

GENERAL MOTORS 3RD GENERATION eAssist PROPULSION SYSTEM

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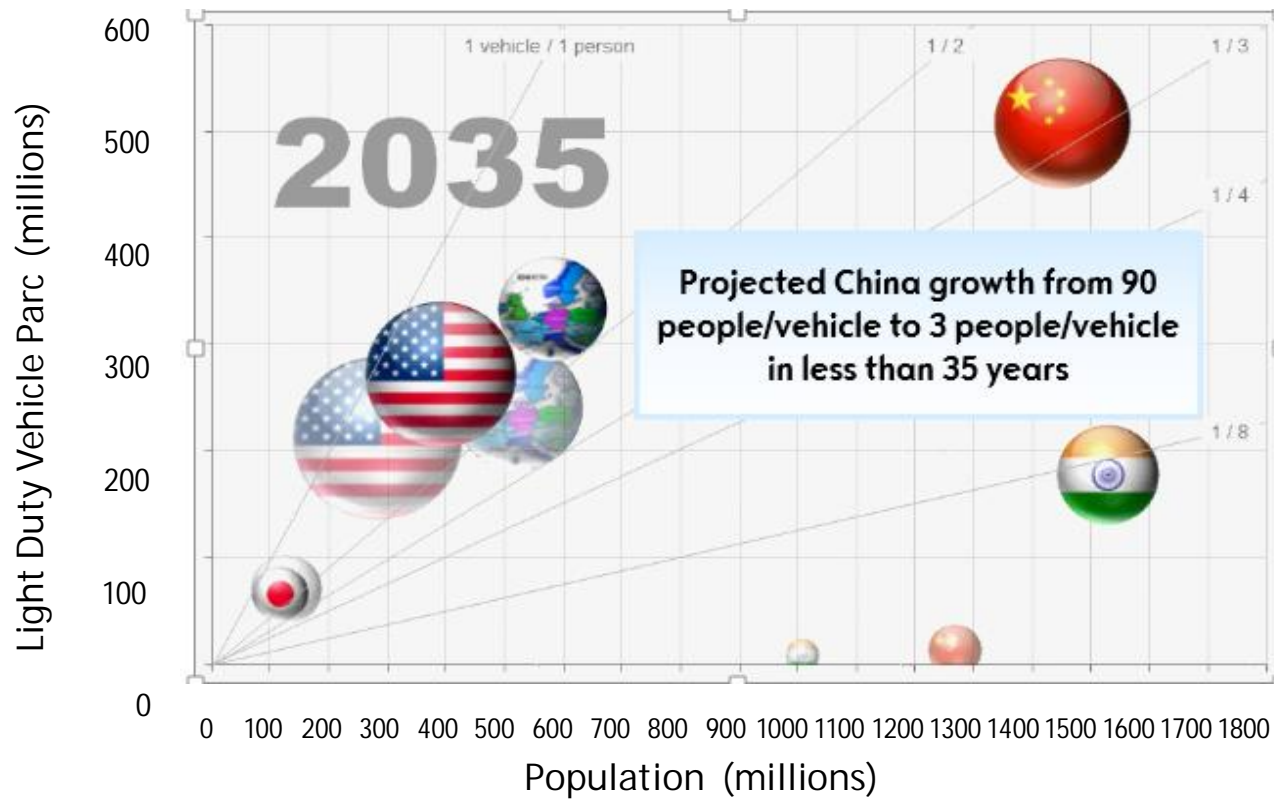
Chief Engineer eAssist Global Propulsion Systems

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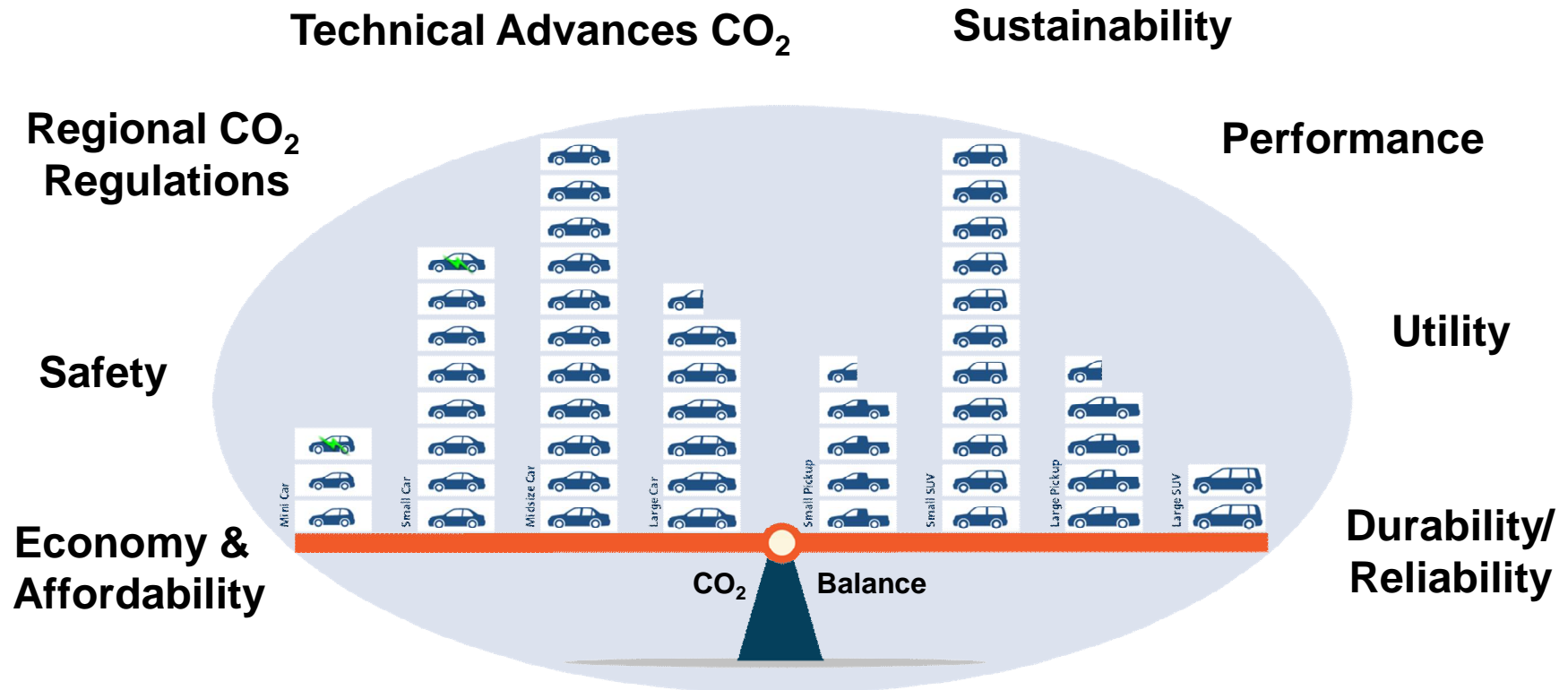
Global Market Personal Transportation



