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15th IAEE European Conference

# 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

# 1 Electric vehicles and variable renewables

## 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

# 1 Three hypotheses

**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

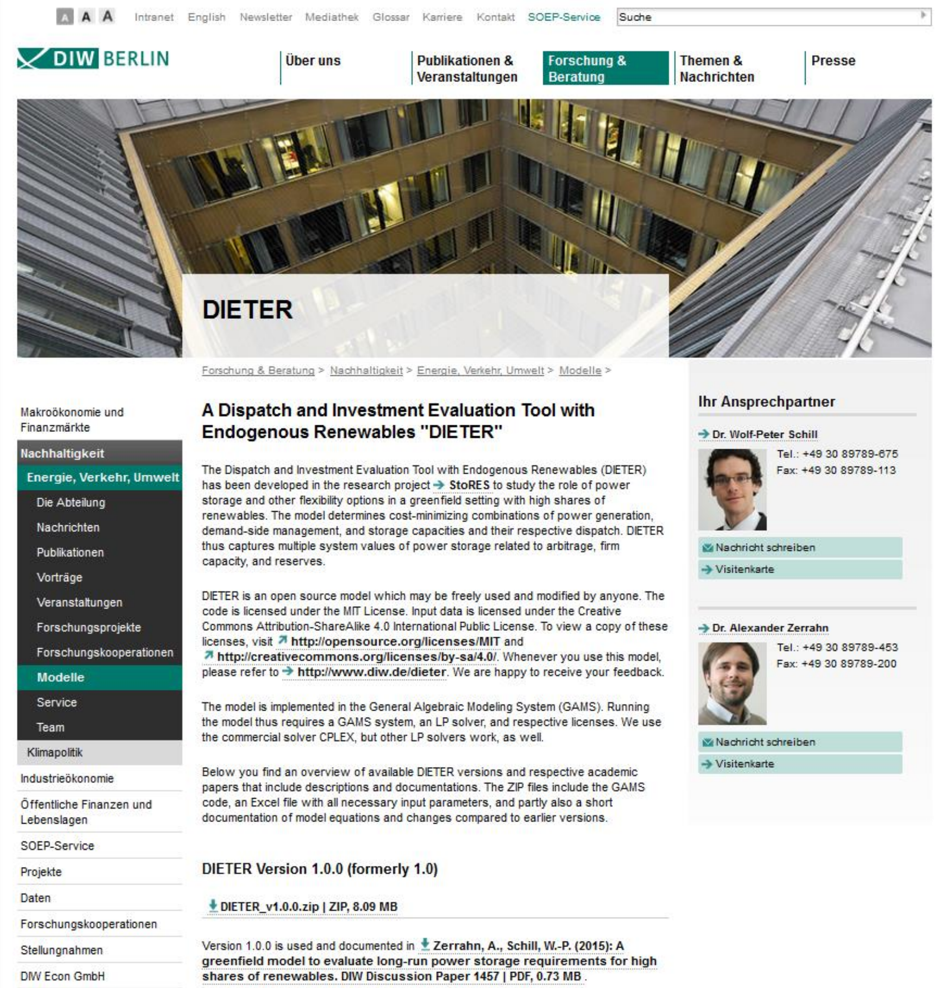
# 2 DIETER‘s website

## 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





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# Electric vehicles in DIETER

