DIW BERLIN

lkDEU langfristige Planung und kurzfristige Optimierung des **Elektrizitätssystems in Deutschland** im europäischen Kontext

Flexible sector coupling in high-RES scenarios: impacts on electrical storage

Mario Kendziorski, Wolf-Peter Schill, Alexander Zerrahn

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1. Introduction
2. The model
3. Data and scenarios
4. Results
5. Conclusions and next steps

1 Introduction

Major energy sector challenges

- Integration of variable renewable energy sources (RES)
- Decarbonization of power sector, but also heat, mobility, industry

Sector coupling as strategy to address both challenges

- Integration of RES through flexible new loads, combined with low-cost storage
- Decarbonization of other sectors through (additional) RES electricity

Research questions

- Electricity system effects of sector coupling in scenarios with high shares of RES
- In particular, effects on electrical storage capacity
- Stylized analysis to address general effects

DIETER…

- … minimizes investment and hourly dispatch costs over one year
- … in greenfield / brownfield settings

Generation, flexibility options, sector coupling

- Thermal and renewable technologies, different types of electrical storage
- Electric vehicles, electric residential heating, hydrogen

Linear program

- Deterministic, perfect foresight → adress uncertainties with scenario analyses
- Here: no transmission constraints, Germany only

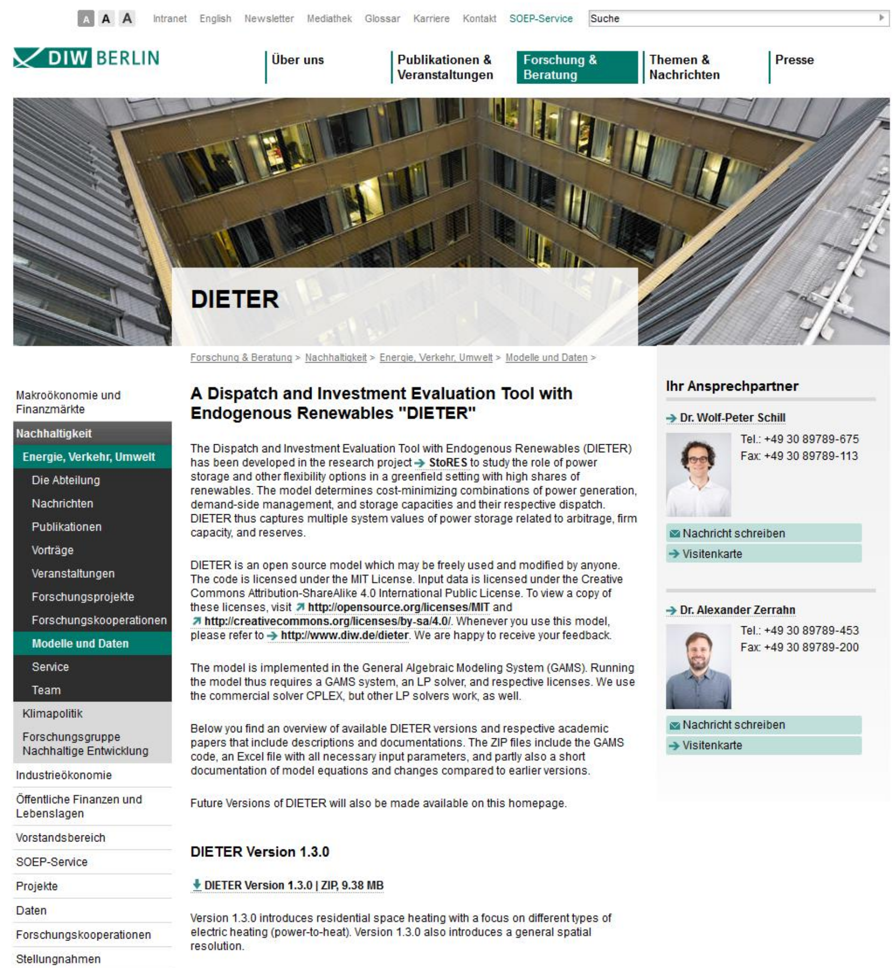
Visit DIETER

- www.diw.de/dieter
- https://github.com/diw-berlin/dieter
- Open-source, code under MIT license

Past and current applications

- Electrical storage requirements
- Electric vehicles to provide reserves
- Prosumage of solar electricity
- Residential heat
- Power-to-X / hydrogen

→ New: julia version



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A Dispatch and Investment Evaluation Tool with Endogenous Renewables "DIETER"

The Dispatch and Investment Evaluation Tool with Endogenous Renewables (DIETER) has been developed in the research project → StoRES to study the role of power storage and other flexibility options in a greenfield setting with high shares of renewables. The model determines cost-minimizing combinations of power generation, demand-side management, and storage capacities and their respective dispatch. DIETER thus captures multiple system values of power storage related to arbitrage, firm capacity, and reserves.