Light Duty Vehicle Parc vs Population for Selected Countries / Regions

Size of icon proportional to light duty parc fuel consumption

OEM Balance

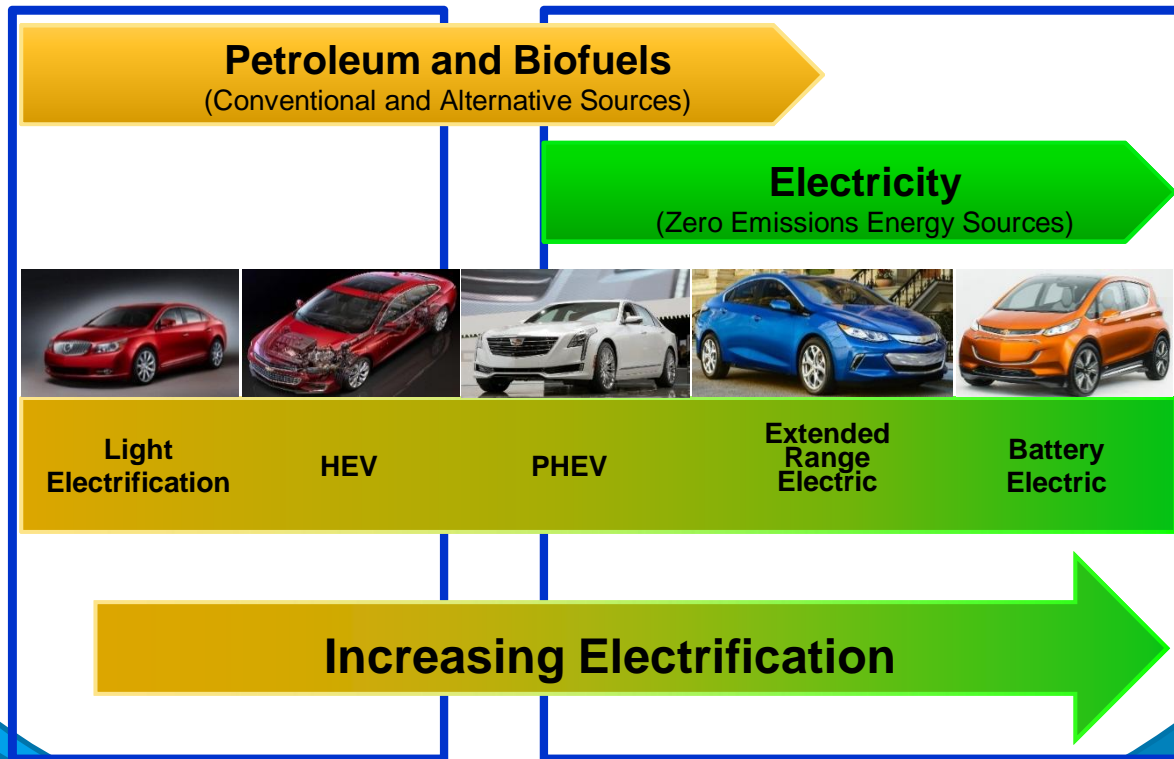


GM Electrification Solutions

Reducing Consumption & Displacing Petroleum



2018



2017

CONSERVATION

DISPLACEMENT

GM Light Electrification – Belt Alternator Starter Systems (BAS) – “P0”



2018 Buick LaCrosse



2016 Full Size Truck eAssist



2013 Malibu eAssist



2012 LaCrosse eAssist



2018 Cadillac XT5



2006 LaCrosse Micro Hybrid

2016 eAssist Applications

Silverado and Sierra Crew Cab

- 2016 Introduction (2wd)
- 5.3 L V8 engine / 8 spd transmission
- Seamless start-stop
- Fuel economy 18 / 24 / 20
+13% / +9% / +11%
- Load capacity / towing matches conventional
 - 11,000 lb towing with max trailering option



2018 LaCrosse eAssist – North America

Premium Sedan System

- 2.5 L 4-cylinder
- 6 speed automatic
- Fuel Economy 25 / 35 / 29
+32% +17% +26%
- Seamless start-stop
- 0-60 of 8.2 sec



2018 Cadillac XT5 eAssist - China

Premium Crossover SUV

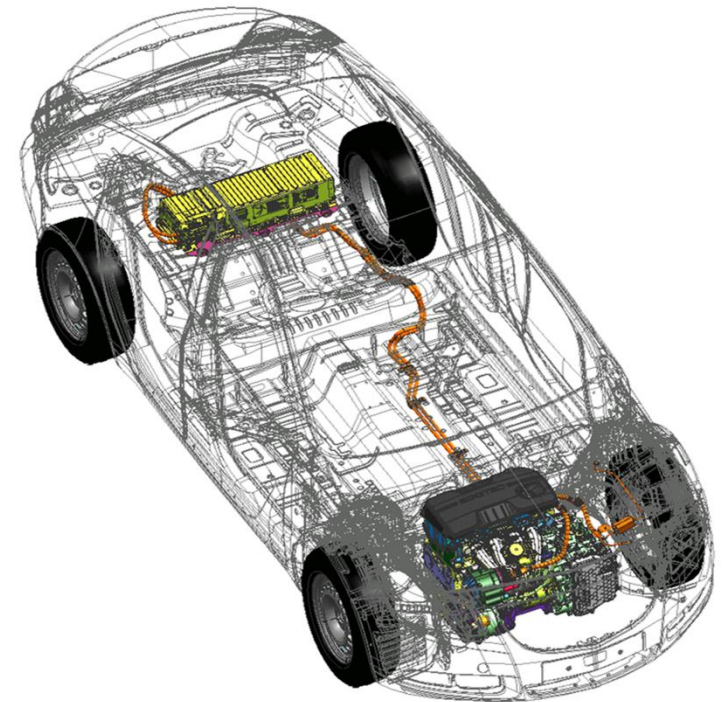
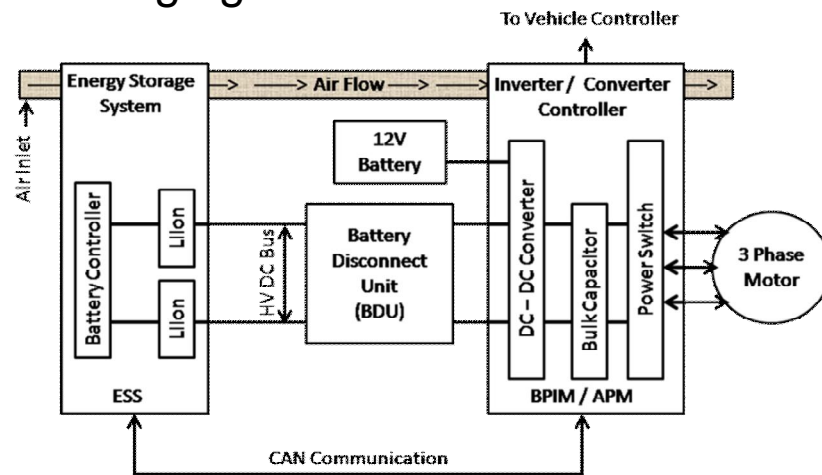
- 2.0 T engine
- 9 speed transmission
- FWD / AWD
- Seamless start-stop
- Fuel consumption (NEDC) 9% improvement
- 0-100 kph – 8.2 sec (AWD)



