MARKET DIFFUSION OF ELECTRIC VEHICLES IN GERMANY

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Workshop Electro Mobility in Northwestern Germany – Experiences and Perspectives
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Sources:
http://www.theicct.org/european-vehicle-market-statistics-2016-2017
https://www.tesla.com/models
http://www.mennekes.de/index.php?id=aktuell_details&tx_ttnews[tt_news]=608&cHash=78756603b971f6891ad935a0f6b579a3
AGENDA

- Motivation for (research in) electro mobility
- Market diffusion of plug-in electric vehicles as passenger cars
  - Status quo
  - Market projections
  - Policy options
  - Impact on the energy system
- Outlook: What’s next?
To achieve Europe’s climate targets, a drastic reduction in transport CO$_2$-emissions is needed

- The EU’s long term goal is to reduce GHG emissions by 80%
- Power production and road transport have to become almost CO$_2$ free
- This is **impossible with** efficiency gains in combustion engines
- New technologies and concepts are clearly needed.
- **Electric vehicles powered by renewable energies** can contribute significantly

Source: www.roadmap2050.eu
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PEV market diffusion in Europe

- Historical **new PEV registrations** in Europe:

  - Norway, The Netherlands and Sweden with market shares above 3%
  - Yet, large car markets with higher number of PEVs: Norway, Spain, France, Germany and The Netherlands above 15,000 PEVs

Data sources: de.statista.com, eafo.eu und EUROPEAN VEHICLE MARKET STATISTICS Pocketbook
China will dominate global PEV sales...

...but will the national government hold on to this plan in the next years?

How will PEV market diffusion evolve in other countries?

And, what determines the diffusion?

Source: https://en.wikipedia.org/wiki/Electric_car_use_by_country
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Vehicle sales of new technologies are hard to estimate but very important

* Uncertain
** Highly uncertain
*** Extremely uncertain

**Idea:** Compare market diffusion models and determine how they differ.

The model ALADIN (Alternative Automobiles Diffusion and Infrastructure)
Market diffusion of PEVs in Germany

Future PEV stock based on simulations with ALADIN (Alternative Automobiles Diffusion and Infrastructure)

Important results
- No lock-in for PEVs in Germany if there is no public charging infrastructure
- High shares of PHEV in next years
- Large influence of framework conditions

Assumptions for 2030 (all prices with VAT in €2014)

<table>
<thead>
<tr>
<th></th>
<th>Contra-EV</th>
<th>Medium scenario</th>
<th>Pro-EV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gasoline price [€/l]</td>
<td>1.50</td>
<td>1.75</td>
<td>2.00</td>
</tr>
<tr>
<td>Diesel price [€/l]</td>
<td>1.42</td>
<td>1.65</td>
<td>1.90</td>
</tr>
<tr>
<td>Electricity price private [€/kWh]</td>
<td>0.35</td>
<td>0.32</td>
<td>0.27</td>
</tr>
<tr>
<td>Battery price [€/kWh]</td>
<td>295</td>
<td>266</td>
<td>235</td>
</tr>
</tbody>
</table>

Comparison of 40 papers from 11 regions shows variety of results and higher PHEV market shares in the short-term

What were “important factors stated” by authors and do they differ in countries?

Main findings:

- A lot of factors are stated to be important after the analysis (16 different factors in 40 models)
- factors with “n/a” were not investigated by us
- Some country-specific differences:
  - For the US vehicle cost seems to be most important
  - For Germany, energy prices and other factors tend to be more important
  - Very heterogeneous in other countries

How do battery prices evolve?

Development of cell cost in €/kWh

- From cell cost to end user price: ~+100% (cf. Schröter et al. 2013)
- Cell to system: +53%
- Mark-up: +15%
- VAT: +32% (19% on price w/o VAT)

Source: Thielmann et al. 2015 – Gesamtroadmap Energiespeicher für Elektromobilität (incl. Aktualisierung); Schröter et al. 2013 - Energiespeicher Monitoring für die Elektromobilität (EMOTOR) - Nachhaltigkeitsbericht Teil 1;
How will the oil price evolve in the next years?

