TRENDS IN ELECTRIFICATION

MHEV – PHEV - BEV

Prepared for:
IAC 2016

Shanghai, Nov 30th, 2016
Shang Zhe, Product Manager
Agenda

- Background and Motivation
- Trends on Battery Electric Vehicles
- Trends on PlugIn Hybrid Vehicles
- Trends on Mild Hybrids
- Summary
Business Unit Electronics & Electrification
Advanced Solutions for Passenger Cars and Trucks

BUSINESS UNIT – ELECTRONICS & ELECTRIFICACTION

- Leading premium partner from mild hybrid to plug-in hybrid and electric vehicles
- High-end services at vehicle, system and component level
- Cutting edge testing facilities for your development

Electrification
Embedded SW Solutions
E/E Systems
Smart Vehicles

Years of experience
18+
60+
300+

Reference projects worldwide
Highly motivated experts worldwide

Background and motivation
All major brands are making good progress towards meeting their 2015 fleet-average CO$_2$ emission target

In 2013, the average CO$_2$ emissions from new cars (as measured by the official test) were 127g/km

In 2013, Renault displaced Fiat as the manufacturer of the lowest carbon, most fuel efficient vehicles

Only 6 major brands have not achieved the required 2015 target level: GM, Honda, Hyundai, Mazda, Nissan and Suzuki

No major manufacturers failed to achieve their 2013 target

The 95g/km 2021 target will be more challenging for carmakers

Source: transportenvironment.org, FEV
Future OEM specific scenarios to meet future CO₂ emission requirements will be predicted based on relevant input parameters.

**FEV CO2-MODEL APPROACH AND INFLUENCING FACTORS FOR CO2-REDUCTION**

- Factor driven tool to calculate future CO₂ fleet emission scenarios
- Consideration of all main drivers and technical levers to improve CO₂ emission
- OEM-specific data base to calculate specific emission averages
- Technology impact based on FEV technology roadmaps
- Future prediction of various CO₂ fleet average scenarios for 2020+
To achieve planned EU 2025 CO$_2$ targets, a massive hybridization is required. P/Ts w/o at least start/stop system will disappear ahead of 2020.

MARKET EXPECTATION BY ELECTRIFICATION DEGREE

 Remarks

- FEV market expectation forecasts are based on CO$_2$ fleet emission requirements (95 g/km in 2020; 78 g/km in 2025), technology availability and cost/benefit assessments.
- FEV expects that by 2020 in Europe nearly no new car will be sold without any electrification/hybrid features.
- Micro hybrids will dominate the market over the entire forecast horizon, with sales plateauing between 2019 and 2023.
- Around 3 mn* vehicles sold in Europe in 2020 will feature a higher electrification degree - HEV, PHEV or EV - rising to over 7 mn* by 2025.
- Mild hybrids are expected to gain traction from ~2018 onwards, but will not rise strongly up to 2025.
Worldwide more than 20 Mio. HEV/PHEV/EV and more than 15 Mio. Mild Hybrids will be sold in 2025
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Increase of energy density by a factor of 2 and decrease of cost by a factor of 2.5 seems possible up to 2025 with current battery technology.

- Price differences between PHEV and EV cells will remain but become smaller.
- Cell price below 200 €/kWh seems possible beyond 2020.
- Tesla announcement of $50/kWh is far below other forecasts.
- PHEV cells need different cell chemistry than EV cells. Therefore, energy density will be lower and price higher.
Reasonable battery capacity is also limited by charging time and available infrastructure to approx. 60-80 kWh usable energy.

Estimated average energy consumption: 14 kWh/100km

Trends on Battery Electric Vehicles

Energy consumption per 100 km in NEDC:
- BMW i3: 12.9 kWh
- BYD e6: 21.6 kWh
- Ford Focus electric: 15.9 kWh
- iMiev: 12.6 kWh
- Tesla S: ~25 kWh

30 min fast charging with 120 kW DC to 80% SoC:
- 60 kWh ~ 400 km range

8 h standard charging at 16 A / 400VAC socket (11 kW) to 100% SoC (CCCV-charging):
- Approx. 70 kWh ~ 500 km range

J. Ogrzewalla / Electrification trends / 2016-05-09
System optimization will contribute to more extended driving range of Battery Electric Vehicles

- Battery improvement with new cells with two times higher capacity on equivalent cost, weight and volume
- Weight reduction by electric machines with higher energy density
- Thermal management with insulation of passenger cabin and heat pumps for less energy consumption under cold conditions
- Simple 2-speed gear-sets for increase of efficiency of drivetrain
- Light-weight body and chassis
- Integration of ADAS and Car2x services to optimize route guidance

Trends on Battery Electric Vehicles
FEV expect a majority of A-segment city cars and small delivery trucks with a range of 300 – 400 km in the segment of electric vehicles in 2025

Will the electric vehicle in 2025 be a luxury sedan, a small delivery commercial vehicle or an ultra light-weight two seater?