History: eAssist 2nd Gen Architecture

Successful 2012-2016 eAssist Propulsion

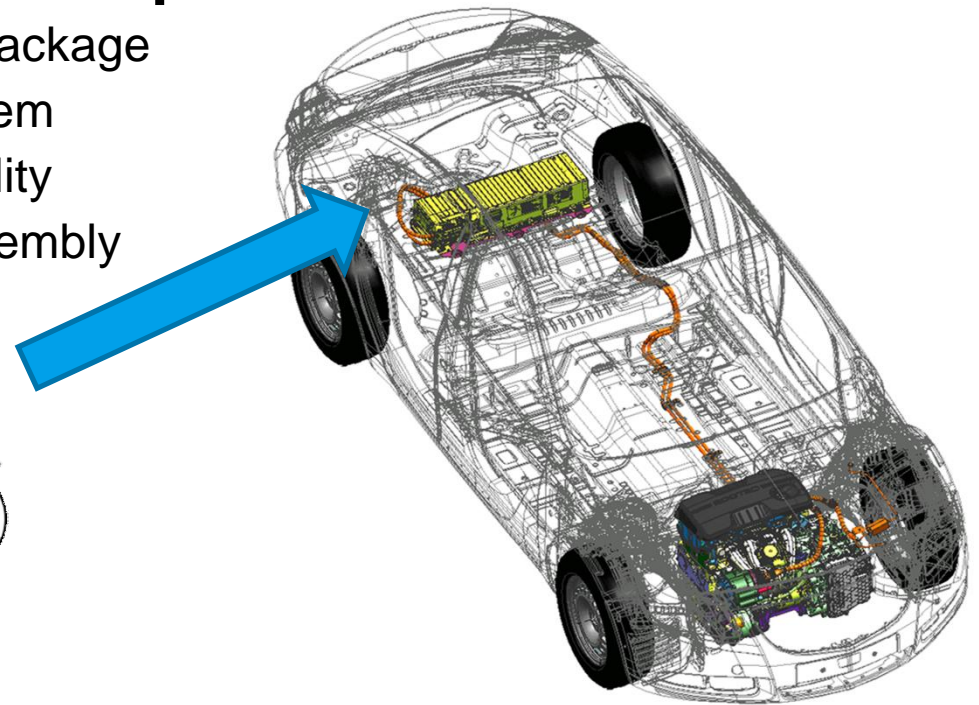
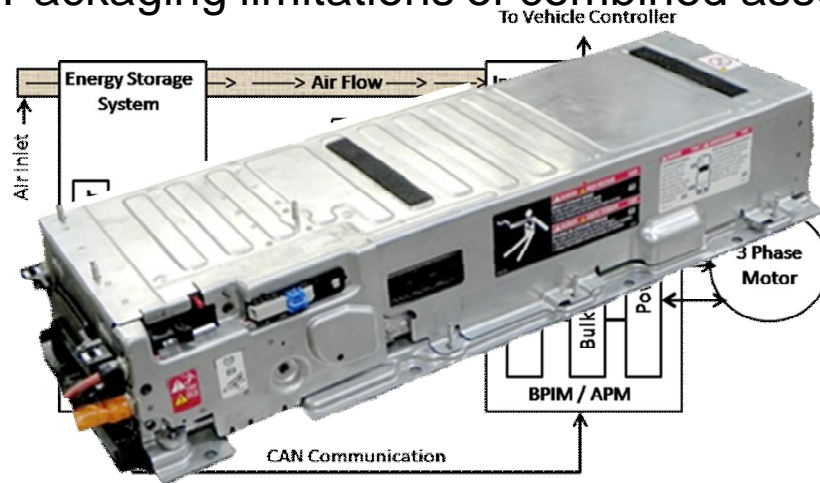
- ESS and Power Electronics in single package
- Technical advantages of compact system
- Excellent field performance and reliability
- Packaging limitations of combined assembly



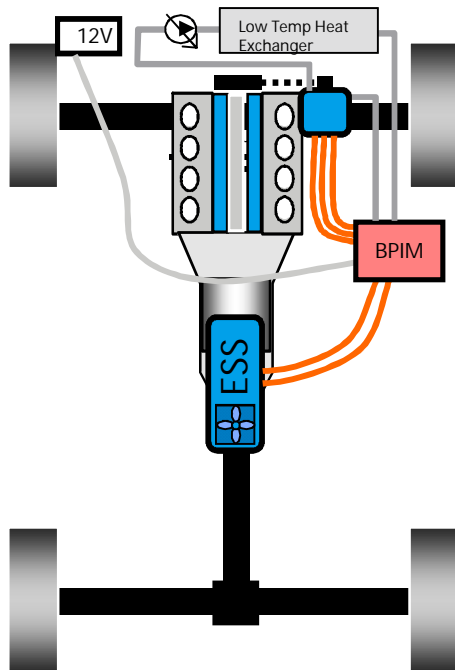
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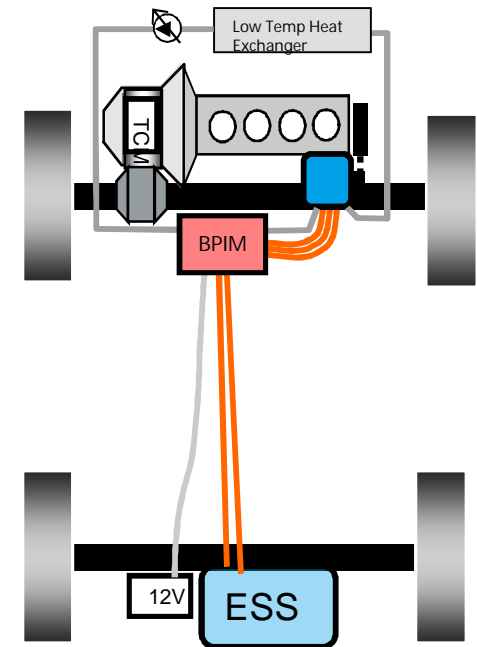


eAssist 3rd Gen Architecture



3rd Gen – Distributed Architecture

- Increased packaging flexibility
- Shorter 3-phase AC cables improve efficiency
- Liquid cooled BPIM shares existing MG cooling loop



eAssist3 Packaging – Silverado / Sierra

Seamless customer experience

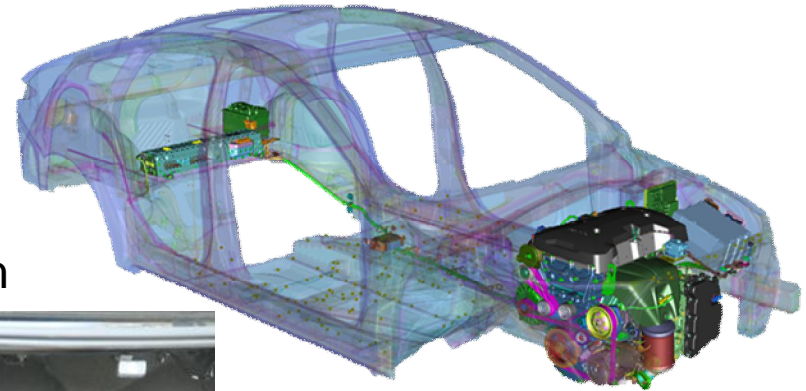
- Battery pack under center front seat or console / MGU-BPIM Under hood



