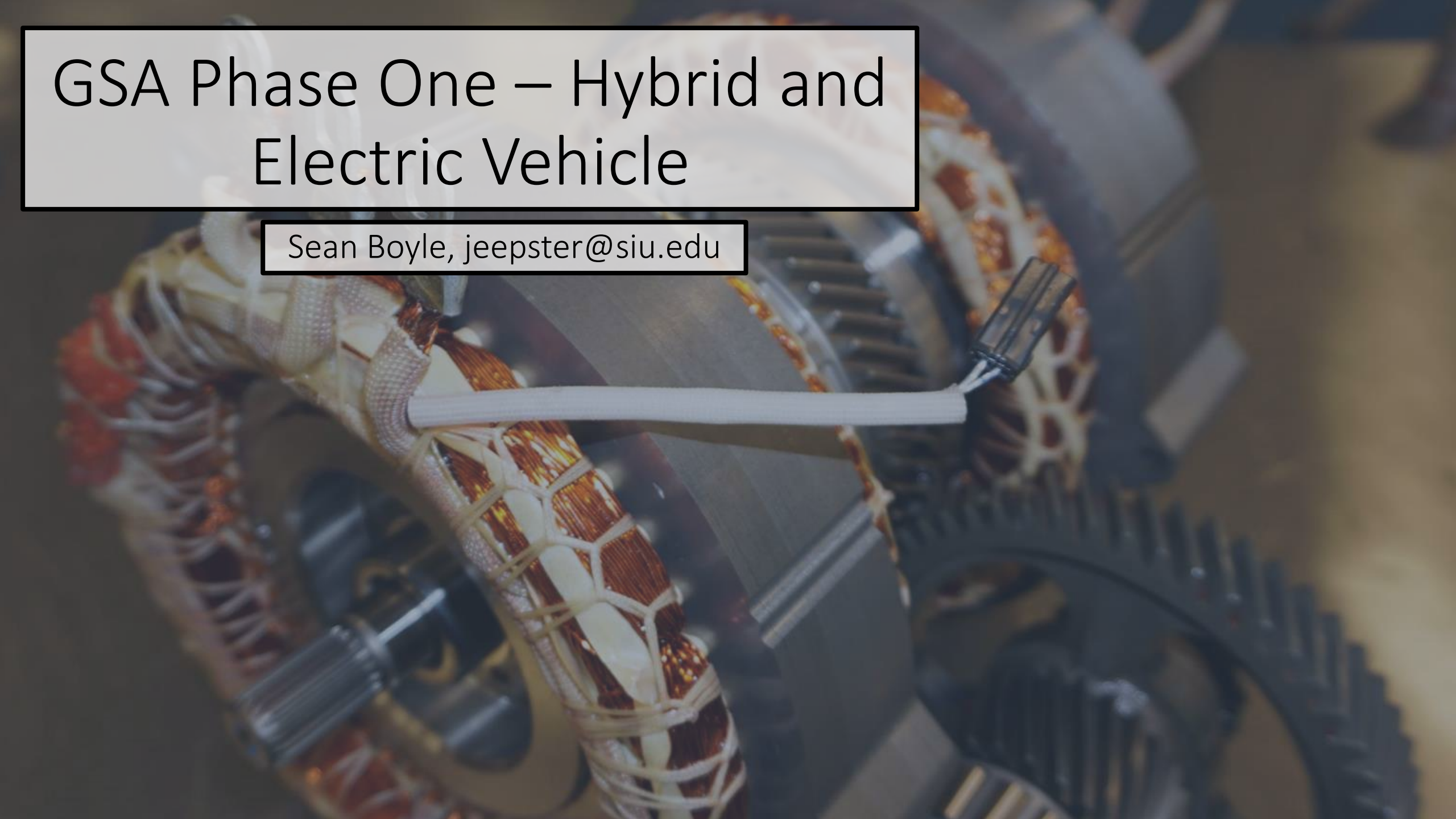
GSA Phase One – Hybrid and Electric Vehicle

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

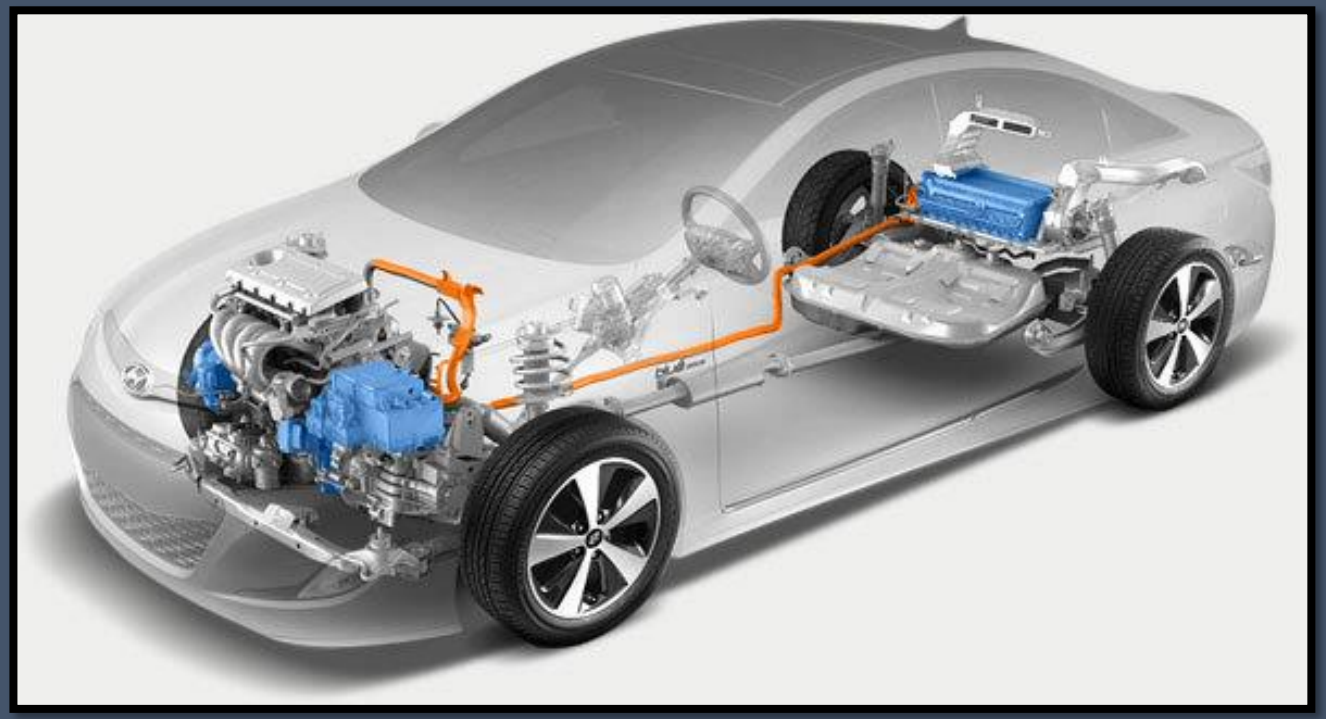
- BEV
  - Driver needs to charge to maintain range
  - Home charging preferred
  - Range issues
    - Long drives
    - Cold weather
- Perfect for customers who:
  - Have multiple vehicles in household
  - Have access to home charging
  - Live where electricity is relatively inexpensive
  - Can charge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



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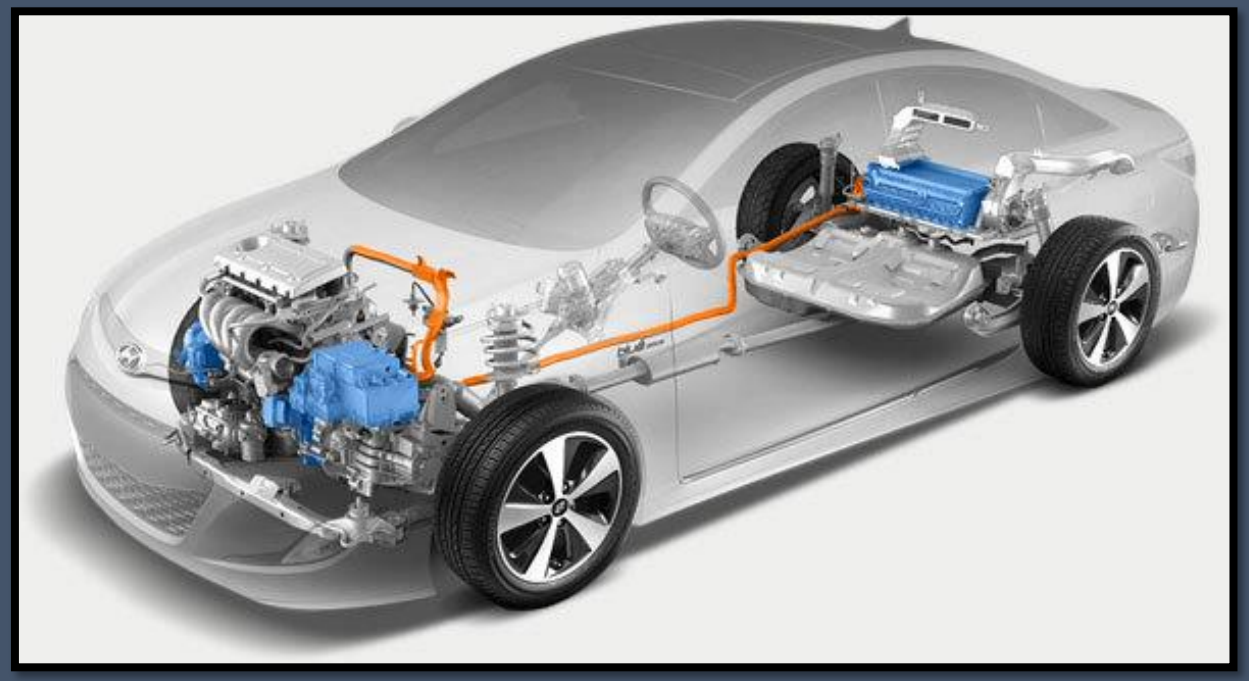
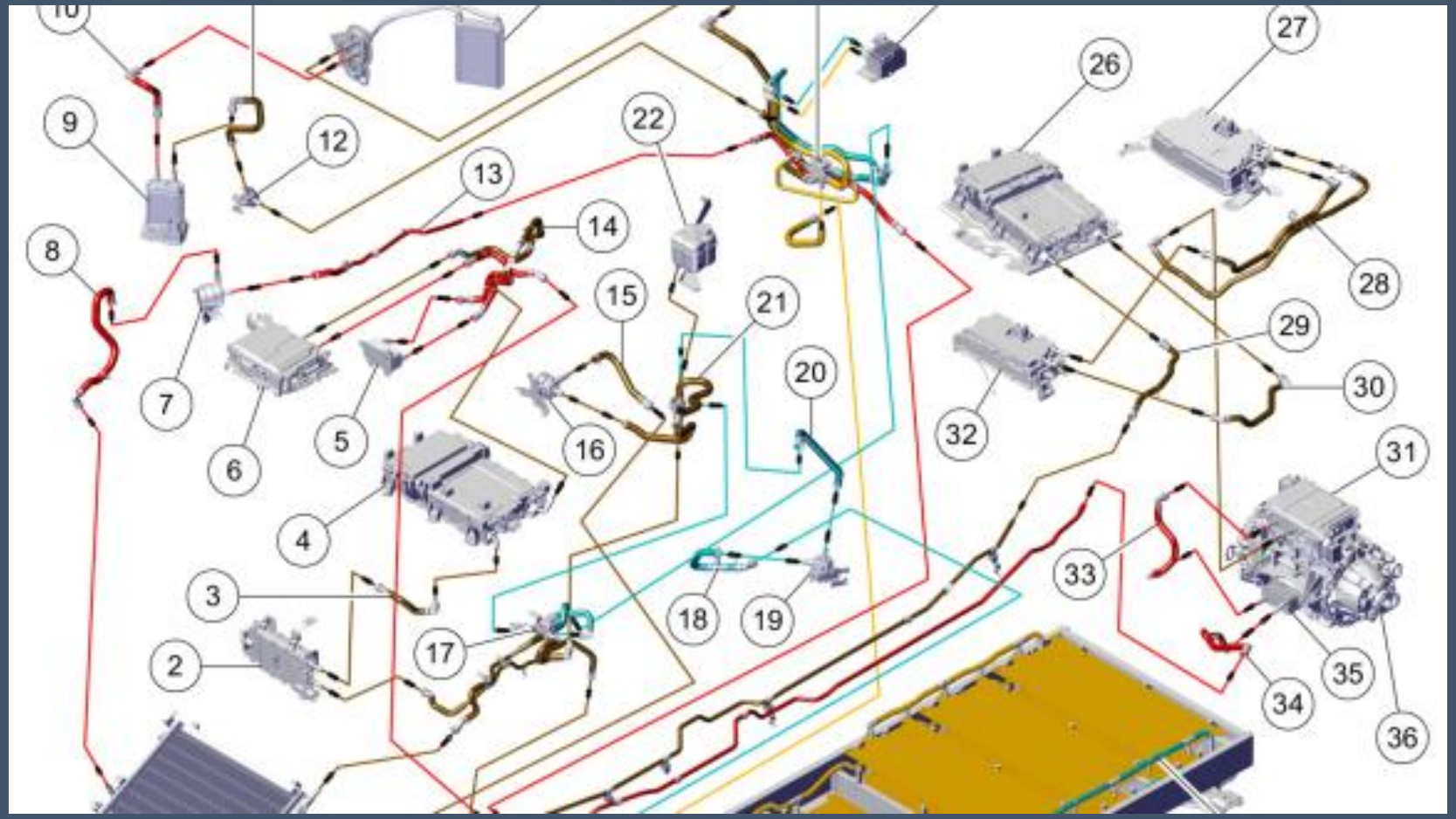
xEV – Efficient Engine (HEV/PHEV)

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



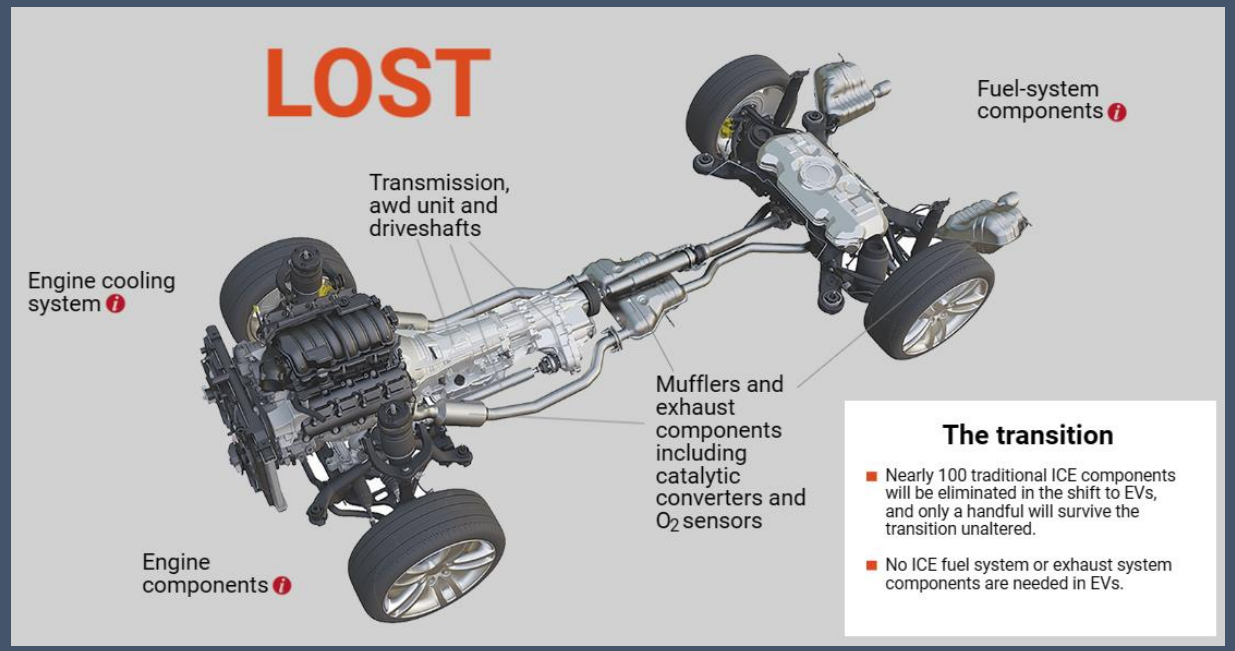
xEV – Heating and cooling

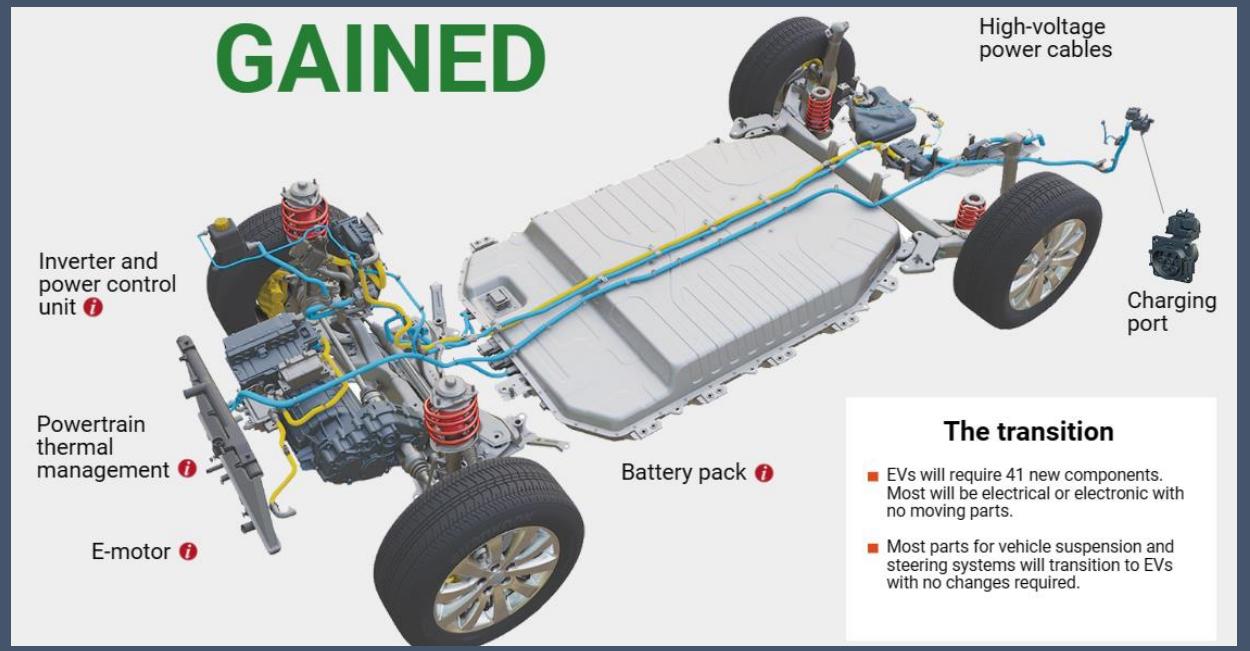
- Heating and cooling is much more complex in an xEV



xEV – Parts reduction

- Estimated about 15k fewer parts!





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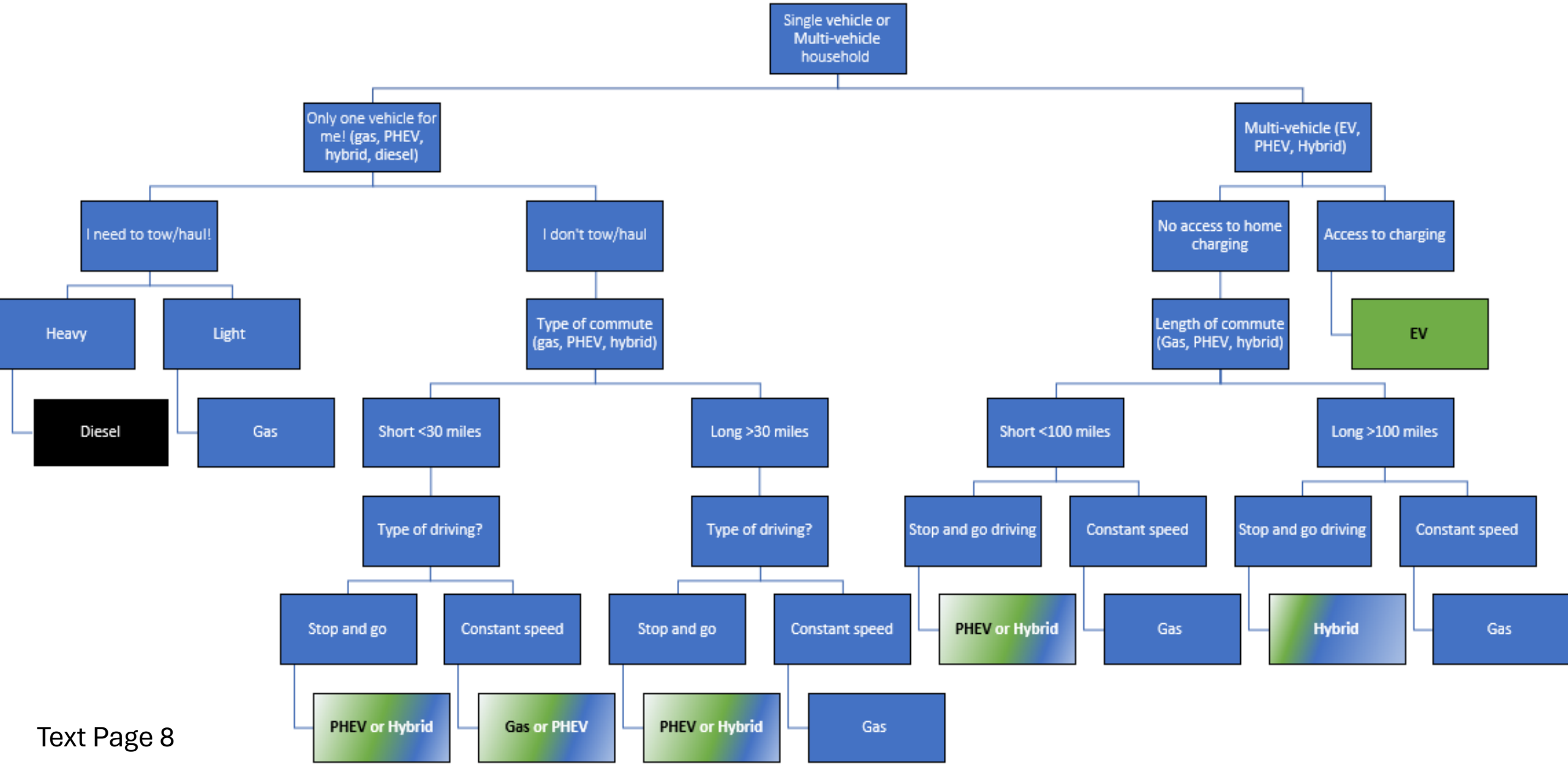
What's best for me?



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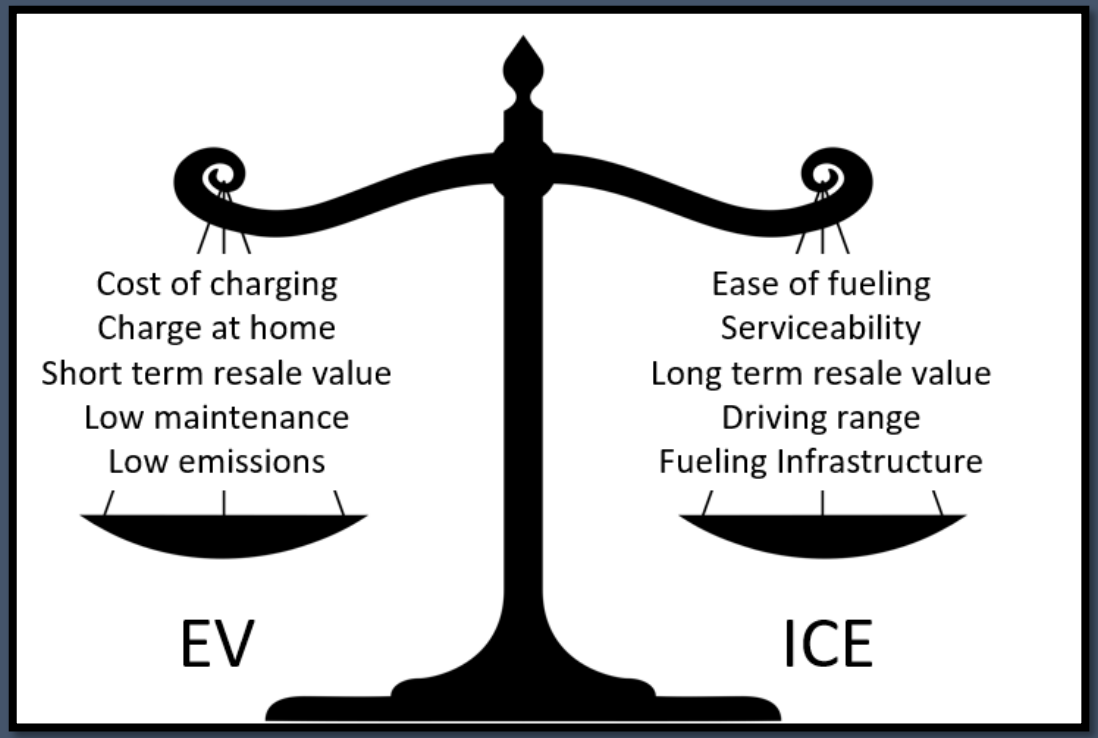
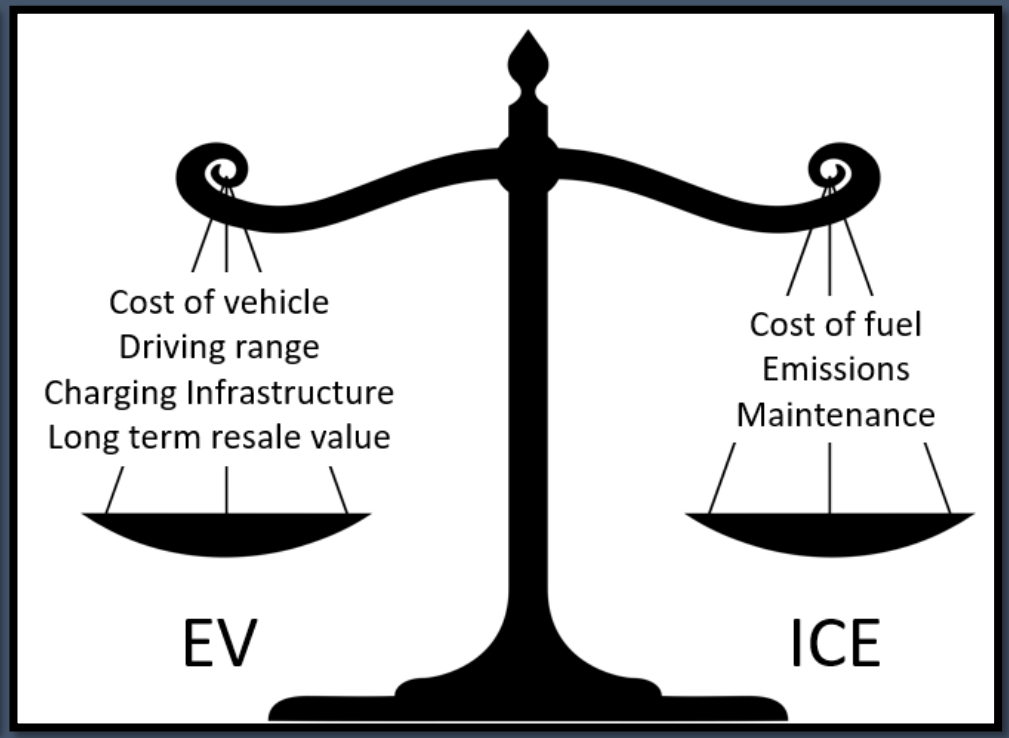
What's best for me?



