E-mobility opportunities & challenges
1st Green Manufacturing Summit – Sectoral Case Automotive

New Dehli, 18 March, 2011
Electricity has a long history in car technology

La Jamais Contente, 1899

Just a hype – or is it for real? ... and what does it mean for the industry?
Bold statements regarding e-Car ramp-up

Aggressive volume plans... with strong strategic ambitions

"We think that scale for us is between 500,000 and 1 million cars a year."

"Volkswagen will be the automaker to mass produce the electric car for everyone."

"This vehicle will change the auto industry we know today significantly."

"We maintain our claim to be the worldwide market leader in e-mobility"
Overall, we expect a multi-step path forward

**Electrification path**

- **Advanced ICE**
  - Advanced gasoline and diesel, Biofuels, CNG, H₂

- **Mild Hybrid**
  - Start stop, regenerative braking, mild acceleration assistance

- **Full Hybrid**
  - Acceleration assistance, electric launch, electric driving at low speeds

- **Plug-in Hybrid**
  - Full hybrid with larger battery and plug-in capability

- **Range Extender**
  - Electric vehicle with ICE to recharge the batteries

- **E-Car**
  - Full hybrid with larger battery and plug-in capability
  - All necessary propulsion energy is stored in the battery

**CO₂ reduction potential**

- **Up to 35%**
- **10-30%**
- **30-40%**
- **50-100%**

**Levers for CO₂ reduction**

- Thermodynamic efficiency
- Pumping losses
- Braking losses
- Idle losses

**Clean energy sources**

1. Well-to-Wheel CO₂ reduction; calculations for European countries. CO₂ reduction potential measured in comparison with gasoline car with 176 g CO₂/km, type Golf 1.6
Three drivers behind electrification trend

1. **CO₂ regulations**
   - World leaders committed to reduce CO₂ emissions
   - Regulation requires partial electrification to meet targets

2. **Innovation**
   - High interest and willingness to invest in alternative, green technologies
   - Govtms thrive for reduced oil dependance

3. **Changing mobility patterns**
   - Free EV+ access to restricted city centers highly attractive
   - Admittance to car pool lanes as additional plus

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**Market model**
- Industry volume path
- Industry profitability
**CO₂ reduction: EV benefit strongly depends on power mix**

WTW CO₂ emissions today  
... vs in 2020

Average CO₂ emission  
in g/km

China, India virtually no overall CO₂ benefit due to carbon intensive power generation

1. Reference vehicle for C segment (1.6l gasoline engine w/ 75kW and 1181 kg vehicle mass); 2. Avg. 15 kWh/100 km (tank to wheel) X CO₂ from respective power generation mix in g/kWh; 3. Assumption: 10% Biofuels addition to fossil fuels (80% CO₂ reduction with biofuels). 20% improvement of baseline gasoline ICE, 5% improvement of hybrid and 10% of diesel; 8% electricity losses and 17% upstream oil losses are assumed; Source: Company Websites; VDEW; EUCAR; European Commission; Concawe; WWF; BCG analysis
2020: Expect 25-30% electrified cars – 5-6% pure EVs

- Expected market share 2020
- Expected sales in M units

Technology challenge:
- Optimized ICE: 70-75%
- Electrification: 25-30%
... with very different market penetrations by region

Share of new car sales 2020 (%)

**WEU**
- WEU: 10, 4, 1, 100
- WEU: 42, 3, 5, 4
- WEU: 44, 40, 33, 100

**NOA**
- NOA: 7, 3, 2, 1, 18
- NOA: 62, 5, 1, 100
- NOA: 74, 32, 18, 100

**Japan**
- Japan: 5, 7, 16, 18
- Japan: 75, 4, 4, 100
- Japan: 86, 5, 5, 100

**China**
- China: 6, 13, 3, 10
- China: 23, 4, 7, 100
- China: 52, 5, 6, 100

**Sum in 2020 (%)**
- Sum: 10, 20, 11, 69
- Sum: 42, 3, 3, 69
- Sum: 14, 11, 10, 69

**Scenarios**
- **1** Slowdown: Concern about climate change shrinks, oil price goes down, regulations are loosened
- **2** Steady pace: Increasing concern about climate change, oil price stays high, regulations follow agreed pattern
- **3** Acceleration: Concern about climate change increases much, oil price hits records, regulations further tightened
Costs will need to drive down to ~35% of current level

<table>
<thead>
<tr>
<th>Components</th>
<th>Cell ($/KWh)</th>
<th>Module ($/KWh)</th>
<th>Pack ($/KWh)</th>
<th>Battery ($/KWh)</th>
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<tbody>
<tr>
<td>2011</td>
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<td>2020(E)</td>
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1. Including process, depreciation, R&D and scrap of active material and component suppliers; DOD = depth of discharge
Note: 90 Wh cell; annual production 73M cells; Assumes 0.1% scrap rate; Rounded numbers
Despite prudent projections, huge battery market evolves

Announced capacity build up of top battery players (~47GWh) already satisfies PC demand until 2016

1. Based on BCG's steady pace scenario; note: assumed battery sizes: HEV 1 KWh, PHEV 10 KWh, full-EV 20 KWh
All need to agree on go-to-market model – jointly!

- Should we offer power contracts?
- Do we need any specific FS offer? (e.g. battery lease)
- How do we provide optimal charging solutions? With which partners?
- How do we enable our dealer network?
- What should our PoS offer look like?
- What kind of premium services can we offer?
- What is the residual value of the battery?
Some key take aways for all players

Deal with new uncertainties
- Act as an entrepreneur: apply trial & error approach to better understand customer e-mobility requirements
- Limit own risks related to unclear battery durability while keeping prices low for customers
- Be agile to react to changes in regulation/incentive schemes

Acquire new capabilities
- Integrate vehicle periphery into existing processes
- Use new technologies to level out e-car-related inconveniences

Profit form changing market environment
- Leverage new market entrants as value-adding partners
- Selectively explore new profit pools
- Secure customer interface

Governmental/municipal authorities and regulators as well as industry associations will play a crucial role