DIETER is an open source model which may be freely used and modified by anyone. The code is licensed under the MIT License. Input data is licensed under the Creative Commons Attribution-ShareAlike 4.0 International Public License. To view a copy of these licenses, visit ↗ http://opensource.org/licenses/MIT and ↗ http://creativecommons.org/licenses/by-sa/4.0/. Whenever you use this model, please refer to → http://www.diw.de/dieter. We are happy to receive your feedback.

The model is implemented in the General Algebraic Modeling System (GAMS). Running the model thus requires a GAMS system, an LP solver, and respective licenses. We use the commercial solver CPLEX, but other LP solvers work, as well.

Below you find an overview of available DIETER versions and respective academic papers that include descriptions and documentations. The ZIP files include the GAMS code, an Excel file with all necessary input parameters, and partly also a short documentation of model equations and changes compared to earlier versions.

Future Versions of DIETER will also be made available on this homepage.

DIETER Version 1.3.0

DIETER Version 1.3.0 | ZIP, 9.38 MB

Version 1.3.0 introduces residential space heating with a focus on different types of electric heating (power-to-heat). Version 1.3.0 also introduces a general spatial resolution.

Ihr Ansprechpartner

→ Dr. Wolf-Peter Schill
Tel.: +49 30 89789-675
Fax: +49 30 89789-113
Nachricht schreiben
→ Visitenkarte

→ Dr. Alexander Zerrahn
Tel.: +49 30 89789-453
Fax: +49 30 89789-200
Nachricht schreiben
→ Visitenkarte

Time series

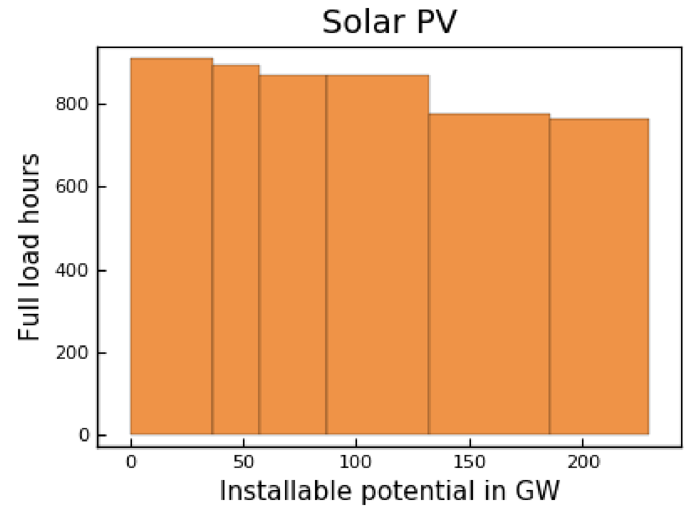
- 2015 values, OPSD & LKD-EU
  https://doi.org/10.1016/j.apenergy.2018.11.097 , https://www.diw.de/documents/publikationen/73/diw_01.c.574130.de/diw_datadoc_2017-092.pdf

