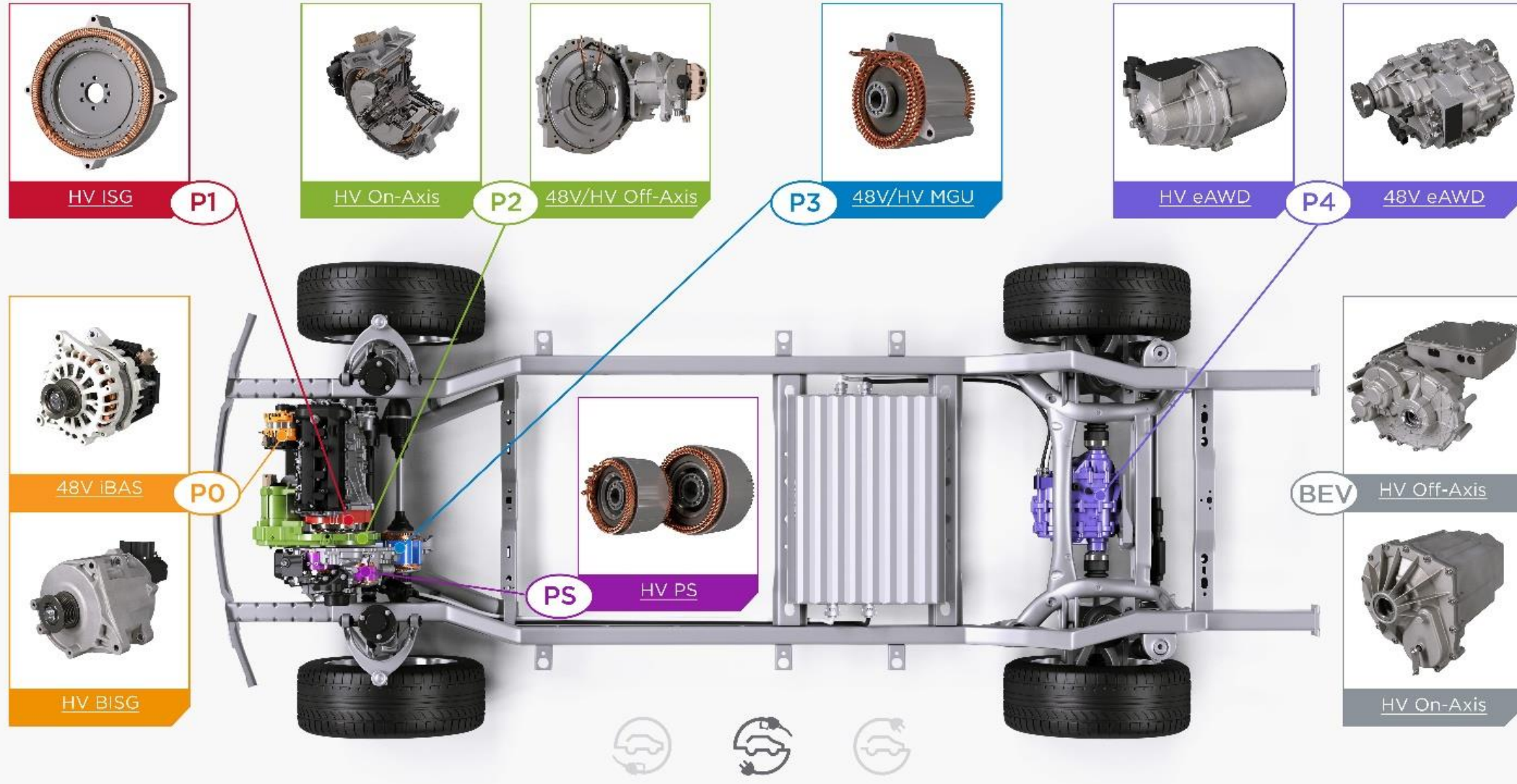
xEV Motors

Electric Motors

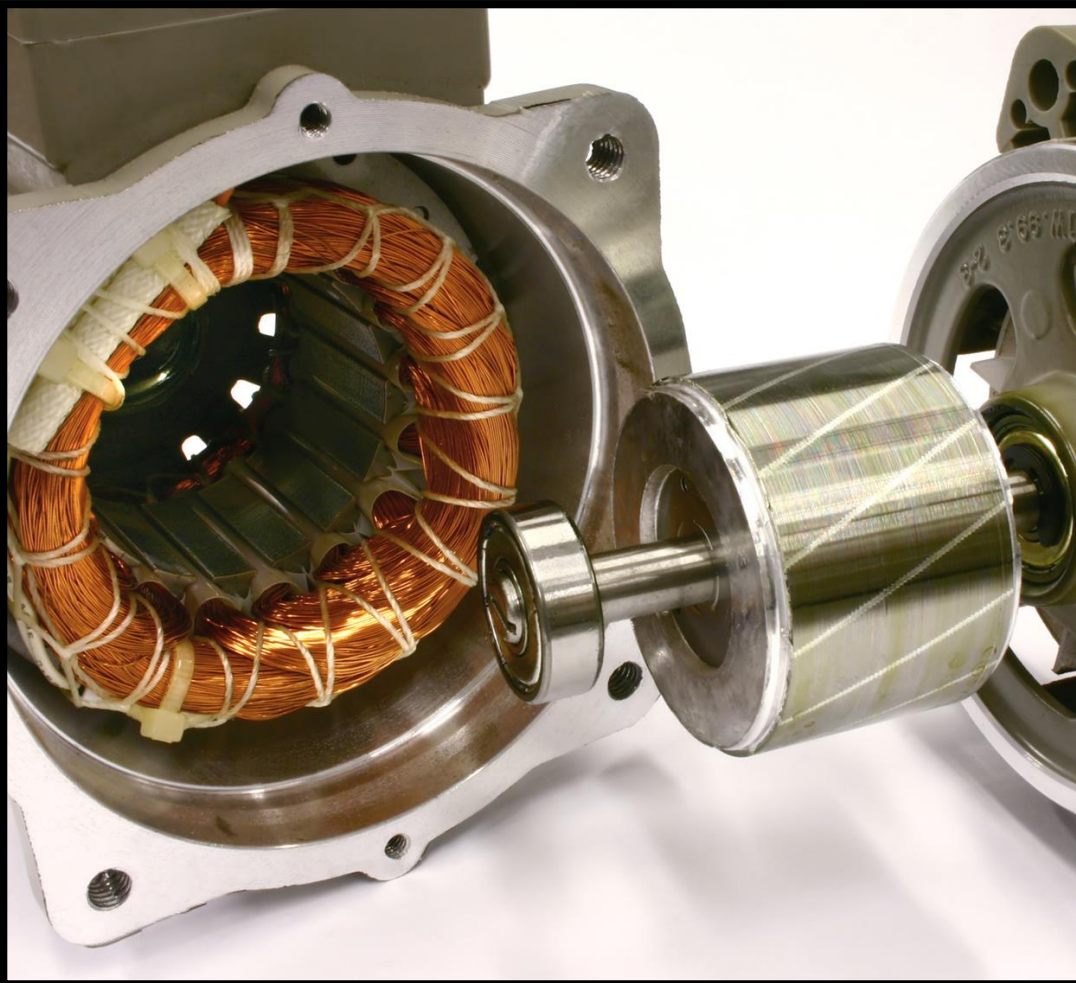
- The muscle for the BEV
- The helper for the HEV



Motor designations



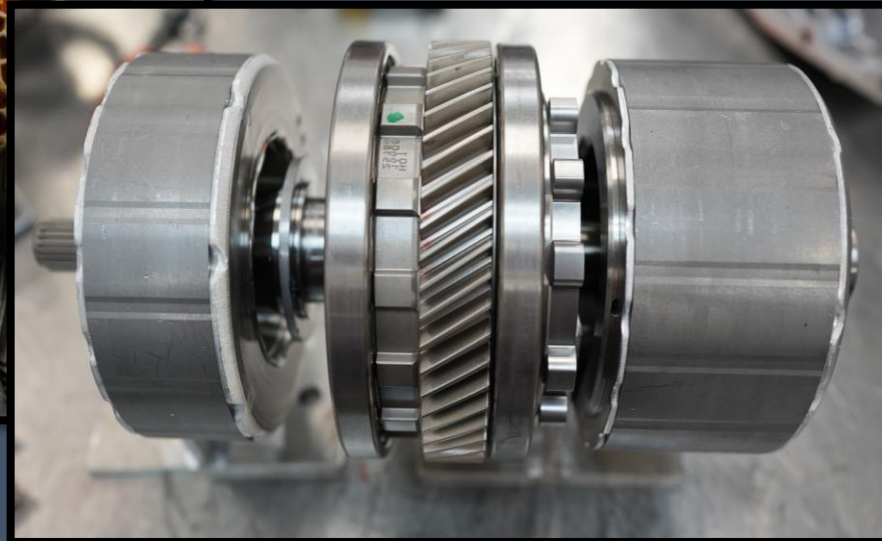
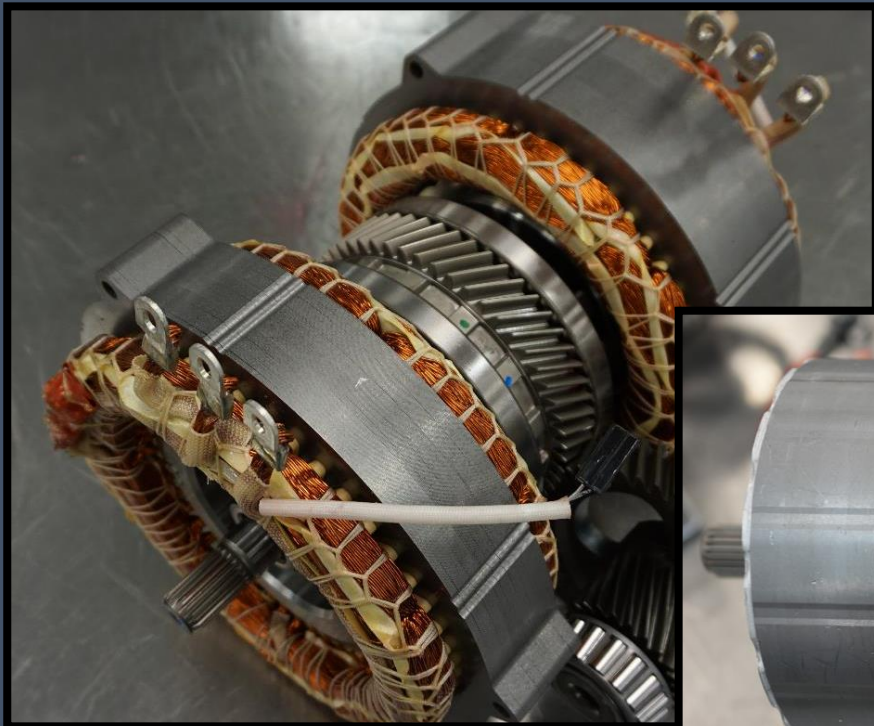
Basic Motor Operation