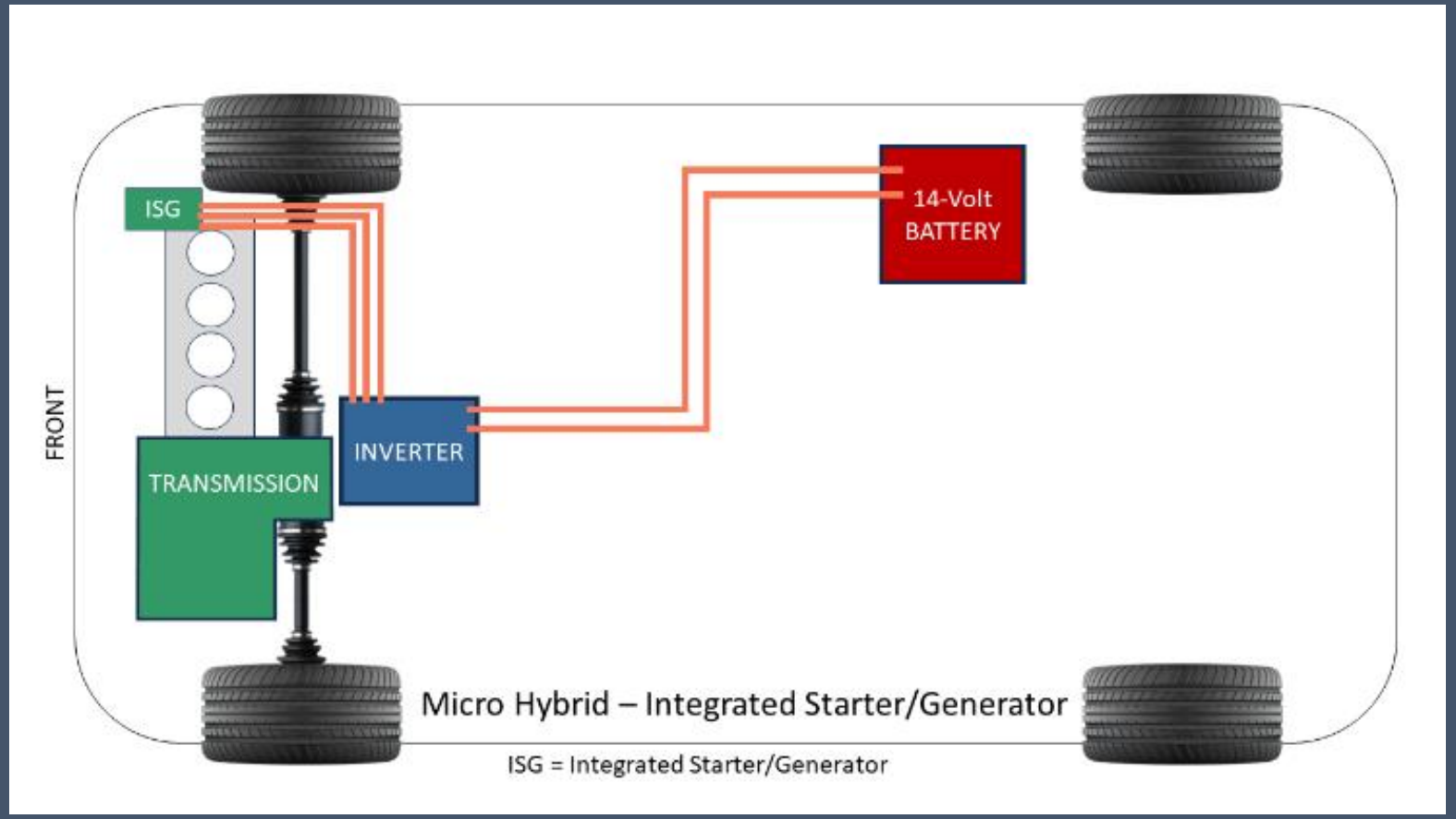
EV Advantages



EV Disadvantages

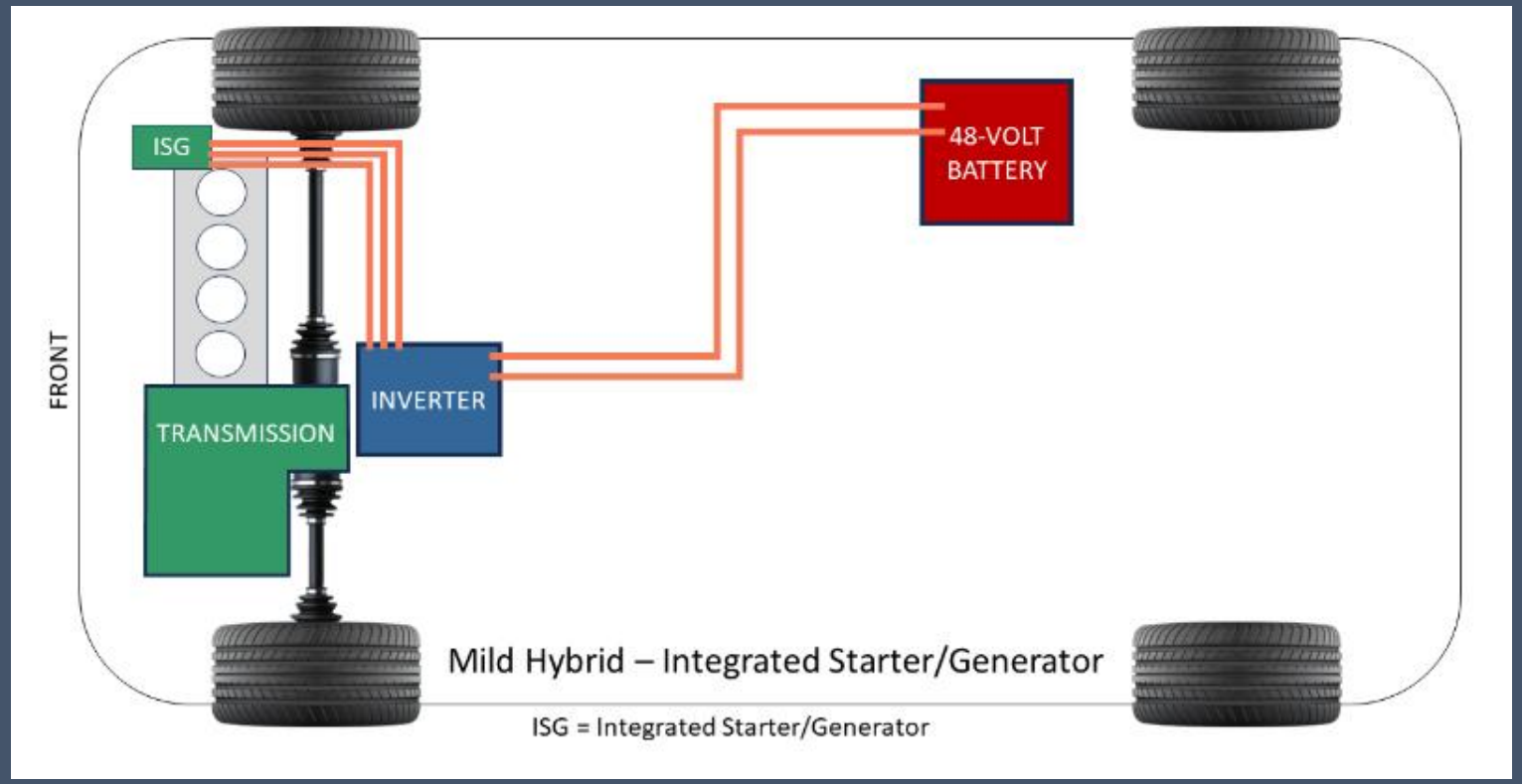
HEV Classifications

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



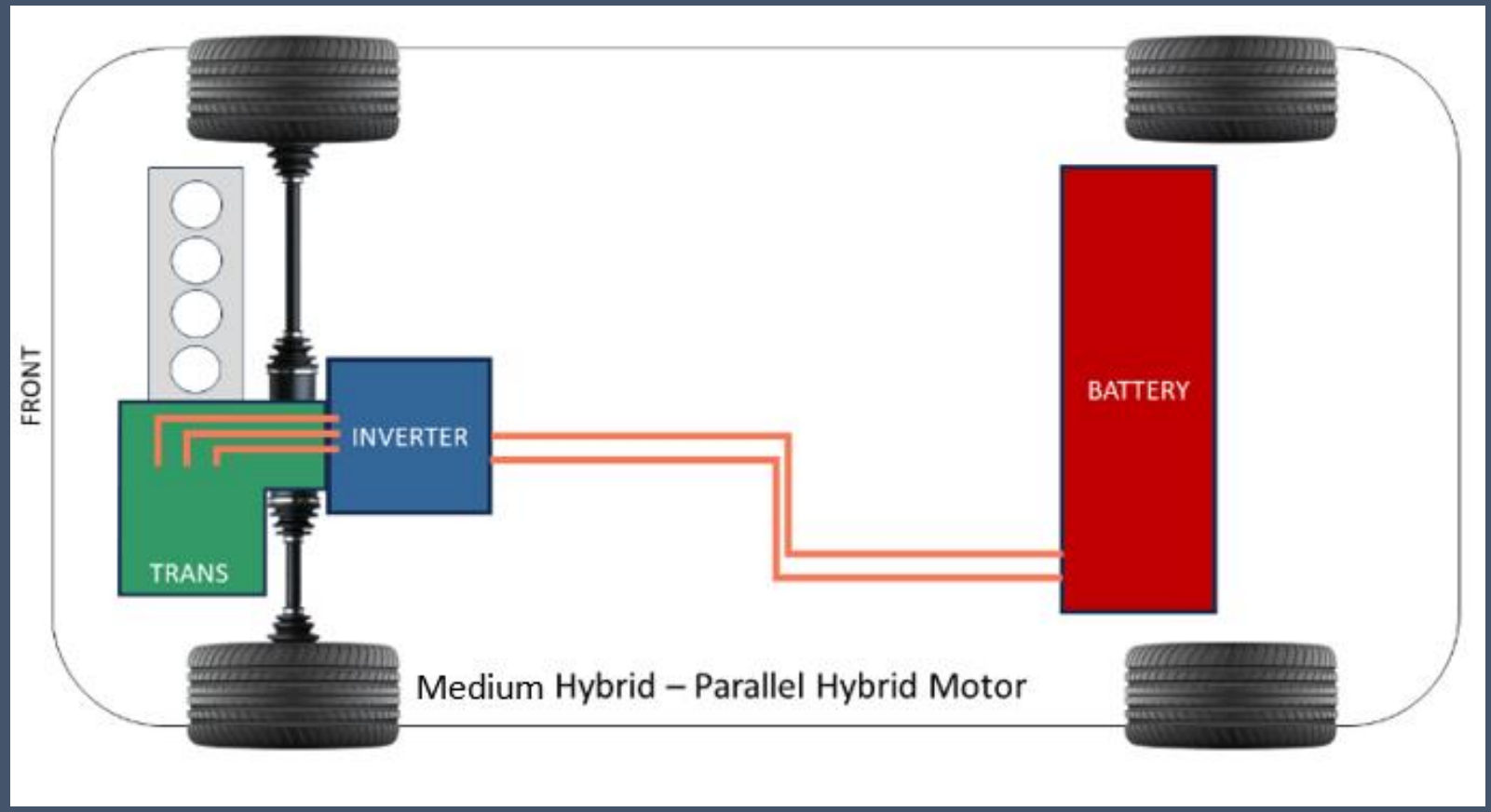
HEV Classifications

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



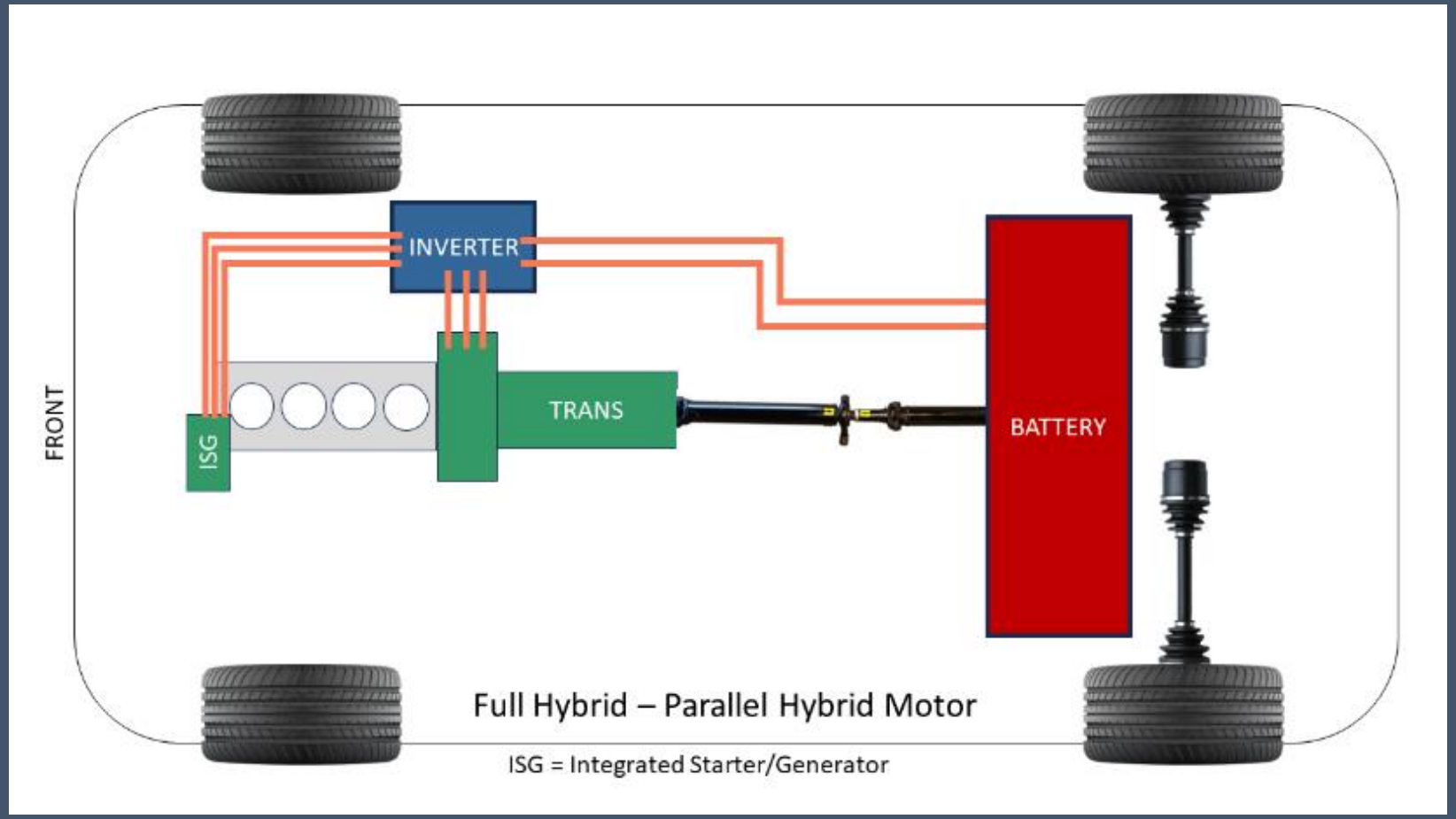
HEV Classifications

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



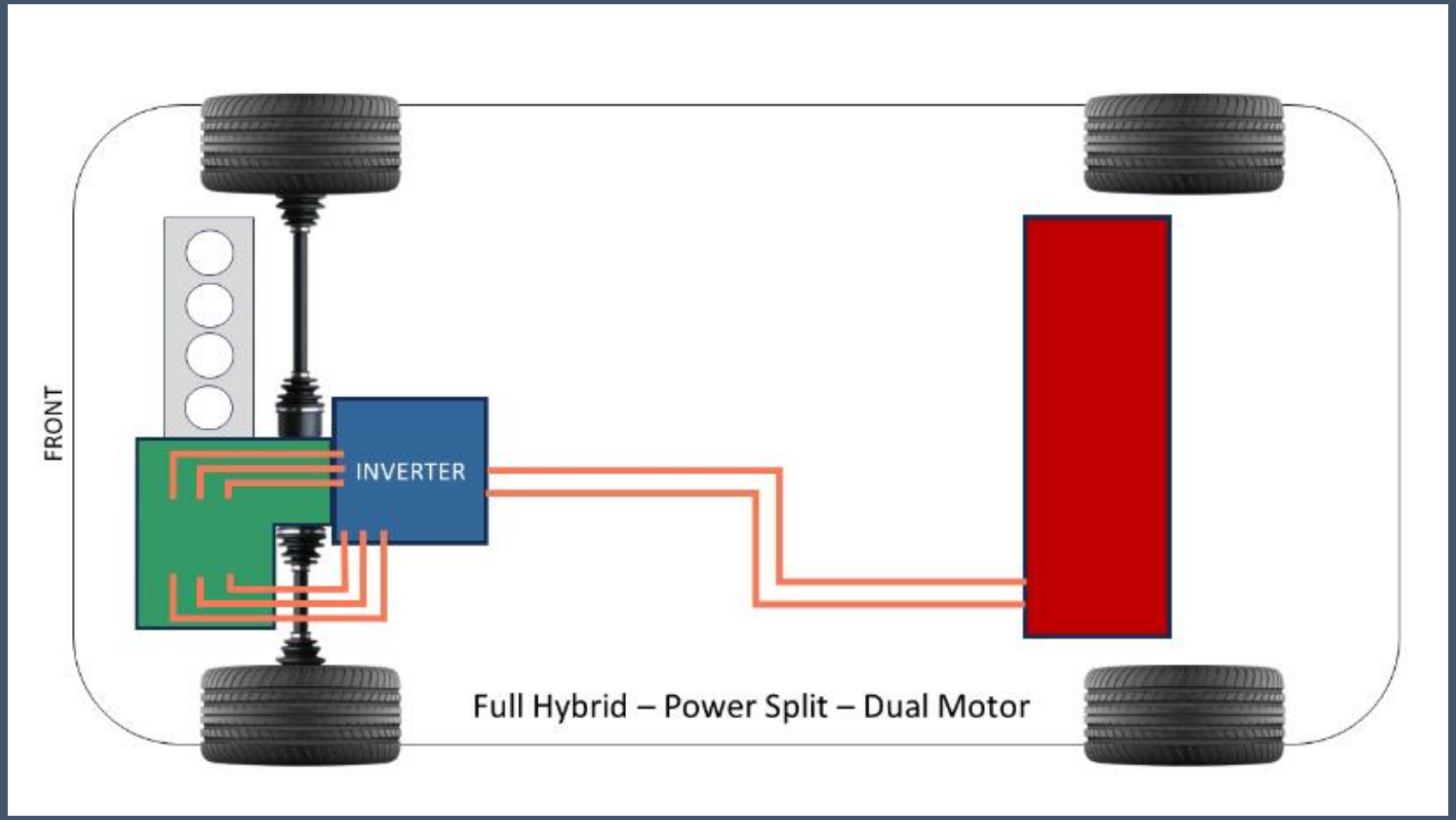
HEV Classifications

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



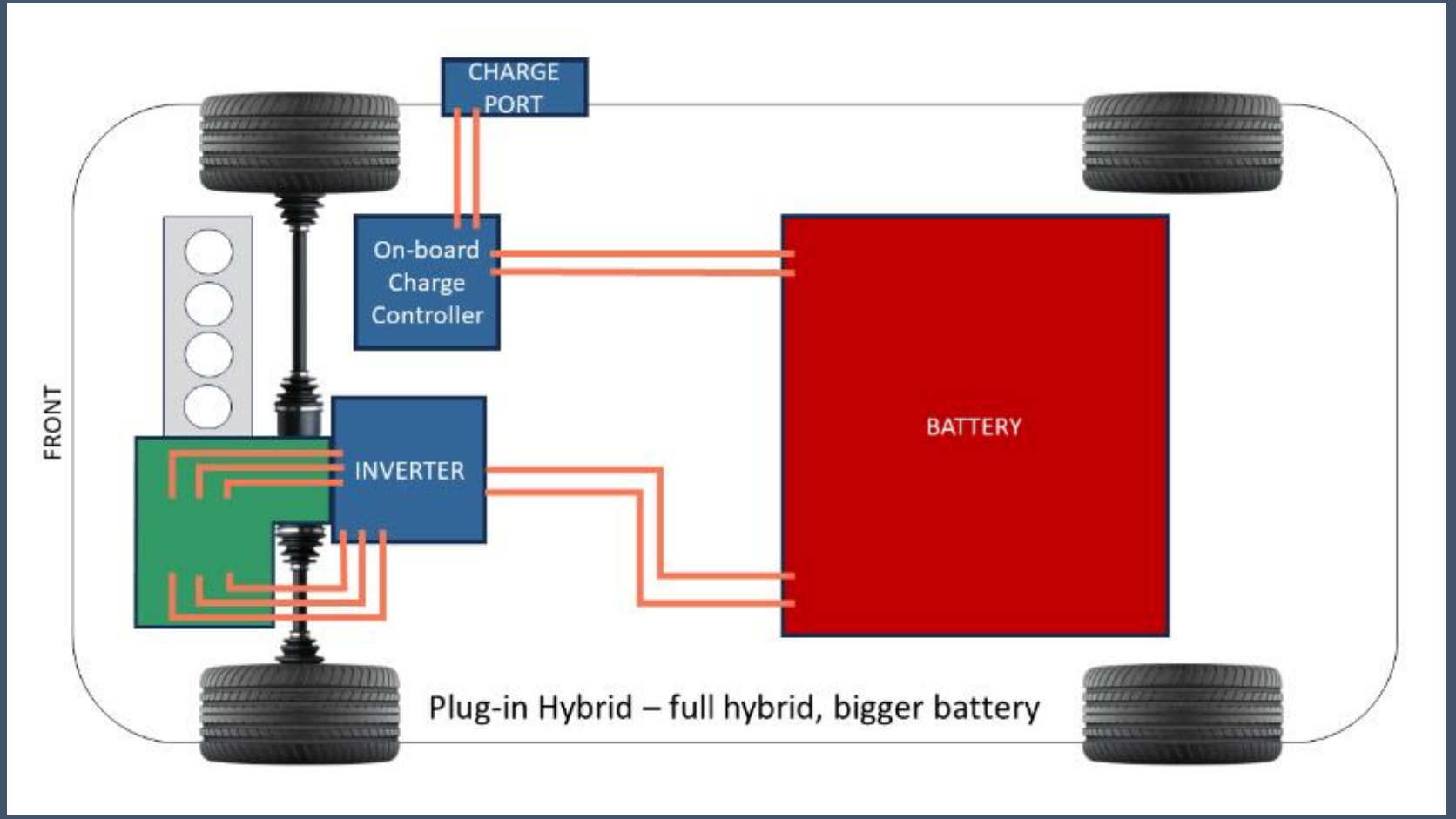
HEV Classifications

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



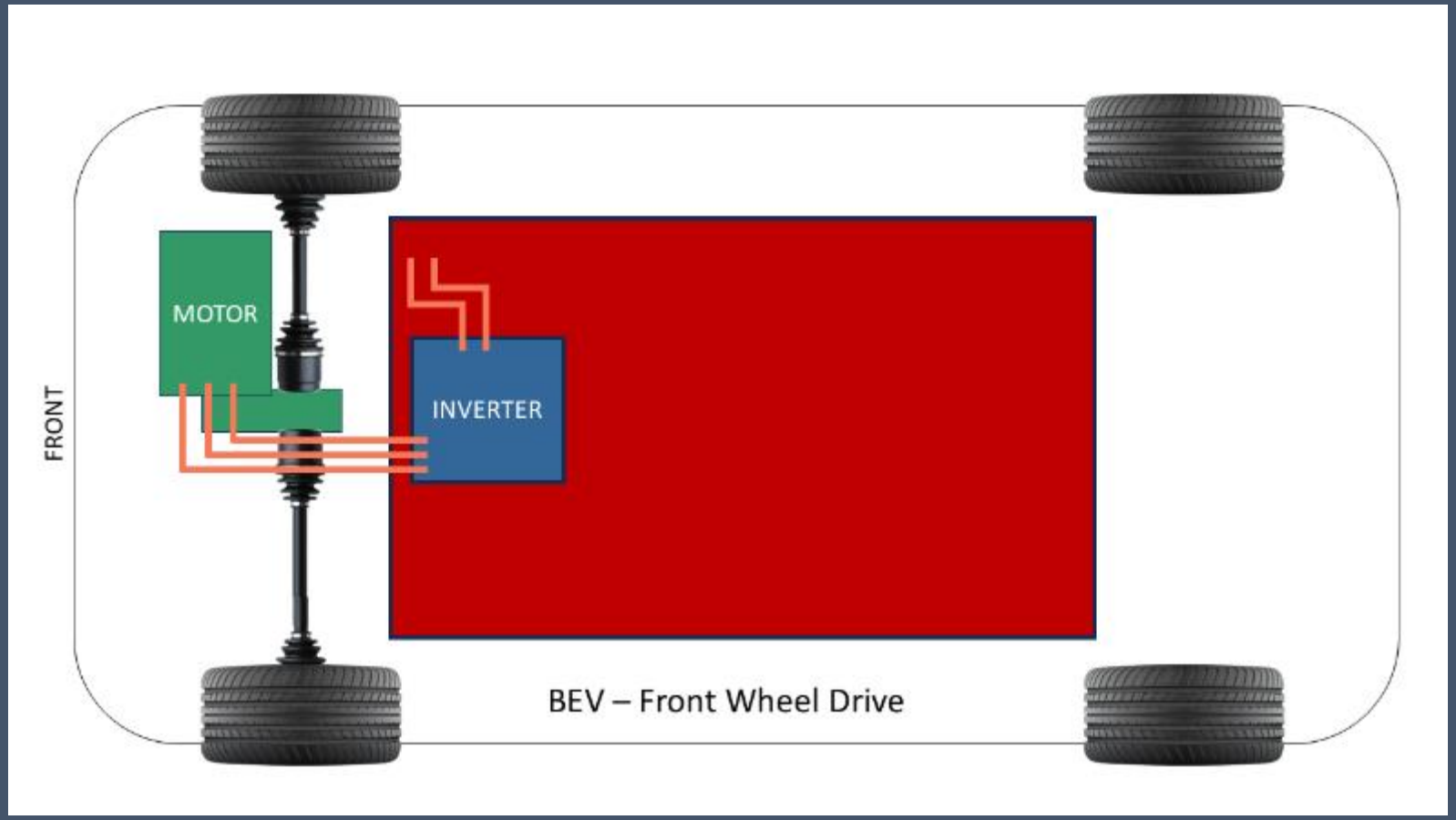
PHEV Classifications

- PHEV



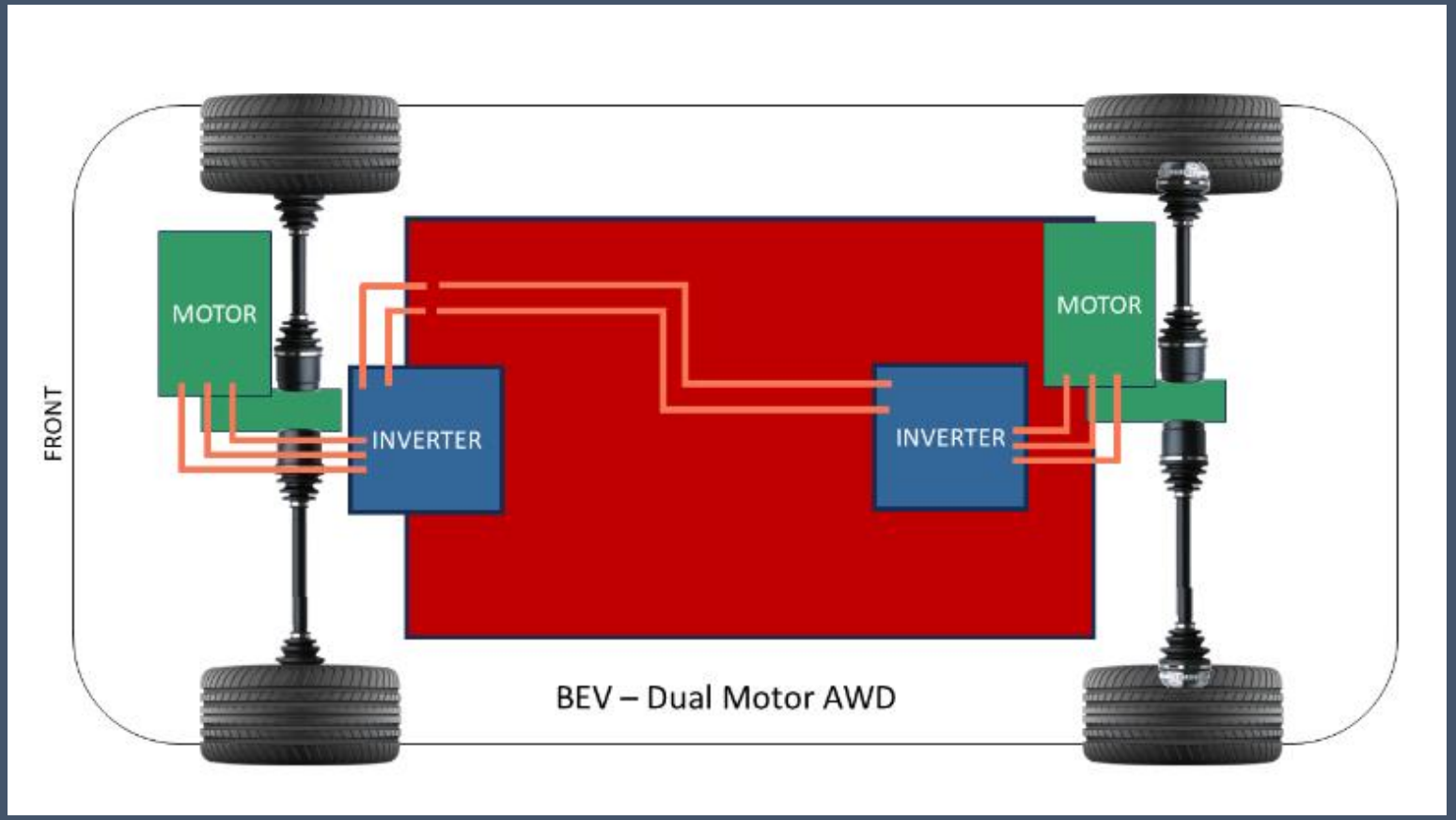
BEV Classifications

- BEV



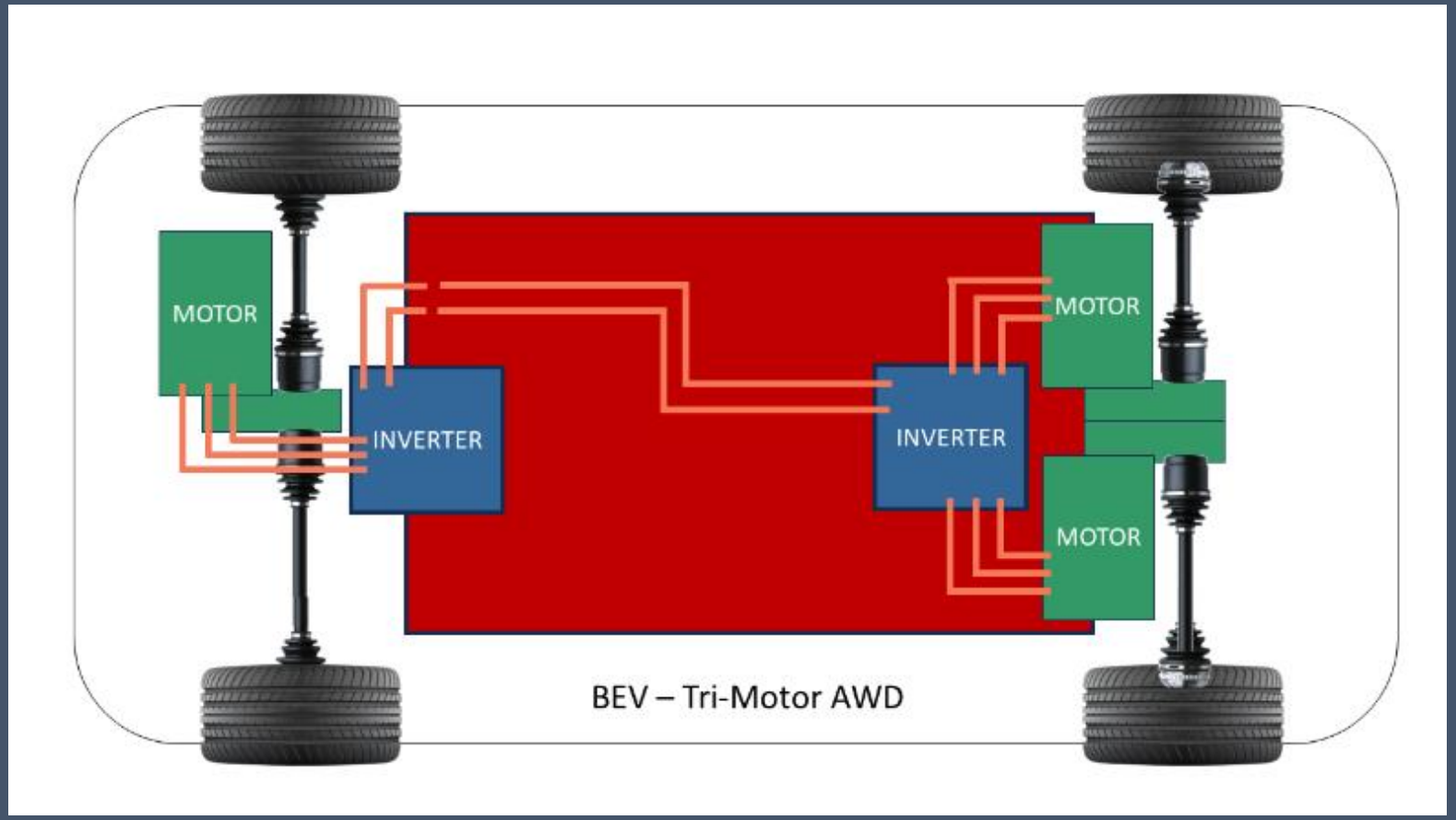
BEV Classifications

- BEV



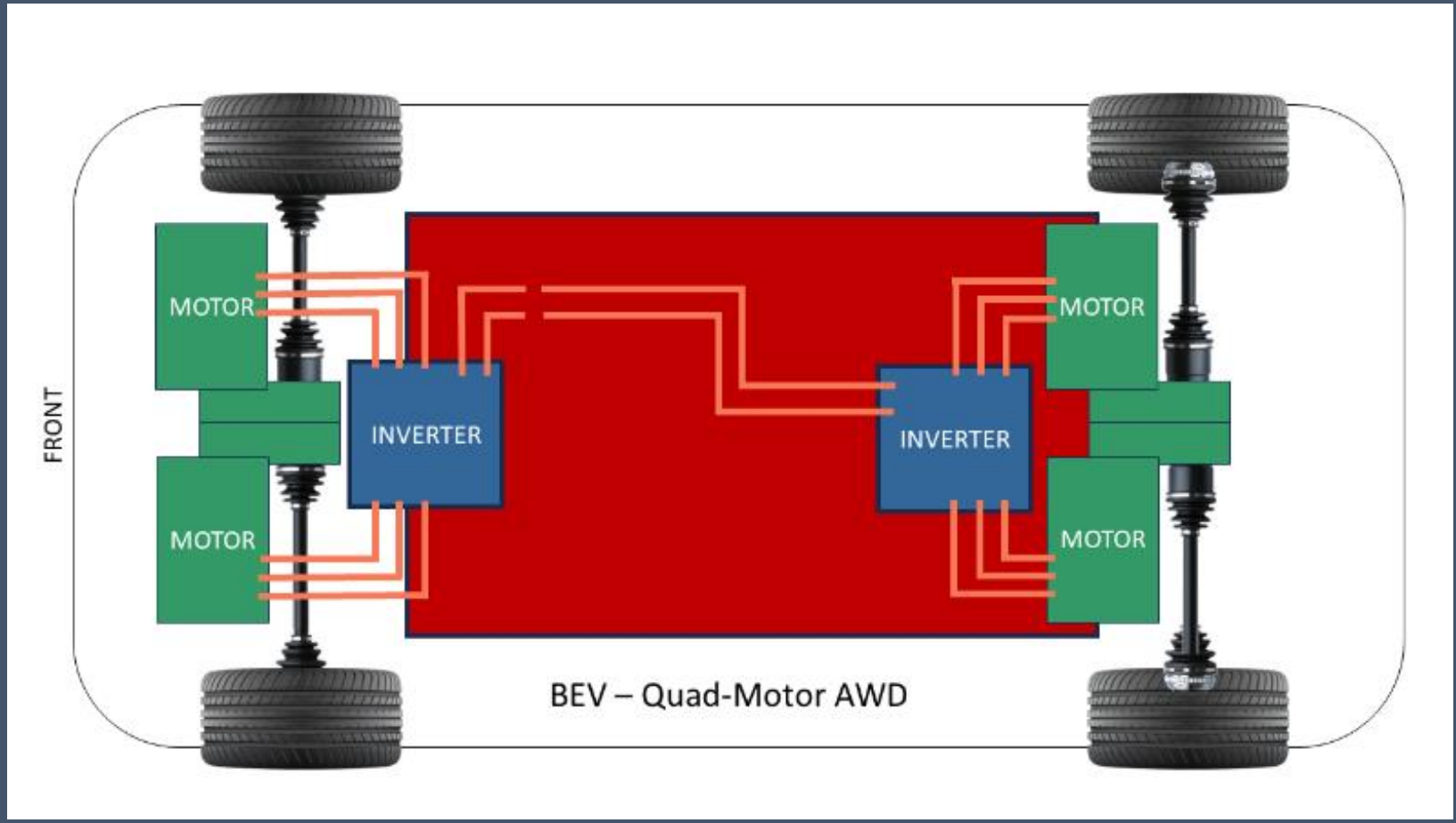
BEV Classifications

- BEV



BEV Classifications

- BEV



xEV High-level Overview

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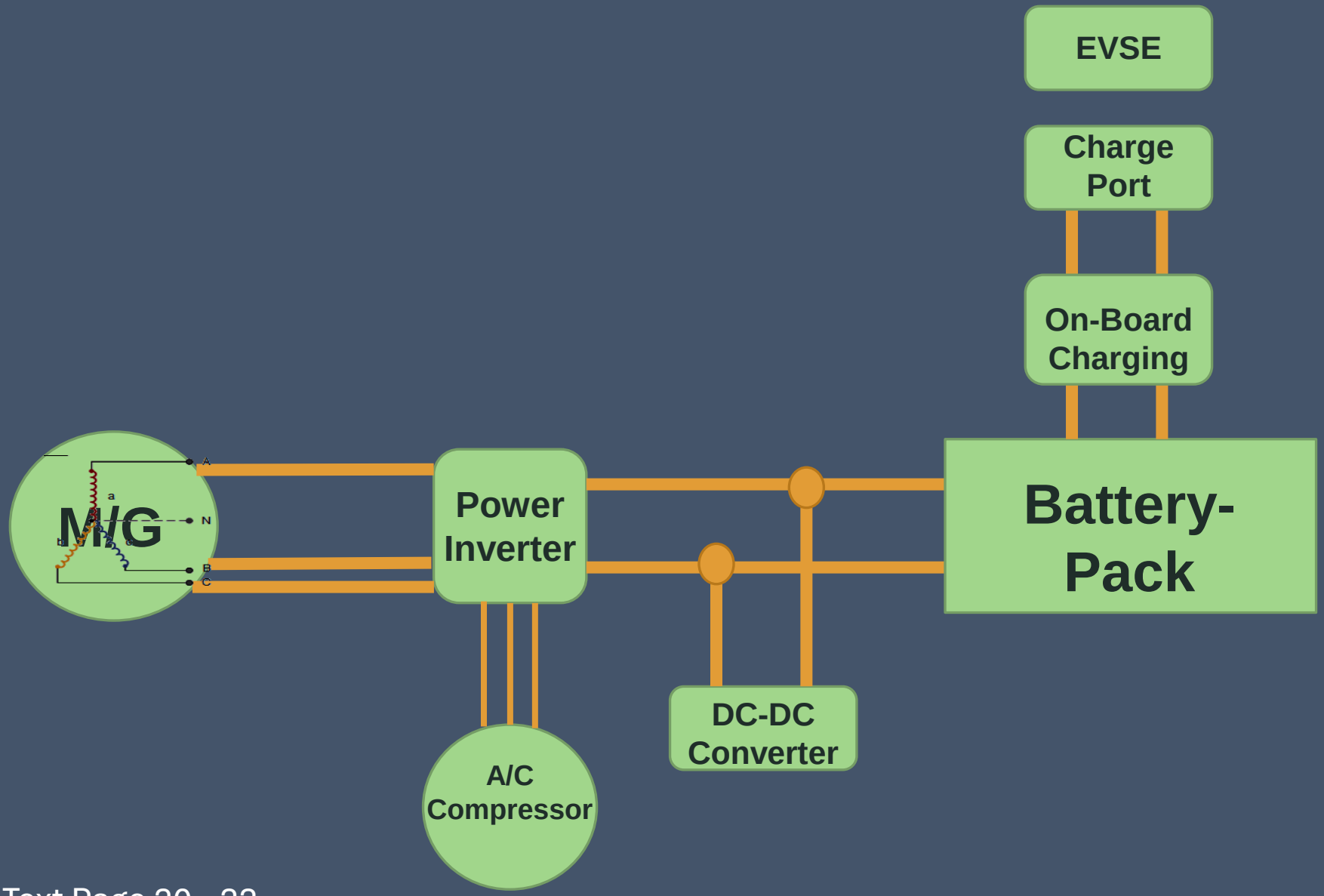
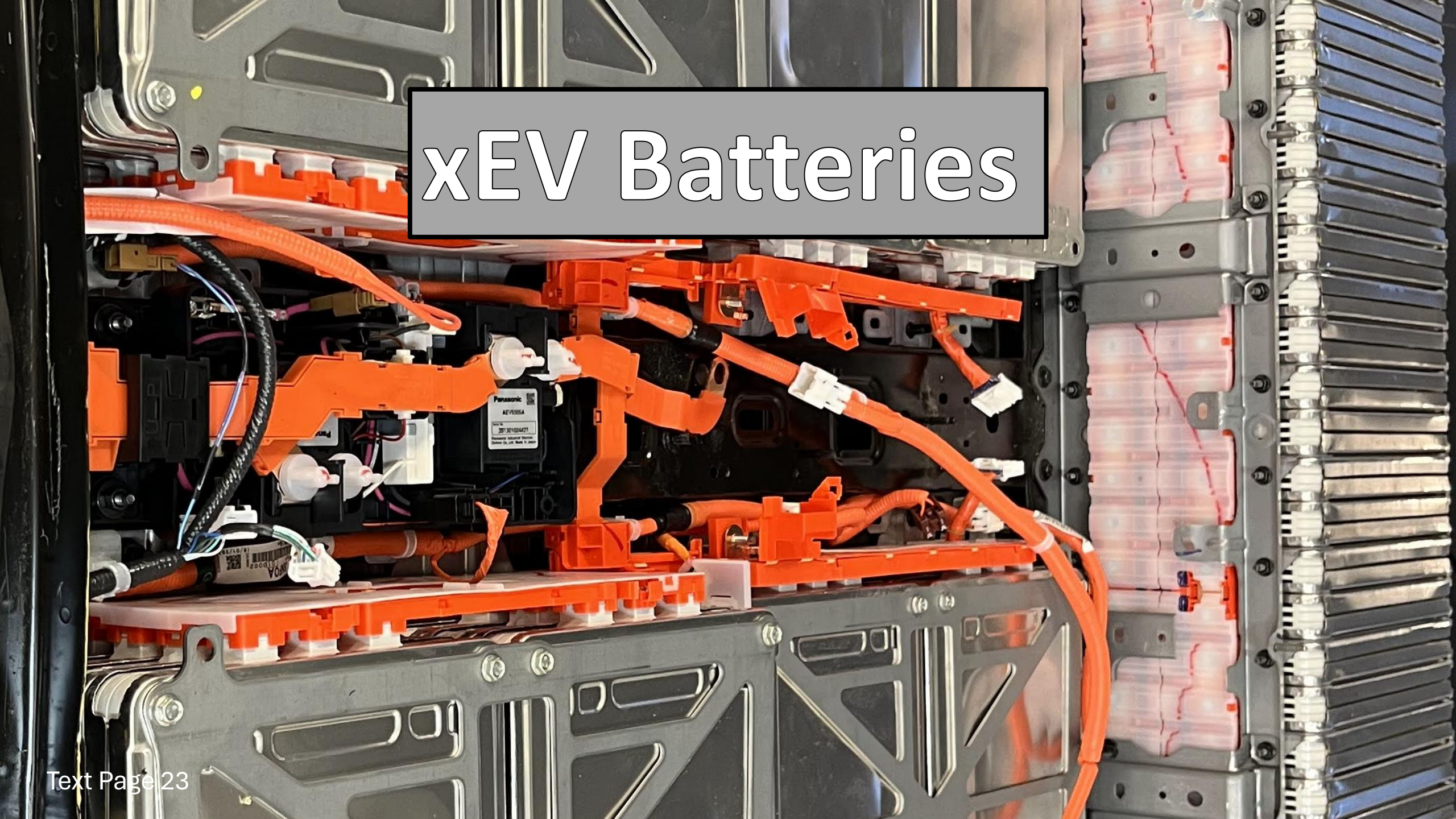
High level overview

