Development of the Li-Ion battery for the Opel Ampera Extended-Range Electric Vehicle

Horst Mettlach

GM Alternative Propulsion Center - Europe
Adam Opel GmbH

3rd International Congress on Advanced

Battery Technology

Wiesbaden, 22nd June 2010

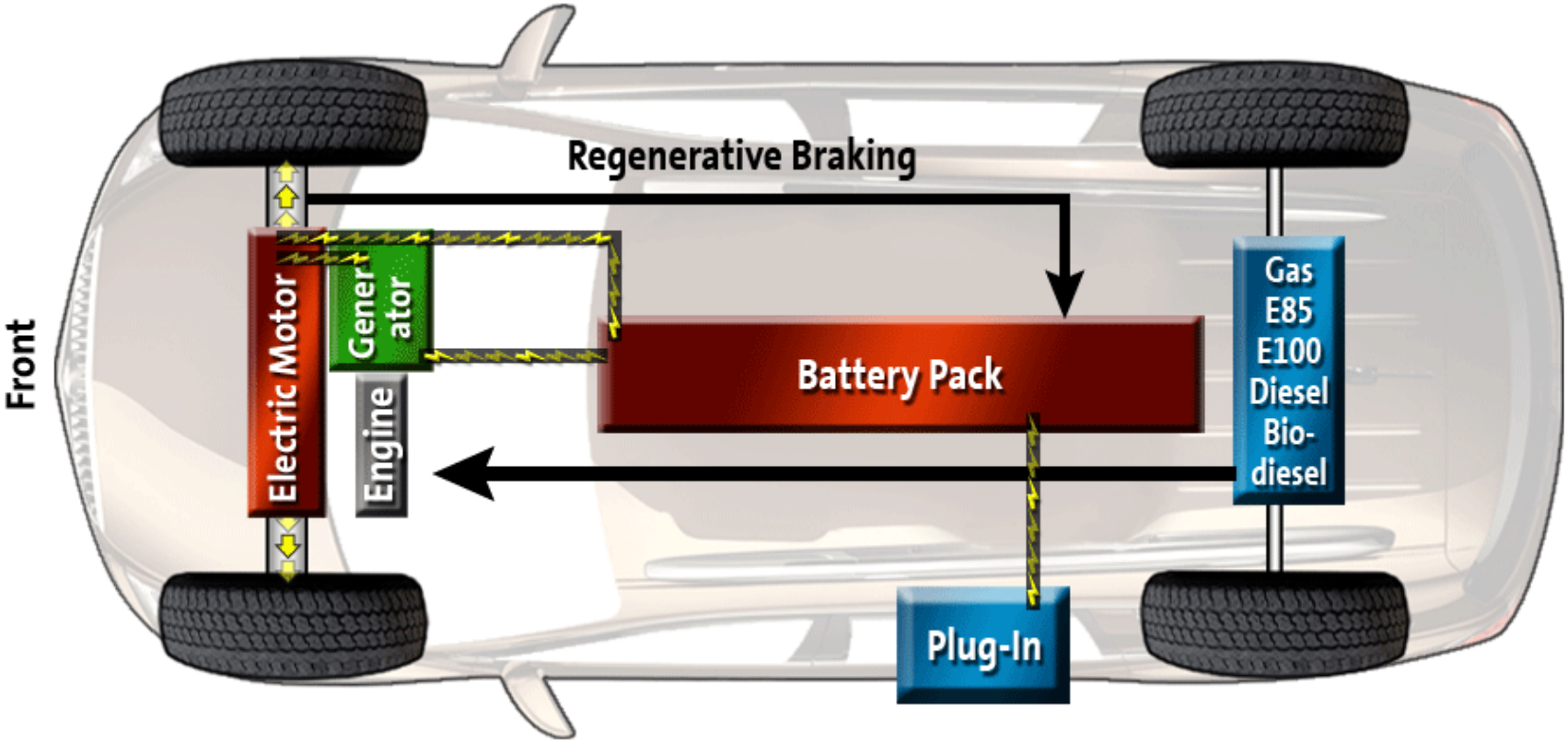
Content

- Extended-Range Electric Vehicles (E-REV)
- VOLTec propulsion system and Opel Ampera
- Requirements for batteries in automotive and E-REV applications
- The Opel Ampera battery system
- Packaging of the battery system
- Operation modes of the Opel Ampera
- Battery testing and validation
- Achievements and future outlook

Extended-Range Electric Vehicle

- Electric propulsion and full performance in EV mode
- Maximized use of electricity as energy for propulsion
- Locally zero emissions in EV mode (up to 60 km)
- Small engine / generator unit to provide several hundred kilometers range in extended-range mode
- Powerful battery to provide peak power in extended range mode
- Recharge in less than 3 hours at standard 230V wall outlet

VOLTec Propulsion System
Combustion Engine with Generator



Opel Ampera
Extended-Range Electric Vehicles

- Production to begin 2011
- Battery development is key challenge
- Opel Ampera will have same battery system as Chevrolet Volt

