# The new Opel Ampera-e.

# Battery, Propulsion System and their operation.

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# CONTENT



# OPEL XEV TECHNOLOGY

## Ampera -E

- 2016 ff
- Pure BEV
- ZEV in City and
- ZEV on long Distance

## Ampera

- 2011 ff
- EREV
- ZEV in City & mid distances
- low dependence on public charge infrastructure

## HydroGen4

- 2006 ff
- ZEV in City & Long Distance
- Dependent from Hydrogen Infrastructure

Pure BEV type(s)

- "Limited" distance
- ZEV, dependent on public charge infrastructure

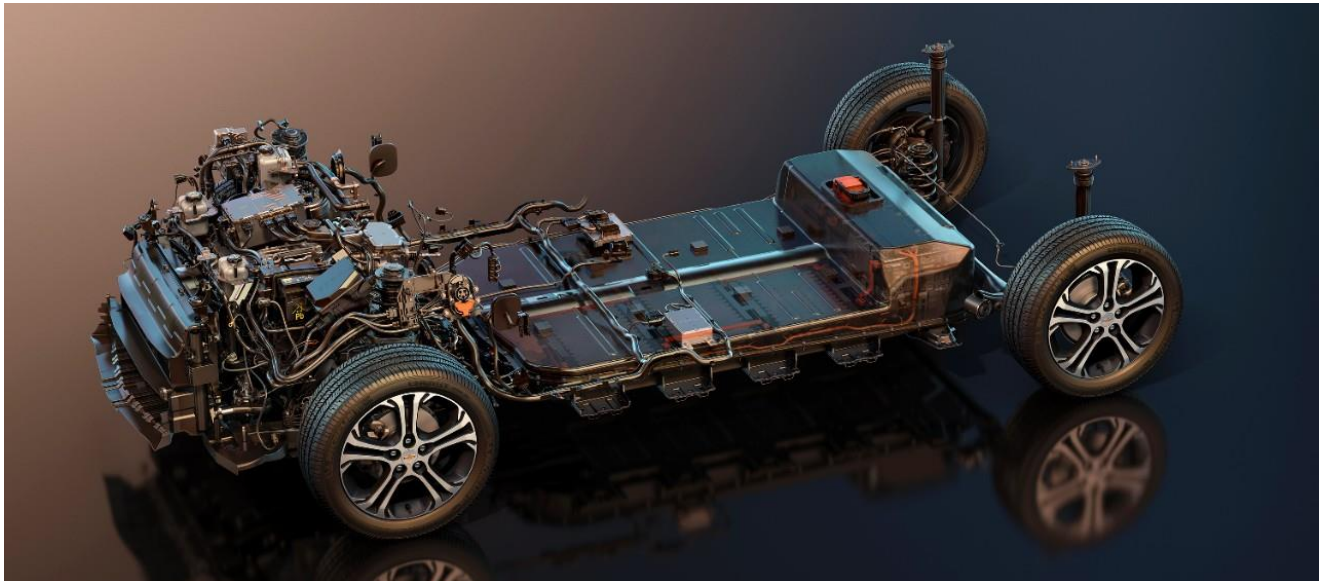
PHEV type(s)

- Universal „unlimited" distance
- Leverages fuel station infrastructure
- ZEV mode dependent on charge infrastructure

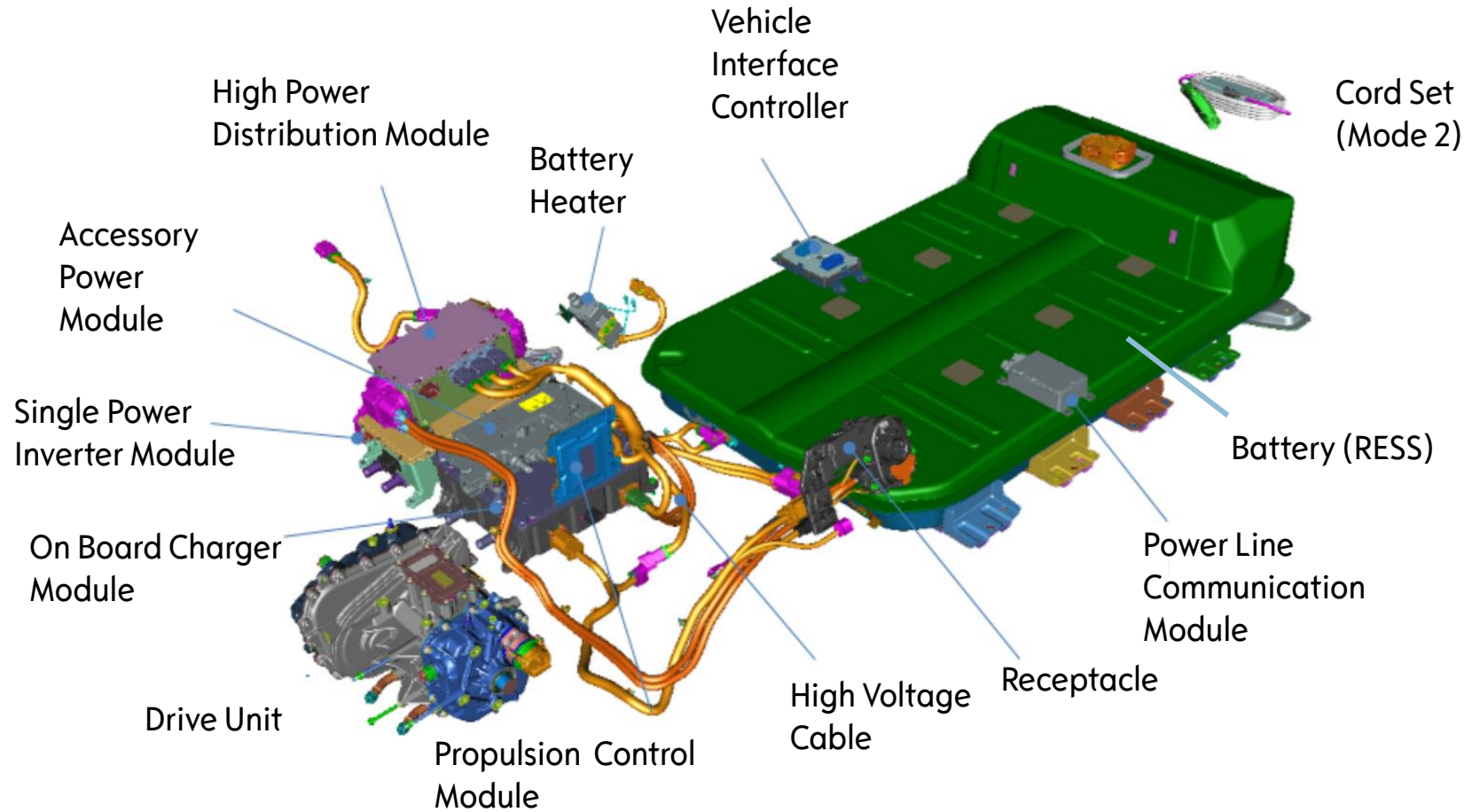
FCEV type(s)