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

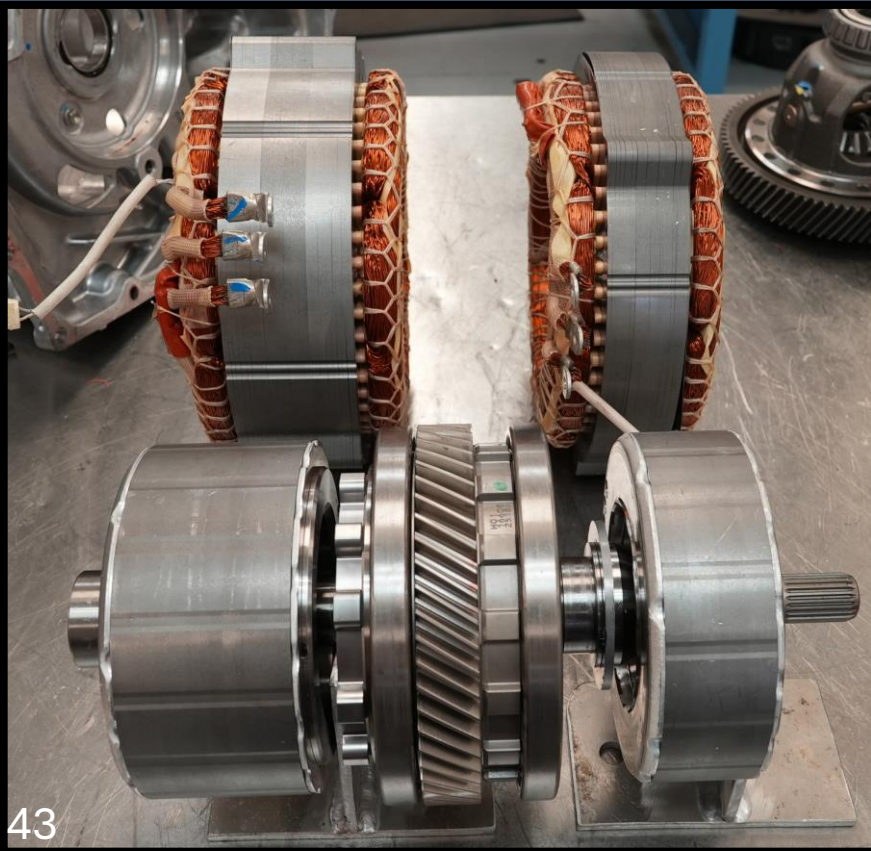
Transaxles – Toyota/Nissan/Ford/Hyundai

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



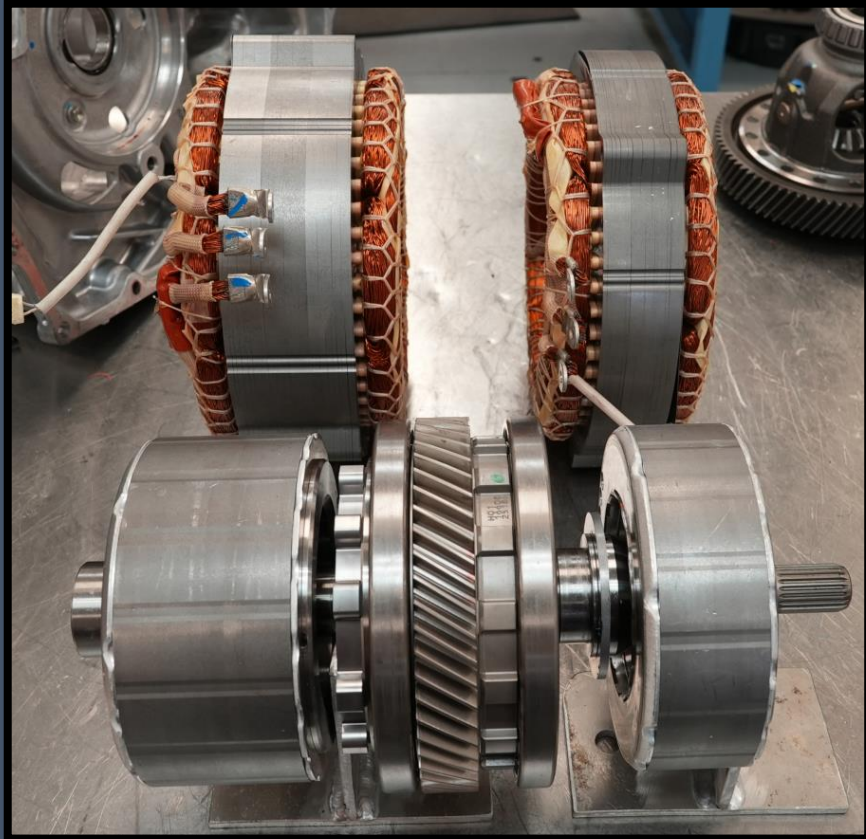
Transaxles – Toyota/Nissan/Ford/Hyundai

- 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

PDM (Power Delivery Module)
Integrates charger, DC/DC converter
and junction box

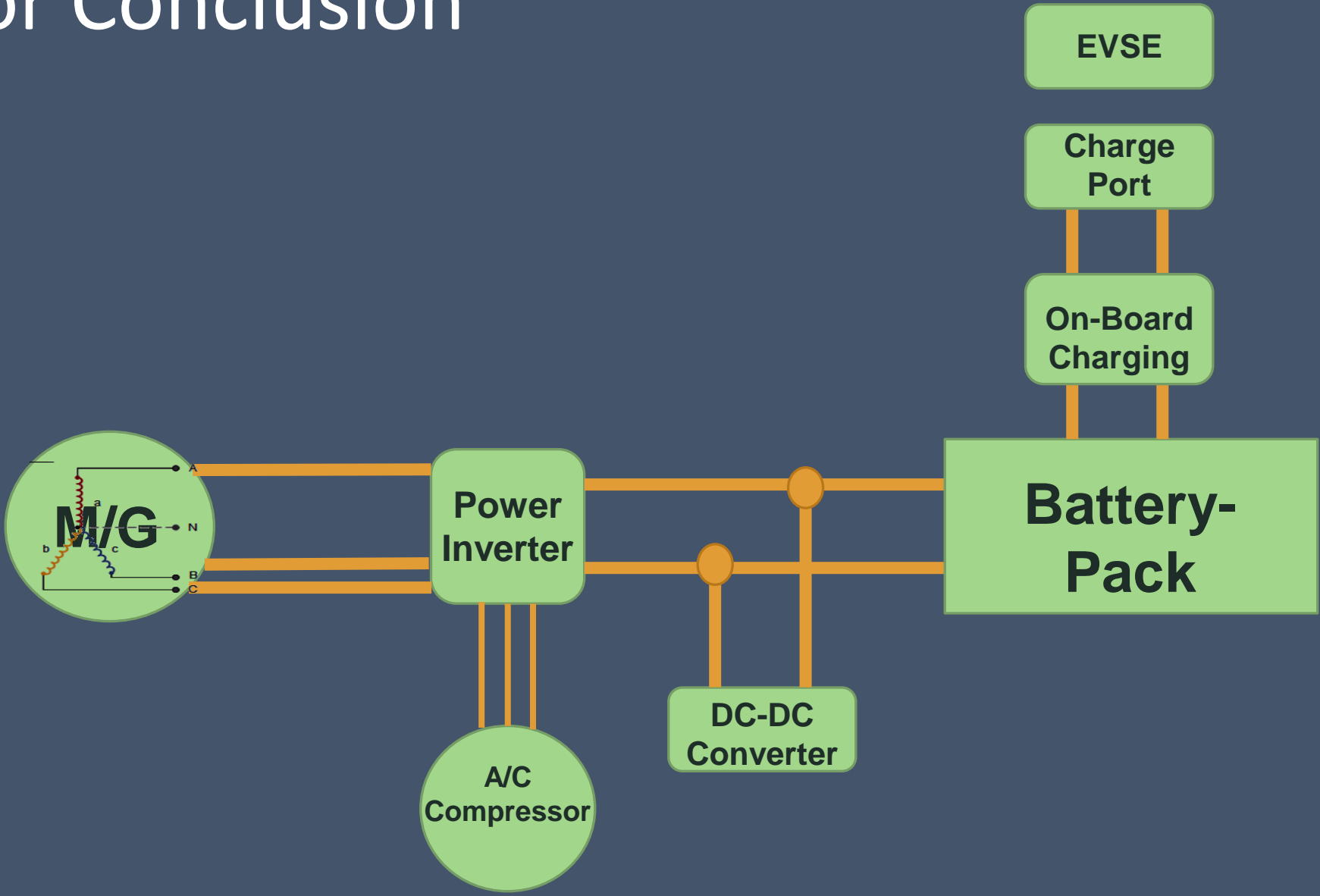
Inverter

Motor

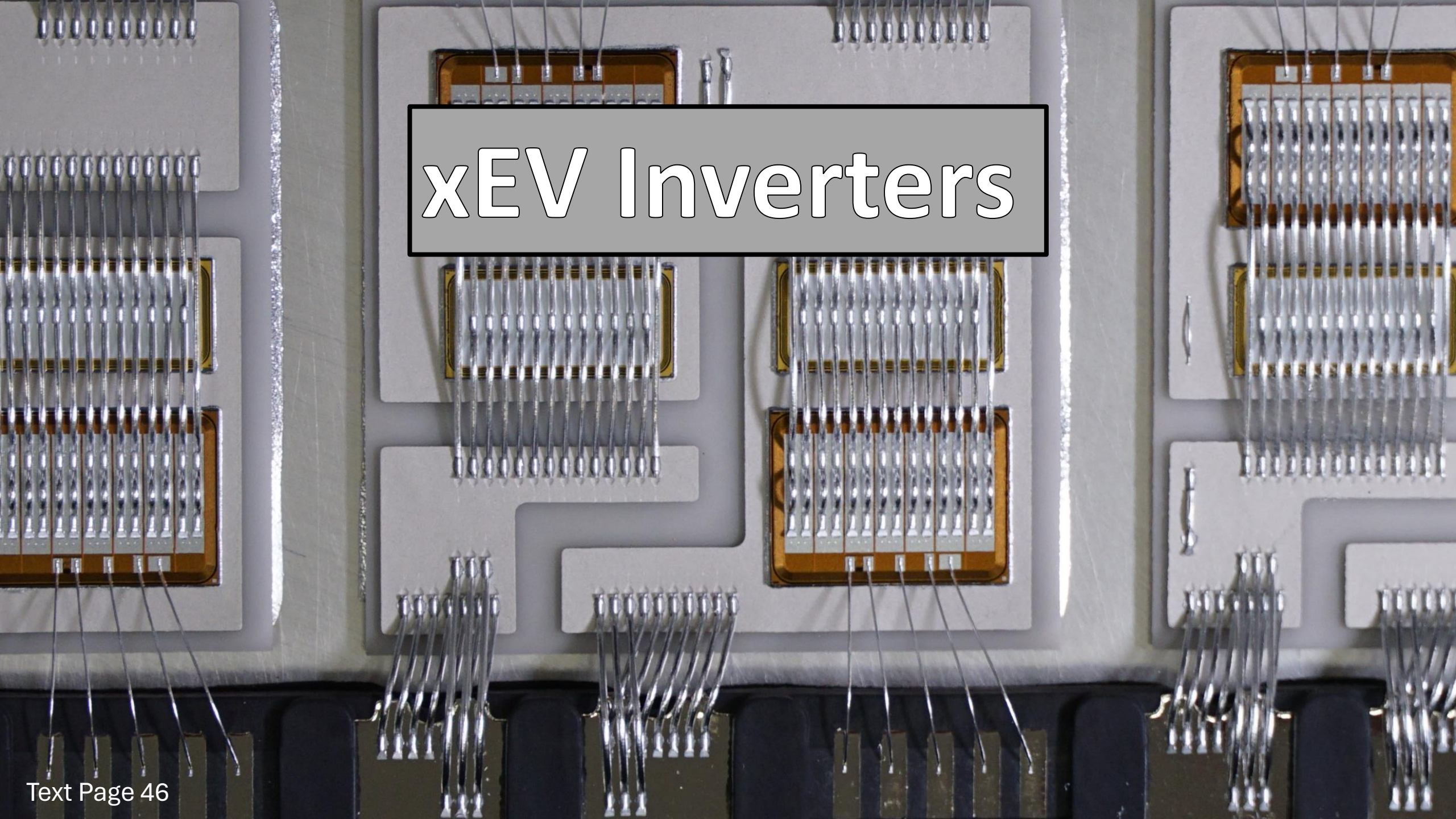
Reduction drive



Motor Conclusion



xEV Inverters

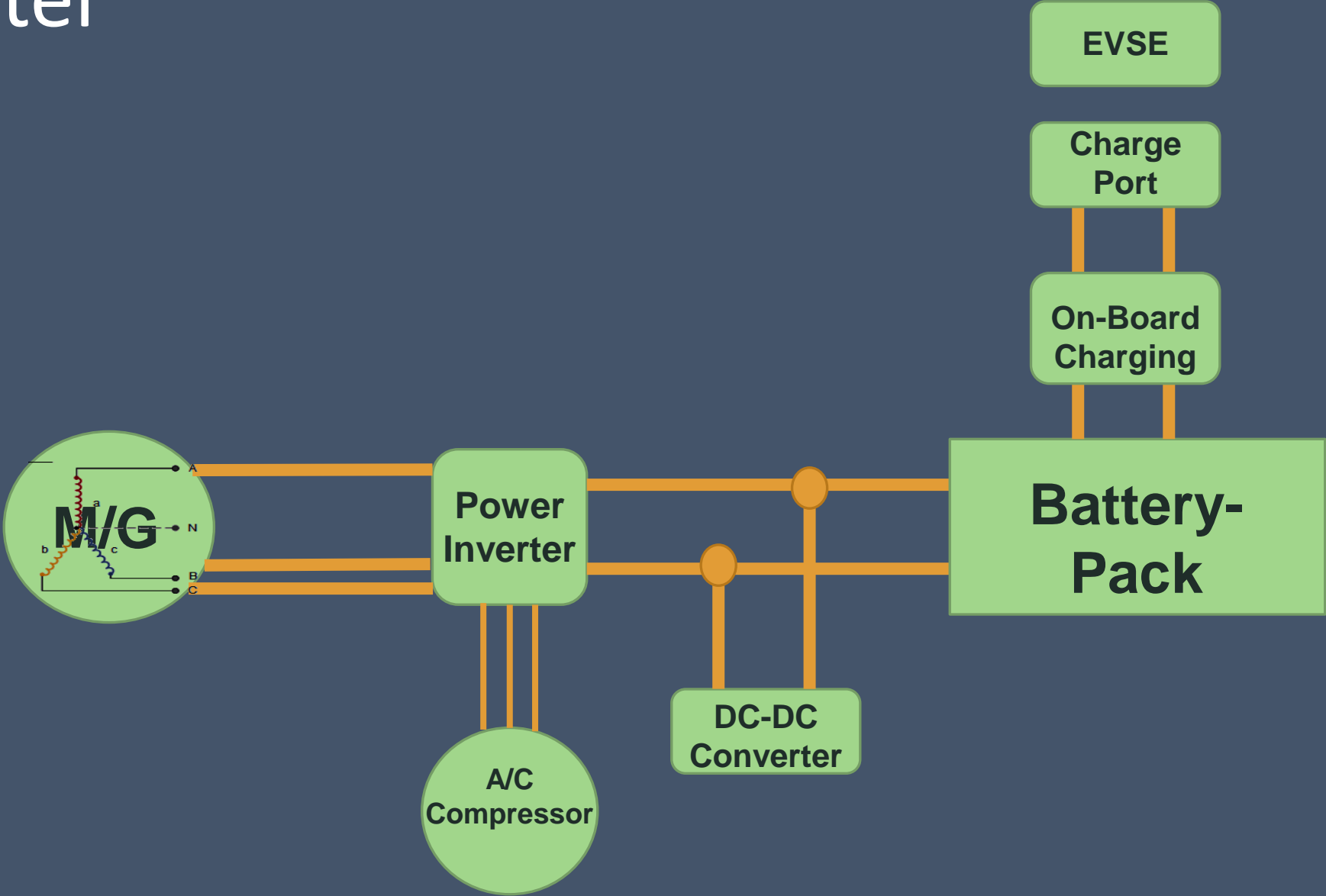


Inverter Technology

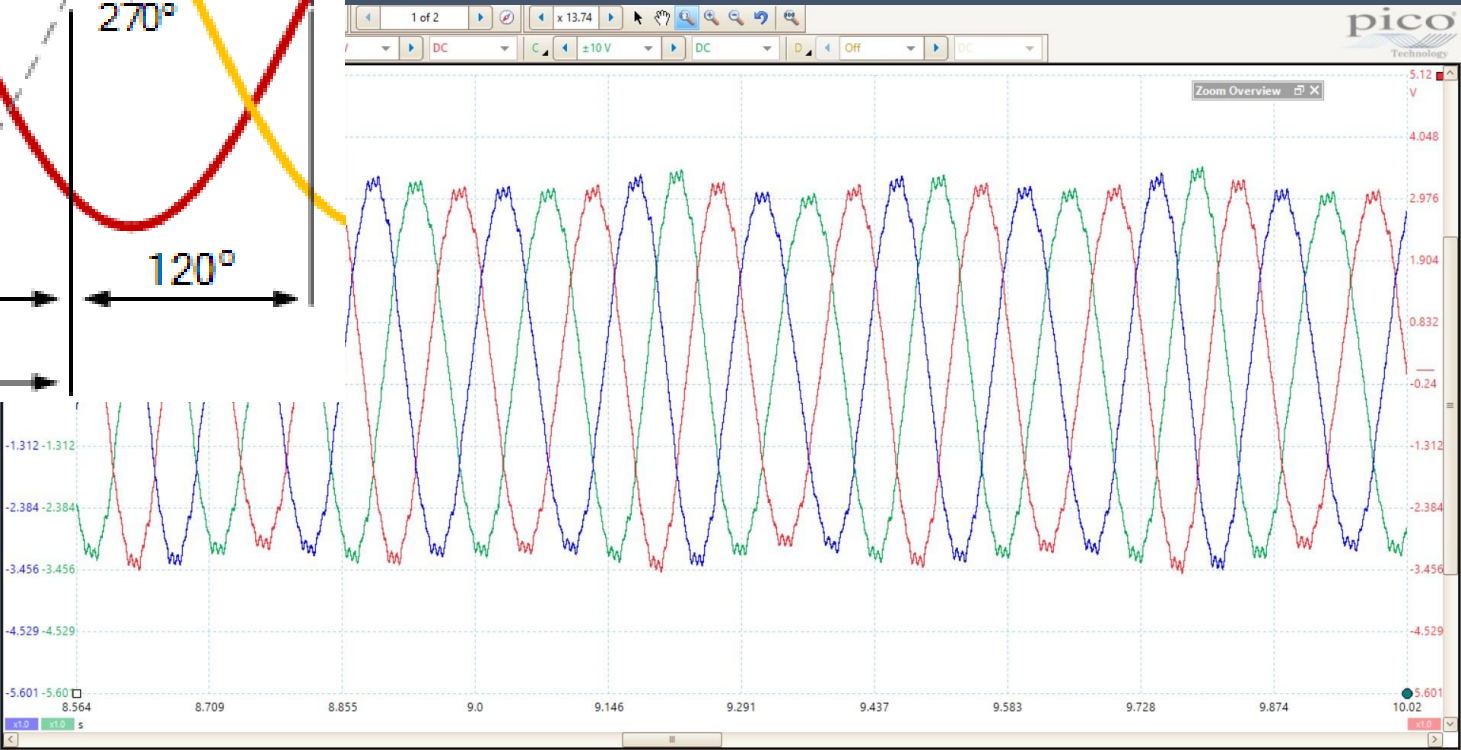
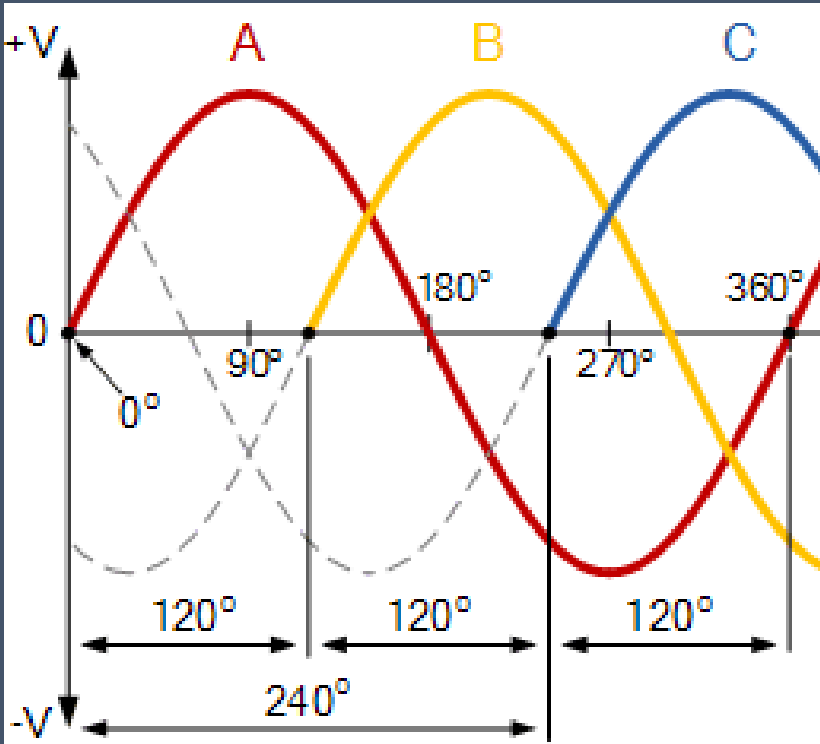
- The inverter will take DC battery voltage and convert it to AC voltage to operate the electric motors
- It will also convert AC voltage created during regeneration to DC voltage to store in the battery
- The transistors will get hot from controlling the current