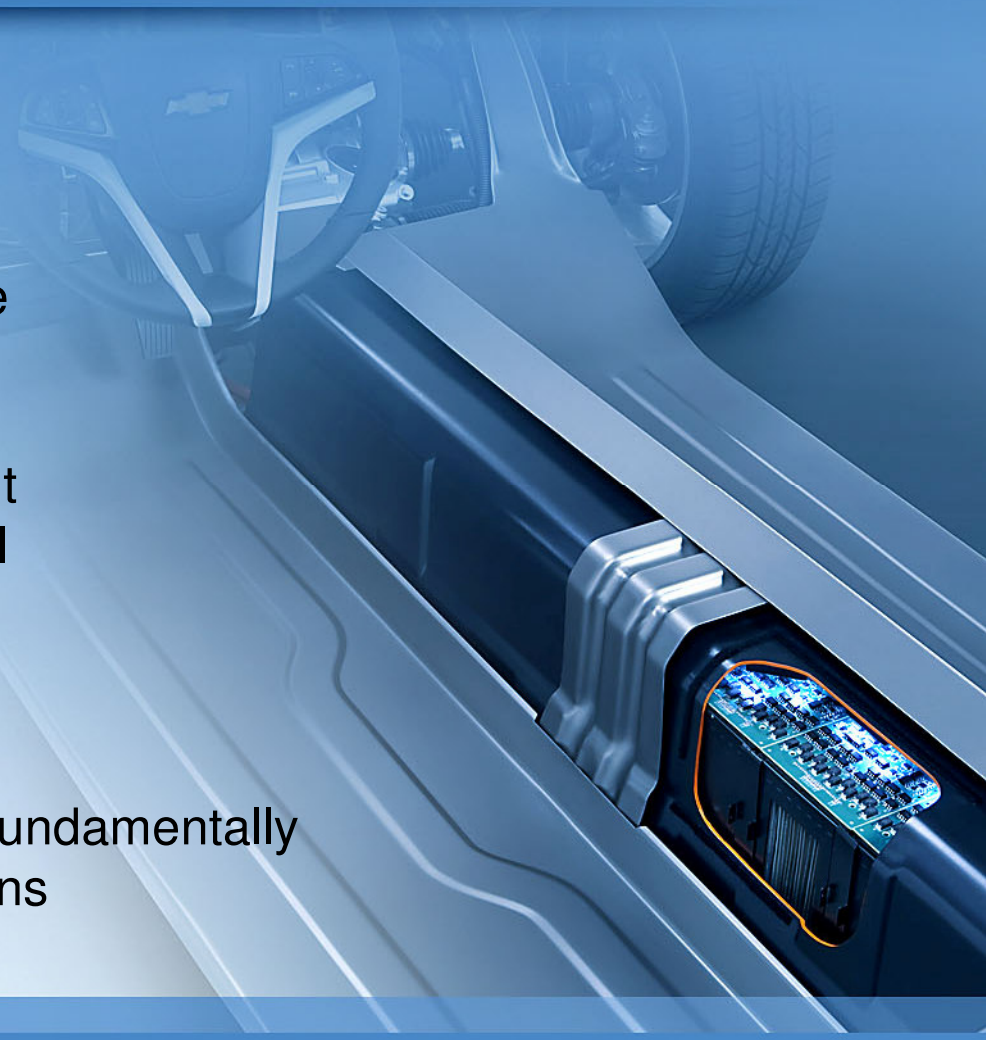
GM

OPEL

Requirements for Automotive Battery Systems

- High power and energy content
- Long lifetime (10 years)
- Cells with enhanced abuse tolerance
- Automotive quality standards
- Integration with thermal management system to comply with environmental influences and power level
- Service aspects

➔ Automotive battery systems differ fundamentally from common consumer applications



Requirements for E-REV batteries

High Power:	power density nearly as high as for HEV applications (750 – 1,000 W/kg)
High Energy:	energy density nearly as high as for EV applications (90 – 150 Wh/kg)
Life time:	10 – 15 years calendar life; 3,000 – 5,000 cycles
	(charge depletion mode)
Temperature:	power needed at temperatures below 0°C to allow EV mode

