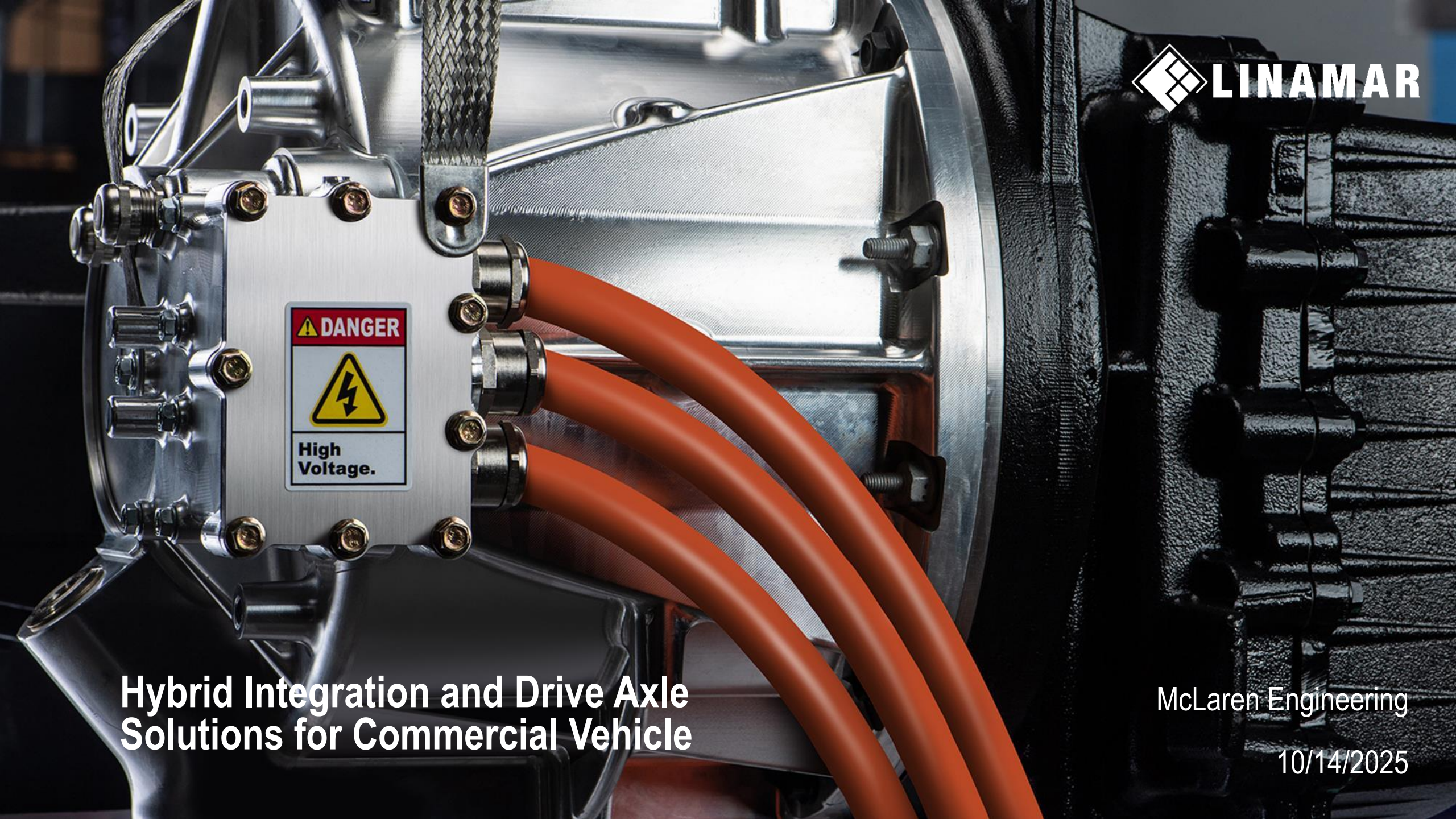

LINAMAR

Hybrid Integration and Drive Axle Solutions for Commercial Vehicle

McLaren Engineering

10/14/2025

Hybrid Integration and Drive Axle Solutions for Commercial Vehicle

Explore the latest in hybrid powertrain and drive axle technologies shaping the future of commercial vehicle upfitting. This session covers the flexibility of motor generator unit (MGU) range extenders — balancing battery size with range — and compares central drive axles versus eAxles in terms of efficiency, cost, regen, and integration complexity. Featuring Class 4–6 examples and an overview of Linamar's customizable eMD15 system, attendees will gain practical insight into how these technologies apply to both upfits and purpose-built platforms.

Eric West
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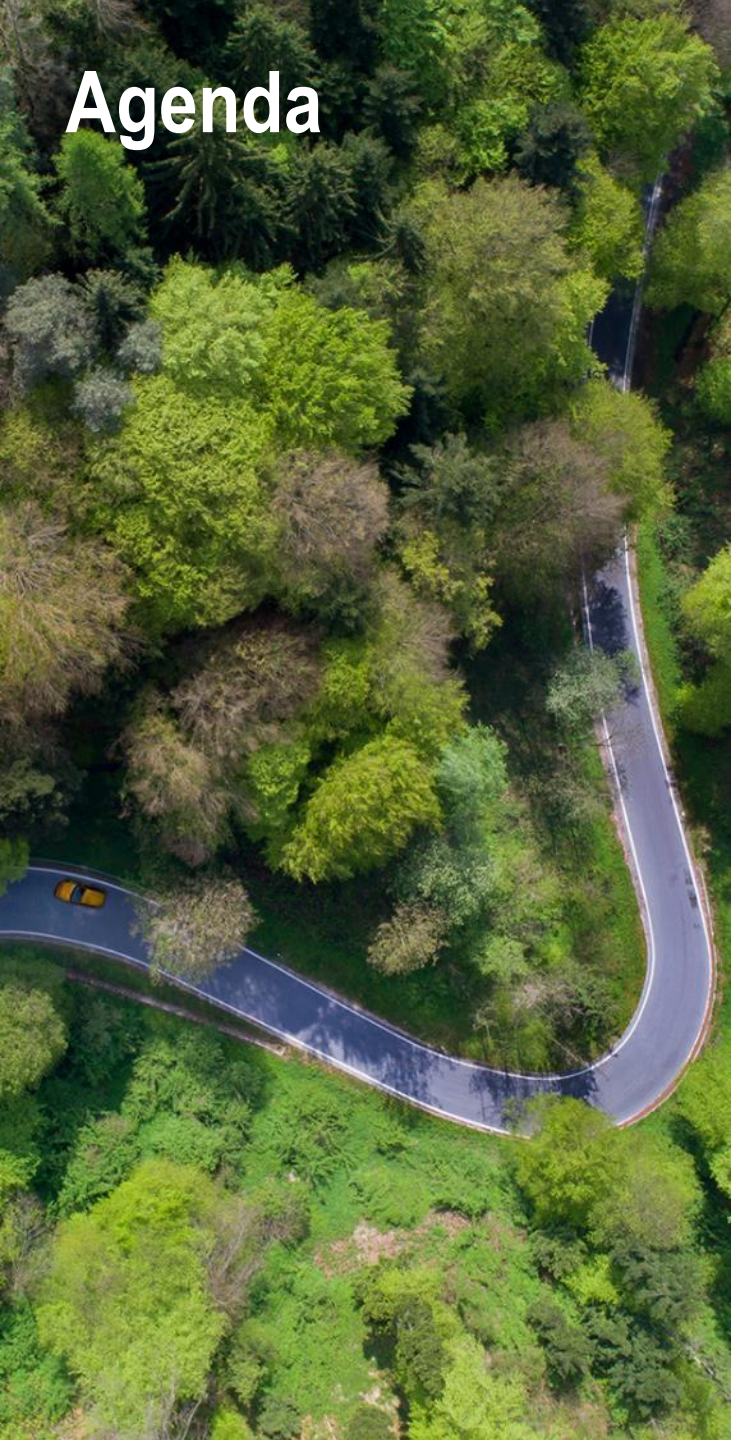
Eric.West@Linamar.com

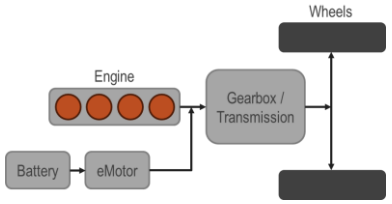
Agenda

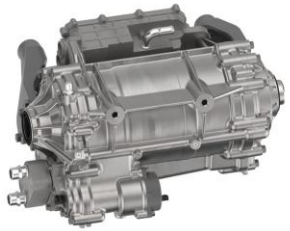


- Motor Generator Unit (MGU) Overview
- Central Drive Axle vs. eAxle
- eMD15 Class 4-6 Commercial Vehicle eAxle

Motor Generator Unit (MGU) Overview

Electrified Powertrain Architectures





Electrification

Micro Hybrid

- Cannot propel the vehicle on electric power alone.
- Supports stop/start and sometimes regenerative braking.
- Battery size: Very small (typically <1 kWh)

Mild Hybrid (MHEV)

- Cannot drive on electricity alone.
- Assists acceleration, enables stop/start, and regenerative braking.
- Battery size: Small (0.5–2 kWh)

Full Hybrid (HEV)

- Limited EV-only operation possible.
- Low speed and light load propulsion.
- Parallel or Series
- Battery size: Medium (up to 3–4 kWh)

Plug-In Hybrid (PHEV)

- Capable of significant EV-only propulsion. ICE required for longer trips or high loads
- Battery size: Large (10–30+ kWh)

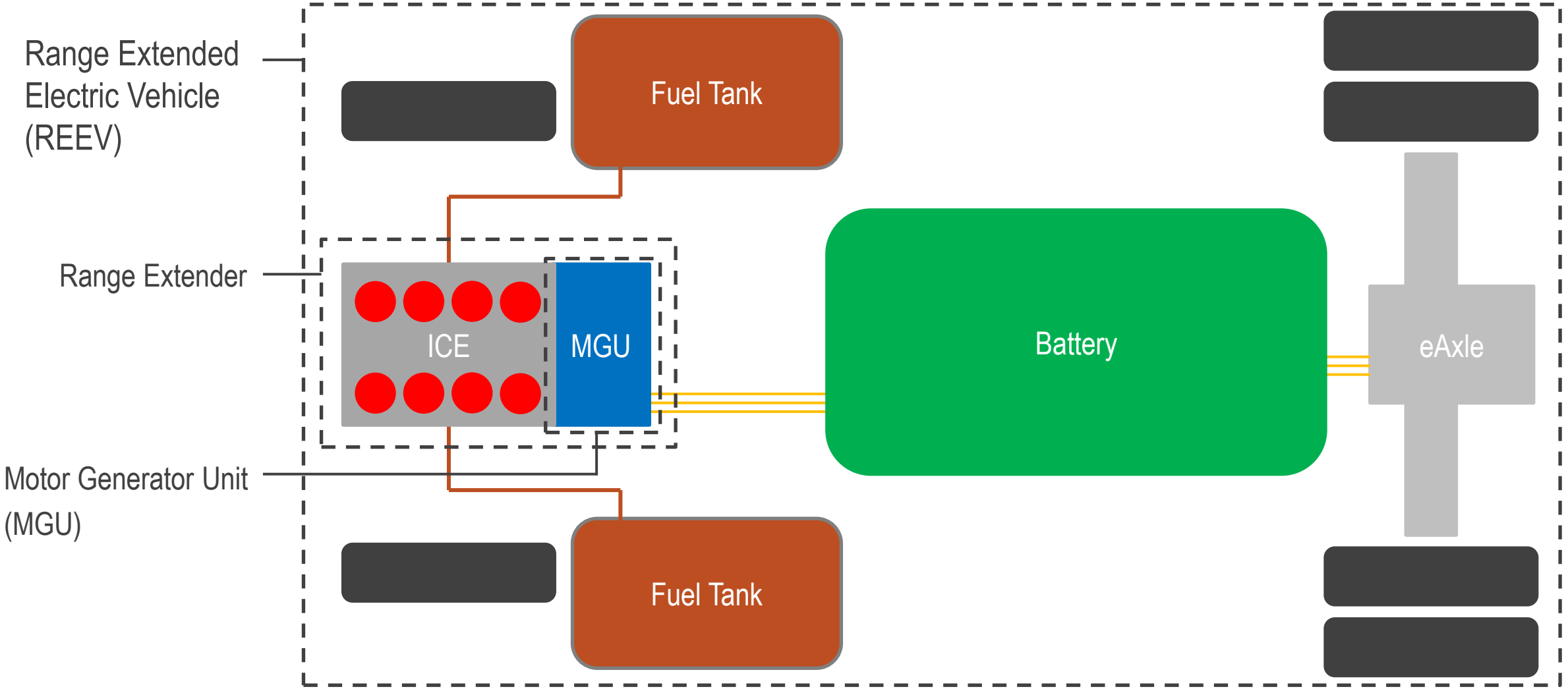
Range-Extended EV (REEV)

- 100% electric propulsion
- ICE generates electricity when the battery depletes.
- Battery size: Large (~20–40+ kWh)

Battery Electric Vehicle (BEV)

- 100% electric propulsion
- Battery: Very large (40–200+ kWh)

Range Extended Electric Vehicle | Block Diagram



REEV Benefits

🔋 Extended Driving Range
- Overcoming “range anxiety”. Internal combustion engine (ICE) generates electricity to recharge the battery and allow longer trips between refueling.