- Until 2007, the oil price was projected to stay stable in the future (until 2030 / 2035)

- Increase of oil price developments thereafter until 2013:
  - WEO2013: 128$/bbl in 2035
  - WEO2014: 128$/bbl in 2040
  - WEO2015: 128$/bbl in 2040)

→ Future development unclear, but a higher price than today can be assumed.

Source:
Left panel: Ludwig-Bölkow Systemtechnik (Werner Zittel) with data from IEA (1998-2012)
Future evolution of electricity prices

Electricity price is largely dependent on surcharges:

- **Decrease and phase out of renewable surcharge from 2020 on as renewables become economical**
- **Cost for grid construction assumed to be at 1€ct/kWh**
- **Stabilization / decrease of end user prices after 2030**

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Motivation

- Major policy attempts world-wide to foster electric vehicle adoption
- Yet, little empirical evidence on effect and efficiency of policies
- Question: **What is the impact of direct and indirect incentives on EV adoption?**

Figure source: Mock, P., & Yang, Z. (2014). Driving electrification: A global comparison of fiscal incentive policy for electric vehicles. *The International Council on Clean Transportation (ICCT).*

Results on PEV sales shares

- Data: Mainly European markets
- Dependent variable: \( \log \text{ PEV sales share} \)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Est.</th>
<th>SE</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Intercept)</td>
<td>-13.5</td>
<td>1.8</td>
</tr>
<tr>
<td>Income ('000 €)</td>
<td>0.083**</td>
<td>0.023</td>
</tr>
<tr>
<td>Electricity price</td>
<td>2.439</td>
<td>4.73</td>
</tr>
<tr>
<td>Gasoline price</td>
<td>2.813*</td>
<td>1.064</td>
</tr>
<tr>
<td>Direct incentive ('000 €)</td>
<td>0.164*</td>
<td>0.078</td>
</tr>
<tr>
<td>Indirect incentives (lin.)</td>
<td>0.712*</td>
<td>0.336</td>
</tr>
<tr>
<td>Indirect incentives (quad.)</td>
<td>0.541</td>
<td>0.594</td>
</tr>
</tbody>
</table>

- +16% PEV sales share per 1,000 € incentive
- Similar results for separate regression on PHEV or BEV sales shares

Positive effect of direct & indirect incentives

Standardized coefficients:

Framework conditions in Germany not advantageous

- high gasoline and low electricity prices make PEVs economical during use

- Norway and The Netherlands provide high subsidies, but their energy prices also favor PEVs

- These conditions are not very favorable in Germany and Denmark

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Substantial PEV market penetration possible with only **domestic/commercial** charging infrastructure.

Charging **@work** (S2) increases market shares and PEV stock.

**Public** slow charging has no impact.

**User groups**

- **2020**: PEV stock dominated by commercial fleet users.
- **2030**: Larger shares for private PEVs 2030 (former fleet vehicles).

**PEV types**

- **PHEVs** dominate in 2020 and 2030.

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**Scenario**

<table>
<thead>
<tr>
<th></th>
<th>Domestic</th>
<th>Work</th>
<th>Public</th>
</tr>
</thead>
<tbody>
<tr>
<td>S1</td>
<td>✔</td>
<td></td>
<td></td>
</tr>
<tr>
<td>S2</td>
<td></td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>S3</td>
<td></td>
<td>✔</td>
<td>✔</td>
</tr>
</tbody>
</table>

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Case study
Electricity demand

Additional electricity demand
- **Private**
  - @work raises 2030 demand by 3.5 TWh
- **Fleet PEVs** same demand in all scenarios
- **Total:** +2-3 TWh (2020) = +0.6%
  - +14-17 TWh (2030) = +3-4%

