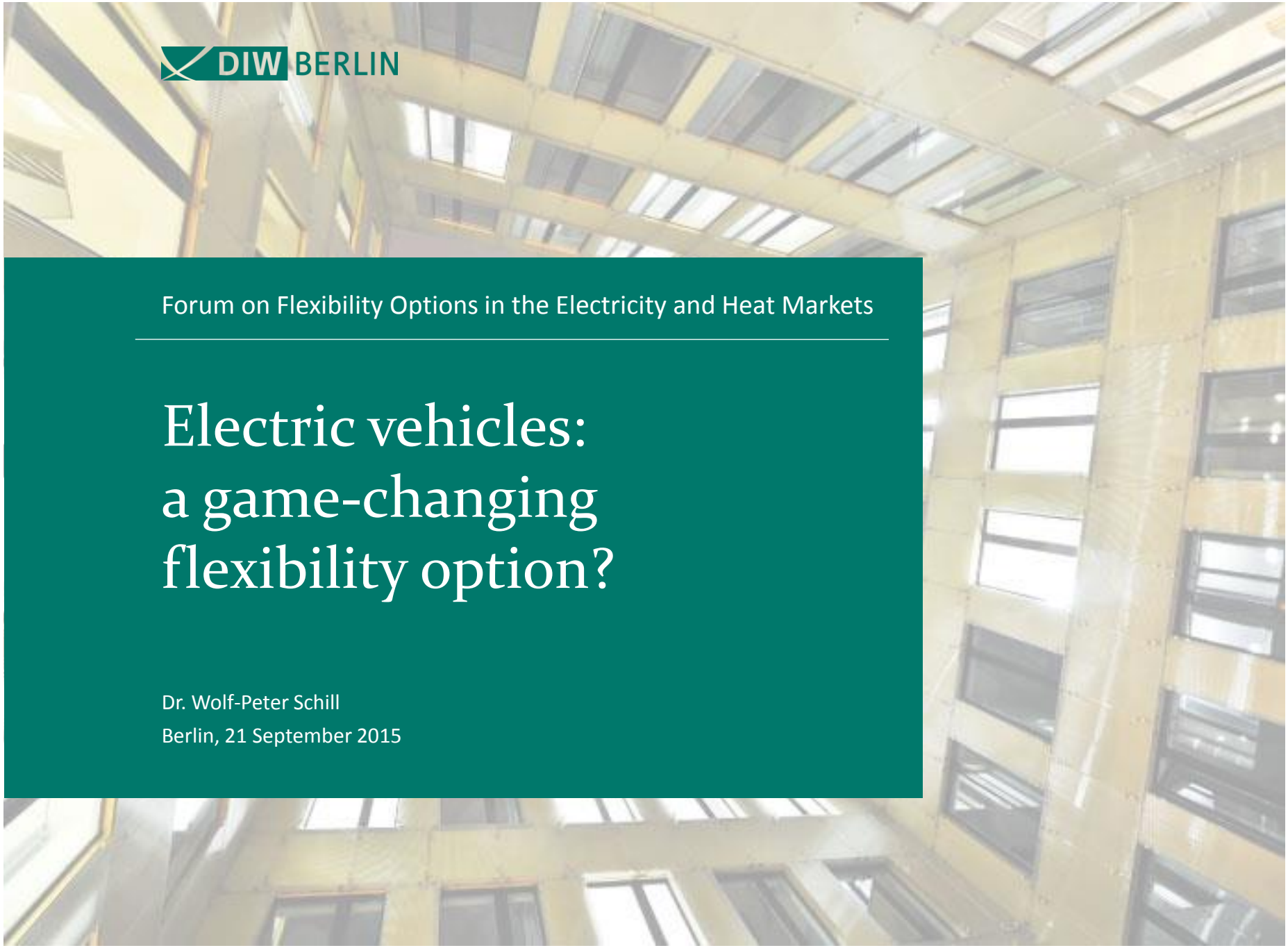


DIW BERLIN

Forum on Flexibility Options in the Electricity and Heat Markets

Electric vehicles: a game-changing flexibility option?

