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Energy demand vs flexibility supply – disentangling effects of electric vehicles in a renewable energy system

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+++ PRELIMINARY +++ WORK IN PROGRESS +++ PRELIMINARY +++ WORK IN

Two building blocks of climate policy

- Decarbonize (individual) mobility
- Integrate growing shares of variable renewable electricity

Energy system perspective...

- Electric vehicles as additional electricity demand
- Electric vehicles as additional flexibility supply

...calls for research needs

- Interaction of electric vehicles and variable renewables
- Tradeoff between additional demand and flexibility supply

Demand and flexibility:

- 1) *Positive net effect of flexibility for small fleets*
- 2) *The more renewables, the lower the relative cost increase from larger fleet*
- 3) *Flexibility benefit decreases in fleet size*

... analyzed with the open-source power system model DIETER for Germany

DIETER...

- minimizes investment and hourly dispatch costs over one year
- greenfield or brownfield setting
- hourly market clearing and minimum shares of renewable energy

Generation and flexibility options

- thermal and renewable technologies
- different types of storage, demand-side management
- representation of reserves

Linear program

- deterministic, perfect foresight
- this version: no transmission network

Visit DIETER

- www.diw.de/dieter
- DIETER is open-source
- code under MIT license

Past and current applications

- energy storage requirements
- electric vehicles to provide reserves
- prosumage of solar electricity
- residential heat
- power-to-X, hydrogen mobility



The screenshot shows the DIETER website interface. At the top, there is a navigation bar with links for 'Über uns', 'Publikationen & Veranstaltungen', 'Forschung & Beratung', 'Themen & Nachrichten', and 'Presse'. A search bar is also present. Below the navigation is a large image of a modern building with the word 'DIETER' overlaid. A breadcrumb trail reads: 'Forschung & Beratung > Nachhaltigkeit > Energie, Verkehr, Umwelt > Modelle >'. On the left, a sidebar menu lists various categories: 'Makroökonomie und Finanzmärkte', 'Nachhaltigkeit', 'Energie, Verkehr, Umwelt' (highlighted), 'Die Abteilung', 'Nachrichten', 'Publikationen', 'Vorträge', 'Veranstaltungen', 'Forschungsprojekte', 'Forschungskooperationen', 'Modelle', 'Service', 'Team', 'Klimapolitik', 'Industrieökonomie', 'Öffentliche Finanzen und Lebenslagen', 'SOEP-Service', 'Projekte', 'Daten', 'Forschungskooperationen', 'Stellungnahmen', and 'DIW Econ GmbH'. The main content area features the title 'A Dispatch and Investment Evaluation Tool with Endogenous Renewables "DIETER"' and a detailed description of the tool's development and purpose. It mentions the MIT license and provides links to the open source repository and Creative Commons license. Below the description, there are two contact cards for 'Ihr Ansprechpartner': Dr. Wolf-Peter Schill and Dr. Alexander Zerrahn, each with a photo, contact information, and buttons for 'Nachricht schreiben' and 'Visitenkarte'. At the bottom, there is a section for 'DIETER Version 1.0.0 (formerly 1.0)' with a download link for 'DIETER_v1.0.0.zip | ZIP, 8.09 MB' and a note that version 1.0.0 is used and documented in a specific paper.

28 driving profiles

- with different shares among overall electric vehicle fleet
- Twelve plug-in hybrids, 16 battery electric vehicles
- differing by battery energy and power capacity

Hourly time series

- Electricity demand for mobility
- Availability for charging

Greenfield setting (2050 perspective)

- Data loosely calibrated to Germany

Inference: vary relevant parameters and constraints

- Minimum renewables share
 - 70, 80, 90, 100%
- Electric vehicle fleet
 - 0 to 32 million
- Charging electricity
 - No restriction, as system, 100% renewables