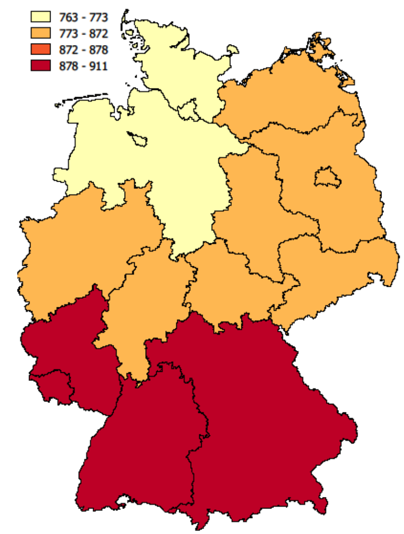
Improved RES input data

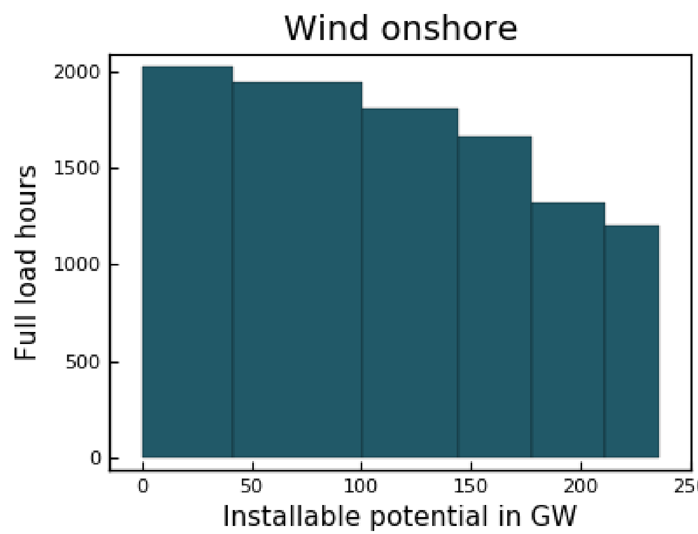
- Six RES zones in Germany
- Wind onshore and solar PV potentials with decreasing FLH

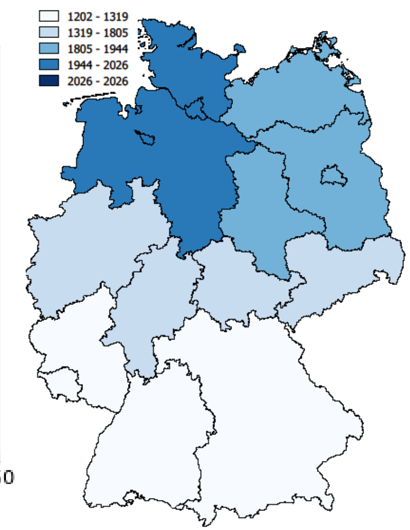
2050 perspective

- Cost parameters mostly from DIW Data Documentation
  https://www.diw.de/documents/publikationen/73/diw_01.c.424566.de/diw_datadoc_2013-068.pdf