Dr. Wolf-Peter Schill

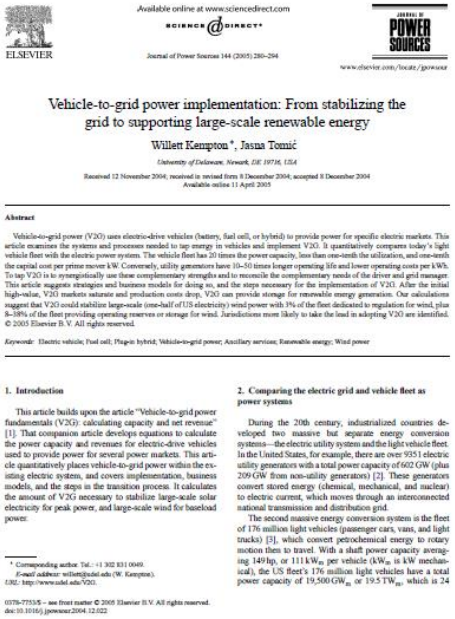
Berlin, 21 September 2015

Overview

1. Introduction: grid-connected vehicles
2. Potential fields of application
3. Research-based insights
4. Important uncertainties
5. Personal conclusions

1 Introduction

- Grid-connected (hybrid) electric vehicles
  - Not only benefits compared to internal combustion engines
  - But also potential synergies with the power system
- V2G concept: Kempton, Tomić (2005)
  - EV may provide storage and quick-response generation
- Differentiation: G2V vs. V2G
- Aggregation and control required
- EVs as grid resources:
  between power storage and DSM
- Batteries are there anyway – “free lunch”?



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Vehicle-to-grid power implementation: From stabilizing the grid to supporting large-scale renewable energy

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Abstract

Vehicle-to-grid power (V2G) uses electric-drive vehicles (battery, fuel cell, or hybrid) to provide power for specific electric markets. This article examines the systems and processes needed to tap energy in vehicles and implement V2G. It quantitatively compares today's light vehicle fleet with the electric power system. The vehicle fleet has 20 times the power capacity, less than one-tenth the utilization, and one-tenth the capital cost per prime mover kW. Conversely, utility generators have 10–50 times longer operating life and lower operating costs per kWh. To tap V2G is to synergistically use these complementary strengths and to reconcile the complementary needs of the driver and grid manager. This article suggests strategies and business models for doing so, and the steps necessary for the implementation of V2G. After the initial high-value, V2G markets saturate and production costs drop, V2G can provide storage for renewable energy generation. Our calculations suggest that V2G could stabilize large-scale (one-half of US electricity) wind power with 3% of the fleet dedicated to regulation for wind, plus 8–38% of the fleet providing operating reserves or storage for wind. Jurisdictions most likely to take the lead in adopting V2G are identified.
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Keywords: Electric vehicle; Fuel cell; Plug-in hybrid; Vehicle-to-grid power; Ancillary services; Renewable energy; Wind power

1. Introduction

This article builds upon the article “Vehicle-to-grid power fundamentals (V2G): calculating capacity and net revenue” [1]. That companion article develops equations to calculate the power capacity and revenues for electric-drive vehicles used to provide power for several power markets. This article quantitatively places vehicle-to-grid power within the existing electric system, and covers implementation, business models, and the steps in the transition process. It calculates the amount of V2G necessary to stabilize large-scale solar electricity for peak power, and large-scale wind for baseload power.

2. Comparing the electric grid and vehicle fleet as power systems

During the 20th century, industrialized countries developed two massive but separate energy conversion systems—the electric utility system and the light vehicle fleet. In the United States, for example, there are over 9351 electric utility generators with a total power capacity of 602 GW (plus 209 GW from non-utility generators) [2]. These generators convert stored energy (chemical, mechanical, and nuclear) to electric current, which moves through an interconnected national transmission and distribution grid.

