Market integration of electric mobility: Analyzing economic efficiency and costs for consumers

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Introduction and Motivation

• The mobility sector in Germany is responsible for around 21%\(^1\) of greenhouse gas emissions

• Electric mobility as a new technology has a potential to:
  • Transform the mobility sector in an environmental friendly system
  • Lower emissions (dependent on electricity production)
  • Reduce dependence on oil (imports)

• Only possible if electric mobility evolves in the market (market integration)

Under which conditions is electric mobility economically efficient for private consumers?

  ▪ Rigorous cost analysis
  ▪ Comparison of electric vehicles with conventional vehicles
  ▪ Focus on battery costs and grid services

\(^1\) UMWELTBUNDESAMT (2007)
Economic model – Total Costs of Ownership

Display of all costs over a given lifetime

- Costs of Acquisition
  - Initial Costs
  - Market
    - Standard Component
      - Battery
    - New Component
      - Buying Incentives
      - Abrasion
      - Maintenance
      - Insurance
      - Subsidies
      - Overall
      - Engine
      - Power electronics
      - Tank
      - Charger

- Costs of Operation
  - Fixed Costs
    - Market
    - Policy
    - Tax Incentives
    - Earnings by V2G
  - Variable Costs
    - Vehicle to Grid
    - Car tax incentives
    - Electricity
    - Electr. tax incentives

- Costs of Disposal
  - End-of-Life Costs
    - Market
    - Policy
    - Des-acquisition
    - Residual value
    - Disposal
Economic model
Total Costs of Ownership

Various ways to calculate TCO, focus on mobility costs (MC)

- All costs over the lifetime divided through the achieved output
  - Output = all driven kilometers (km)
  - One-time costs are distributed over the lifetime by an annuity factor a
  - Result: costs per km

\[
MC \left( \frac{€}{km} \right) = \left( (CSC + CNC) + In + DC \right) \ast a + FC \ast Tkm
\]

\[
a = \frac{1 - (1 + r)^{-1}}{1 - (1 + r)^{-T}}
\]

- Calculations for different points in time (2010, 2015, 2020, 2030)
- Development of costs as ‘expert guess’

MC: mobility costs; CSC: costs of acquisition, standard components; CNC: costs of acquisition, new components; In: incentives; DC: disposal costs; a: annuity factor; FC: fixed costs of operation; VC: variable costs of operation; Tkm: total km over lifetime; r: interest rate; T: total lifetime
### Frame of analysis

**Vehicles**

<table>
<thead>
<tr>
<th></th>
<th>Compact class</th>
<th>Subcompact class</th>
<th>Micro car class</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Reference car</td>
<td>New concepts</td>
<td>Reference car</td>
</tr>
<tr>
<td></td>
<td>Ford Focus 1,6 Concept&lt;sup&gt;1&lt;/sup&gt;</td>
<td>PHEV</td>
<td>REV</td>
</tr>
<tr>
<td>Elec. driving range NEDC&lt;sup&gt;2&lt;/sup&gt;</td>
<td>-</td>
<td>30</td>
<td>50</td>
</tr>
<tr>
<td>Drive power electric (kW)</td>
<td>-</td>
<td>25</td>
<td>55</td>
</tr>
<tr>
<td>Drive power combustion engine (kW)</td>
<td>74</td>
<td>85</td>
<td>36</td>
</tr>
<tr>
<td>Battery capacity (kWh)</td>
<td>-</td>
<td>6</td>
<td>10</td>
</tr>
<tr>
<td>Elec. consumption urban NEDC (kWh/100km)</td>
<td>-</td>
<td>16.2</td>
<td>16.1</td>
</tr>
<tr>
<td>Elec. consumption non-urban NEDC (kWh/100km)</td>
<td>-</td>
<td>16.2</td>
<td>16.1</td>
</tr>
<tr>
<td>Gasoline consumption urban NEDC (l/100km)&lt;sup&gt;1&lt;/sup&gt;</td>
<td>8.7</td>
<td>8.7</td>
<td>8.7</td>
</tr>
<tr>
<td>Gasoline consumption non-urban NEDC (l/100km)&lt;sup&gt;1&lt;/sup&gt;</td>
<td>5.5</td>
<td>5.5</td>
<td>5.5</td>
</tr>
<tr>
<td>Elec. driving (%)&lt;sup&gt;3&lt;/sup&gt;</td>
<td>-</td>
<td>60</td>
<td>80</td>
</tr>
<tr>
<td>Fuel driving (%)&lt;sup&gt;3&lt;/sup&gt;</td>
<td>100</td>
<td>40</td>
<td>20</td>
</tr>
<tr>
<td>Urban driving (%)&lt;sup&gt;4&lt;/sup&gt;</td>
<td>35</td>
<td>35</td>
<td>35</td>
</tr>
</tbody>
</table>