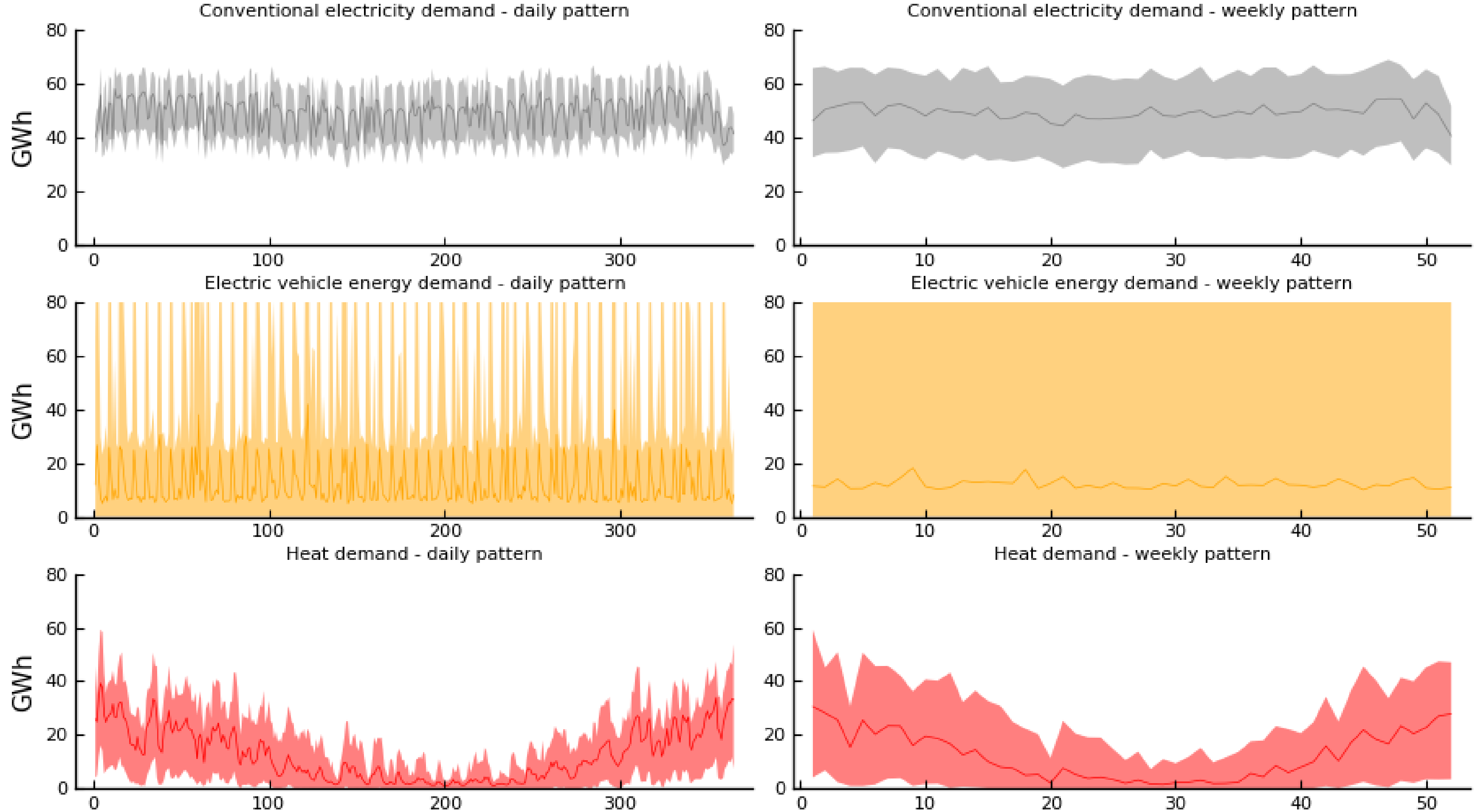


Base case and three sector coupling scenarios

- „Base case“ without any sector coupling – but Power-to-H2-to-Power
- Scenario „Electric vehicles“
  - 20 mio or 40 mio electric vehicles (G2V and V2G)
  - Additional yearly electricity demand: 53 TWh or 106 TWh
  - Ø E/P ratio: 4.7 hours (ranging from 3 to 9 hours)
- Scenario „Heat pumps“
  - 30% or 60% of buildings equipped with heat pumps (50% air-/ground-sourced)
