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

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Overview

1. Introduction
2. Methodology
3. Scenarios and input data
4. Results
5. Conclusions

1 Introduction

- Two energy system trends – 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 a dispatch (and investment) model

2 Methodology

- We use the open-source model DIETER
  - Dispatch and Investment Evaluation Tool with Endogenous Renewables
  - Fully open source including input data
  - www.diw.de/dieter
- Power sector model for medium-/long-term analyses
- 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
- Hourly resolution, solved for whole year

2 Methodology

- DIETER Version 1.1.0: includes electric vehicles
  - Building on European research project DEFINE (Schill, 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)

2 Methodology

- Model setup allows representing different system values of EVs:
  - Arbitrage in wholesale market
  - Reserve provision
  - Capacity value (substitution of other flexibility options)

3 Scenarios and input data

- Scope:
  - 2035, Germany only
- Leaning on NEP scenario framework 2035
  - Installed capacities, fuel prices
  - Gross RES share of ~60%
- Historic hourly profiles
  - Load, RES availability, reserve activation, EVs
- Reserves
  - Provision: endogenous, based on RES capacity
  - Activation: according to (relative) historic profiles

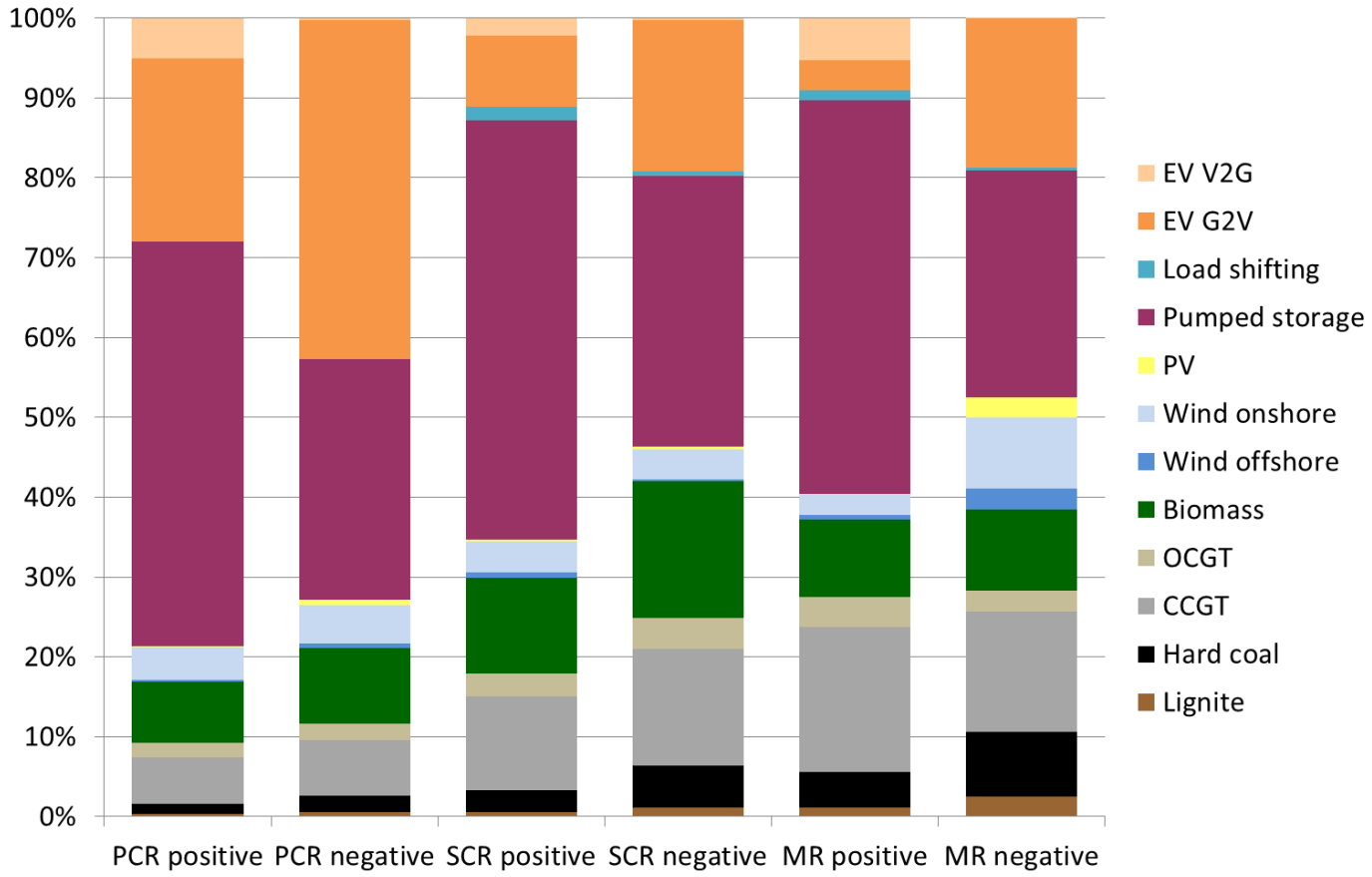
3 Scenarios and input data

- 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
- Sensitivity analysis: zero V2G costs
- Each for different charging strategies