(i) Uncontrolled charging

Vehicles charge as soon as connected to the grid until battery full

(ii) Controlled charging G2V

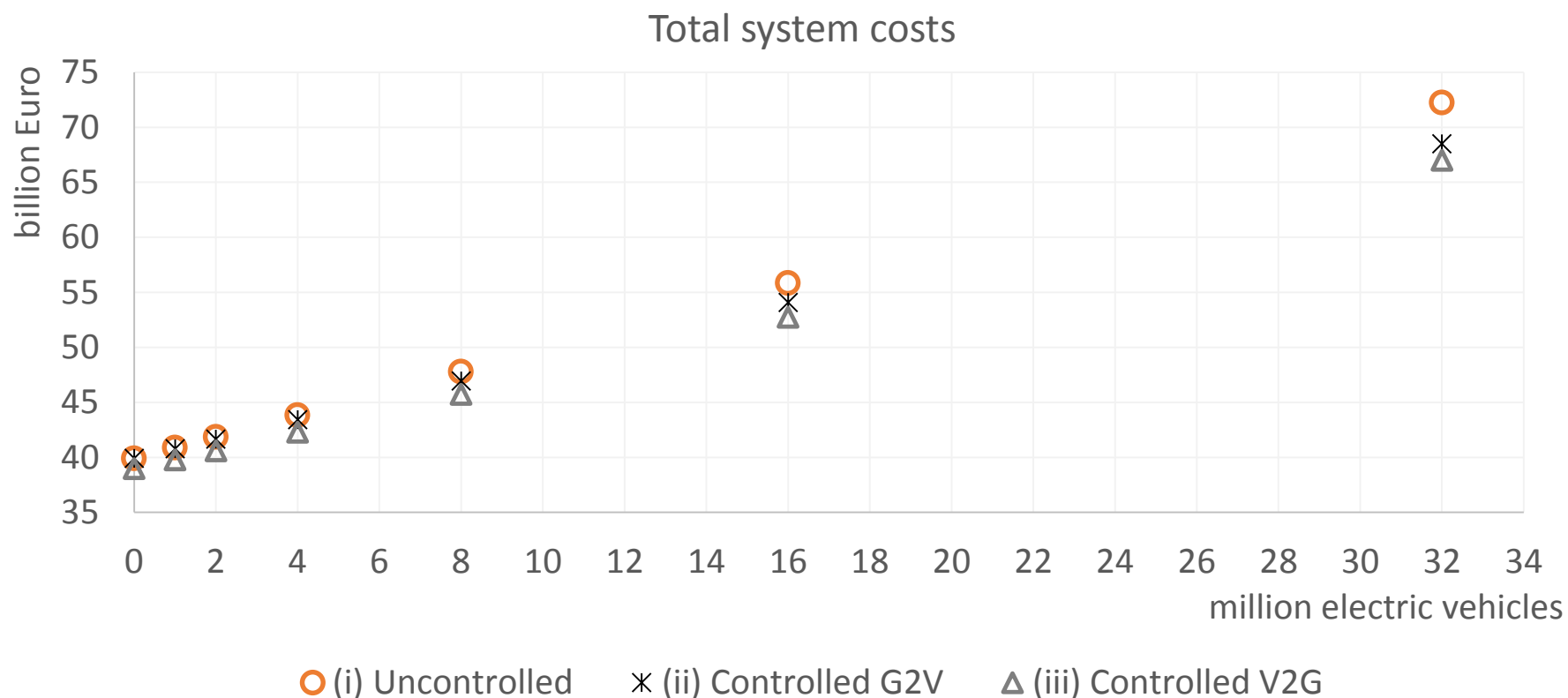
Vehicles charging endogenously optimized concerning timing and level