  - Additional yearly electricity demand: 48 TWh or 96 TWh
  - E/P ratio: 3 hours
- Scenario „Additional hydrogen demand“
  - 45 or 90 TWh exogenous hydrogen demand (e.g. industry or mobility)
  - Additional yearly electricity demand: 53 TWh or 106 TWh

→ Each scenario solved for varying minimum RES constraints: 80%, 81%, …, 99%, 100%

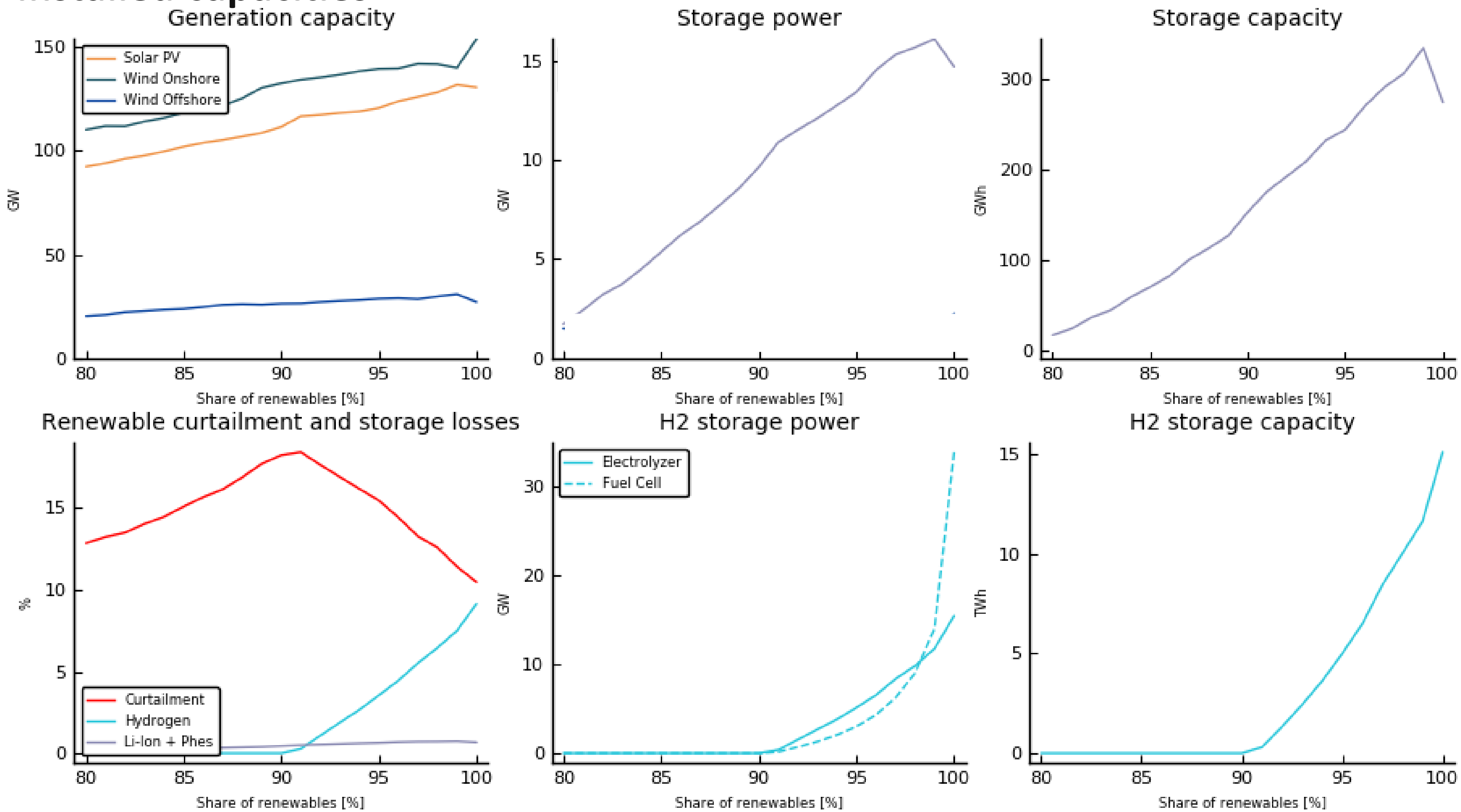
Patterns of hourly energy demand (average, min, max)