⛽ Flexible Refueling
- Can refuel, making it practical where charging infrastructure is limited.

⚡ Primary Electric Drive Experience
- High torque and quiet operation from the EV powertrain.

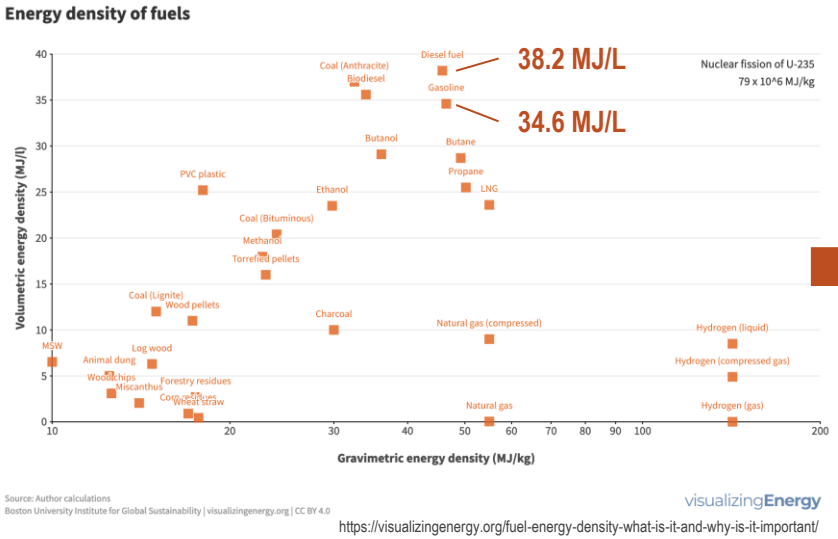
🌍 Lower Emissions Than Conventional Vehicles
- Fuel consumption and emissions are significantly reduced compared to traditional ICE vehicles.

💰 Reduced Battery Size Requirement
- A smaller and less expensive battery can be used to achieve the same vehicle range.

🔧 Reduced Engine and Brake Wear
- The ICE operates at constant high efficiency load points and regenerative braking reduce wear and maintenance.

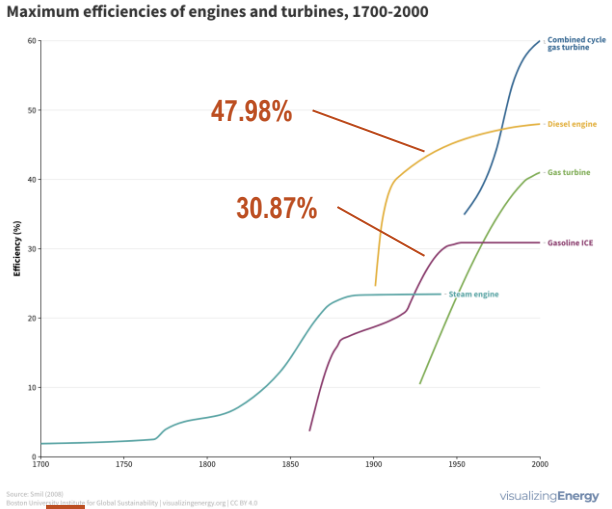
Range Extender Principle

Gasoline or Diesel Fuel Stores Chemical Energy



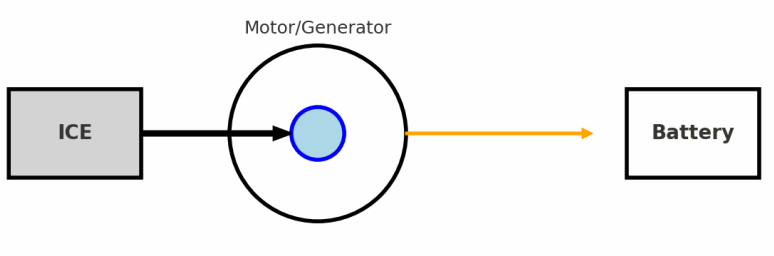
https://visualizingenergy.org/fuel-energy-density-what-is-it-and-why-is-it-important/

Internal Combustion Engine Converts Stored Energy to Mechanical Power w/ Losses



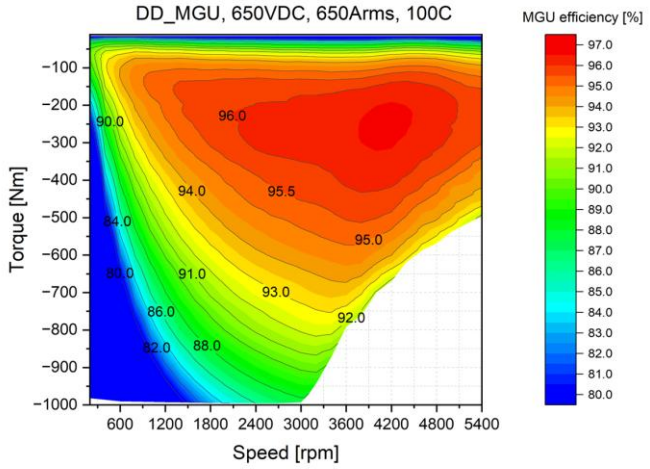
https://visualizingenergy.org/maximum-efficiencies-of-engines-and-turbines-1700-2000/

Electrical Power Sent to the Battery to Maintain or Increase State of Charge (SoC)



Fuel	Conversion kW-hr / gal	Consumption kW-hr / km	Range km / gal
Gasoline	10.7	0.7	15.3
Diesel	18.5	0.7	26.4