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

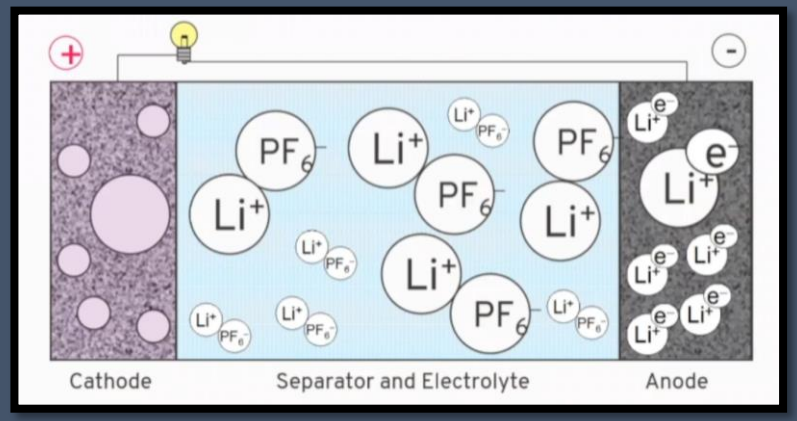
High level overview of HV components



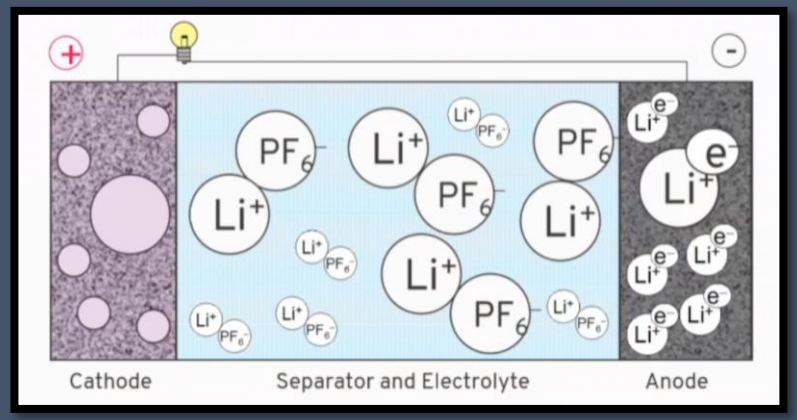

xEV Batteries
Panasonic

High voltage battery

- Charging

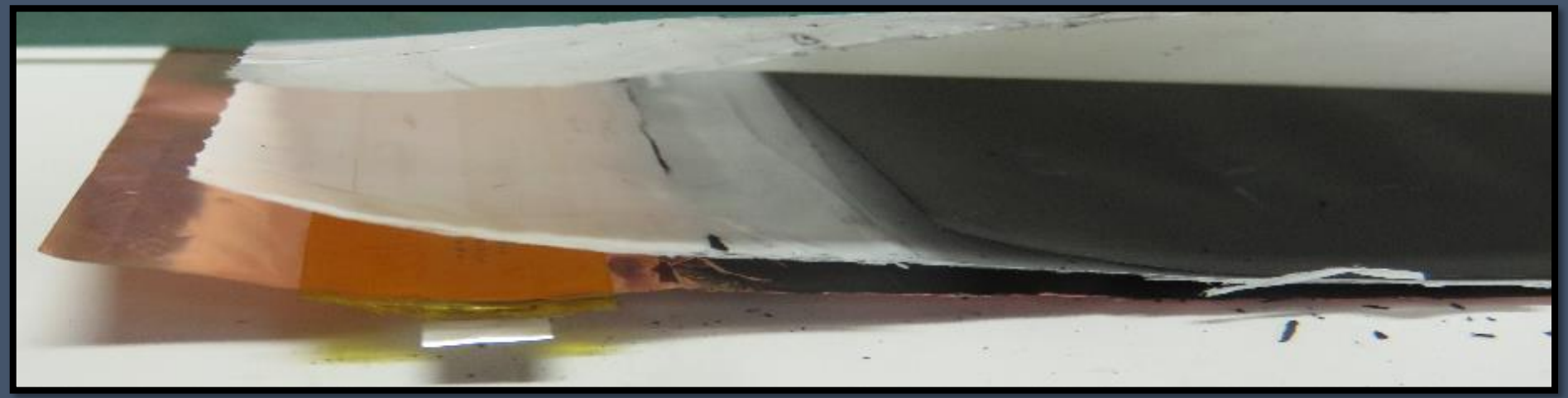


- Discharging



High voltage battery

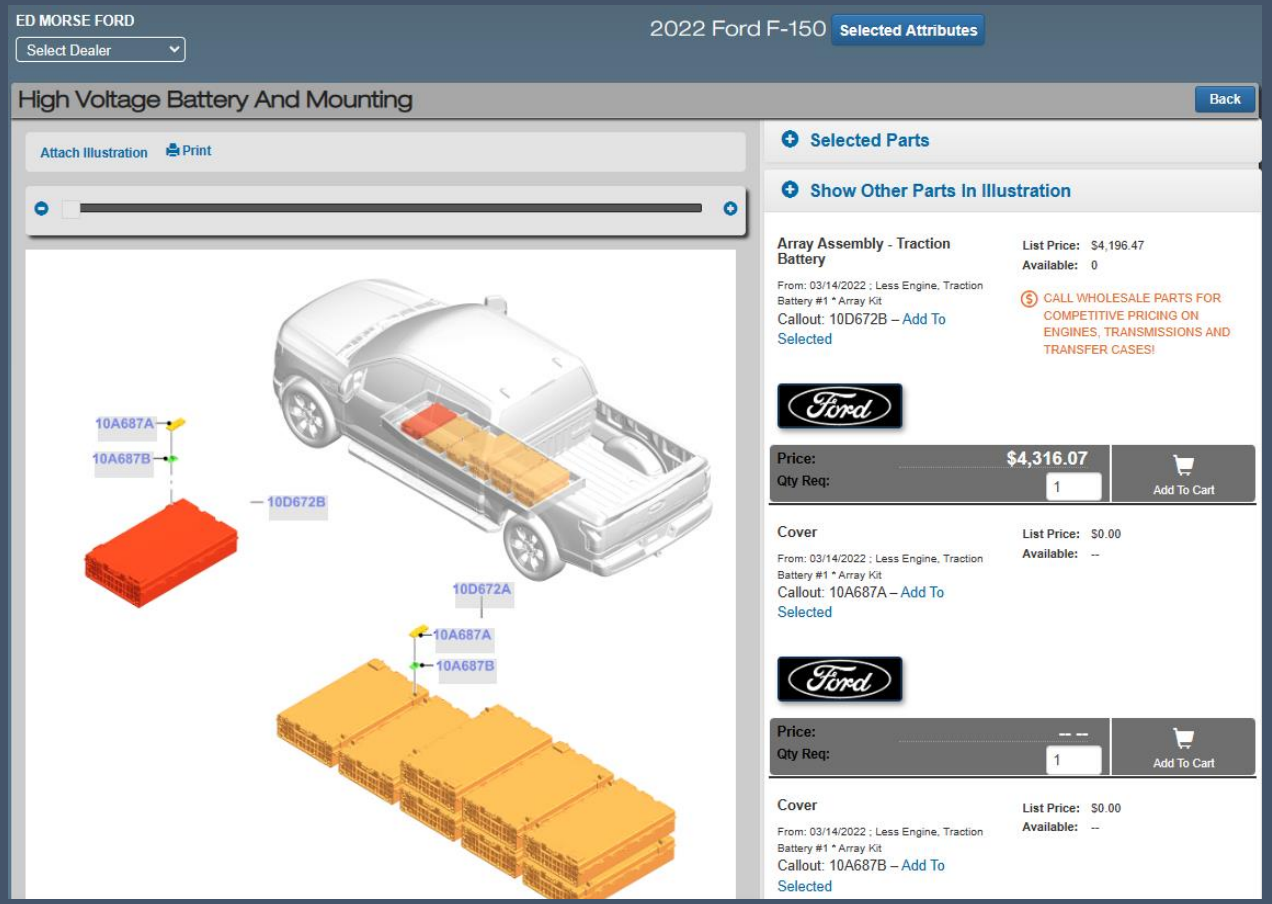
- Rated voltage
- Specific Power
- Specific Energy
- Energy Density
- Cycle live
- C-rate
- Thermal stability
- Safety
- Cost

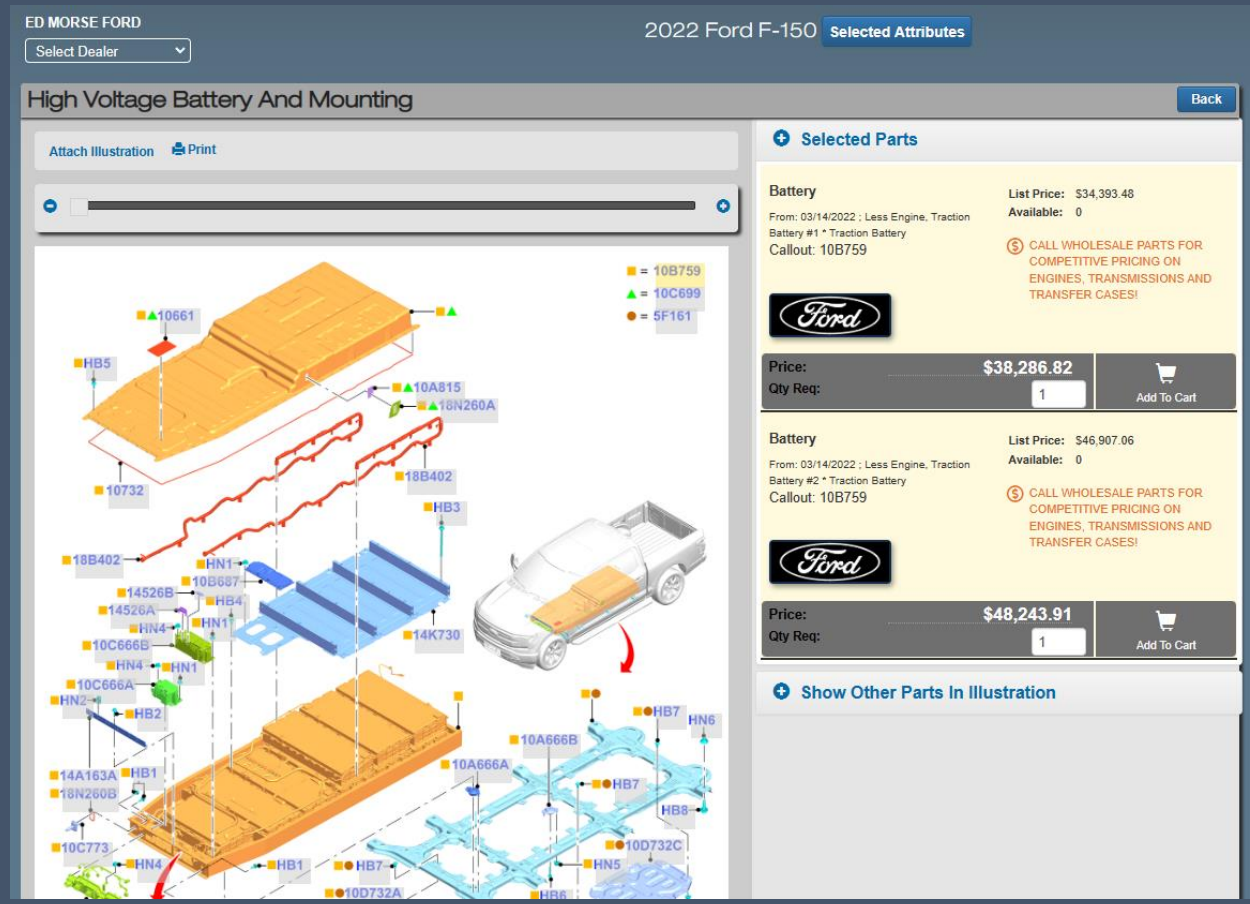


High voltage battery

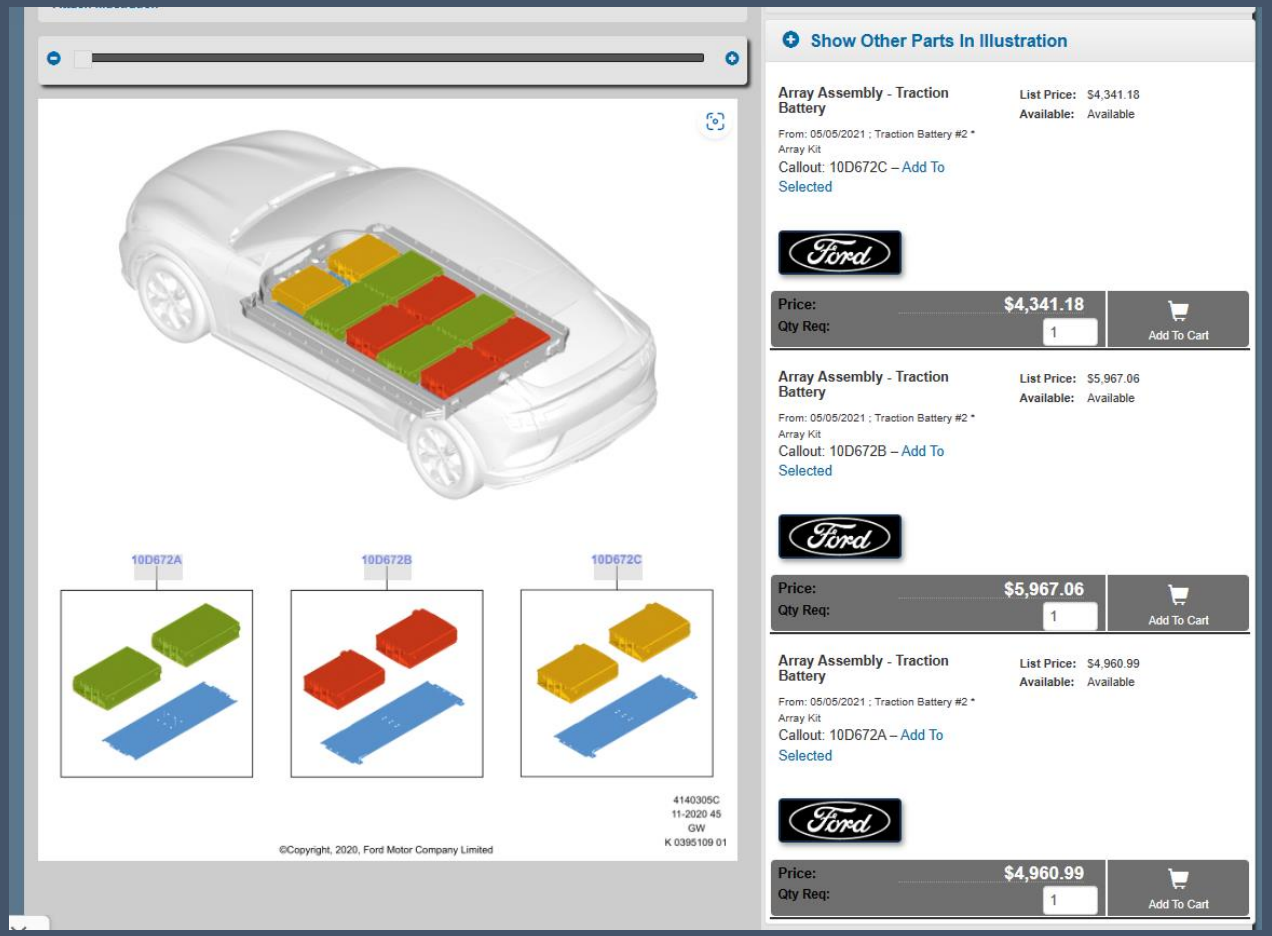
Manufacturer	Standard Warranty	% degraded
Tesla	8 year, 150K (S and X), 120K (M3 LR, MY LR and Perf), 100K M3 and MY standard range)	70
Ford	8 years, 100K miles	70
Rivian	8 years, 175K miles	70
GM	8 years, 100K	60
Hyundai, Kia	10 years, 100K	70

Ford F150 Lightning Battery Costs





2022 Ford Mach-e



Show Other Parts In Illustration

Array Assembly - Traction Battery
From: 05/05/2021 ; Traction Battery #2 * Array Kit
Callout: 10D672C – Add To Selected
List Price: $4,341.18
Available: Available
Price: $4,341.18
Qty Req: 1
Add To Cart

Array Assembly - Traction Battery
From: 05/05/2021 ; Traction Battery #2 * Array Kit
Callout: 10D672B – Add To Selected
List Price: $5,967.06
Available: Available
Price: $5,967.06
Qty Req: 1
Add To Cart

Array Assembly - Traction Battery
From: 05/05/2021 ; Traction Battery #2 * Array Kit
Callout: 10D672A – Add To Selected
List Price: $4,960.99
Available: Available
Price: $4,960.99
Qty Req: 1
Add To Cart

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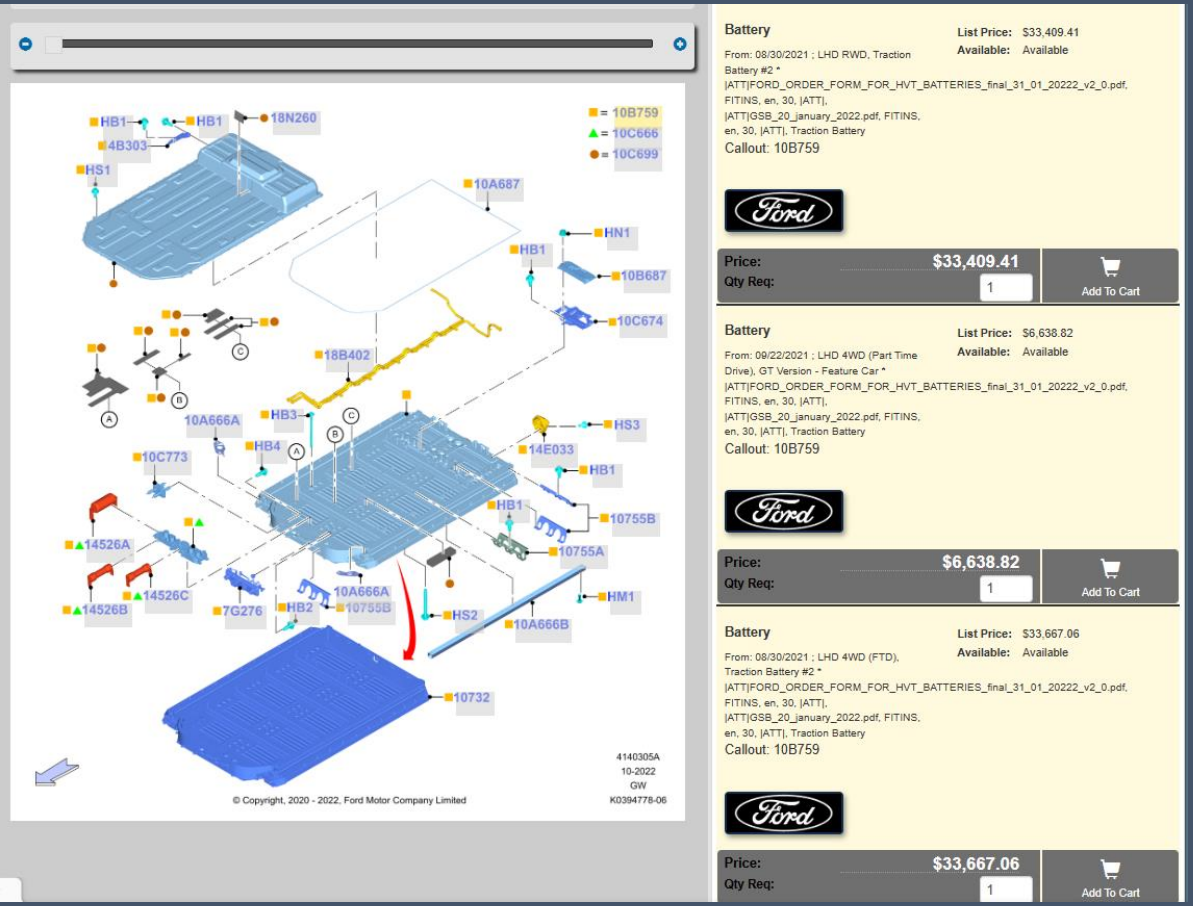
2022 Mach-e



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

List Price: $33,409.41
Available: Available

Price: $33,409.41
Qty Req: 1
Add To Cart

Battery

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Callout: 10B759

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Available: Available

Price: $6,638.82
Qty Req: 1
Add To Cart

Battery

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Callout: 10B759

List Price: $33,667.06
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Price: $33,667.06
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Battery

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Callout: 10B759

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Available: Available

Price: $41,060.00
Qty Req: 1
Add To Cart

Battery

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

Callout: 10B759

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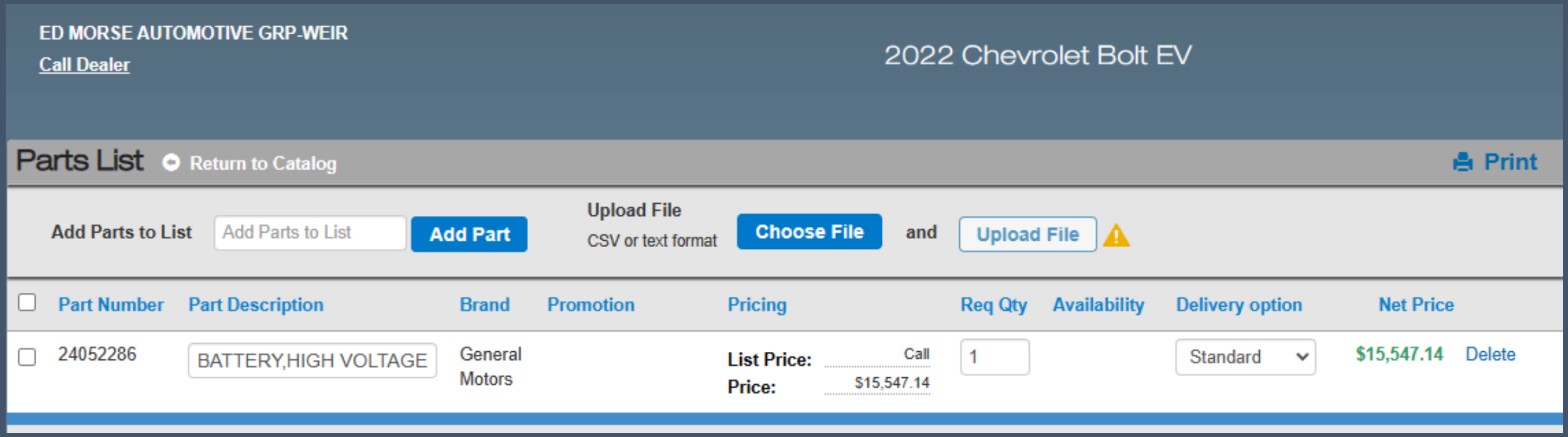
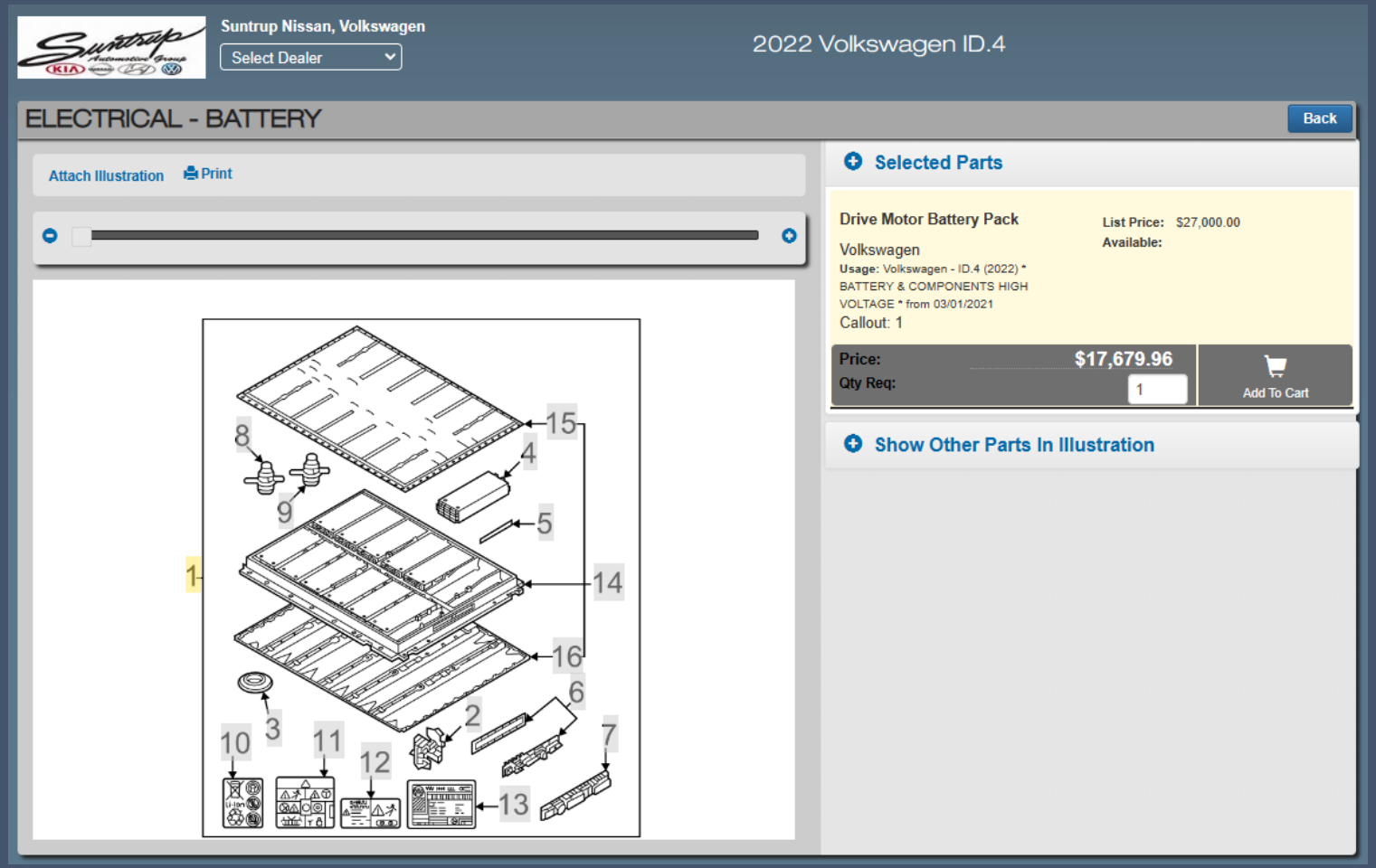
Price: $37,383.53
Qty Req: 1
Add To Cart

2022 Chevrolet Bolt



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
Volkswagen
Usage: Volkswagen - ID.4 (2022) * BATTERY & COMPONENTS HIGH VOLTAGE * from 03/01/2021
Callout: 1
List Price: $27,000.00
Available:
Price: $17,679.96
Qty Req: 1
Add To Cart
Show Other Parts In Illustration
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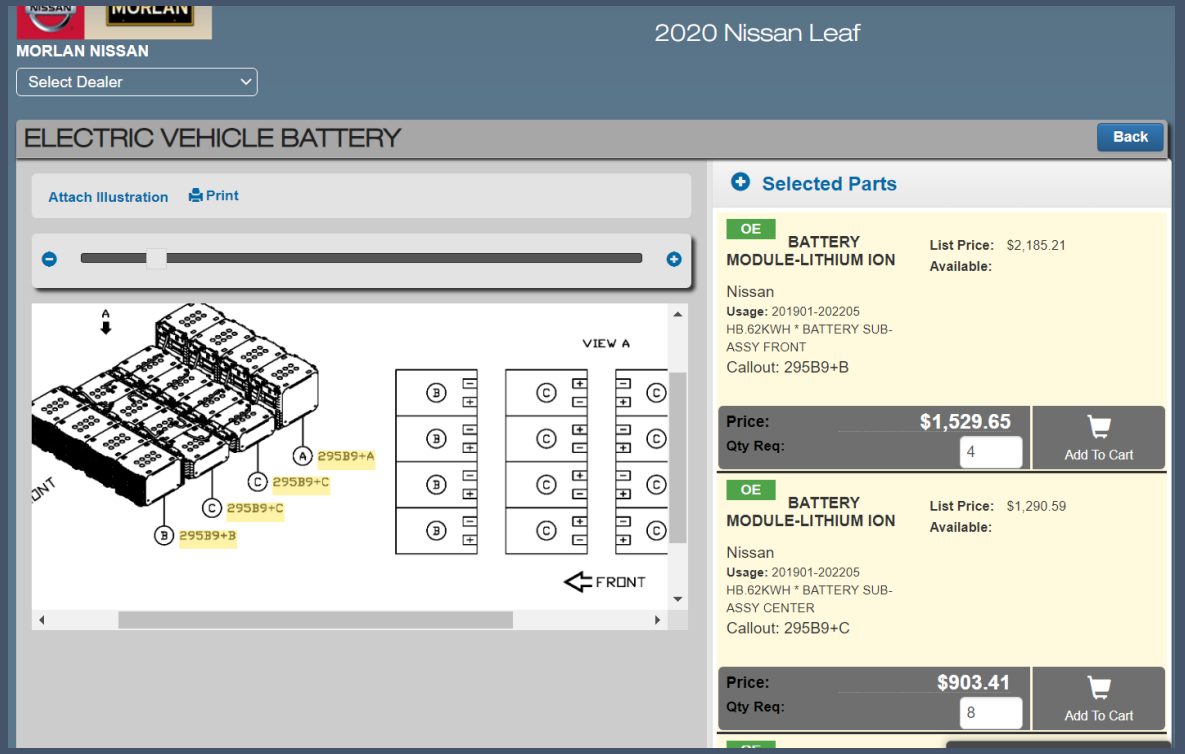
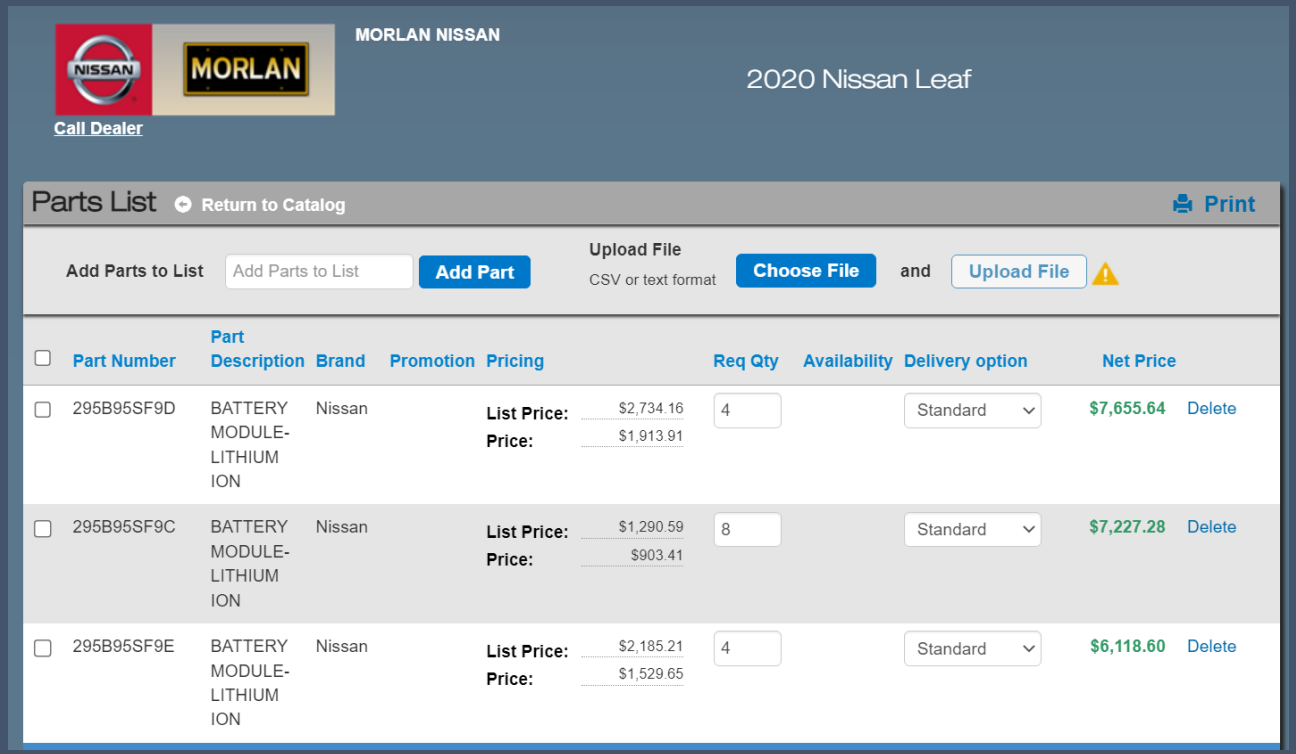
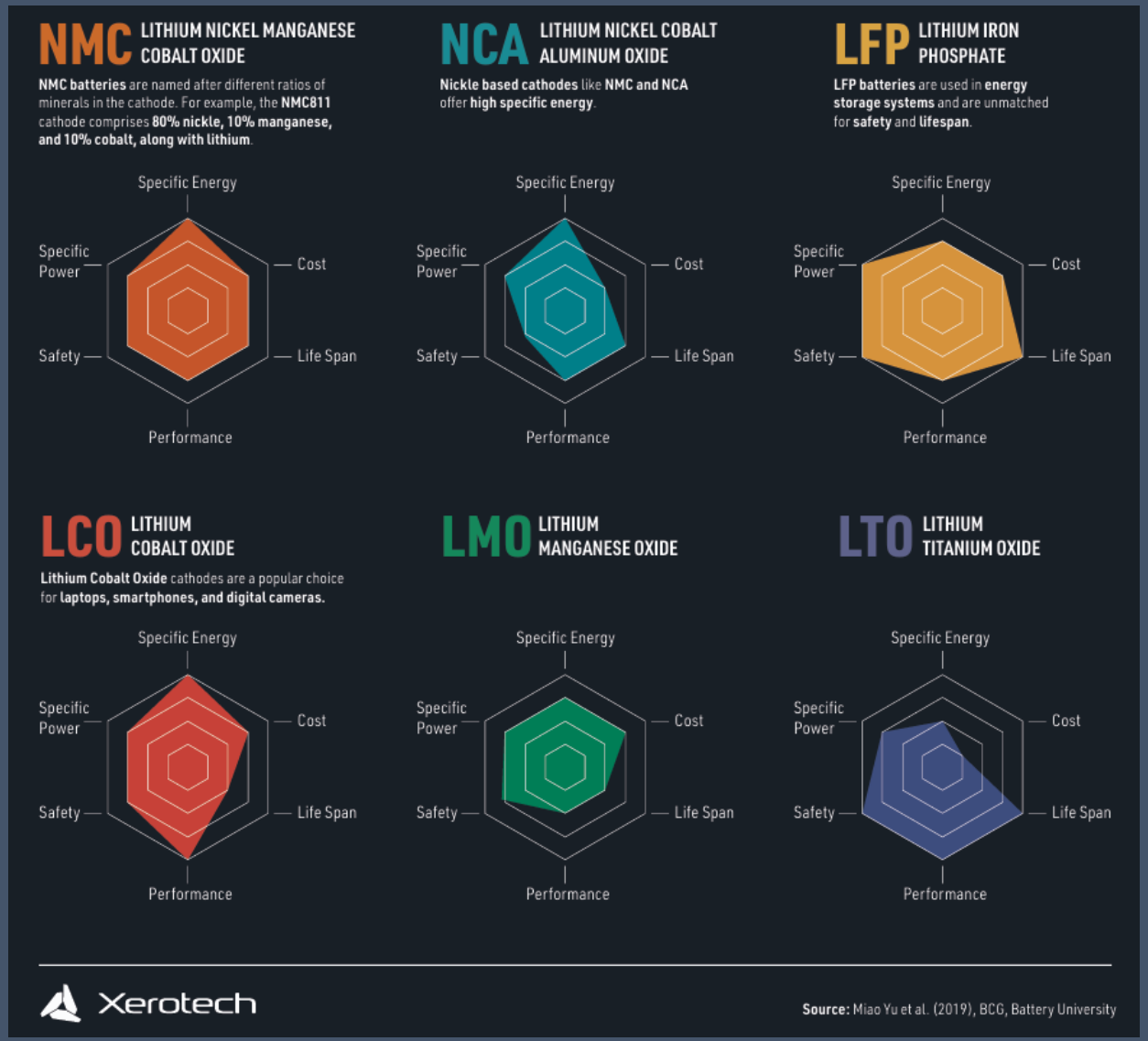
2020 Nissan Leaf 62kw