- ZEV „unlimited" distance
- dependent on hydrogen infrastructure

# THE PROPULSION SYSTEM AT A GLANCE

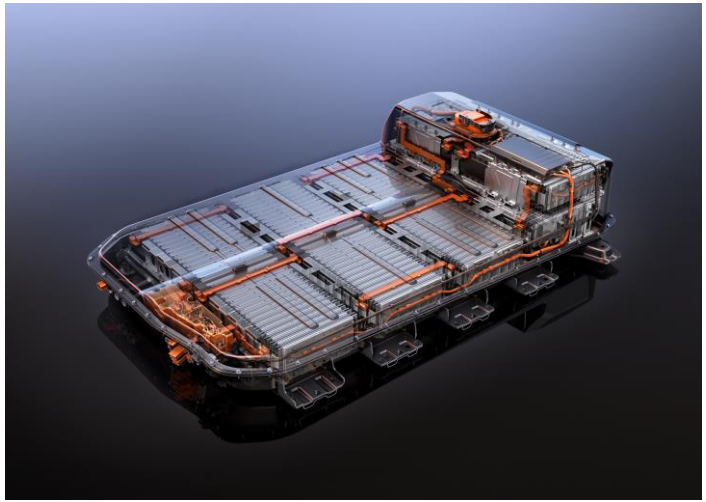


# THE PROPULSION SYSTEM AT A GLANCE



# BATTERY DESIGN

1. **Packaging/Space Utilization:** 5 sections with 2 modules each
2. **Cell and Electrode Format:** 288 cells in 96 cell groups (3P96S), nom. 350V
3. **Chemistry Selection:** Nickel-rich Li-ion chemistry for improved thermal performance
4. **Active Cooling and Heating:** Liquid cooled thermal system with fins on heatexchanger-plate
5. **Safety and Crash Regulation Requirement:** Meet rigorous internal crash design requirements in addition to applicable regulations (FMVSS, UN ECE etc.)



| | Opel Ampera-E |
|---|---|
| **Battery Chemistry** | Lithium Ion (Nickel – rich) |
| **Battery nom. Energy** | 60 kWh |
| **Battery Mass** | 429 kg |
| **Max Battery Power** | 160 kW |
| **Battery nom. Voltage** | 350V |



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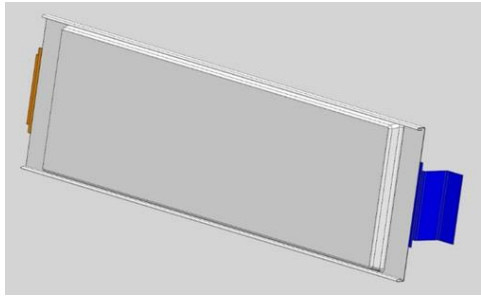
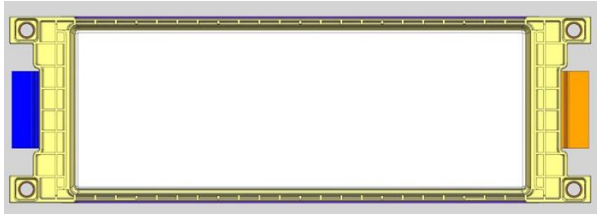
# PROGRESS BEV BATTERY

- **Triple the energy content to 60 kWh**
  - +50% energy density in Wh/kg
- **Power increase by 33% to 160 kW**
- **Effective vehicle integration**
- **Greater than 100 % more volumetric energy density Wh/l on pack level**
  - More than double the cell capacity in Ah
  - Large format pouch cells, footprint to enable „flat pack“
  - lower P/E ratio, while meeting power requirements
- **Designed for long-life:** advanced thermal system and controls



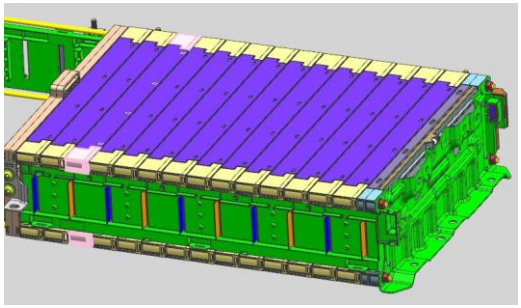
*BEV Gen 2 cell*



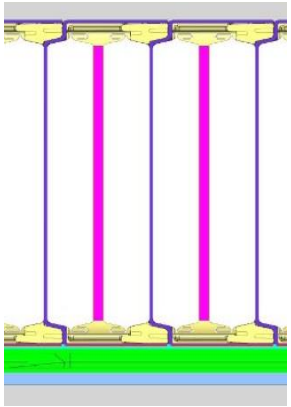
*BEV Gen 2 cell with frame*

# CELL MODULE ASSEMBLY (CMA)

- Interlocking cartridge holds two cells;  Repeating construction
- One cell cover acts as the cooling fin for a 2-cell assembly
- Cell Interfaces to a liquid-cooled cold plate through a thermally conductive material
- Cells are connected 3P96S, 2 module sizes 10s (30 cells in 10 groups) and 8s (24 cells in 8 groups)
- Equalized cooling to maximize battery life