E-REV batteries need power like HEV and energy like EV

GM

OPEL

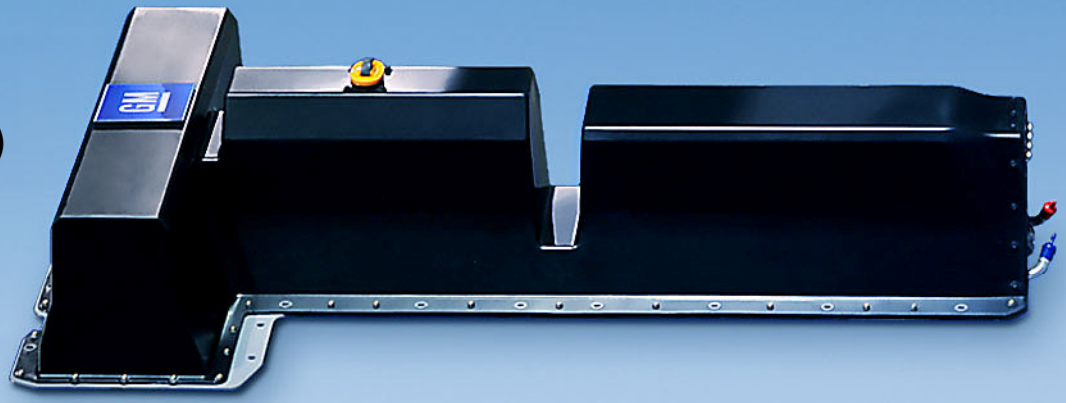
Battery Specification for Opel Ampera

Category	Requirement
Max. discharge power (2 s)	115 kW
Max. discharge power (10 s)	110 kW
Max. regen power (10 s)	60 kW
Usable energy (end of life)	> 8 kWh
Max. discharge current	400 A
Nominal voltage	360 V
Round trip efficiency (reference cycle)	> 90%
Calendar life	> 10 years
Cycle life (EV cycles)	> 4,700
Max. system weight	180 kg

Unique power requirement → 2.5 times USABC plug-in spec.

Li-Ion Battery System for Opel Ampera

- Pouch cells (> 220)
- Liquid cooling
- Energy content: 16 kWh (8 kWh usable)
- Max. discharge power: > 111 kW
- Nominal voltage: 360 V
- Charging time: 3 h @ 230 V, 16 A
- Life: 10 years / 240,000 km
- System weight: 180 kg



VOLTec Battery System for Opel Ampera

- Li-Ion technology provides required energy and power density
- LG Chem supplies Li-Ion battery cells:
  - Pouch form factor
  - Manganese-based cathode chemistry and Safety Reinforced Separator (SRS™)
  - Electro-chemistry with enhanced abuse tolerance and relatively low raw material cost
- GM designed and developed the battery system:
  - Novel thermal integration concept to ensure optimum battery temperature as much as possible
  - Integrated into vehicle structure
- GM developed sophisticated controls system:
  - Battery algorithms
  - Power management
  - Thermal management
- GM will produce battery packs in Michigan

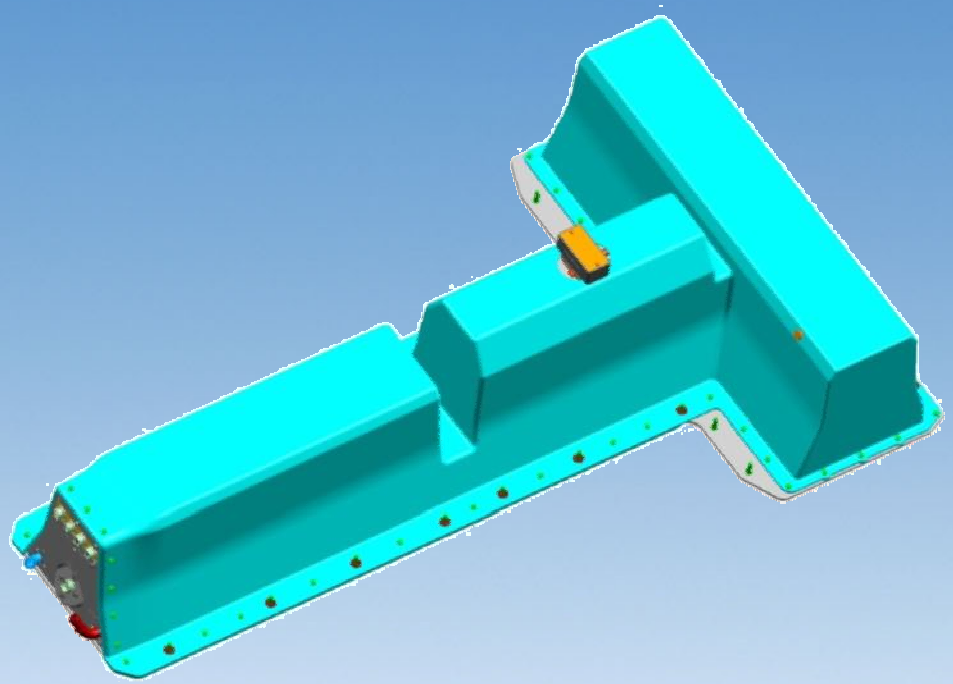
Brownstown Battery Plant

- GM VOLTec battery plant officially opened
- 1st battery pack manufactured on January 7th, 2010.
- Three primary assembly areas:
  - Battery module pre-assembly
  - Final assembly
  - Battery pack main line