Battery Chemistries



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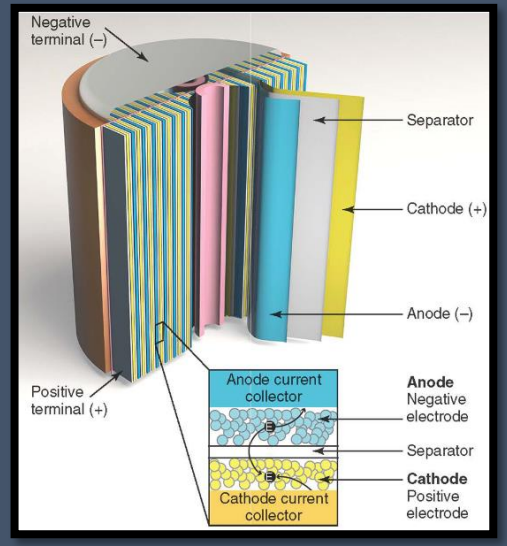
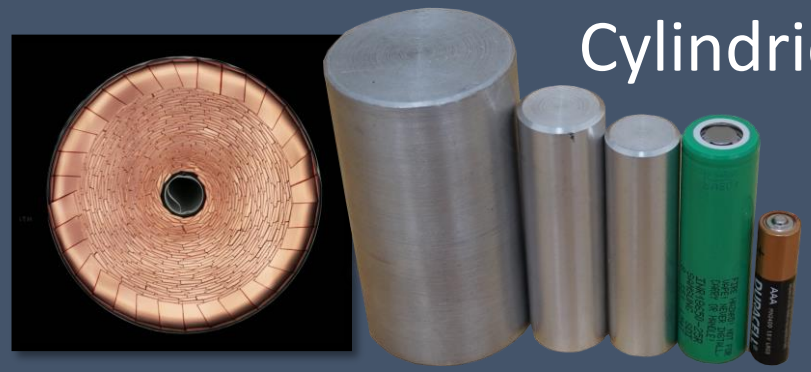
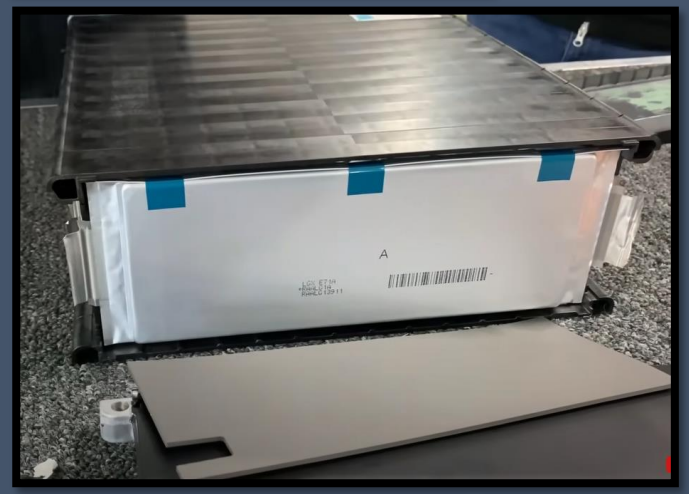
Battery Form Factor



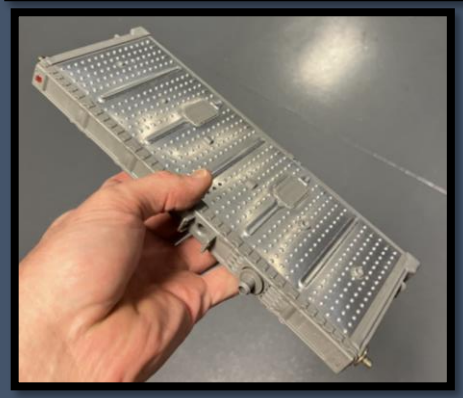
Cylindrical

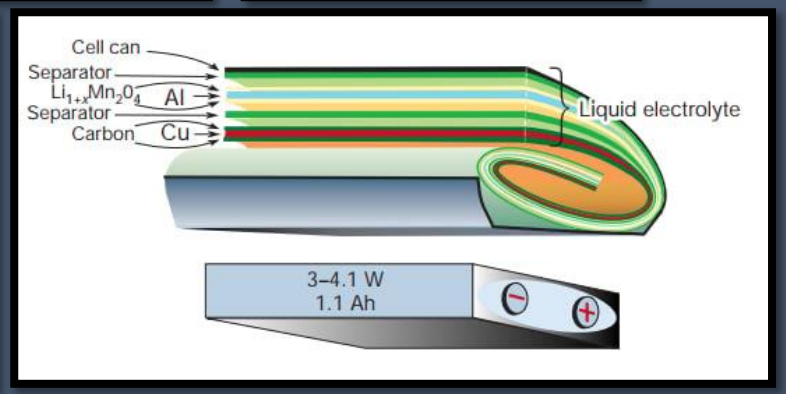


Pouch

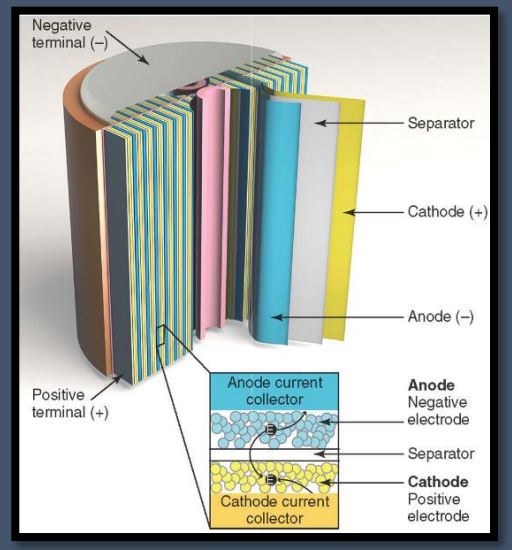


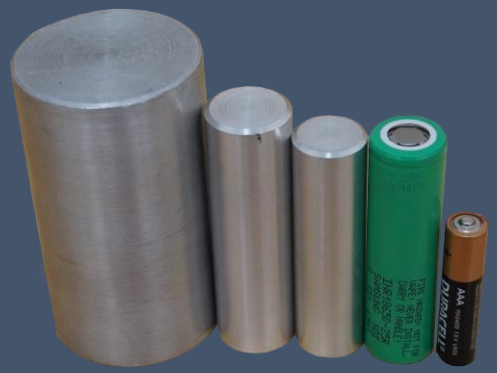
Prismatic





Battery Form Factor - Cylindrical





Advantages

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

Disadvantages

- Packaging
- Round cells
- Smaller cells

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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

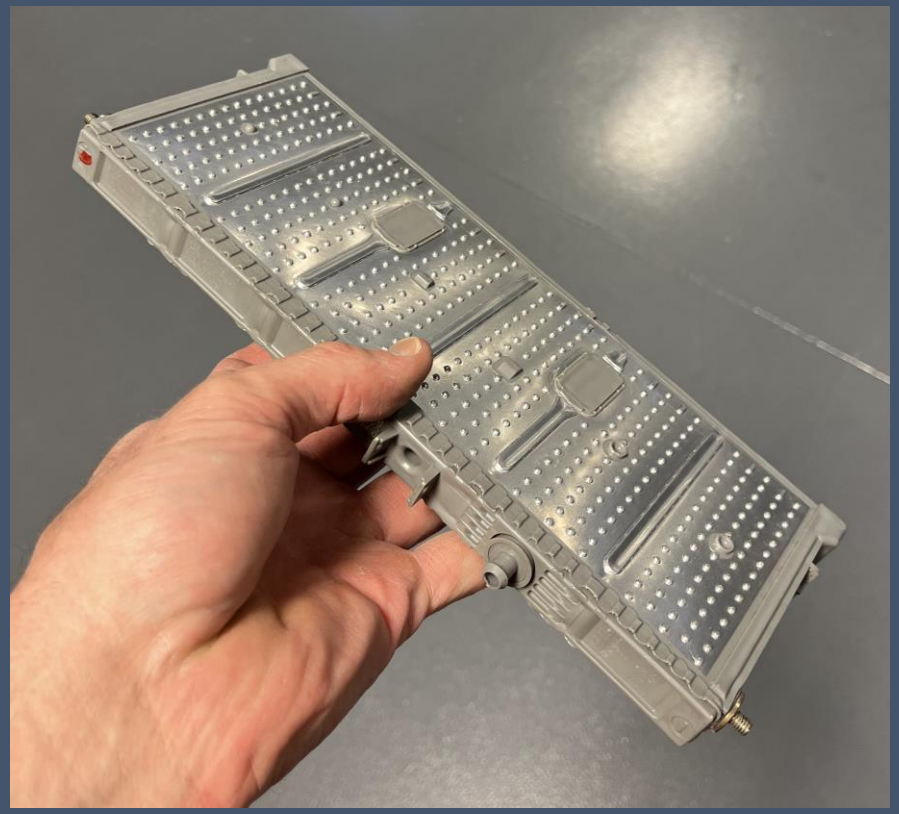
Battery Form Factor - Pouch

Advantages:

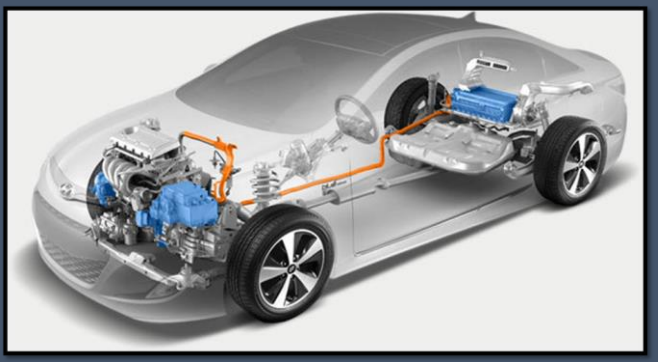
- One container holds a lot of cell material
- Packaging options
- Ease of construction

Disadvantages:

- Thermal control of the cell – uneven cooling



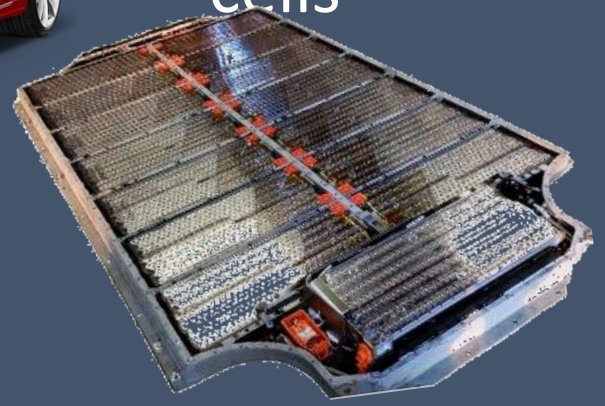
Battery Layout Examples



- 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



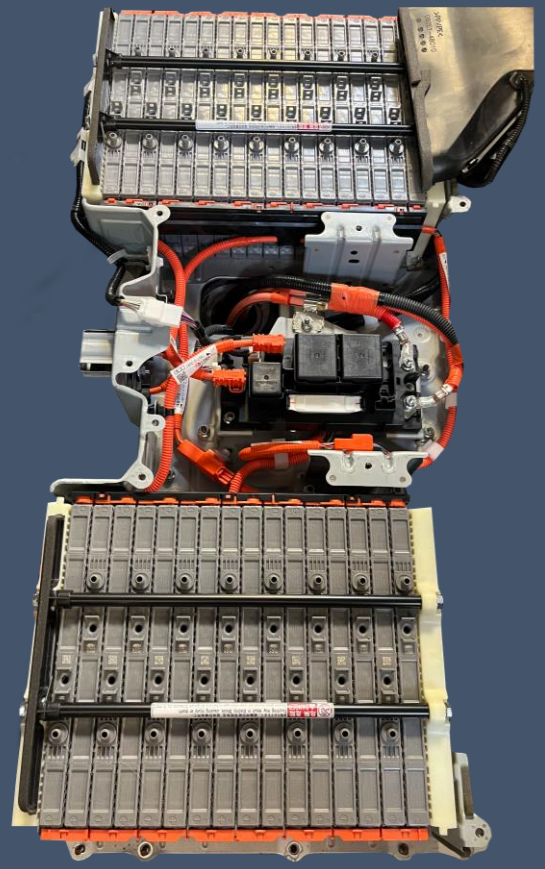
- Lucid Air – 6600 “2170” cells

Battery Layout Examples

- Rivian R1T – 7776 “2170” cells

- Tesla MY – 828 “4680” cells

Battery Layout Examples



Toyota Rav 4 Hybrid

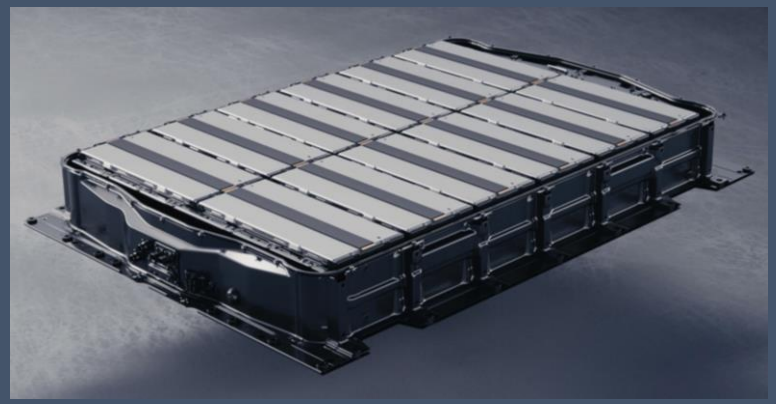
Jeep 4xE

Text Page 31

Arrays and Modules

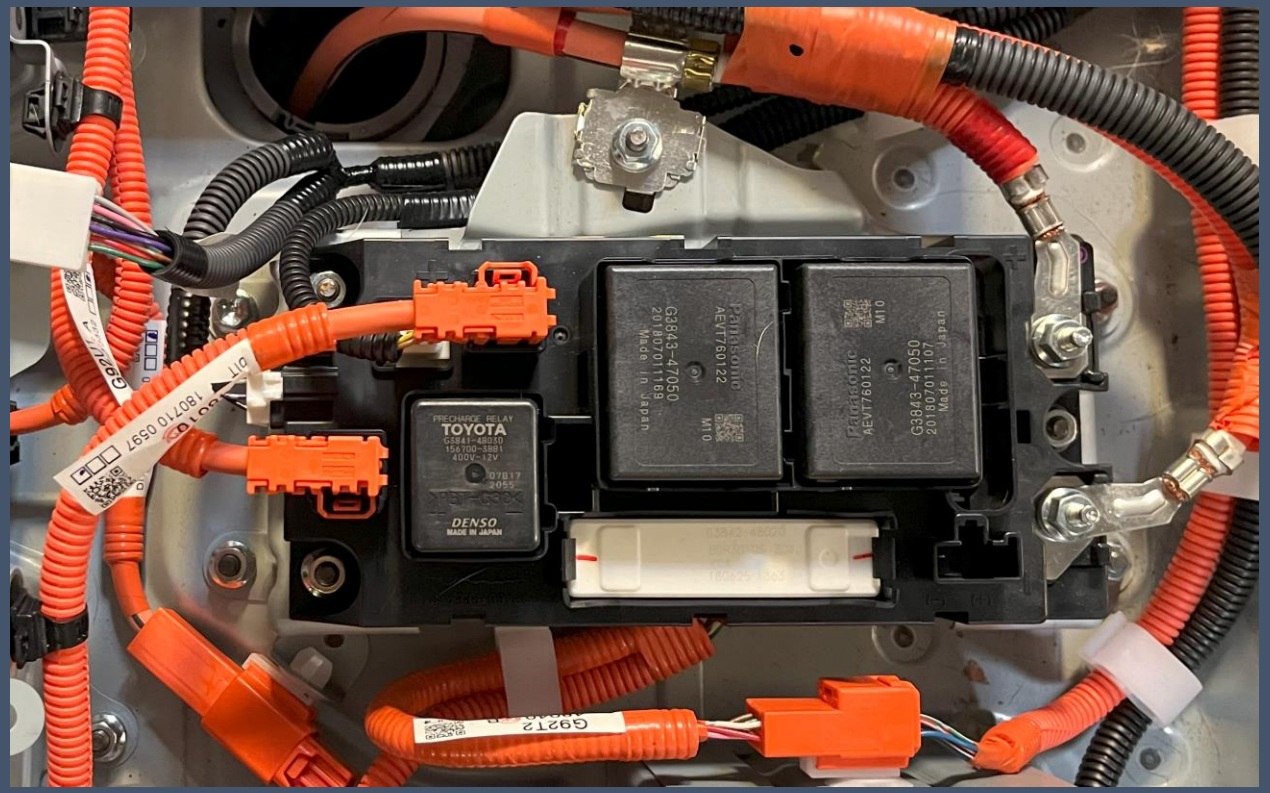
- Hyundai electric global module platform

- GM Ultium battery pack



High Voltage Contactors – Delivering the power

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



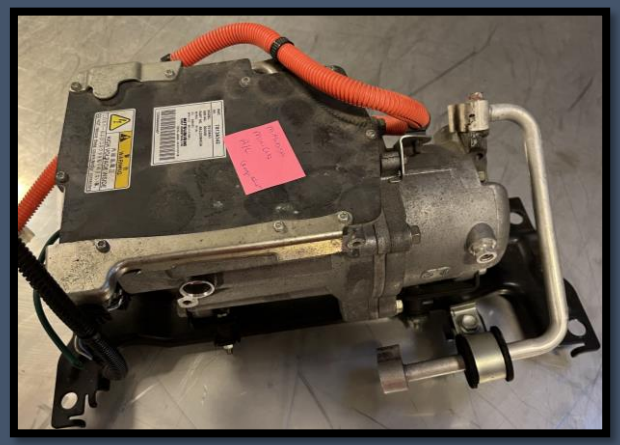
High voltage battery temperature

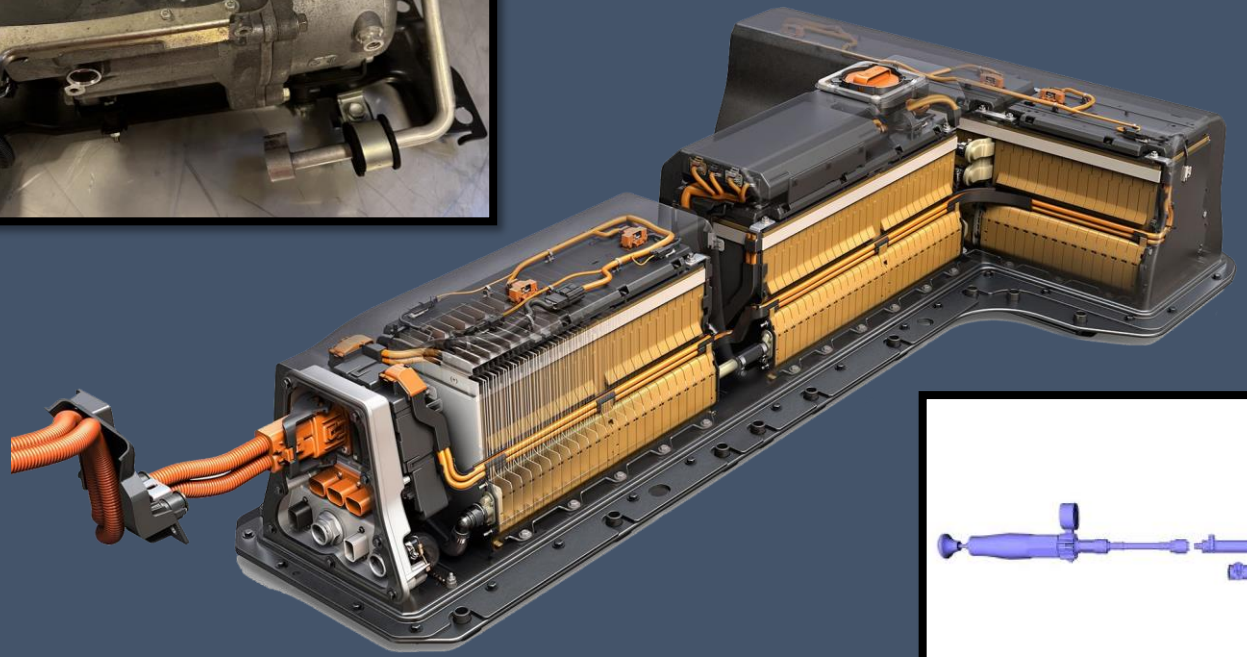
- Li Ion doesn’t perform as well in cold temperature
  - Battery heater
    - PTC – electric resistance heater
  - Heat Pump
    - Uses refrigerant to heat coolant to heat the battery

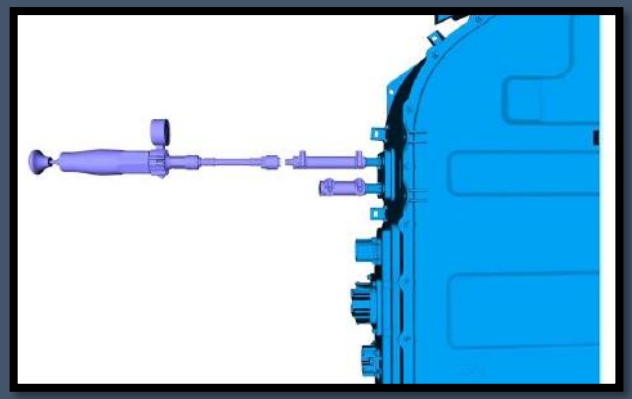
Text Page 33

High voltage battery temperature

- Li Ion needs to be cooled in high temperatures

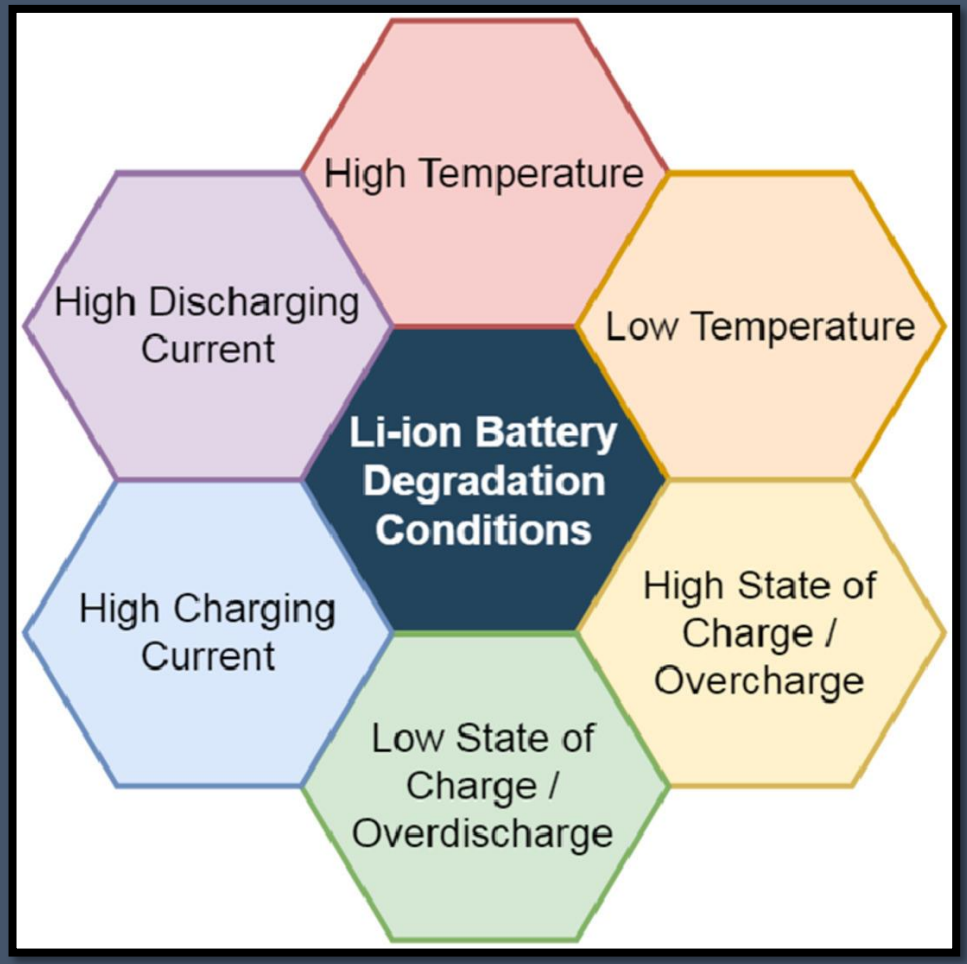






Why do batteries degrade?

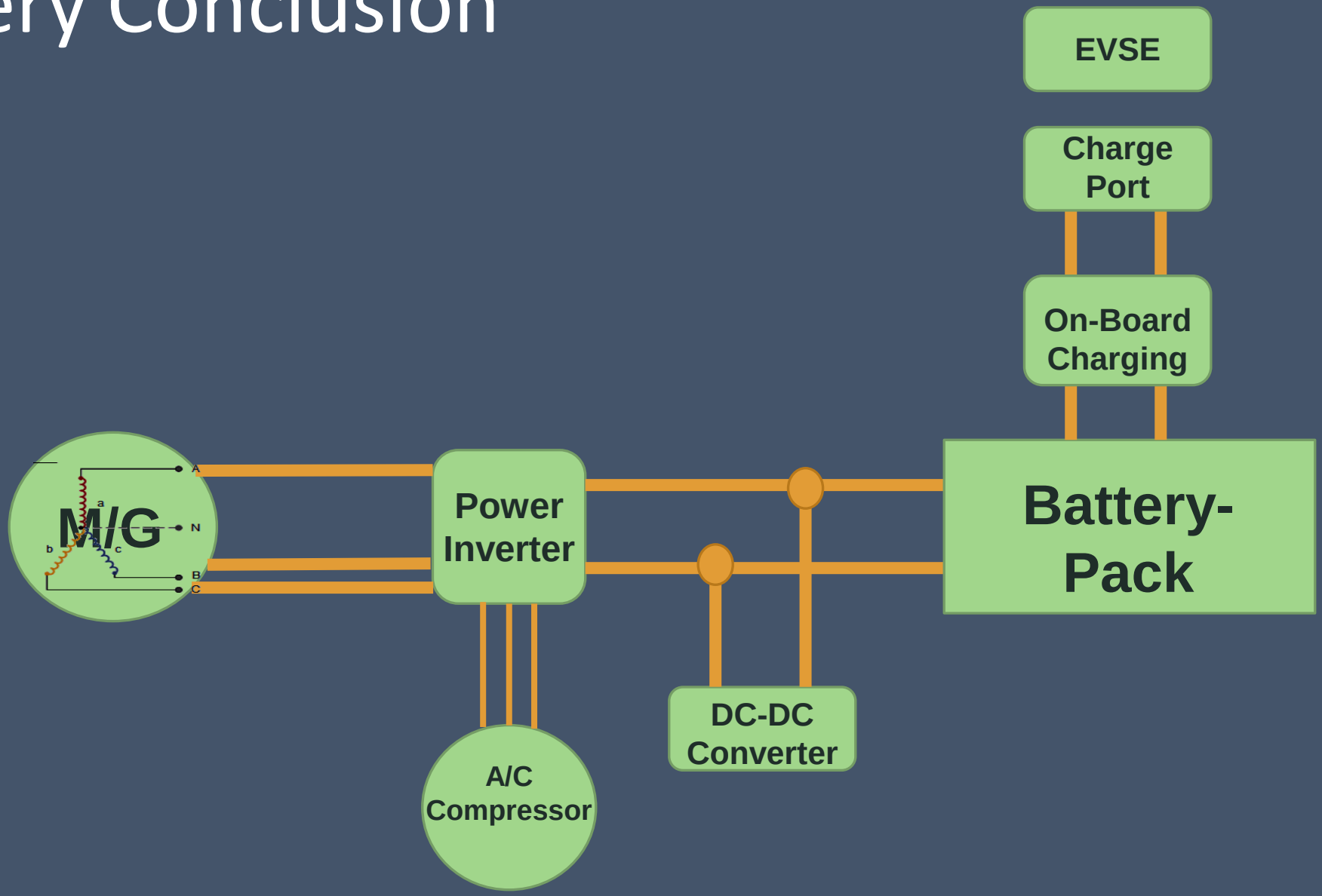
- Temperature
- State of Charge (SOC)
- Depth of Discharge (DoD)
- Charge rate
- Discharge rate
- Cycling



Why do batteries degrade?

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

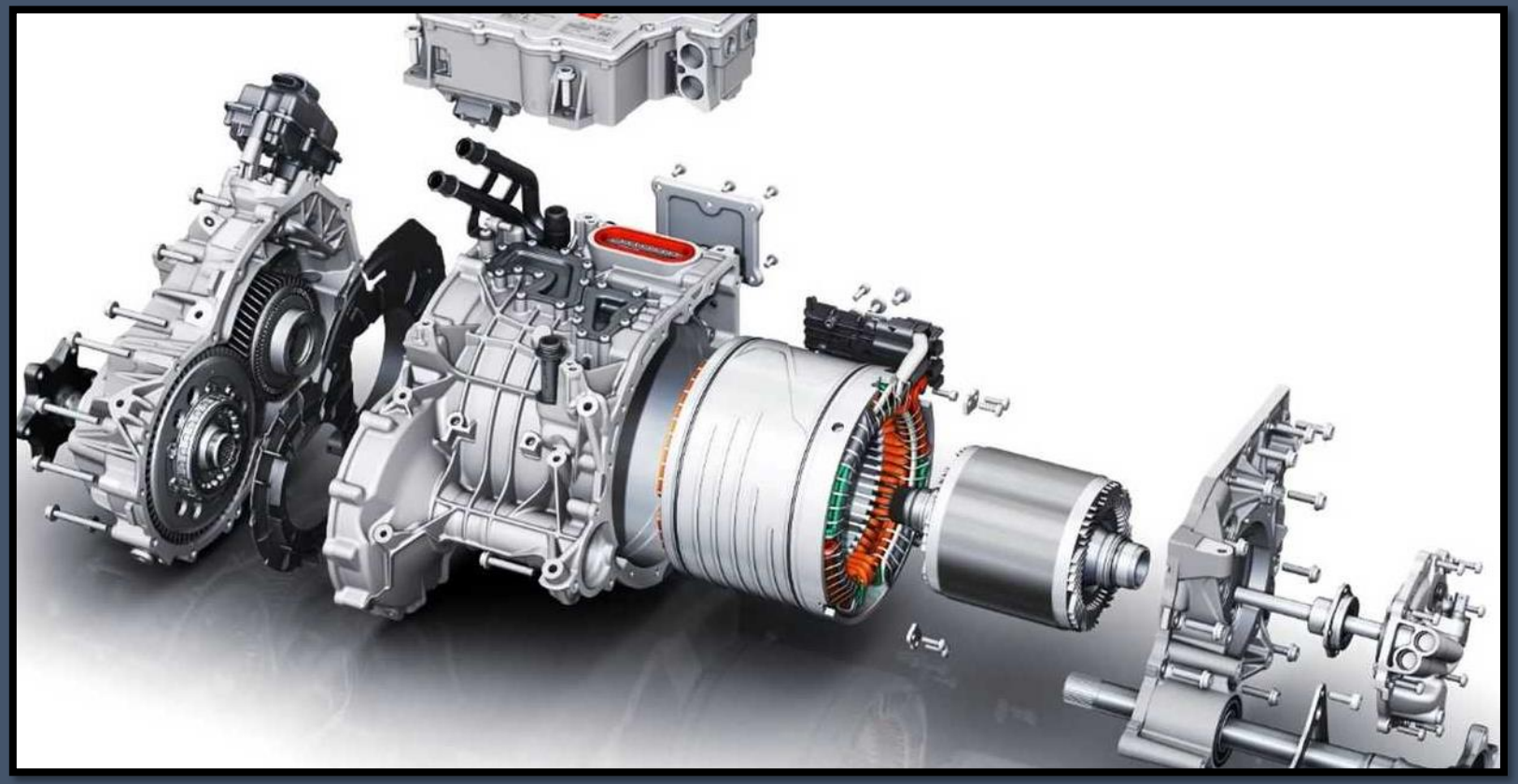
Battery Conclusion



xEV Motors

Electric Motors

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



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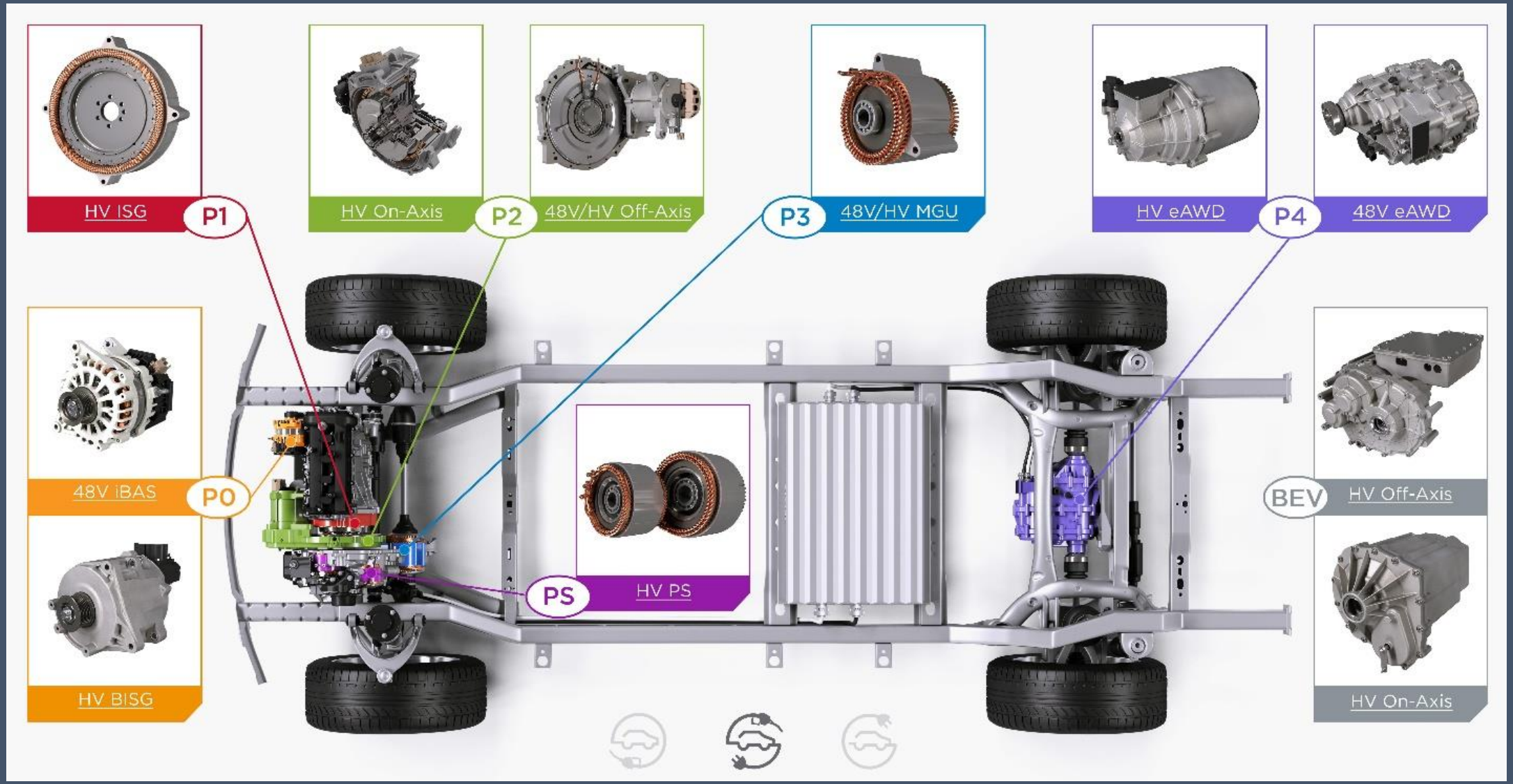
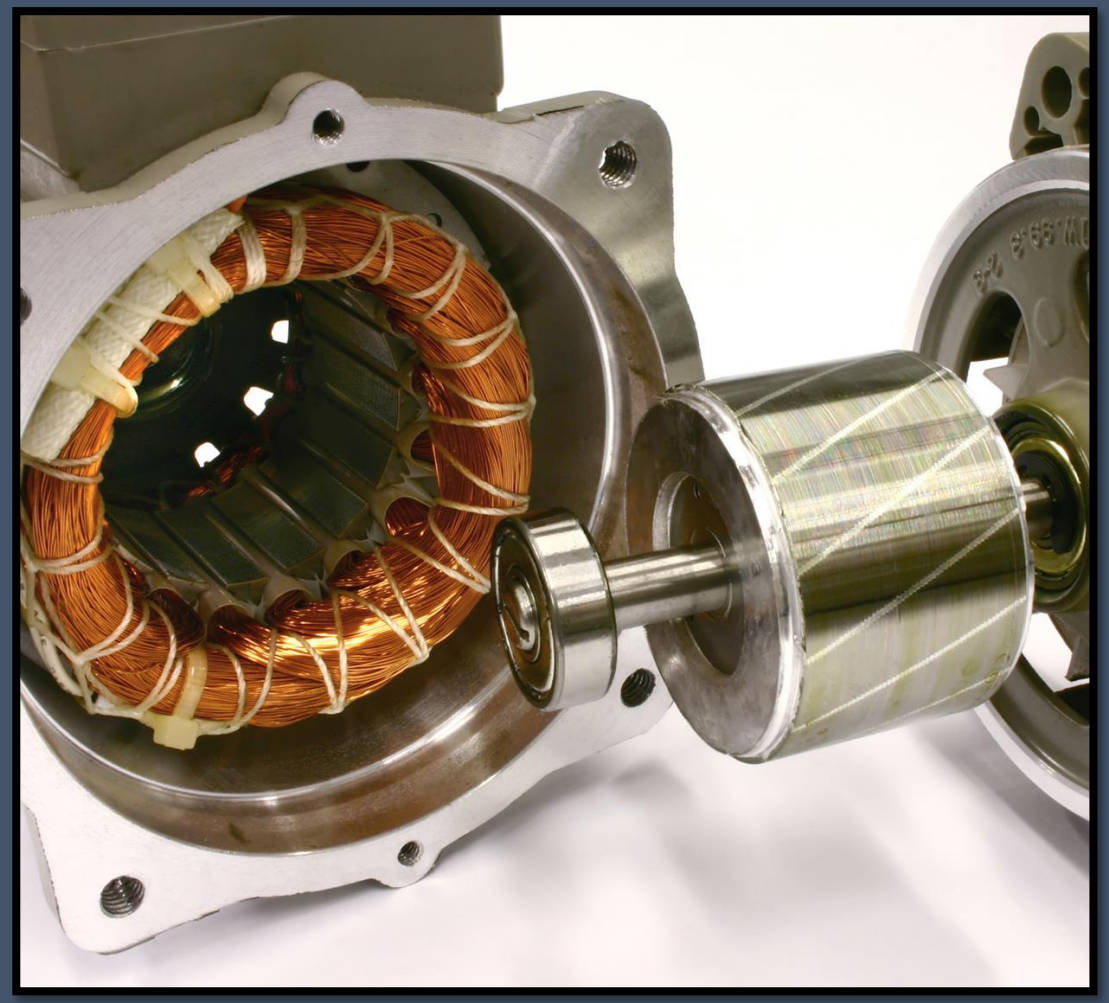
Motor designations