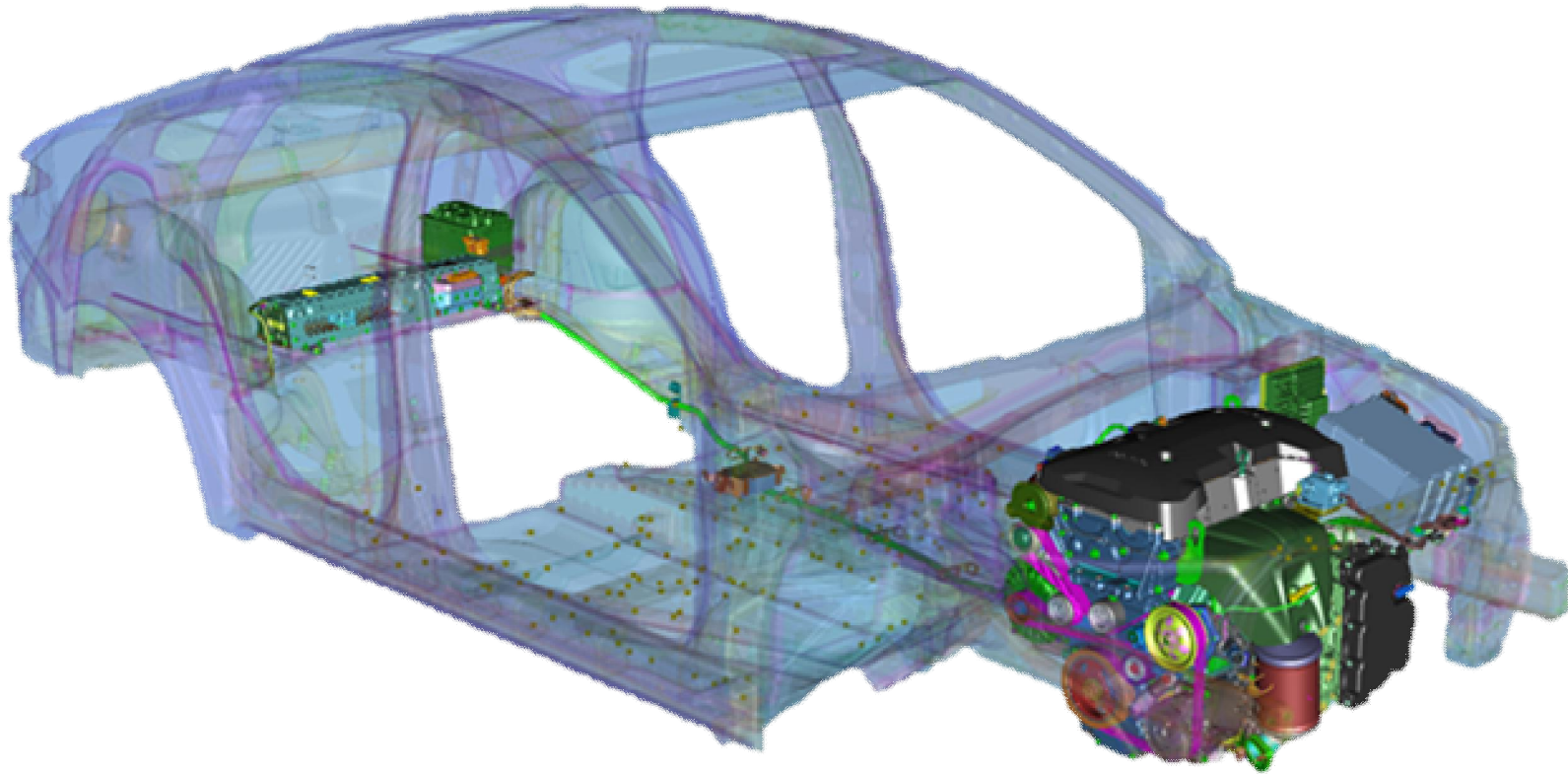
eAssist3 Packaging - LaCrosse

Improved packaging from Gen2

- Smaller battery pack / cooling system
- BPIM under hood
- Trunk space 1/3 larger with full pass through



eAssist3 Packaging - LaCrosse



eAssist3 Packaging – XT5

Seamless customer experience

- Battery under load floor behind 2nd row seat / MGU-BPIM under hood



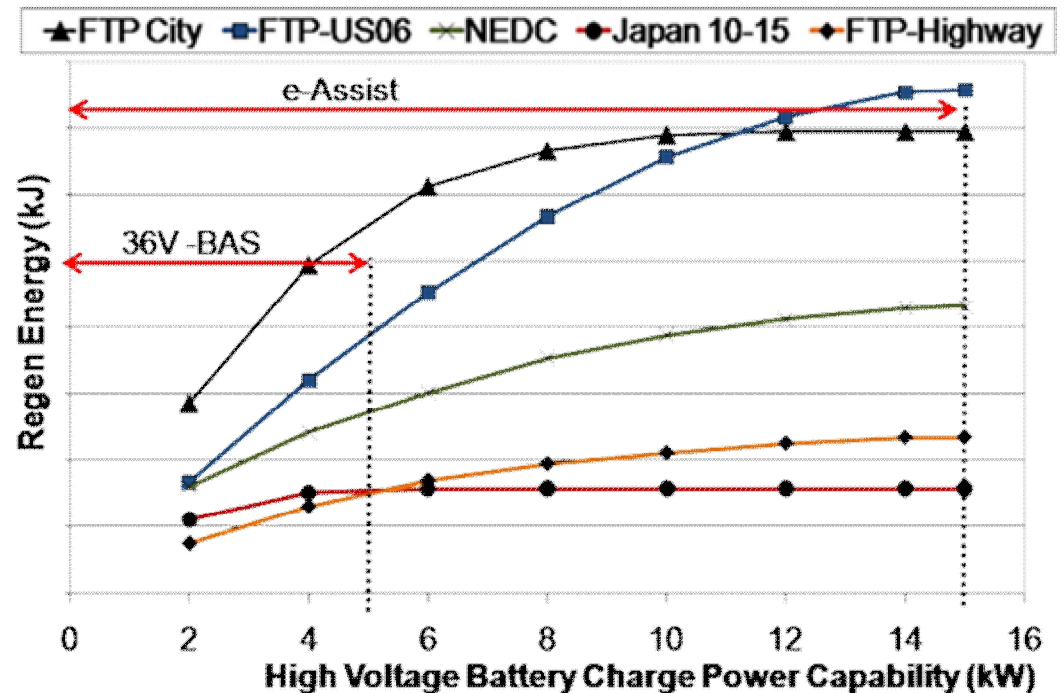
eAssist3 Packaging – XT5



Charge Power for eAssist3 systems

Optimized Energy

- Focus On Customer
- Fuel economy gains are limited above 14 kW
- Gen3 ESS allows up to 15 kW @ 86V, equal to Gen2 @ 115V
- Battery cell design to recover regeneration efficiently
- Gains through system optimization