- not valid for electric vehicles, respectively combustion engine vehicles

<sup>1</sup>NEDC: New European Driving Cycle
<sup>2</sup>ADAC (2011) Autodatenbank
<sup>3</sup>Infas & DLR (2010) Mobilität in Deutschland 2008
<sup>4</sup>Biere, D., et al. (2009)
Frame of analysis
Assumptions

- Analysis of private costs for consumers
  - Additional social and external costs, costs for the government or the industry are not part of the analysis
- Total lifetime: 11 years
- Yearly driving performance: 12,000km
- All daily distances <120km
- Discount rate: 5%
- No governmental incentives
- No costs of disposal
Frame of analysis
Costs of acquisition

Costs of acquisition\(^1\)
- Costs of standard components (car body, tank, combustion engine, drive train) are assumed as constant
- Electric engine: 8.75\% cost decrease per year
- Power electronics: 17.5\% cost decrease per year

One-time infrastructure costs\(^2\): 800\€

\(^1\)Blesl, M., et al. (2009)
\(^2\)Biere, D., et al. (2009)
Frame of analysis
Costs of operation

Costs of operation
• Annual tax on motor vehicles + insurance (constant)$^1$: 3% of purchase price
• Maintenance and repair (constant)$^2$:
  • Reference vehicle: 3.6 €ct$_{2010}$/kWh
  • PHEV / REV: 4.5 €ct$_{2010}$/kWh
  • BEV: 2.1 €ct$_{2010}$/kWh

• Grid services (constant)$^3$: 200€/a / 100€/a - as fixed yearly payment

• Costs for electricity and fuel develop following the reference scenario of recent energy scenario$^4$:

<table>
<thead>
<tr>
<th></th>
<th>2010</th>
<th>2015</th>
<th>2020</th>
<th>2030</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electricity (€ct$_{2010}$/kWh)</td>
<td>23.7</td>
<td>21.7</td>
<td>21.7</td>
<td>22.2</td>
</tr>
<tr>
<td>Fuel (€$_{2010}$/l)</td>
<td>1.35</td>
<td>1.44</td>
<td>1.52</td>
<td>1.69</td>
</tr>
</tbody>
</table>

$^1$Blesl, M., et al. (2009)
$^2$CARB (2000)
$^3$Hackbarth, A., et al. (2009)
$^4$ewi et al. (2010)
## Frame of analysis

### Uncertainties

<table>
<thead>
<tr>
<th>Component</th>
<th>Low uncertainty</th>
<th>Medium uncertainty</th>
<th>High uncertainty</th>
</tr>
</thead>
<tbody>
<tr>
<td>Car body</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Combustion engine</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tank</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electric engine</td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Battery</td>
<td></td>
<td></td>
<td>X (compare path 1-3)</td>
</tr>
<tr>
<td>Infrastructure</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Net services</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Incentives</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Energy prices</td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Residual value / disposal</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Sensitivity analysis
Optimistic development of battery costs
Sensitivity analysis
Pessimistic development of battery costs
Sensitivity analysis
Grid services

Assumption of 200€/a and 100€/a

• Results without compensation show no significant difference in the TCO (around 1€ct)
• The overall picture does not change
• Another analysis\(^1\) even points out compensations below 100€ for tertiary control

It is questionable if grid services with the assumed compensation has an influence on the economic efficiency of electric vehicles for private consumers

• This might change if prices for grid services rise in the future
• But: loss in value of battery due to additional charging has to be considered

\(^1\)Hennings, W., Linssen, J., (2010)
Summary

Analysis of economic efficiency of electric mobility by displaying Total Costs of Ownership of electric vehicles in comparison to conventional vehicles

- Lower costs of operation of electric vehicles cannot compensate higher costs of acquisition in comparison to conventional vehicles today (in 2010)
- Battery costs and development of battery costs have significant influence on the economic efficiency
- Compensation of grid services has insignificant influence

- Electric vehicles can have an economic advantage for private consumers under certain conditions in comparison to conventional vehicles
- But: Results of TCO point out, that conventional vehicles are economically advantageous to electric vehicles today and also in the near future
Discussion and Outlook

This analysis can and should be expanded to achieve an overall picture of the economic efficiency of electric mobility:

• Incentive schemes
• Taxation
• Electricity and fuel costs
• Grid services – different operation models
• Loss in value of battery
• Behavior of consumers
• Loss in utility due to limited driving range and long charging periods
Thank you for your attention!
Contact information

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Literature