Basic Motor Operation

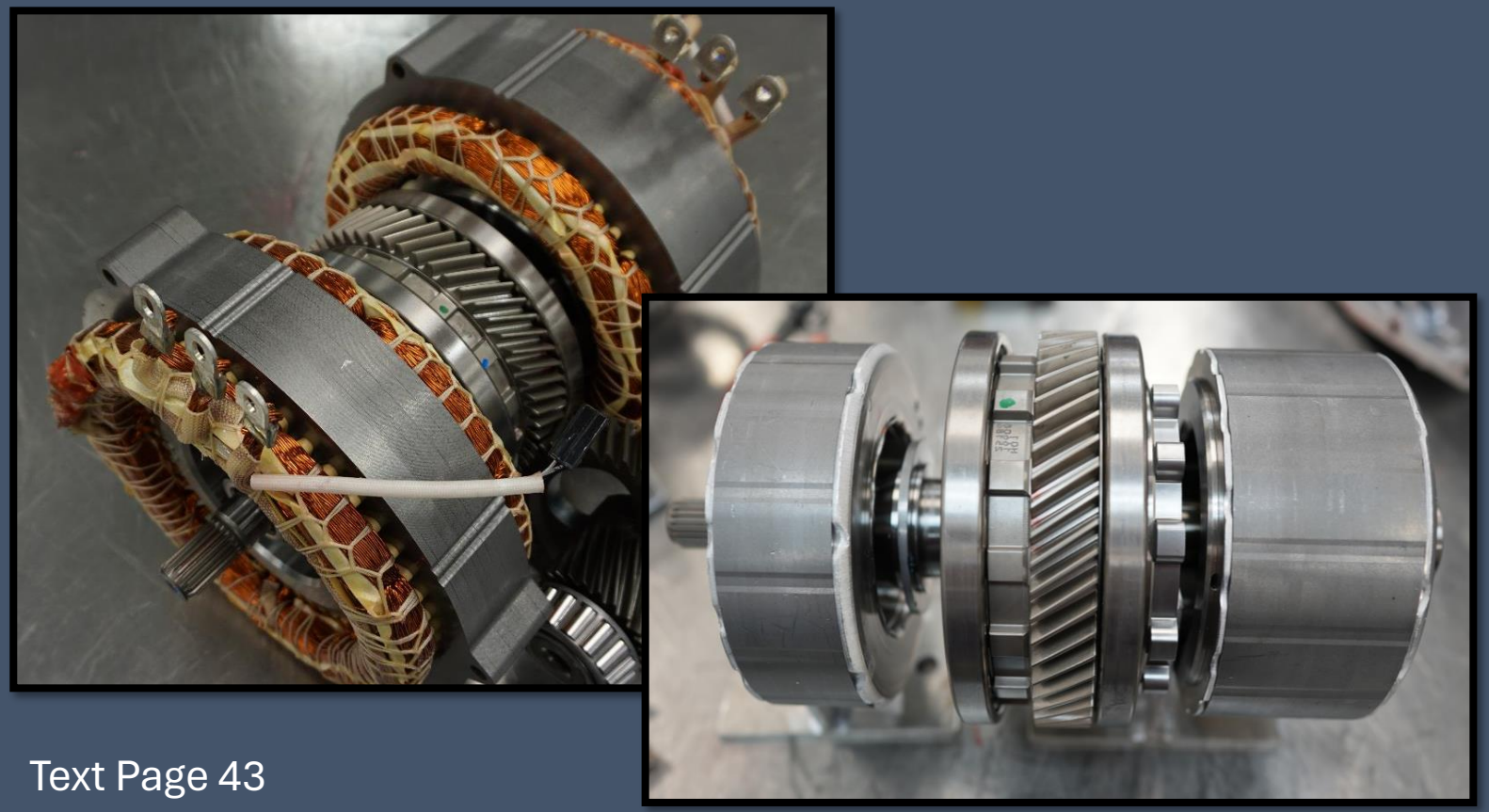


- Main components
  - Stator
    - Windings to create a “rotating magnetic field”
  - Rotor
    - Most common - Permanent magnet to chase that rotating magnetic field

Text Page 43

Transaxles – Toyota/Nissan/Ford/Hyundai

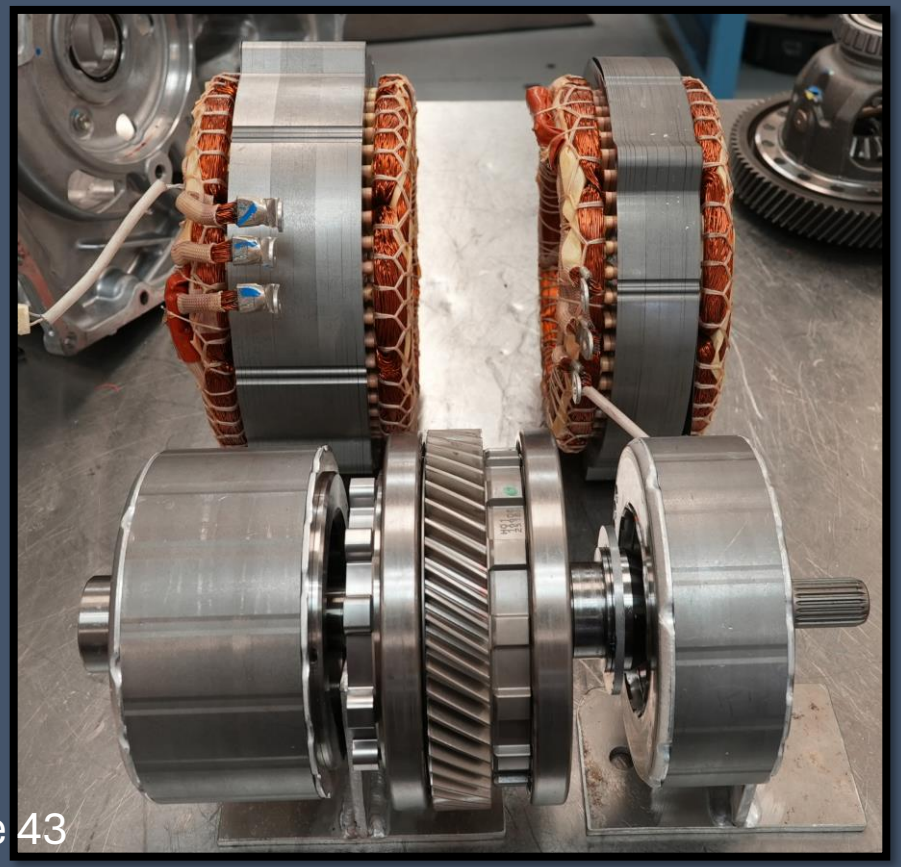
- Two Electric Motors (in one transaxle housing)
  - Permanent magnets in rotors
  - 3-phase stator windings



Text Page 43

Transaxles – Toyota/Nissan/Ford/Hyundai

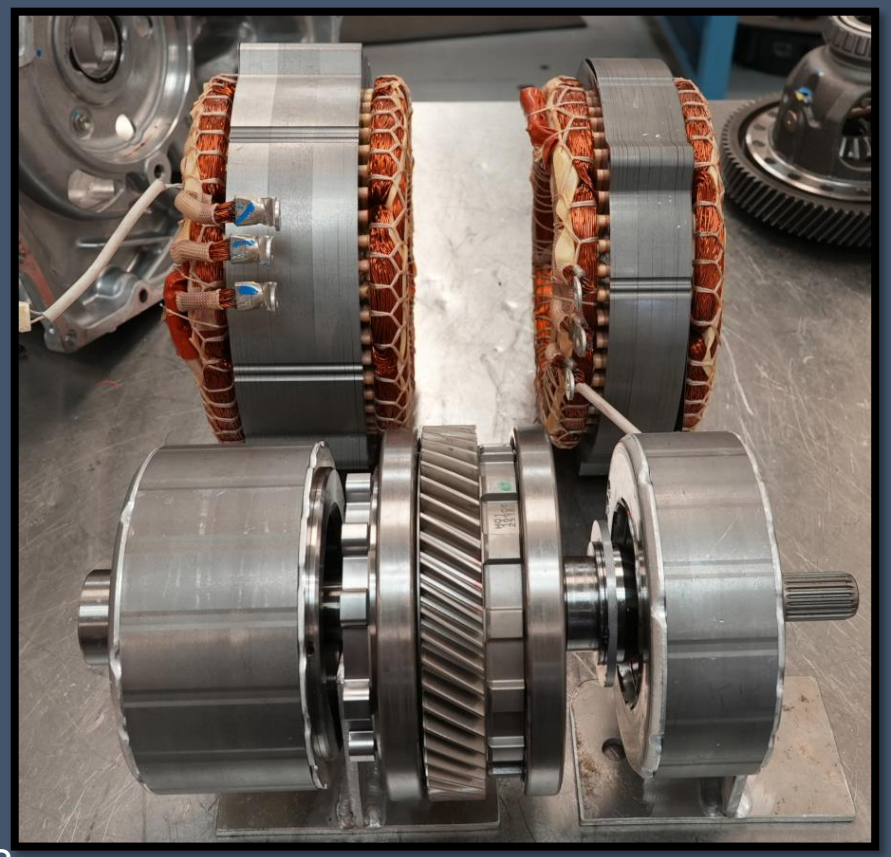
- MG 1 (smaller)
  - Works as a generator
  - Works as an engine starter
  - Provides resistance to a planetary gear to allow the engine to vary RPM



Text Page 43

Transaxles – Toyota/Nissan/Ford/Hyundai

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



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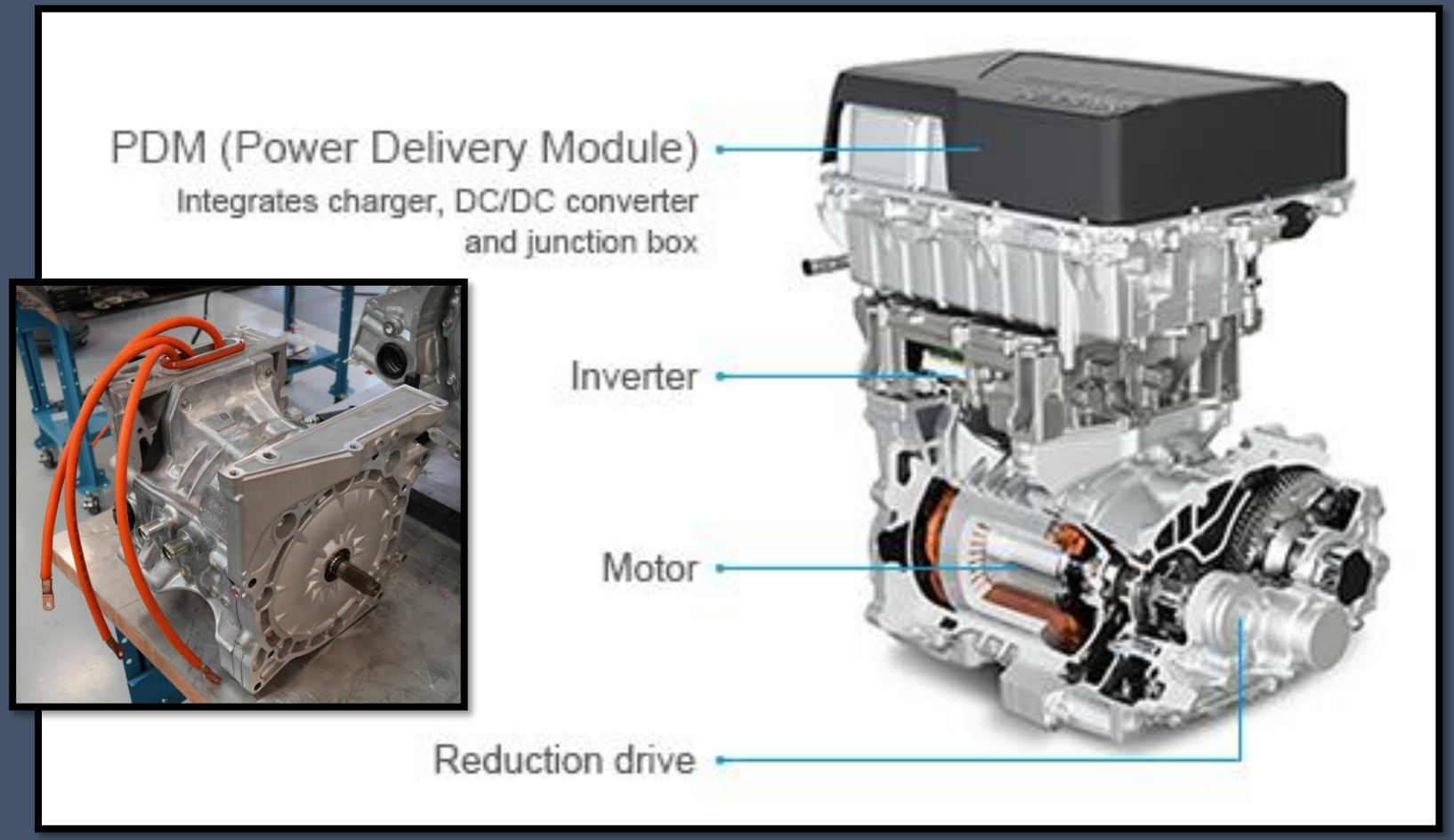
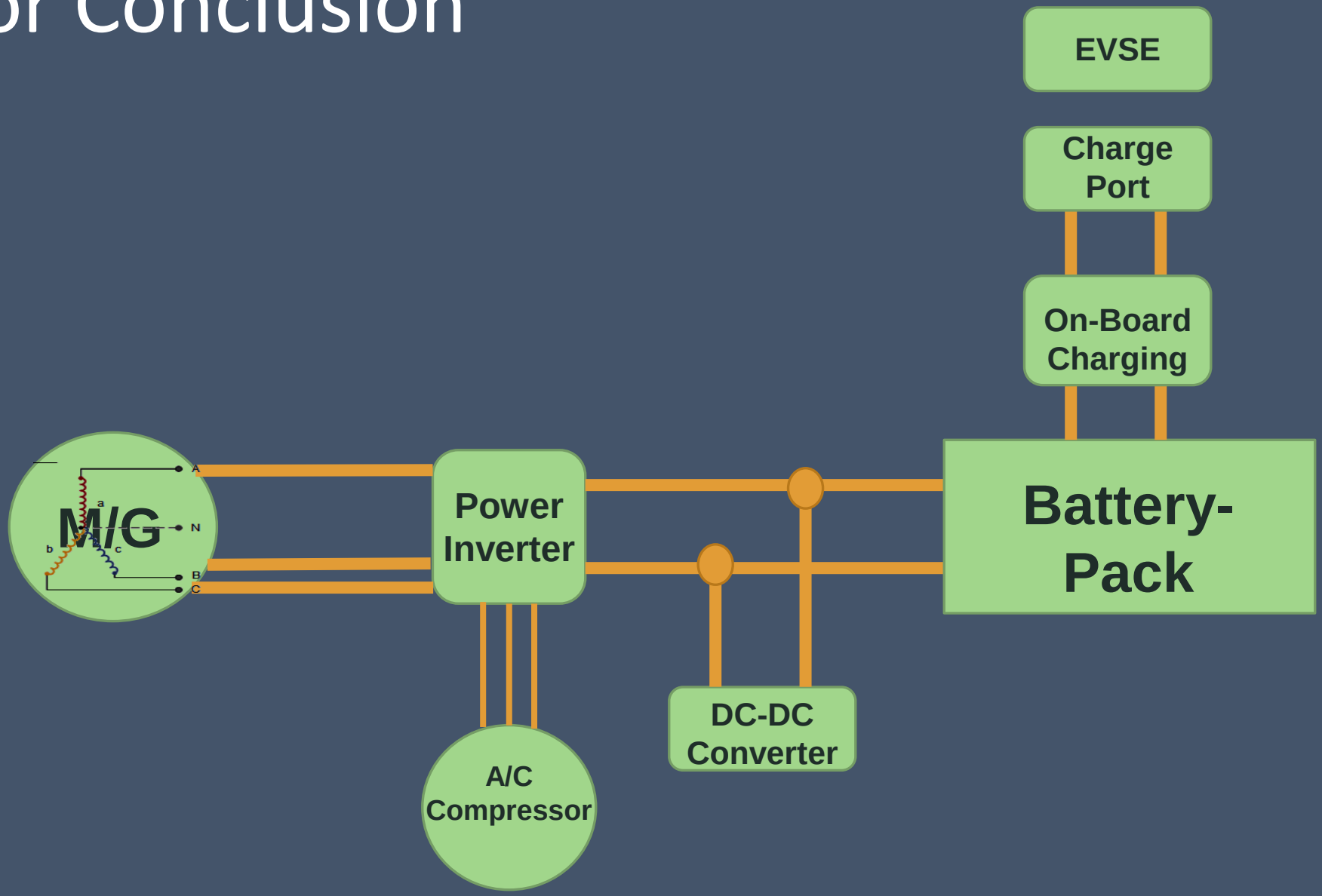
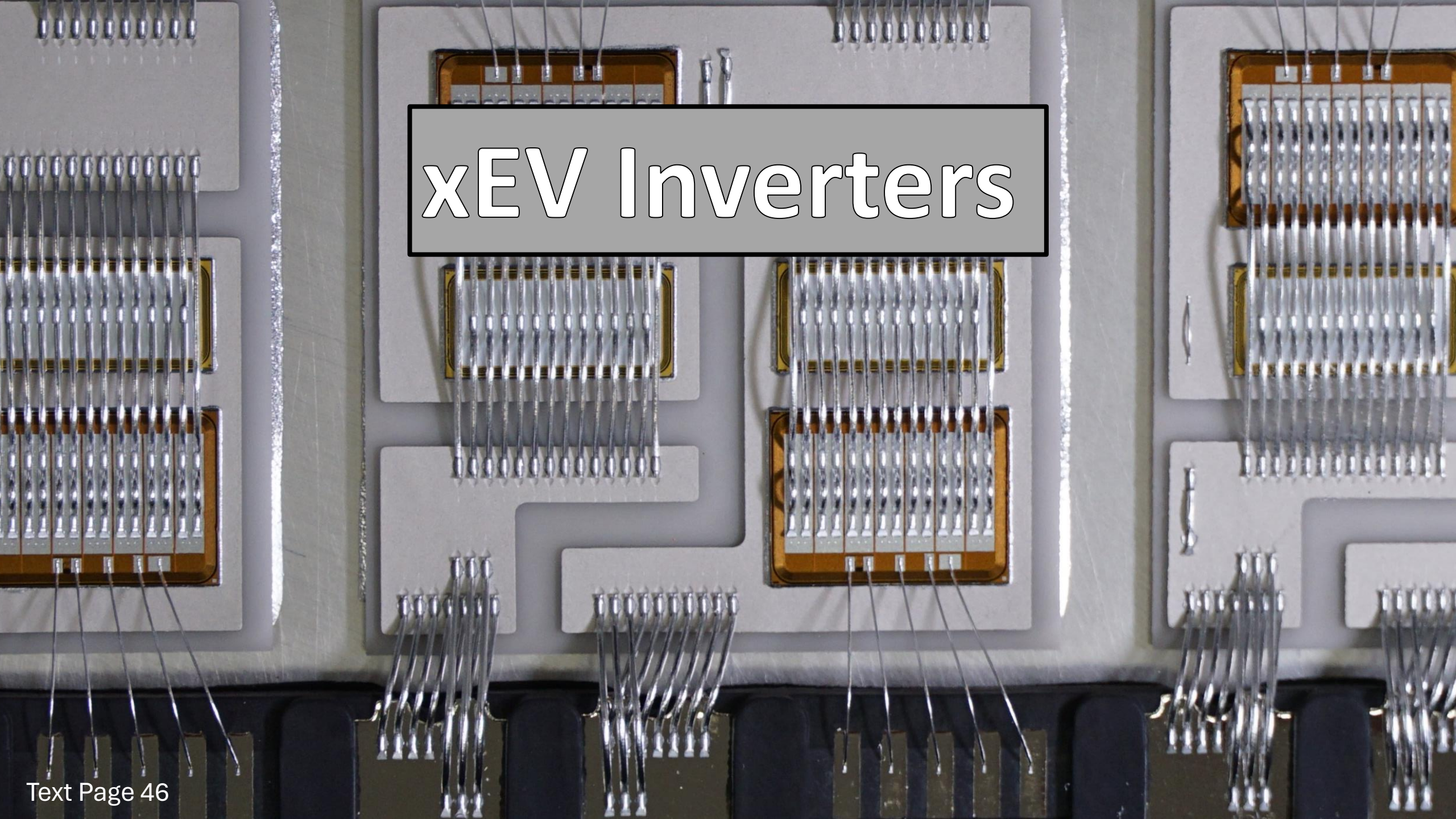
Nissan Leaf Motor

- 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

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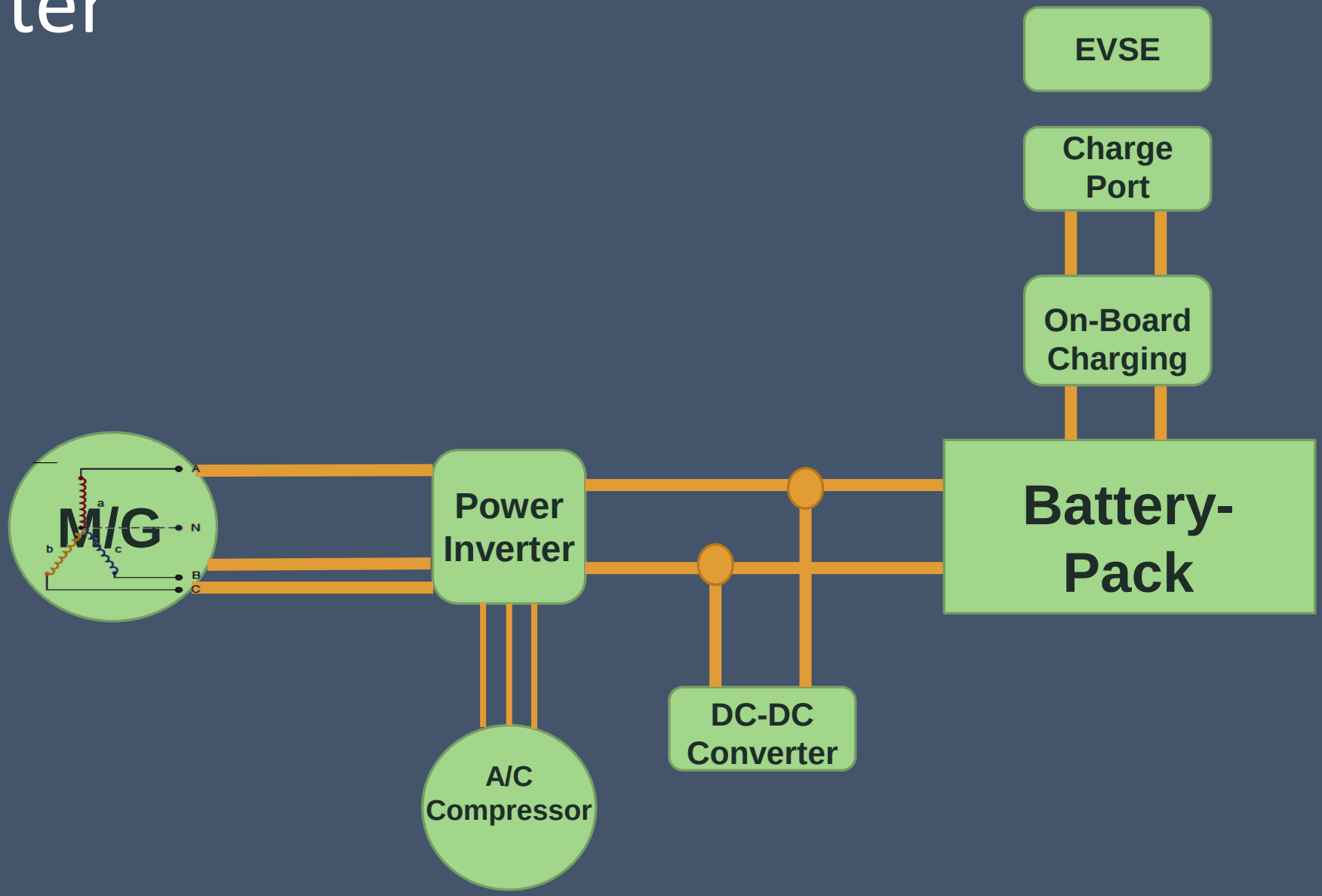
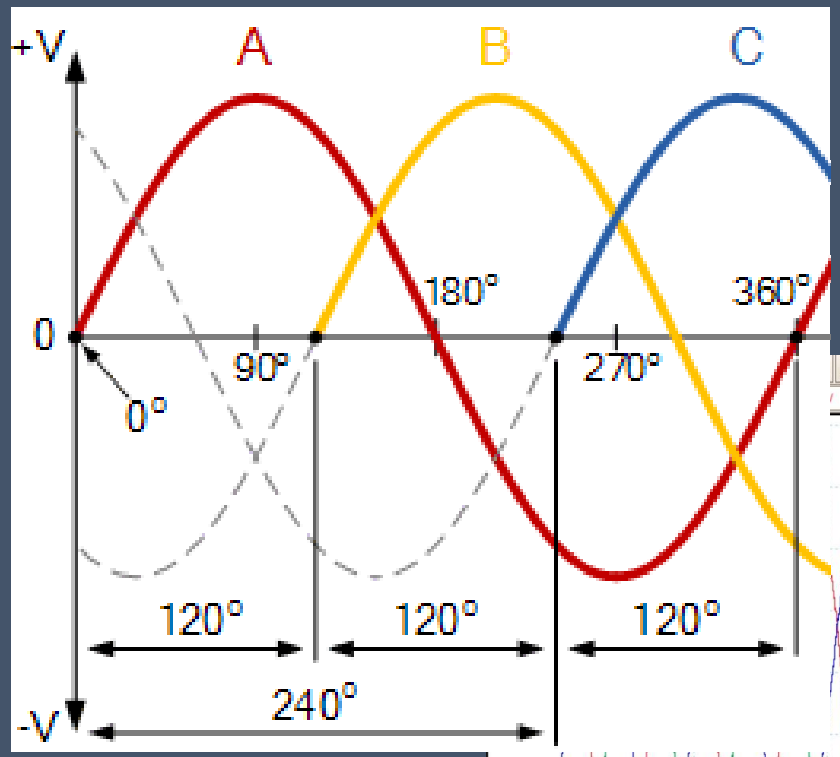
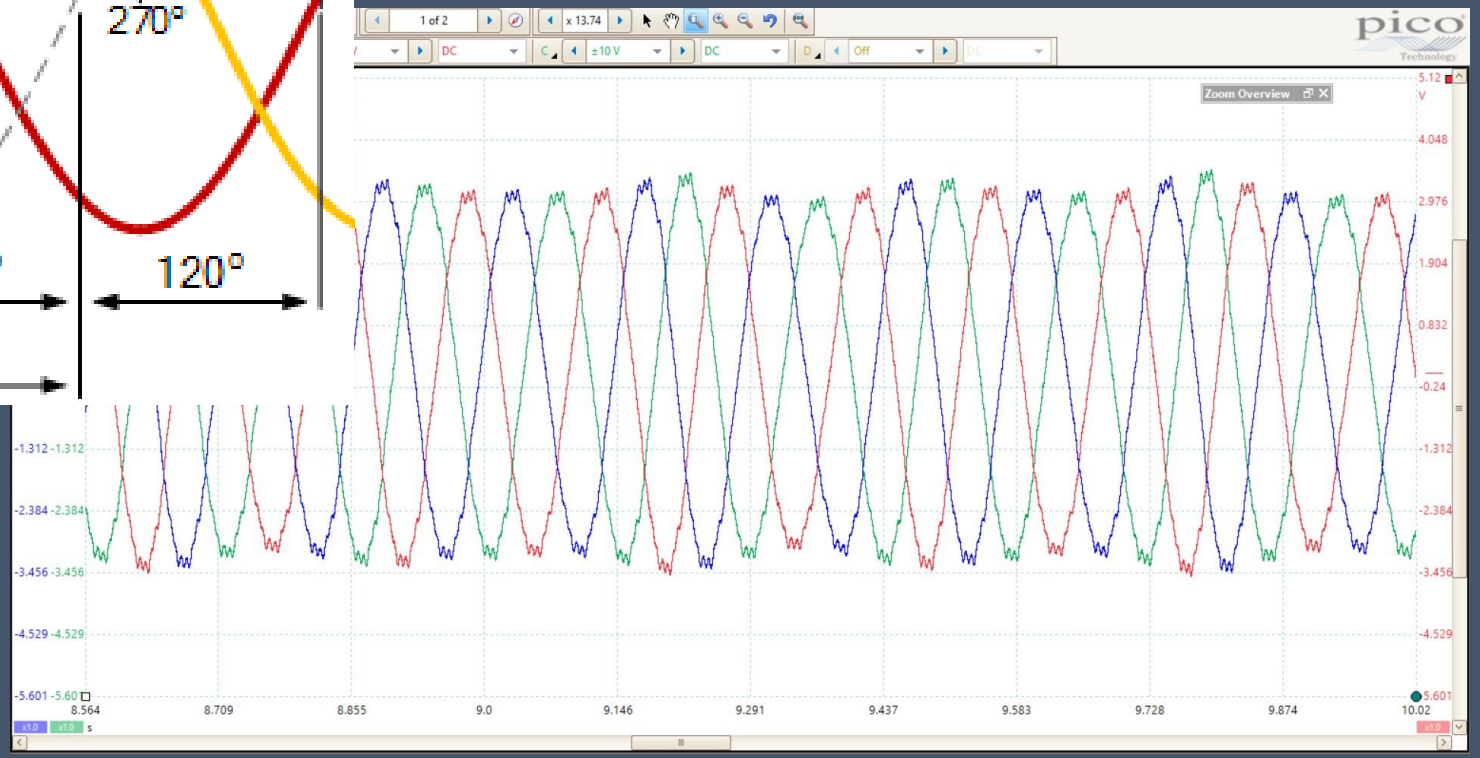
Inverter

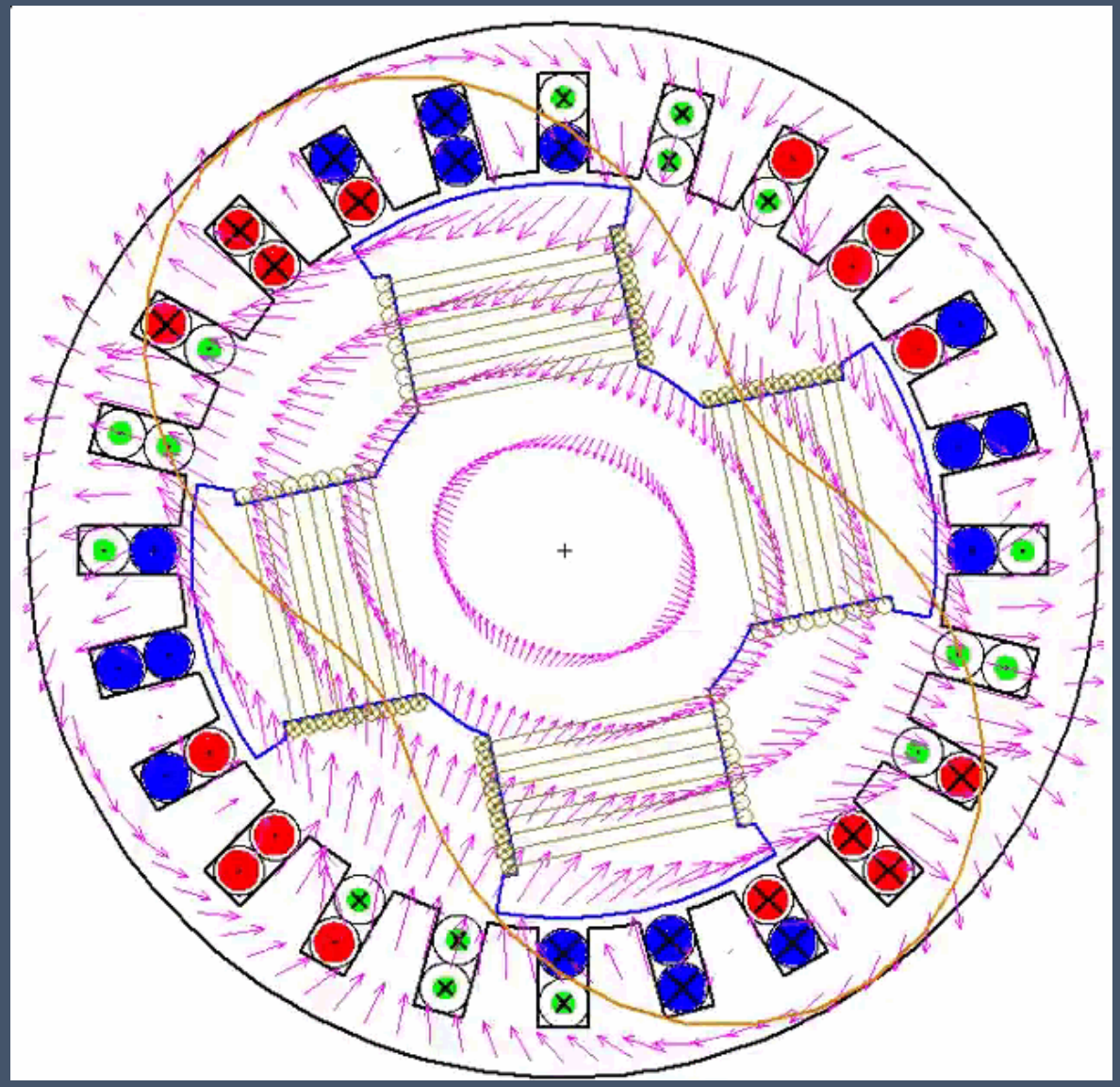

EVSE
Charge Port
On-Board Charging
M/G
A
N
B
C
a
b
c
Power Inverter
Battery-Pack
DC-DC Converter
A/C Compressor