3 Scenarios and input data: Different charging strategies

	Charging (G2V)		Discharging (V2G)		Description
	Wholesale	Reserves	Wholesale	Reserves	
a) Charging only	✓	-	-	-	Only cost-minimal charging (for mobility purposes)
b) Reserves only by G2V	✓	✓	-	-	Reserves by adjusted charging
c) Reserves by G2V and V2G	✓	✓	-	✓	Reserves by adjusted charging and discharging
d) Only arbitrage	✓	-	✓	-	Wholesale arbitrage by V2G, but no reserves
e) Full flexibility	✓	✓	✓	✓	Reserves by adjusted charging and discharging and wholesale arbitrage

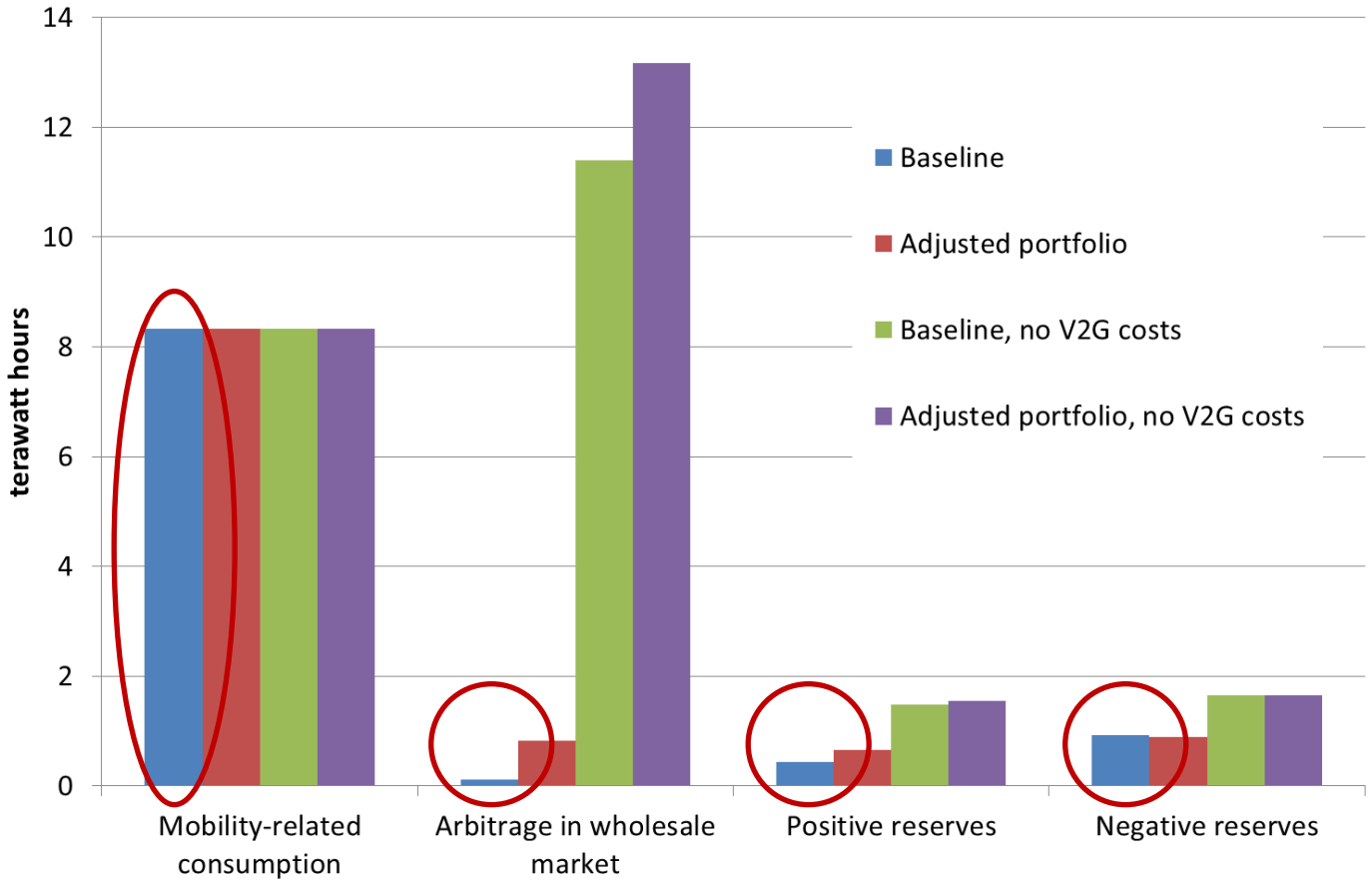
4 Results: Reserve provision shares (Baseline, Full Flexibility)