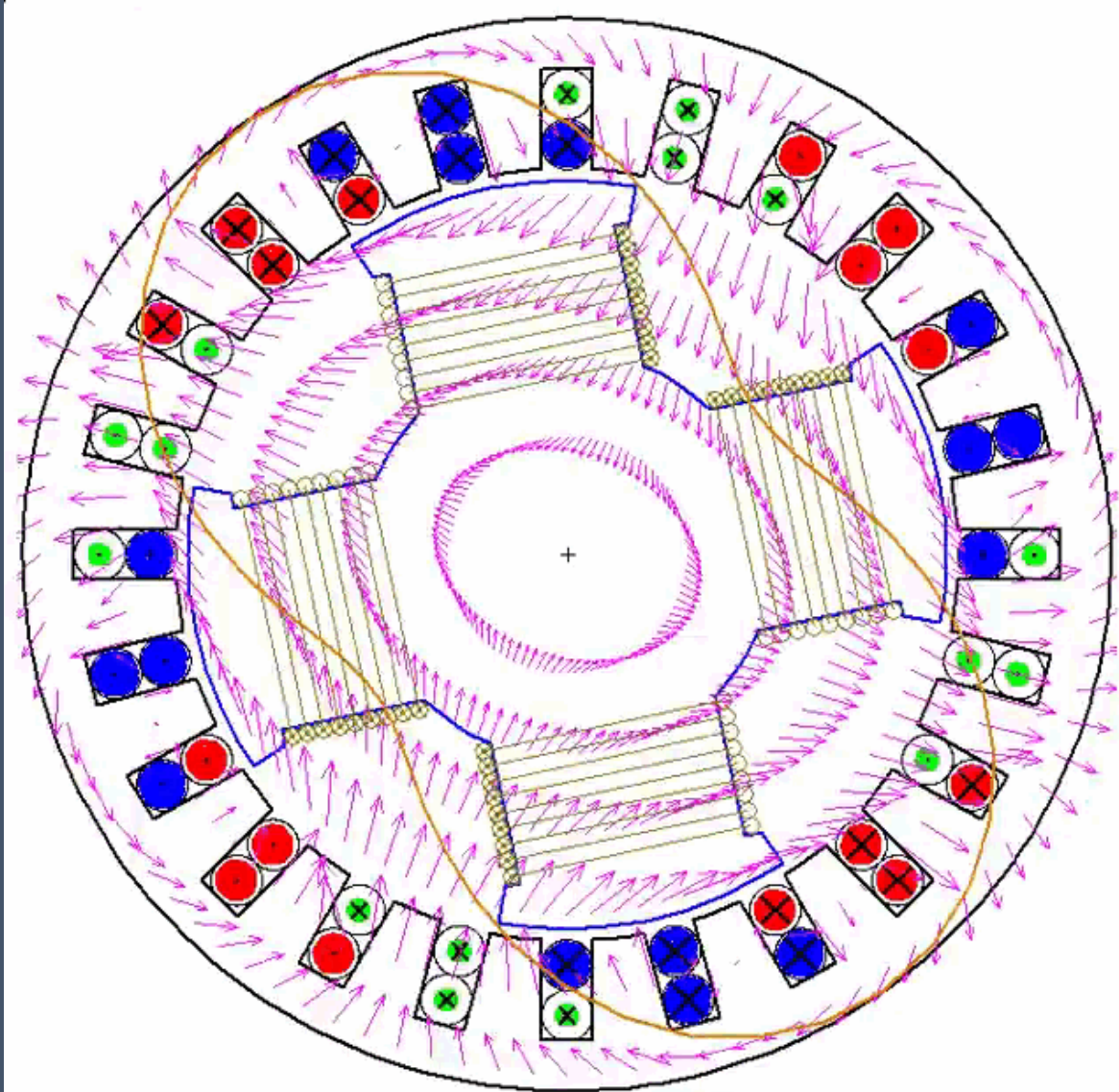
Inverter



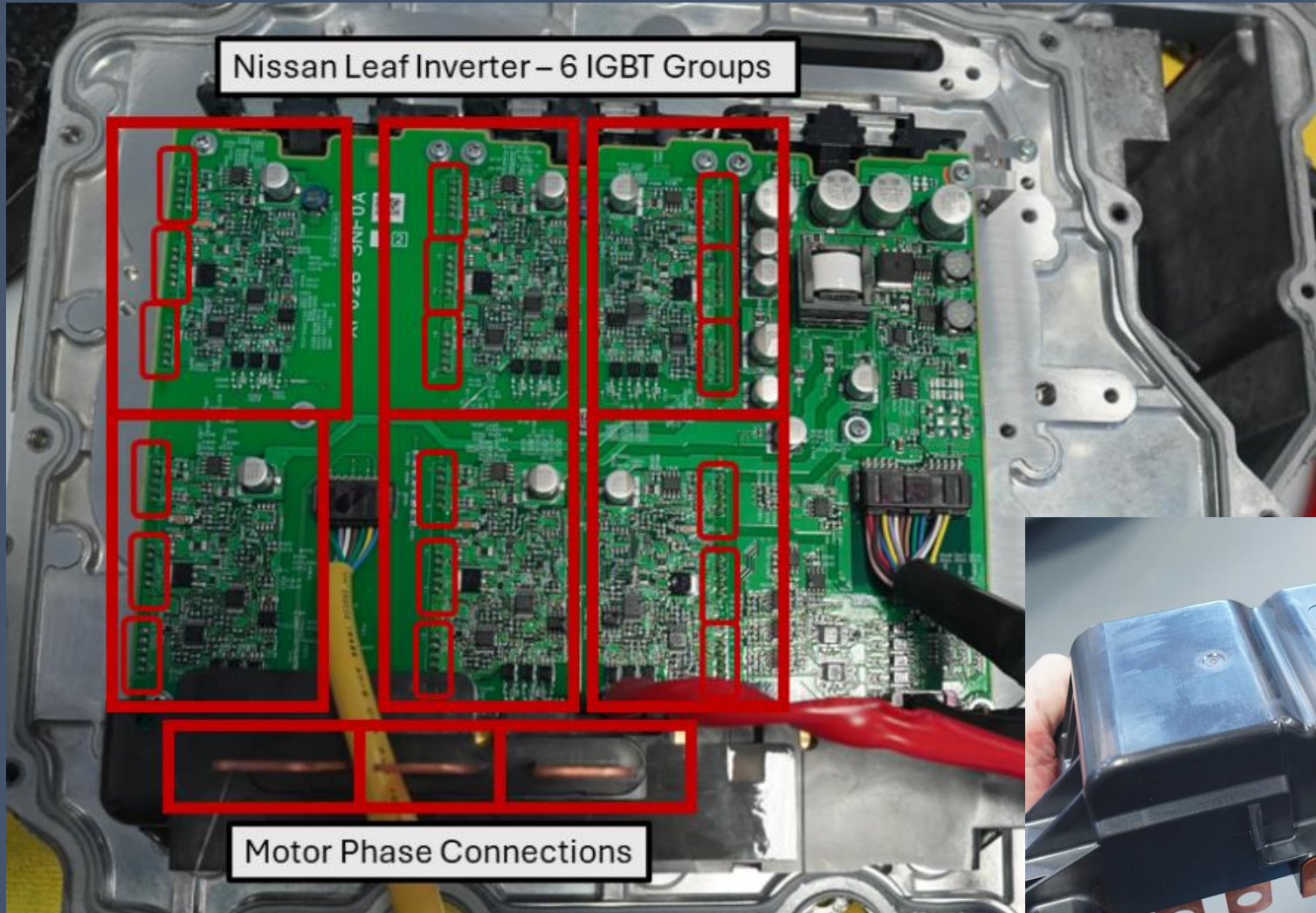
Inverter



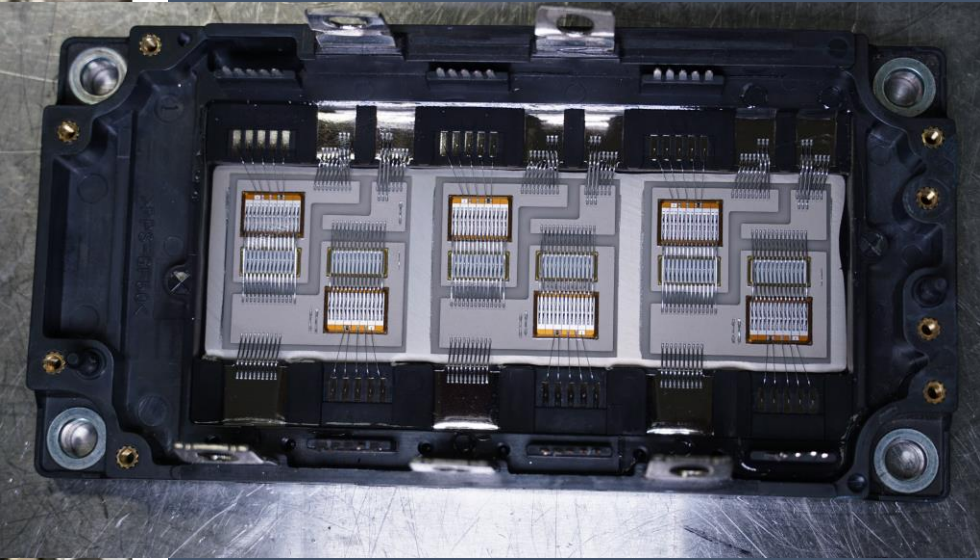
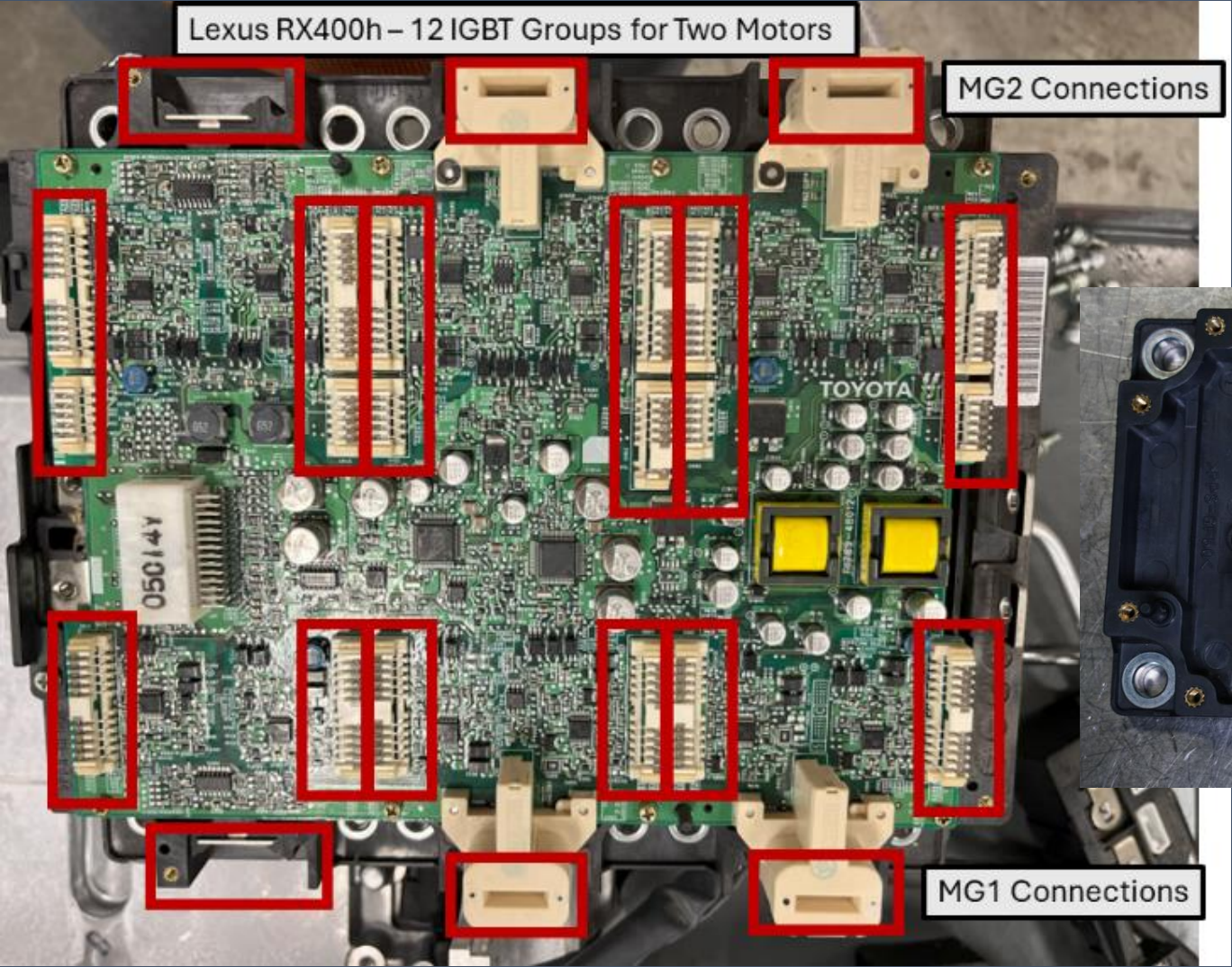
Inverter Technology