T-shaped Battery Pack for Opel Ampera

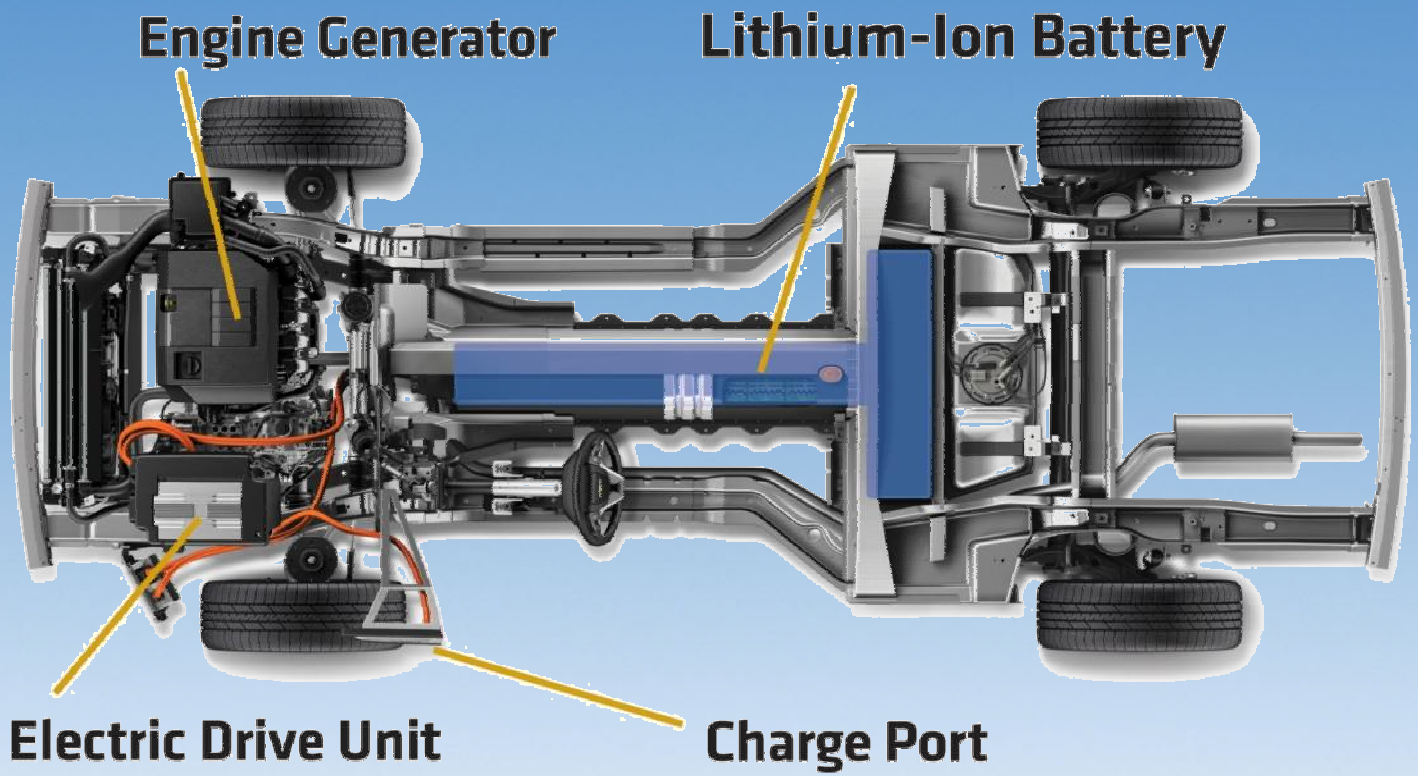
Packaging challenges :

- Package enough energy for 60 kilometers range
- Ensure enough space for passengers
- Do not reduce trunk space
- Find safe location for battery pack



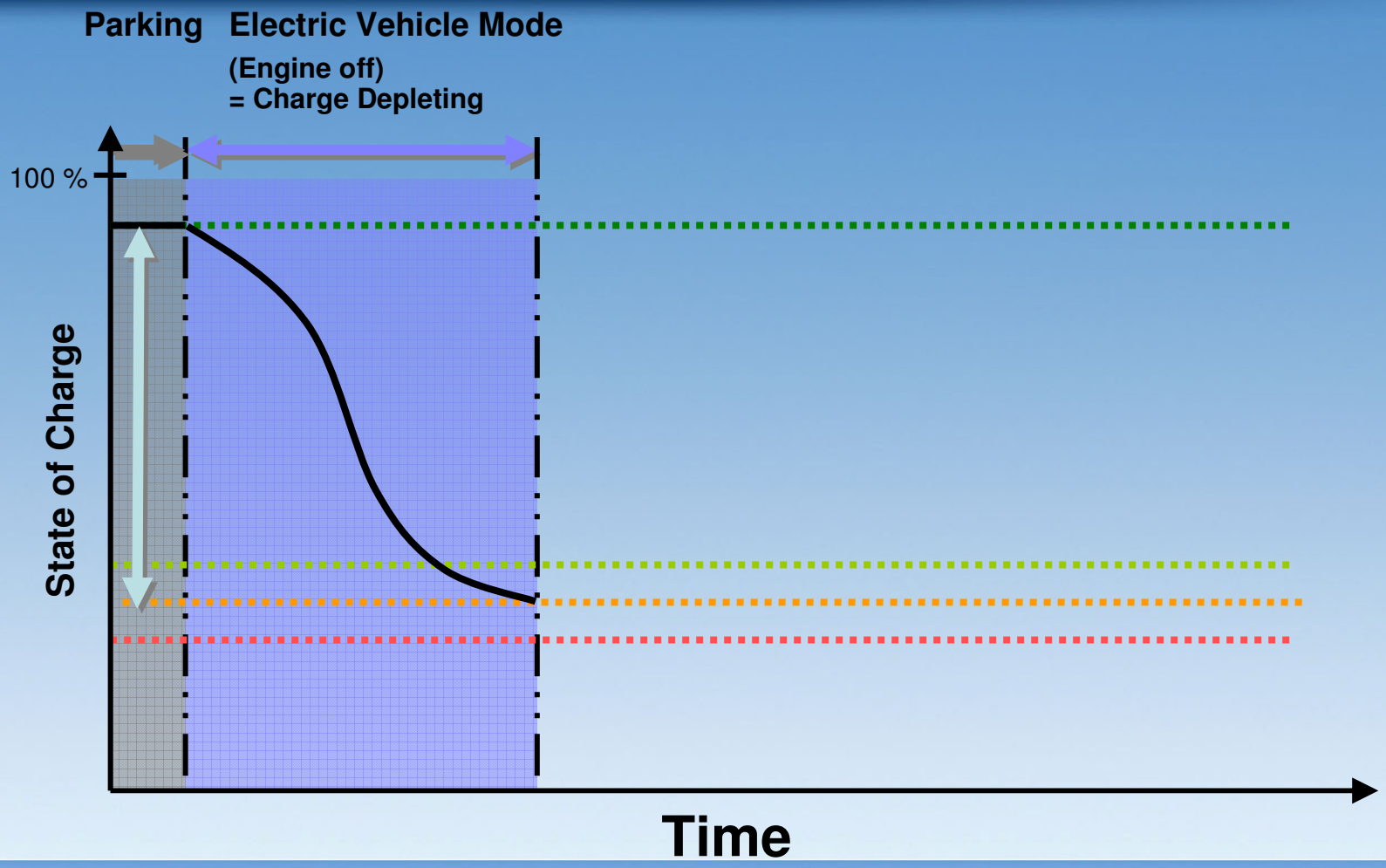
T-shaped battery pack adapted to vehicle