→ EVs substantially contribute to reserve provision

→ Even in case of a pure G2V operation mode

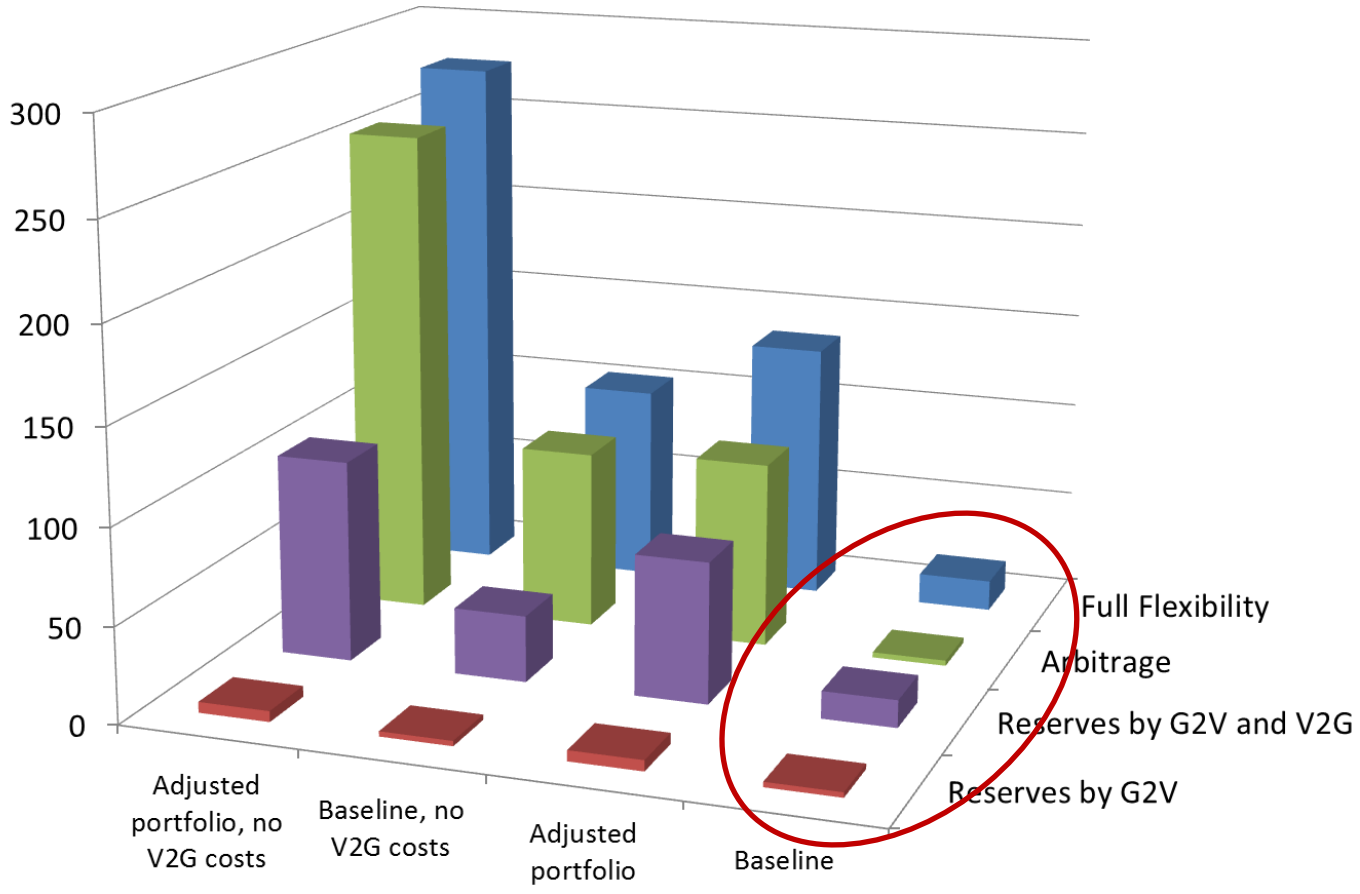
4 Results: Yearly energy provided by EVs in different markets (Full Flexibility)