The second massive energy conversion system is the fleet of 176 million light vehicles (passenger cars, vans, and light trucks) [3], which convert petrochemical energy to rotary motion then to travel. With a shaft power capacity averaging 149 hp, or 111 kW_m per vehicle (kW_m is kW mechanical), the US fleet's 176 million light vehicles have a total power capacity of 19,500 GW_m or 19.5 TW_m, which is 24

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URL: http://www.udel.edu/V2G.

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2 Potential fields of application

- Residual load smoothing
  - Load gradients
  - Daily fluctuations
  - Longer-term / seasonal fluctuations
- Integration of RES surplus generation
- Provision of peak generation capacity
- Reserves and other ancillary services

- In addition: decentralized / off-grid applications
  - E.g., combined with local PV

2 Potential fields of application

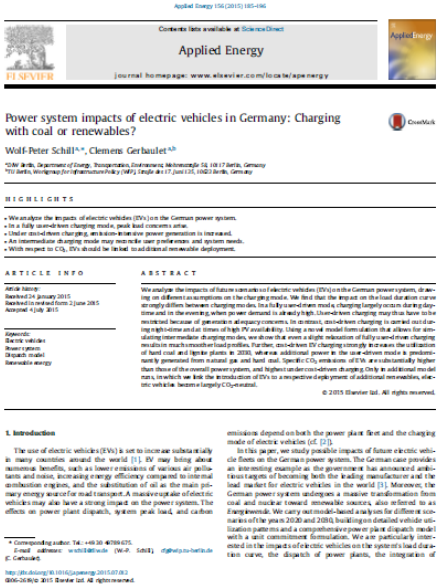
	G2V	V2G
Residual load gradients	(✓)	✓
Daily fluctuations	(✓)	✓
Seasonal fluctuations		?
RES surplus integration	✓	✓
Peak generation capacity		✓
Reserves	(✓)	✓

3 Research-based insights: The role of EVs as grid resources

- Very broad literature in energy journals
- Broad spectrum of findings:
  - EVs as major game changer or as a non-issue
- Broad consensus:
  - Controlled charging is beneficial (if not indispensable)
- Many papers suggest that reserves are a promising field
  - Wholesale price differentials not high enough
  - Low energy capacity but high power rating
  - Yet a niche (and competition with many other options)
- If EVs are linked to additional RES, still open question:
  - Do EVs bring more flexibility to the power system than is required for integrating the additional RES?

3 Some results from our own work

- European research project (ERA-NET+)
- Power system impacts of EVs in Germany by 2030
  - Under different charging strategies
  - In a unit commitment framework
  - Only G2V, only wholesale
- Major outcomes:
  - Fully user-driven charging: peak load concerns
  - Fully cost-driven charging: increase of emission-intensive power generation
  - Intermediate charging mode may reconcile user preferences and system needs



Applied Energy

Power system impacts of electric vehicles in Germany: Charging with coal or renewables?