## 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

# 3 Scenarios

## (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

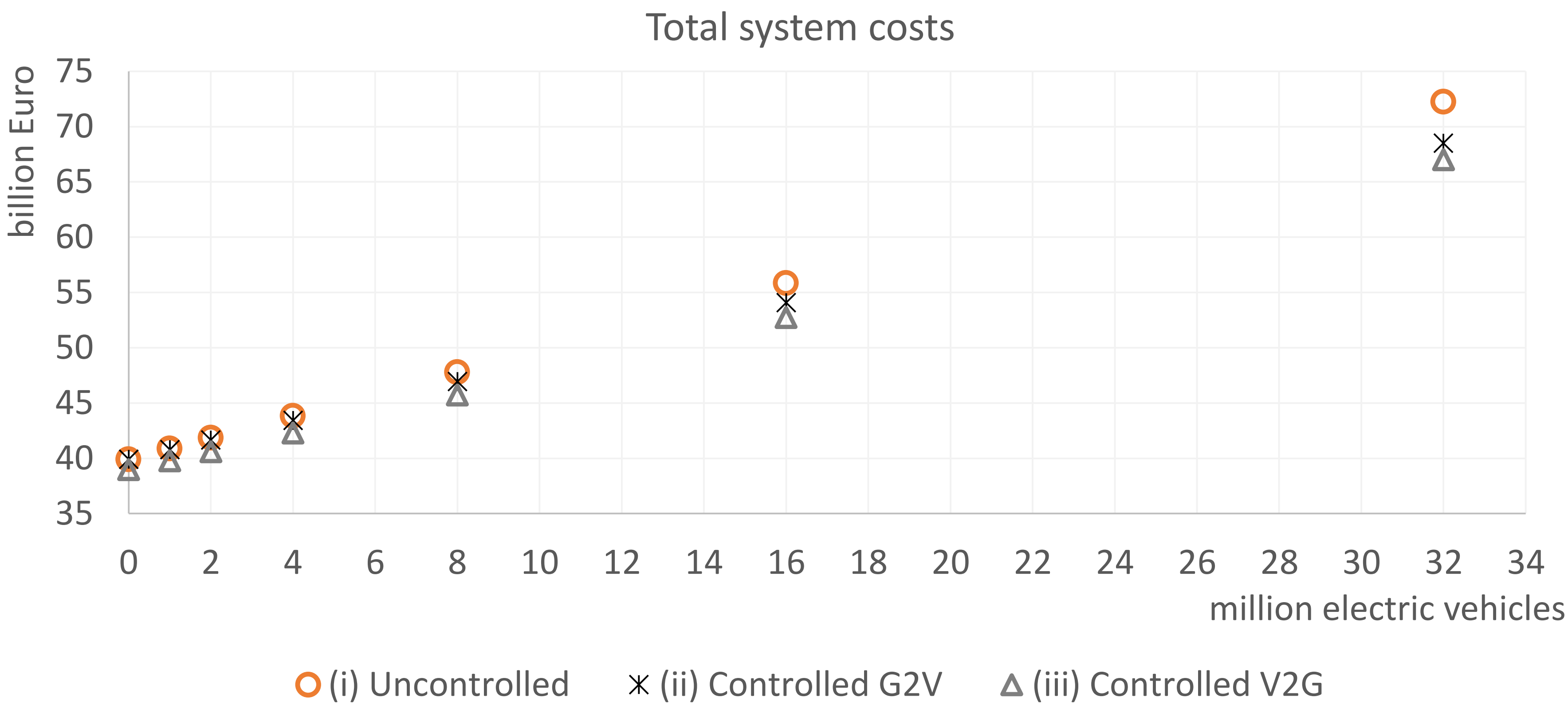
## (iii) Controlled charging with V2G

Vehicles can additionally discharge to the grid

## (iv) Controlled charging with V2G and reserve provision

Vehicles can additionally provide balancing reserves

# Results – preliminaries: absolute costs




**Total sytem costs rise with number of electric vehicles**

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