→ Baseline: reserve activation small cp. to mobility-related consumption

→ Arbitrage negligible

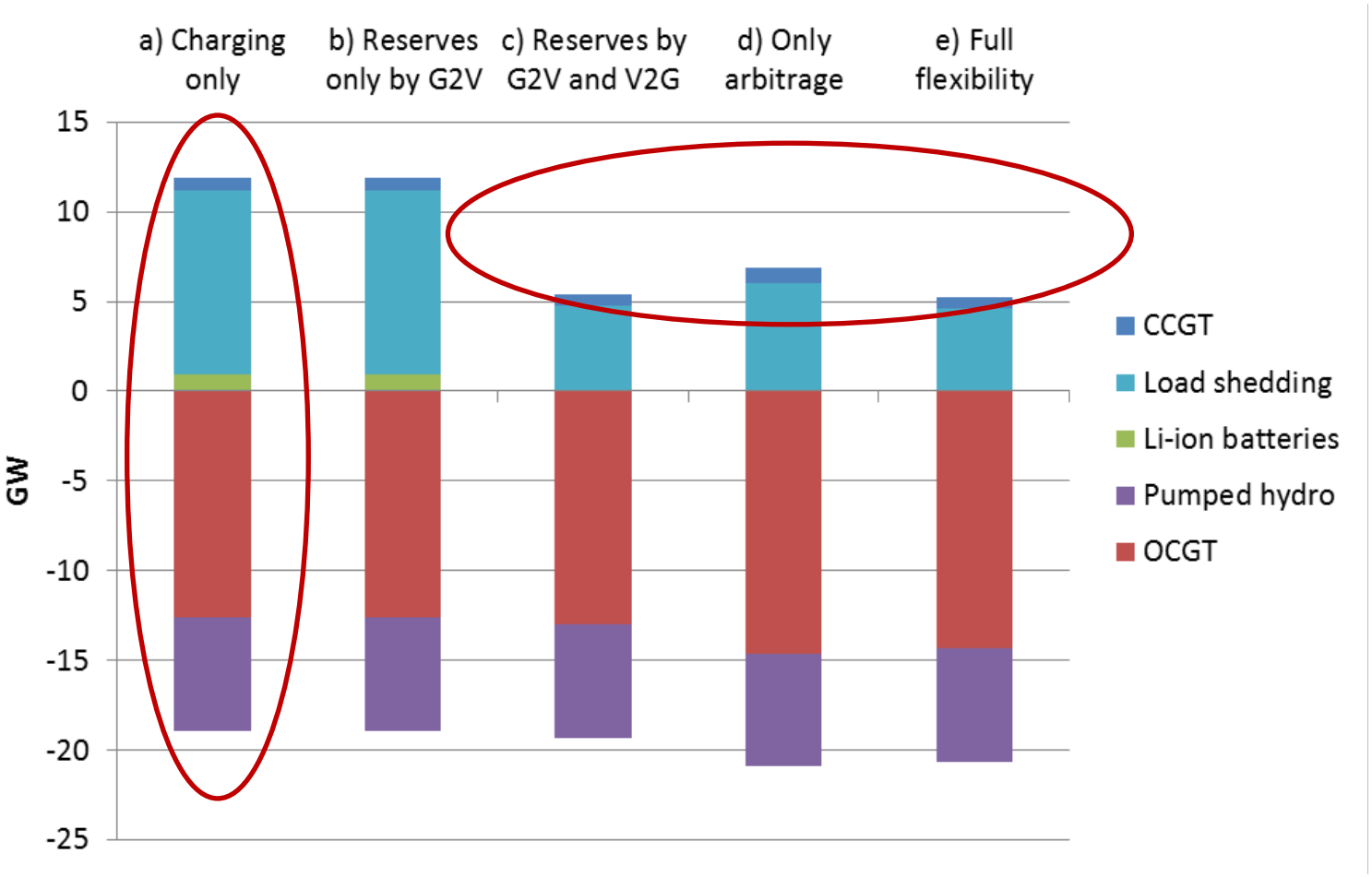
4 Results: System cost differences to reference scenario



→ System cost savings very low in baseline: no scarcity of flexibility!