Inverter

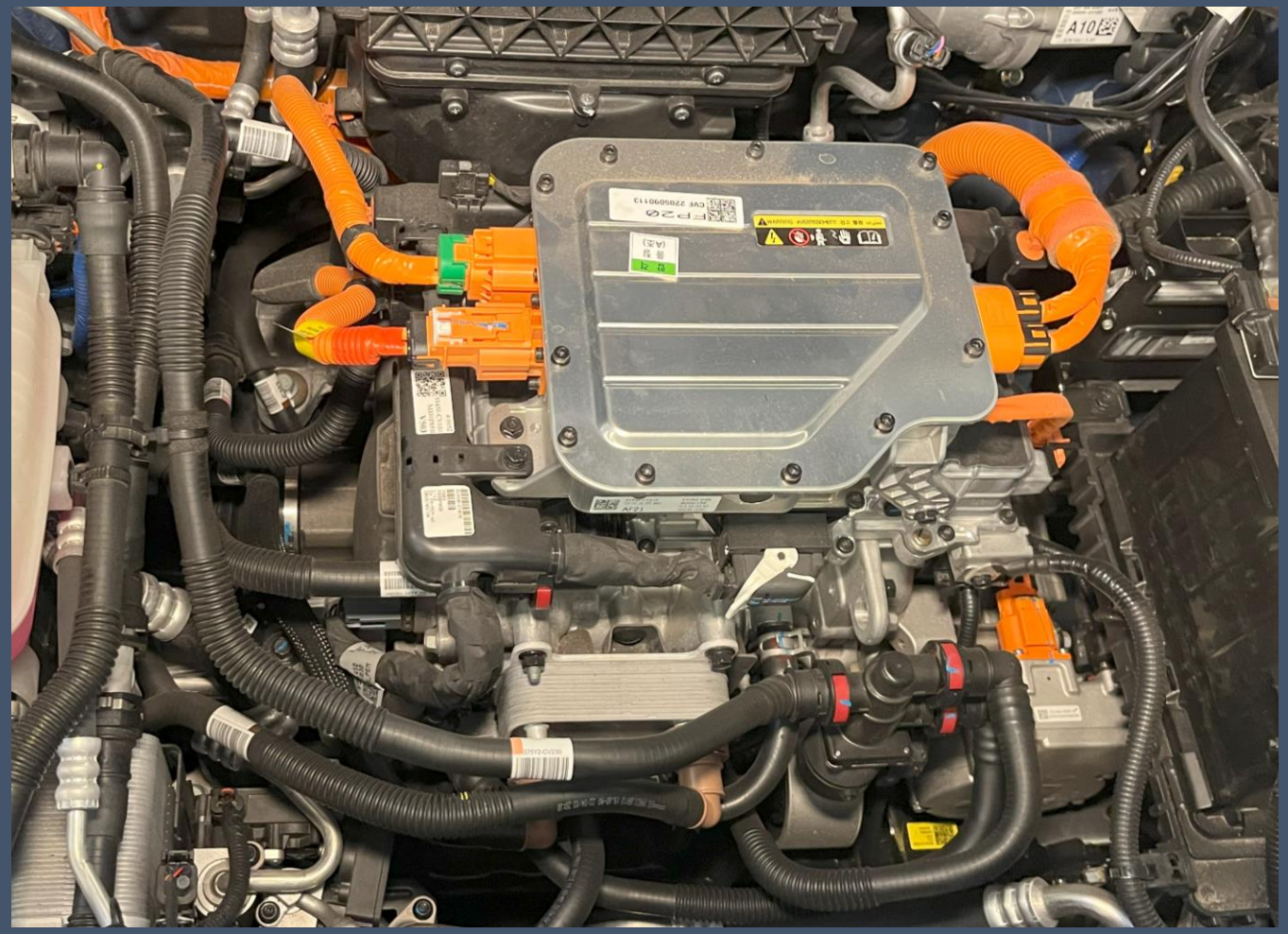

+V
A
B
C
0
180°
360°
90°
270°
0°
120°
120°
120°
240°
-V


pico
Zoom Overview
5.12
4.048
2.976
1.904
0.832
-0.24
-1.312
-2.384
-3.456
-4.529
-5.601
8.564
8.709
8.855
9.0
9.146
9.291
9.437
9.583
9.728
9.874
10.02

Inverter Technology



Kia EV6 Front Motor Inverter



Inverter

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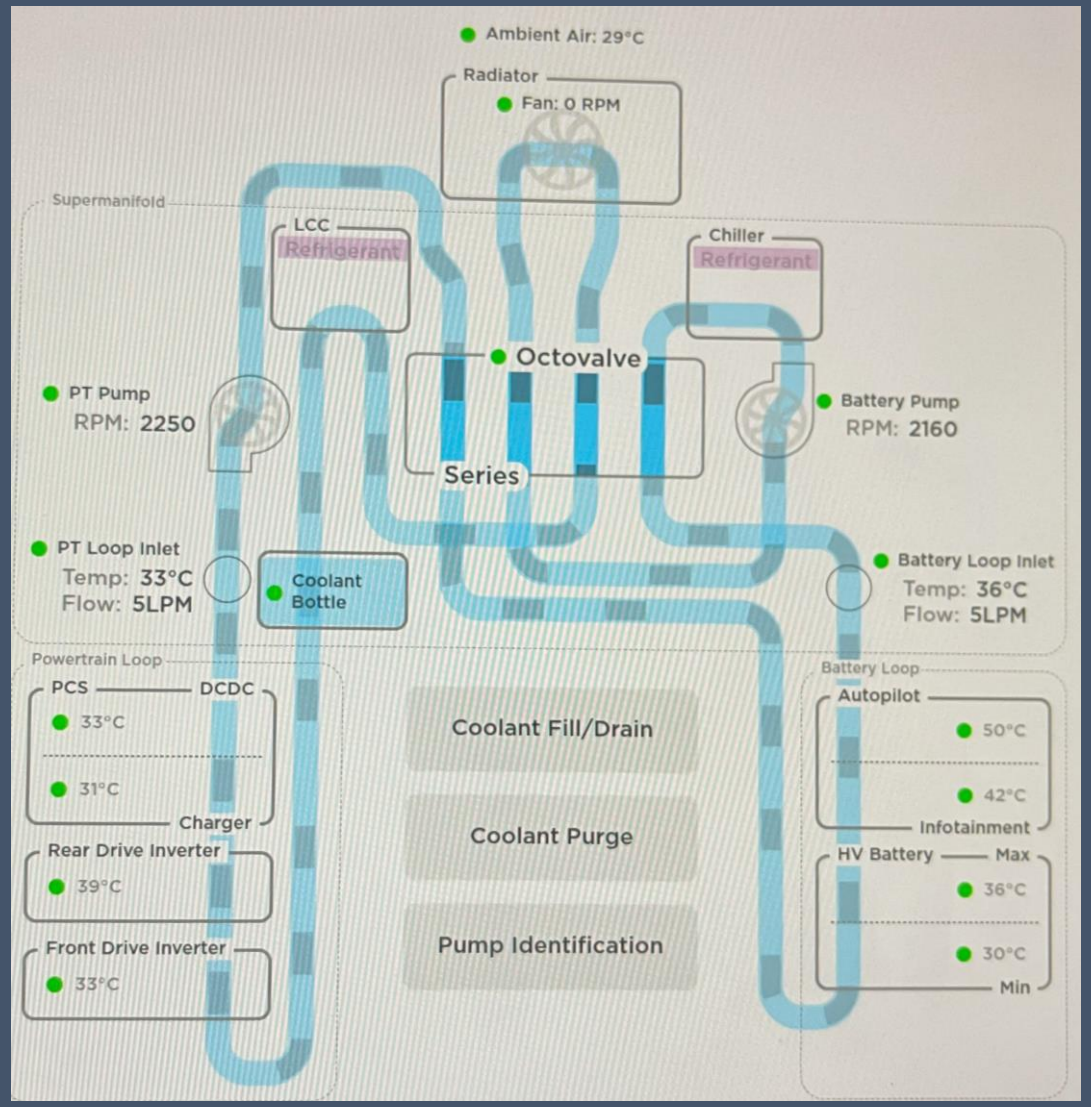
Inverter



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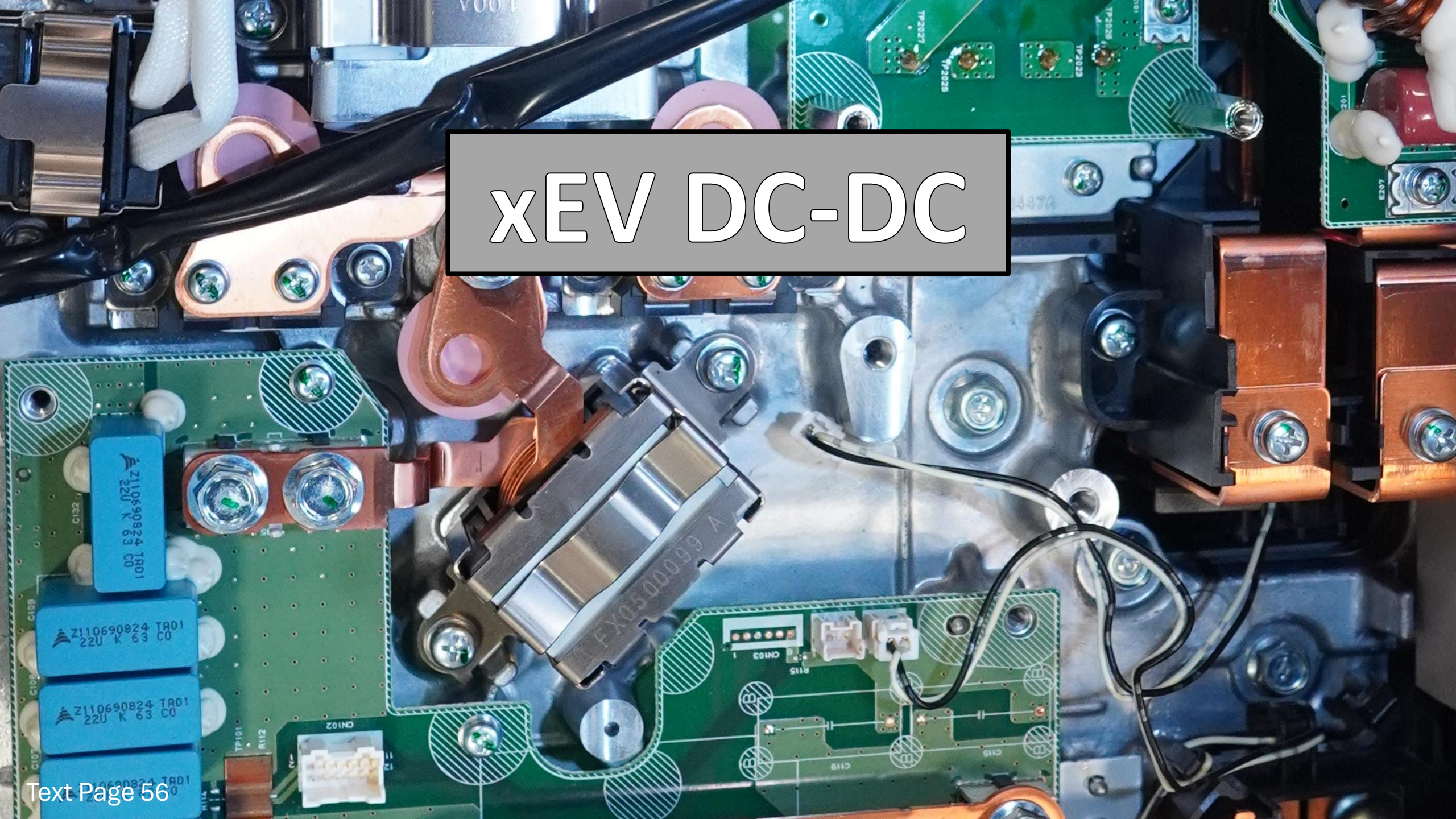
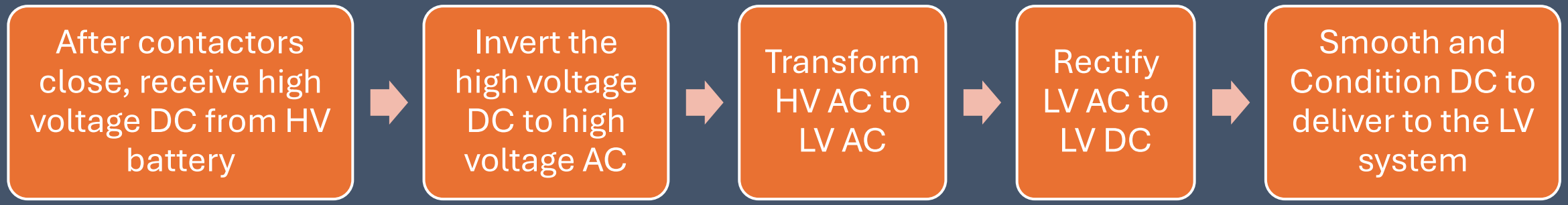
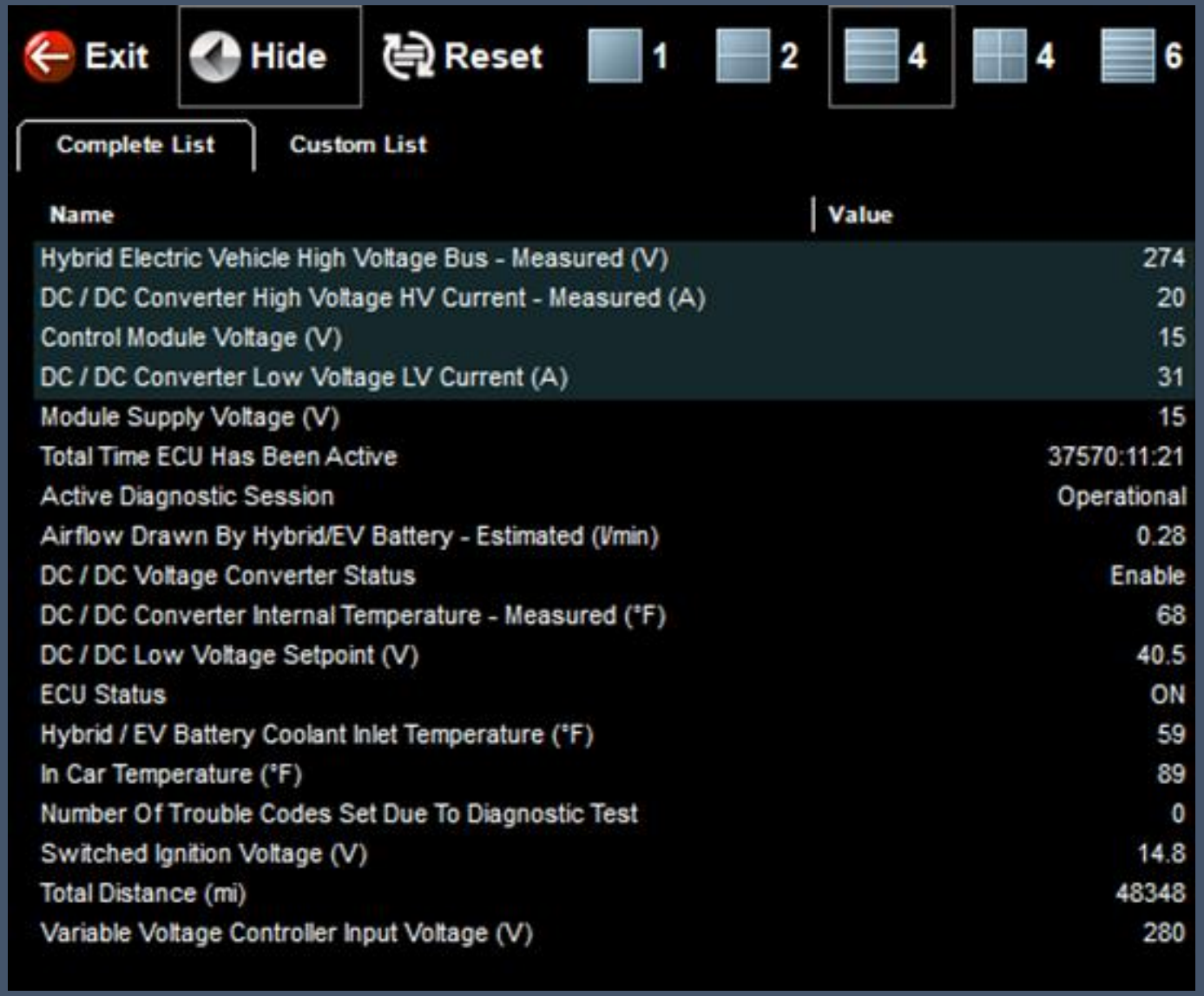

xEV DC-DC

DC – DC Conversion Process



Converter diagnostics



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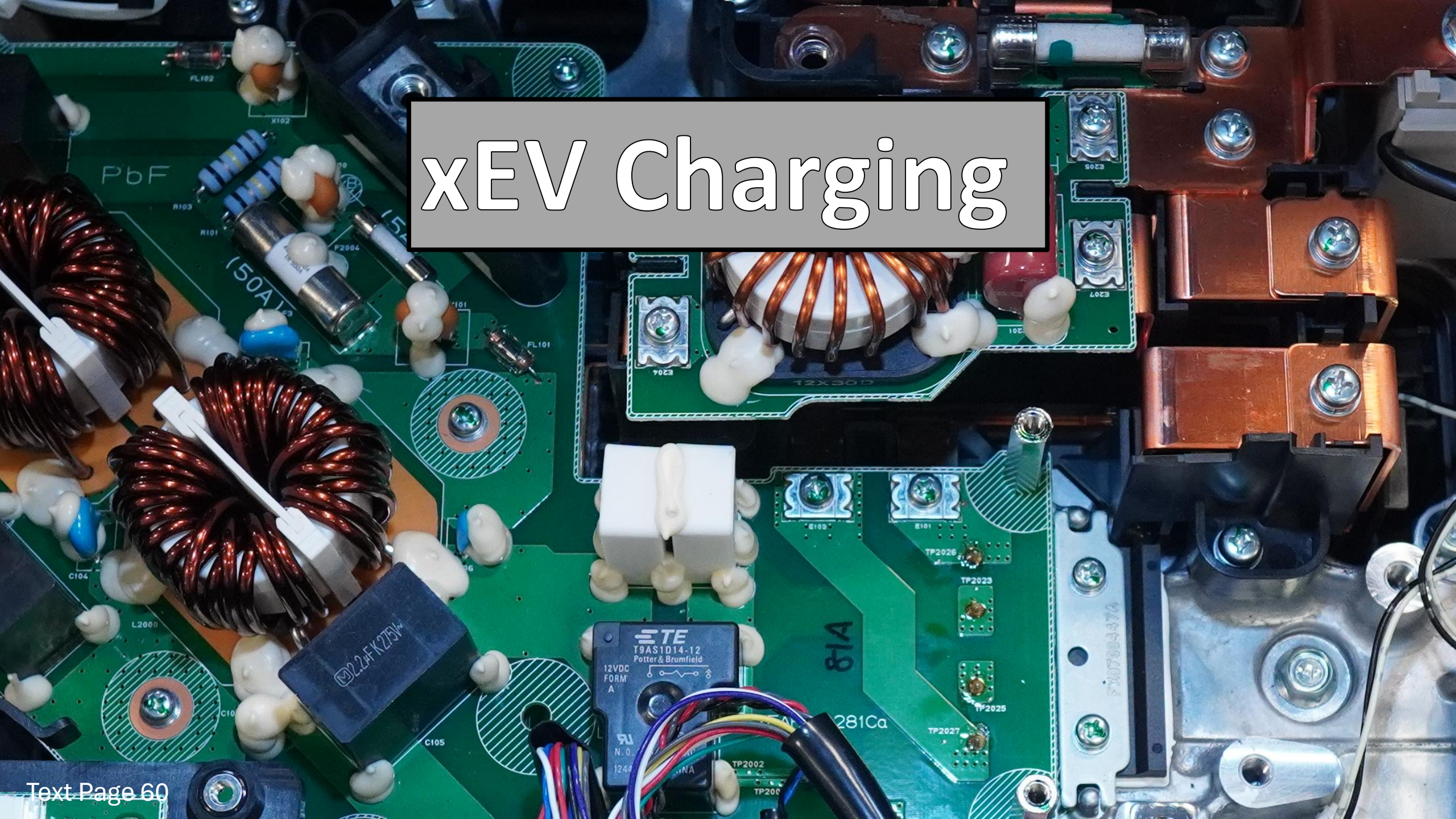
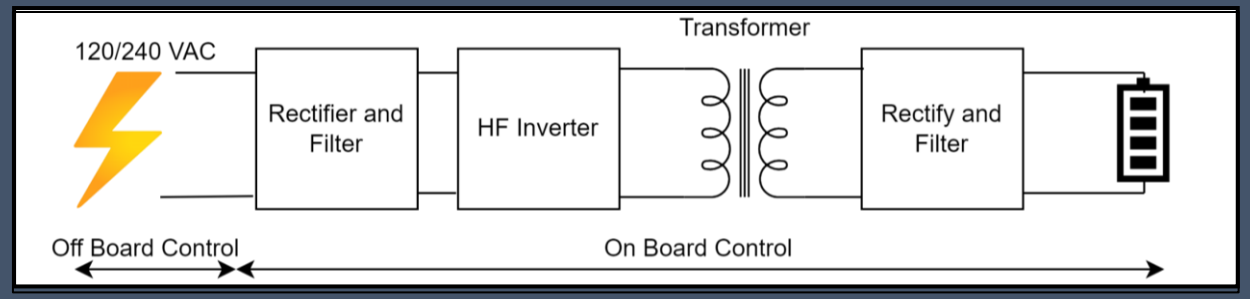
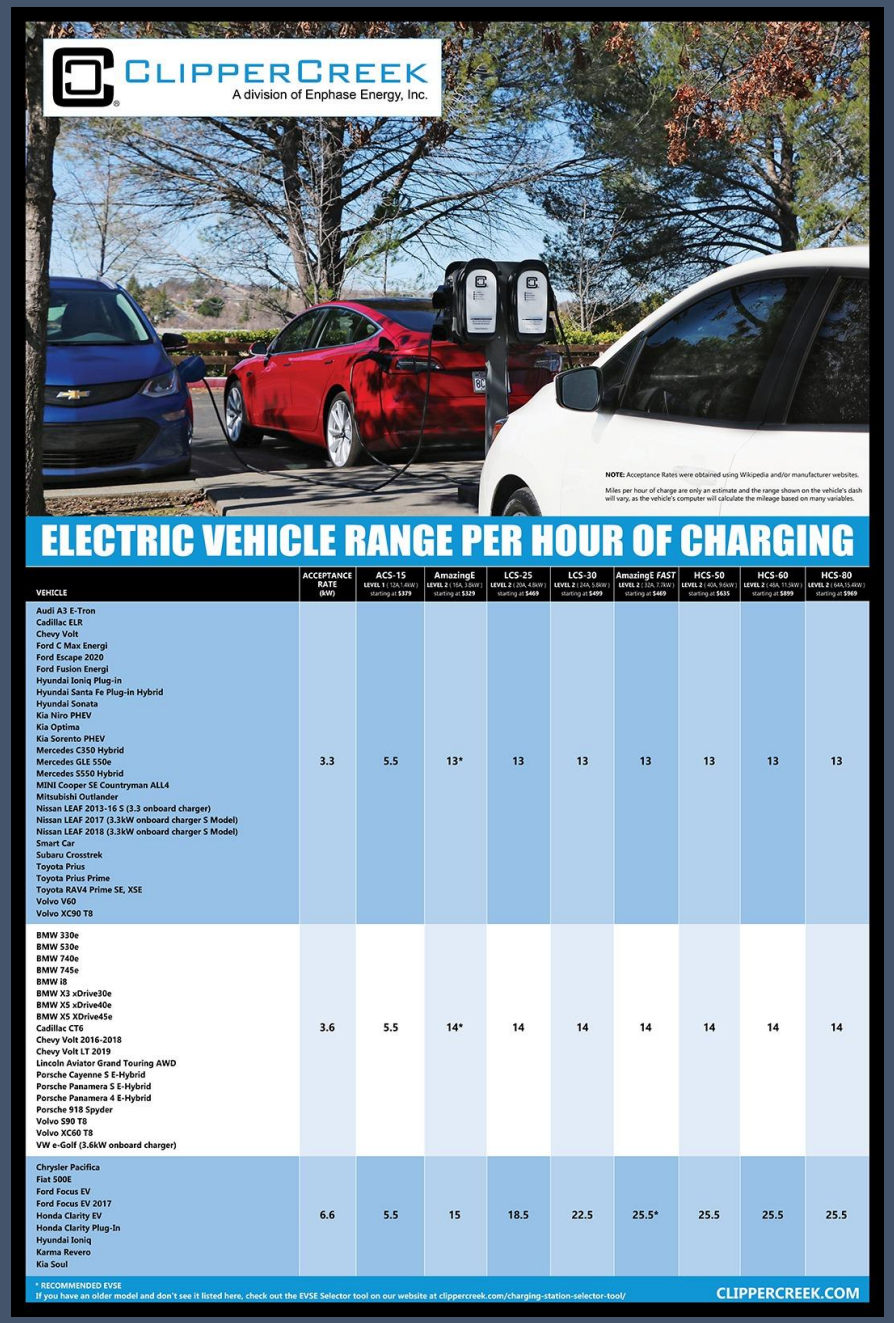

xEV Charging

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



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
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

Text Page 62

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

Text Page 62

Miles per hour of charging

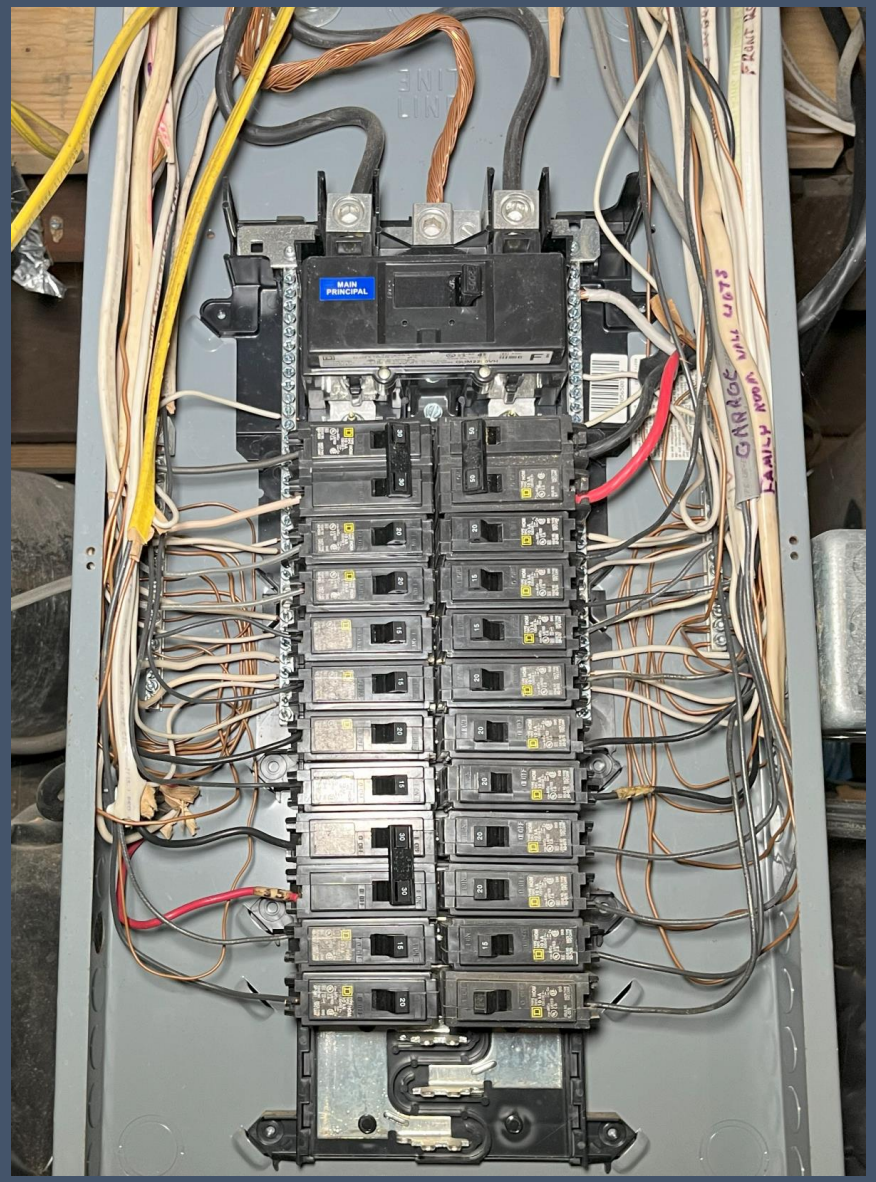
VEHICLE	ACCEPTANCE RATE (kW)	ACS-15 LEVEL 1 (12A,1.4kW) starting at $379	AmazingE LEVEL 2 (16A, 3.8kW) starting at $329	LCS-25 LEVEL 2 (20A, 4.8kW) starting at $469	LCS-30 LEVEL 2 (24A, 5.8kW) starting at $499	AmazingE *FAST* LEVEL 2 (32A, 7.7kW) starting at $469	HCS-50 LEVEL 2 (40A, 9.6kW) starting at $635	HCS-60 LEVEL 2 (48A, 11.5kW) starting at $899	HCS-80 LEVEL 2 (64A,15.4k 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

Text Page 62

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?



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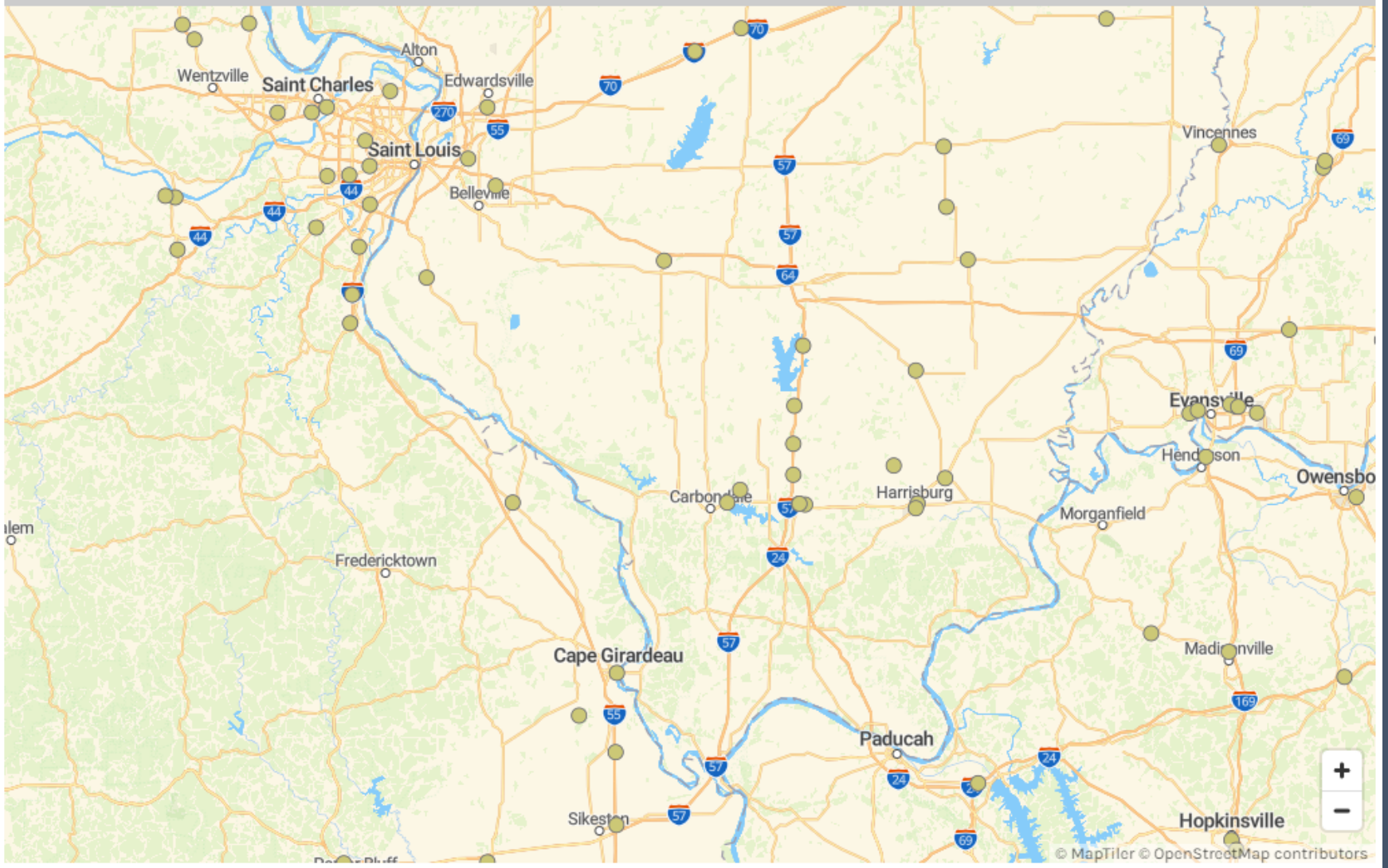
Electric Vehicle Charging Station Locations

Find electric vehicle charging stations in the United States and Canada. For Canadian stations in French, see Natural Resources Canada.