# Results – preliminaries: flexibility

## Competing flexibility options

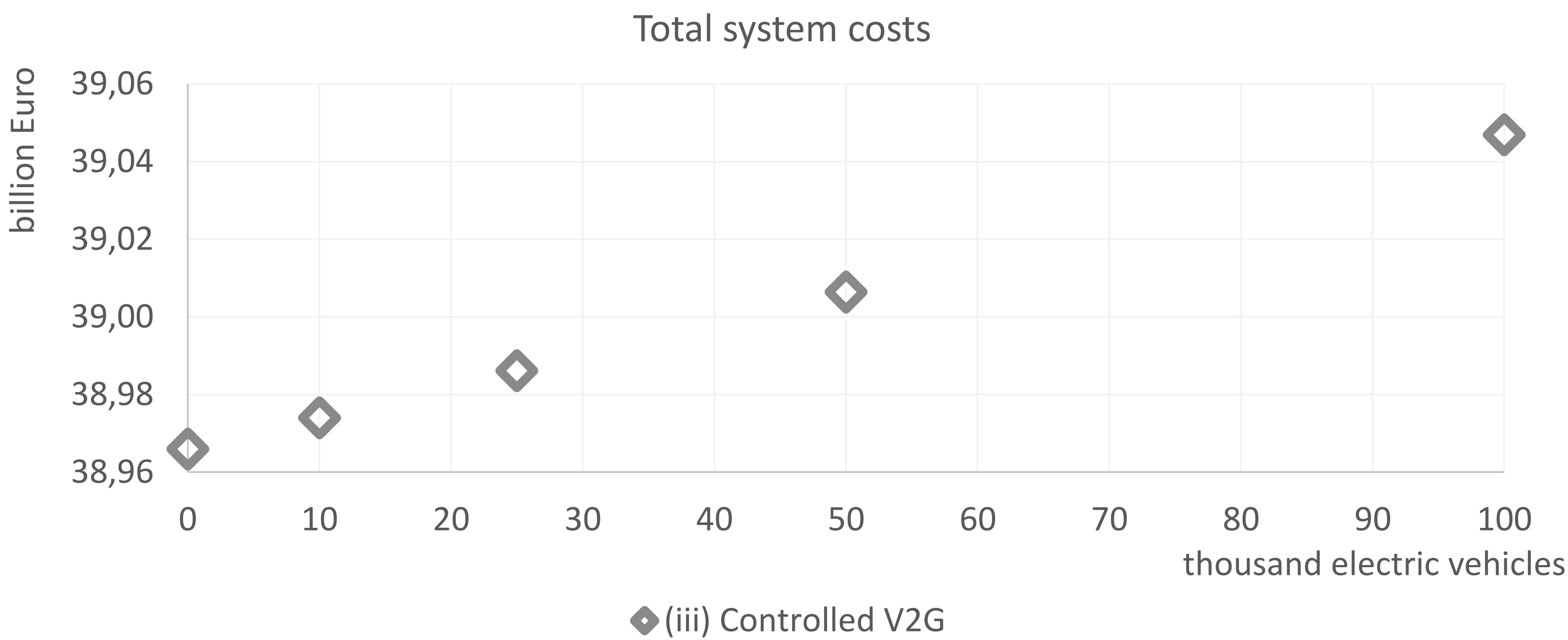
| 70% renewables, 4 million vehicles | Li-ion GW | Li-ion GWh | PHS GW | PHS GWh |
|---|---|---|---|---|
| (i) Uncontrolled | 9999 | 14002 | 4531 | 34119 |
| (ii) Controlled G2V | 5063 | 6674 | 3744 | 29672 |
| (iii) Controlled V2G | 3928 | 5159 | 1238 | 10187 |
| (iv) Controlled V2G plus reserves |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