Inverter



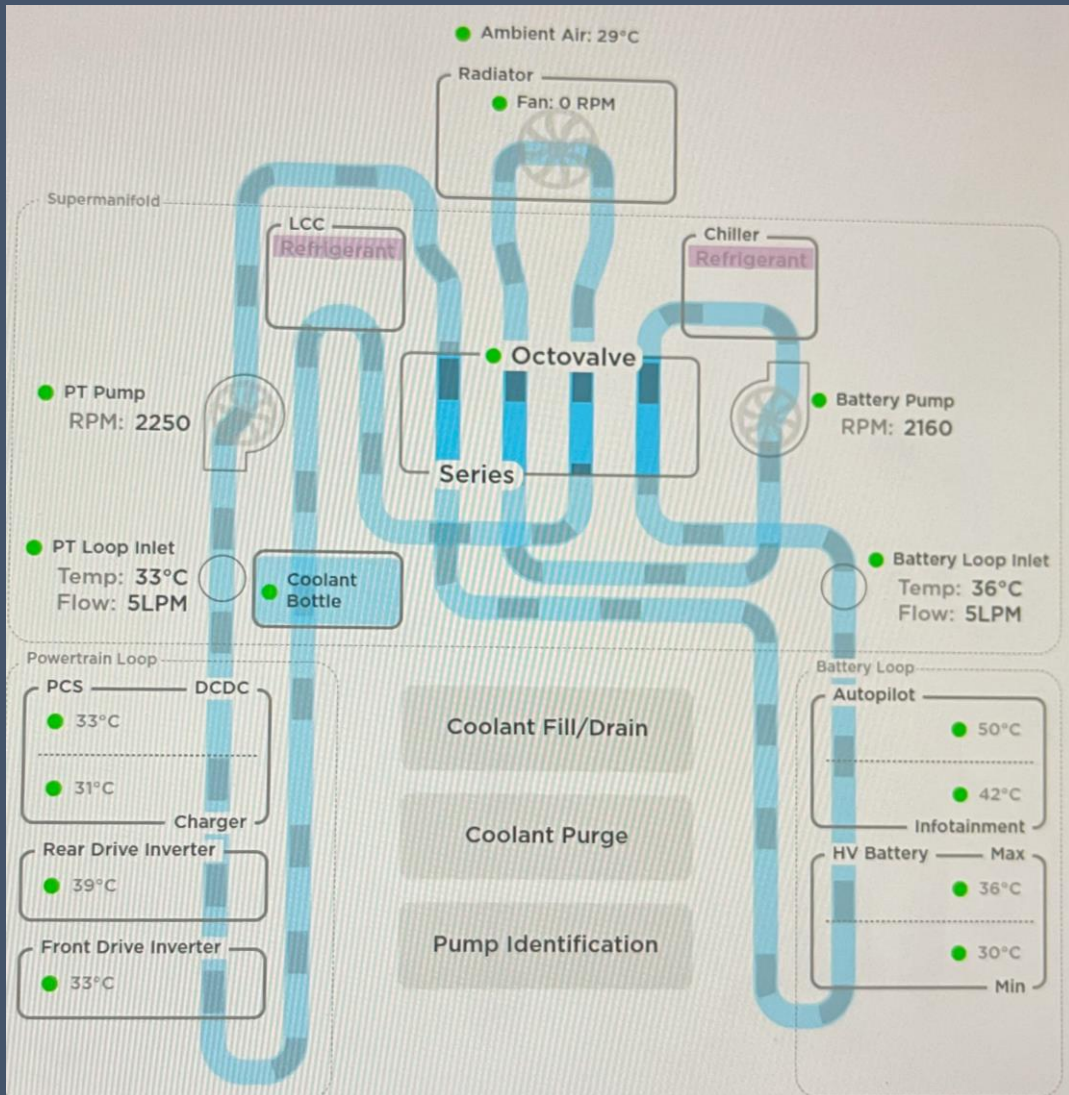
Inverter



Inverter

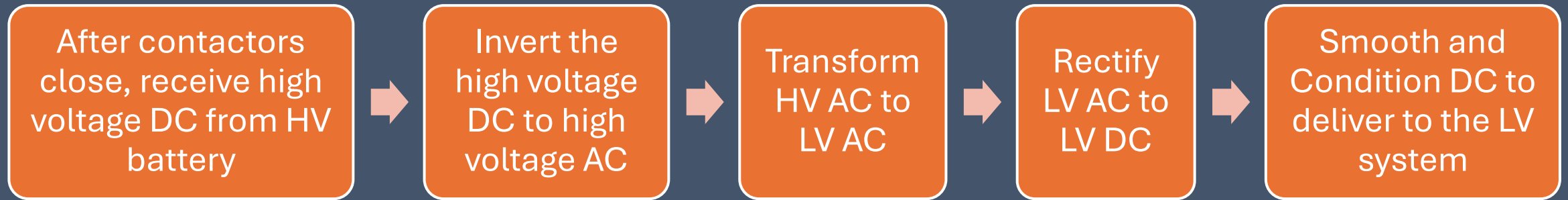


Inverter



xEV DC-DC

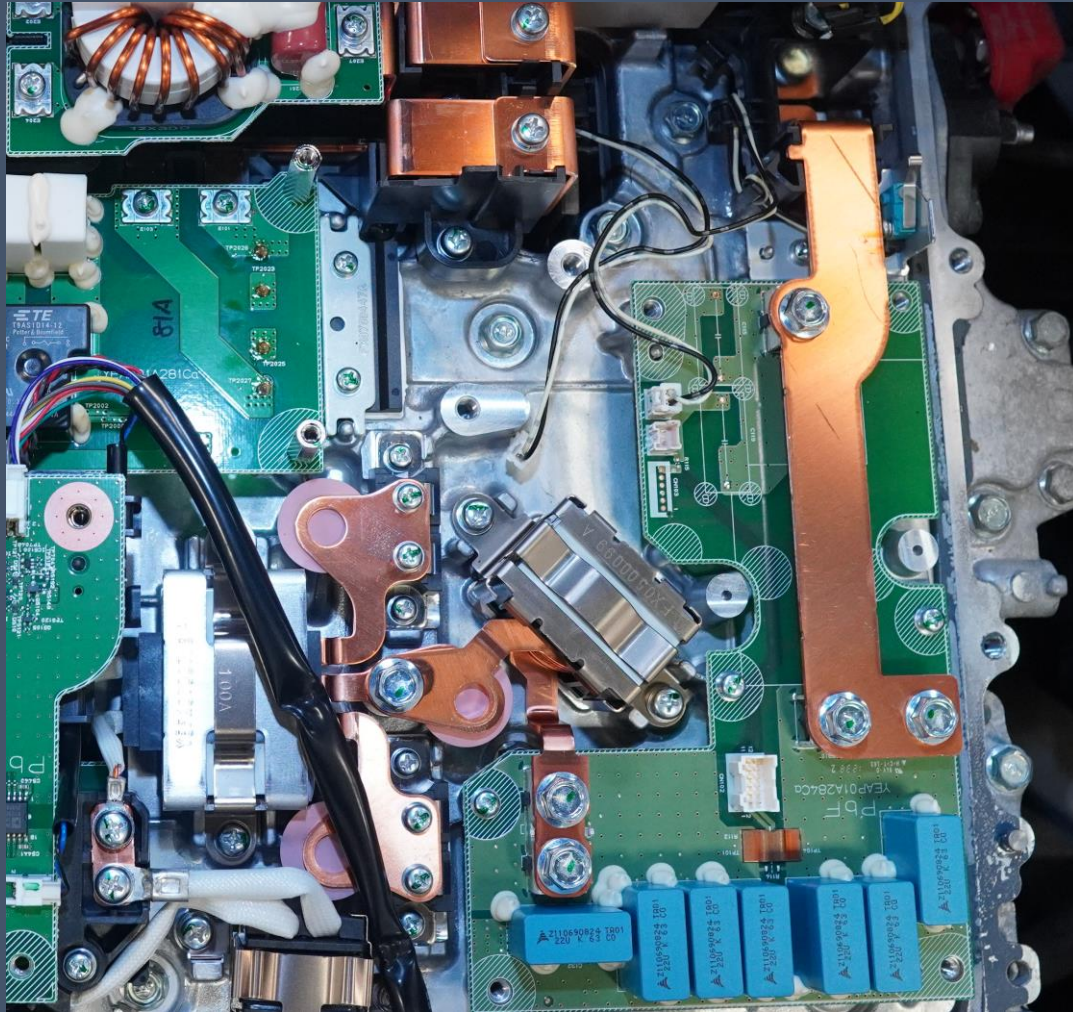
DC – DC Conversion Process



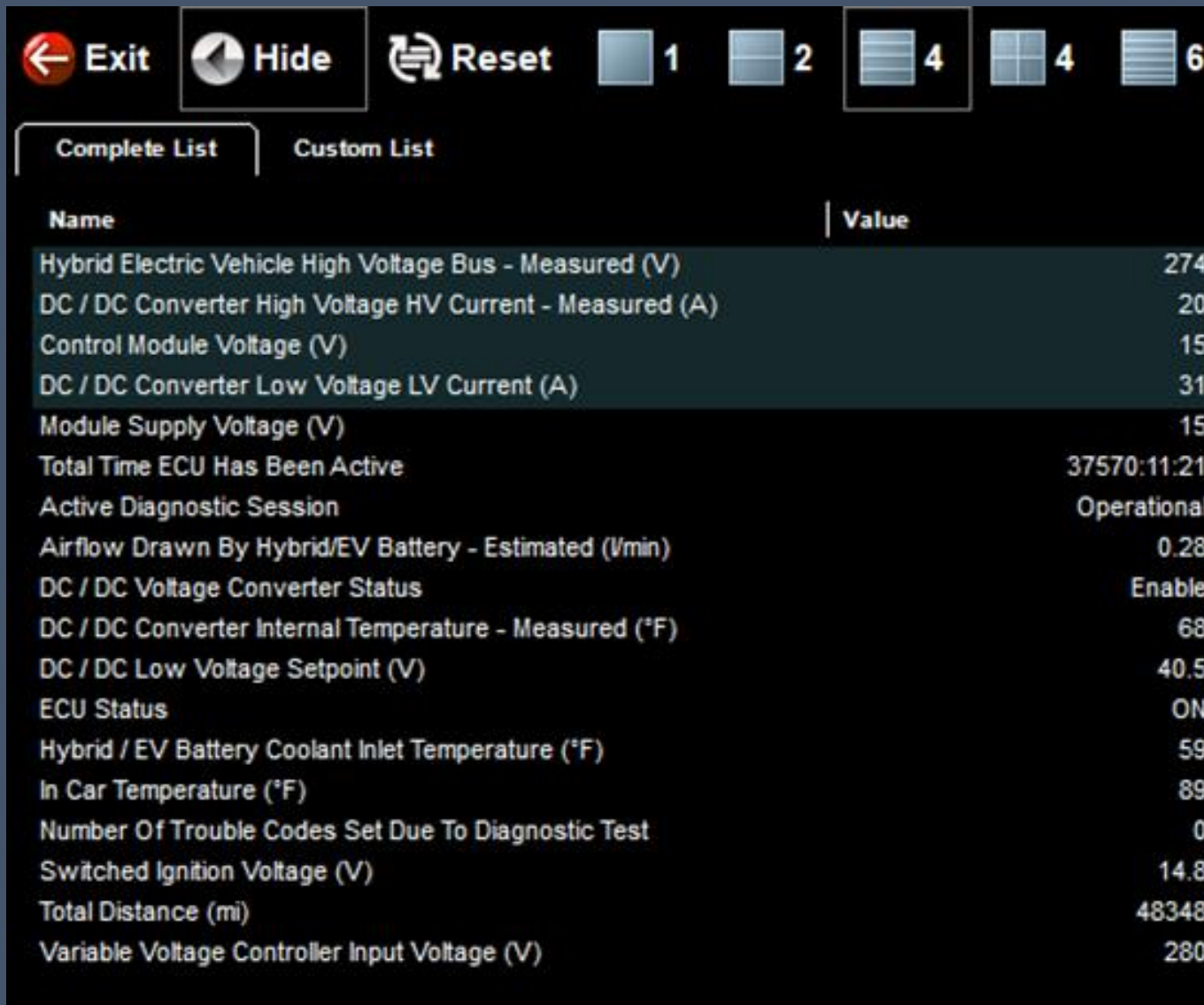
Kia EV6 Front Motor Inverter



Leaf inverter circuitry

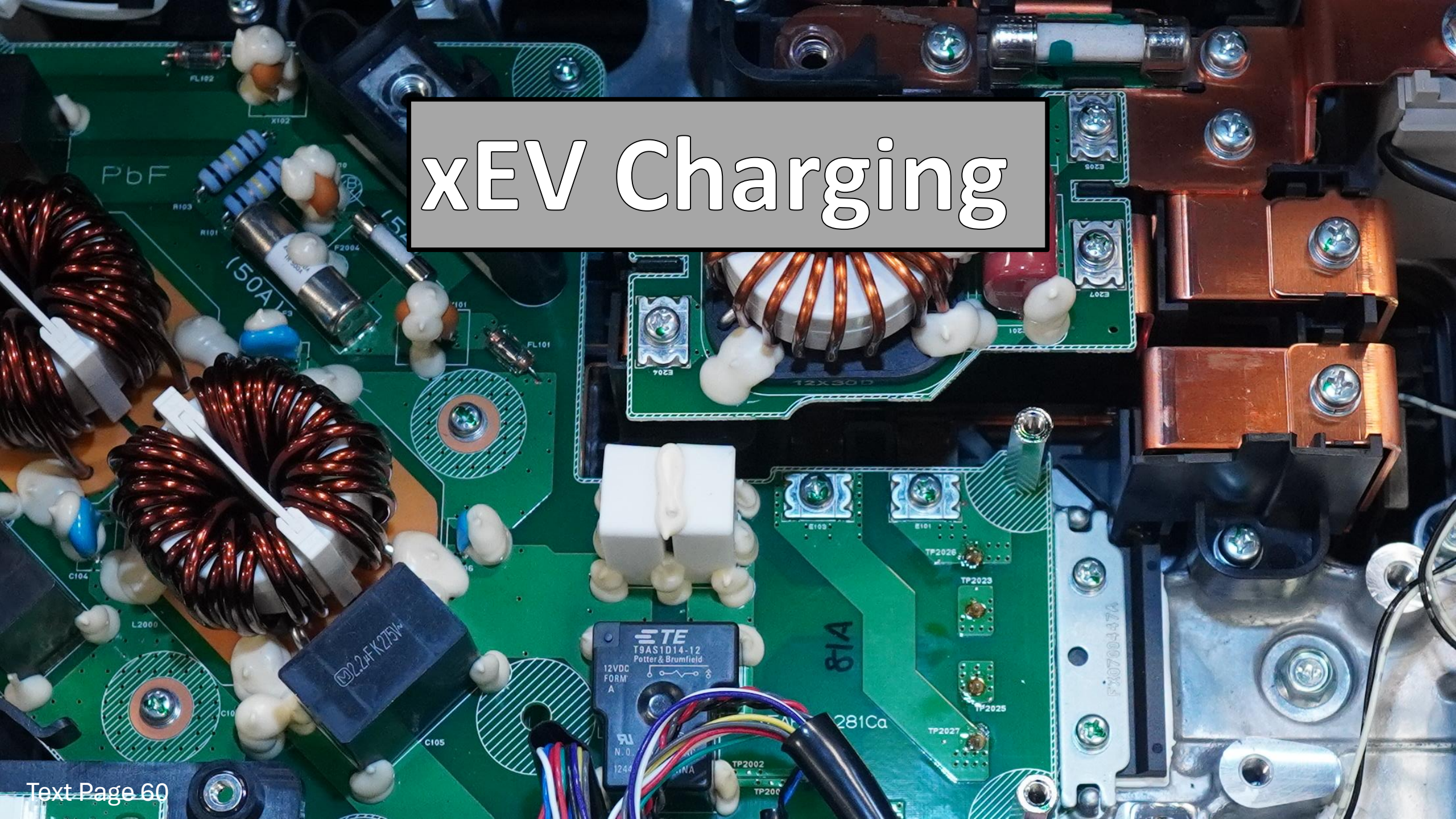


Inverter diagnostics



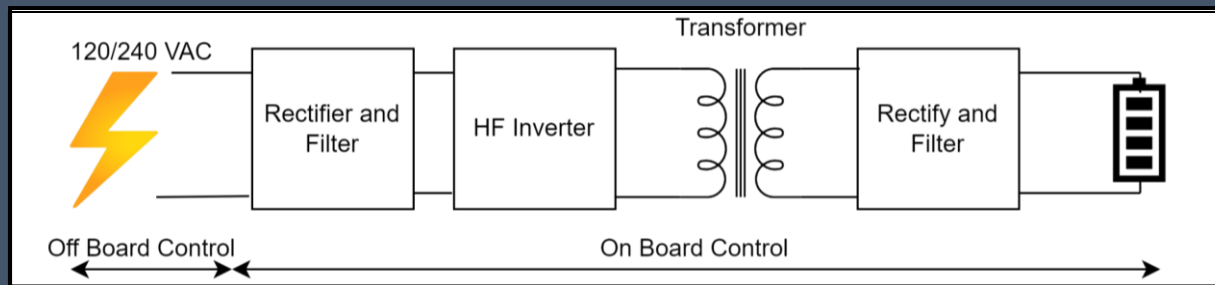
Name	Value
Hybrid Electric Vehicle High Voltage Bus - Measured (V)	274
DC / DC Converter High Voltage HV Current - Measured (A)	20
Control Module Voltage (V)	15
DC / DC Converter Low Voltage LV Current (A)	31
Module Supply Voltage (V)	15
Total Time ECU Has Been Active	37570:11:21
Active Diagnostic Session	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



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) (15.0kW) starting at \$379	AmazingE (kW) (7.0kW) starting at \$329	LCS-25 (kW) (2.5kW) starting at \$449	LCS-30 (kW) (3.0kW) starting at \$499	AmazingE FAST (kW) (2.0kW) starting at \$449	HCS-50 (kW) (5.0kW) starting at \$635	HCS-60 (kW) (6.0kW) starting at \$899	HCS-80 (kW) (8.0kW) starting at \$969
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	3.3	5.5	13*	13	13	13	13	13	13
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									
BMW 330e									
BMW 530e									
BMW 740e									
BMW 745e									
BMW i8									
BMW X3 xDrive30e									
BMW X5 xDrive40e									
BMW X5 xDrive45e									
Cadillac CT6	3.6	5.5	14*	14	14	14	14	14	14
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)									
Chrysler Pacifica									
Fiat 500e									
Ford Focus EV									
Ford Focus EV 2017									
Honda Clarity EV	6.6	5.5	15	18.5	22.5	25.5*	25.5	25.5	25.5
Honda Clarity Plug-In									
Hyundai Ioniq									
Karma Revero									
Kia Soul									

* 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, 3.6kW) 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	3.6	5.5	14*	14	14	14	14	14	14
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)									
Chrysler Pacifica	6.6	5.5	15	18.5	22.5	25.5*	25.5	25.5	25.5
Fiat 500E									
Ford Focus EV									
Ford Focus EV 2017									
Honda Clarity EV									
Honda Clarity Plug-In									
Hyundai Ioniq									
Karma Revero									
Kia Soul									

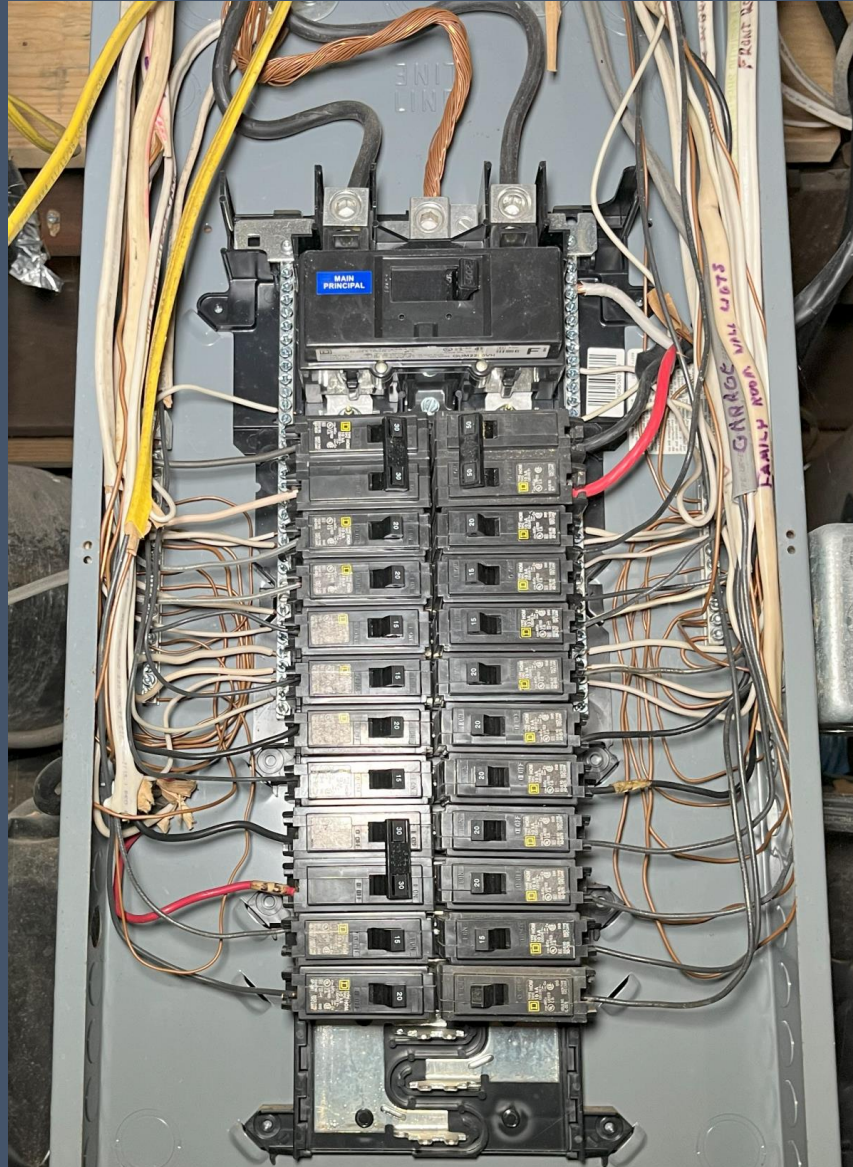
Miles per hour of charging

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*

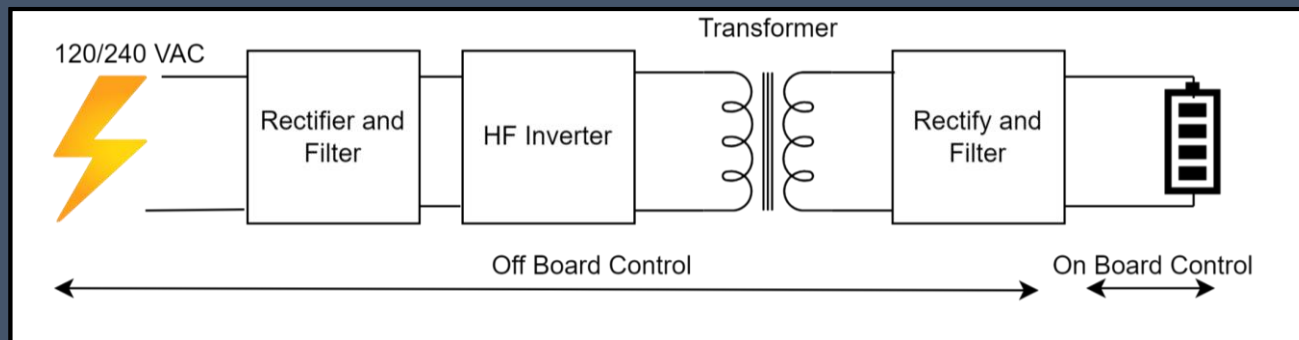
Wiring a level two charger

- 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?



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

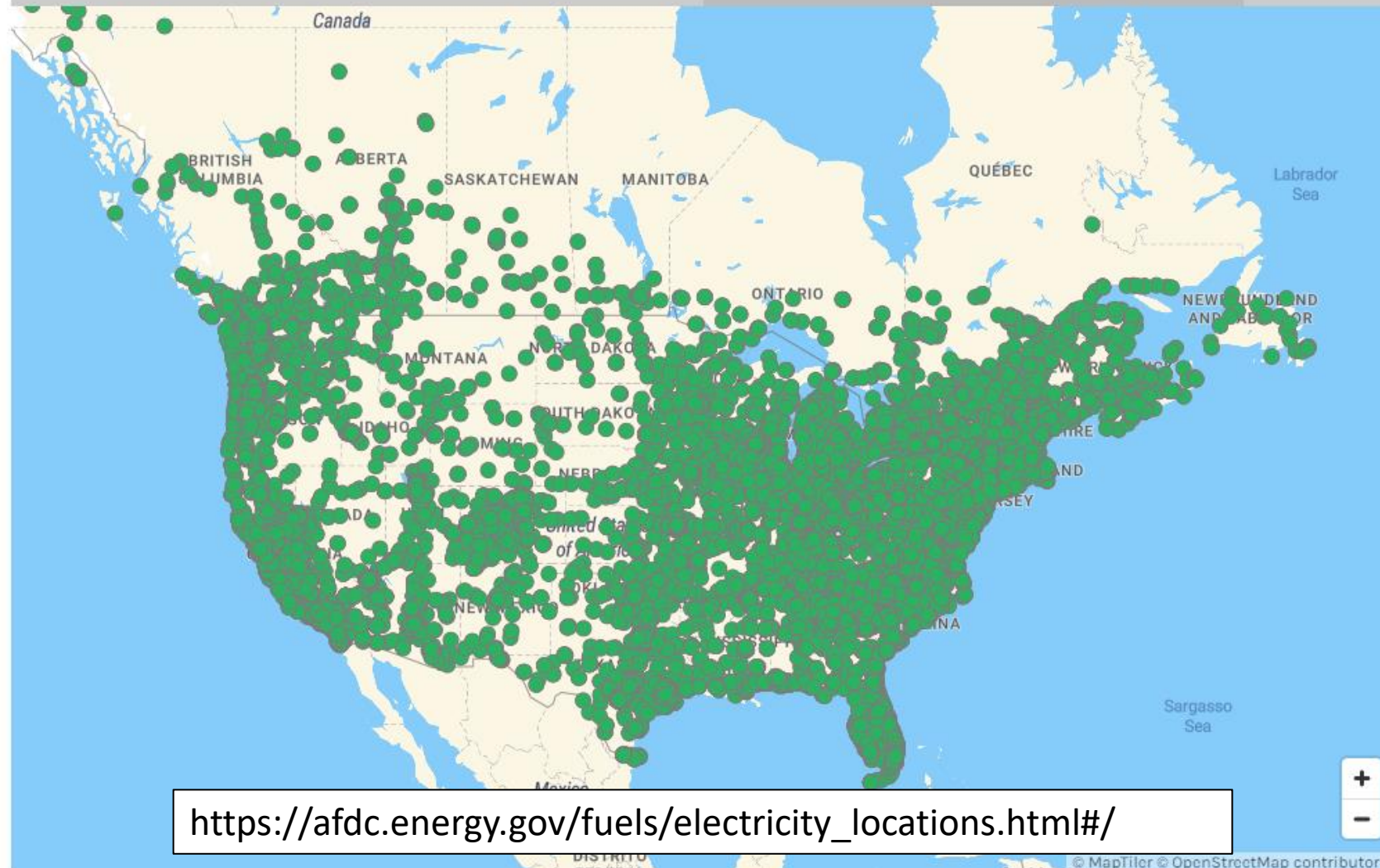


Electric Vehicle Charging Station Locations

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

Enter location Charger Types: Level 2, DC Fa... Connectors: All Map a Route



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

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

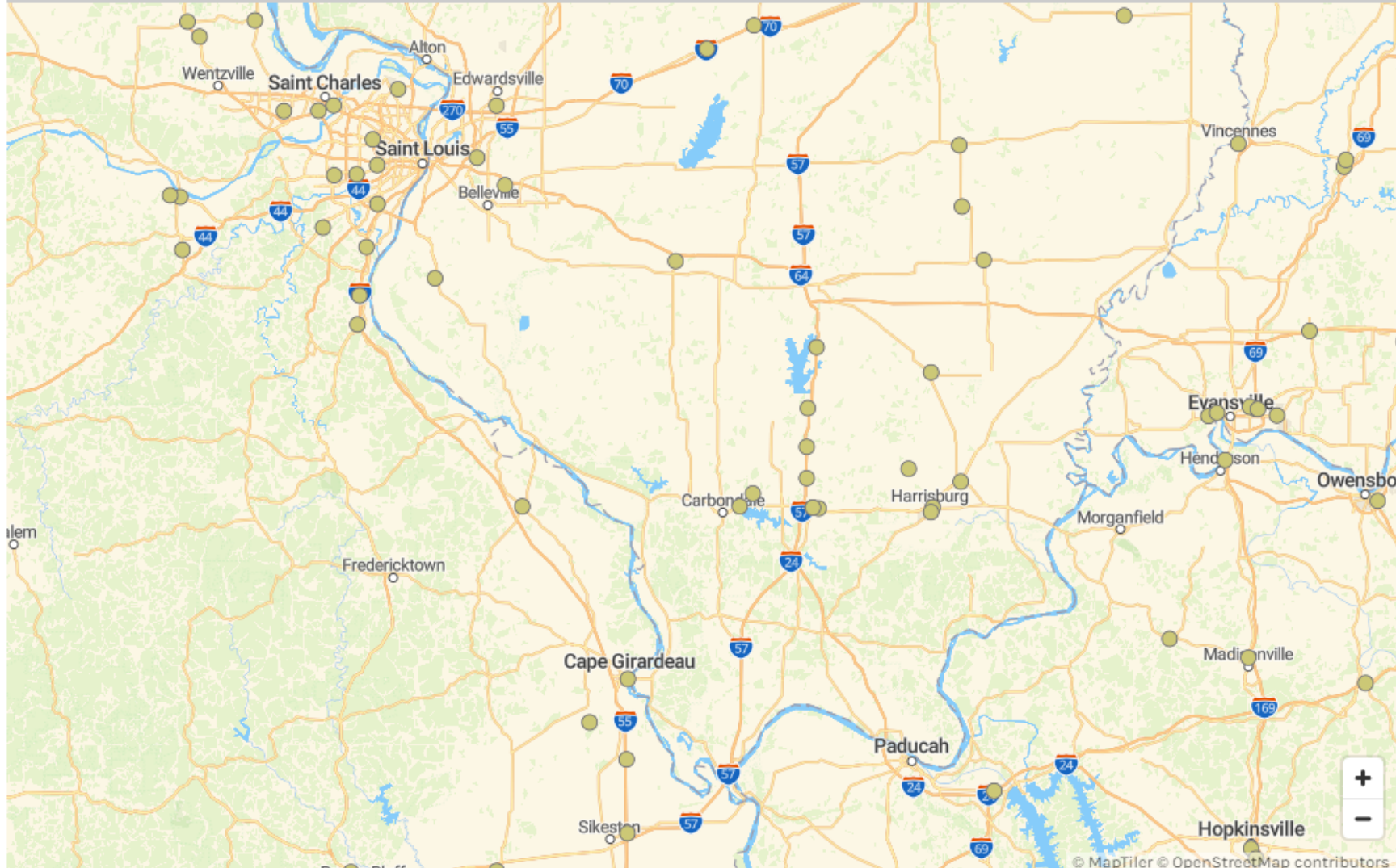
Enter location



Ethanol (E85)



