Reserve provision by electric vehicles in Germany: model-based analyses for 2035

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Berlin, September 2, 2016
Introduction

Energy system development – not only in Germany

- Expansion of fluctuating renewables
- Introduction of electric vehicles (EVs)

Questions of interactions between these trends arise

- Particular focus here:
  - provision of reserves by EVs and role of vehicle-to-grid (V2G)
- Under different assumptions on charging strategy
- In the context of other flexibility options

Scenario-based analyses for Germany 2035 with DIETER
(Dispatch and Investment Evaluation Tool with Endogenous Renewables)
Methodology

We use the open-source model DIETER

- Power sector model for medium-/long-term analyses
- Fully open source including input data
- [www.diw.de/dieter](http://www.diw.de/dieter)

Minimization of overall system costs

- Subject to a range of constraints
- Energy balance for wholesale and reserve markets

Detailed representation of flexibility options

- Power storage, DSM, flexible biomass & conventionals
- Hourly resolution, solved for whole year
DIETER is open-source

DIETER’s website

- www.diw.de/dieter

DIETER grows and improves

- Electric vehicles
- District heating
- Bottom-up weather data
- Multiple countries
- Dynamic investment framework
- Stochasticity
- …
DIETER Version 1.1.0 includes electric vehicles

- Building on European research project DEFINE (Schill and Gerbaulet, *Applied Energy* 2015)

Grid-to-vehicle (G2V) and vehicle-to-grid (V2G)

- For both wholesale and reserve markets

**EVs may provide reserves in different ways**

- Positive reserves
  - Additionally feed back electricity to the grid (V2G)
  - Do not charge in wholesale market (G2V)

- Negative reserves
  - Additional charging (G2V)
  - Do not feed back electricity to the grid in wholesale market (V2G)
Model setup allows representing different system values of EVs

- Arbitrage in wholesale market
- Reserve provision
- Capacity value (substitution of other flexibility options)
Scenarios and input data

Scope

• 2035, Germany only

Calibrated to grid development (NEP) scenario framework 2035

• Installed capacities, fuel prices
• Gross RES share of ~60%

Historic hourly profiles

• Load, RES availability, reserve activation, EVs
EVs

- Hourly patterns of grid availability and power consumption
- 28 different vehicle profiles: 16 BEV, 12 PHEV
- 4.4 million: 25% BEV, 75% PHEV
- V2G incurs additional depreciation costs: 41 €/MWh

Scenarios

- Baseline: all capacities like NEP
- Adjusted portfolio: CCGT, OCGT, PHS, DSM partly endogenous
- Each for different charging strategies
- Sensitivity analysis: zero V2G costs
### Scenarios and input data: Different charging strategies

<table>
<thead>
<tr>
<th>Charging (G2V)</th>
<th>Discharging (V2G)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wholesale</td>
<td>Reserves</td>
<td>Wholesale</td>
</tr>
<tr>
<td>a) Charging only</td>
<td>✔</td>
<td>-</td>
</tr>
<tr>
<td>b) Reserves only by G2V</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>c) Reserves by G2V and V2G</td>
<td>✔</td>
<td>✔</td>
</tr>
<tr>
<td>d) Only arbitrage</td>
<td>✔</td>
<td>-</td>
</tr>
<tr>
<td>e) Full flexibility</td>
<td>✔</td>
<td>✔</td>
</tr>
</tbody>
</table>
→ EVs substantially contribute to reserve provision
→ Even in case of a pure G2V operation mode
Results:
Yearly energy provided by EVs in different markets (Full Flexibility)

→ Baseline: reserve activation small cp. to mobility-related consumption
→ Arbitrage negligible
Results:
System cost differences to reference scenario

→ System cost savings very low in baseline: no scarcity of flexibility!
→ Up to €16 mio, € 4 per vehicle and year
Results for „Adjusted portfolio“: Installed capacity (differences to baseline)

- a) Less OCGT and PHS, more load shedding
- c), d), e) additional vehicle flexibility substitutes capacity
Results:
Yearly energy provided by EVs in different markets (Full Flexibility)

Because of lower “flexibility reserves” in adjusted generation portfolio
Results: System cost differences to reference scenario

System cost savings increase substantially in less flexible system
Up to €135 mio, €31 per vehicle and year
→ No V2G costs: EVs provide even more reserves
→ EVs heavily used for arbitrage
Results:
System cost differences to reference scenario

→ No V2G costs: much higher system cost savings
→ Up to €276 mio, € 63 per vehicle and year
Conclusions

EVs can contribute substantially to reserve provision

• Even without vehicle-to-grid

Yet the system value is low under baseline assumptions

• Plenty of other (short-term) flexibility options in the future
• Challenge to find viable business cases
• But only little additional costs cp. to optimal charging?

The value of EV flexibility grows if...

• ... the power plant portfolio considers EVs
• ... V2G does not incur additional battery depreciation costs

EVs become a relevant bulk storage option only under optimistic V2G cost assumptions
Bereitstellung von Regelleistung durch Elektrofahrzeuge: Modellrechnungen für Deutschland im Jahr 2035

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Reserve provision by electric vehicles: model-based analyses for Germany in 2035

Abstract The German government has set ambitious goals for both the expansion of renewable energy supply and electrification. According to its Energiewende policy, electricity supply from fluctuating renewables is supposed to increase considerably. This will tend to require a greater provision of balancing reserves. At the same time, supply from conventional dispatchable plants, which used to provide the bulk of reserves, will decrease. Against this background, this article analyzes the scope for an assumed fleet of 4.4 million electric vehicles to supply balancing reserves in 2035. Examining two different future power...
Vielen Dank für Ihre Aufmerksamkeit.
Results
Reserve provision for different charging strategies (Baseline)

- b) RL nur durch G2V
- c) RL durch G2V und V2G
- e) Volle Flexibilität

Positive Regelleistung

- b) RL nur durch G2V
- c) RL durch G2V und V2G
- e) Volle Flexibilität

Negative Regelleistung

Megawatt

- V2G
- G2V

Alexander Zerrahn, September 02, 2016
Results
Energy provided in wholesale market by DSM, PHS and EV

![Bar chart showing energy provided in wholesale market by DSM, PHS and EV.](chart.png)