Motor Generator Unit (MGU) Converts Mechanical Power to Electrical Power

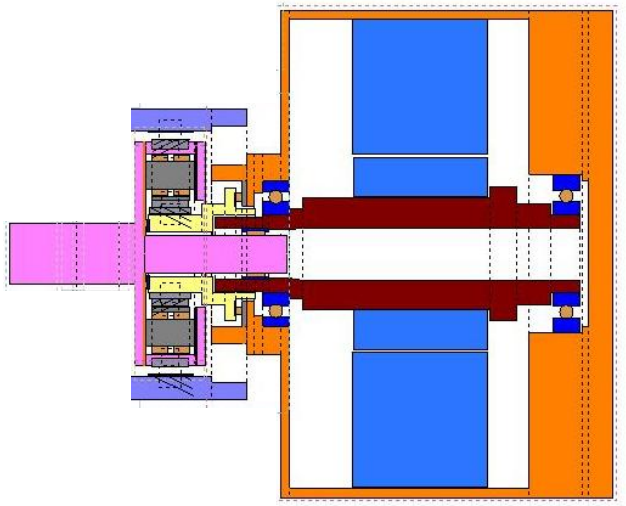


Motor Generator Unit | Architecture Types

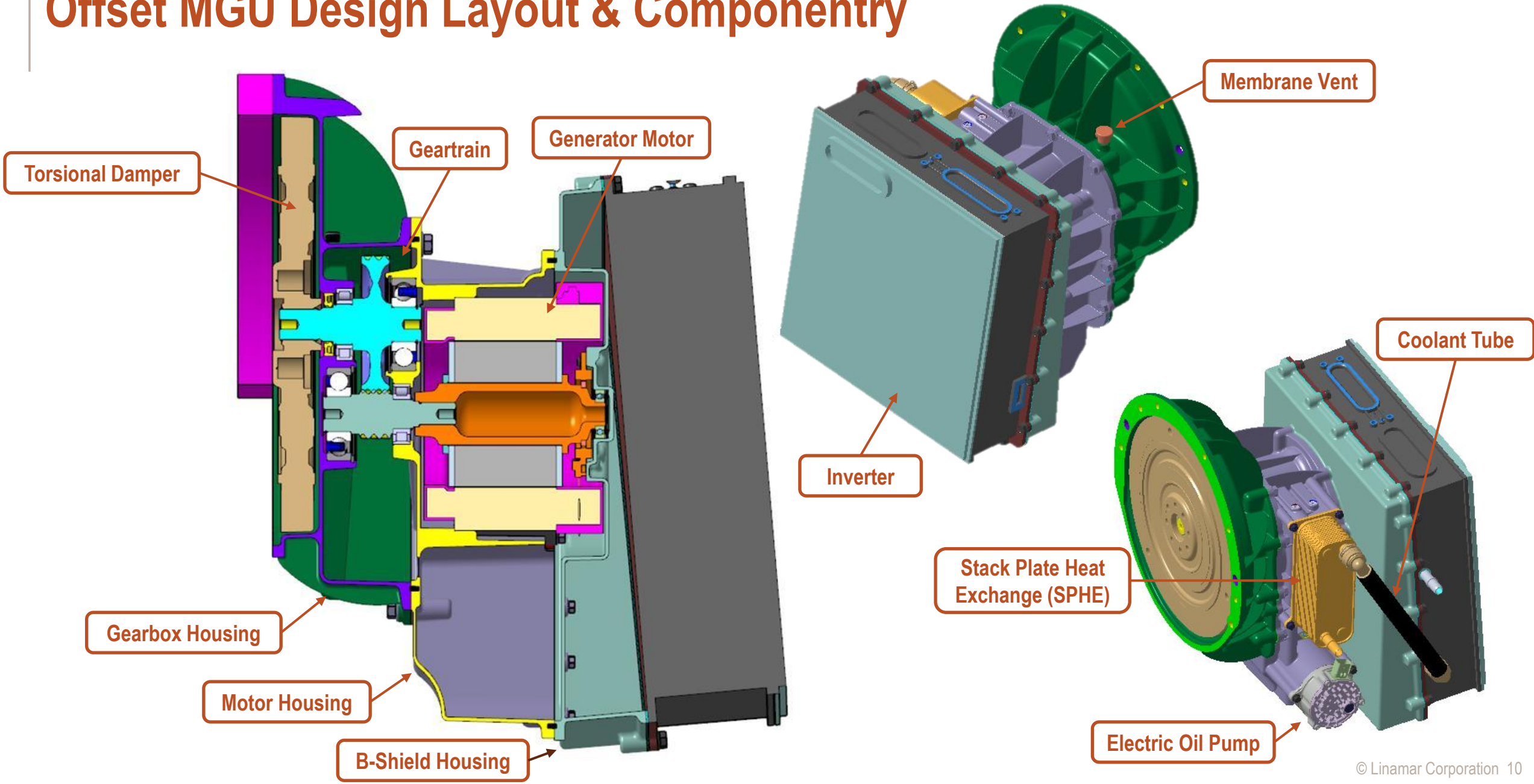
Offset / Geared

Direct Drive

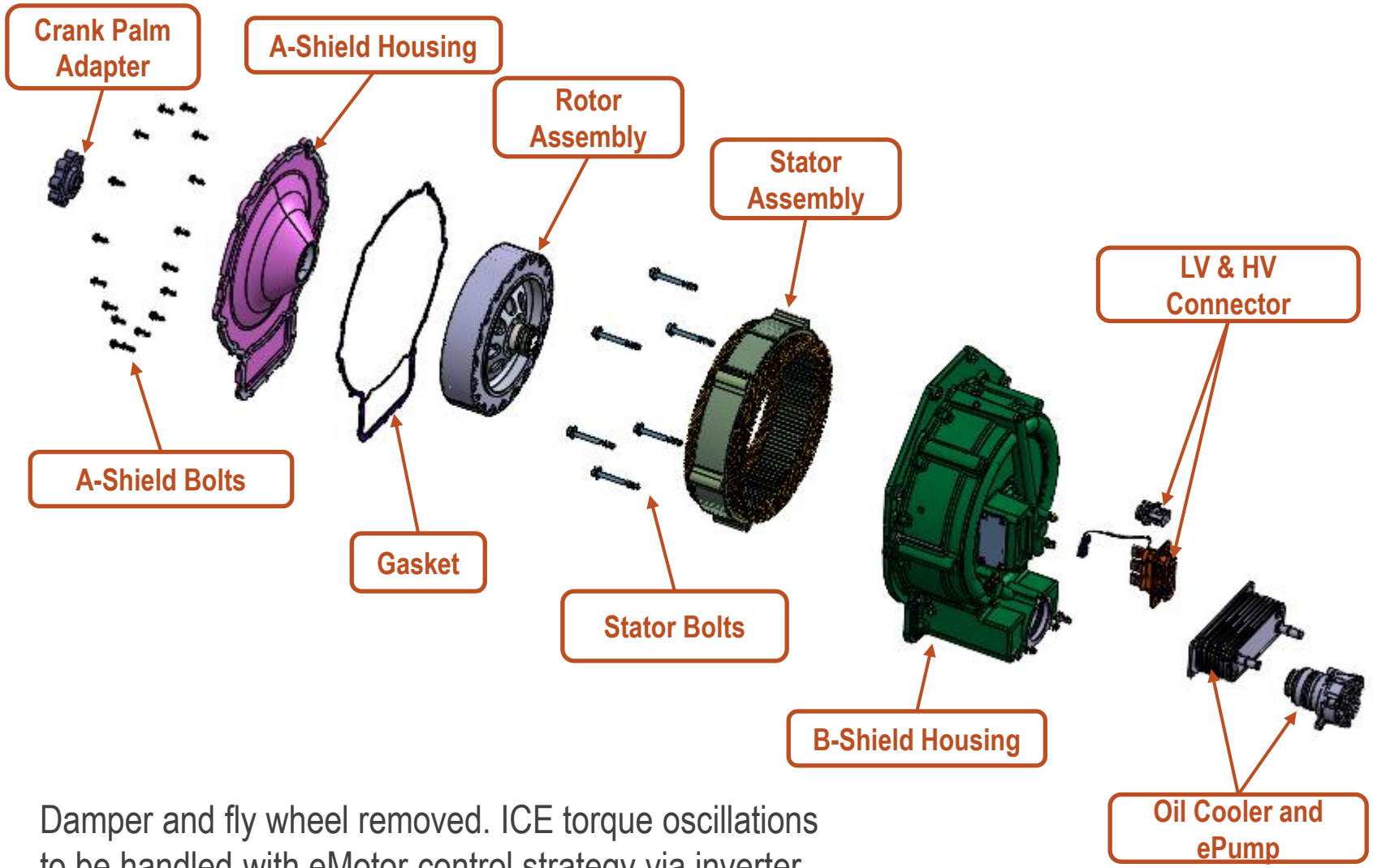
Coaxial Geared

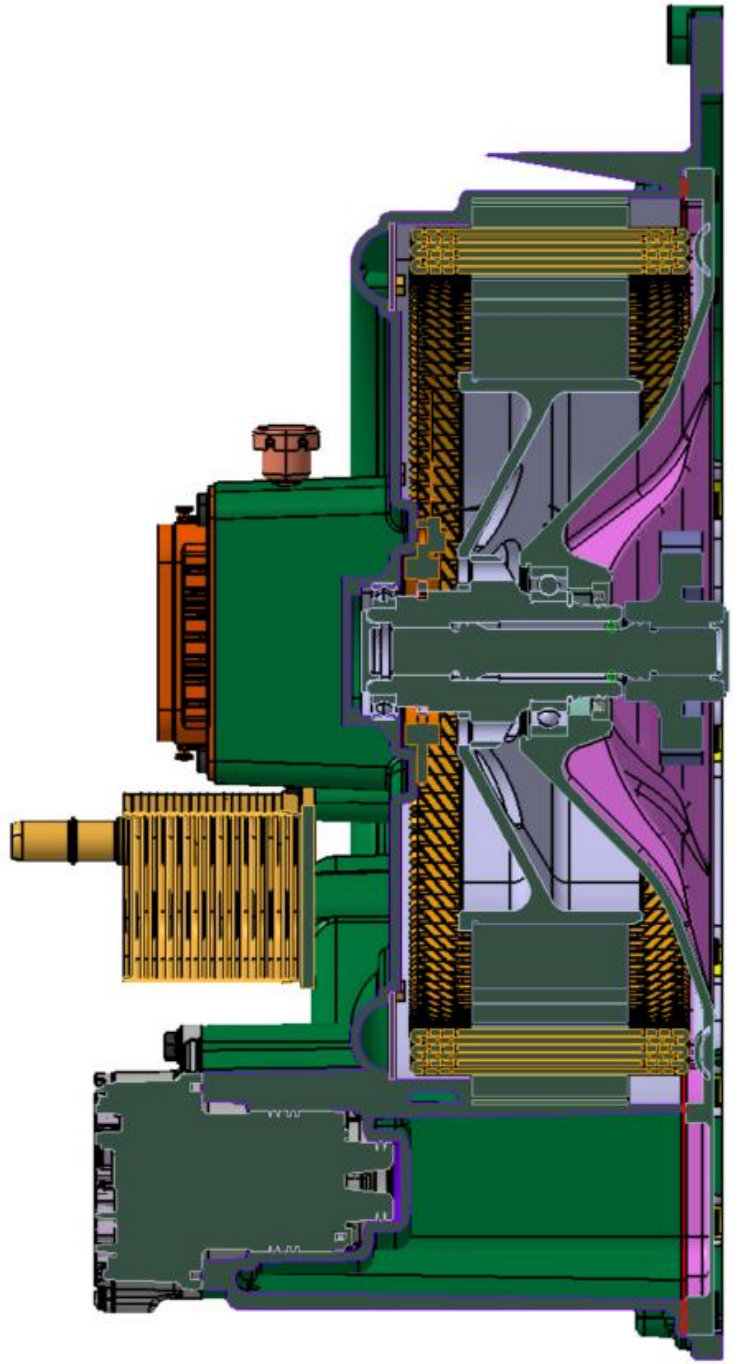


Offset MGU Design Layout & Componentry



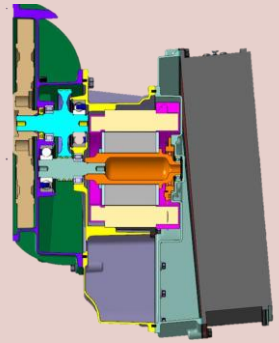
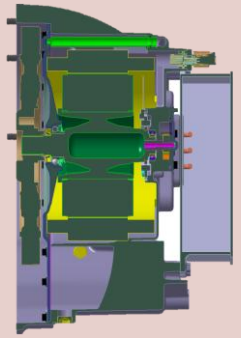
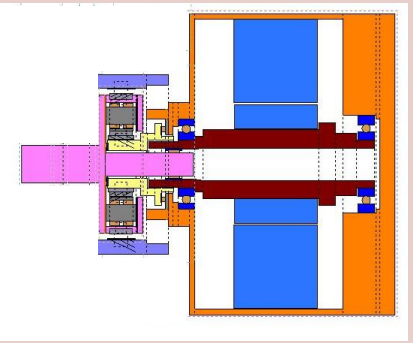
Direct Drive MGU Design Layout & Componentry





Damper and fly wheel removed. ICE torque oscillations to be handled with eMotor control strategy via inverter

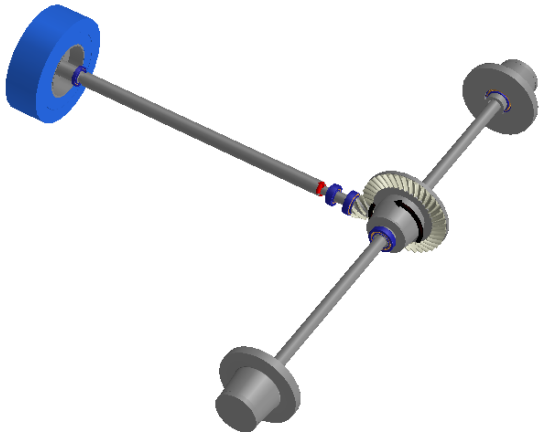
Motor Generator Unit | Architecture Types

Criteria	Offset MGU	Direct Drive MGU	Coaxial Geared MGU
General Layout			
Cost	✓✓	✓	✗
Package	✓	✓✓	✓✓
Mass	✓	✓✓	✓
Efficiency	✓✓	✓✓	✓
NVH	✓	✓	✗
Assembly	✓	✓✓	✗
Design Flexibility	✓✓	✓	✓✓

Central Drive Axle vs. eAxle

Commercial Vehicle Electrification

Central Drive Motor

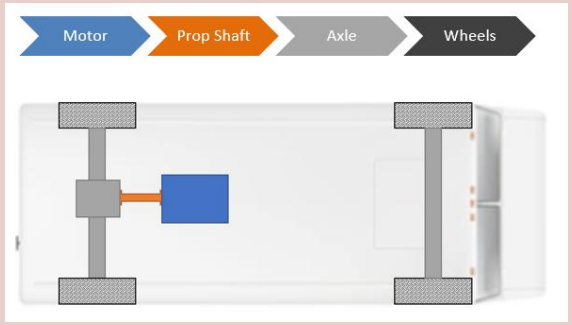
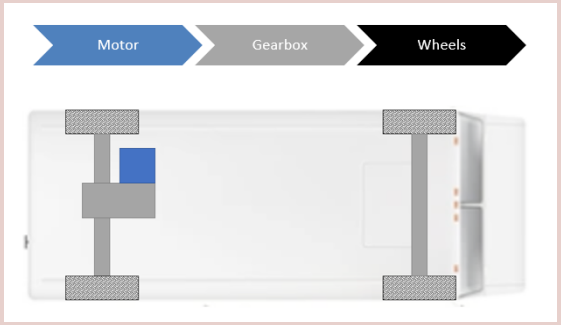


🚗 Great for retrofit – Fits where the transmission usually is in ICE vehicles, making it easy to adapt existing designs.
⚙️ “Conventional” architecture – Maintains a familiar layout for manufacturers between ICE and BEV production.
🛠️ Reliable axle – Uses proven axle technology, avoiding new validation or reliability risks.
💰 Integration costs savings – Retrofit can reuse existing vehicle rear axle for reduced cost.