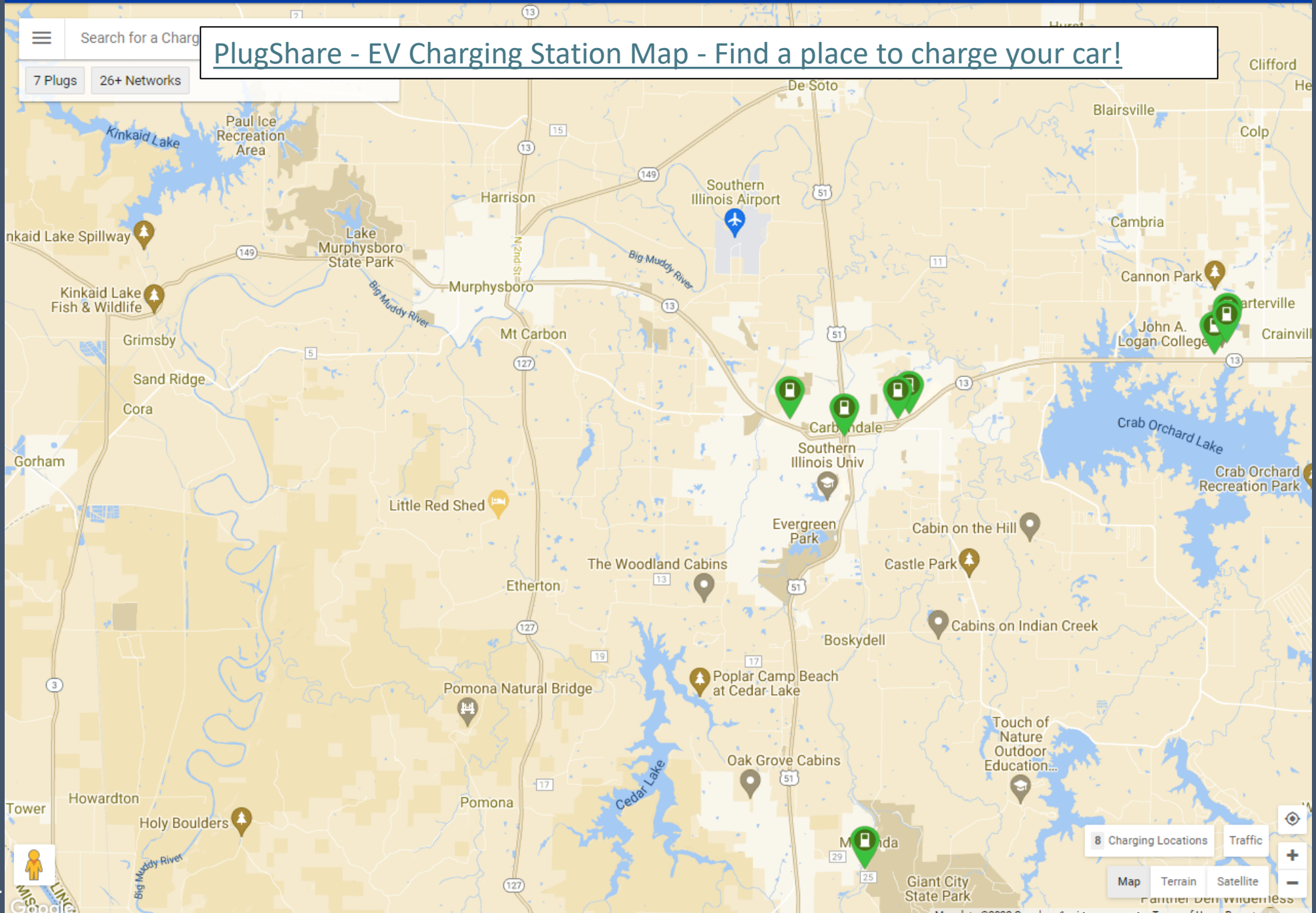
Map a Route



Search for a Charge

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

7 Plugs 26+ Networks



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)



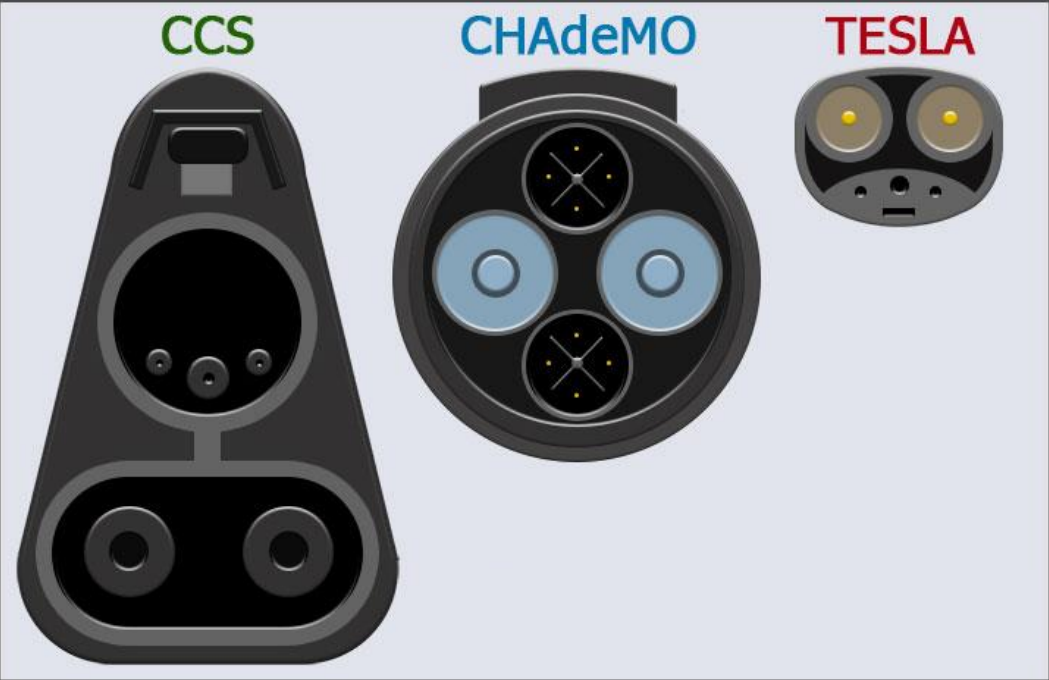
CHAdeMO Connector (DC)



NACS

Plug Configurations

- Some plug sizes are out of control!



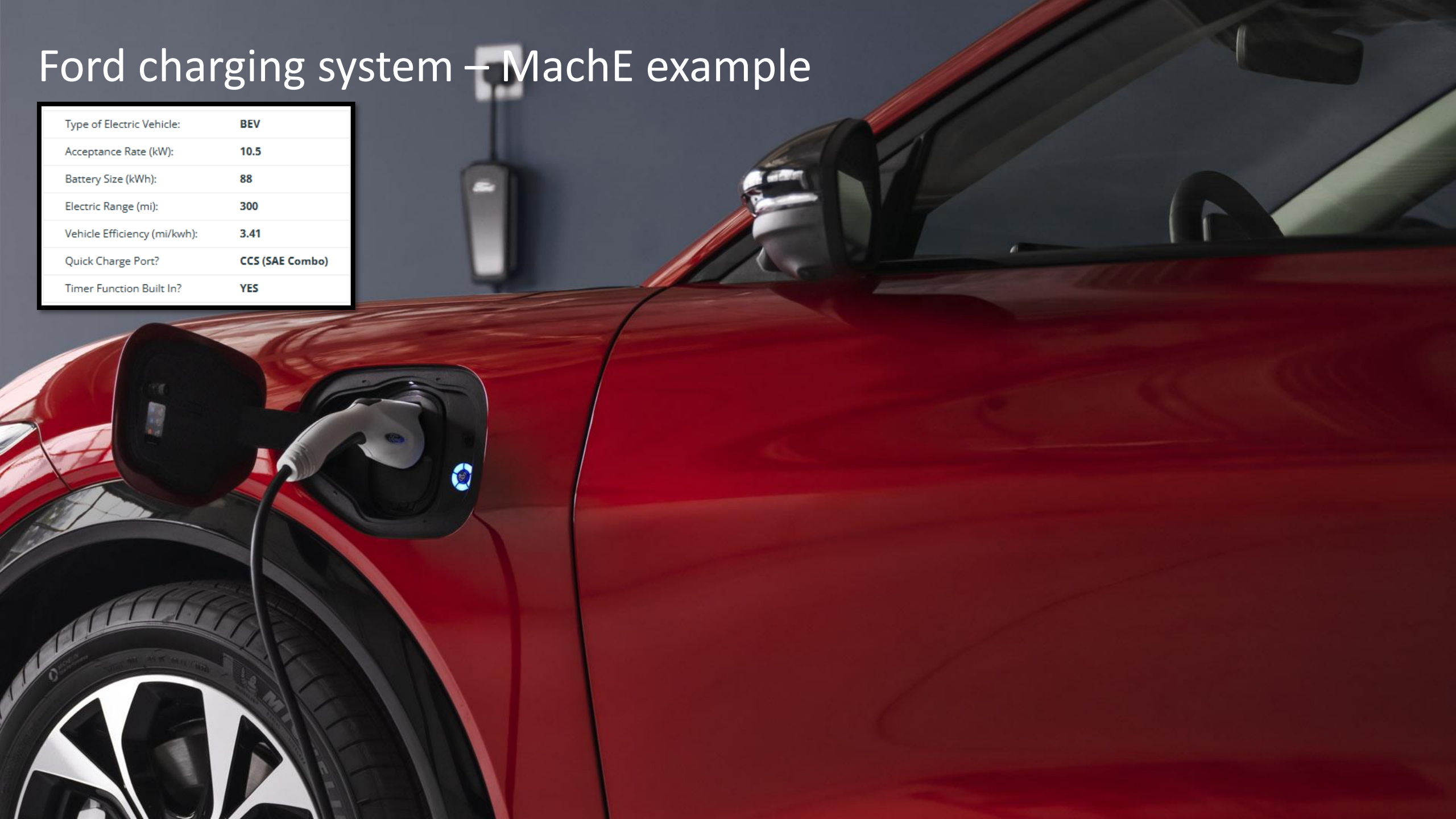
Plug Configurations

- NACS vs. CCS1

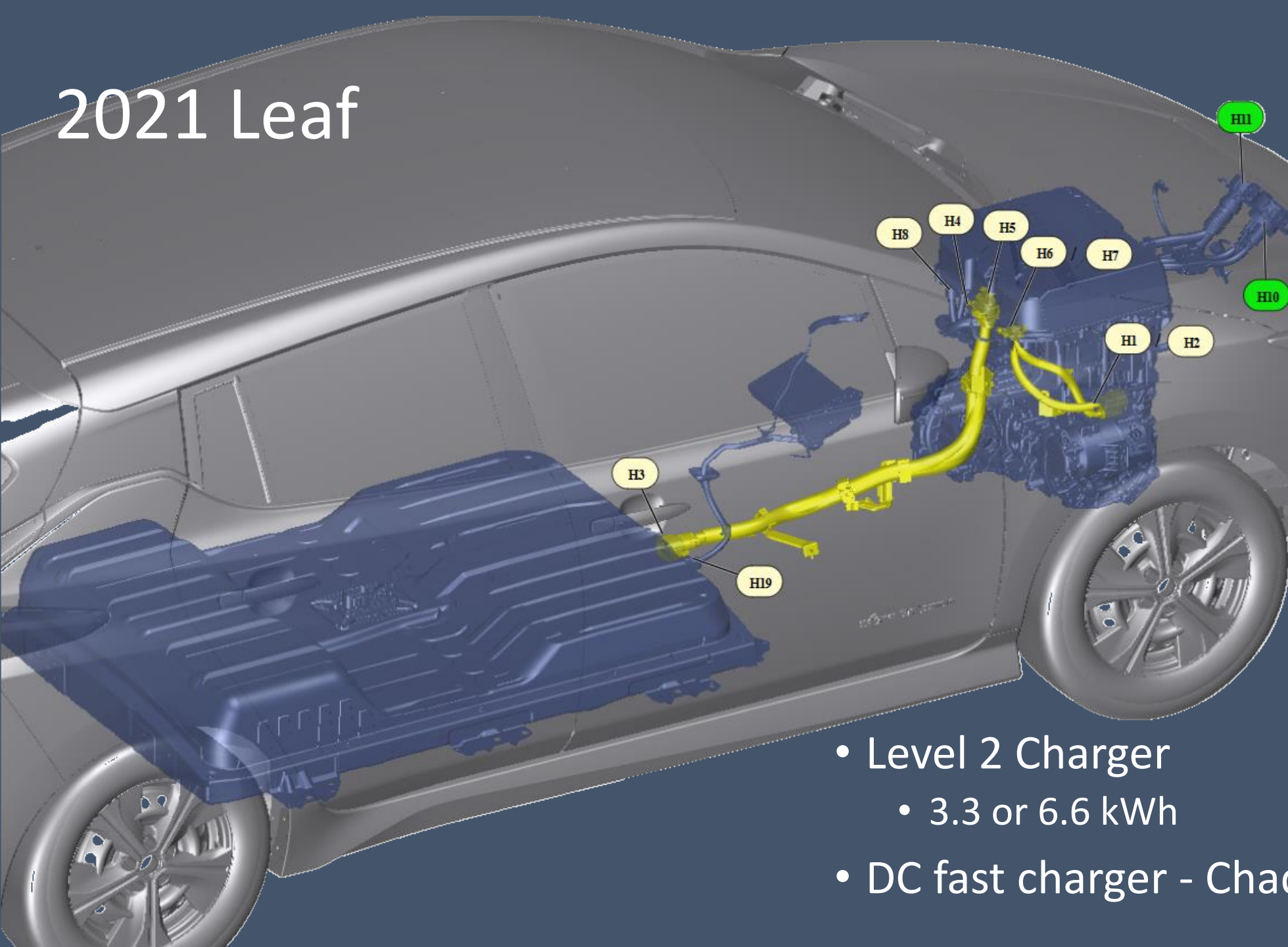


Ford charging system – MachE example

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



2021 Leaf

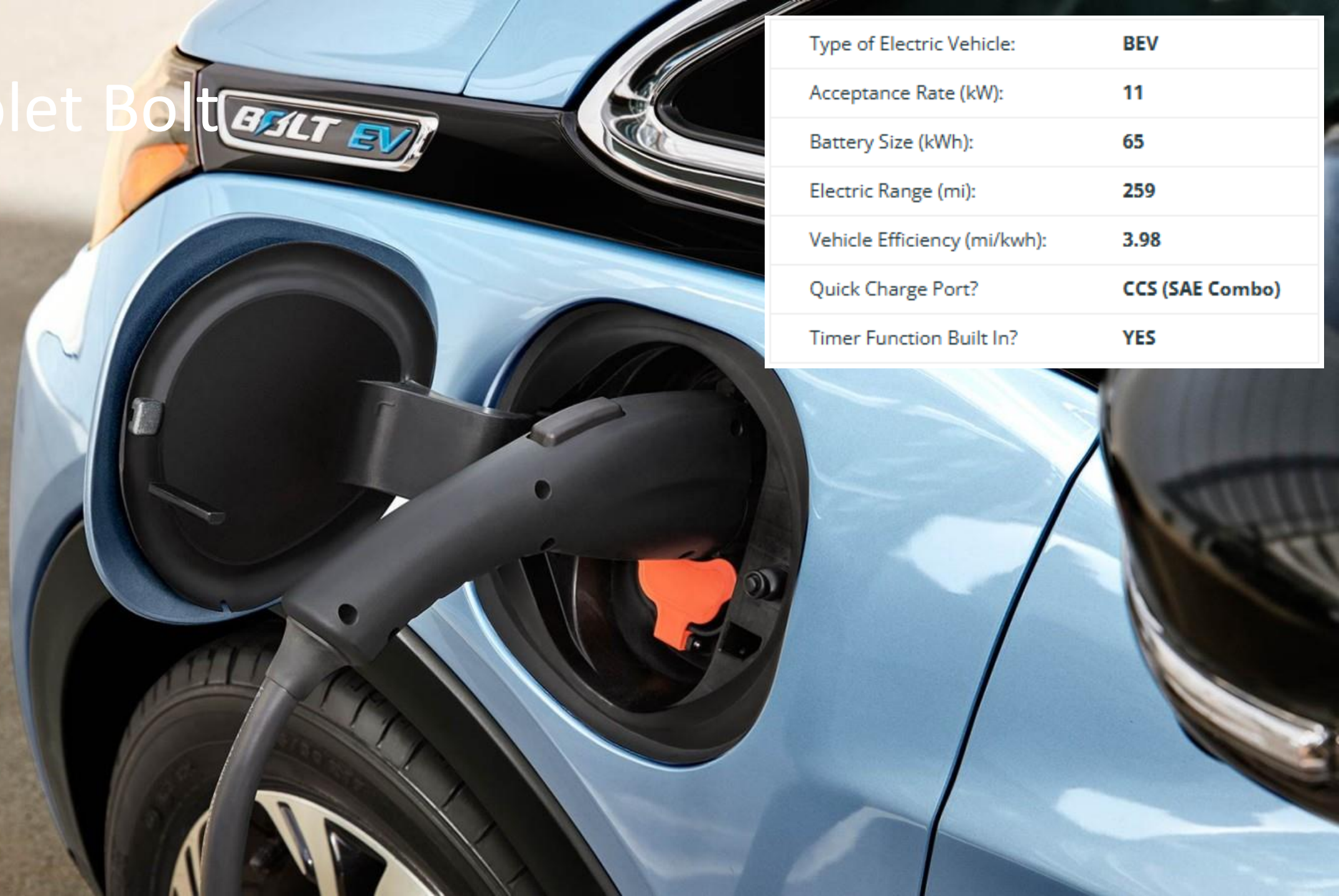


Type of Electric Vehicle:	BEV
Acceptance Rate (kW):	6.6
Battery Size (kWh):	30
Electric Range (mi):	107
Vehicle Efficiency (mi/kwh):	3.57
Quick Charge Port?	Chademo
Timer Function Built In?	YES

Type of Electric Vehicle:	BEV
Acceptance Rate (kW):	3.3
Battery Size (kWh):	30
Electric Range (mi):	107
Vehicle Efficiency (mi/kwh):	3.57
Quick Charge Port?	NO
Timer Function Built In?	YES

- Level 2 Charger
 - 3.3 or 6.6 kWh
- DC fast charger - Chademo

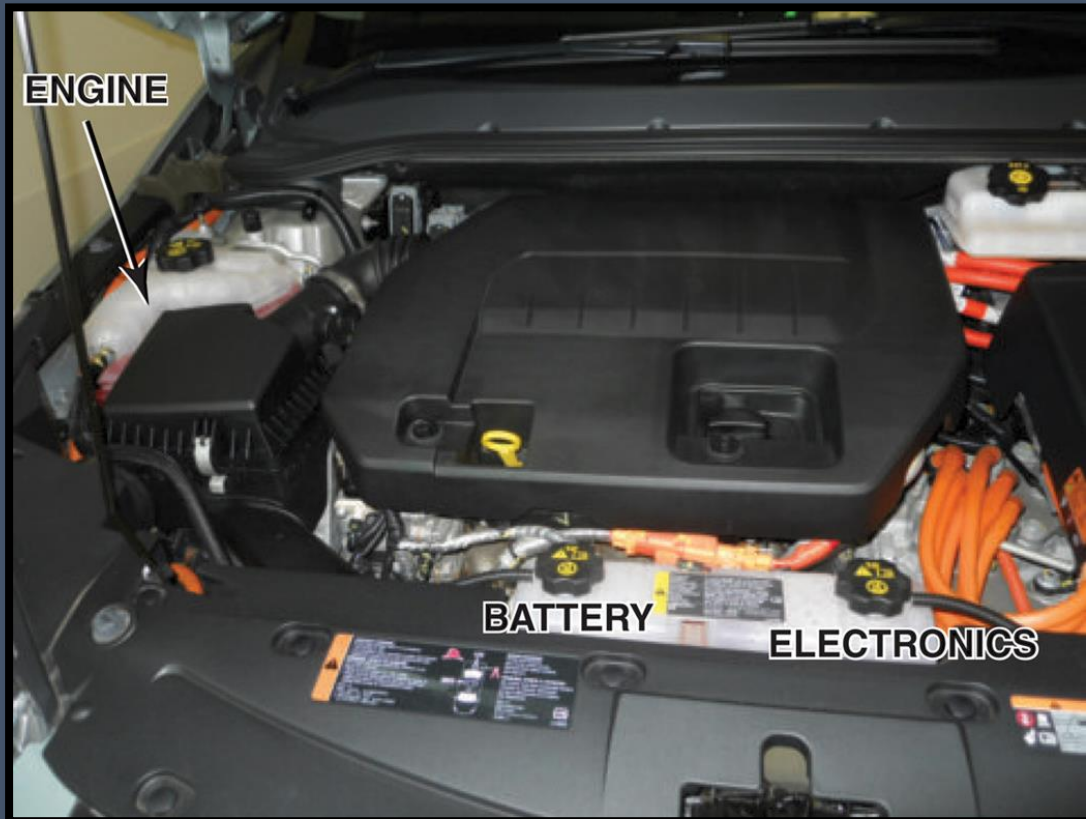
Chevrolet Bolt



Type of Electric Vehicle:	BEV
Acceptance Rate (kW):	11
Battery Size (kWh):	65
Electric Range (mi):	259
Vehicle Efficiency (mi/kwh):	3.98
Quick Charge Port?	CCS (SAE Combo)
Timer Function Built In?	YES