(iii) Controlled charging with V2G

Vehicles can additionally discharge to the grid

(iv) Controlled charging with V2G and reserve provision

Vehicles can additionally provide balancing reserves



Total system costs rise with number of electric vehicles

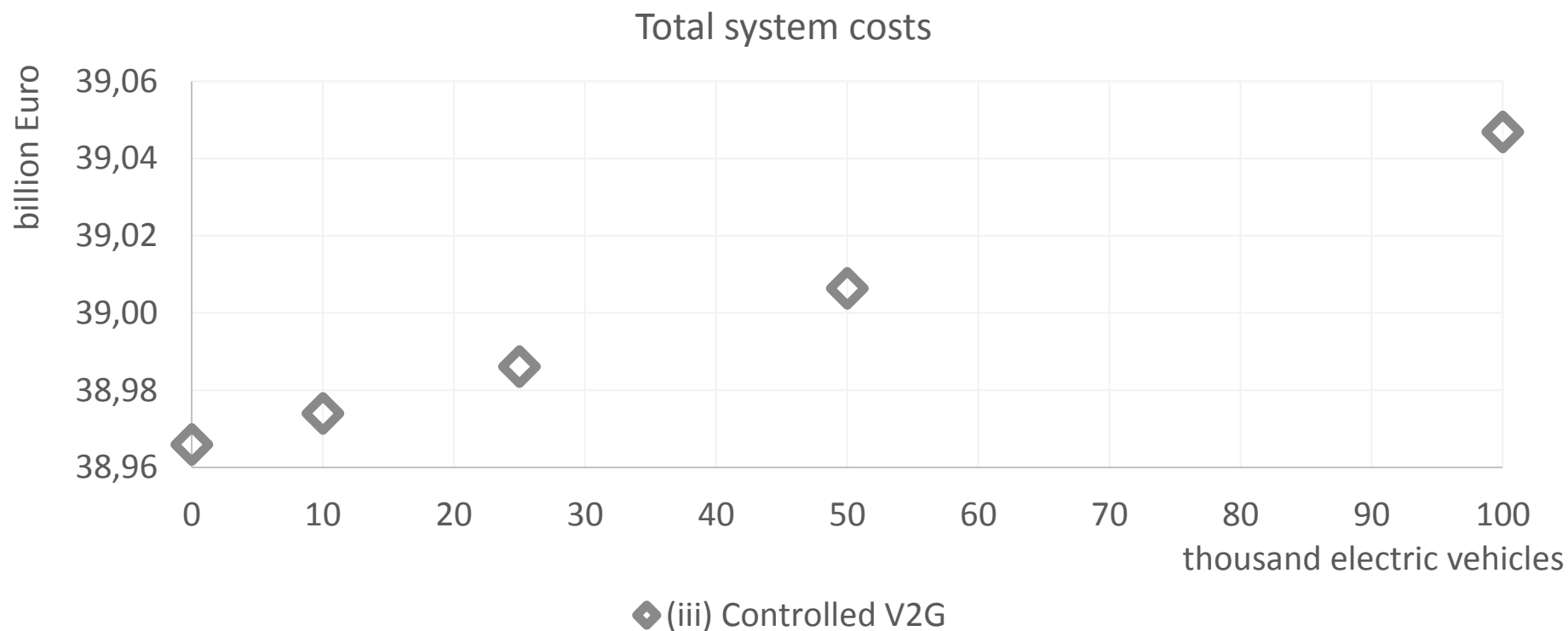
- lower growth for better system integration
- but appears close to linear

Competing flexibility options

70% renewables, 4 million vehicles	Li-ion GW	Li-ion GWh	PHS GW	PHS GWh
(i) Uncontrolled	9999	14002	4531	34119
(ii) Controlled G2V	5063	6674	3744	29672
(iii) Controlled V2G	3928	5159	1238	10187
(iv) Controlled V2G plus reserves	1536	2446	603	4880

Vehicle perspective

70% renewables, 4 million vehicles	Average charging price	Average discharging price
(i) Uncontrolled	95.3 Euro/MWh	
(ii) Controlled G2V	55.1 Euro/MWh	
(iii) Controlled V2G	69.9 Euro/MWh	143.5 Euro/MWh