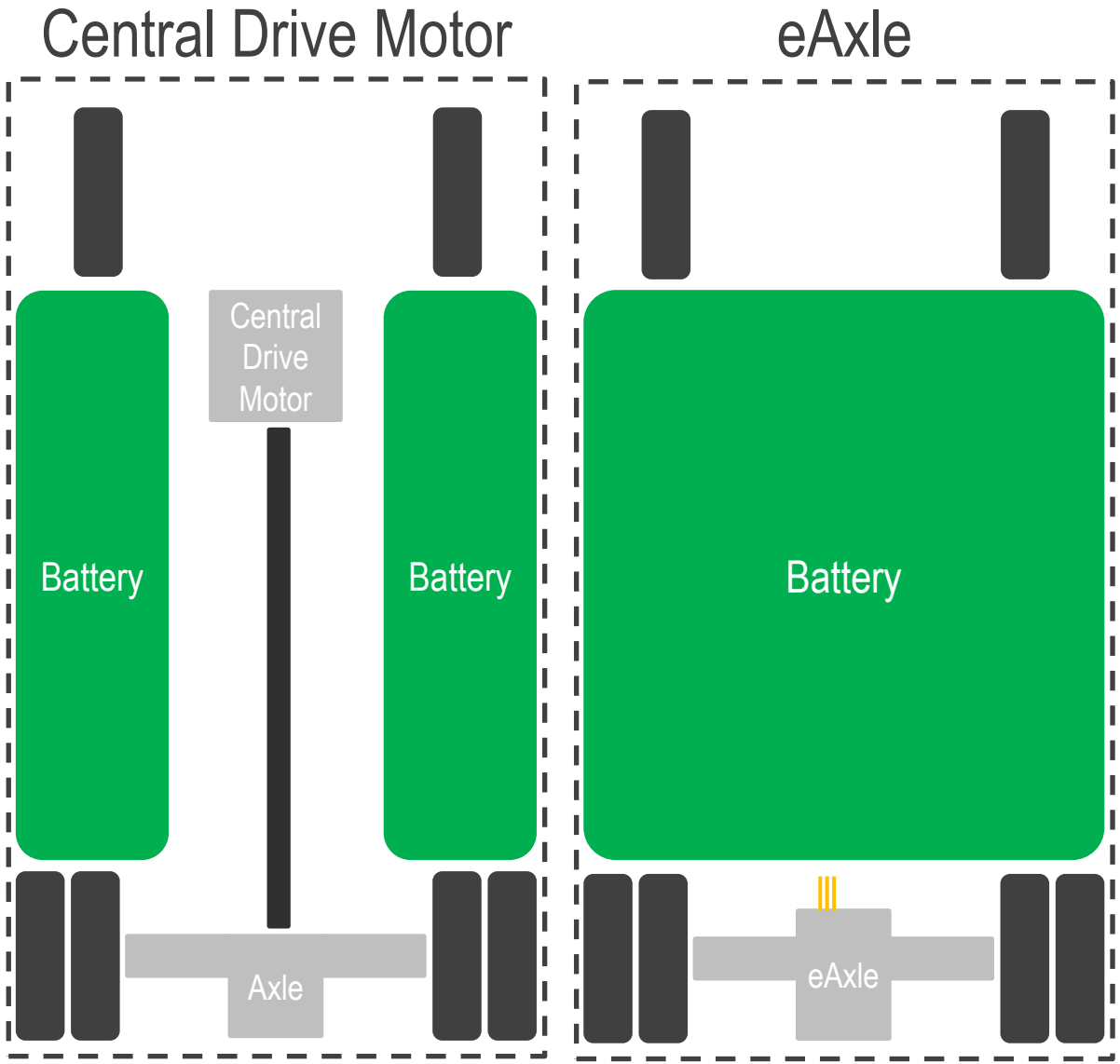
eAxle

📦 Space optimization – Eliminates transmission and driveline, freeing space for larger battery placement.
⚖️ Weight savings – Lighter than a separate motor, driveline, and axle combination.
💰 High volume costs savings – Integrated design can reduce material and manufacturing costs.
⚡ Efficiency improvement – Avoids driveline power losses, improving overall vehicle range.
🚙 Shorter wheelbase – Space efficiency can reduce wheelbase, enhancing drivability.

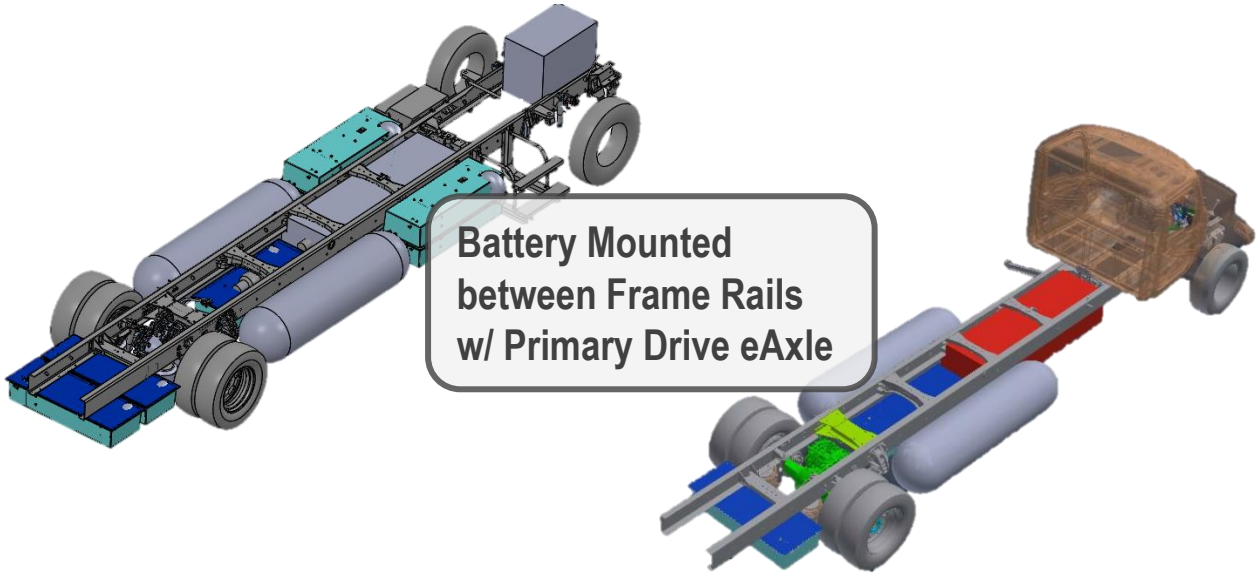
Commercial Vehicle Electrification | Architecture Types

Criteria	Central Drive Motor	eAxle
General Layout		
Cost	✓✓	✓
Package	✓	✓✓✓
Efficiency	✓	✓✓
NVH	✘	✓
Conversion Complexity	✓✓✓	✓
Battery Capacity	✓	✓✓✓
Regenerative Braking	✘	✓

Package & Battery Capacity



- Central drive motor and drive shaft occupy space between the frame rails that could otherwise be used for batteries, hydrogen storage, etc.
- eAxle systems allow increased battery capacity coupled with improved efficiency for extended vehicle range.



Drive System Efficiency

eAxle

Torque [Nm] \ Speed [RPM]	500	1000	1500	2000	2500	3000	3500	4000	4500	5000	5500	6000	6500	7000	7500	8000	8500	9000	9500	10000	10500	11000	11500	12000	12500
1000	0.937	0.922	0.909	0.898	0.887	0.877																			
975	0.942	0.930	0.920	0.910	0.901	0.893																			
950	0.947	0.937	0.928	0.920	0.912	0.905																			
925	0.950	0.942	0.935	0.928	0.922	0.916																			
900	0.953	0.947	0.941	0.935	0.930	0.924																			
875	0.956	0.951	0.945	0.941	0.936	0.931	0.927																		
850	0.958	0.954	0.949	0.945	0.941	0.937	0.934																		
825	0.959	0.956	0.953	0.949	0.946	0.942	0.939																		
800	0.961	0.958	0.955	0.952	0.949	0.947	0.944																		
775	0.962	0.960	0.958	0.955	0.953	0.950	0.948																		
750	0.963	0.962	0.960	0.957	0.955	0.953	0.951	0.949																	
725	0.964	0.963	0.961	0.959	0.958	0.956	0.954	0.952																	
700	0.965	0.964	0.963	0.961	0.959	0.958	0.956	0.954																	
675	0.966	0.965	0.964	0.963	0.961	0.960	0.958	0.957																	
650	0.966	0.966	0.965	0.964	0.963	0.961	0.960	0.959																	
625	0.967	0.967	0.966	0.965	0.964	0.963	0.961	0.960	0.959																
600	0.968	0.968	0.967	0.966	0.965	0.964	0.963	0.962	0.961																
575	0.968	0.969	0.968	0.967	0.966	0.965	0.964	0.963	0.962																
550	0.969	0.969	0.969	0.968	0.967	0.966	0.965	0.964	0.963	0.962															
525	0.969	0.970	0.969	0.969	0.968	0.967	0.966	0.965	0.964	0.963															
500	0.970	0.970	0.970	0.969	0.969	0.968	0.967	0.966	0.965	0.964															
475	0.970	0.971	0.971	0.970	0.969	0.968	0.967	0.967	0.966	0.965	0.964														
450	0.971	0.971	0.971	0.970	0.970	0.969	0.968	0.967	0.966	0.965	0.965														
425	0.971	0.972	0.971	0.971	0.970	0.969	0.968	0.968	0.967	0.966	0.965	0.963													
400	0.971	0.972	0.972	0.971	0.970	0.970	0.969	0.968	0.967	0.966	0.966	0.963													
375	0.972	0.972	0.972	0.971	0.971	0.970	0.969	0.968	0.968	0.967	0.966	0.964	0.960												
350	0.972	0.973	0.972	0.972	0.971	0.970	0.969	0.969	0.968	0.967	0.966	0.964	0.961												
325	0.972	0.973	0.973	0.972	0.971	0.970	0.969	0.969	0.968	0.967	0.966	0.964	0.961	0.957											
300	0.973	0.973	0.973	0.972	0.971	0.970	0.969	0.969	0.968	0.967	0.966	0.964	0.961	0.958	0.953										
275	0.973	0.973	0.973	0.972	0.971	0.970	0.969	0.968	0.967	0.966	0.966	0.964	0.961	0.958	0.954	0.948									
250	0.973	0.973	0.973	0.972	0.971	0.970	0.969	0.968	0.967	0.966	0.965	0.963	0.961	0.958	0.954	0.949	0.943	0.934							
225	0.973	0.973	0.973	0.971	0.970	0.970	0.968	0.967	0.966	0.965	0.964	0.962	0.960	0.957	0.954	0.949	0.944	0.937	0.928						
200	0.973	0.973	0.972	0.971	0.971	0.970	0.969	0.968	0.966	0.965	0.964	0.963	0.961	0.959	0.956	0.953	0.949	0.945	0.939	0.931	0.921	0.908			
175	0.973	0.972	0.971	0.970	0.969	0.968	0.966	0.965	0.964	0.962	0.961	0.959	0.957	0.954	0.951	0.948	0.944	0.939	0.932	0.925	0.914	0.901	0.883		
150	0.972	0.971	0.970	0.969	0.967	0.966	0.964	0.963	0.961	0.960	0.958	0.956	0.954	0.951	0.949	0.945	0.941	0.937	0.932	0.925	0.917	0.907	0.894	0.877	0.852
125	0.971	0.970	0.968	0.966	0.965	0.963	0.961	0.959	0.958	0.956	0.954	0.952	0.950	0.947	0.944	0.941	0.937	0.933	0.929	0.923	0.917	0.909	0.899	0.887	0.871
100	0.969	0.967	0.965	0.963	0.960	0.958	0.956	0.954	0.952	0.950	0.948	0.945	0.943	0.940	0.937	0.934	0.930	0.926	0.922	0.917	0.911	0.905	0.897	0.888	0.877
75	0.965	0.962	0.959	0.956	0.953	0.950	0.947	0.944	0.942	0.939	0.936	0.933	0.930	0.927	0.924	0.920	0.917	0.913	0.908	0.904	0.898	0.893	0.886	0.879	0.871
50	0.955	0.951	0.946	0.941	0.937	0.933	0.929	0.925	0.921	0.917	0.913	0.910	0.906	0.902	0.898	0.893	0.889	0.885	0.880	0.875	0.870	0.864	0.858	0.852	0.844
25	0.926	0.917	0.908	0.899	0.891	0.884	0.876	0.869	0.863	0.856	0.850	0.844	0.837	0.831	0.825	0.819	0.813	0.808	0.801	0.795	0.788	0.781	0.775	0.768	0.760
0																									
-25	0.919	0.908	0.898	0.886	0.876	0.868	0.858	0.849	0.840	0.831	0.822	0.814	0.805	0.796	0.788	0.779	0.770	0.761	0.751	0.741	0.730	0.720	0.708	0.697	0.684
-50	0.952	0.947	0.942	0.936	0.932	0.927	0.922	0.918	0.913	0.909	0.904	0.900	0.895	0.890	0.885	0.880	0.874	0.869	0.863	0.856	0.849	0.842	0.834	0.825	0.815
-75	0.962	0.960	0.956	0.953	0.950	0.947	0.943	0.940	0.937	0.934	0.931	0.928	0.924	0.921	0.917	0.913	0.908	0.904	0.898	0.893	0.886	0.879	0.871	0.862	0.851
-100	0.967	0.965	0.963	0.960	0.958	0.956	0.953	0.951	0.949	0.946	0.944	0.942	0.939	0.935	0.932	0.928	0.924	0.920	0.915	0.909	0.902	0.894	0.885	0.874	0.859
-125	0.969	0.968	0.967	0.965	0.963	0.961	0.959	0.957	0.955	0.953	0.951	0.949	0.947	0.944	0.940	0.937	0.933	0.928	0.923	0.916	0.909	0.899	0.888	0.872	0.851
-150	0.971	0.970	0.969	0.967	0.966	0.964	0.962	0.961	0.959	0.958	0.956	0.954	0.952	0.949	0.945	0.942	0.938	0.933	0.926	0.919	0.910	0.898	0.882	0.859	0.826
-175	0.971	0.971	0.970	0.969	0.967	0.966	0.965	0.963	0.962	0.960	0.959	0.957	0.955	0.952	0.949	0.945	0.940	0.934	0.927	0.918	0.906	0.890	0.867		
-200	0.972	0.972	0.971	0.970	0.969	0.967	0.966	0.965	0.964	0.962	0.961	0.959	0.957	0.954	0.950	0.946	0.941	0.934	0.926	0.914	0.898				
-225	0.972	0.972	0.971	0.970	0.969	0.968	0.967	0.966	0.965	0.964	0.963	0.961	0.958	0.955	0.951	0.947	0.941	0.933	0.922						
-250	0.972	0.972	0.972	0.971	0.970	0.969	0.968	0.967	0.966	0.965	0.963	0.962	0.959	0.956	0.951	0.946	0.939	0.929							
-275	0.971	0.972	0.972	0.971	0.970	0.969	0.968	0.967	0.966	0.965	0.964	0.962	0.960	0.956	0.951	0.945									
-300	0.971	0.972	0.972	0.971	0.970	0.969	0.968	0.967	0.966	0.965	0.964	0.962	0.960	0.956	0.950										
-325	0.971	0.972	0.971	0.971	0.970	0.969	0.968	0.967	0.966	0.966	0.965	0.963	0.959	0.955											
-350	0.971	0.971	0.971	0.971	0.970	0.969	0.968	0.967	0.966	0.966	0.965	0.962	0.959												
-375	0.970	0.971	0.971	0.970	0.970	0.969	0.968	0.967	0.966	0.965	0.964	0.962	0.958												
-400	0.970	0.971	0.971	0.970	0.969	0.968	0.968	0.967	0.966	0.965	0.964	0.962													
-425	0.970	0.970	0.970	0.970	0.969	0.968	0.968	0.967	0.966	0.965	0.965	0.964	0.961												
-450	0.969	0.970	0.970	0.969	0.968	0.968	0.967	0.966	0.965	0.964	0.963														
-475	0.969	0.970	0.969	0.969	0.968	0.967	0.966	0.965	0.964	0.963	0.962														
-500	0.968	0.969	0.968	0.968	0.967	0.966	0.965	0.964	0.963	0.963															
-525	0.968	0.969	0.968	0.967	0.966	0.966	0.965	0.964	0.963	0.962															
-550	0.967	0.968	0.967	0.967	0.966	0.965	0.964	0.963	0.961	0.960															
-575	0.967	0.967	0.967	0.966	0.965	0.964	0.963	0.961	0.960																
-600	0.966	0.967	0.966	0.965	0.964	0.963	0.961	0.960	0.959																
-625	0.966	0.966	0.965	0.964	0.962	0.961	0.960	0.958	0.957																
-650	0.965	0.965	0.964	0.963	0.961	0.960	0.958	0.957																	
-675	0.964	0.964	0.963	0.961	0.960	0.958	0.956	0.955																	
-700	0.963	0.963	0.961	0.960	0.958	0.956	0.954	0.952																	
-725	0.963	0.962	0.960	0.958	0.956	0.953	0.951	0.949																	
-750	0.961	0.960	0.958	0.955	0.953	0.951	0.948	0.946																	
-775	0.960	0.958	0.956	0.953	0.950	0.947	0.945																		
-800	0.959	0.956	0.953	0.950	0.947	0.943	0.940																		
-825	0.957	0.954	0.950	0.946	0.942	0.939	0.935																		
-850	0.956	0.951	0.947	0.942	0.938	0.933	0.929																		
-875	0.953	0.948	0.942	0.937	0.931	0.926	0.922																		
-900	0.951	0.944	0.937	0.930	0.924	0.918																			
-925	0.947	0.939	0.931	0.923	0.915	0.908																			
-950	0.943	0.933	0.923	0.913	0.904	0.896																			
-975	0.939	0.925	0.913	0.901	0.890	0.880																			
-1000	0.932	0.915	0.900	0.886	0.873	0.860																			