→ Substantial differences of short- and long-term fluctuations

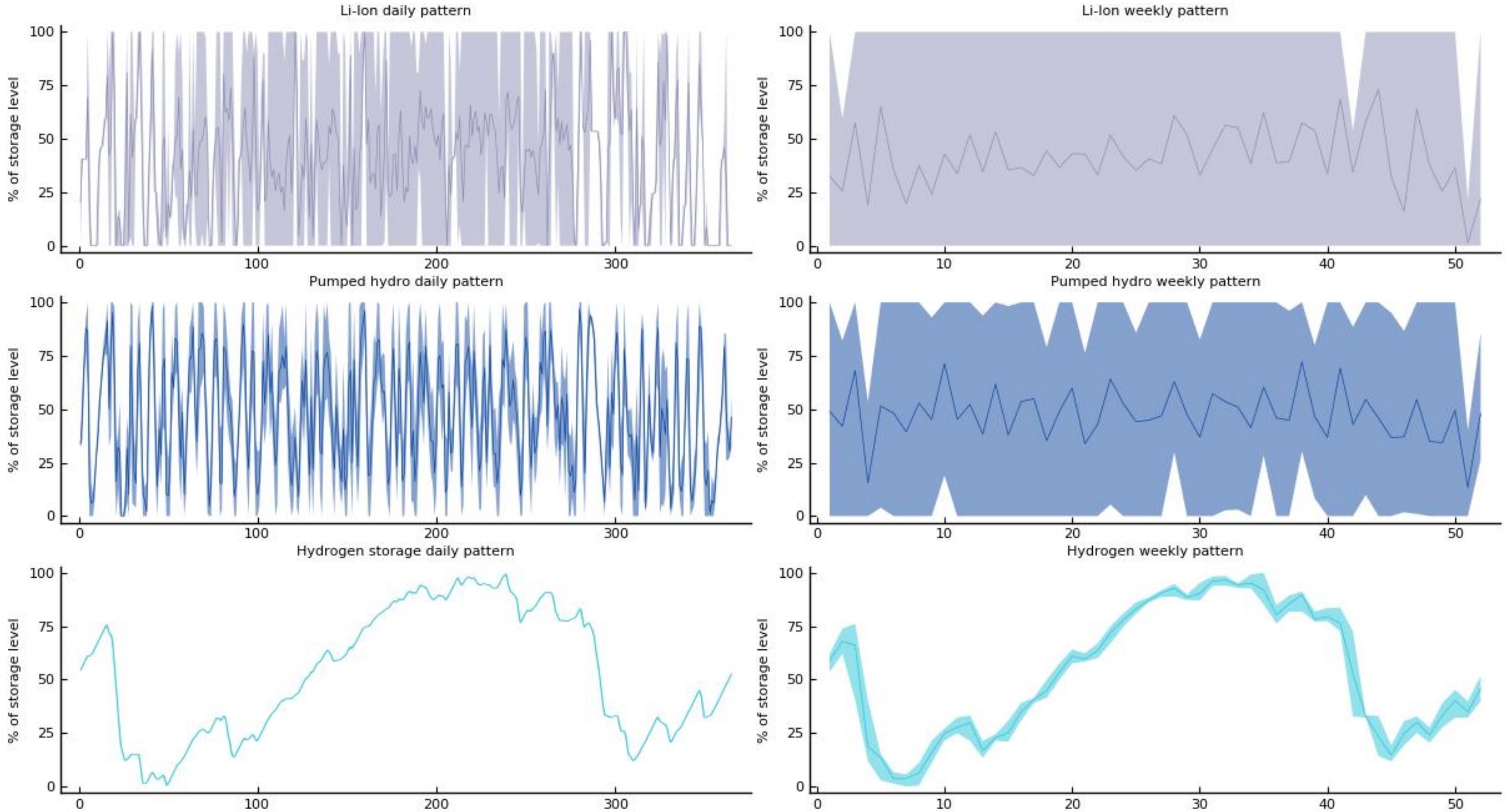
Results: Base case (no sector coupling)