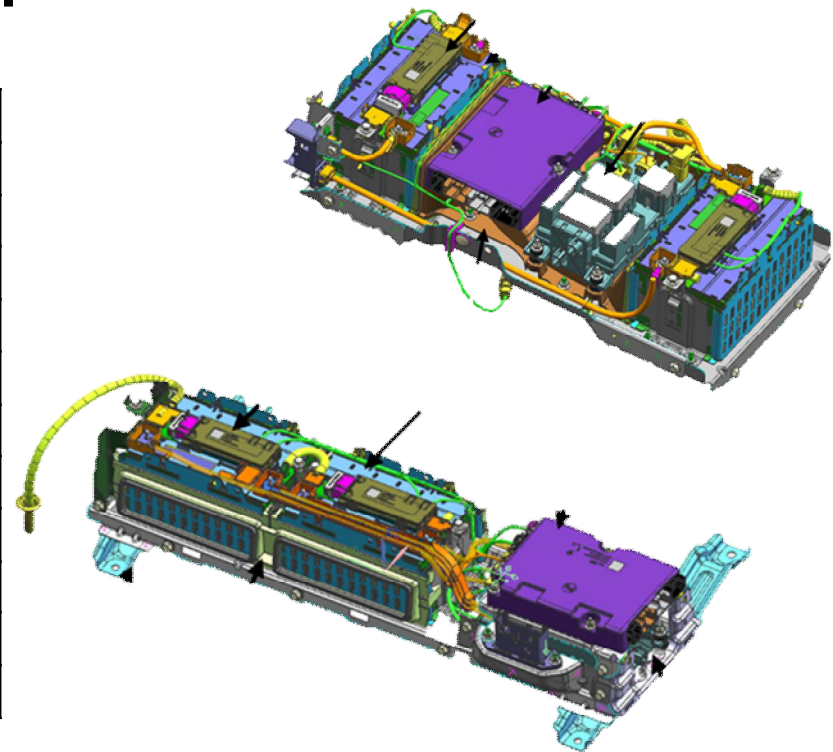


eAssist3 Battery Packs

Two variants with shared components

- Internal fan or external fan

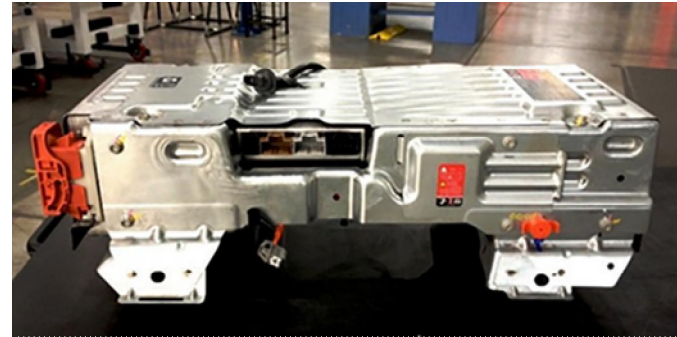
Specification	eAssist Module	eAssist3 Module
Cell Chemistry	NMC / Graphite	NMC / Graphite Mixture
Cell Configuration	16 Cylindrical Cans	12 Prismatic Cans
Discharge Power (2s)	8.0 kW	7.8 kW
Charge Power (2s)	7.5 kW	9.7 kW
Capacity	4.4 Ah	5.2 Ah
Power Density	Baseline	+75%
Nominal Voltage	60 V	45 V
Mass	6.1 kg	4.1 kg
Volume	5.0 L	2.5 L
Cooling System	Air Cooled 2s x 8p	Air Cooled – 12p
# of Modules in Pack	2	2



eAssist3 Battery Packs

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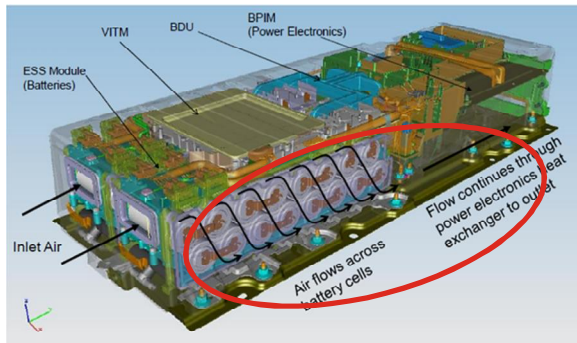
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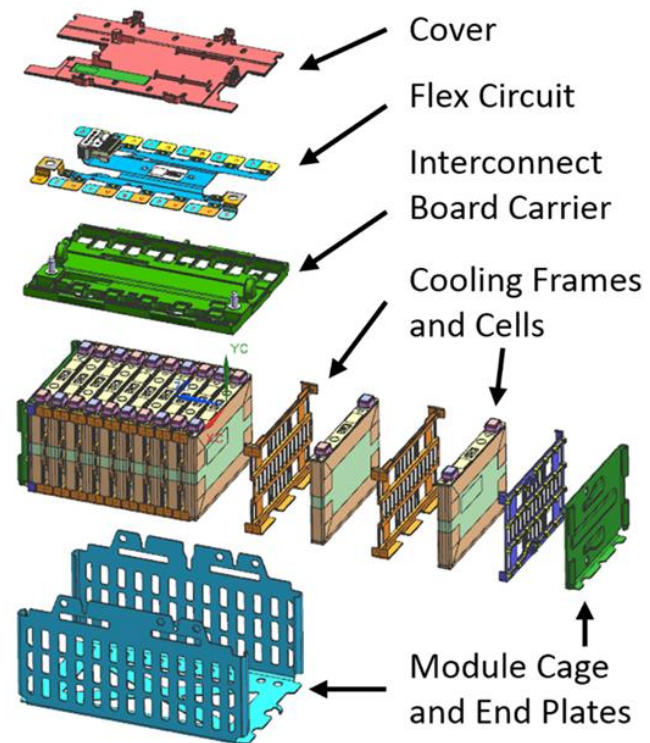
eAssist3 Battery Modules

Smaller modules in eAssist3

- Gen2 – 16 cylindrical cells
- Gen3 – 12 prismatic cells
- Gen3 – module 50% smaller



Gen2 module (inside Powerpack)



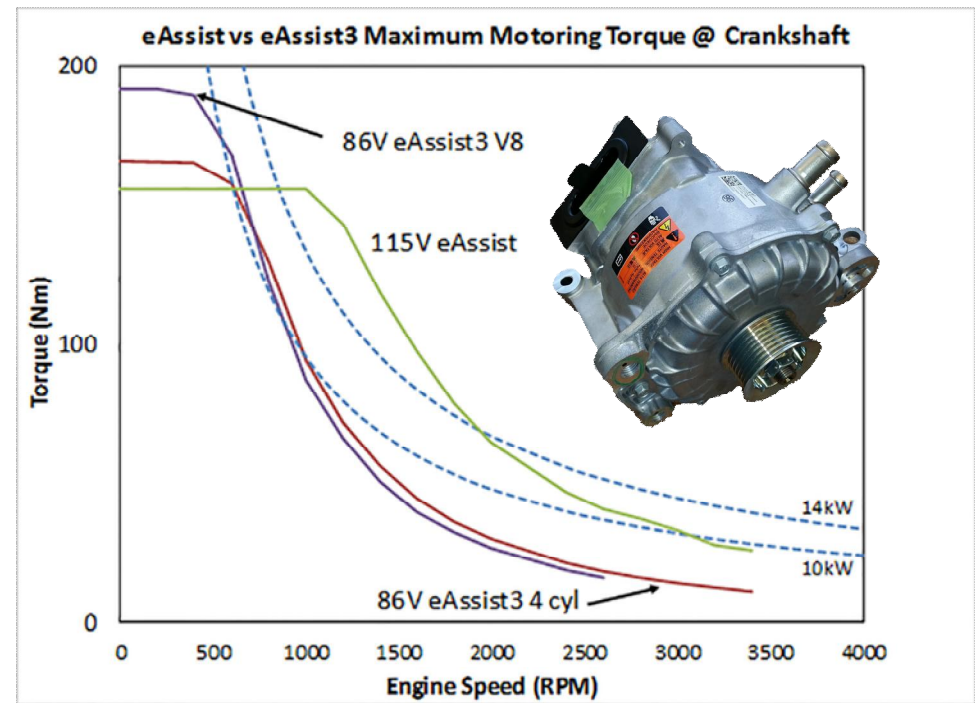
Gen3 module

New eAssist3 Motor Generator

New induction motor / generator – 8 pole

- Equivalent electromagnetic design
- Enables higher pulley ratio
- Peak generating – 15 kW electric