# Results – preliminaries: prices

## 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 |

# 4 Hypothesis 1 – electricity demand vs flexibility supply




→ **Also for small fleets:**

- no absolute cost advantage
- apparently linear cost increase

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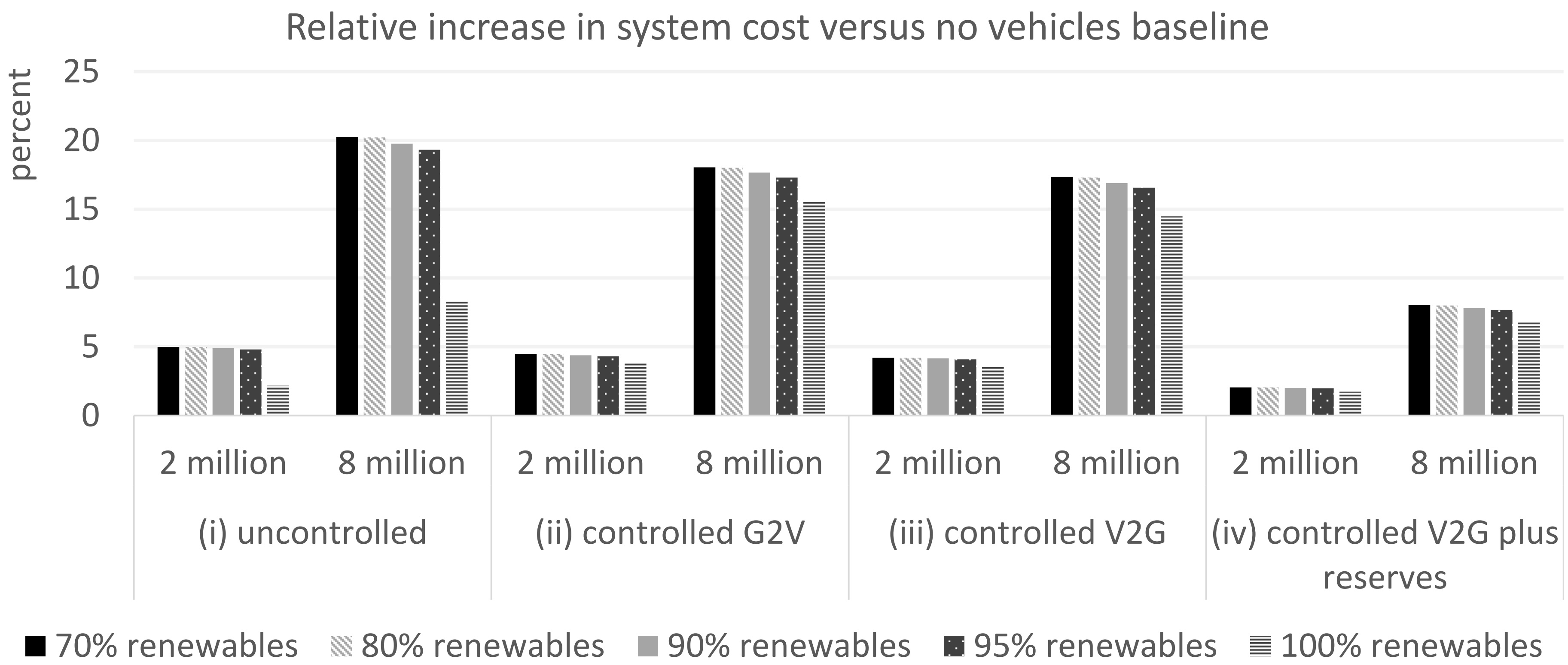
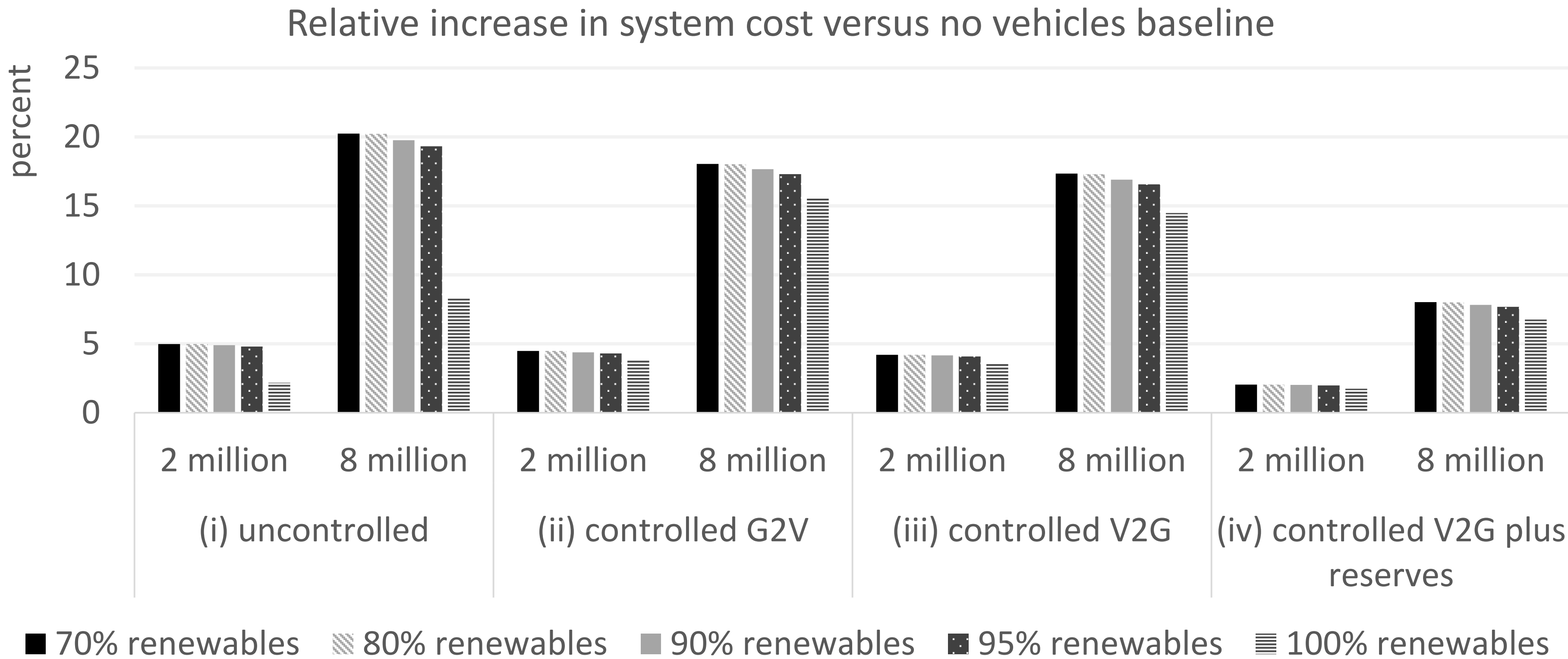
# Hypothesis 2