Battery Package for Opel Ampera

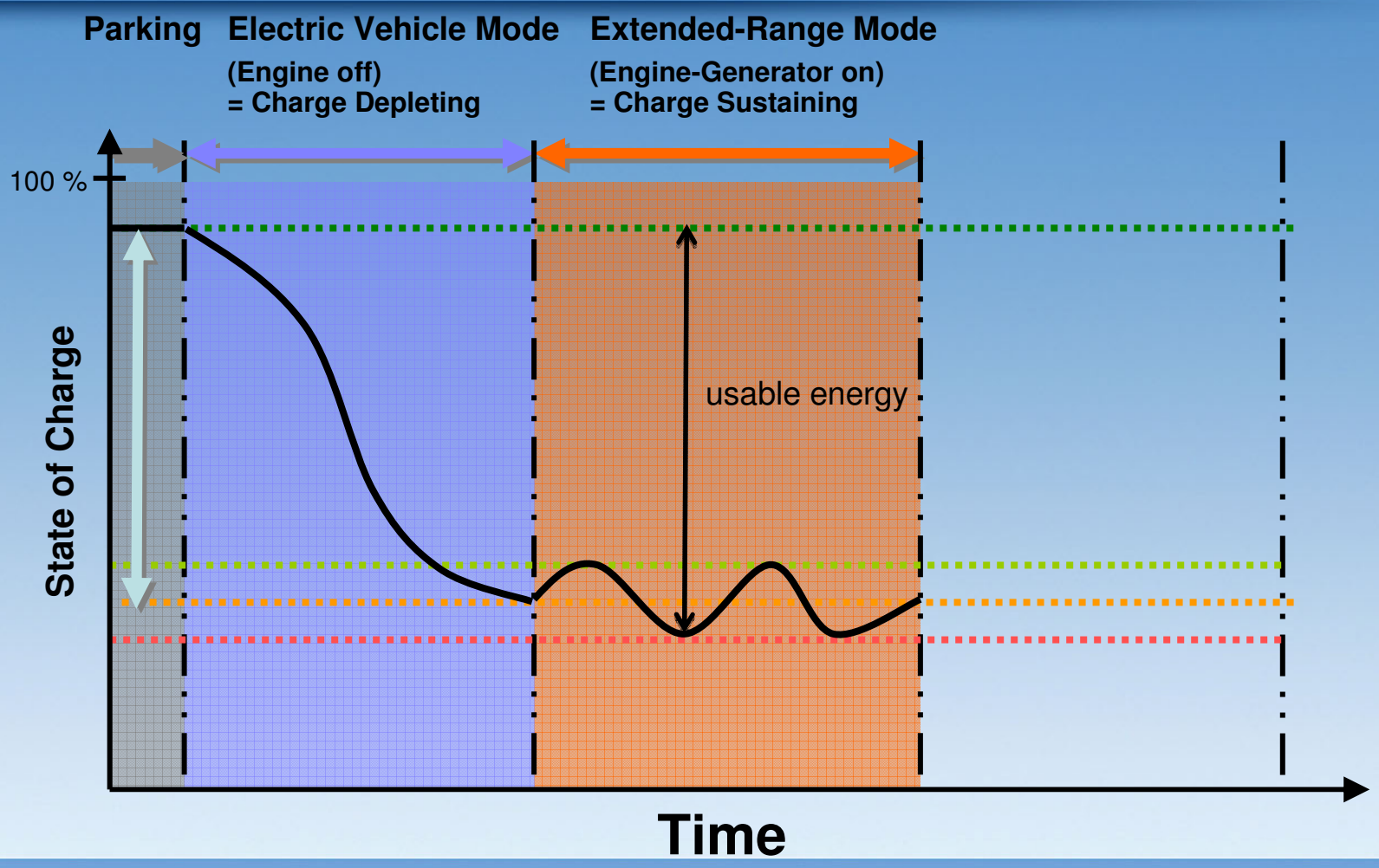


Battery is packaged in tunnel and under rear seat

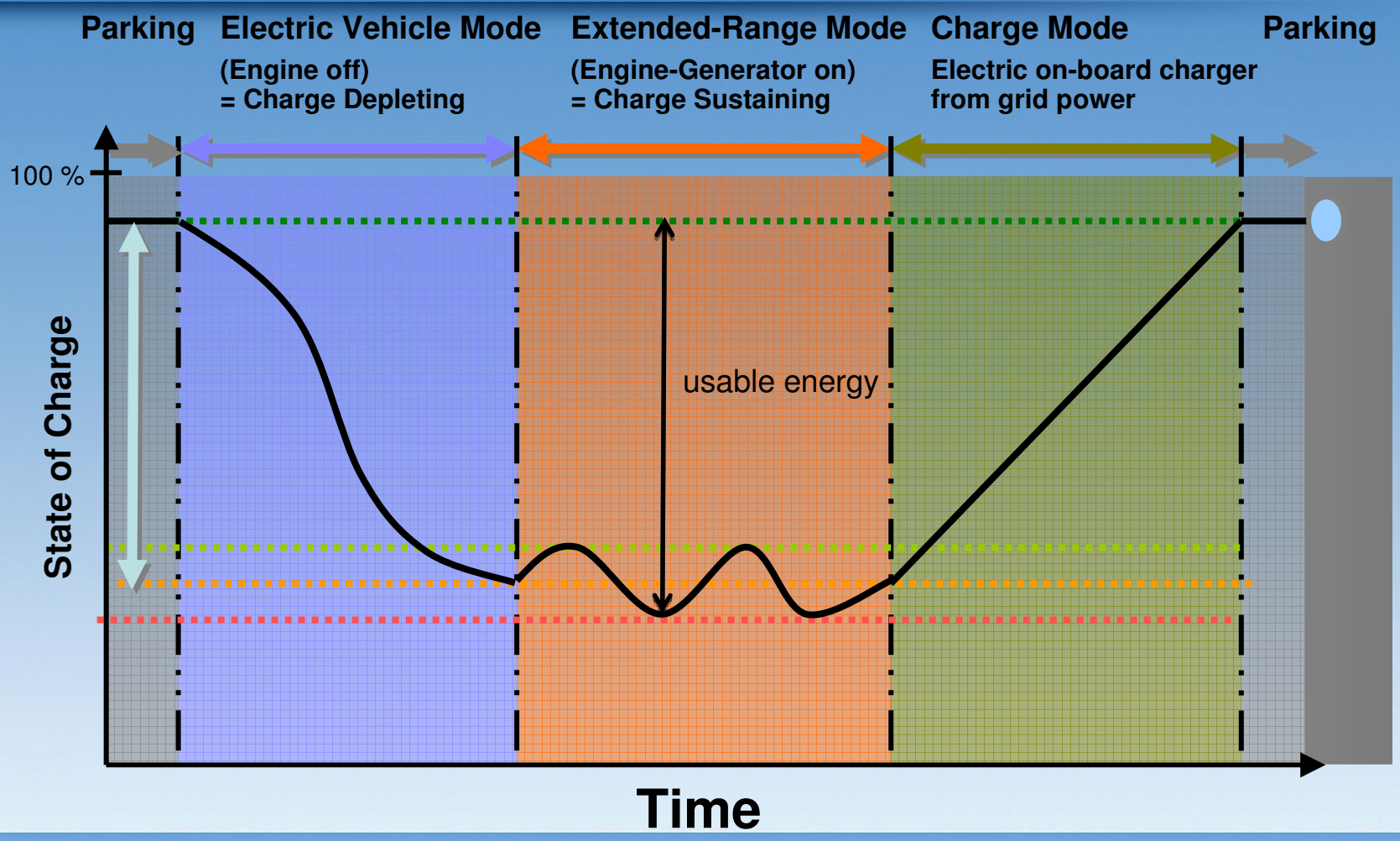
Operation Modes of the Opel Ampera



Operation Modes of the Opel Ampera



Operation Modes of the Opel Ampera



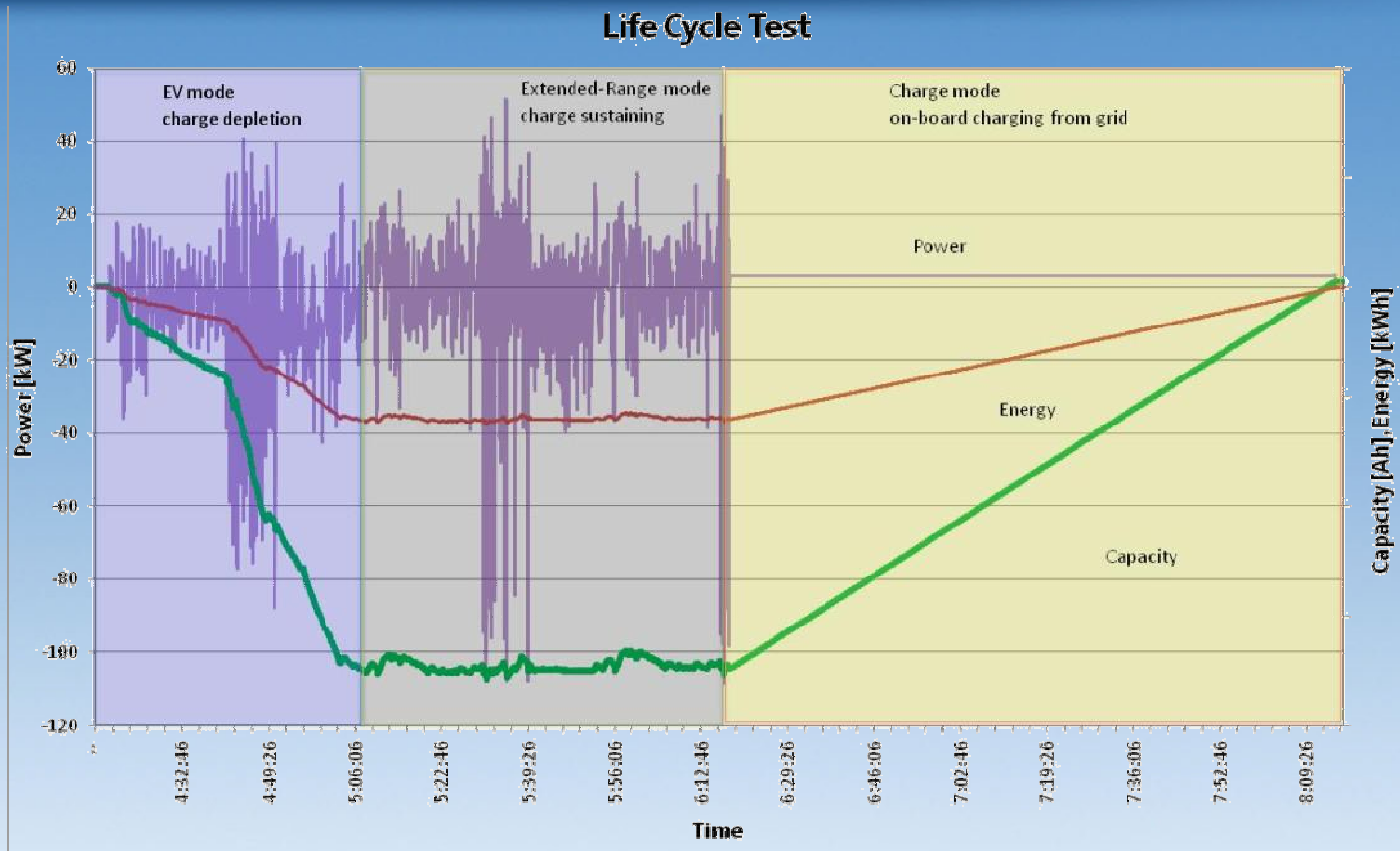
Battery Testing on Bench