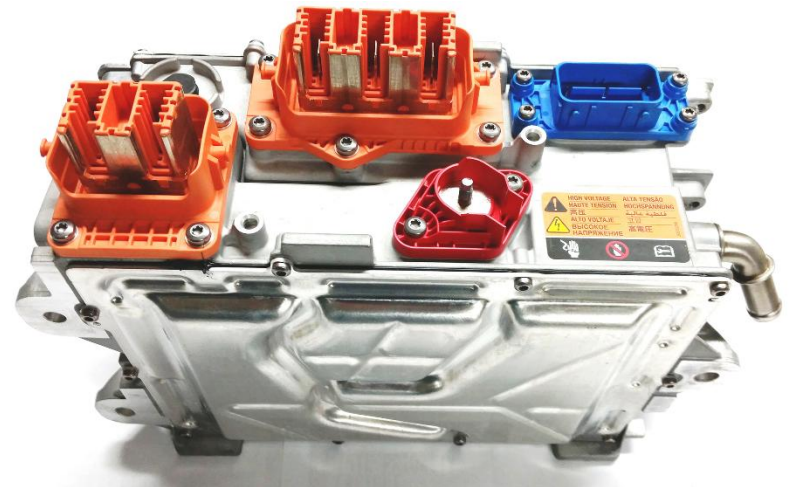
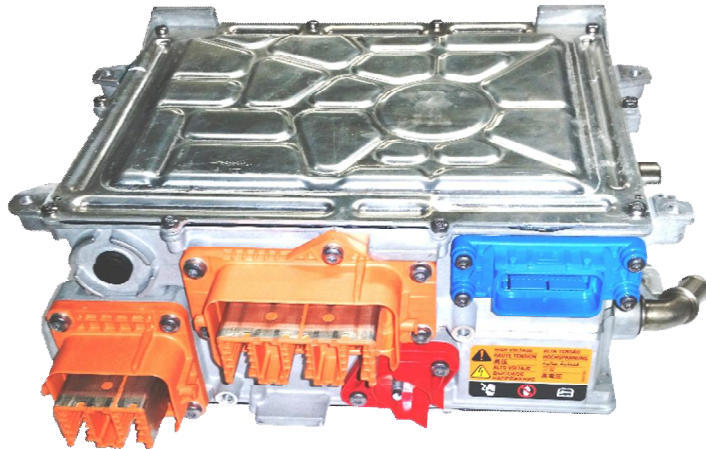
	eAssist	eAssist3
Machine type	AC Induction	AC Induction
# Poles	8	8
Peak Motoring Torque	>60 N-m	>60 N-m
Peak Motoring Power	>14 kW, mechanical	>10 kW, mechanical
Peak Generating Power	>18 kW electrical	>15 kW electrical
Cooling	Water / glycol mixture	Water / glycol mixture
Mass	< 13 kg (dry) (excluding 3-phase cables)	< 13.2 kg (dry) (excluding 3-phase cables)



eAssist3 Power Electronics - BPIM / APM

eAssist3 – Vertical and Horizontal mounting

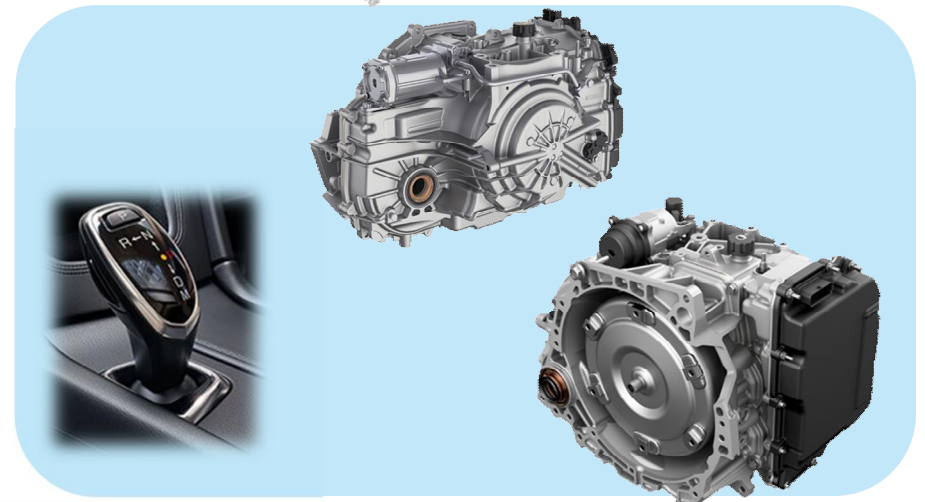
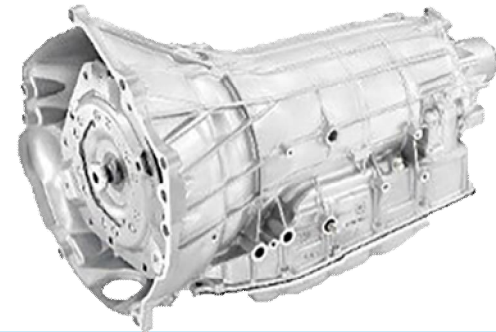
- Common internal parts, similar format as 12V Battery
- 230 ARMS IGBT
- 1.8 kW 12 V. DC-DC
- Hybrid Propulsion and Motor controller



eAssist3 Transmission Family

Common System For Multiple Transmissions

Description	eAssist3 8L90	eAssist3 6T40	eAssist3 9T60
1 st Gear Ratio	4.560	4.58	4.690
2 nd Gear Ratio	2.970	2.96	3.310
3 rd Gear Ratio	2.080	1.91	3.010
4 th Gear Ratio	1.690	1.45	2.450
5 th Gear Ratio	1.270	1.00	1.920
6 th Gear Ratio	1.000	0.75	1.450
7 th Gear Ratio	0.850	N/A	1.000
8 th Gear Ratio	0.650	N/A	0.750
9 th Gear Ratio	N/A	N/A	0.620
Reverse Gear Ratio	3.820	2.94	2.960
Overall FDR	3.08 or 3.42	2.64	3.47
Power Transfer	N/A	2-axis, output link chain	2-axis, output link chain
Shift pattern & shift quality	6 variable force solenoids, one for each clutch	Variable bleed solenoids	Linear Force Solenoids
Converter size	258 mm	236 mm	228 mm



eAssist3 Engine Families

Common System Adapted For Multiple Engine Solutions

	eAssist	eAssist3 2.5 NA	eAssist3 2.0 T	eAssist3 V8
Engine Type	L4 DOHC DI w / Intake and Exhaust Cam Phasers	L4 DOHC DI w / Intake and Exhaust Cam Phasers	L4 DOHC DI T w / Intake and Exhaust Cam Phasers	Gen 5 V8 5.3L DI VVT
Displacement	2.384 liters	2.457 liters	1.998 liters	5.328 liters
Compression Ratio	11.2:1	11.2:1	9.5:1	11.0:1
Max Power (estimate)	136 kW @ 6700 rpm (182 hp)	144 kW @ 6300 rpm (194 hp)	192 kW @ 5500 rpm (257 hp)	265kW @ 5600 rpm (355 hp)
Max Torque (estimate)	233 N-m @ 4900 rpm	254 N-m @ 4400 rpm	400 N-m @ 3000 - 4300 rpm	519 N-m @ 4100 rpm
Idle Speeds (unfueled / base / boosted - rpm)	460 700 800	450 650 800	550 650 850	380 500 (V8) 650 (V4) 650
Fuel	Regular Unleaded	Regular Unleaded	Premium Recom- mended	Regular Unleaded