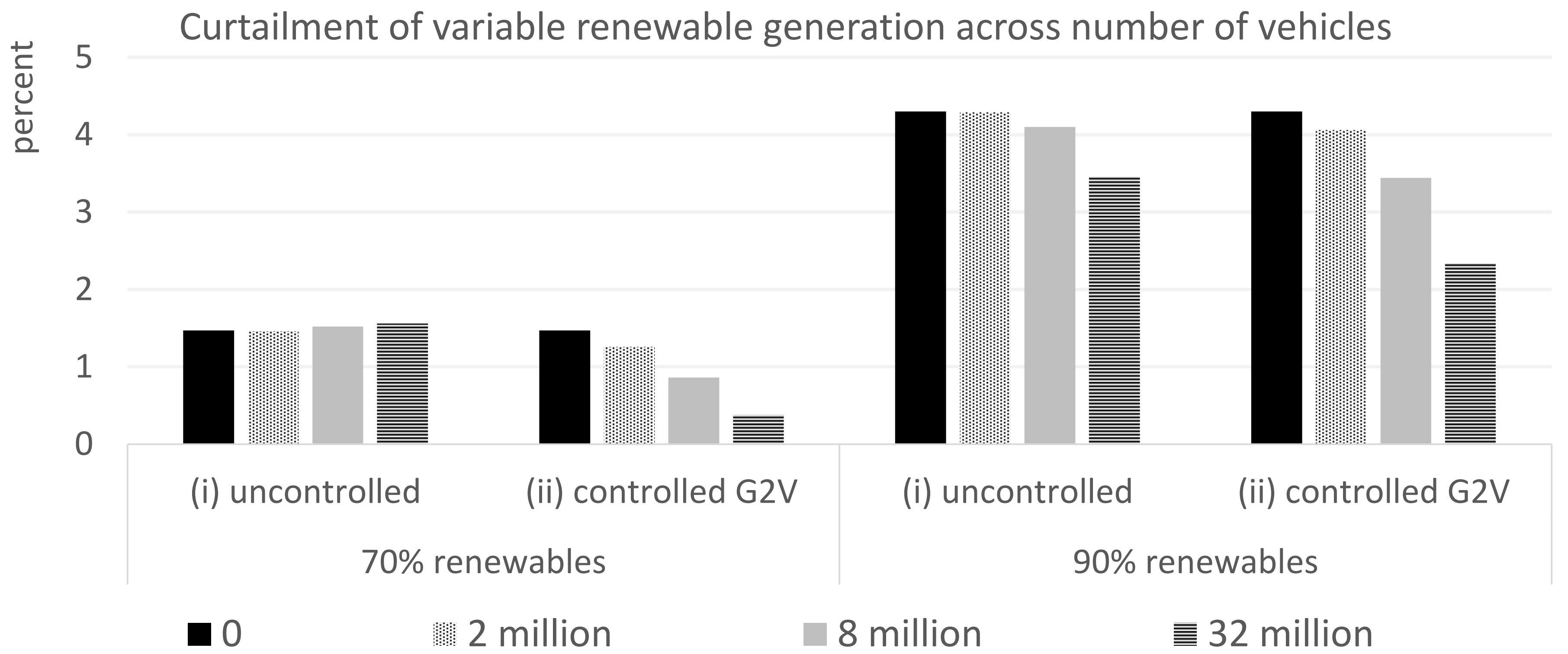
# 4 Hypothesis 2 – lower relative cost increase at more RES