Central Drive Motor

Torque [Nm] \ Speed [RPM]	500	1000	1500	2000	2500	3000	3500	4000	4500	5000	5500	6000	6500	7000	7500	8000	8500	9000	9500	10000	10500	11000	11500	12000	12500
1000	0.684	0.799	0.854	0.878	0.894	0.906																			
975	0.691	0.804	0.858	0.881	0.897	0.908																			
950	0.698	0.809	0.862	0.885	0.900	0.911																			
925	0.704	0.813	0.865	0.887	0.902	0.913																			
900	0.711	0.818	0.868	0.890	0.905	0.915																			
875	0.717	0.823	0.872	0.893	0.907	0.918	0.932																		
850	0.724	0.828	0.875	0.896	0.910	0.920	0.934																		
825	0.730	0.832	0.878	0.899	0.912	0.922	0.936																		
800	0.737	0.836	0.881	0.901	0.914	0.924	0.938																		
775	0.743	0.841	0.884	0.904	0.917	0.926	0.939																		
750	0.750	0.845	0.888	0.907	0.919	0.928	0.941	0.925																	
725	0.756	0.849	0.890	0.909	0.921	0.929	0.942	0.928																	
700	0.762	0.853	0.893	0.911	0.923	0.931	0.943	0.931																	
675	0.769	0.858	0.896	0.914	0.925	0.933	0.945	0.934																	
650	0.776	0.862	0.899	0.916	0.926	0.934	0.946	0.937																	
625	0.782	0.865	0.902	0.918	0.928	0.936	0.947	0.939	0.926																
600	0.788	0.869	0.904	0.920	0.930	0.937	0.948	0.941	0.930																
575	0.795	0.874	0.907	0.922	0.932	0.939	0.949	0.944	0.934																
550	0.801	0.877	0.909	0.924	0.933	0.940	0.950	0.945	0.937	0.915															
525	0.807	0.881	0.912	0.926	0.934	0.941	0.950	0.947	0.940	0.919															
500	0.813	0.884	0.914	0.927	0.936	0.942	0.951	0.948	0.942	0.923															
475	0.820	0.888	0.916	0.929	0.937	0.943	0.951	0.950	0.945	0.928	0.930														
450	0.825	0.891	0.918	0.930	0.938	0.943	0.951	0.951	0.947	0.931	0.933														
425	0.831	0.894	0.920	0.931	0.939	0.944	0.951	0.951	0.948	0.934	0.936	0.924													
400	0.837	0.898	0.922	0.933	0.940	0.944	0.951	0.952	0.950	0.937	0.939	0.928													
375	0.844	0.901	0.924	0.934	0.941	0.945	0.951	0.953	0.951	0.940	0.942	0.933	0.920												
350	0.849	0.904	0.925	0.935	0.941	0.945	0.951	0.953	0.951	0.941	0.943	0.935	0.923												
325	0.855	0.906	0.927	0.936	0.942	0.945	0.951	0.952	0.952	0.943	0.945	0.937	0.926	0.927											
300	0.861	0.910	0.929	0.937	0.942	0.946	0.951	0.952	0.952	0.944	0.946	0.939	0.929	0.930	0.939										
275	0.868	0.913	0.930	0.938	0.943	0.946	0.950	0.952	0.952	0.946	0.947	0.941	0.932	0.932	0.941	0.948									
250	0.872	0.915	0.931	0.938	0.943	0.945	0.949	0.951	0.952	0.945	0.947	0.941	0.932	0.932	0.940	0.947	0.953	0.958							
225	0.878	0.917	0.932	0.939	0.942	0.945	0.948	0.950	0.951	0.945	0.946	0.940	0.932	0.932	0.939	0.945	0.951	0.956	0.961						
200	0.885	0.920	0.934	0.939	0.943	0.945	0.947	0.949	0.950	0.945	0.946	0.940	0.933	0.932	0.939	0.944	0.949	0.954	0.958	0.961	0.964				
175	0.890	0.922	0.934	0.939	0.942	0.944	0.946	0.947	0.948	0.944	0.944	0.939	0.932	0.931	0.937	0.942	0.947	0.951	0.954	0.957	0.960	0.963	0.965		
150	0.894	0.923	0.934	0.939	0.941	0.943	0.944	0.945	0.946	0.942	0.942	0.937	0.929	0.928	0.934	0.939	0.943	0.947	0.950	0.953	0.956	0.958	0.960	0.962	0.963
125	0.900	0.925	0.934	0.938	0.940	0.941	0.942	0.942	0.943	0.940	0.938	0.933	0.926	0.924	0.930	0.934	0.938	0.942	0.945	0.948	0.950	0.952	0.954	0.955	0.957
100	0.908	0.927	0.934	0.936	0.938	0.938	0.938	0.938	0.938	0.935	0.933	0.927	0.920	0.918	0.923	0.927	0.931	0.934	0.936	0.939	0.941	0.943	0.944	0.945	0.946
75	0.892	0.913	0.921	0.923	0.925	0.925	0.924	0.924	0.924	0.921	0.917	0.910	0.901	0.899	0.905	0.910	0.914	0.918	0.921	0.924	0.926	0.928	0.930	0.931	0.933
50	0.843	0.875	0.886	0.889	0.891	0.891	0.890	0.889	0.889	0.885	0.880	0.869	0.855	0.851	0.860	0.868	0.874	0.880	0.885	0.889	0.893	0.896	0.898	0.900	0.903
25	0.695	0.756	0.777	0.784	0.787	0.788	0.785	0.784	0.784	0.774	0.764	0.742	0.715	0.707	0.725	0.740	0.753	0.764	0.774	0.782	0.790	0.796	0.800	0.805	0.810
-25	0.695	0.756	0.777	0.784	0.787	0.788	0.785	0.784	0.784	0.774	0.764	0.742	0.715	0.707	0.725	0.740	0.753	0.764	0.774	0.782	0.790	0.796	0.800	0.805	0.810
-50	0.843	0.875	0.886	0.889	0.891	0.891	0.890	0.889	0.889	0.885	0.880	0.869	0.855	0.851	0.860	0.868	0.874	0.880	0.885	0.889	0.893	0.896	0.898	0.900	0.903
-75	0.892	0.913	0.921	0.923	0.925	0.925	0.924	0.924	0.924	0.921	0.917	0.910	0.901	0.899	0.905	0.910	0.914	0.918	0.921	0.924	0.926	0.928	0.930	0.931	0.933
-100	0.908	0.927	0.934	0.936	0.938	0.938	0.938	0.938	0.938	0.935	0.933	0.927	0.920	0.918	0.923	0.927	0.931	0.934	0.936	0.939	0.941	0.943	0.944	0.945	0.946
-125	0.900	0.925	0.934	0.938	0.940	0.941	0.942	0.942	0.943	0.940	0.938	0.933	0.926	0.924	0.930	0.934	0.938	0.942	0.945	0.948	0.950	0.952	0.954	0.955	0.957
-150	0.894	0.923	0.934	0.939	0.941	0.943	0.944	0.945	0.946	0.942	0.942	0.937	0.929	0.928	0.934	0.939	0.943	0.947	0.950	0.953	0.956	0.958	0.960	0.962	0.963
-175	0.890	0.922	0.934	0.939	0.942	0.944	0.946	0.947	0.948	0.944	0.944	0.939	0.932	0.931	0.937	0.942	0.947	0.951	0.954	0.957	0.960	0.963	0.965		
-200	0.885	0.920	0.934	0.939	0.943	0.945	0.947	0.949	0.950	0.945	0.946	0.940	0.933	0.932	0.939	0.944	0.949	0.954	0.958	0.961	0.964				
-225	0.878	0.917	0.932	0.939	0.942	0.945	0.948	0.950	0.951	0.945	0.946	0.940	0.932	0.932	0.939	0.945	0.951	0.956	0.961						
-250	0.872	0.915	0.931	0.938	0.943	0.945	0.949	0.951	0.952	0.945	0.947	0.941	0.932	0.932	0.940	0.947	0.953	0.958							
-275	0.868	0.913	0.930	0.938	0.943	0.946	0.950	0.952	0.952	0.946	0.947	0.941	0.932	0.932	0.941	0.948									
-300	0.861	0.910	0.929	0.937	0.942	0.946	0.951	0.952	0.952	0.944	0.946	0.939	0.929	0.930	0.939										
-325	0.855	0.906	0.927	0.936	0.942	0.945	0.951	0.952	0.952	0.943	0.945	0.937	0.926	0.927											
-350	0.849	0.904	0.925	0.935	0.941	0.945	0.951	0.953	0.951	0.941	0.943	0.935	0.923												
-375	0.844	0.901	0.924	0.934	0.941	0.945	0.951	0.953	0.951	0.940	0.942	0.933	0.920												
-400	0.837	0.898	0.922	0.933	0.940	0.944	0.951	0.952	0.950	0.937	0.939	0.928													
-425	0.831	0.894	0.920	0.931	0.939	0.944	0.951	0.951	0.948	0.934	0.936	0.924													
-450	0.825	0.891	0.918	0.930	0.938	0.943	0.951	0.951	0.947	0.931	0.933														
-475	0.820	0.888	0.916	0.929	0.937	0.943	0.951	0.950	0.945	0.928	0.930														
-500	0.813	0.884	0.914	0.927	0.936	0.942	0.951	0.948	0.942	0.923															
-525	0.807	0.881	0.912	0.926	0.934	0.941	0.950	0.947	0.940	0.919															
-550	0.801	0.877	0.909	0.924	0.933	0.940	0.950	0.945	0.937	0.915															
-575	0.795	0.874	0.907	0.922	0.932	0.939	0.949	0.944	0.934																
-600	0.788	0.869	0.904	0.920	0.930	0.937	0.948	0.941	0.930																
-625	0.782	0.865	0.902	0.918	0.928	0.936	0.947	0.939	0.926																
-650	0.776	0.862	0.899	0.916	0.926	0.934	0.946	0.937																	
-675	0.769	0.858	0.896	0.914	0.925	0.933	0.945	0.934																	
-700	0.762	0.853	0.893	0.911	0.923	0.931	0.943	0.931																	
-725	0.756	0.849	0.890	0.909	0.921	0.929	0.942	0.928																	
-750	0.750	0.845	0.888	0.907	0.919	0.928	0.941	0.925																	
-775	0.743	0.841	0.884	0.904	0.917	0.926	0.939																		
-800	0.737	0.836	0.881	0.901	0.914	0.924	0.938																		
-825	0.730	0.832	0.878	0.899	0.912	0.922	0.936																		
-850	0.724	0.828	0.875	0.896	0.910	0.920	0.934																		
-875	0.717	0.823	0.872	0.893	0.907	0.918	0.932																		
-900	0.711	0.818	0.868	0.890	0.905	0.915																			
-925	0.704	0.813	0.865	0.887	0.902	0.913																			
-950	0.698	0.809	0.862	0.885	0.900	0.911																			
-975	0.691	0.804	0.858	0.881	0.897	0.908																			
-1000	0.684	0.799	0.854	0.878	0.894	0.906																			