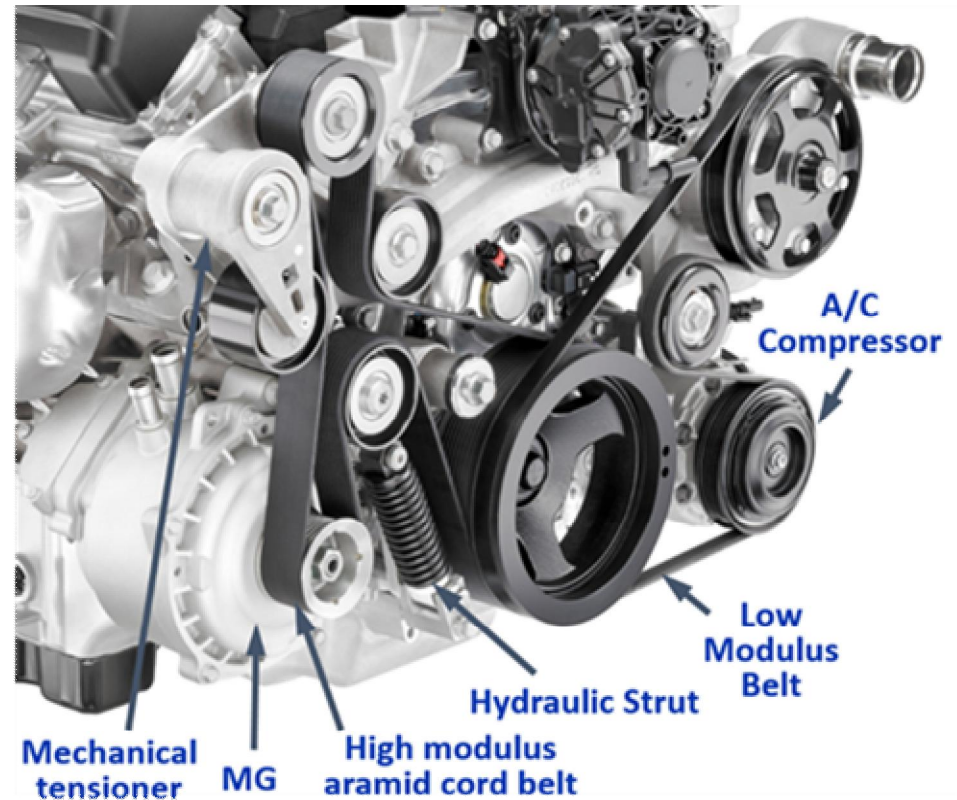


*All torque and speed values are @ engine crankshaft

V8 eAssist3 Belt Drive

Dual plane drive

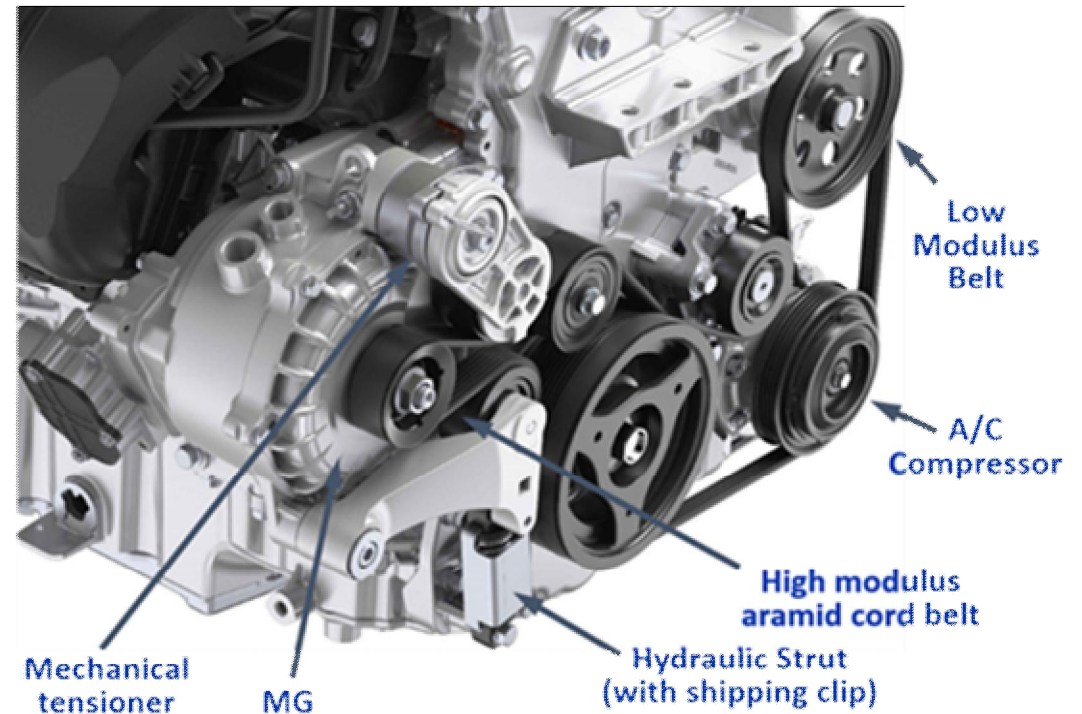
- MGU
 - 10 rib aramid cord MG belt for
 - Hydraulic linear tensioner
 - Low wrap mechanical rotary tensioner
- Accessory
 - Low modulus second accessory belt drive conventional accessories



ECOTEC 4 Cylinder Belt Drive

Dual plane drive

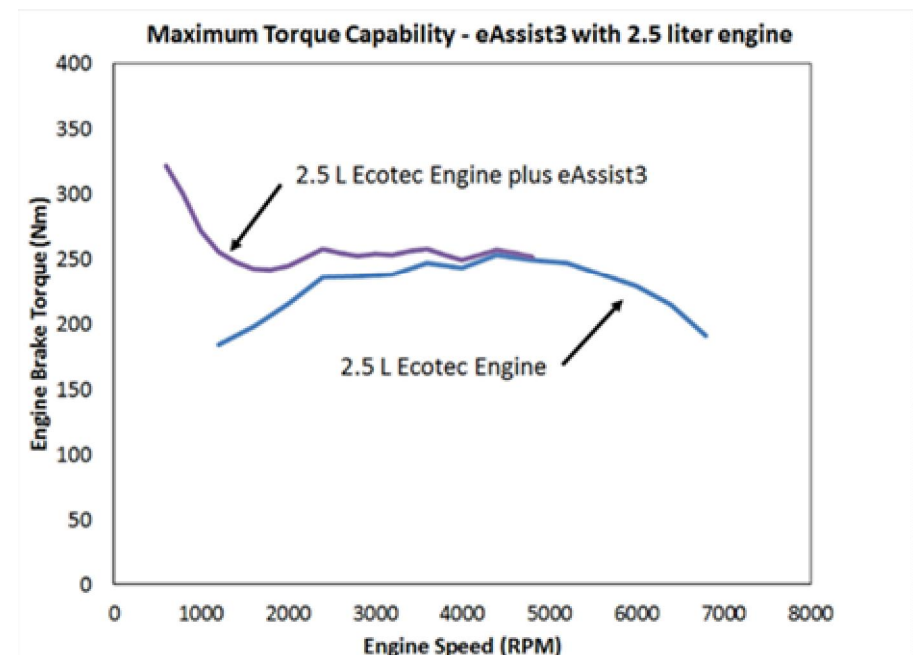
- MGU
 - 7 rib aramid cord MG belt
 - Tensioners mounted to MG
 - Hydraulic linear tensioner
 - Low wrap mechanical rotary
- Accessory
 - Low modulus accessory belt