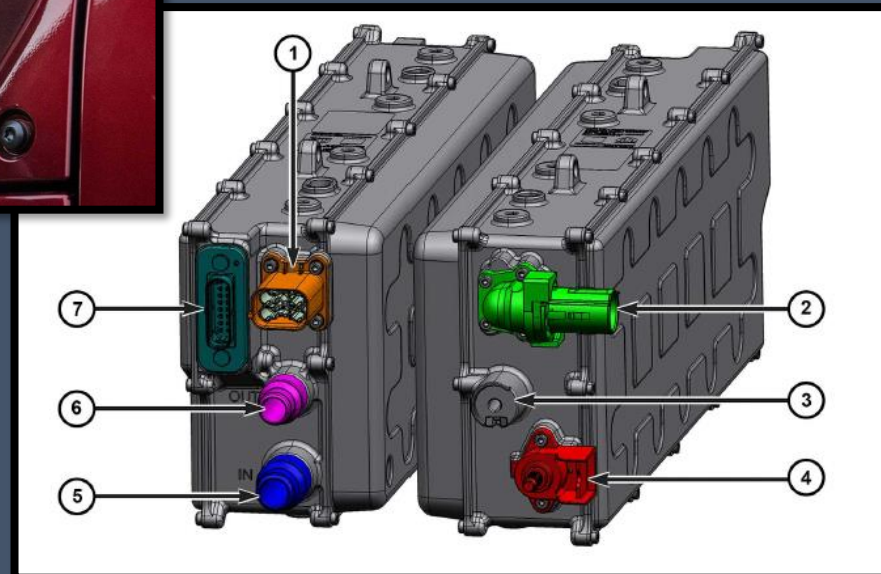
Volt charging system

- Battery Charger
 - Located behind passenger's headlamp assembly
 - Water cooled with the power inverter



Jeep 4xe charging system

- Integrated Dual Charging Module
 - High voltage and low voltage
 - Water cooled through coolant loop
 - ESVE Locked until door unlock is requested



Ford charging system

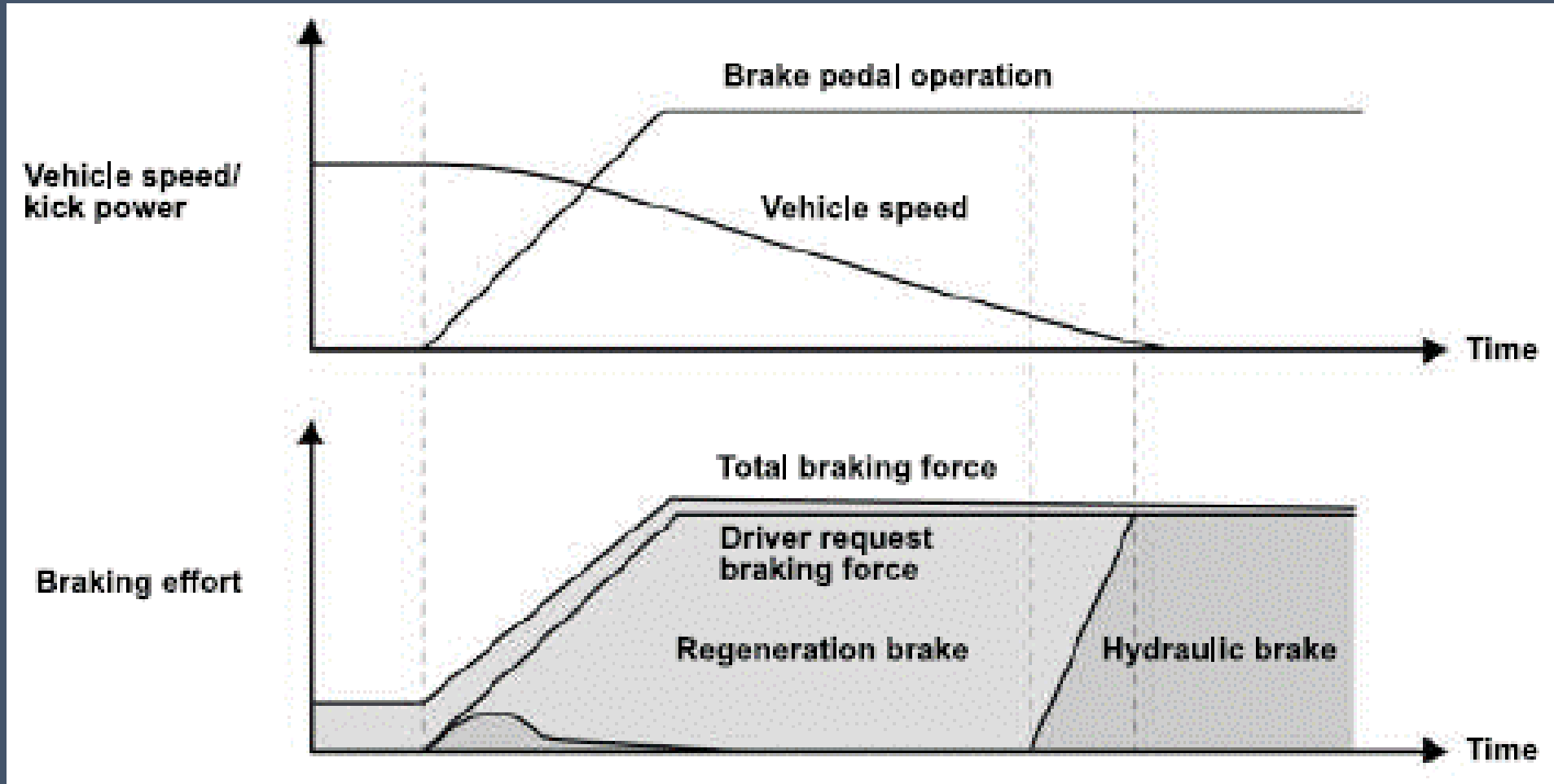
- Charging port light ring (CPLR)
 - Current SOC
 - Light ring
 - Charging, faults, status
 - 25%, 50%, 75%, and full charge



xEV Brakes

A close-up photograph of an xEV (extended-range electric vehicle) brake system. The central focus is a white plastic brake fluid reservoir with a black, textured master cylinder cap on top. To the right, various metal components, including a master cylinder and brake lines, are visible. A black hose is connected to the system. In the background, a metal part has a white label with a QR code and the text 'A9A0008C3' and '88211336'. The overall scene is dimly lit, highlighting the mechanical details of the brake assembly.

Regen vs. Hydraulic vs. Blended

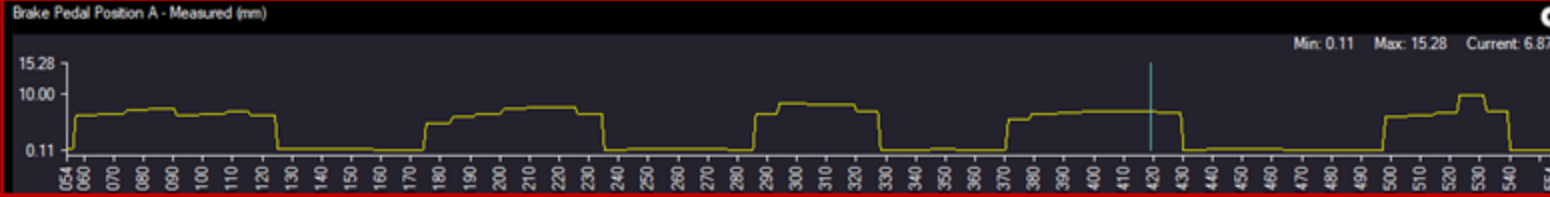


Ford Fusion Vacuum Actuated Electronic Braking

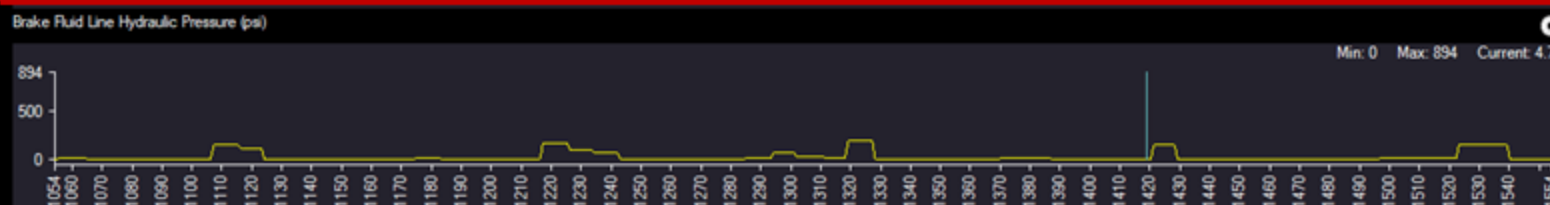
Vehicle speed – A series of acceleration and deceleration



Pedal Position – the higher the voltage, the harder the stop



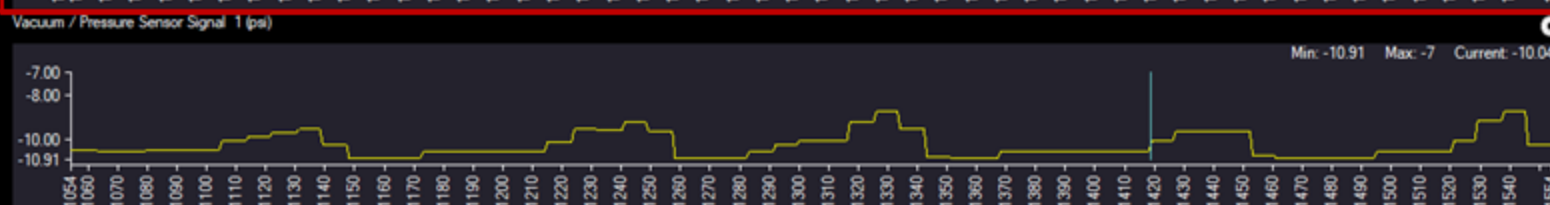
Hyd Pressure – pressure climbs when speed is low



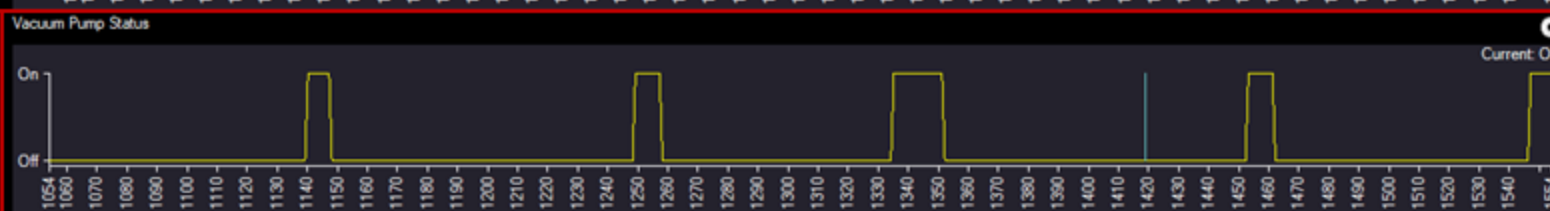
Booster Travel – diaphragm movement



Vacuum – Stored vacuum for the booster



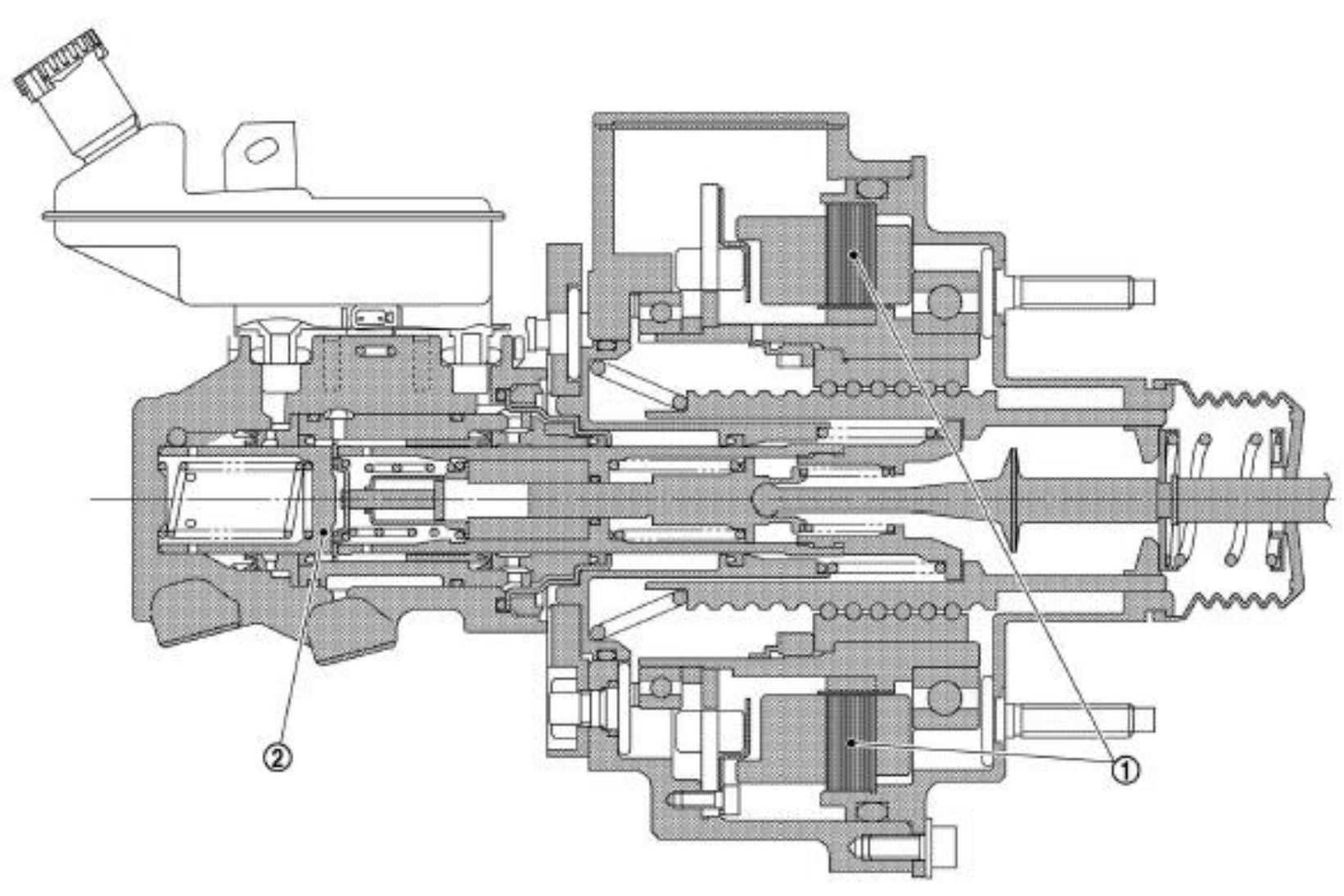
Vacuum pump – cycling the pump to restore vacuum



Variations of Electronic Braking

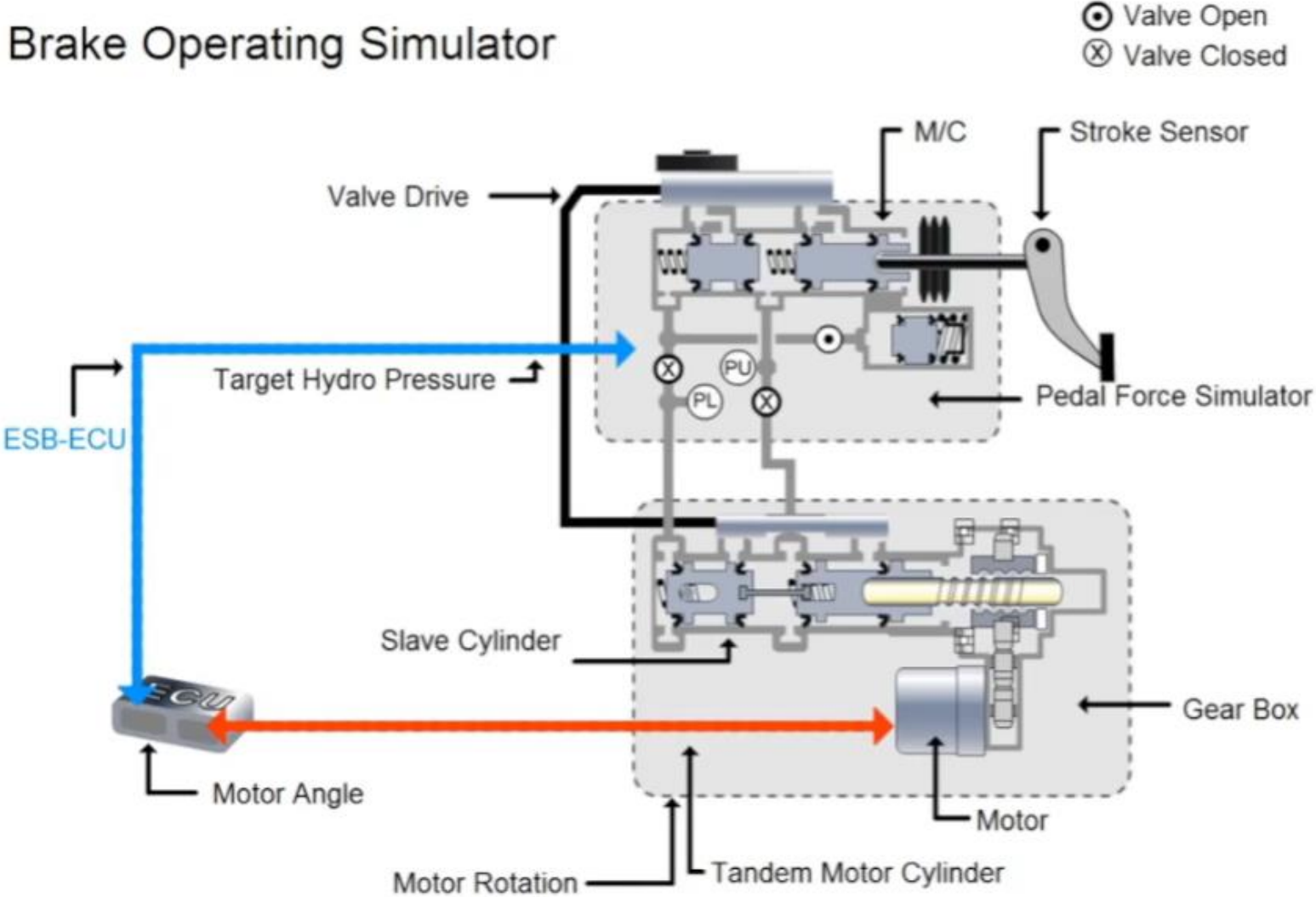
- Accumulator stored pressure (Toyota hybrid, Ford hybrid, and early Honda hybrid are examples)
- Motor and piston-generated pressure (Hyundai Sonata Hybrid/Ionic 6, Ford Gen 4 vehicles with electronic brake booster)
- Motor-actuated master cylinder (Nissan Leaf, Honda Accord Hybrid, Tesla)
- Vacuum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