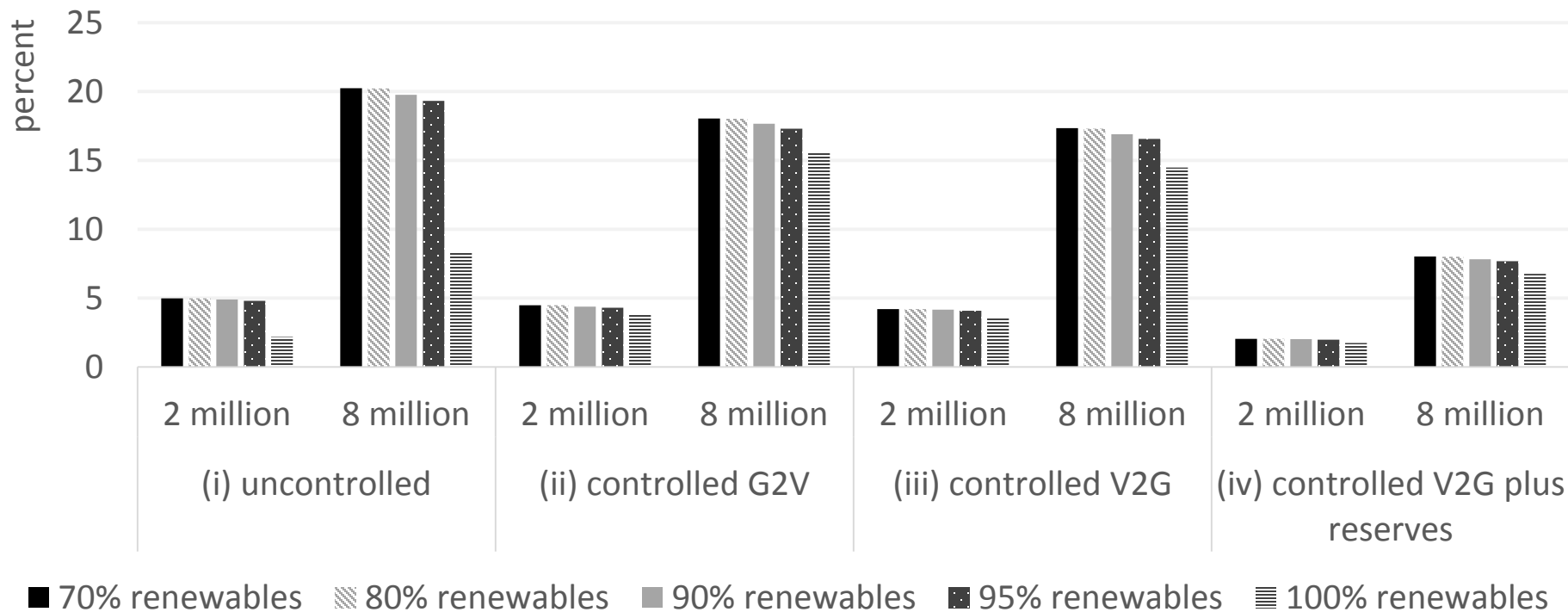
→ Also for small fleets:

- no absolute cost advantage
- apparently linear cost increase

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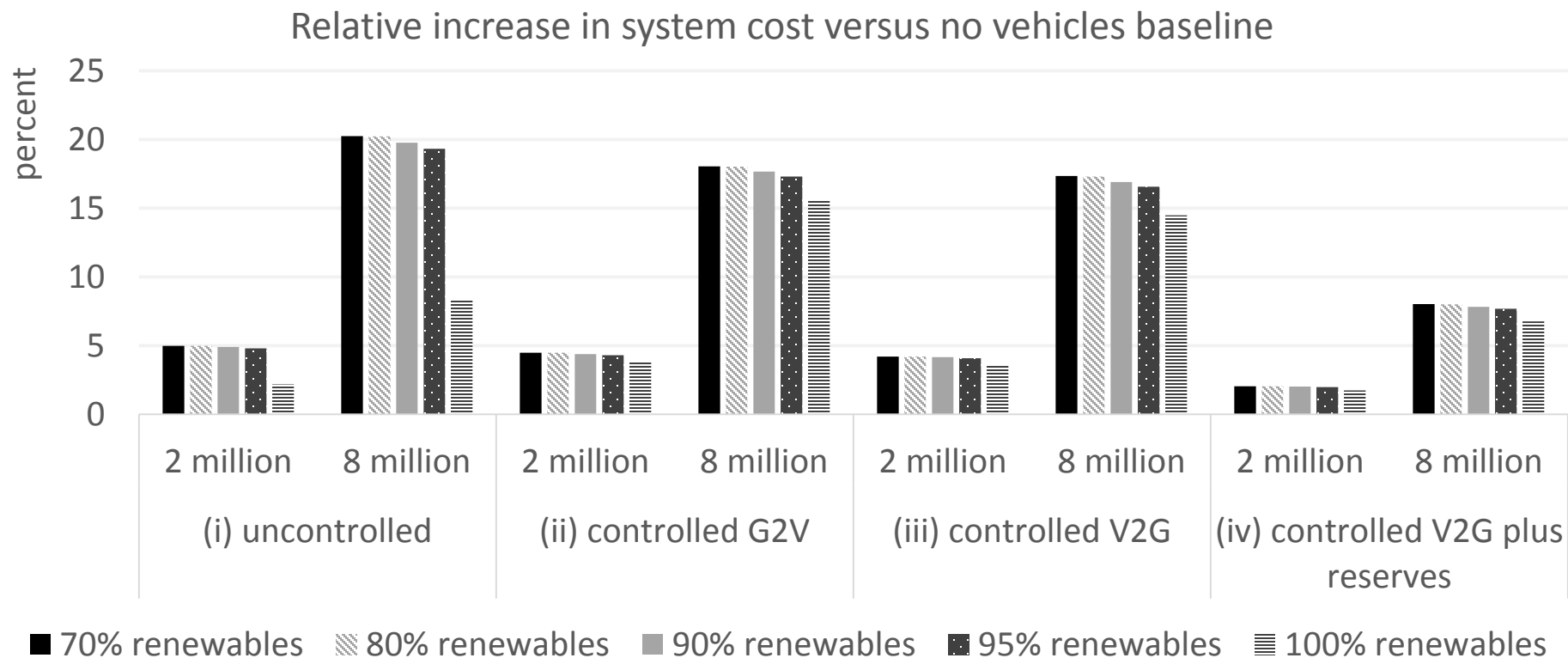
Hypothesis 2