Wolf-Peter Schill, Clemens Gerbaulet

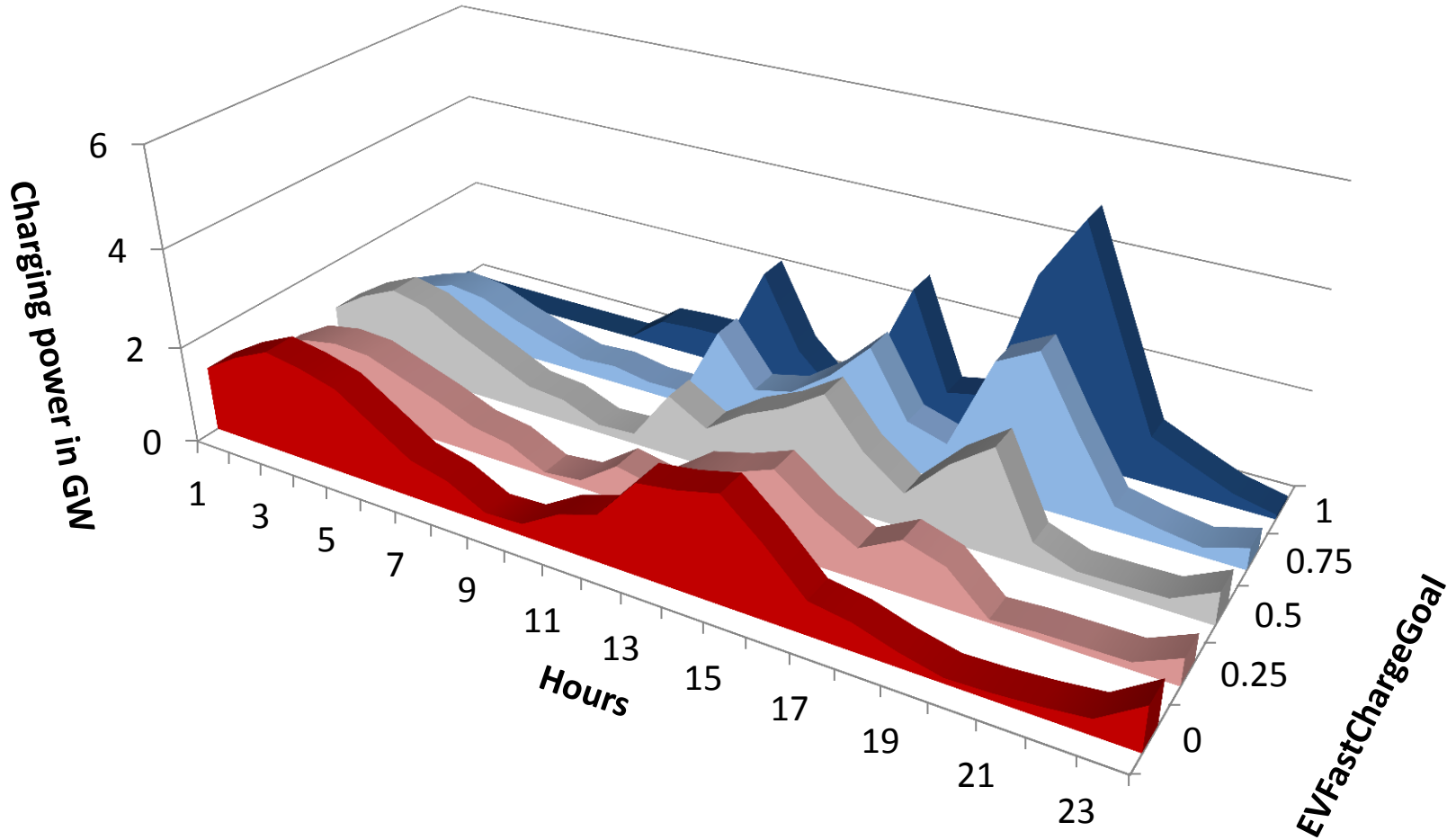
HIGHLIGHTS

ARTICLE INFO

ABSTRACT

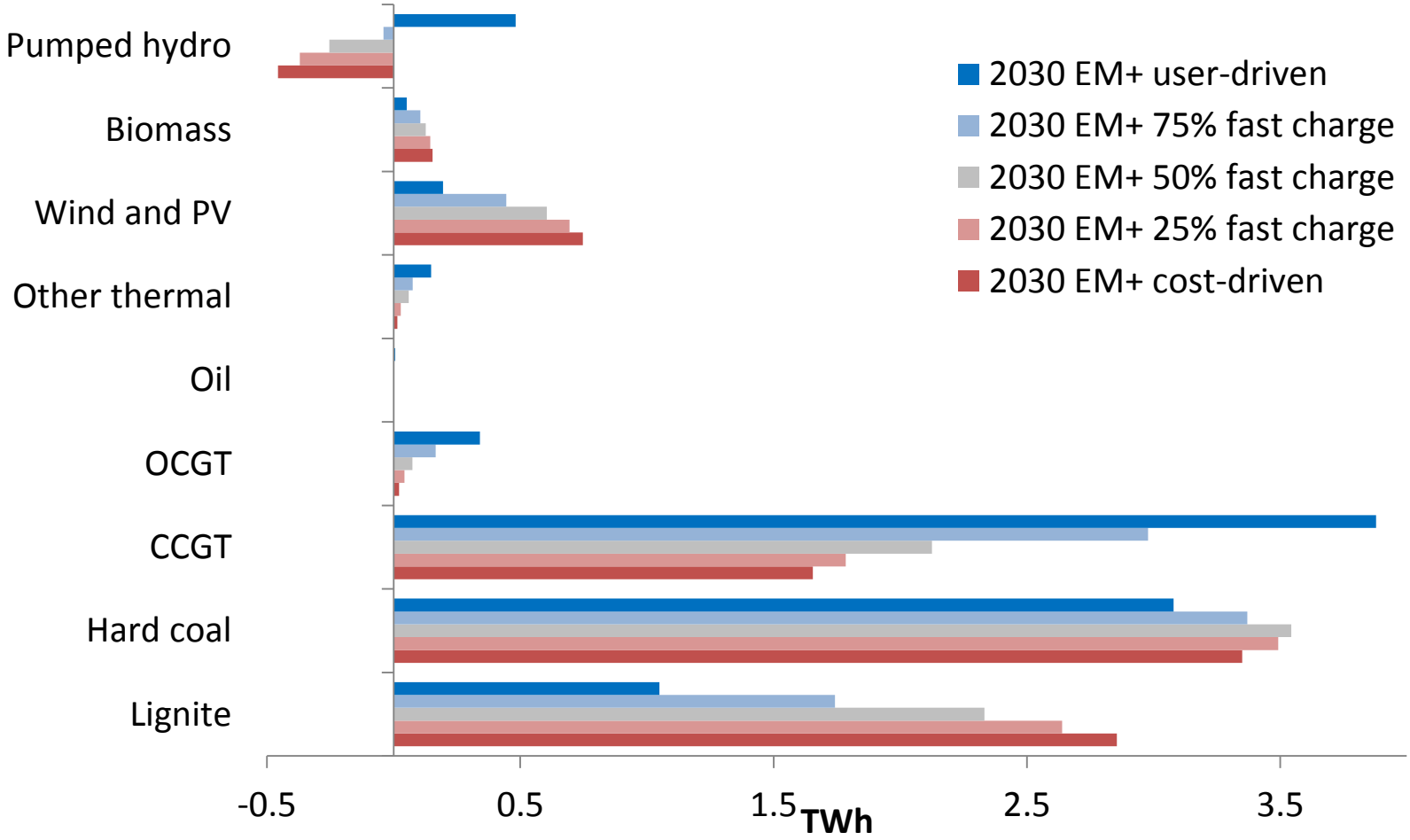
1. Introduction

3 Average charging power over 24 hours in 2030



→ Even under „G2V only“, substantial demand-side flexibility potential

3 Dispatch changes relative to scenario without EVs in 2030



→ Flexible EVs compete with power storage (and other flexibility options)

3 Ongoing work at DIW

- Integration of EV module in open-source dispatch and investment model
- Covering both reserves and V2G
- First results:
  - EVs may have relevant shares in reserve provision
  - This is true even without V2G
  - Full system value of EVs only in optimized system

  → Dispatch model analyses may underestimate EVs impacts

4 Important uncertainties

- Size of future EV fleets
- Driving patterns
  - Car sharing, fleets, autonomous vehicles?
- Charging infrastructure
- Distribution grid constraints
- Battery depreciation
- Willingness / incentives to participate
- Market design
  - Bid sizes, prequalification etc.

5 Personal conclusions

- EVs are likely to play an increasing role with respect to short-term flexibility
- Yet I would not expect EVs to become the dominant flexibility option
- Competition with many other short-term options
- But EV development could indirectly spur the development of stationary batteries

Thank you.

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