Installed capacities



→ Electrical storage more relevant for higher RES shares, in particular H2 for 100%

Storage level patterns (average, min, max)



→ Hydrogen used for seasonal storage

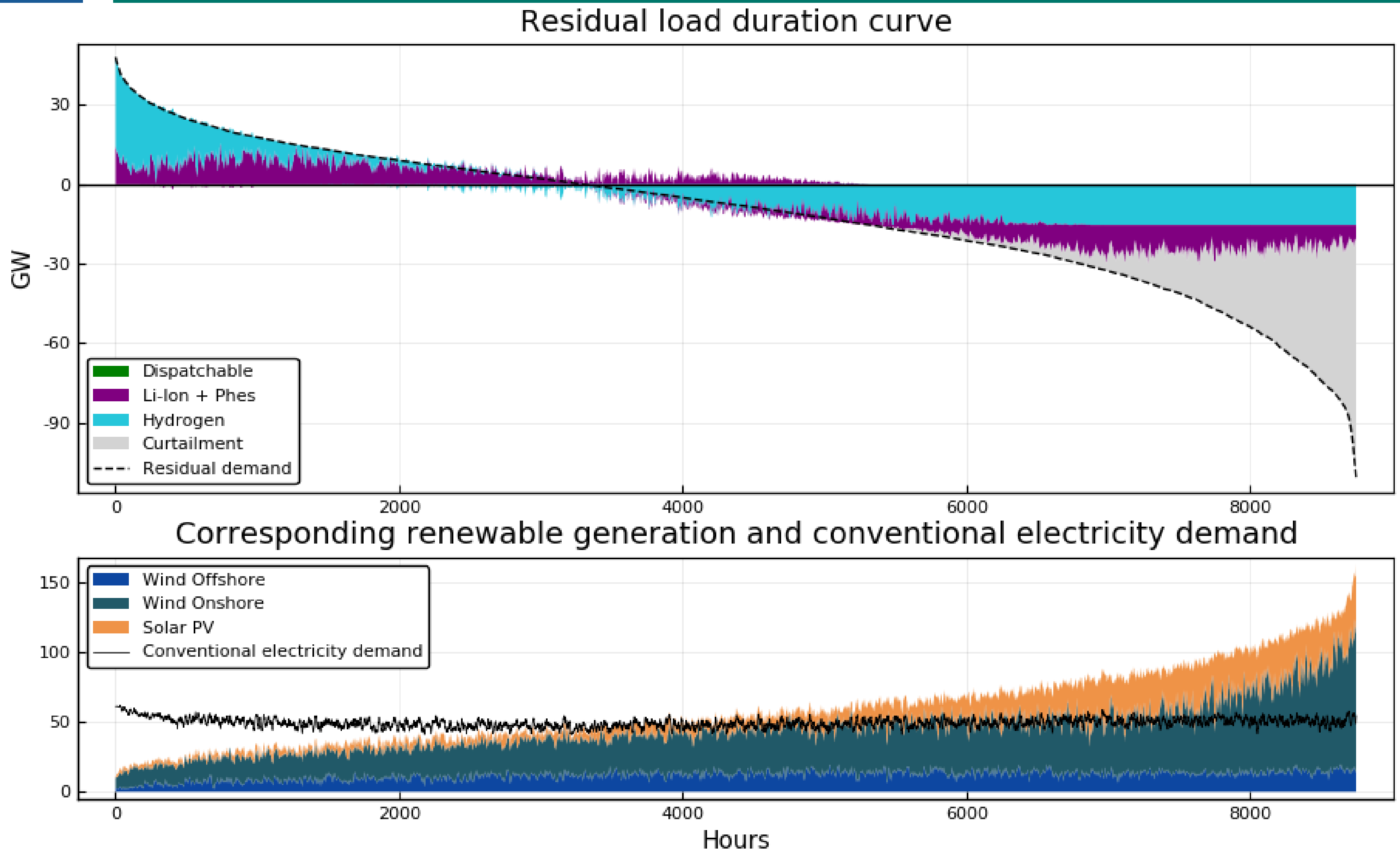
→ Li-Ion hourly to daily, Phes daily to weekly energy shifting