- Charging infrastructure and driving range due to battery capacity will limit the introduction of pure electric vehicles
- City cars and vehicle fleets for car-sharing or parcel services seems to be the most realistic application
- Range Extender for BEVs will only be optional for special applications and some markets/regions
- PHEVs or Fuel Cell Vehicles will be the long term solution for long distance driving
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Trends on PlugIn Hybrid Vehicles

Inner city interdiction of driving with ICE may become the most important reason to buy a diesel PHEV for long distance drivers

Paris: 11th of March 2015

- Overall Speed limit minus 20 km/h
- 50% prohibition of drive (even/uneven number of license plate)
Trends on PlugIn Hybrid Vehicles

Increase of PHEV sales volume is essential to achieve 2025 CO₂-limits in Europe for nearly all OEMs

- Chinese government forces introduction of EVs and PHEVs with more than 50 km range due to pollutant emissions in mega-cities. Increase of range to more than 70 km is expected for the next years.
- Most important challenges for introduction are costs and package constrains.
- To provide adequate driving performance an electric power of more than 50 kW up to 100 kW are necessary.
- Integration of high power e-motor into P2 topology requires highly integrated transmission solution or clever hybrid module, like FEV ePGS.
Increased peak load potential of traction machines by optimization of cooling design and more accurate prediction of heat distribution.
Wireless charging is under investigation by several OEMs and will provide higher comfort and acceptability of premium EVs and PHEVs.

Inductive charging will become a standard into the next decade. Major OEMs are working on solutions. VW, BMW and Daimler published to offer systems until 2017/2018.

- New EV and PHEV platforms have to consider wireless charging
- Park assist systems should be able to provide accurate positioning on top of transmitter
- Active damping system is able to reduce distance and increase efficiency
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48 V board net will be implemented into the market in the next 2-3 years. €/g-CO₂-reduction exceed todays market acceptance in A/B segment.

**Forecast of 48 V system**

- **Introduction in premium vehicle segments**
- **48 V mild hybridization**
- **Roll-out to high volume segments**

**Comfort aspects 2017/2018**

- Introduction of 48 V system will start in premium segment due to comfort and cost reasons.
- New features like:
  - EPS, ABC
  - Active rear axle steering
  - Engine-off climatisation
  - E-charger

EPS: Electric Power Steering, ABC: Active Body Control
**Mild Hybrids 2017/2018**

- 48 V system will also be used for new functionalities like:
  - Coasting
  - Early engine stop
  - Electric creeping / parking
- Higher degree of brake energy recovery and boosting with power of up to 15 kW
48 V board net will be implemented into the market in the next 2-3 years. €/g-CO₂-reduction exceed todays market acceptance in A/B segment.

**Forecast of 48 V system**

- **Introduction in premium vehicle segments**
- **48 V mild hybridization**
- **Roll-out to high volume segments**

**High volume > 2020**

- To achieve CO₂-targets in EU and CN up to 20% of vehicles need mild hybridization.
- 48 V system provide 8-10% reduction in fuel consumption (WLTC, compared to conventional vehicle without Start/Stop).
- Todays system cost of 600-800 € will decrease to approx. 400 €.
Some features of 48 V system can also be introduced with 12 V board net:

- Coasting
- Stop/start, early engine stop
- 12 V e-charger

Implementation of second 12 V battery (w/o supercaps) and 12 V BSG / 12 V enhanced starter:

- Today's add-on cost below 250 €
- CO2-reduction in NEDC of up to ~8%
Some features of 48 V mild hybridization are also possible with advanced 12 V components, CO₂-emission reduction of up to 8% is possible.

### COMPARISON OF 12 V AND 48 V MILD HYBRID FEATURES

<table>
<thead>
<tr>
<th>Features</th>
<th>Conv. 12 V</th>
<th>12 V BSG</th>
<th>48 V BSG</th>
<th>48 V ISG</th>
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<tbody>
<tr>
<td>Recuperation</td>
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<td>Boosting</td>
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<td>E-charging</td>
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<td><strong>High power consumers:</strong></td>
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<tr>
<td>ABC, EPS, engine-off climatization,</td>
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<td><strong>Early engine-off, engine-off coasting</strong></td>
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<td>Engine-on sailing</td>
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<td>Electric creeping &lt; 15 km/h</td>
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<td>Electric driving &gt; 50 km/h</td>
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</tbody>
</table>

- ● strong
- ○ weak
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- Degree of powertrain electrification will increase worldwide due to more stringent CO₂-limits and pollutant emissions as well as

- Market share of EVs will increase up to 7% in Europe up to 2025 due to improvements of batteries in terms of energy density and cost reduction. Infrastructure and battery cost and weight will still limit the driving range of EV and restrict use on smaller city-vehicles and fleets.

- Plug-In hybrids are the key to achieve the CO₂-targets for Europe and fulfill Chinese government requirements. Battery improvement helps to reduce cost, but customer acceptance will be the challenge. Additional performance increase with high power e-machines and wireless charging may contribute to customer satisfaction.

- Mild Hybrids based on 48 V will come into the market in the next years starting from premium segments due to comfort reasons. Fuel reduction of up to 8% will close the gap to 2025 CO₂-limits. For cost sensitive segments 3-5% fuel consumption reduction can also be achieved with 12 V system incl. functions like coasting, early engine stop, etc.