- Tests on cell level
  - Power and energy
  - Calendar life at various temperatures
  - Cycle life (USABC DST profile & Volt specific profile)
  - Abuse tolerance (overcharge, short circuit, crush, over temperature, etc.)
- Tests on pack level
  - Power
  - Energy
  - Efficiency
  - Thermal system
  - Controls
  - Cycle life

GM

OPEL

Battery Testing – Volt Specific Profile

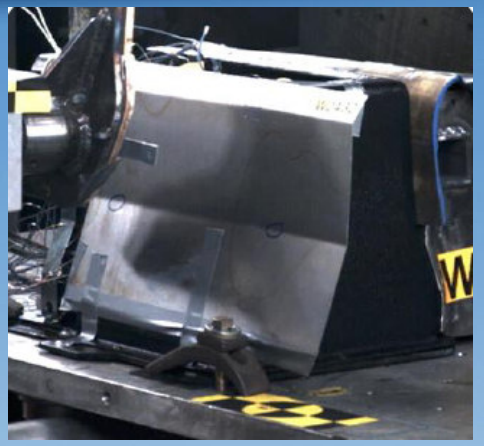


Opel Ampera battery packs are tested in life cycle tests 24/7

Battery Validation

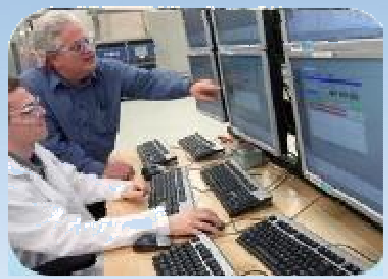
Validation

- Crash
- Mechanical: shock, vibration
- Environmental: temperature, salt, water
- Electric: e.g. EMC
- Customer use life cycle