→ Upt to €16 mio, € 4 per vehicle and year

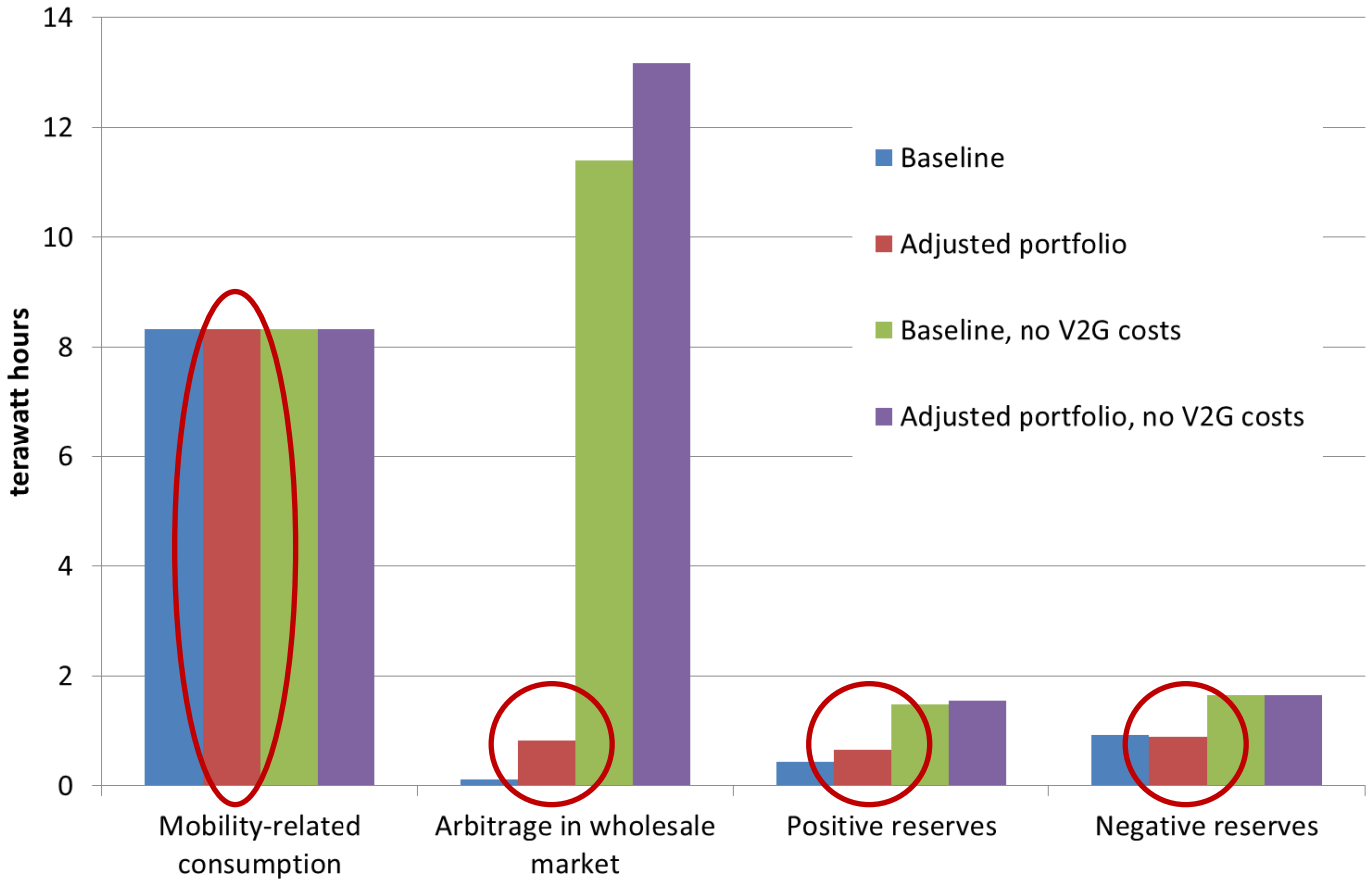
4 Results for „Adjusted portfolio“: Installed capacity (differences to baseline)



→ a) Less OCGT and PHS, more load shedding

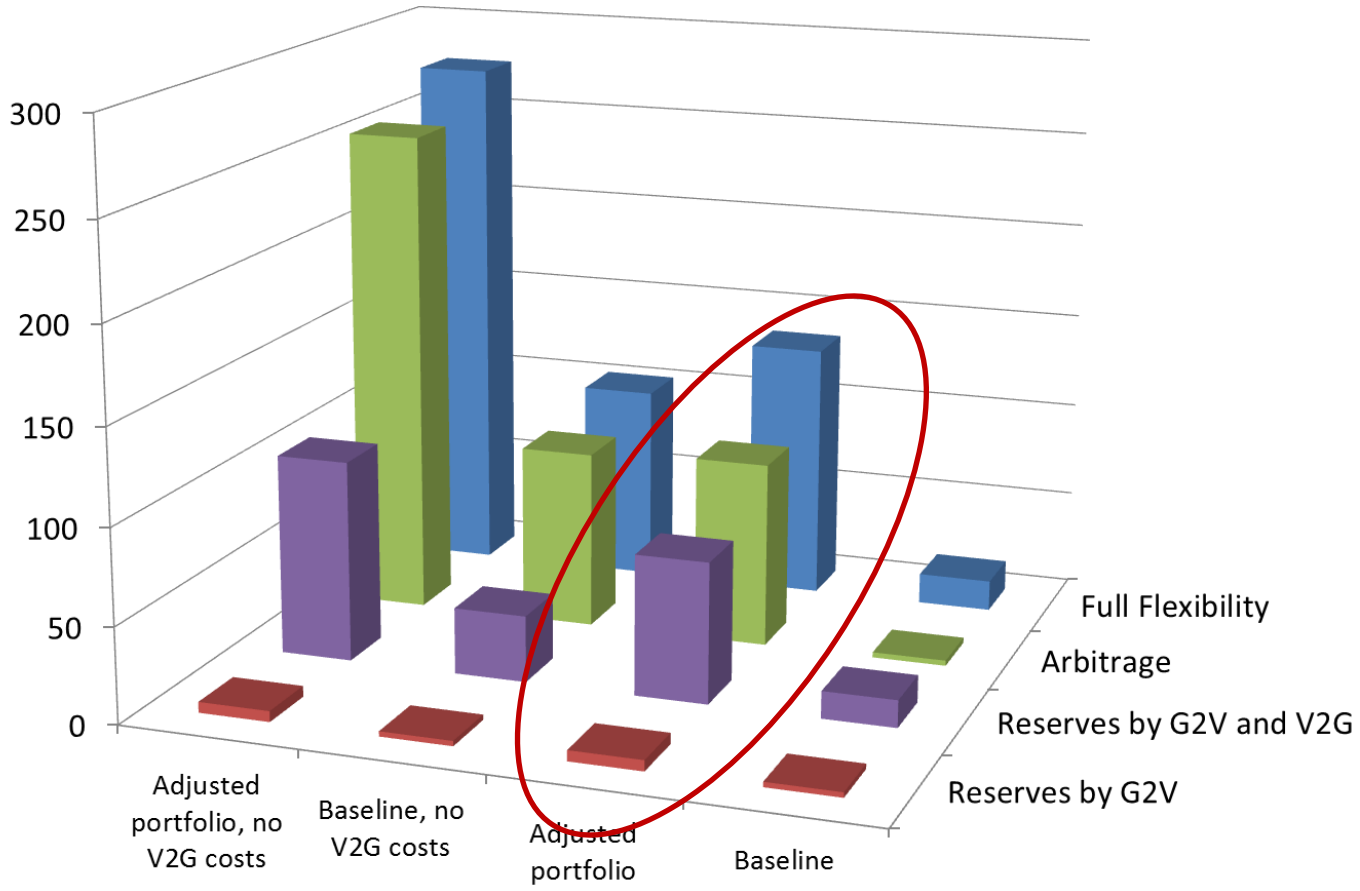
→ c), d), e) additional vehicle flexibility substitutes capacity