Leaf and Ariya Intelligent Brake Unit

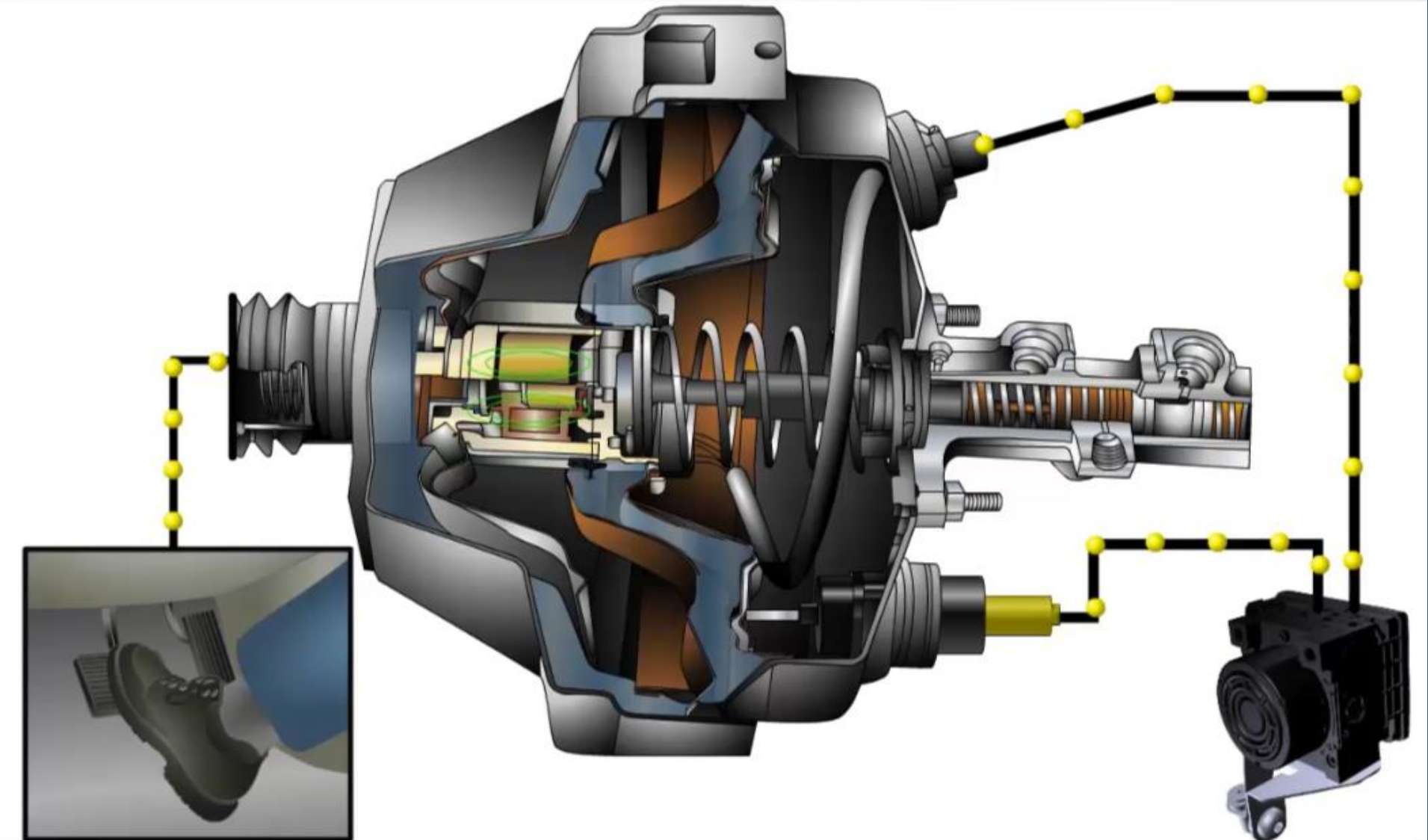



2023 Honda Accord Hybrid

Brake Operating Simulator



Ford 2nd and 3rd Generation Electronic Braking

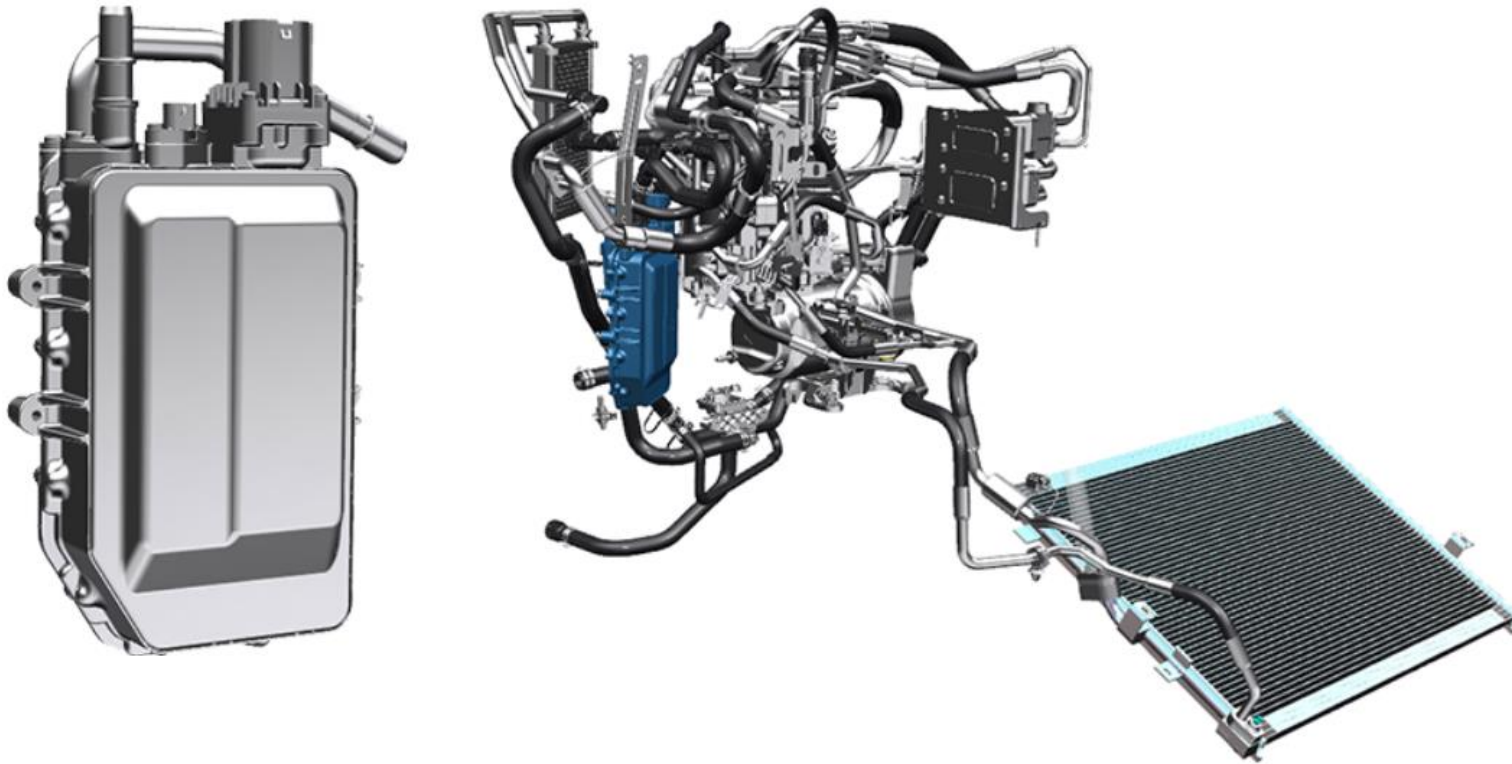


A close-up photograph of a metal HVAC coil. The coil consists of numerous parallel metal fins. In the center, there is a small, oval-shaped control knob or sensor. The metal has a brushed or polished appearance. A semi-transparent grey box with a black border is overlaid on the top center of the image, containing the text 'xEV HVAC' in white, bold, sans-serif font.