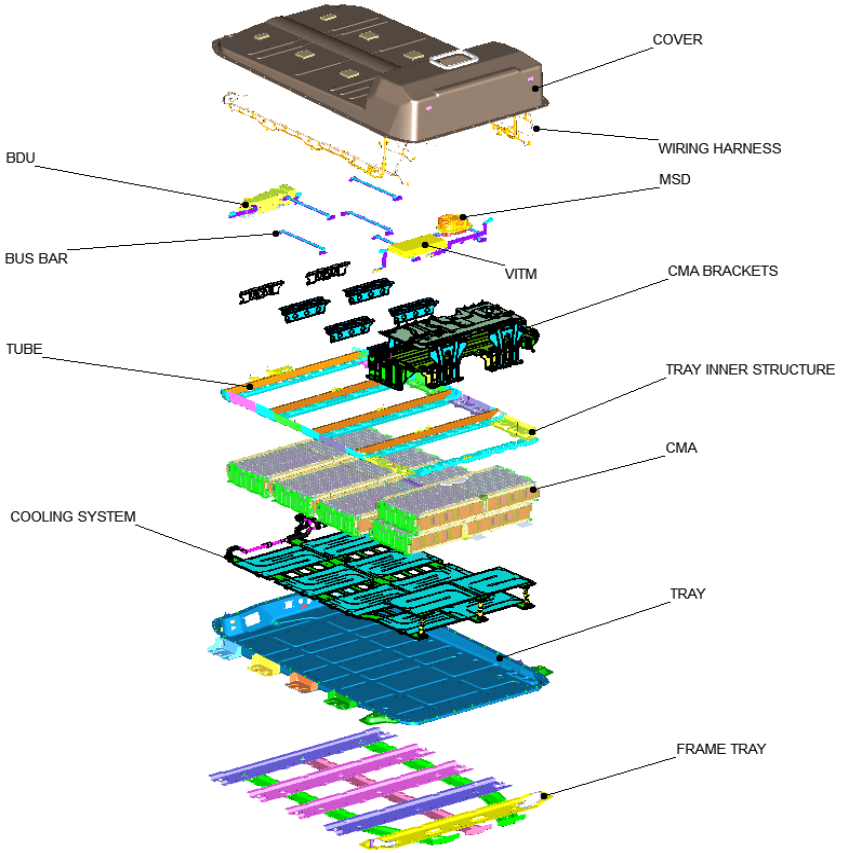


- *Cell Module Assembly (CMA)*



*Side view CMA to heat exchanger*

# BATTERY SYSTEM, COMPONENTS




Abbreviations:

- BDU Battery Disconnect Unit
- CMA Cell Module Assembly
- MSD Manual Service Disconnect
- VITM Voltage-Current- Temp. Module

# OPEL AMPERA-E BATTERY SYSTEM (CELL MODULE ASSEMBLY)

# OPEL AMPERA-E BATTERY SYSTEM (CELL MODULE ASSEMBLY)

# OPEL AMPERA-E BATTERY SYSTEM (BUSBARS, TUBES, BDU, MSD, BSM)

# OPEL AMPERA-E BATTERY SYSTEM WITH TRAY

# OPEL AMPERA-E BATTERY SYSTEM WITH TRAY AND COVER



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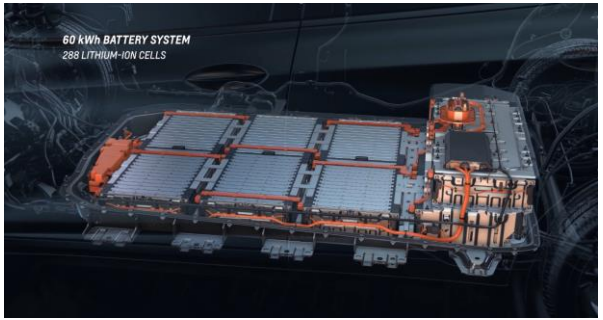
# OPEL AMPERA-E BATTERY SYSTEM COMPLETE

# SUMMARY OF BEV BATTERY




- **BEV battery system enables**

  **long range and great driving performance**

  - **60kWh of energy at 430kg providing a peak power of 160kW**
  - Specific Energy (mass) **Wh/kg plus >50% (system level)**
  - Energy density (volume) **Wh/L plus > 100 % (system level)**
  - Reduction of specific ($/kWh) system cost