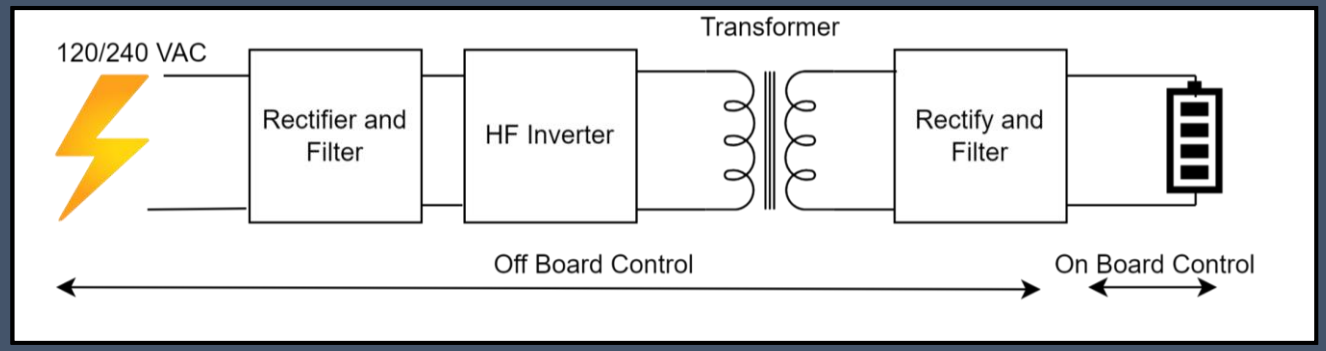
Public Stations | Advanced Filters | Fuel Corridors | 4,176 results in U.S. and Canada

Enter location | Ethanol (E85) | Map a Route

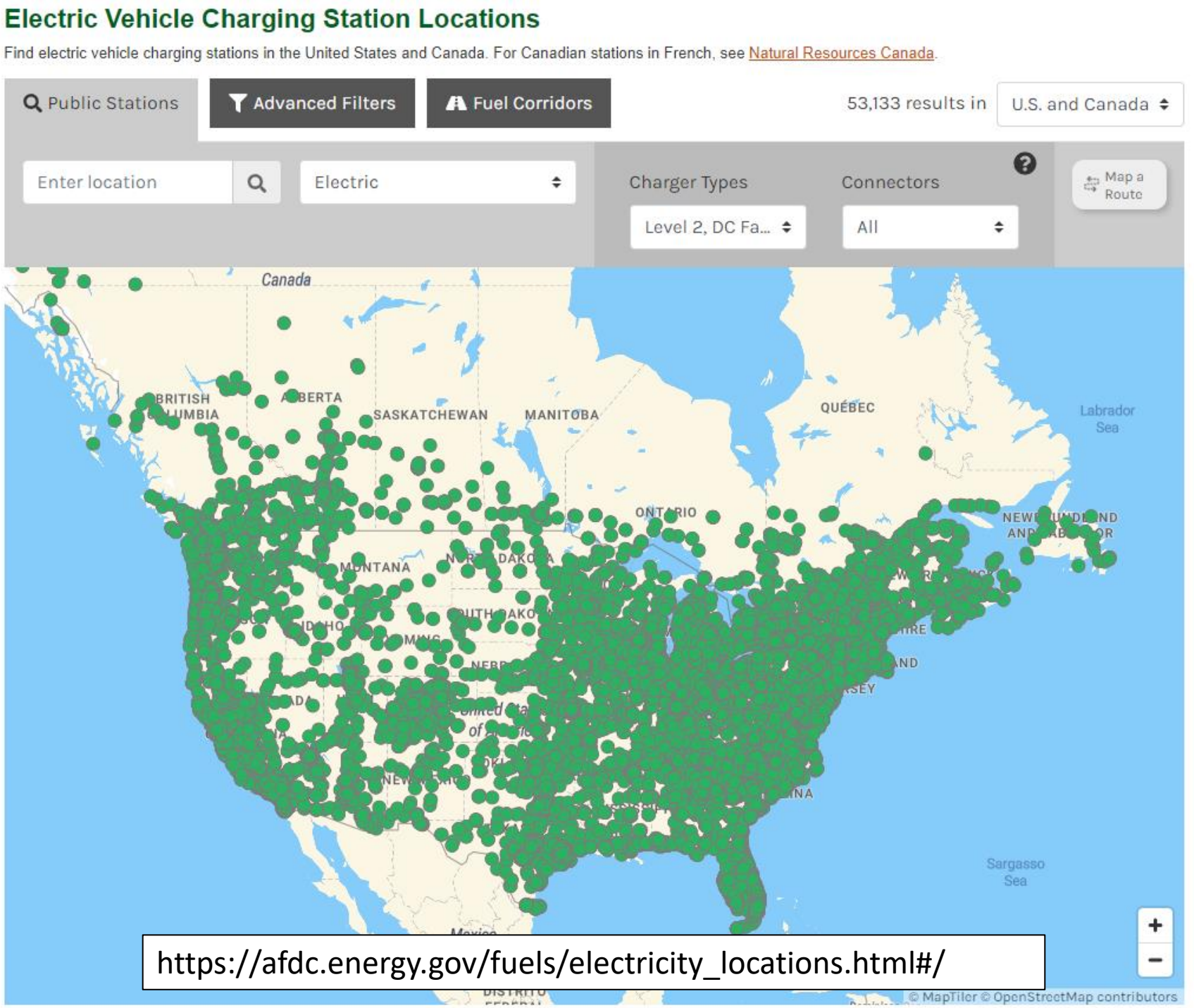


Charging Configurations

- 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



Text Page 63


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
Electric
Charger Types
Level 2, DC Fa...
Connectors
All
Map a Route
Canada
BRITISH
ALBERTA
SASKATCHEWAN
MANITOBA
QUÉBEC
Labrador Sea
ONTARIO
MONTANA
Sargasso Sea
https://afdc.energy.gov/fuels/electricity_locations.html#/
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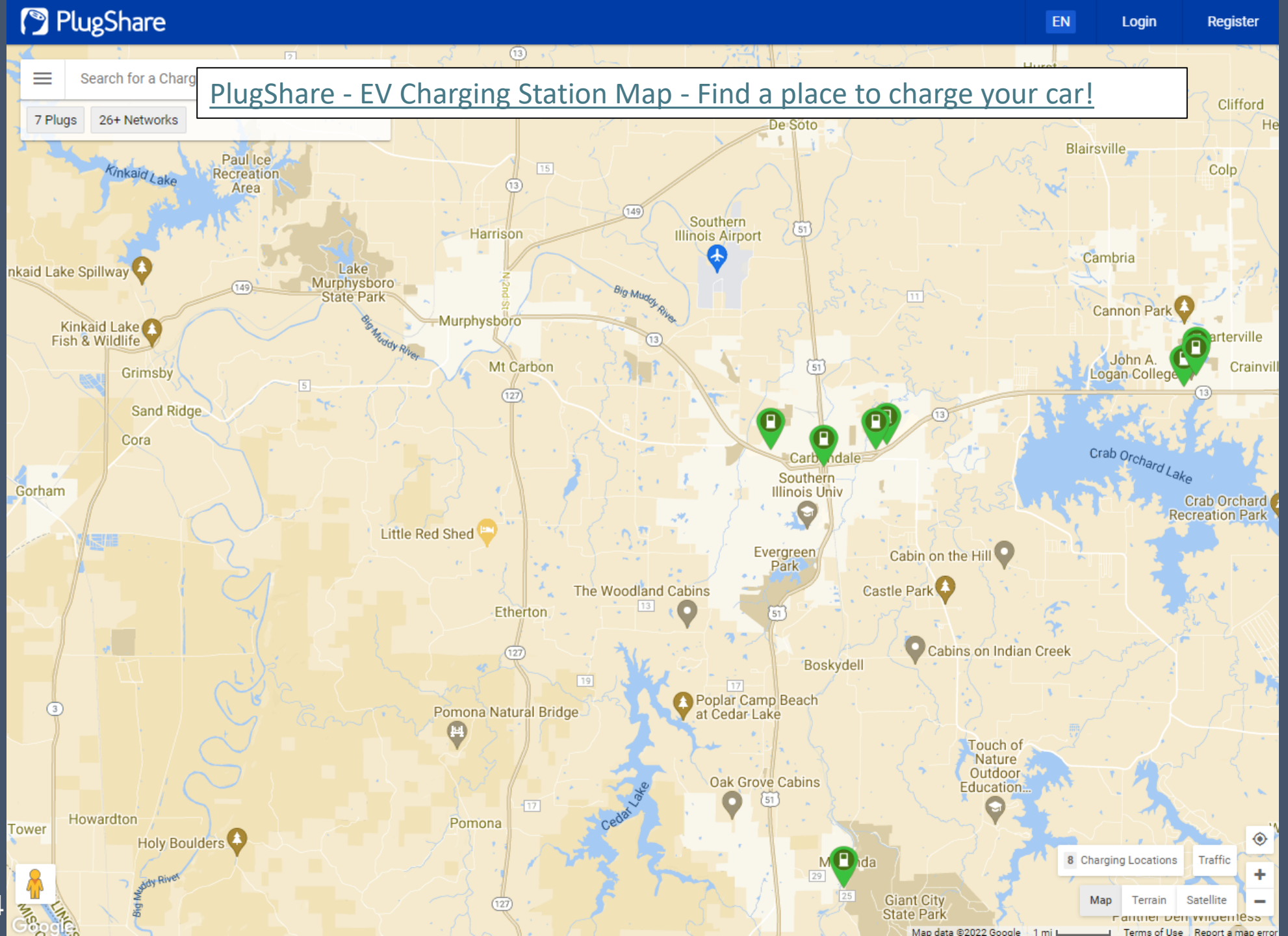

PlugShare
EN
Login
Register
Search for a Charg
7 Plugs
26+ Networks
PlugShare - EV Charging Station Map - Find a place to charge your car!
Kinkaid Lake
Paul Ice Recreation Area
Harrison
Southern Illinois Airport
De Soto
Blairsville
Colp
Clifford
Cambria
Lake Murphysboro State Park
Big Muddy River
Murphysboro
Kinkaid Lake Spillway
Kinkaid Lake Fish & Wildlife
Grimsby
Sand Ridge
Cora
Mt Carbon
Cannon Park
John A. Logan College
Crab Orchard Lake
Crab Orchard Recreation Park
Gorham
Little Red Shed
Southern Illinois Univ
Evergreen Park
Cabin on the Hill
Castle Park
The Woodland Cabins
Etherton
Cabins on Indian Creek
Boskydell
Poplar Camp Beach at Cedar Lake
Pomona Natural Bridge
Touch of Nature Outdoor Education...
Oak Grove Cabins
Cedar Lake
Howardton
Tower
Holy Boulders
Pomona
Giant City State Park
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)

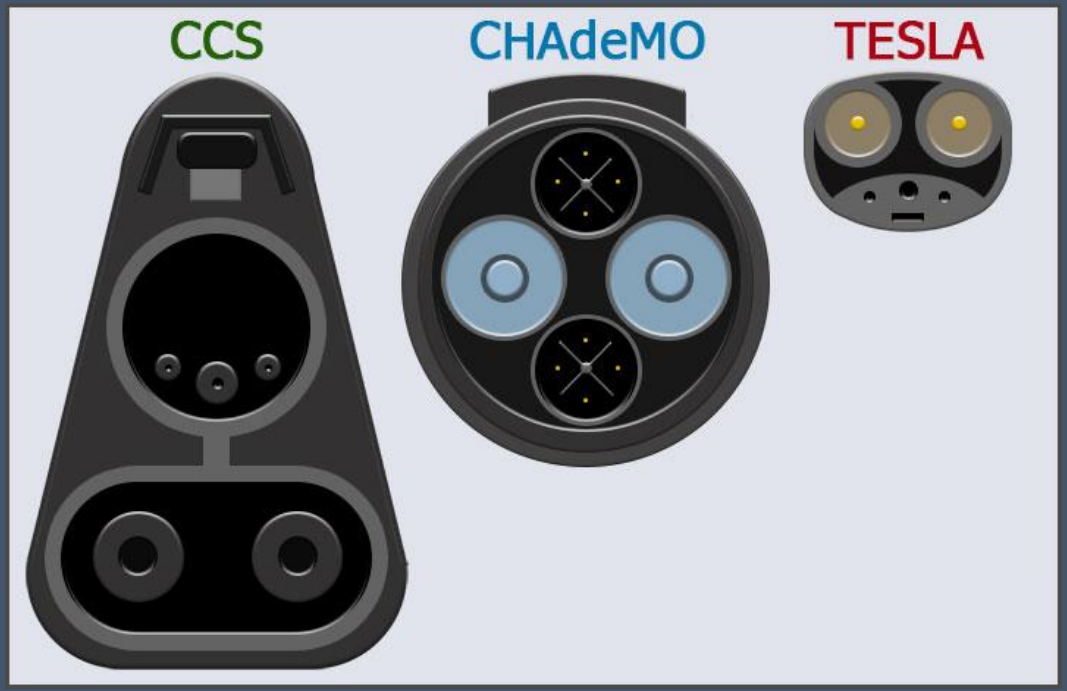
Combo Charging System (AC/DC)

CHAdeMO Connector (DC)

NACS

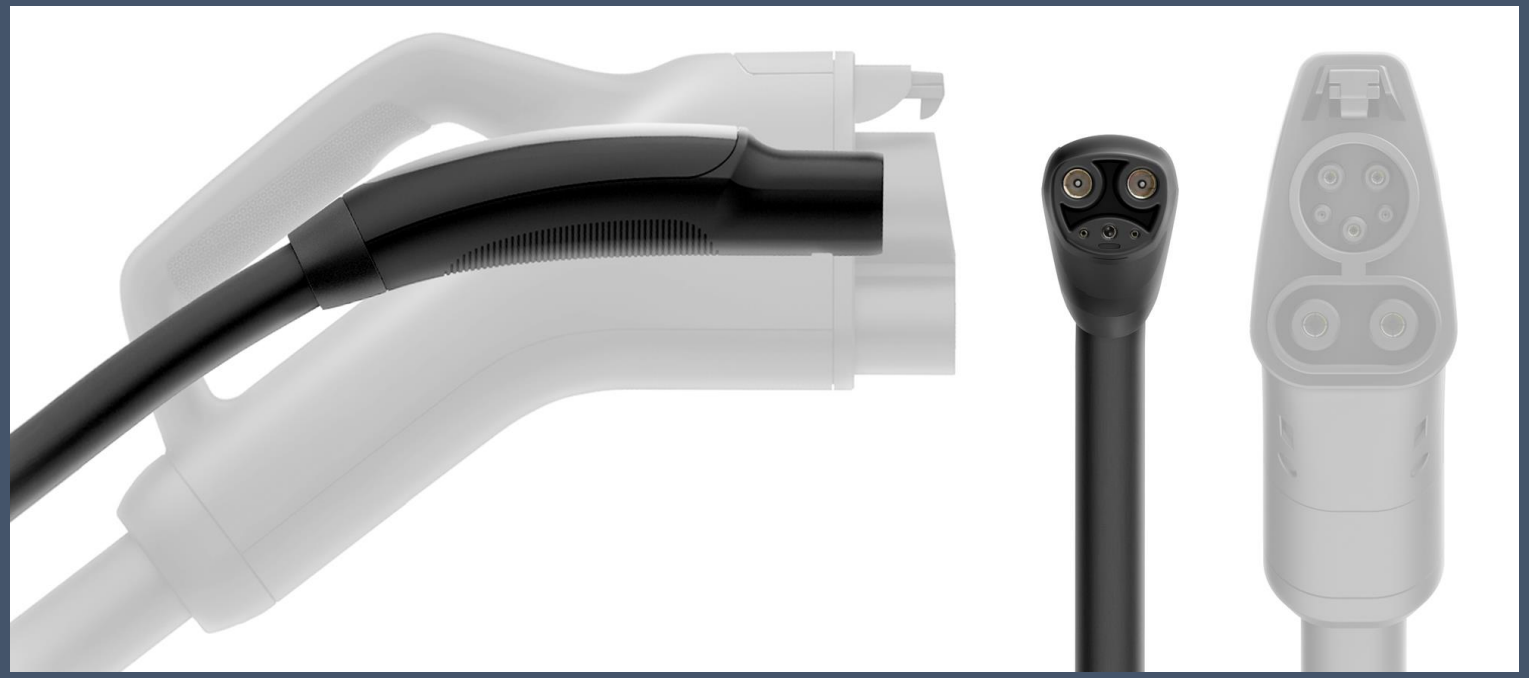
Plug Configurations

- Some plug sizes are out of control!



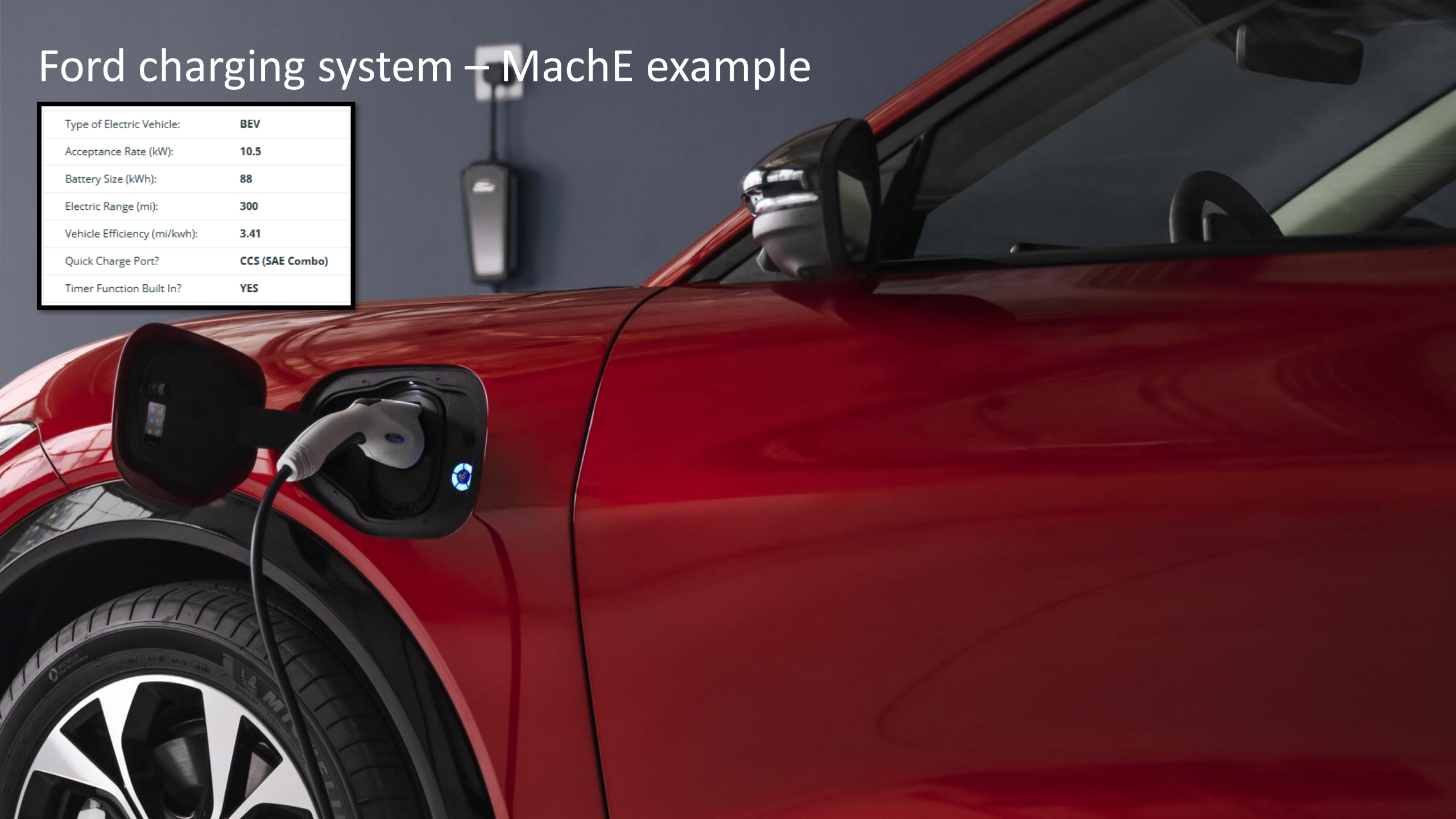
Plug Configurations

- NACS vs. CCS1



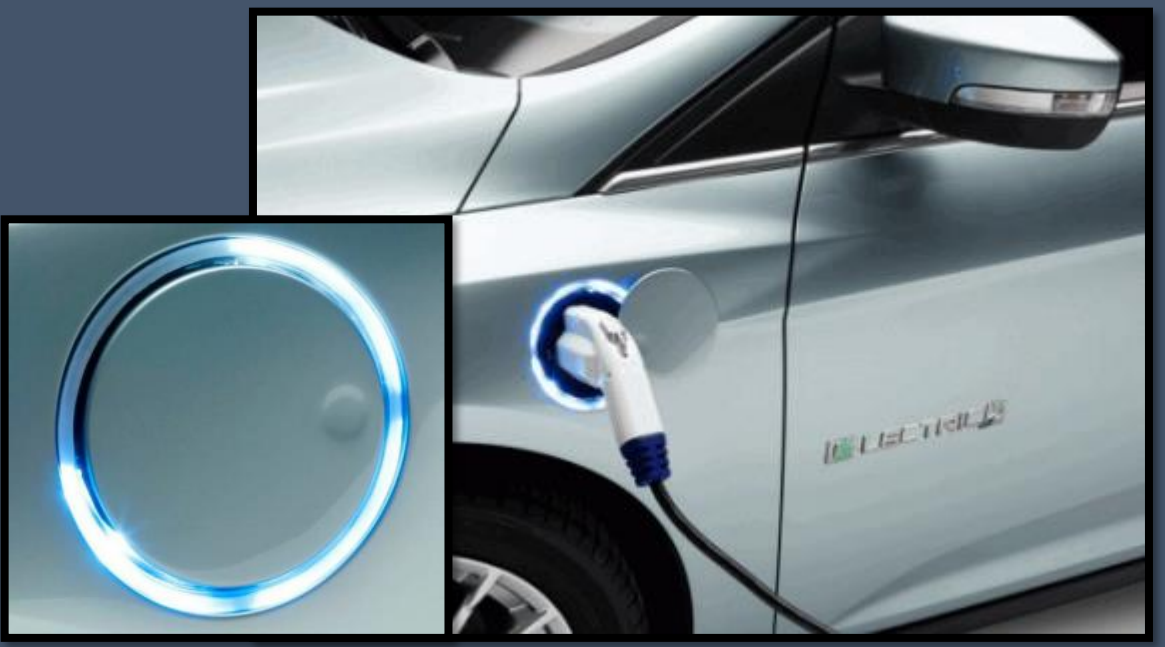
Ford charging system – MachE example

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**



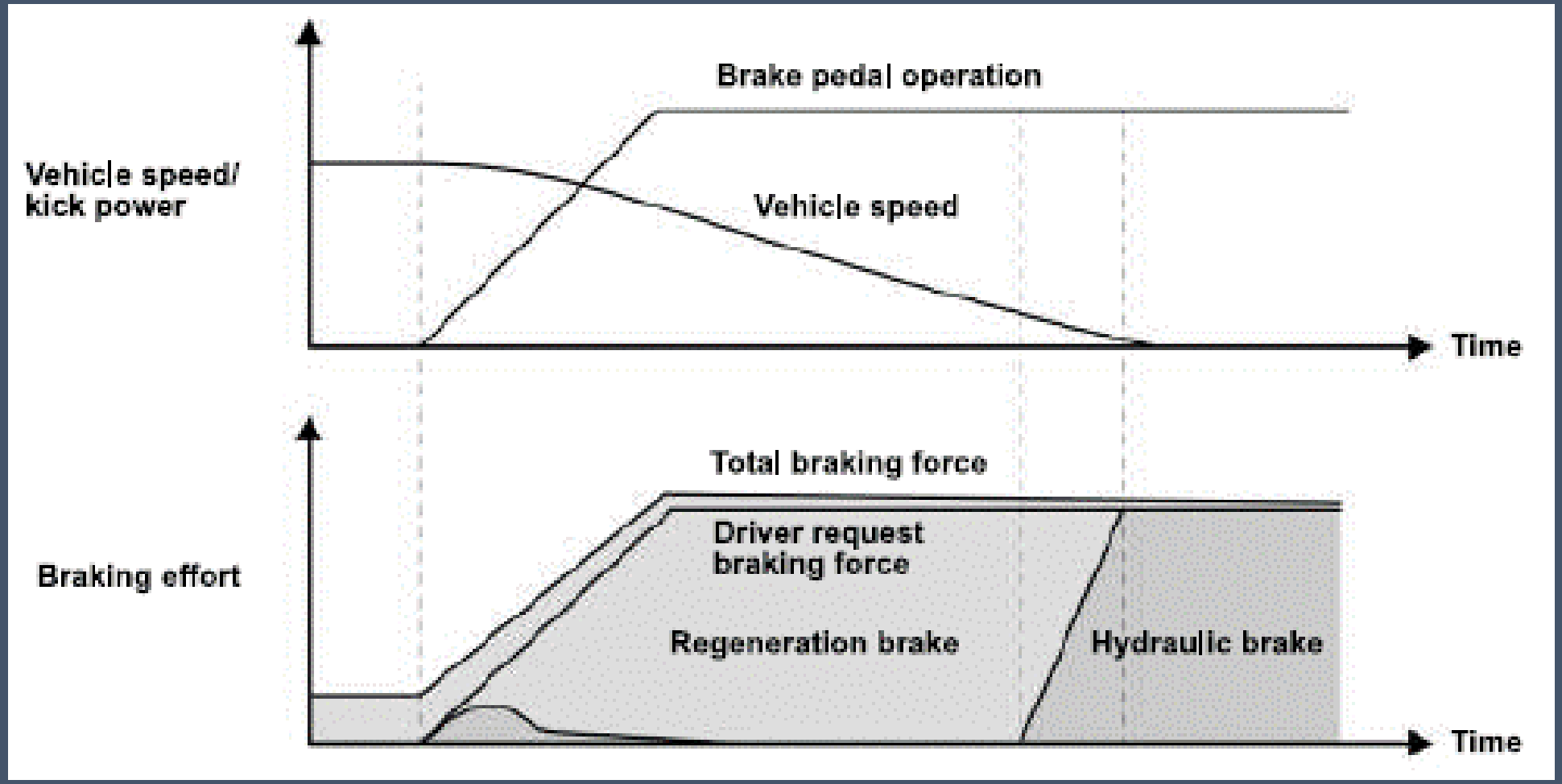
Ford charging system

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



xEV Brakes

Regen vs. Hydraulic vs. Blended



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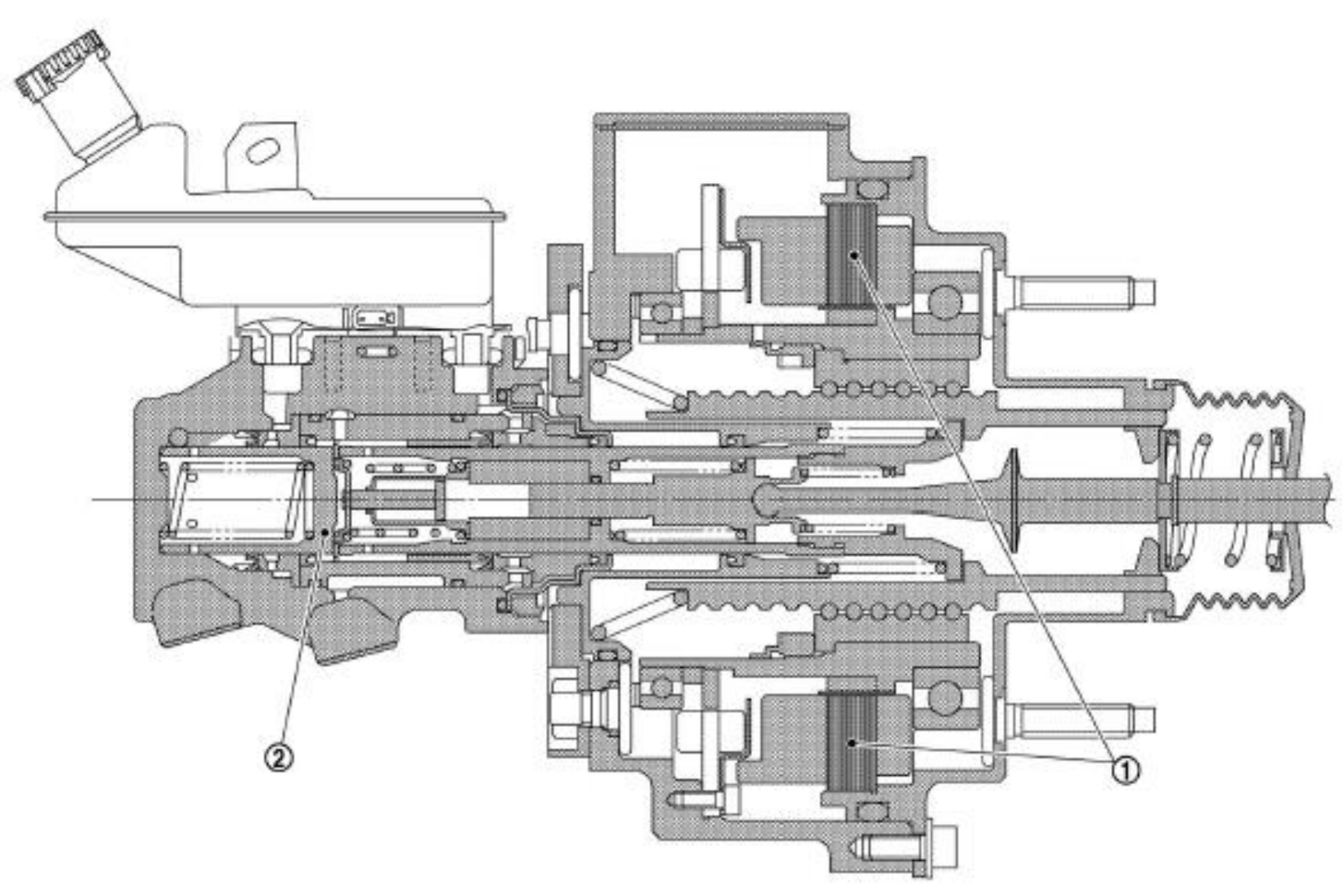
Variations of Electronic Braking

- 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



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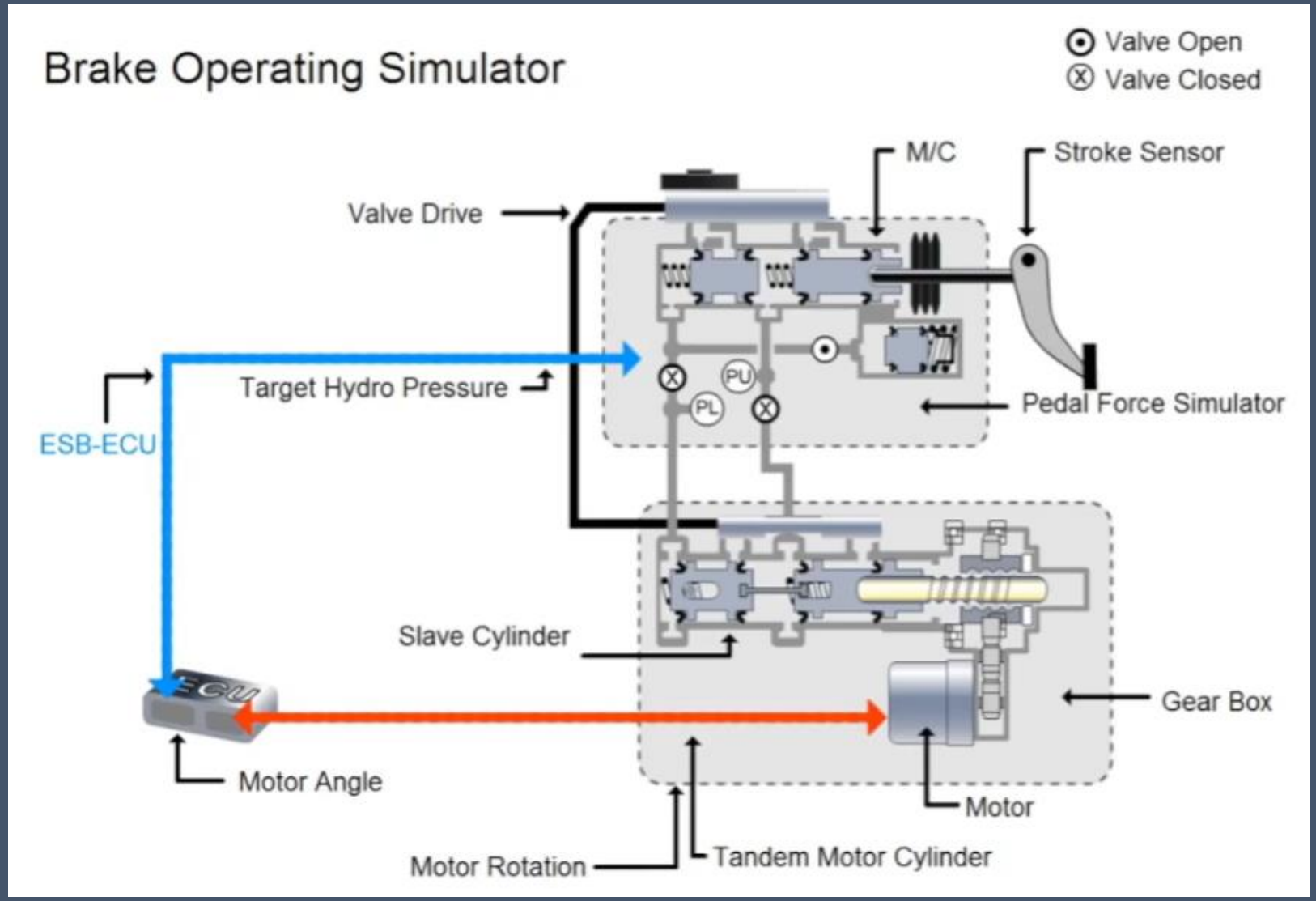
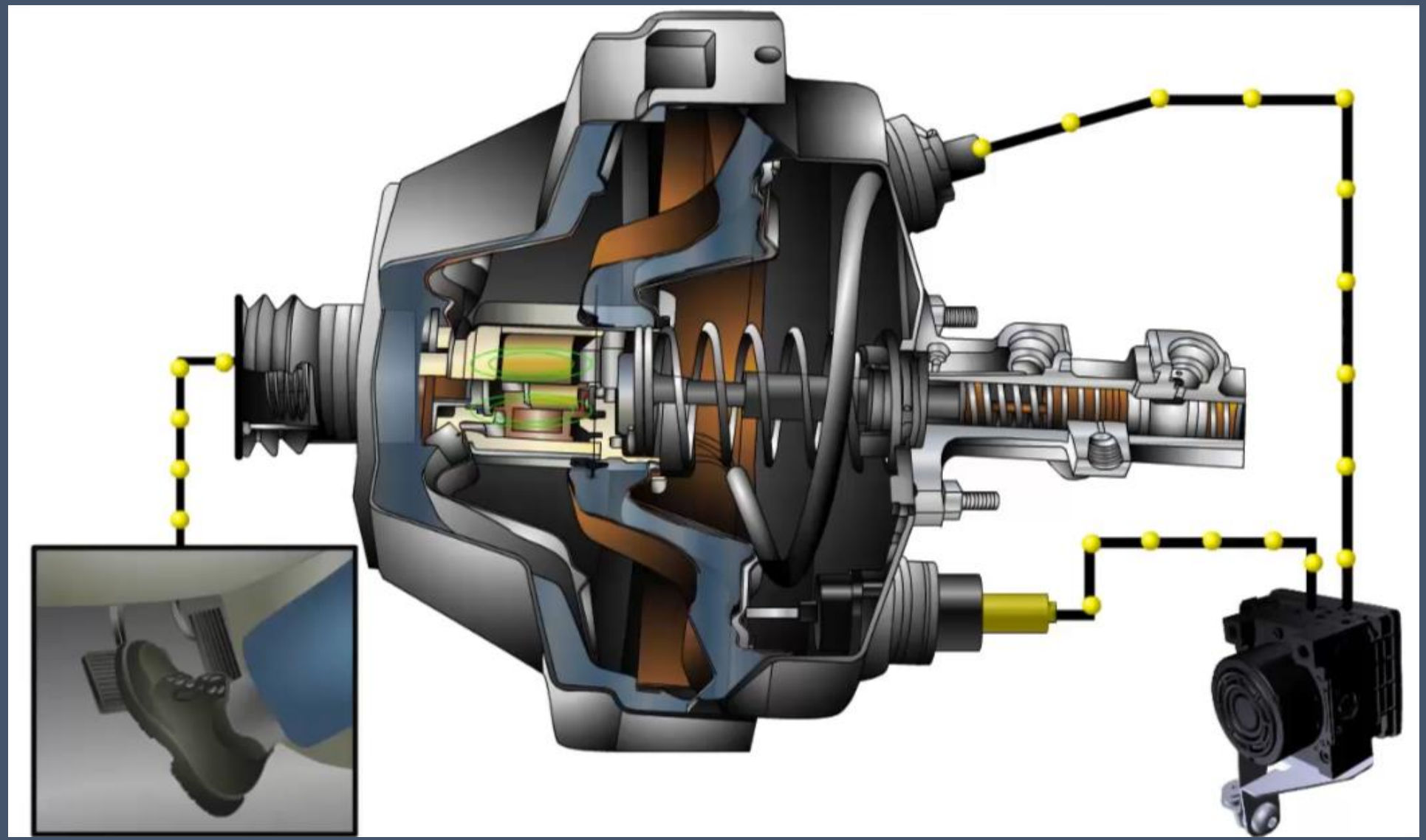
2023 Honda Accord Hybrid