Uncontrolled charging
- Charging **@home**: 
  - Private PEVs in evening hours: +3 GW
  - Fleet PEVs charge during the day => less impact on system load peaks
- Charging **@work**: additional morning peak
- Public charging has no impact

Case study
Flexibility potentials

Impact on charging profile
- Shiftable load of smart charging @home:
  - In midday hours limited to 3 GW for private PEVs
- @work/public: +5 GW for private PEVs; no impact on comm. PEVs

Impact on peak load and curtailment
- Smart charging @home:
  - Max. net load: -2.4GW / -3.6%
  - Curtailment: -1.6 TWh / -26%
- + @work: Curtailment: -1.8 TWh / -30%; but no further peak load reduction
- + @public: No additional impact

Summary on market diffusion, charging infrastructure and load shifting potentials

- **PEV market uptake** already **takes place** with charging infrastructure **at home**
- PEV stock is dominated by **PHEVs** (80% in 2020 and 70% in 2030 in all scenarios)
  - However, reduced DR potential due to smaller batteries and lower electricity demand
- **Commercial fleet vehicles** have significant shares but low impact on system peak load
- **Smart charging** facilitates the **integration** of **private** PEVs in the system

- **Charging** infrastructure **at work facilitates** PEV market penetration and increases flexibility potential
- **Public charging** infrastructure has **no additional benefit** on PEV diffusion AND load shifting potential.
- **Smart charging** smoothens the net load but may imply **new** system load **peaks locally** that may additionally challenge the grid.

- Consider impact of smart PEV charging on **power market and prices**
- Compare **flexibility potential** of PEVs with other flexiblity options

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HEAVY-DUTY VEHICLES NEED MORE ATTENTION AND RESEARCH

Source: Siemens AG
How do heavy duty vehicles differ from passenger cars?

<table>
<thead>
<tr>
<th>Attributes</th>
<th>Passenger car</th>
<th>40t heavy-duty truck</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vehicle stock</td>
<td>40 million</td>
<td>180,000</td>
</tr>
<tr>
<td>Average annual vehicle mileage</td>
<td>14,000 km</td>
<td>115,000 km</td>
</tr>
<tr>
<td>Annual CO\textsubscript{2} emissions</td>
<td>~80 m tons CO\textsubscript{2}/a total</td>
<td>~20 m tons CO\textsubscript{2}/a total</td>
</tr>
<tr>
<td></td>
<td>~2 ton CO\textsubscript{2}/a per vehicle</td>
<td>~110 ton CO\textsubscript{2}/a per vehicle</td>
</tr>
<tr>
<td>Daily usage</td>
<td>~1 hour/day</td>
<td>~4-6 hrs/day (for 115,000 km/year)</td>
</tr>
</tbody>
</table>

Currently no optimal technical solutions and research is far behind passenger cars...

Studies on alternative drive trains for heavy duty vehicles to be published soon...
Motivation for research in electro mobility → necessity to decarbonize road transport, regulations force car makers to act

Market diffusion of plug-in electric vehicles as passenger cars
- Status quo → China will dominate the PEV market (in the next years?)
- Market projections → Tendency to more PHEV in the short term, absolute evolution uncertain because of energy prices and consumer adoption
- Policy options → Impact of incentives also depends on market conditions, probably regulations more helpful
- Impact on the energy system → Rising load shift potential with higher availability of charging infrastructure at work

Outlook: What’s next? → Think about strategies to decarbonize heavy road transport
Thank you for your attention!

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www.profilregion-ka.de
Lots of users could easily charge at home.

German passenger vehicle stock subdivided into typical parking spots and city sizes.*

- 60% of all users leave their car in garages overnight
- Another 30% park their cars close by
- Only 10% of so-called lantern parkers

→ Initial charging infrastructure can be provided rather simple

**But:** Not sure if all garages do have electricity connection.