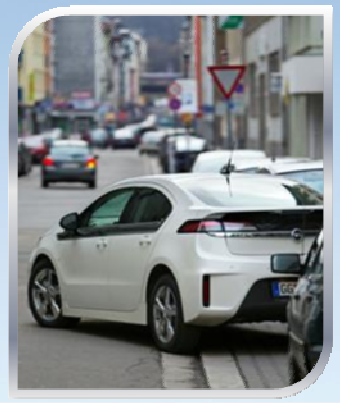
Recent VOLTec Battery Milestones

- Milestone 1
  > 50,000 cells on test
- Milestone 2
  > 300 prototype battery packs built
- Milestone 3
  > 300,000 miles of customer use lab testing up to date
- Milestone 4
  > 20 pack channels in Battery Systems Lab fully dedicated to VOLTec battery



Battery Testing in Vehicle

- Hot weather testing in Death Valley
- Winter testing in Canada
- Mountain testing on Pikes Peak and Bakers Grade
- Several hundred thousand kilometers driven with the development fleet

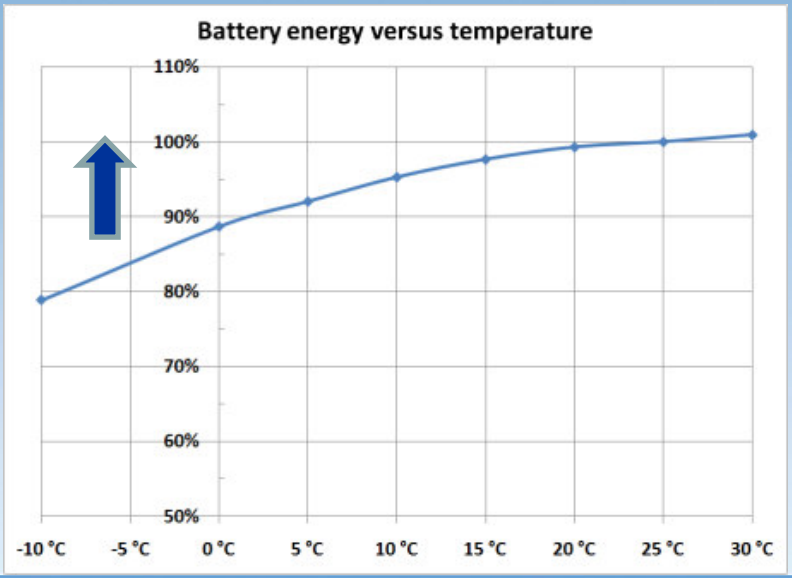


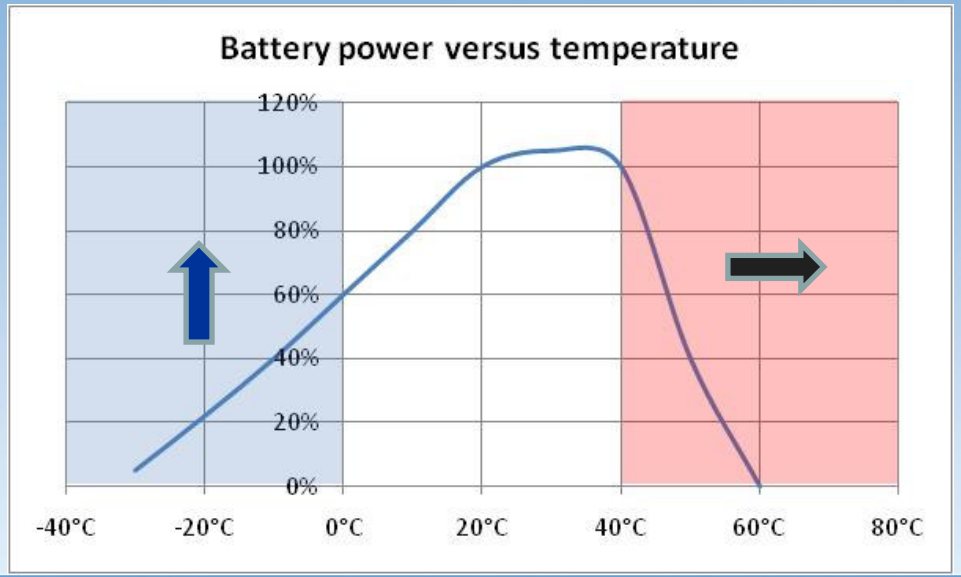
GM

OPEL

Future Outlook

- Future outlook
  - Reduce battery cost
  - Improve temperature behavior
    - Battery power & energy at low temperature
    - Improved life at high temperature





Summary

- Achievements
  - Battery system for 60 km range could be packaged
  - Total range of > 500 km
  - Ample space for 4 passengers
  - Unchanged trunk capacity
  - Outstanding performance (0 – 100 km/h in 9 s)
  - Start of production in 2011 on schedule

GM Alternative Propulsion Center - Europe