Ford 2nd and 3rd Generation Electronic Braking



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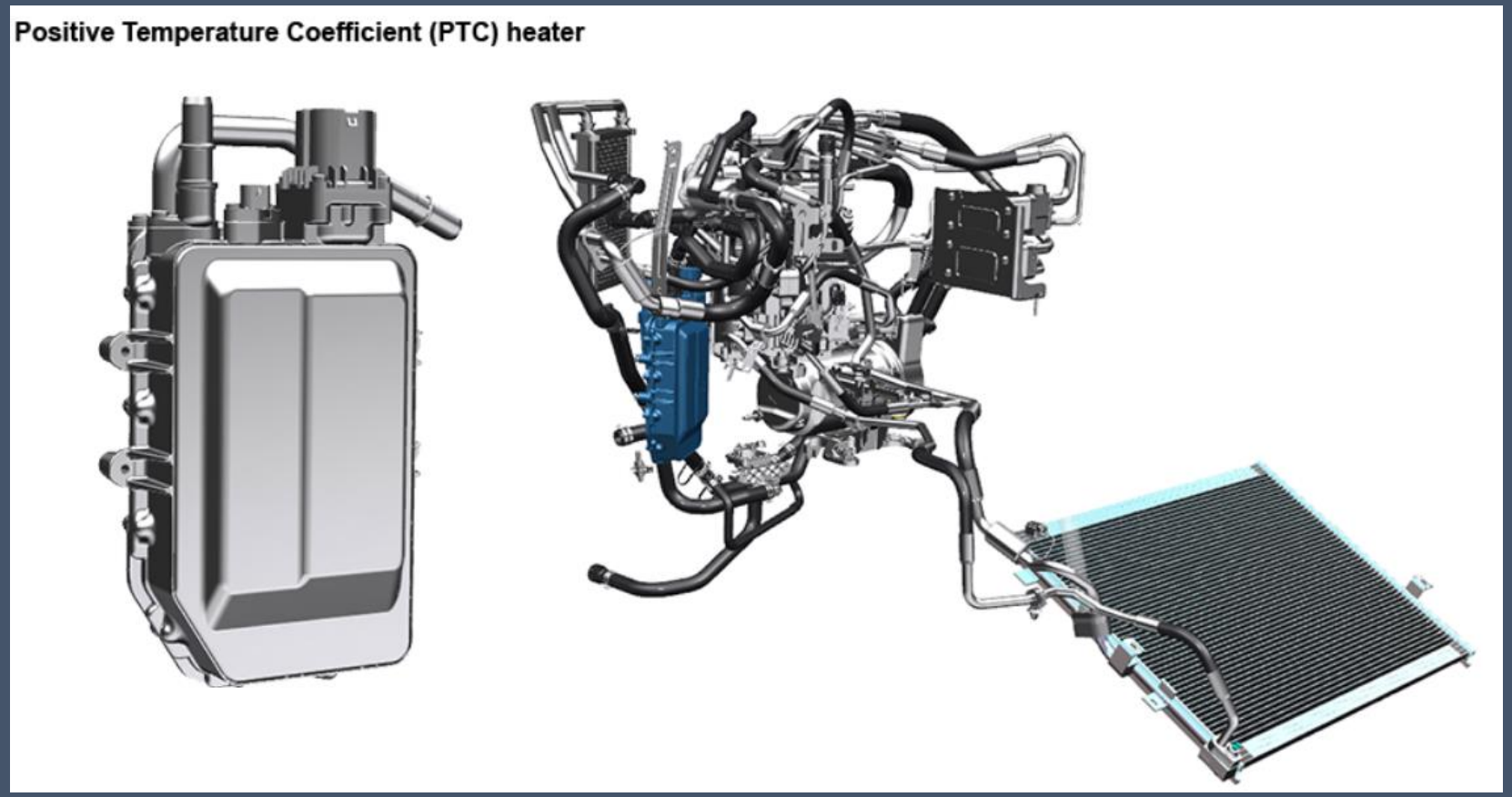
xEV HVAC

Electric Heating Elements



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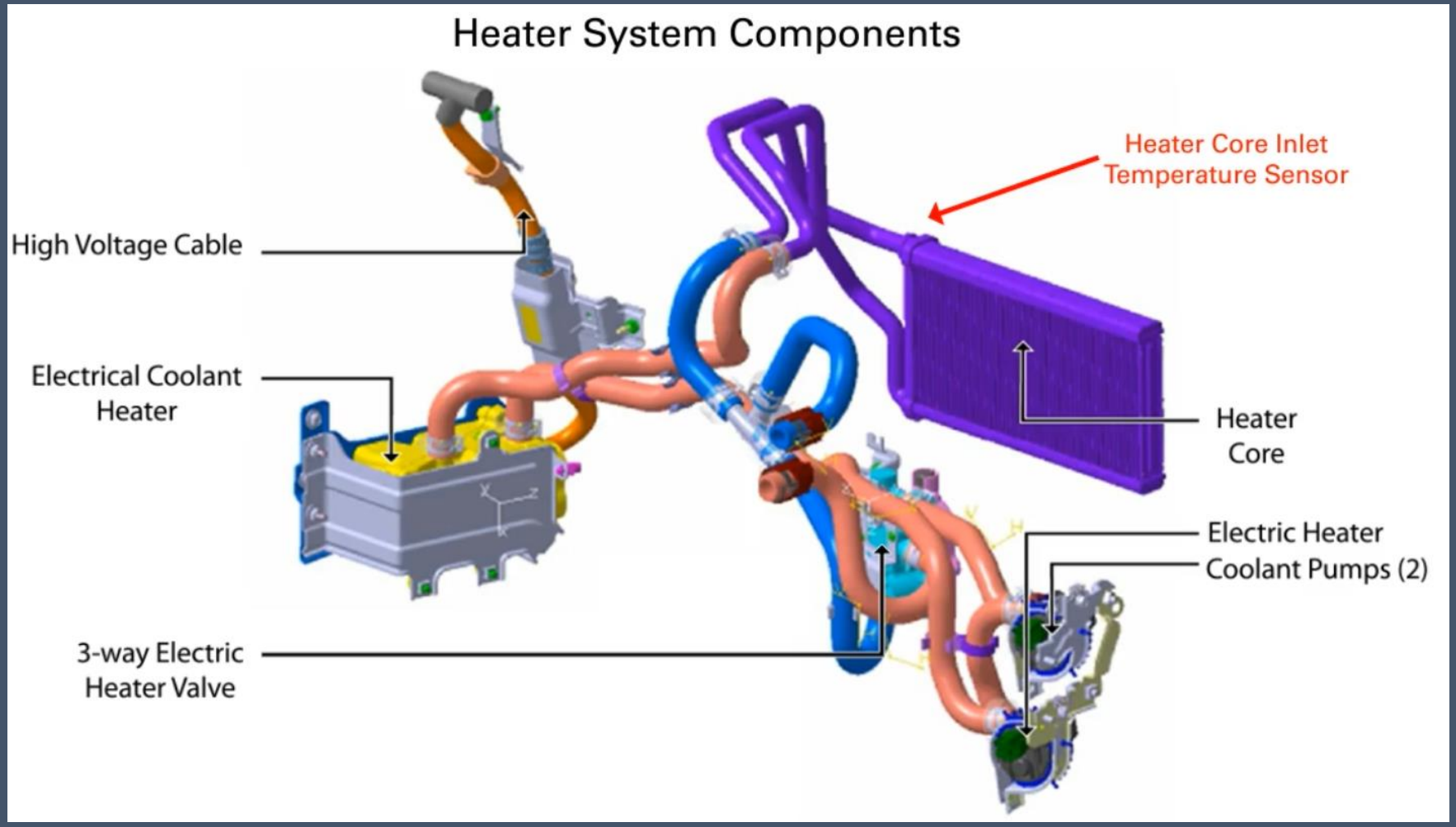
Electric Heating Elements



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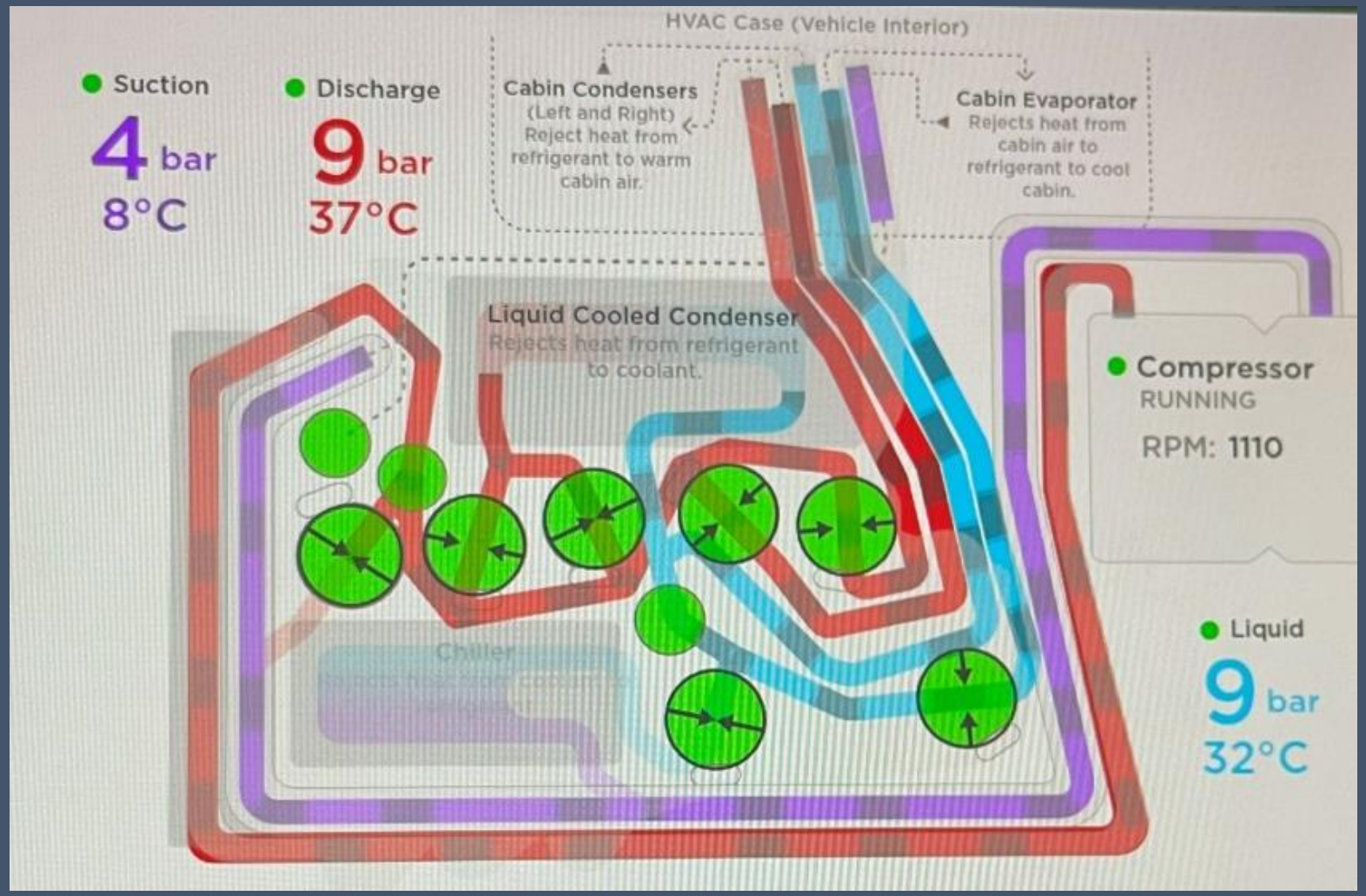
Heat Pump



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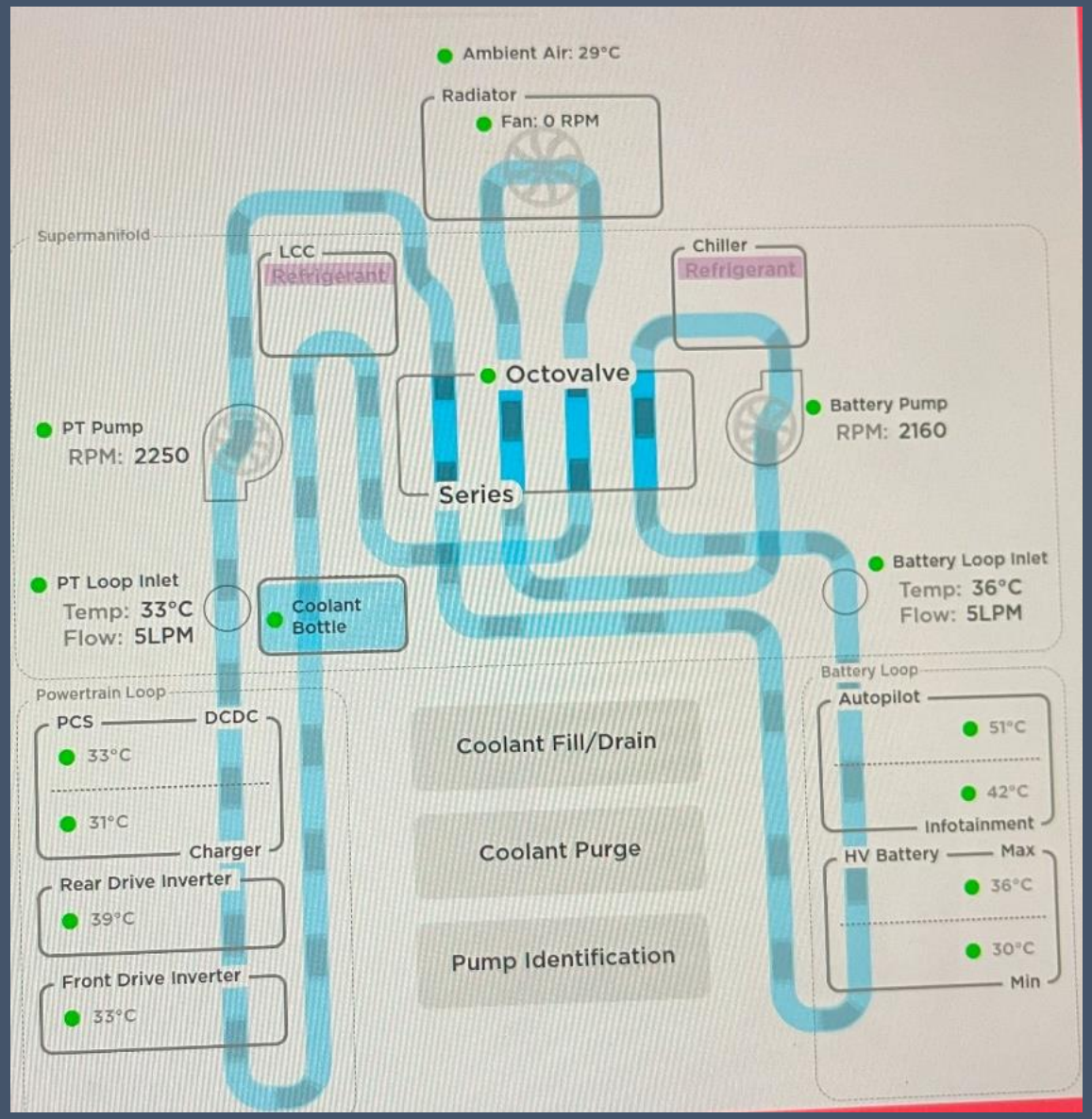
Heat Pump



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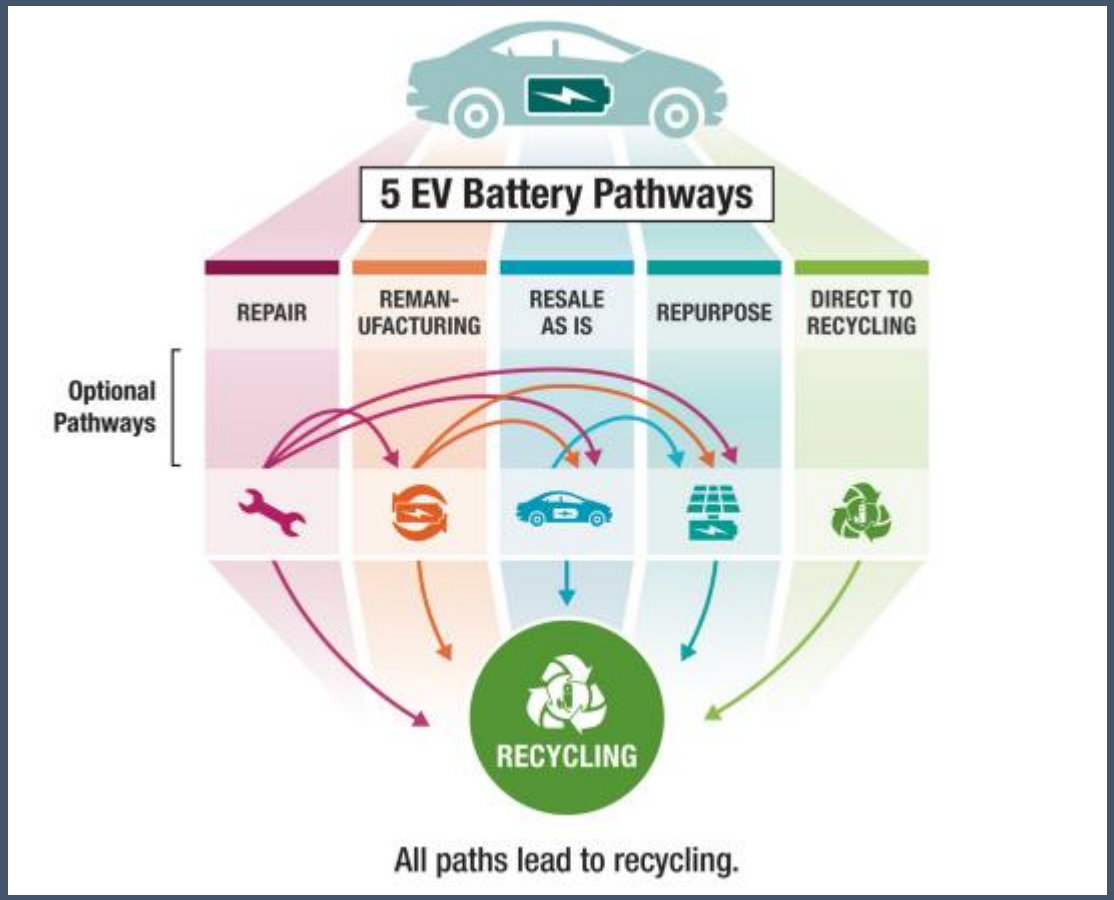
Environmental Impact

Text Page 79

Environmental Concerns: Recycling

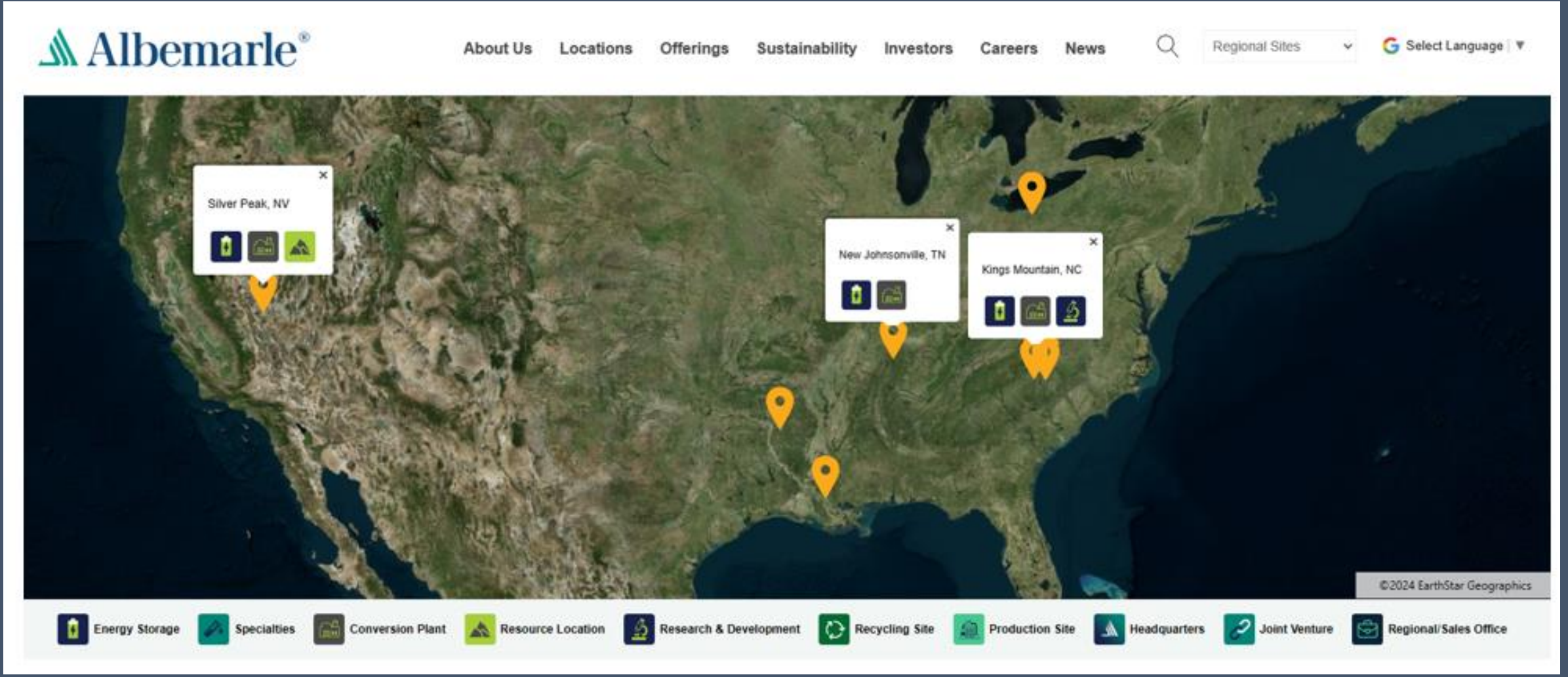
- https://www.lithiontechnologies.com
- https://www.cirbasolutions.com
- https://www.call2recycle.org
- https://www.globaltechenvironmental.com
- https://www.redwoodmaterials.com



Battery recycling – Can these batteries be recycled?

Text Page 80

Mining – Are we running out of minerals?



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Mining – Are we running out of minerals?

Text Page 81

Emissions – Are EVs really better?

The US generates:

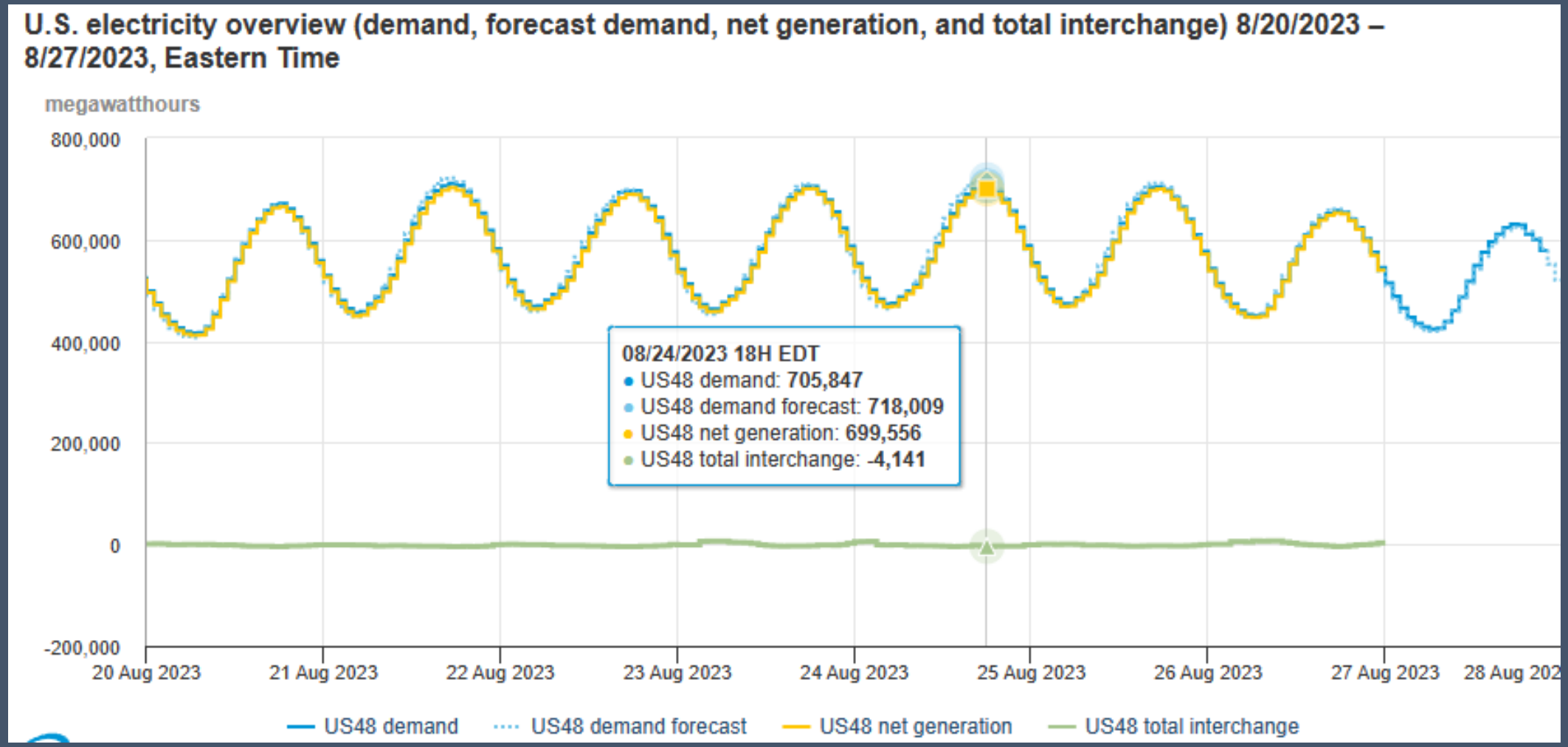
- 60% of its electricity from fossil fuels:
- 19% (828 TWh) from coal
- 39% (1,695 TWh) from gas
- 0.9% (40 TWh) from other fossil fuels
- Wind and solar 15% (644 TWh)
- Nuclear 18% (772 TWh)
- Hydro 5.9% (251 TWh)
- Bioenergy 1.2% (52 TWh)

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

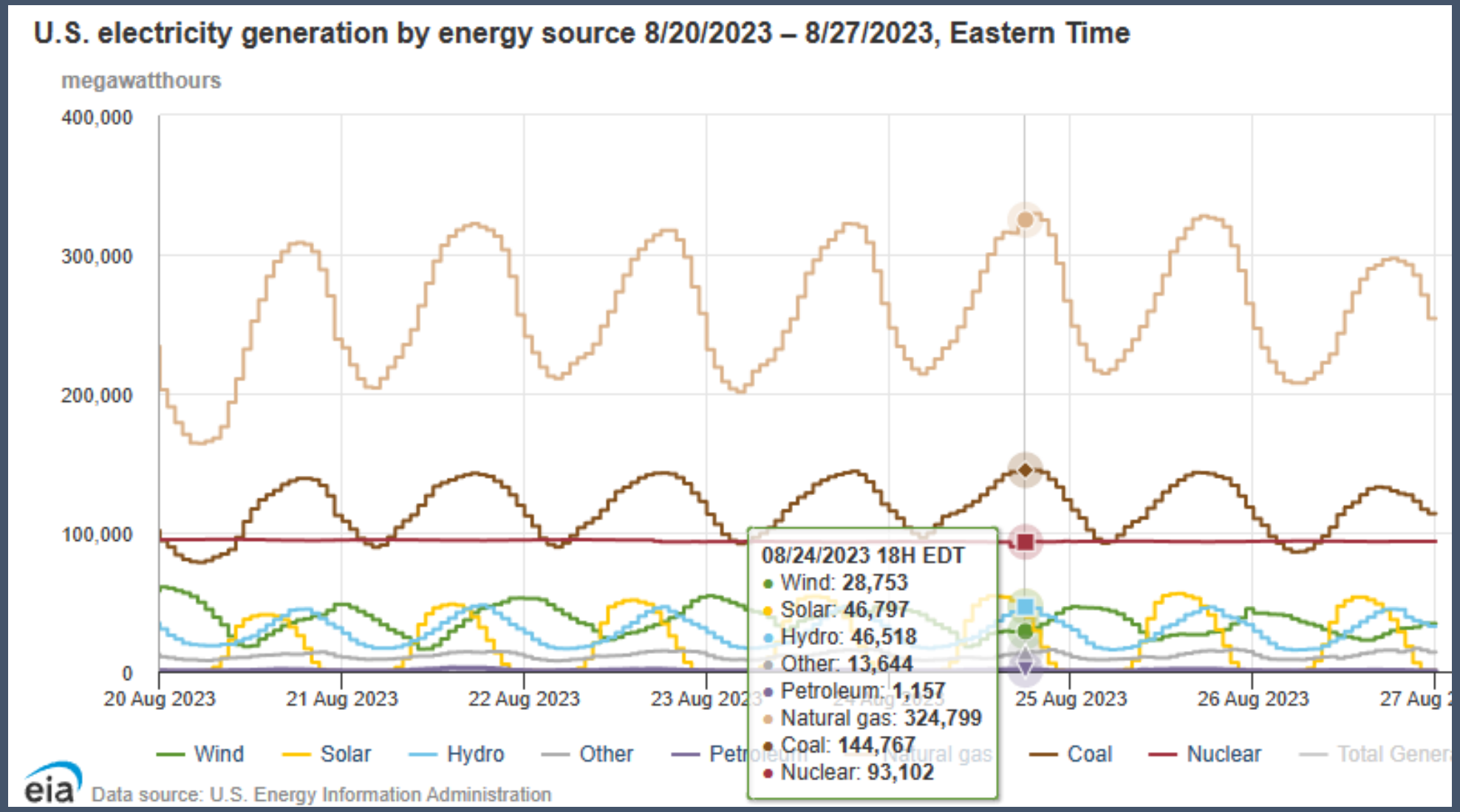
Vs

118 grams CO2/mile

Power Grid – can it handle it?



Power Grid



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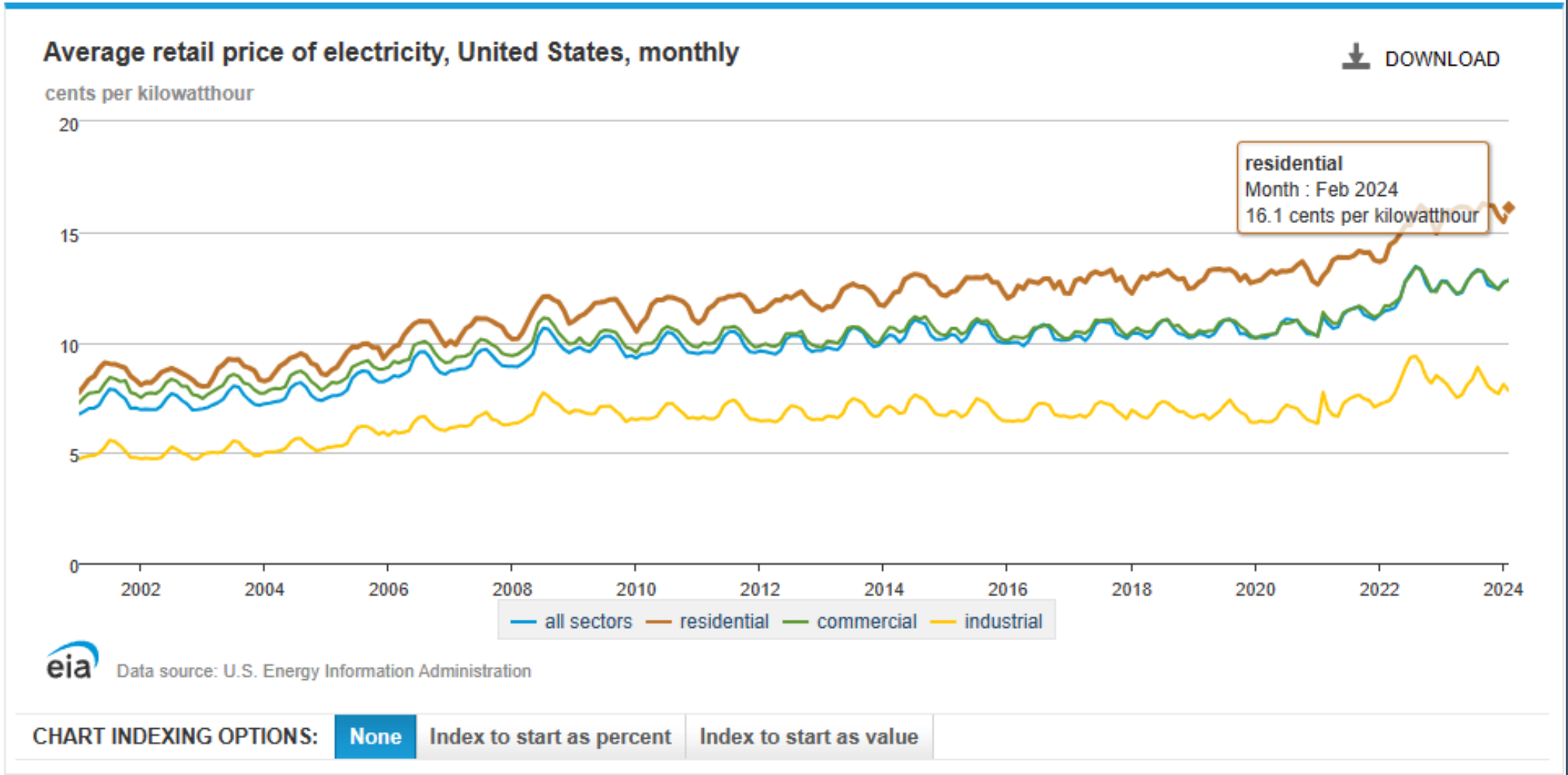
Power Grid



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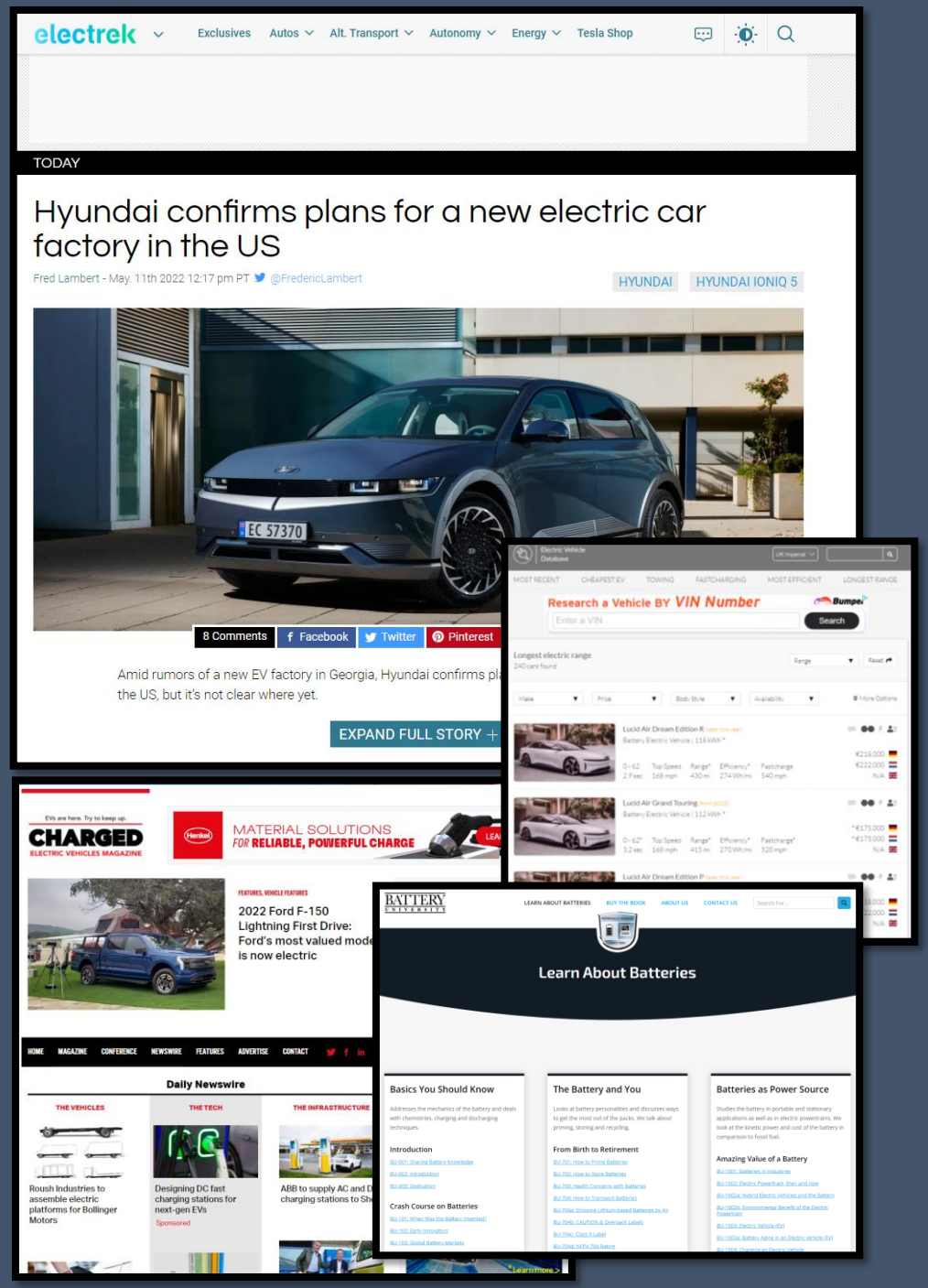

Great Resources

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