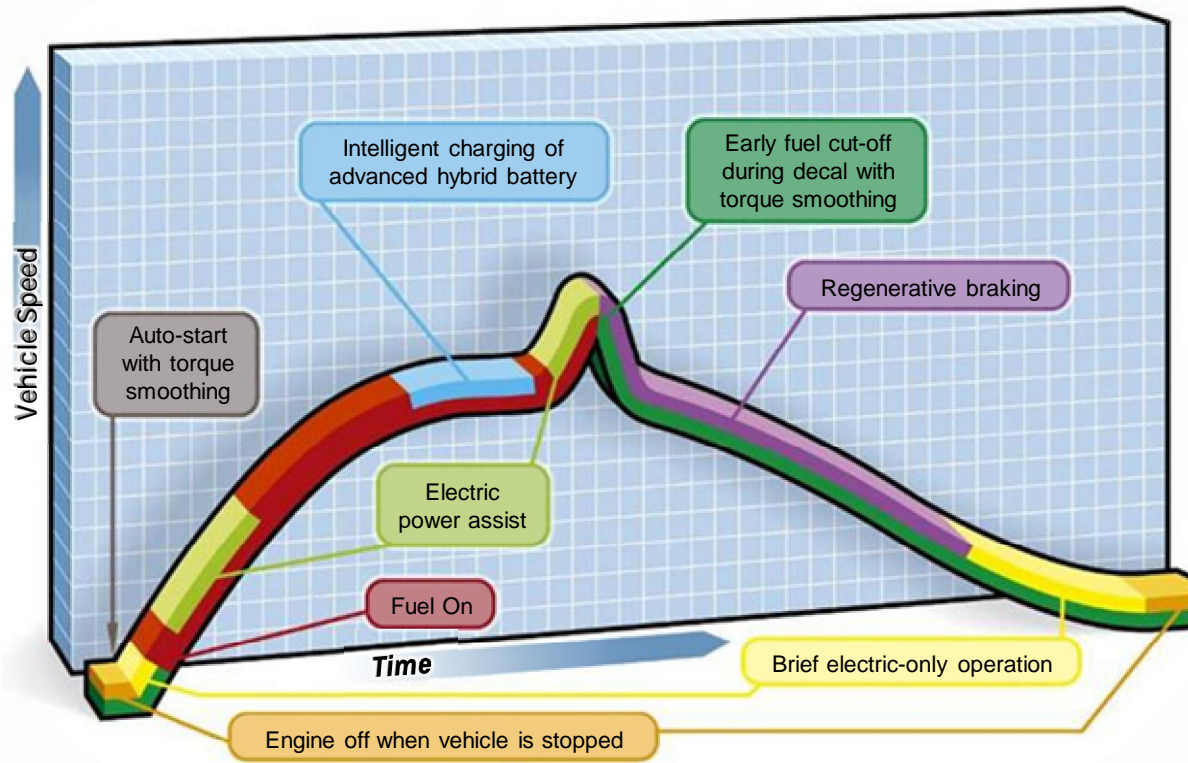
eAssist3 Combined Torque Capability

Example of eAssist3 Torque Assist

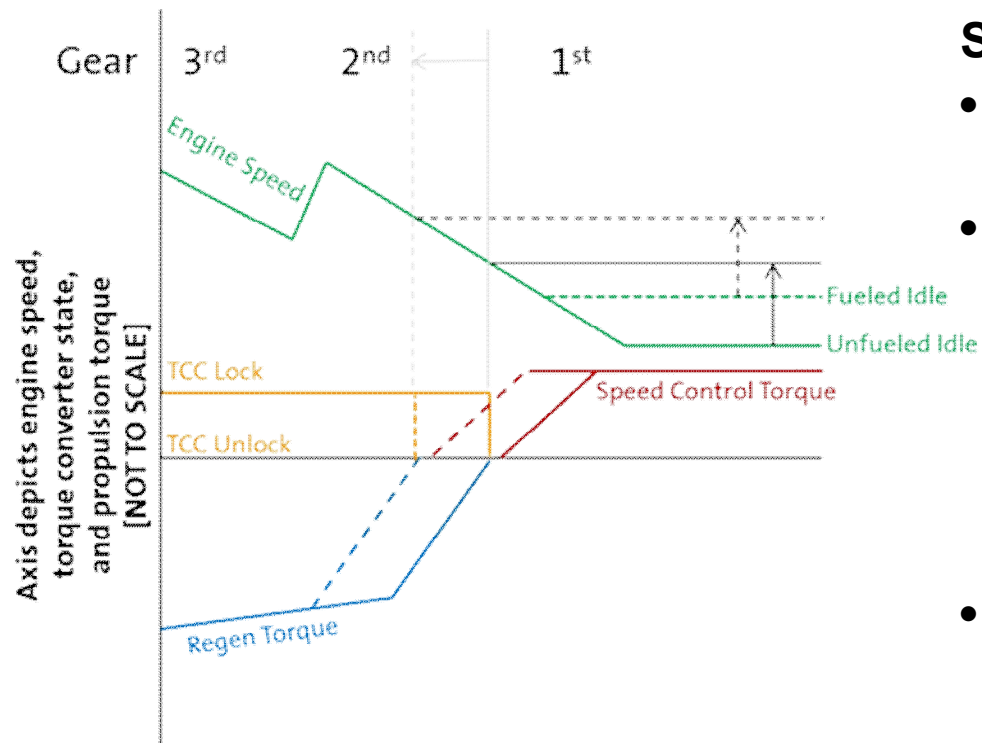
- Maximum assist below 1000 RPM
- 2.5 L – grade and acceleration assist
- V8 - extends AFM for fuel economy
- 2.0 Turbo
 - Torque fill to aid turbo response
 - Reduce boost for fuel economy gain



eAssist3 System Operation



eAssist3 System Engineering



System Approach Multiplies Gains

- 15kW Kinetic Recovery enables multiple utilization options
- Real time controls optimizes maximum utilization of energy
 - Fuel off / Idle off
 - Power assist enables engine BSFC
 - Motor control enables locked TC
 - Motor control enables shift schedule
- **Results Achieves >10% FE & Customer Satisfaction**

GENERAL MOTORS 3RD GENERATION eAssist PROPULSION SYSTEM

February 21 2018

SAE Dan Diego – Mission Valley, California USA