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

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

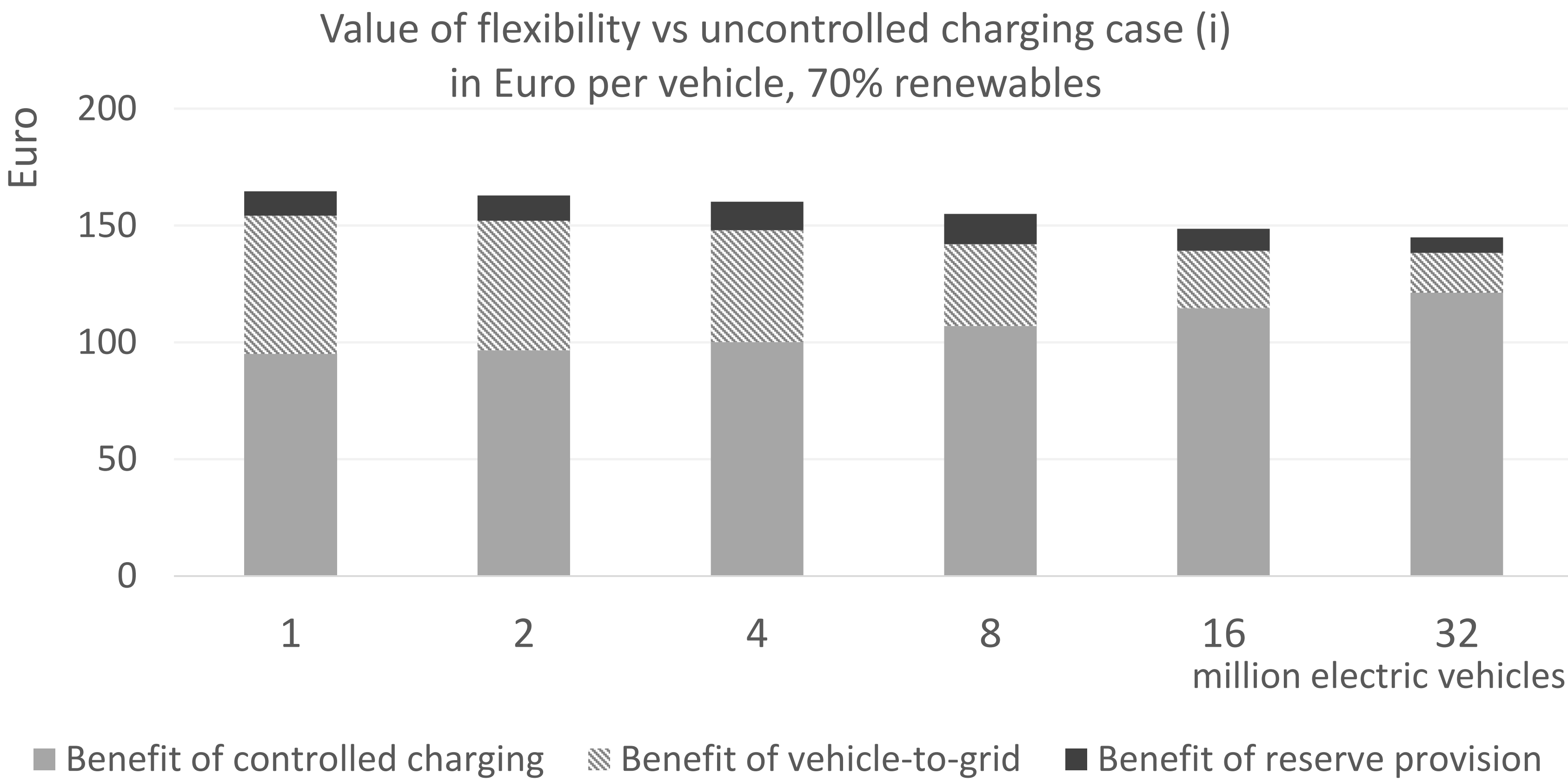
# 4 Hypothesis 2 – lower relative cost increase at more RES




→ **Additional demand (that)**

- lowers curtailment of variable renewables if charging controlled

# 4 Hypothesis 3 - flexibility benefit and fleet size




**→ 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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