- eAxle: 290 mm OD eMotor & 14.711:1 gearbox
- Central Drive: 430 mm OD eMotor & 5.57:1 gearbox
- Simulated eAxle efficiency exceeds Central Drive efficiency at all points with the exception high speed / low torque operation.
- Contributors:
  - Larger eMotor
  - Hypoid Gears (sliding mesh losses)
  - Additional U-Joint Losses
  - Additional Seal Losses
  - Higher Oil Churning Losses

Vehicle Range

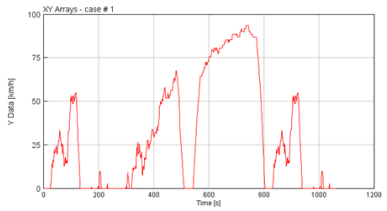
Common Vehicle Parameters

Parameter	Value	Unit
Mass	11,000	kg
Tire radius	0.398	m
Rolling friction	0.01	
Wheelbase	3.683	m
Frontal Area	6.5	m^2
Aero Drag Coef.	0.606	

Common Electrical Parameters

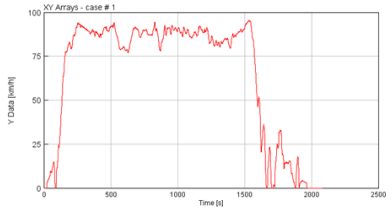
Parameter	Value	Unit
Max Voltage	800	V
Nominal Voltage	700	V
Min Voltage	600	V
Max Discharge Current	475	Amps
Max Charging Current	300	Amps

Heavy-Duty Urban Dynamometer Driving Schedule (HDUDDS)



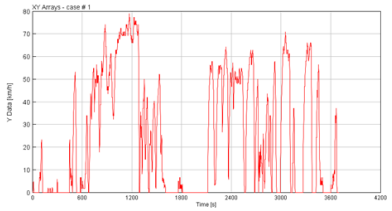
City Drive Cycle

Heavy Heavy-Duty Diesel Truck (HHDDT)



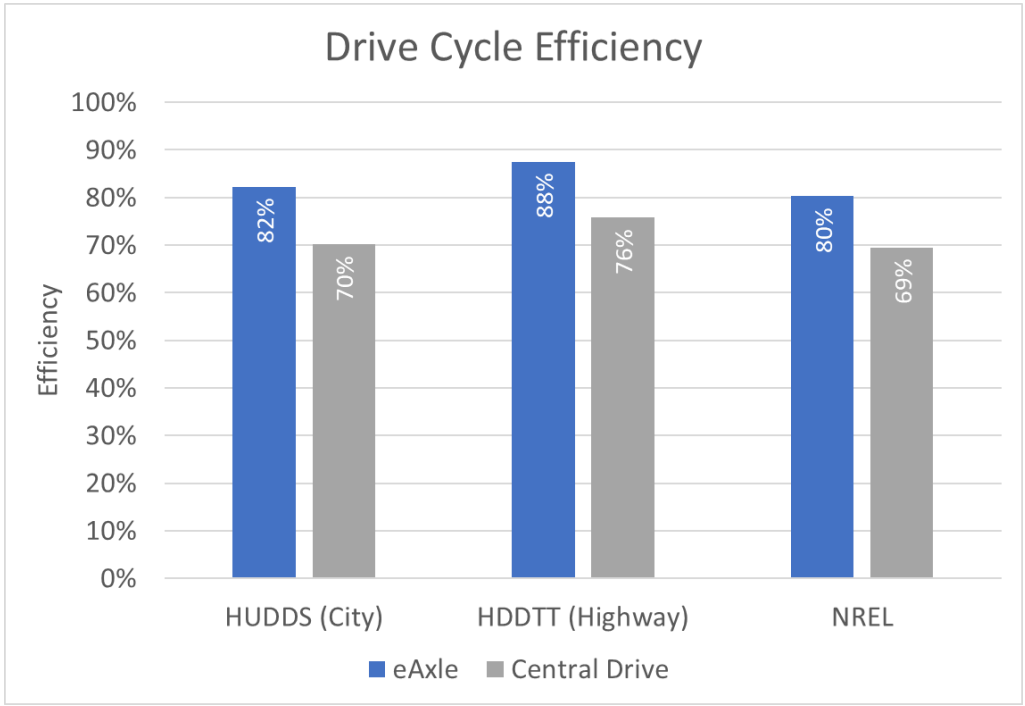
Highway Drive Cycle

NREL Class 6 EV Cycle (NREL)



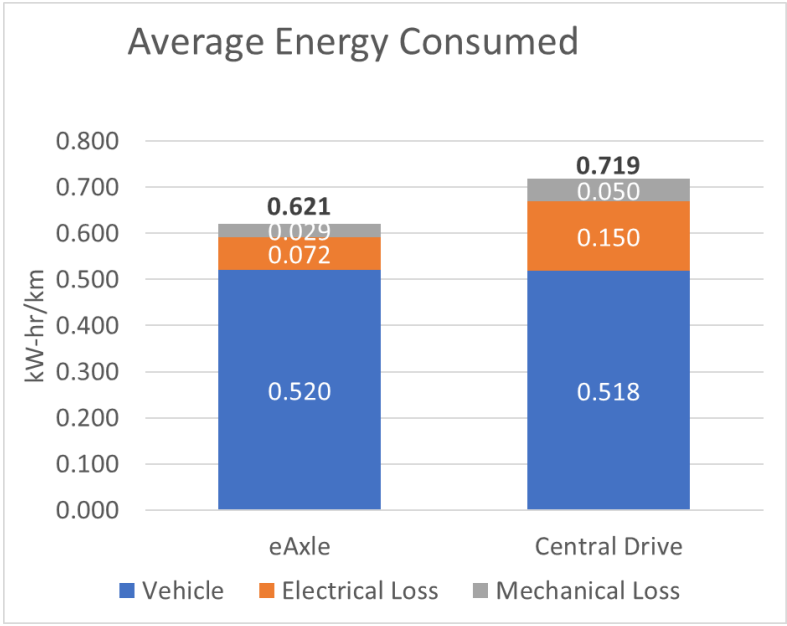
Mixed Use EV

- Range analysis completed for a standard Class 6 vehicle equipped with an 800 V electrical system
- eAxle efficiency exceeds that of a central drive system over a diverse range of drive cycles
  - Mechanical gearbox losses do play a role but electrical losses from a larger eMotor and higher currents are the primary contributor.

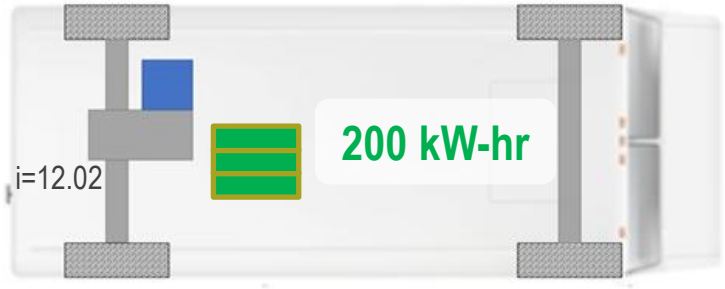


Vehicle Range

- Vehicle range calculated for a 200kW-hr Battery
  - Range delta expected to be more drastic w/ additional battery capacity onboard eAxle-equipped vehicles