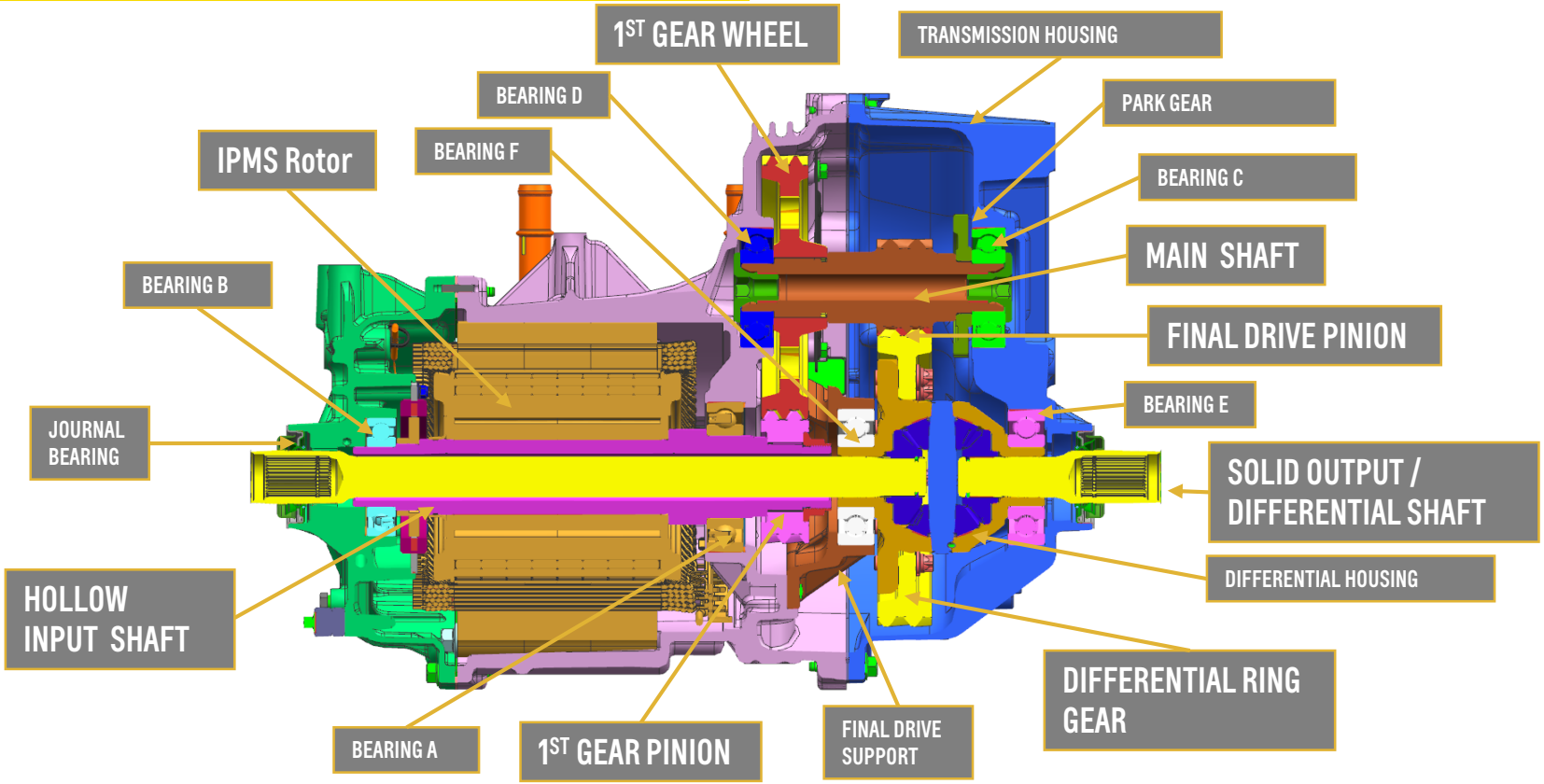
# THE DRIVE UNIT

## Overall Highlights:

- 2-shaft constant ratio (2 gear pairs), designed for increased e-Motor speeds at $v_{max}$
- Optimized lubrication with 12V oil pump (on demand)
- Cooled oil sump
- Optimized for N&V
- Interface: Shift Lever similar to AT

| | Opel Ampera-e |
|---|---|
| **Peak Axle Torque** | 2500 Nm |
| **Gear ratio** | 7.05 |
| **Mass** | 76 kg |
| **Oil Type** | DEXRON VI |
| **Total ATF Volume** | 2.9 ltr |

# THE DRIVE UNIT



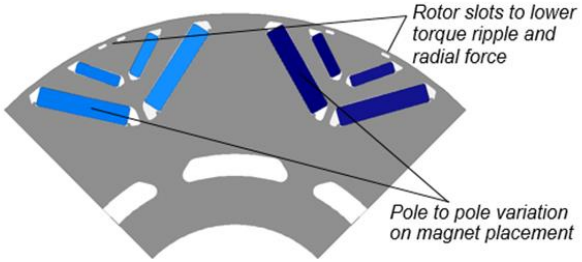
# THE ELECTRIC MOTOR (IPMS TYPE)

## Highlights:

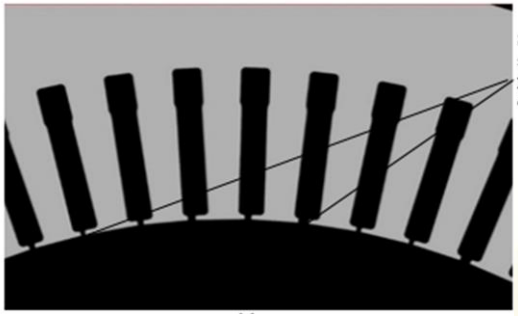
- Permanent Magnet Synchronous , IPMS type
- Double layer V-arrangement
- 30% total magnet mass reduction
- Max speed and Peak Power (density) increased, torque decreased
- 72 slots stator geometry, bar-wound, 6-conductors per slot
- 8-pole rotor geometry
- No skew in either Stator or Rotc

| | Opel Ampera-e |
|---|---|
| Peak Torque | 360 Nm |
| Peak Power | 150 kW |
| Max speed | 8810 rpm |
| Rated curr. | 400 Arms |
| Stack length | 125 mm |
| Outer Ø | 204 mm |
| Pole pairs | 4 |

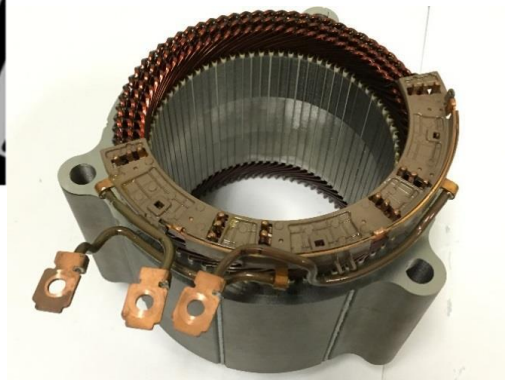
# DESIGN DETAILS OF THE IPMS MOTOR:




*Reduced torque ripple without skew, due to Rotor slots and Magnet placement varied*



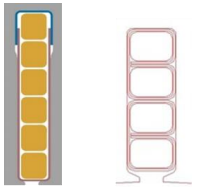

*Stator slot opening varied*



**6 conductor per slot design**

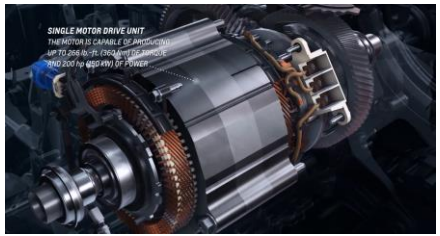
- Resistance AC effect reduced by smaller size
- Lowered voltage stress between conductors
- Simpler slot liner
- Better fill factor

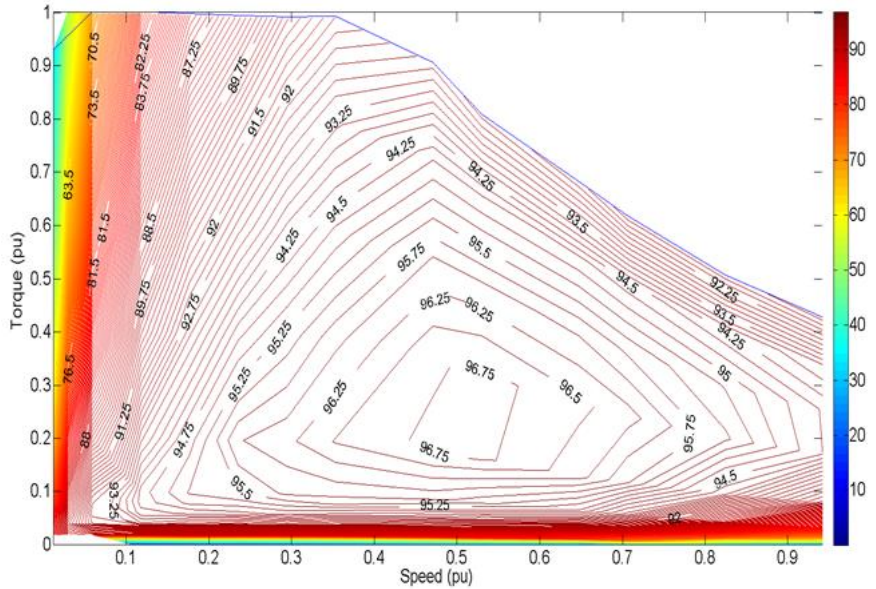
*„Hairpin“ Winding-Design*



*Ampera-e* *Previous Design*

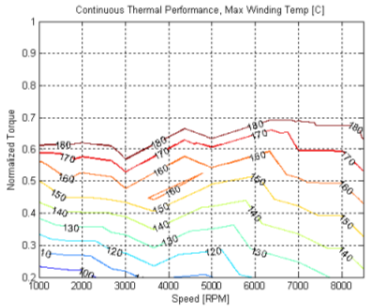
# PERMANENT AND TRANSIENT PERFORMANCE




## Very high efficiency

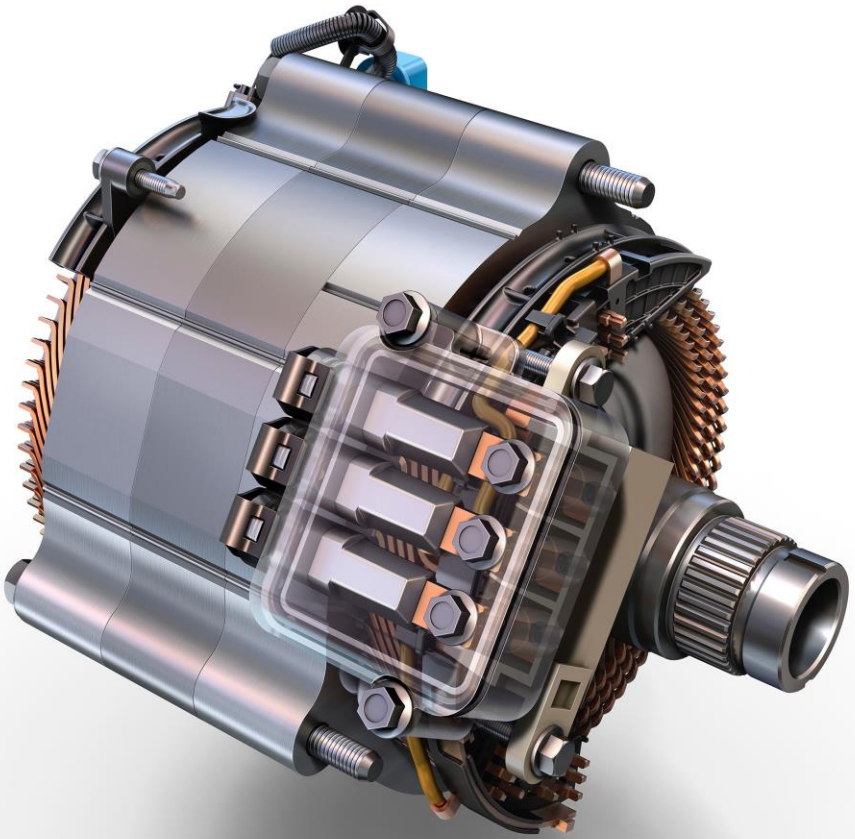
- Best area η >= 96,75%
- Huge n/M area with η > 95%




## Continuous thermal performance

- Can deliver 60-70% of peak power continuously
- Can deliver peak power to meet all drive performance requirements, e.g. passing