4 Results: Yearly energy provided by EVs in different markets (Full Flexibility)



→ Because of lower “flexibility reserves” in adjusted generation portfolio

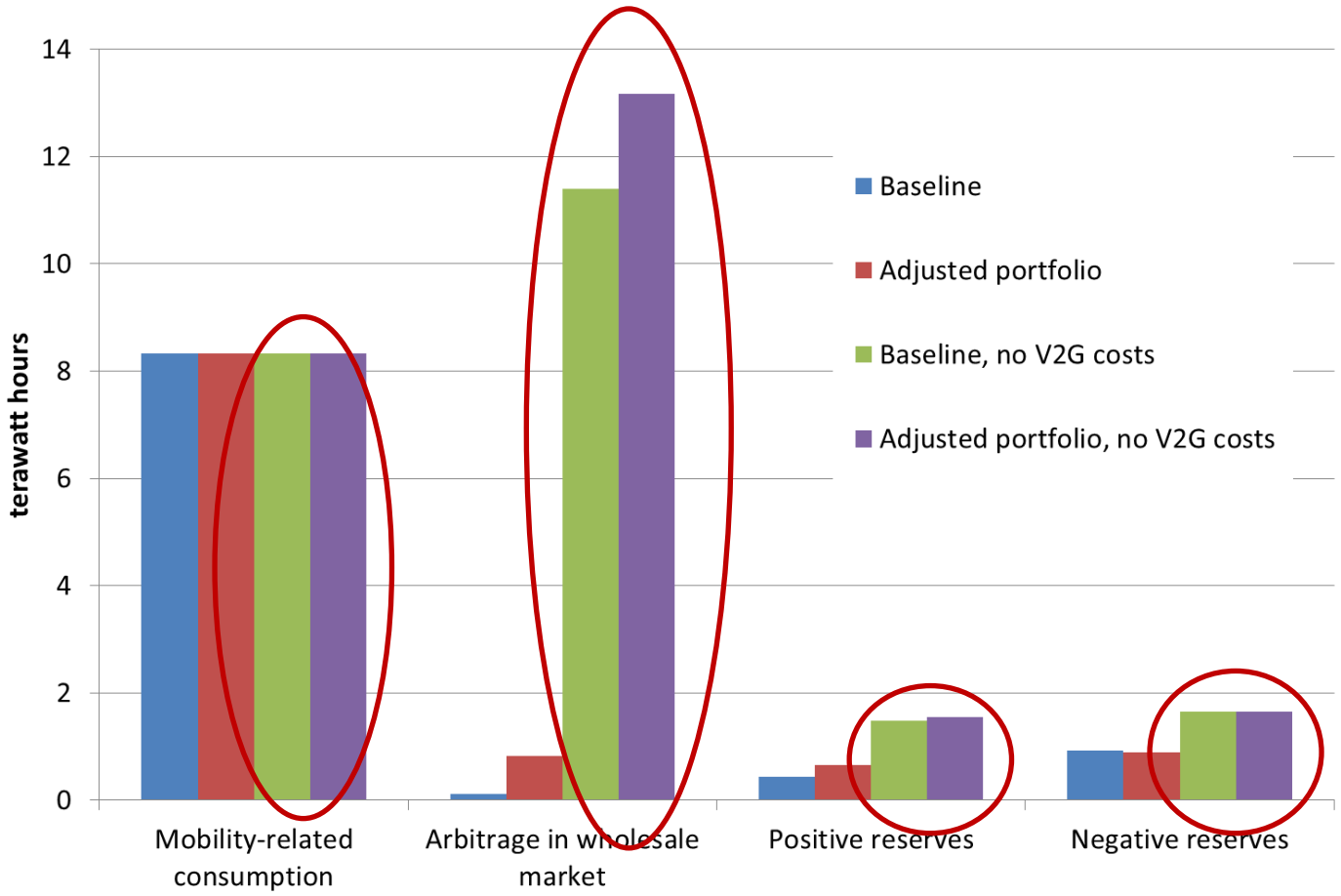
4 Results: System cost differences to reference scenario