xEV HVAC

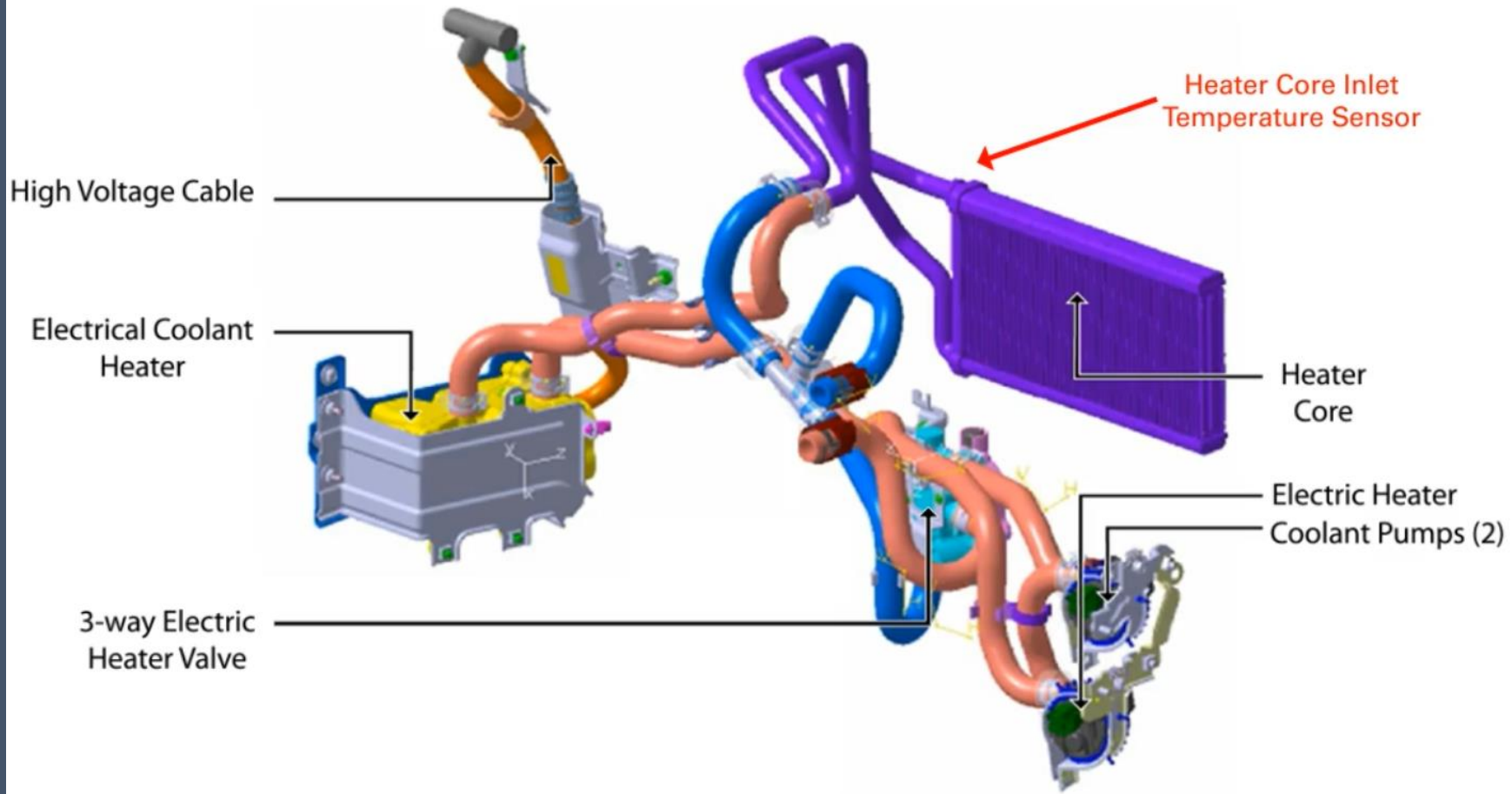
Electric Heating Elements

Positive Temperature Coefficient (PTC) heater

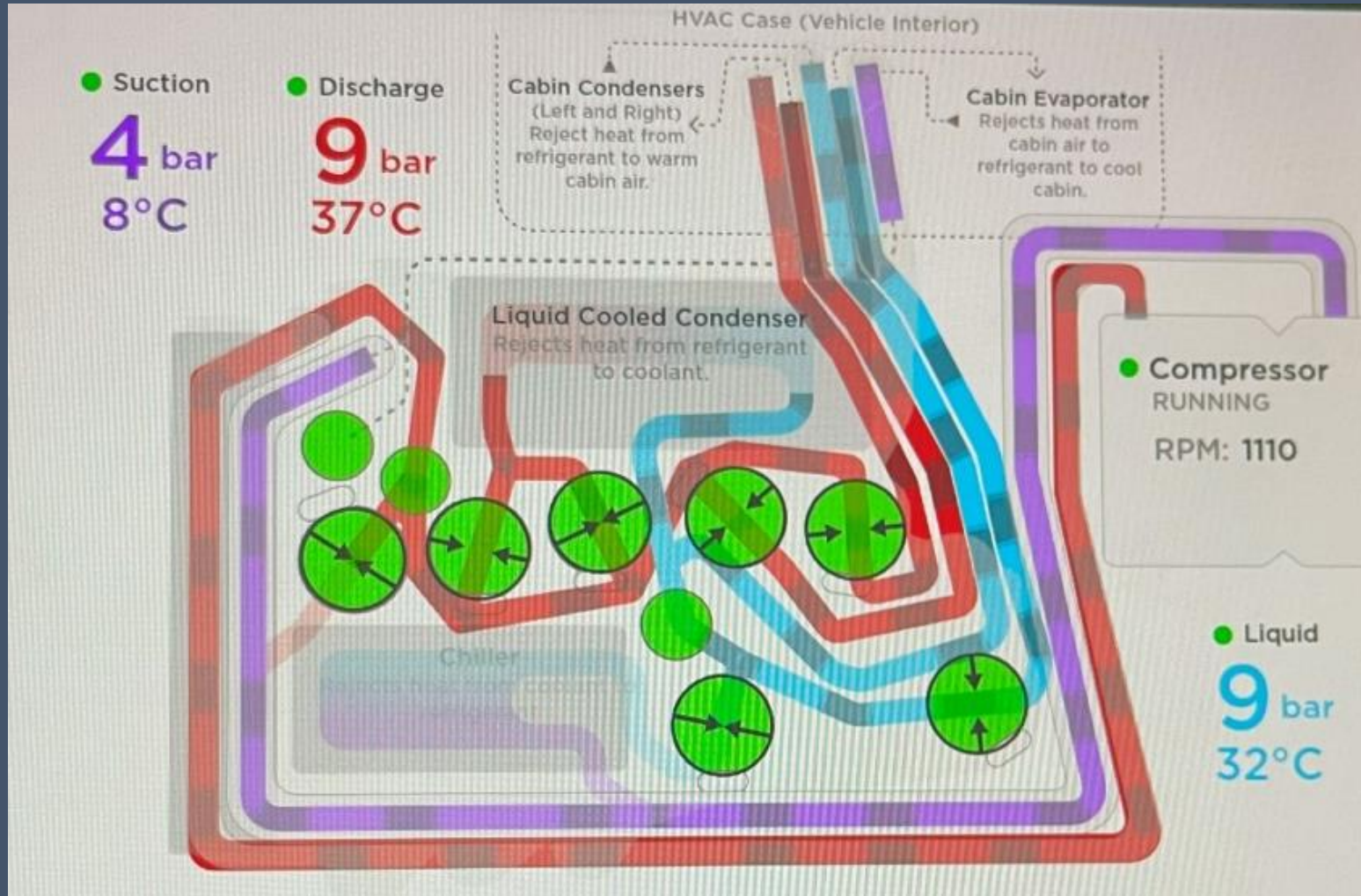


Electric Heating Elements

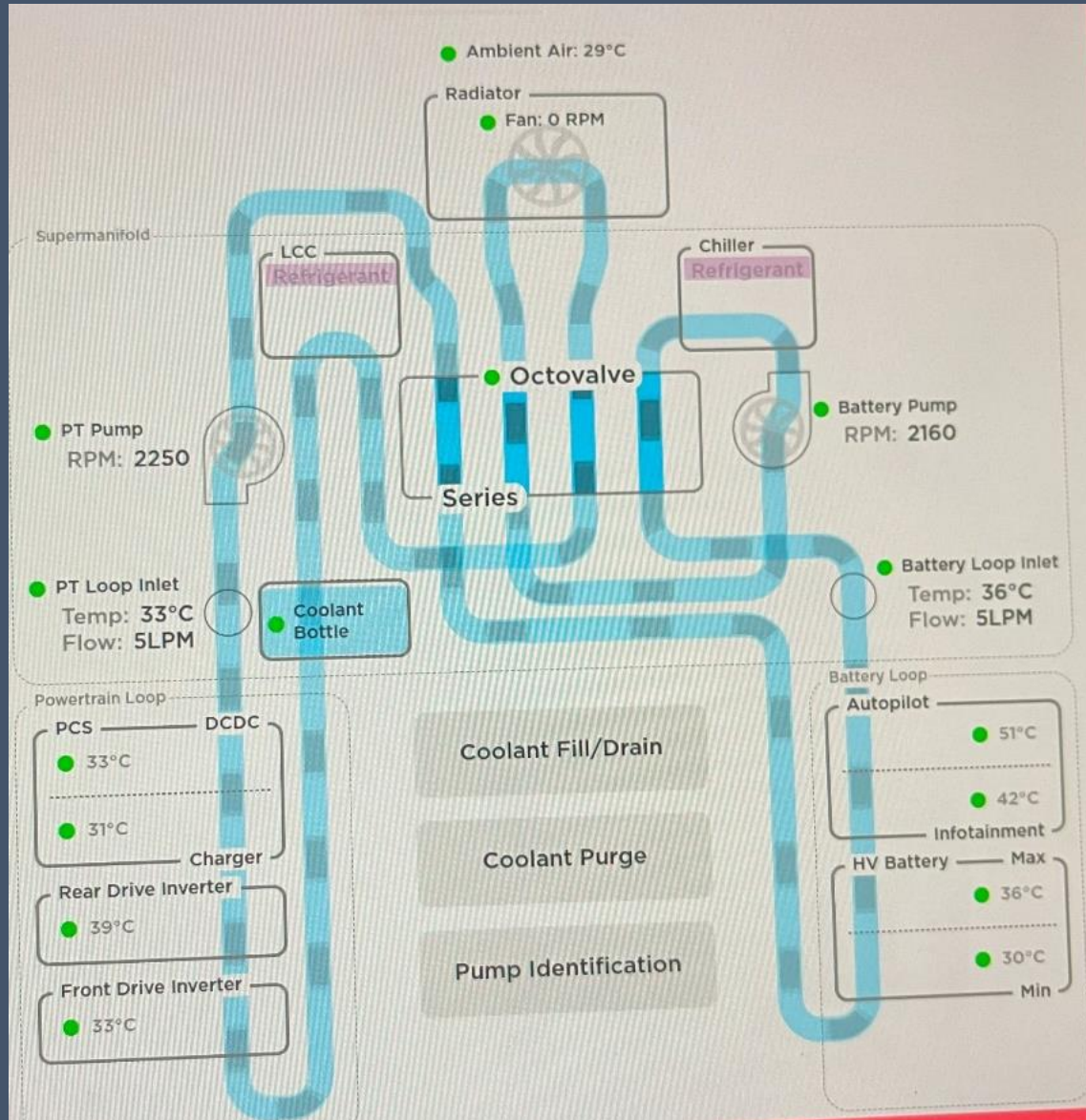
Heater System Components



Heat Pump



Heat Pump

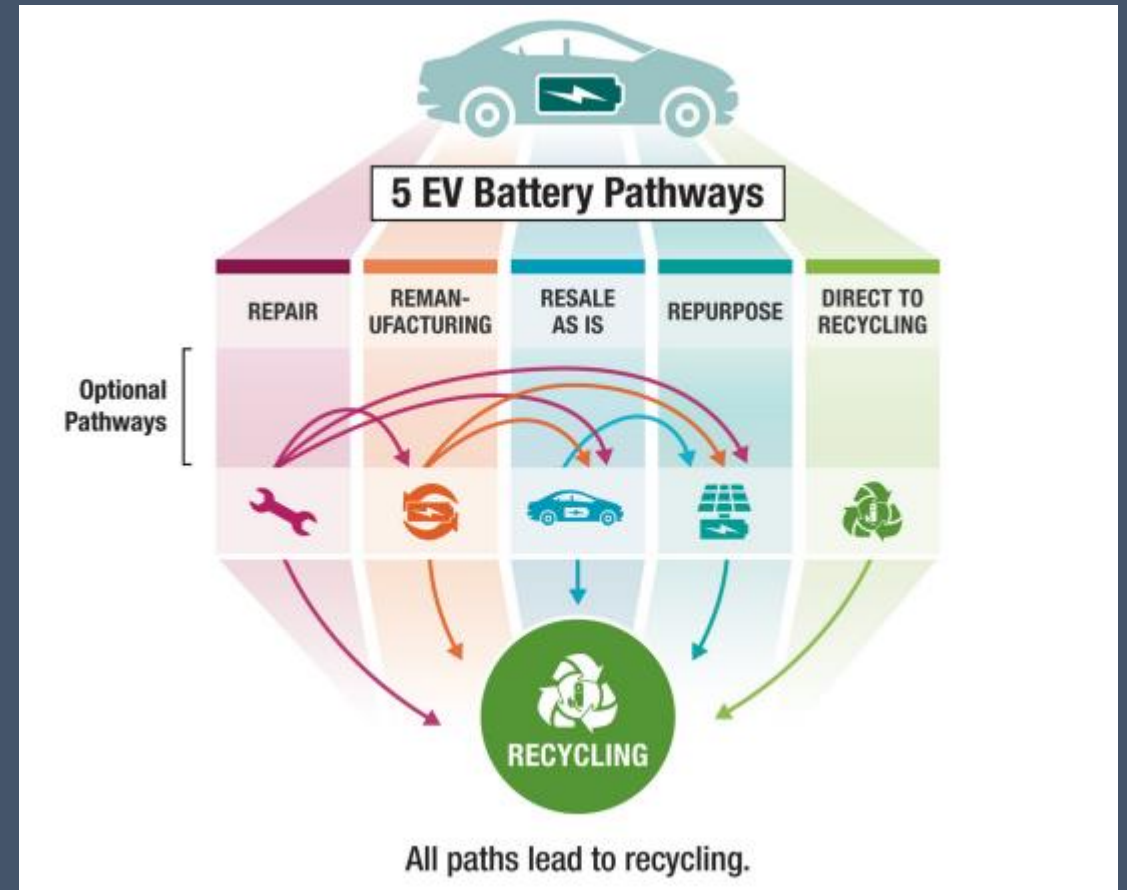


Environmental Impact

An aerial photograph showing a vast, rectangular area divided into a grid of smaller plots. The plots are filled with various colors, including shades of green, yellow, and brown, suggesting different stages of growth or different types of crops. The surrounding area is dark and appears to be a natural landscape, possibly a wetland or a coastal area. The overall scene is one of large-scale human intervention in a natural environment.

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?

The screenshot displays the Albemarle website's interface. At the top left is the Albemarle logo. The navigation menu includes: About Us, Locations, Offerings, Sustainability, Investors, Careers, News, a search icon, a 'Regional Sites' dropdown menu, and a 'Select Language' option. The main content area features a satellite map of the United States with several orange location pins. Three pop-up windows are visible: 'Silver Peak, NV' (with icons for Energy Storage, Conversion Plant, and Resource Location), 'New Johnsonville, TN' (with icons for Energy Storage and Conversion Plant), and 'Kings Mountain, NC' (with icons for Energy Storage, Conversion Plant, and Research & Development). A copyright notice '© 2024 EarthStar Geographics' is located in the bottom right corner of the map area. At the bottom of the page is a legend with icons and labels for: Energy Storage, Specialties, Conversion Plant, Resource Location, Research & Development, Recycling Site, Production Site, Headquarters, Joint Venture, and Regional/Sales Office.

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)

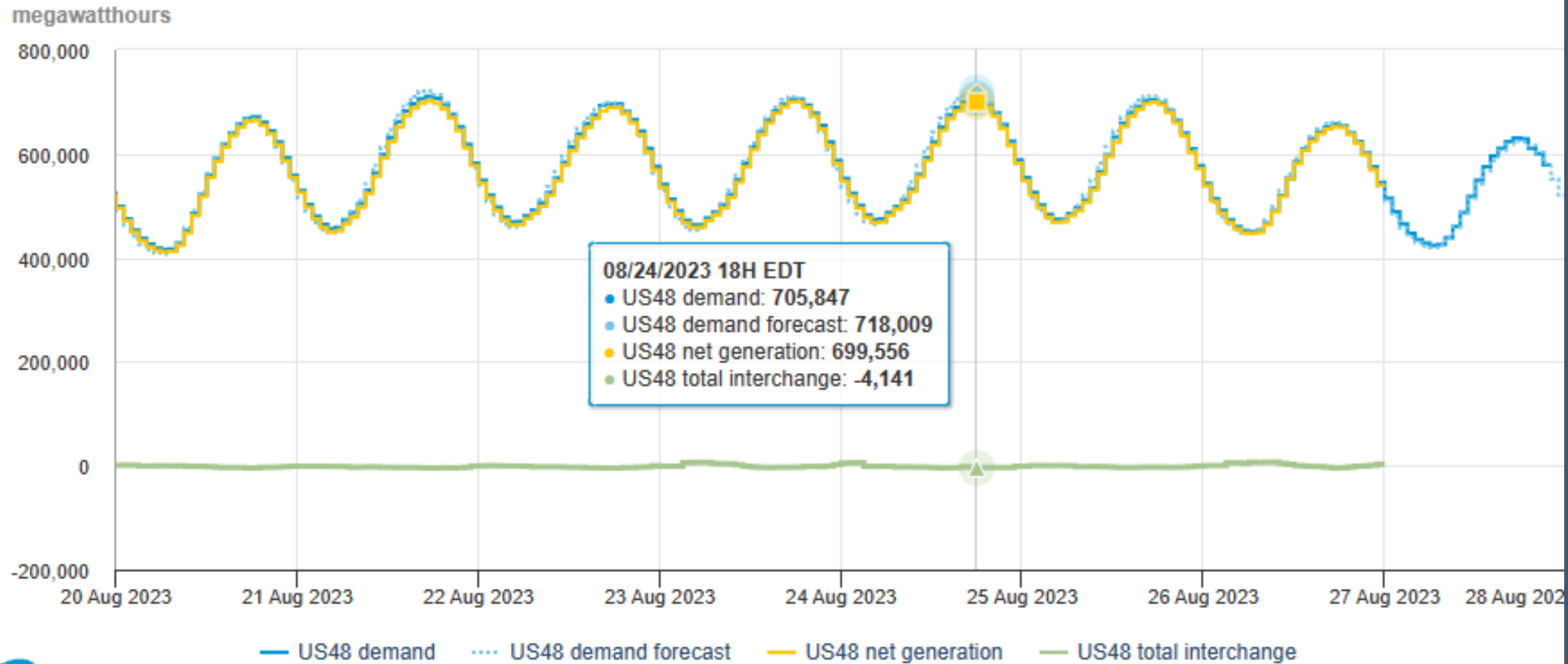
355 grams CO₂/mile (gas) or 407 grams CO₂/mile (diesel)

Vs

118 grams CO₂/mile

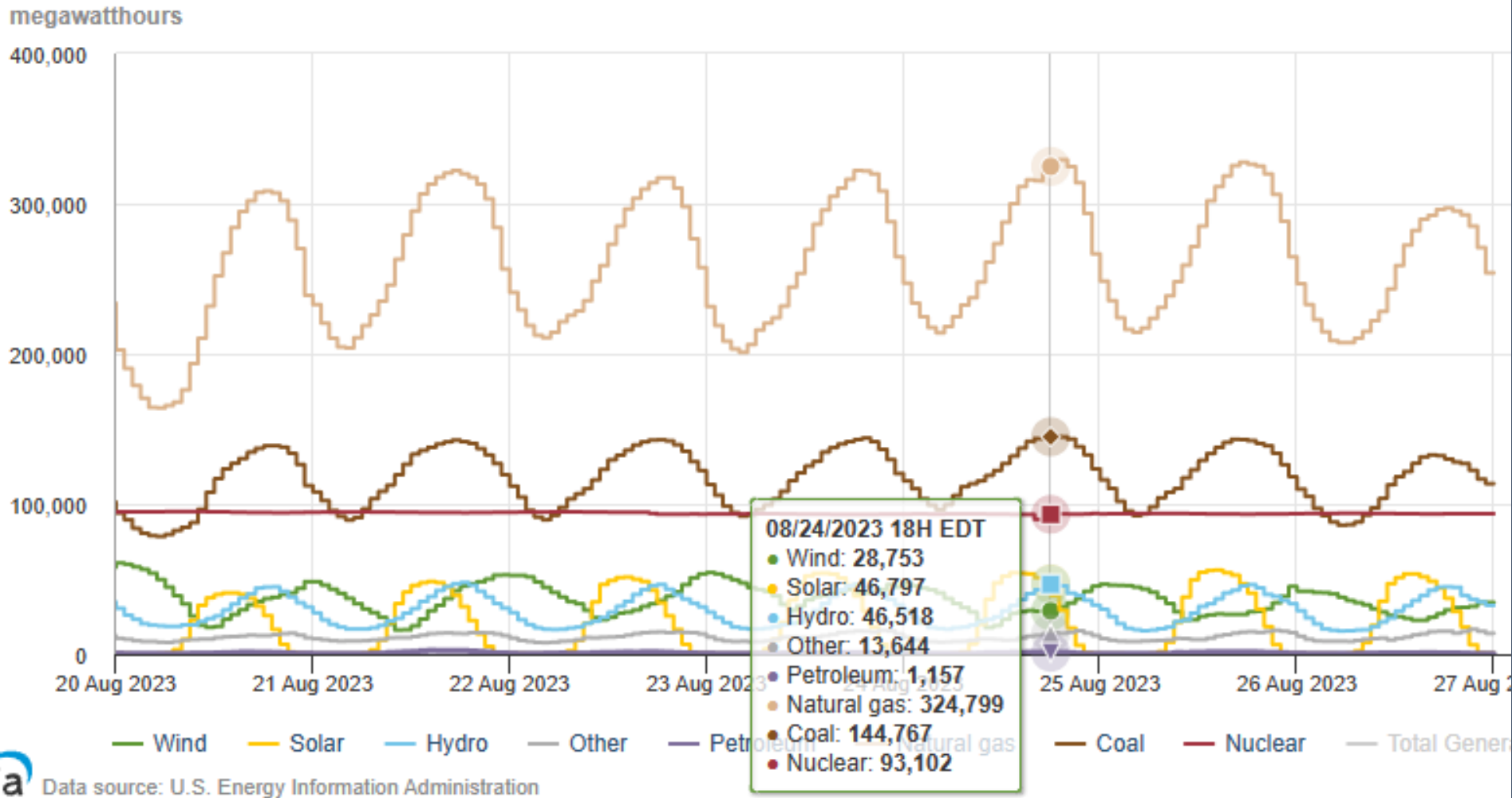
Power Grid – can it handle it?

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



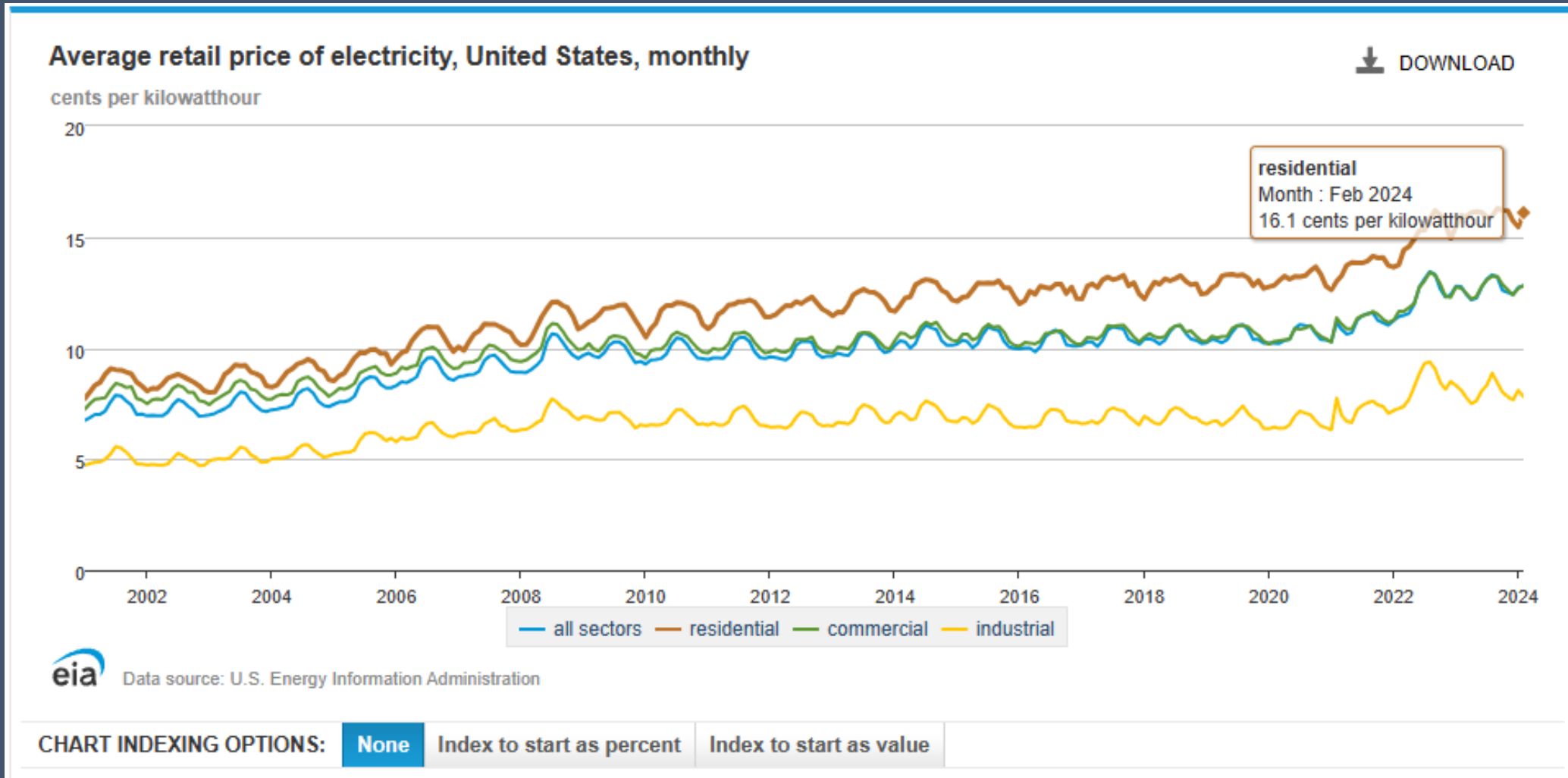
Power Grid

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



Data source: U.S. Energy Information Administration

Power Grid

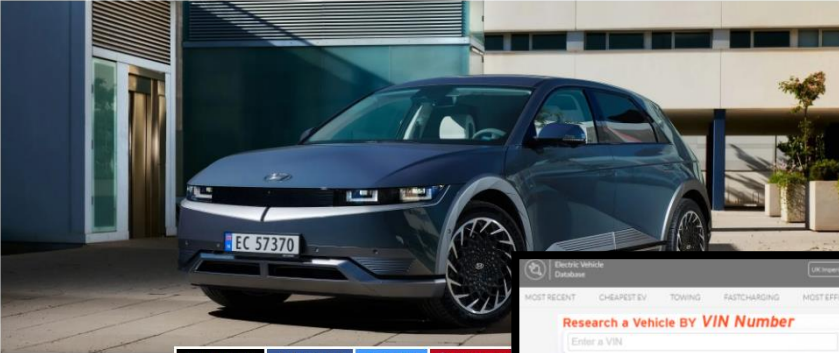


TODAY

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

Fred Lambert - May, 11th 2022 12:17 pm PT @FredericLambert

HYUNDAI | HYUNDAI IONIQ 5



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

8 Comments | Facebook | Twitter | Pinterest

EXPAND FULL STORY +

EVs are here. Try to keep up.

CHARGED
ELECTRIC VEHICLES MAGAZINE

HERNOLD
MATERIAL SOLUTIONS
FOR RELIABLE, POWERFUL CHARGE

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

DAILY NEWSWIRE

THE VEHICLES | THE TECH | 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

Electric Vehicle Database

Research a Vehicle BY VIN Number

Enter a VIN

Longest electric range: 240+mi found

Make	Price	Body Style	Availability	More Options
Lucid Air Dream Edition R	\$422,000	Battery Electric Vehicle	118 kWh	
Lucid Air Grand Touring	\$417,500	Battery Electric Vehicle	111 kWh	
Lucid Air Dream Edition P	\$417,500	Battery Electric Vehicle	118 kWh	

BATTERY UNIVERSITY

LEARN ABOUT BATTERIES | BUY THE BOOK | ABOUT US | CONTACT US

Learn About Batteries

Basics You Should Know

Address the mechanics of the battery and deals with alternatives, charging and discharging techniques.

The Battery and You

Looks at battery personalities and discusses ways to get the most out of the pack. We talk about priming, storing and recycling.

Batteries as Power Source

Studies the battery in portable and stationary applications as well as in electric powertrains. We look at the kinetic power and cost of the battery in comparison to fossil fuel.

Amazing Value of a Battery

Buy 2021: How to Drive Batteries
Buy 2021: How to Store Batteries
Buy 2021: How to Connect with Batteries
Buy 2021: How to Transport Batteries
Buy 2021: Storing Lithium-Ion Batteries by Air
Buy 2021: Callouts & Chemical Labels
Buy 2021: Class 3 Label
Buy 2021: EPA Fuel Gauge
Buy 2021: EPA Fuel Gauge

Great Resources

- Ev-database.org
- Chargedevs.com
- Electrek.co
- Batteryuniversity.com
- Greencarreports.com
- Insideevs.com
- evspecifications.com