# THE ELECTRIC MOTOR



# CONTENT

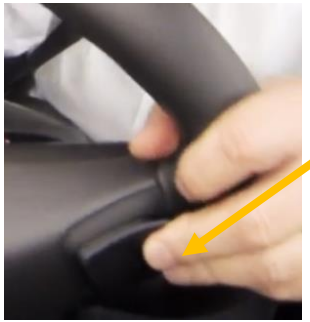
1. Electrification at Opel
2. Opel Ampera-e: Propulsion System Overview
3. BEV High Energy Battery
4. Drive Unit with Electric Motor
5. **Real World Data**
    1. Propulsion Highlight: One Pedal drive
    2. Battery usage
    3. Distances between Charges
    4. Engineering vs. “normal user“
6. **Summary**

# MODES OF ENERGY RECUPERATION

**Shifter**

“D” DRIVE

“L” LOW One-Pedal Mode (OPM)



Regen on Demand Paddle

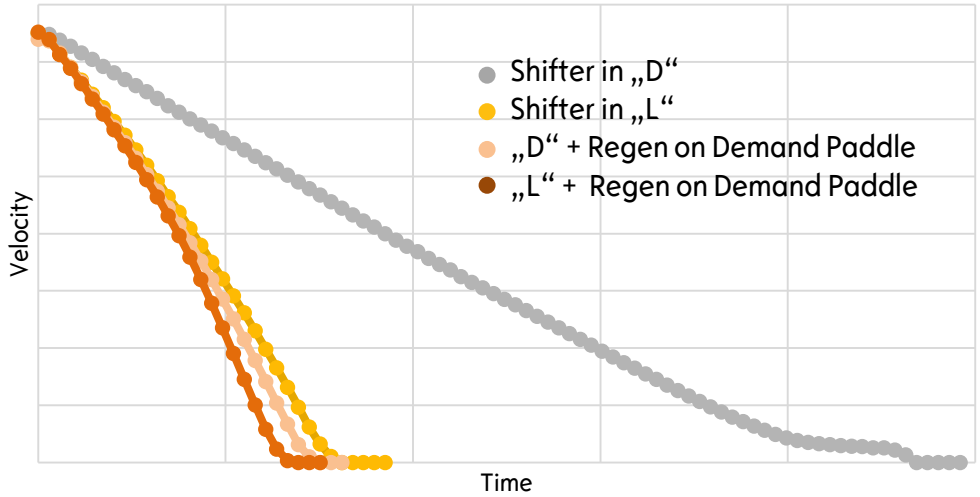