→ System cost savings increase substantially in less flexible system

→ Up to €135 mio, € 31 per vehicle and year

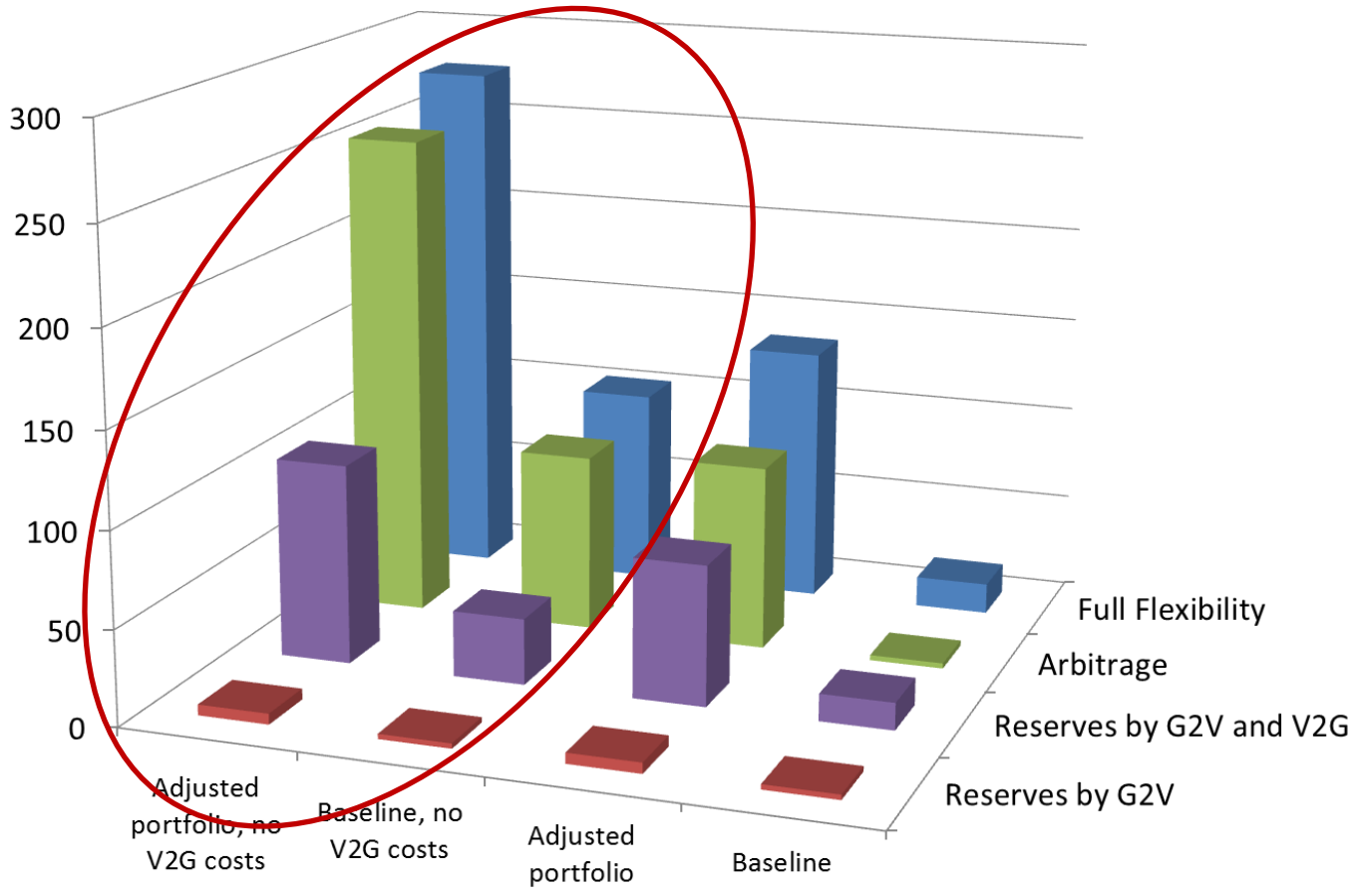
4 Results: Yearly energy provided by EVs in different markets (Full Flexibility)