Relative increase in system cost versus no vehicles baseline



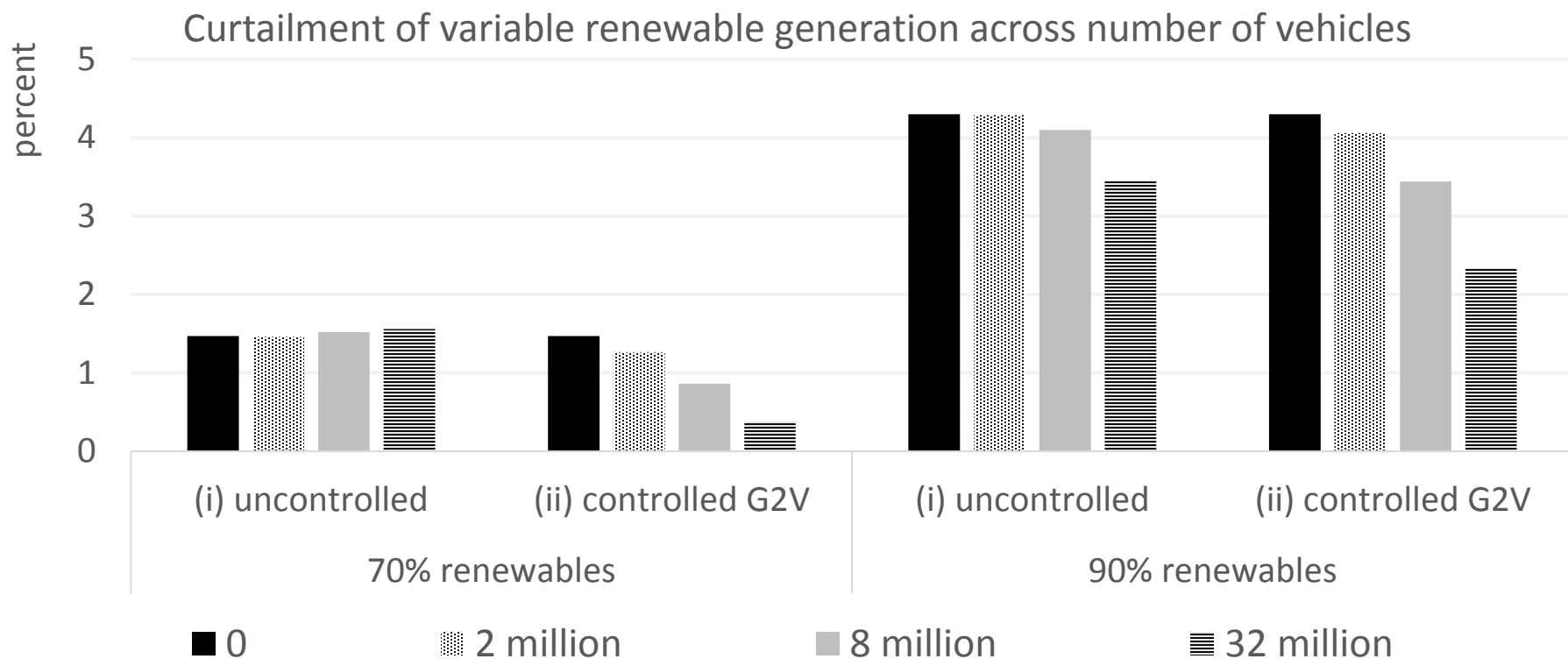
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Hypothesis 2 – lower relative cost increase at more RES