**Shifter in „D“**

**Shifter in „L“ = „One-Pedal mode“**

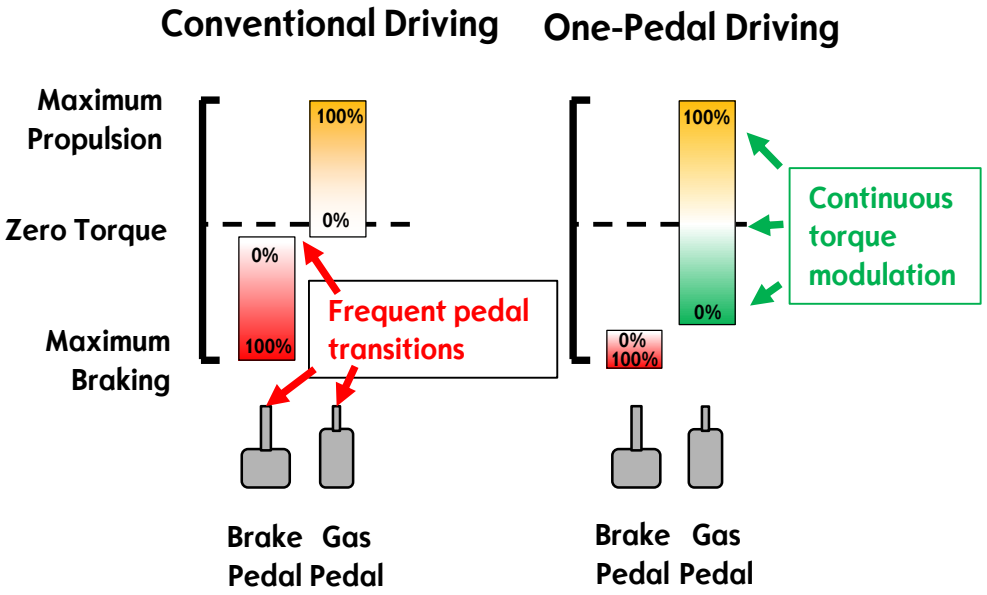
**„D“ + Regen on Demand Paddle**

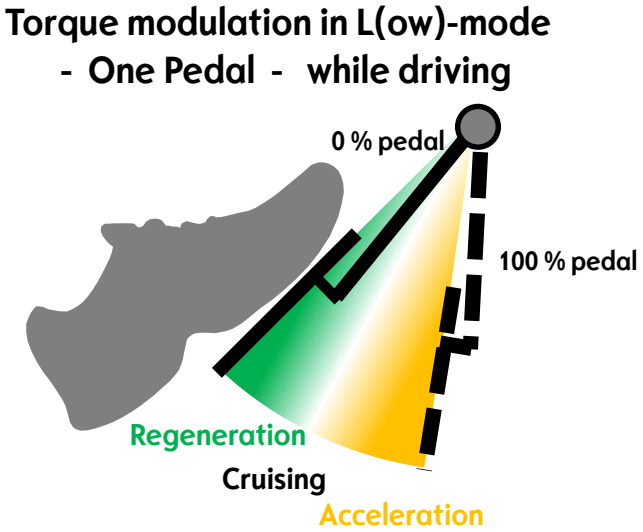
**„L“ + Regen on Demand Paddle**

**Deceleration in different drive modes**



# ONE-PEDAL MODE DRIVING

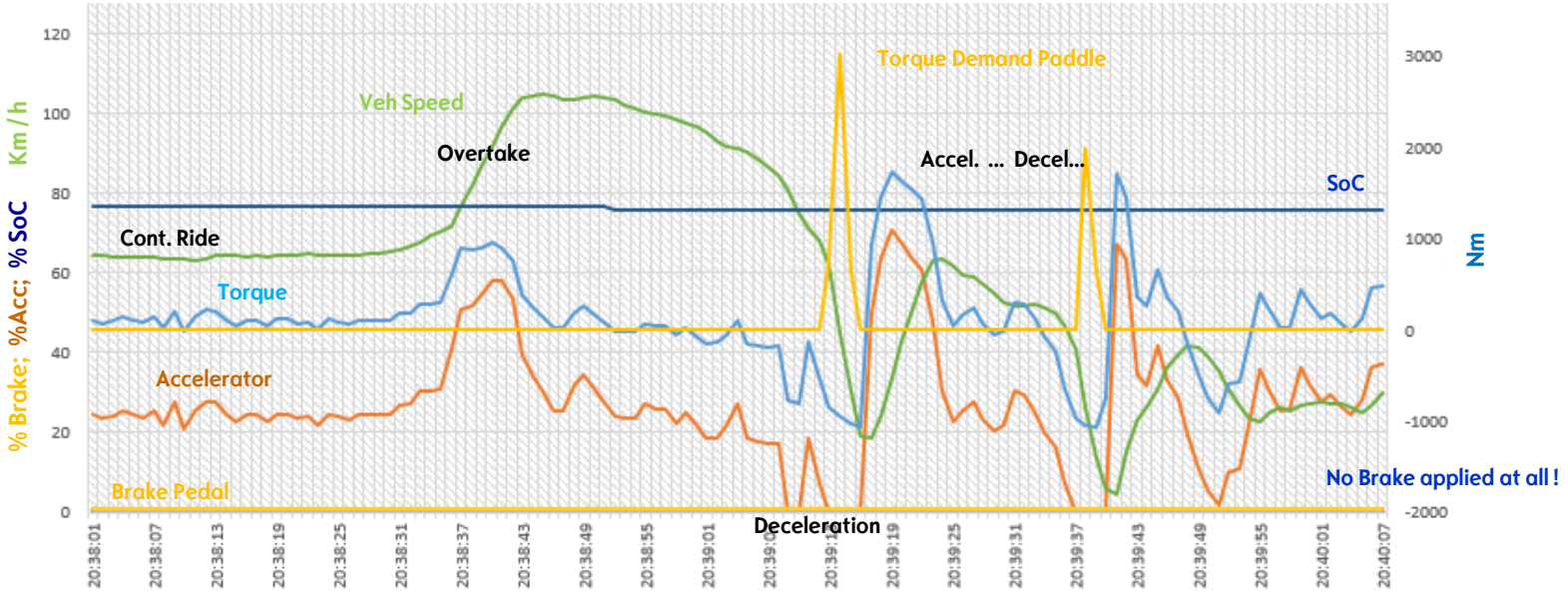



- One-Pedal Driving - slows down the vehicle to a complete stop with a maximum of regenerative braking
- One-Pedal Driving - improves real-world EV range due to increased regeneration