→ No V2G costs: EVs provide even more reserves

→ EVs heavily used for arbitrage

4 Results: System cost differences to reference scenario



→ No V2G costs: much higher system cost savings

→ Up to €276 mio, € 63 per vehicle and year

5 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 plant portfolio considers EVs
  - … V2G does not incur additional battery depreciation costs
- EVs become a relevant bulk storage option only under optimistic cost assumptions

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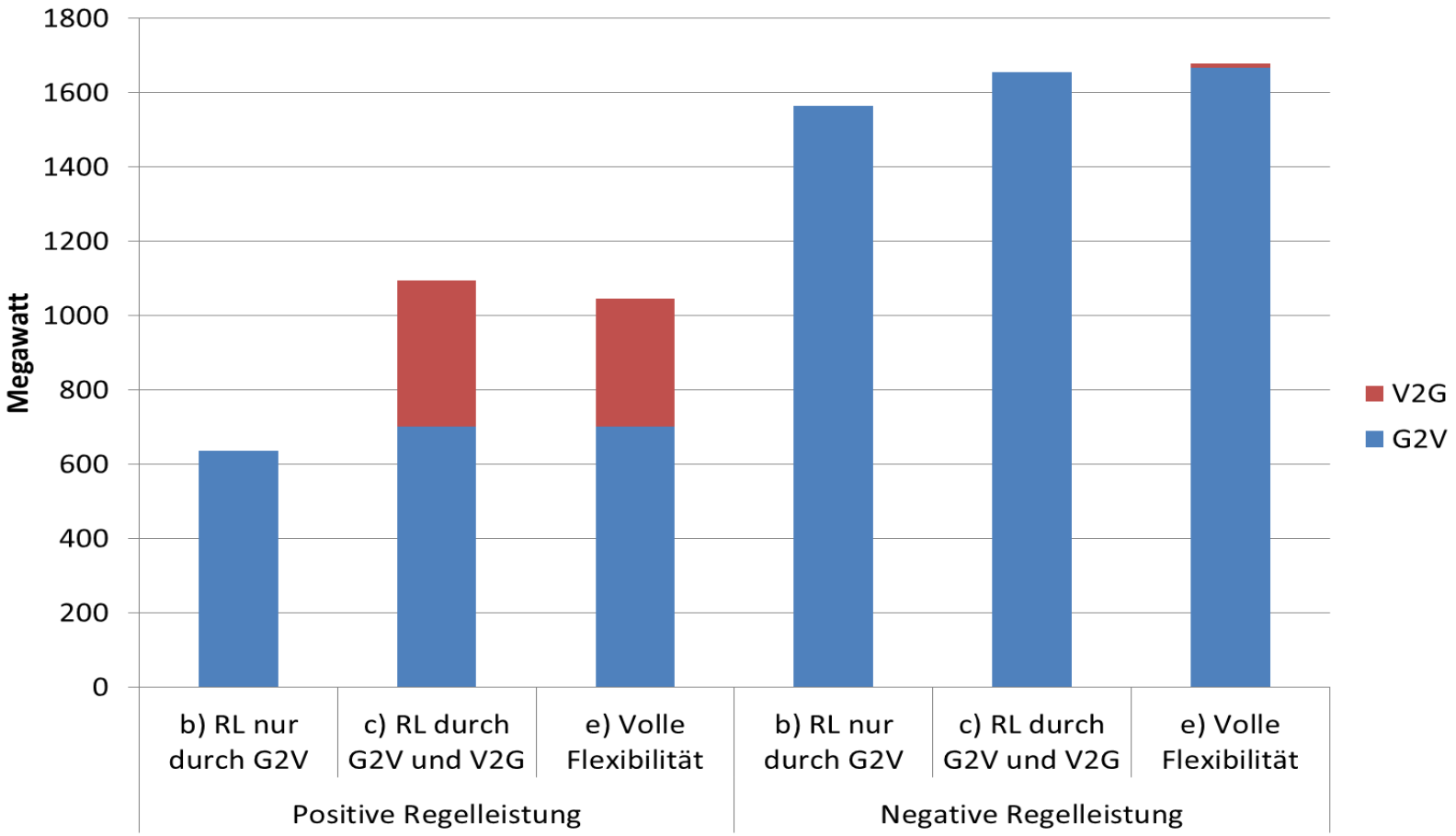
Results
Reserve provision for different charging strategies (Baseline)



Results
Energy provided in wholesale market by DSM, PHS and EV