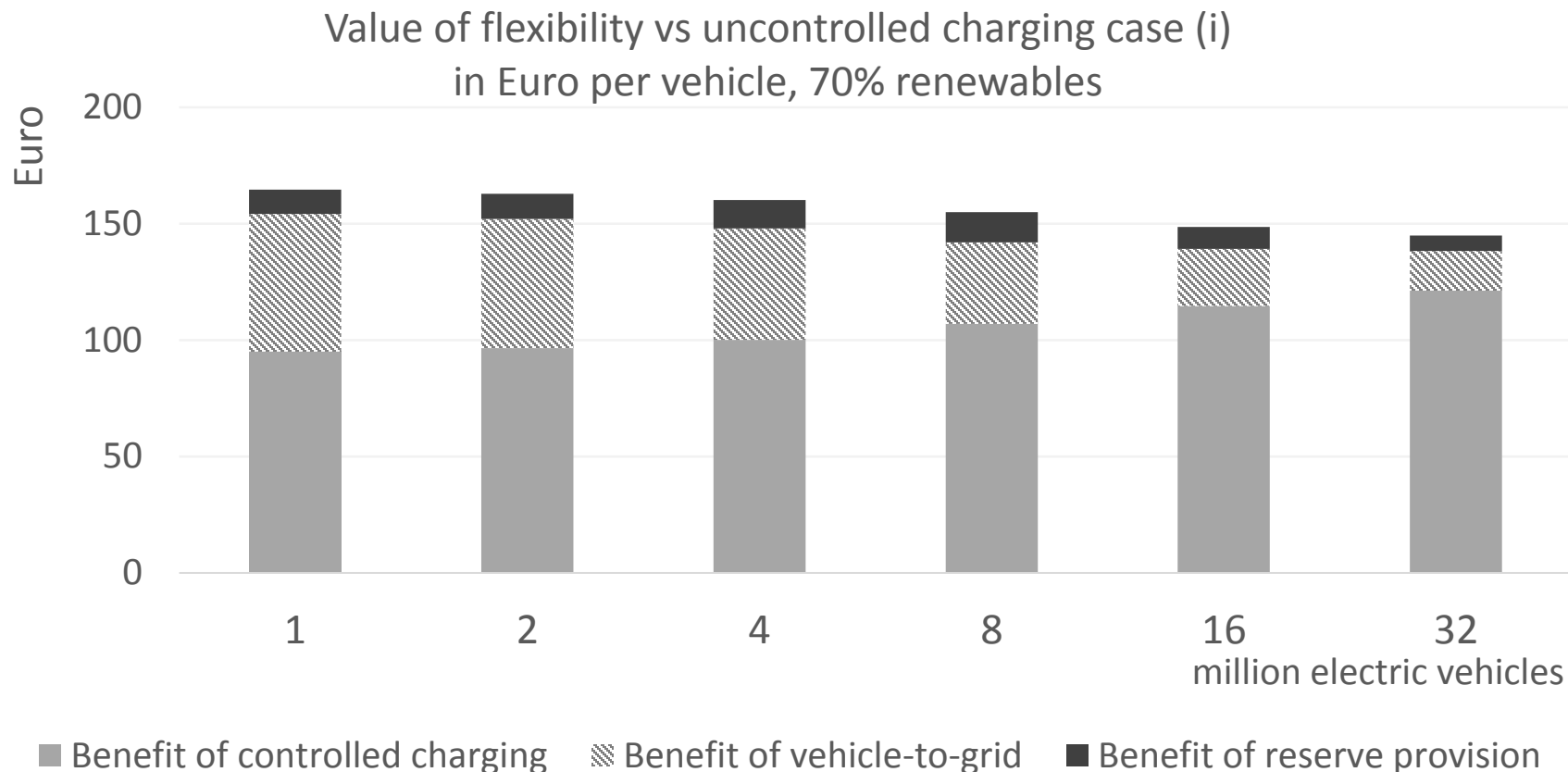
→ **Additional demand (that) *and* flexibility (when)**

- Vehicles consume energy *that* is curtailed otherwise
- Use of energy *when* available, intertemporal arbitrage



→ Additional demand (that)

- lowers curtailment of variable renewables if charging controlled



→ Simultaneity effects

- saturation: total value of flexibility decreases in fleet size
- but value of controlled G2V charging increases in fleet size

Thank you for listening



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