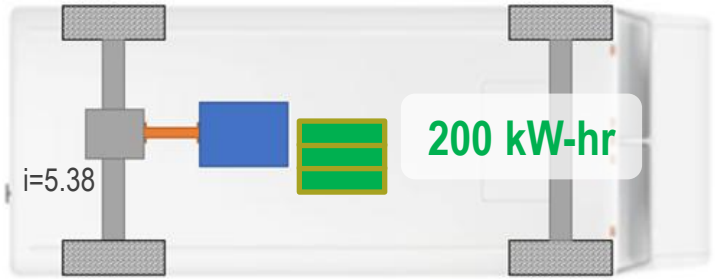


eAxle



322 km Range

Central Drive

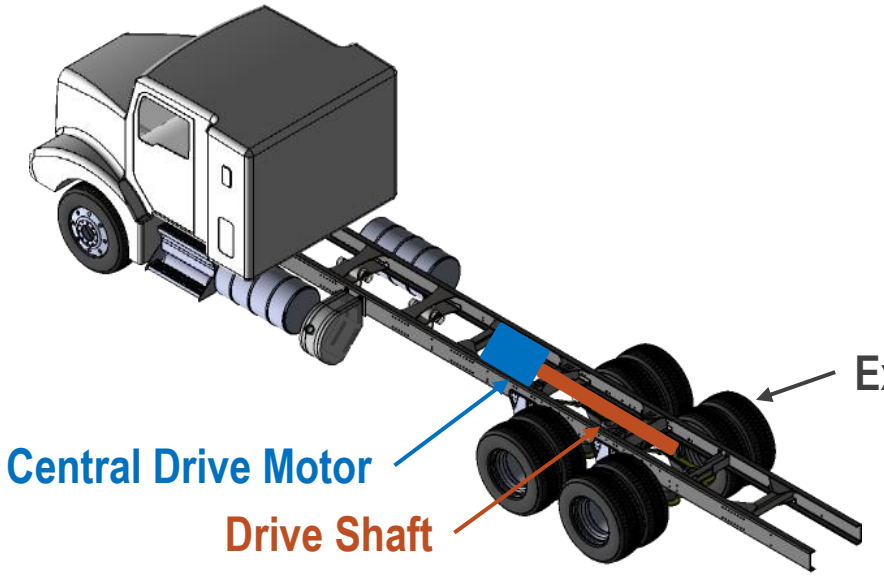


264 km Range

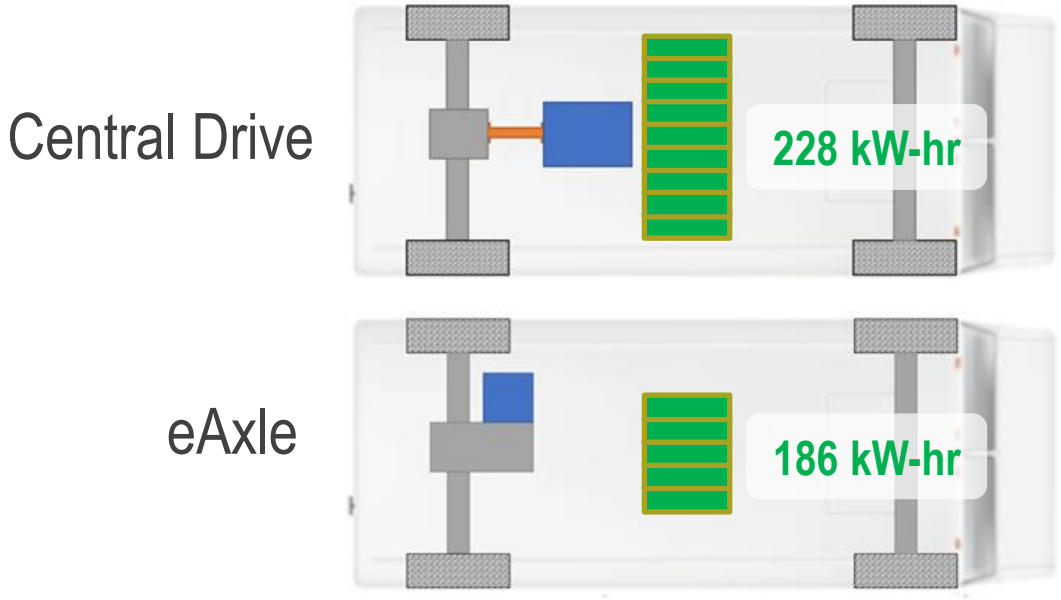
+58 km Range

Conversion Complexity and Cost

- Central Drive
  - Integration costs savings – Retrofit can reuse existing vehicle rear axle for reduced cost.
- eAxle
  - High volume costs savings – Integrated design can reduce material and manufacturing costs.
    - Lower eMotor cost (smaller motor)
    - Eliminate drive shaft
    - Reduce duplicate components (housings, seals, bearings, etc.)
  - Higher efficiency system means smaller battery for equal range
    - eAxle from previous study shows a 42 kW-hr battery size reduction for the same 300 km vehicle range
    - Approximate $4,200 cost reduction, assuming a $100 / kW-hr battery pricing

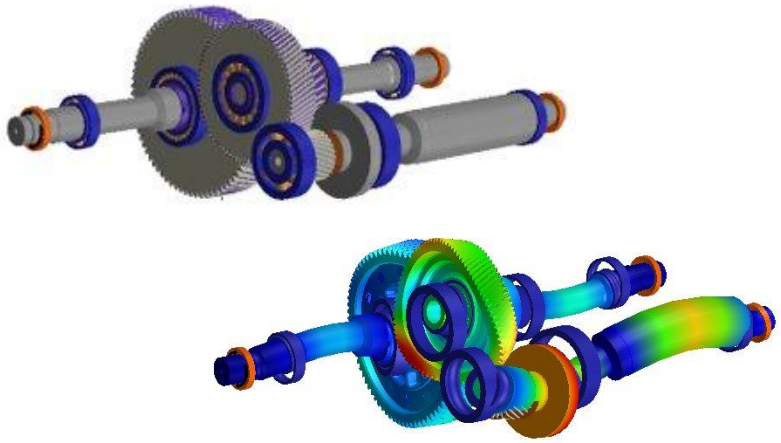


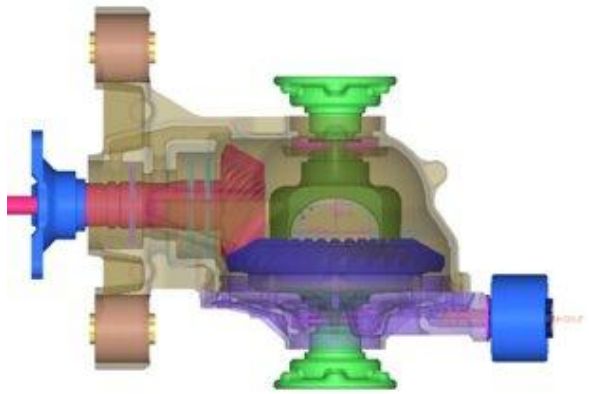
Battery size for a 300-km range



NVH | eAxle (Helical Gears) vs. Central Drive (Hypoid Gears)

	eAxle	Central Drive
eMotor Noise	Higher frequency noise due to typical operating speed range	Lower frequency (potentially more audible) noise
eMotor Vibration	Motor mounted farther from the driver and isolated by the suspension.	Motor mounted closer to the driver and typically on chassis. Increased chance of structure borne NVH.
Gear Noise	Generally lower noise	Prone to gear whine in automotive applications
Tooth Engagement	Smooth, low-impact, quiet contact	Mixed rolling and sliding contact
Gear Vibration	Lower vibration due to higher contact ratio	Typically, increased vibration due to mixed rolling and sliding contact

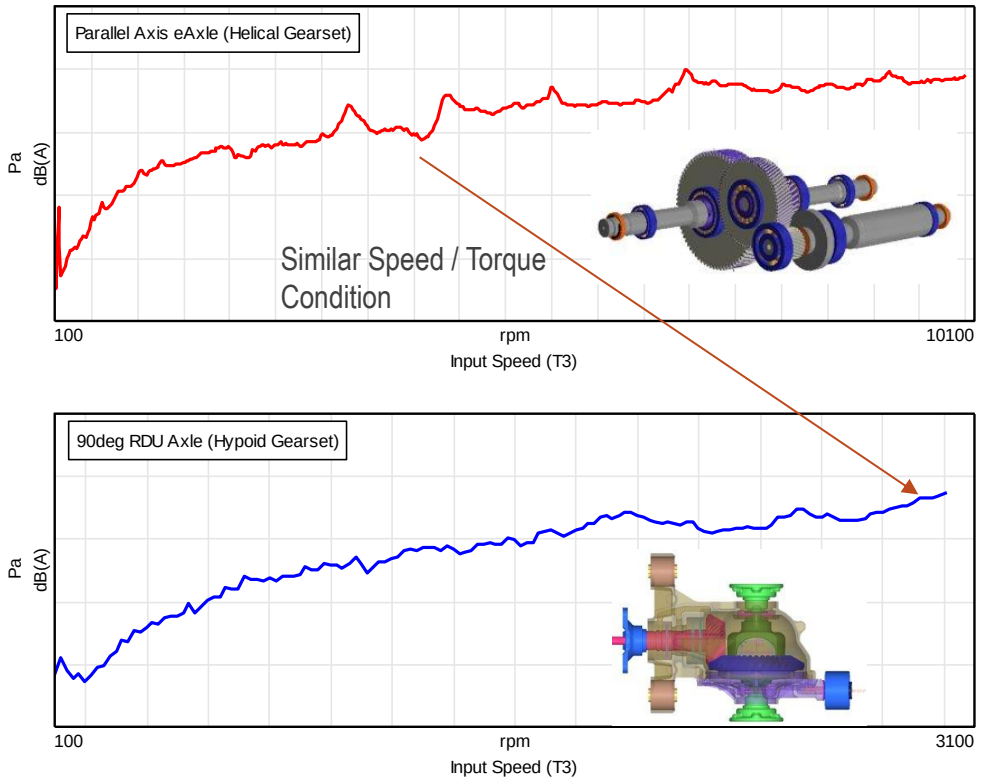




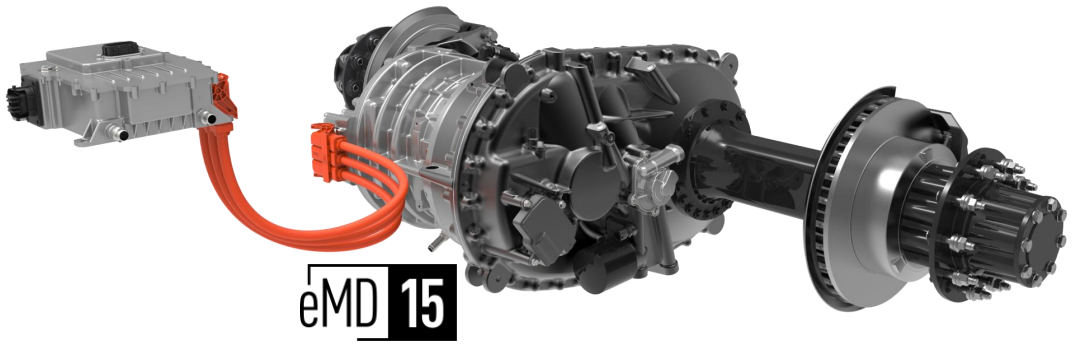
Regenerative Braking Capability

- ~25% reduction in bending fatigue strength in regen for hypoid gears
- Hypoid gearset NVH performance typically worse due to lower contact ratio in regen
  - Helical gear teeth can be optimized in both drive and regen conditions for NVH
  - Comparing hypoid to helical systems in coast condition shows significant reduction to overall sound pressure level and whine
    - Comparison shows as much as 7 dBA at comparable speeds

	Safety Factor
Central Drive (Hypoid)	1.2
eAxle (Helical)	1.5
Difference	+25%

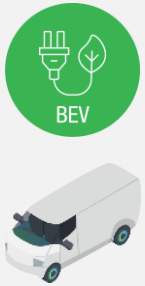


eMD15 Class 4-6 Commercial Vehicle eAxle



Features

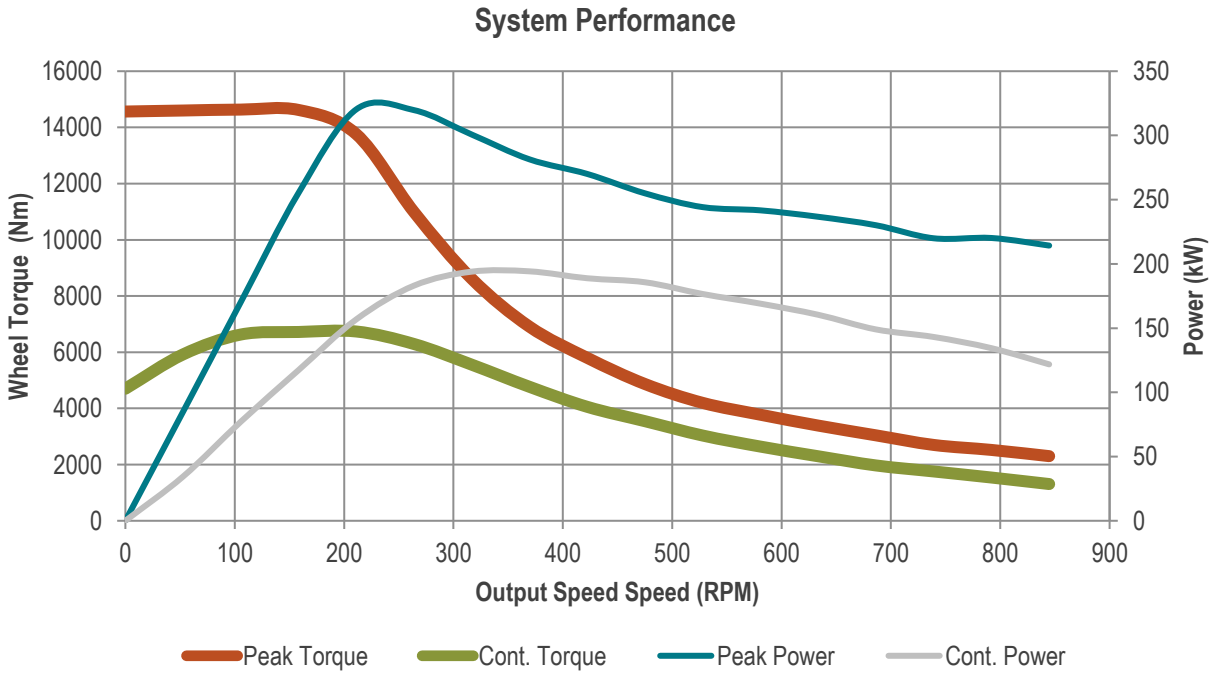
- Designed for Classes 5 & 6
- Forced Lubrication w/Filter
- Optional Electric Park Lock
- Single Speed Gearbox
- Optional Limited Slip Differential
- Multiple Gear Ratios Available
- Customizable Track Width
- Adaptable to Preferred Wheel Ends