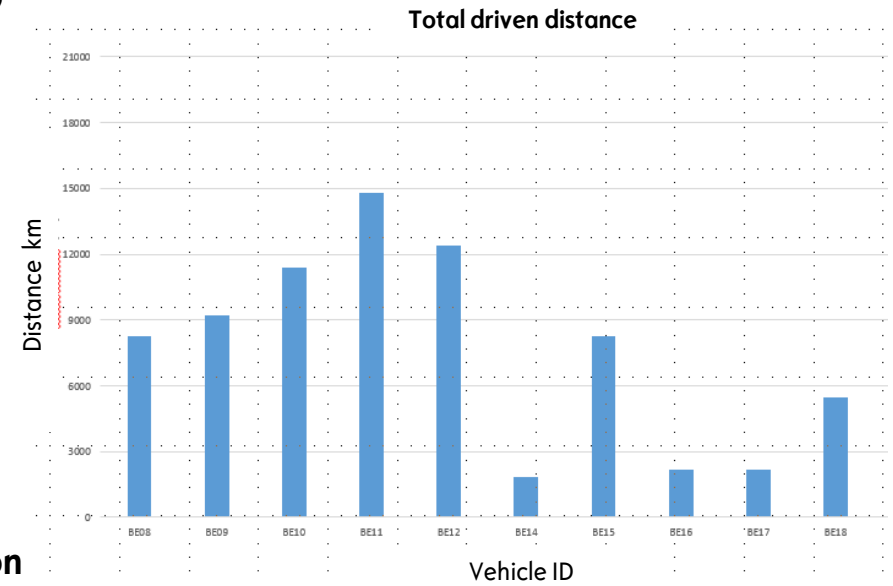
# ONE PEDAL DRIVE MODE

Example: Up Hill Hairpin Riding with One Pedal Drive and Torque demand Paddle



# OPEL FLEET EVALUATION

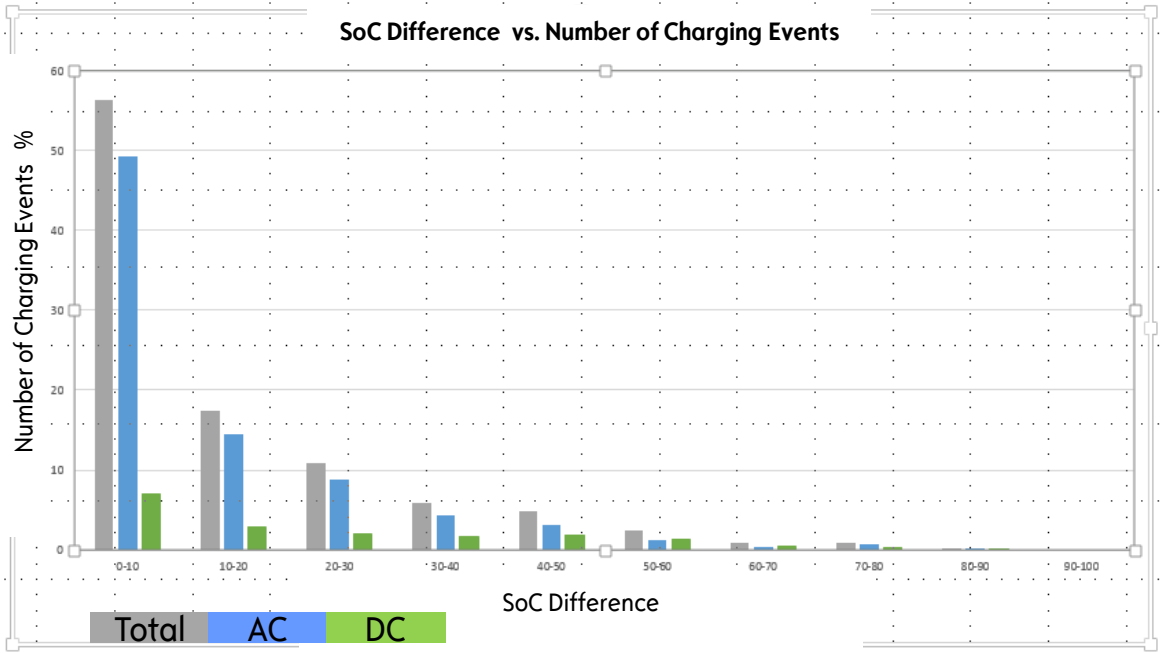
- 10 Vehicles Ampera-e - “ Real World”
- Operated Dec 2016 to May 2017
- Opel Employees as user
  - No development vehicles
  - No representative group
- Overall ~80000km Testdistance
- + 1 Engineering Vehicle in Comparison ( +21000km)



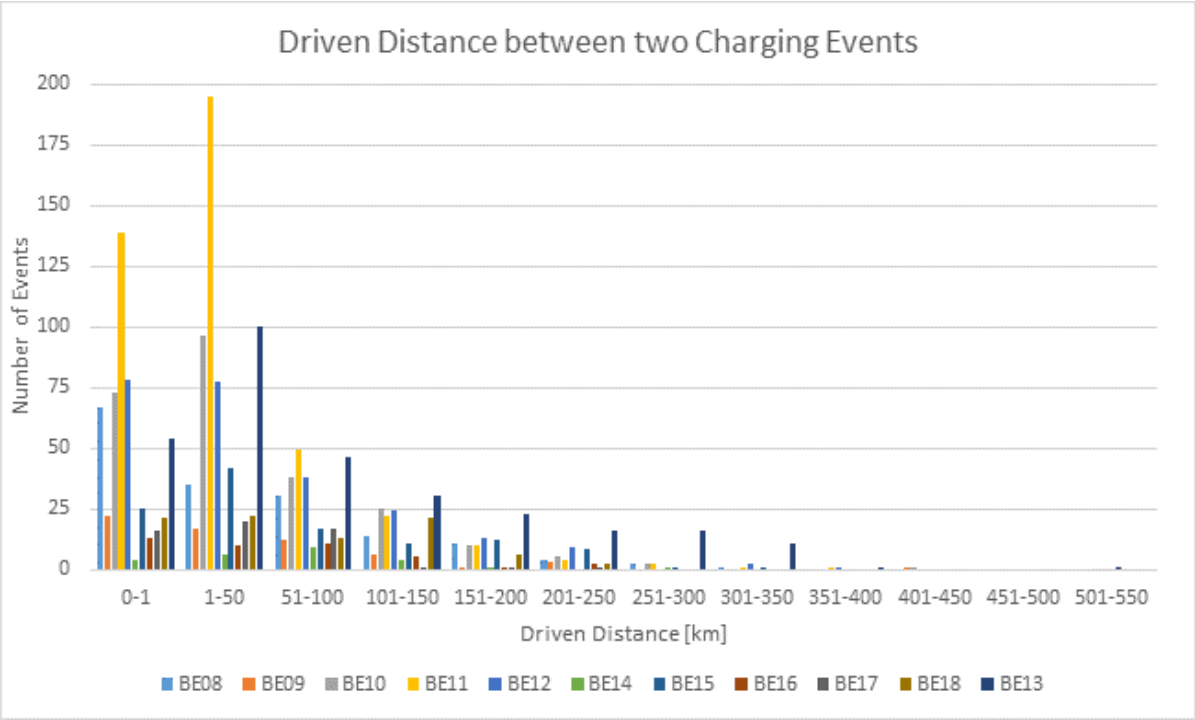
# CHARGE BEHAVIOR

- High number of charging events with small SoC difference
- Vehicles frequently plugged in ( e.g. at home and/or at Opel )
- Around 10% DC-Charge

→ Available battery capacity seldom used.



# RIDE BEHAVIOR




- Vehicles in daily use mainly operated below 150km before next Charge event.
- Only some few ride up to 300km
- Particularly enthusiastic engineers in this case drive cars for hours

# SUMMARY
# VEHICLE PERFORMANCE AND HIGHLIGHTS


- Power (kW) 150
- Torque (Nm) 360

- 0 - 100km/h 7,3s
- 0 – 50 km/h 3,2s
- 80 – 120km/h 4,5s

- Battery (kWh) 60

Features:

- Maximum Recuperation
- One Pedal drive to a full Stop
- 50kW fast charge with CCS system

- Unrivaled Range:

  520km NEDC / 380km WLTP

# Thank You

THE OPEL AMPERA-E