Class 1	Class 2	Class 3	Class 4	Class 5	Class 6	Class 7	Class 8

Performance Specifications	
Voltage (V)	**800**
GAWR	17,500 lbs. / 7,938 kg
Peak Output Torque (Nm)	15,000*
Continuous Output Torque (Nm):	7,546*
Peak Power (kW)	295
Continuous Power (kW):	195
Max Output Shaft Speed (RPM):	856*
Park Lock	Optional (Electric Actuation)
Limited Slip Differential	Optional
Weight (kg)	1256 lbs. / 570 kg

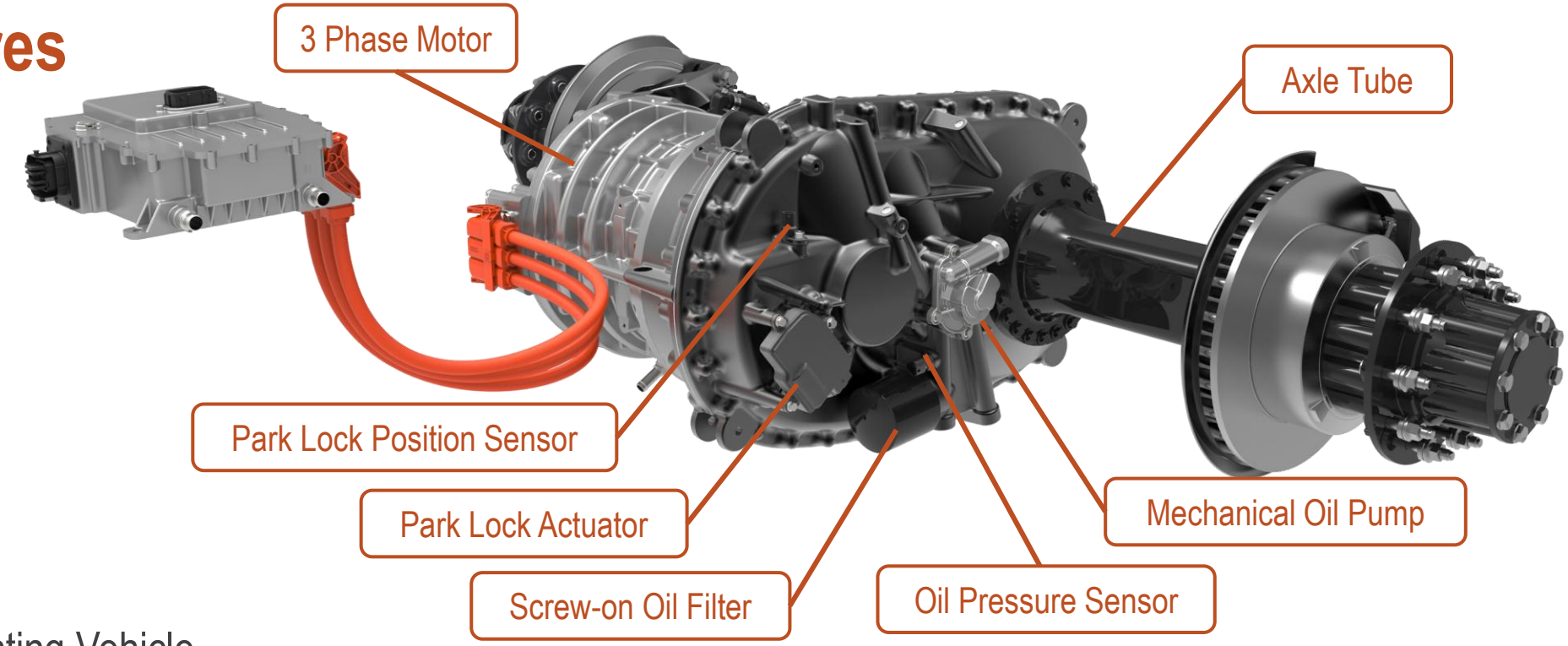
**Varies with Ratio Selected*

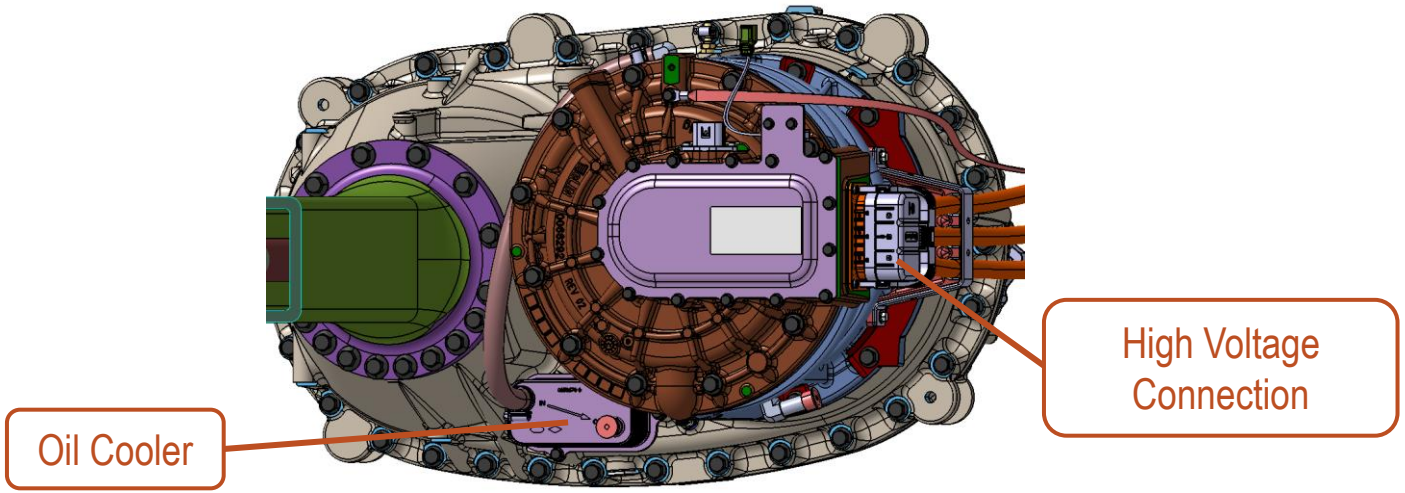


800V System evaluated with 14.711:1 Ratio

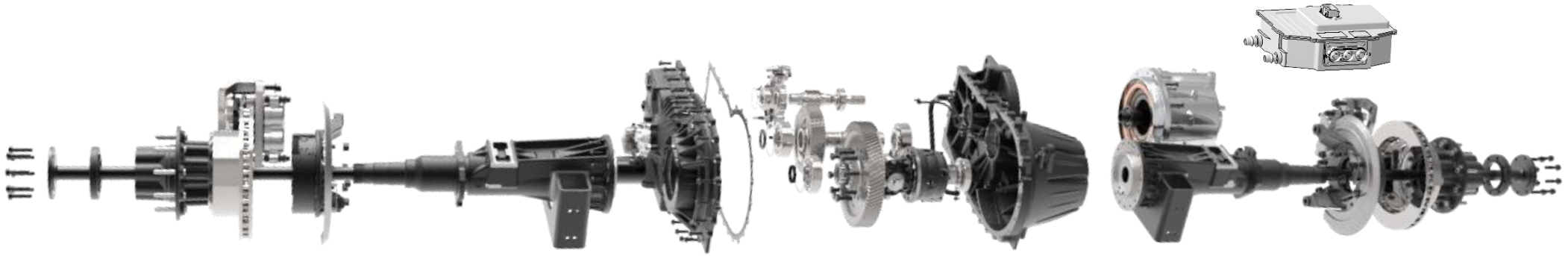
Key Design Features

- Single Speed Gearbox
- Regenerative Braking
- Integrated Park Lock
- Oil and Water-Cooled Motor
- Oil Cooler
- Forced Lubrication
- Open Differential
- Drop-In Replacement for Existing Vehicle Applications
  - Standard Banjo Style Suspension Interface
  - Customizable Track Width and Brake Flange





eMD15 Commercial Beam eAxle | Customization



Axle Tubes

- Variable Track Widths and Frame Rail Widths
- Scalable Design for Various Class 4 to 6 GAWR Requirements
- Cast and Welded Tube Designs

Park Lock

- Park Lock Standard
- Park Lock Delete Options Available

Gearbox

- Multiple Ratios Available
- mLSD Optional

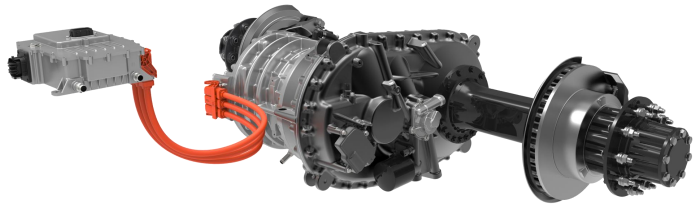
Brakes / Hubs

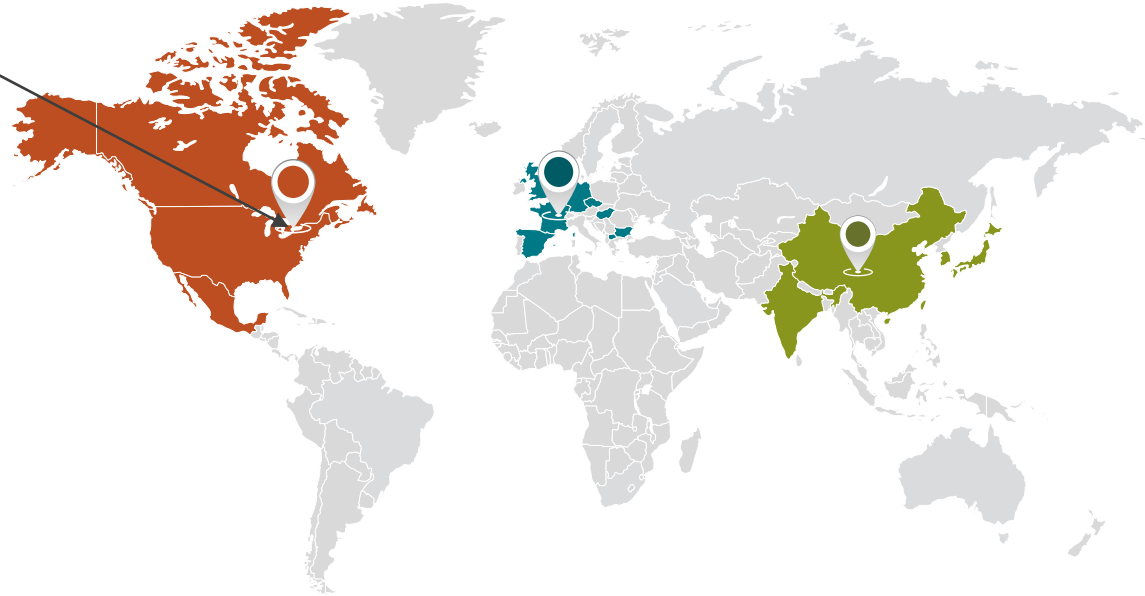
- L-Series and R-Series Spindles Available
- Flexible for Customer Dictated Hub and Brake Assemblies
- Drum and Disc Brake Variants

eMD15 Commercial Beam eAxle | Manufacturing

Linamar production manufacturing and assembly lines installed in Guelph Ontario. Flexible capacity. This includes equipment for gear manufacturing, laser welding, differential assembly, complete gearbox assembly, complete eAxle assembly with quality checking machines, and full end of line testing.

eMD15 Commercial Beam Axle Production
Guelph Canada 2023



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