Storage charge and discharge pattern

→ Short-term storage shifts solar PV surplus from day to night during summer

→ Electrolyzers are active the most part of the year, fuel cells only for short periods

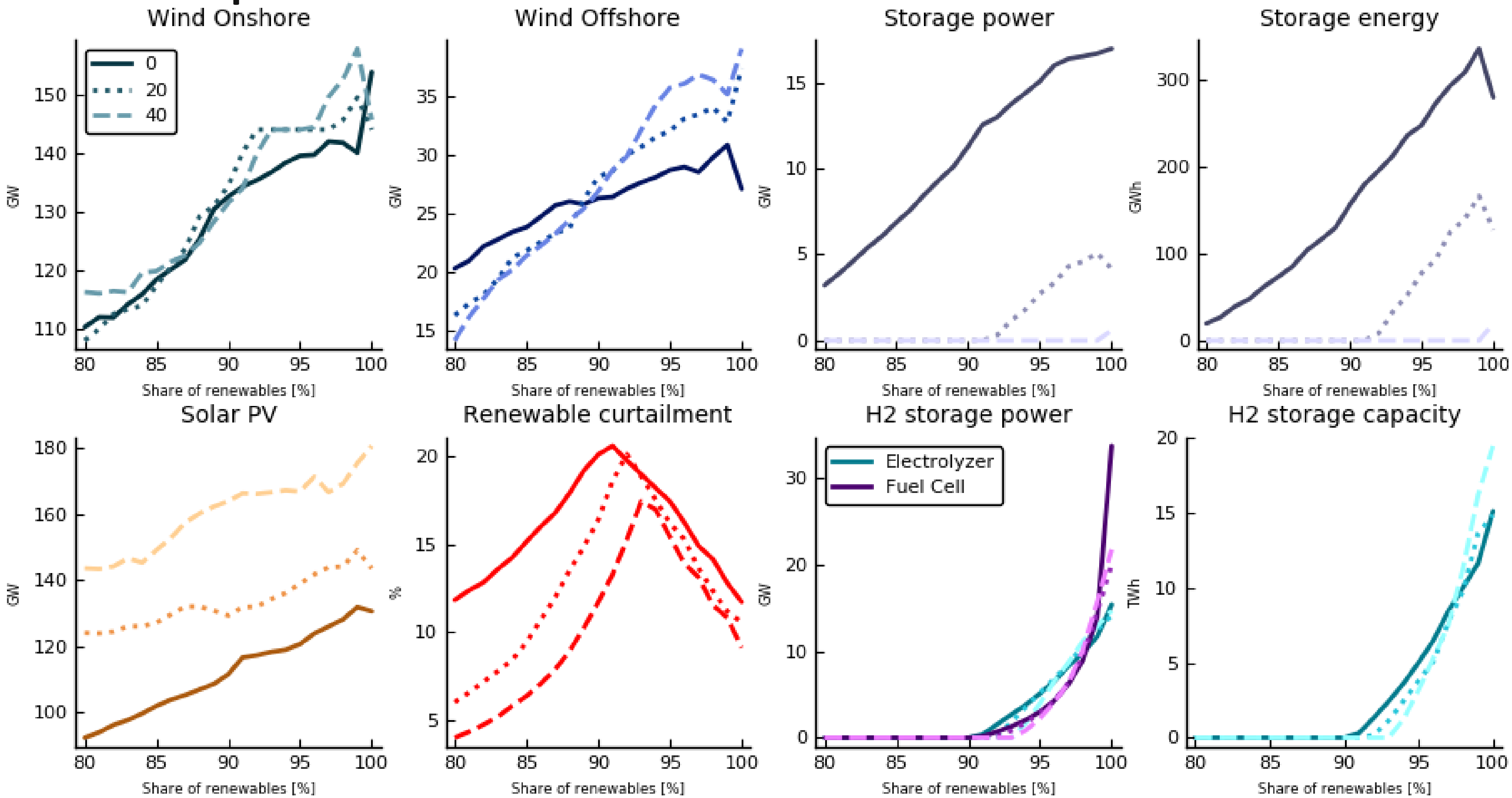
Results: Base case – 100% RES



→ Seasonal storage smoothes excessive PV (+wind) generation in summer

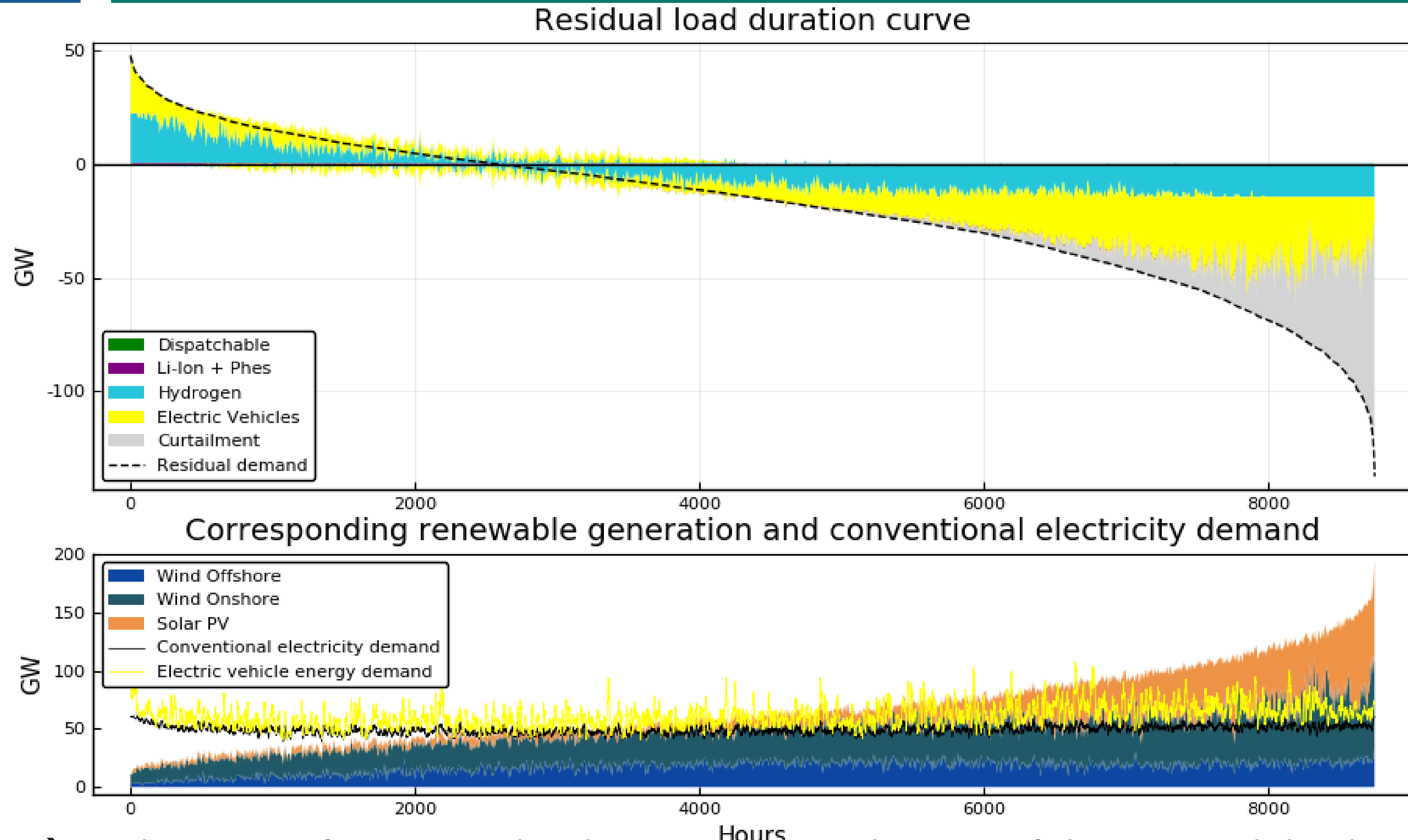
Results: Electric vehicles (20 mio, 40 mio electric vehicles)

Installed capacities



→ Much larger effect on Li-Ion and pumped hydro, not so much on hydrogen storage

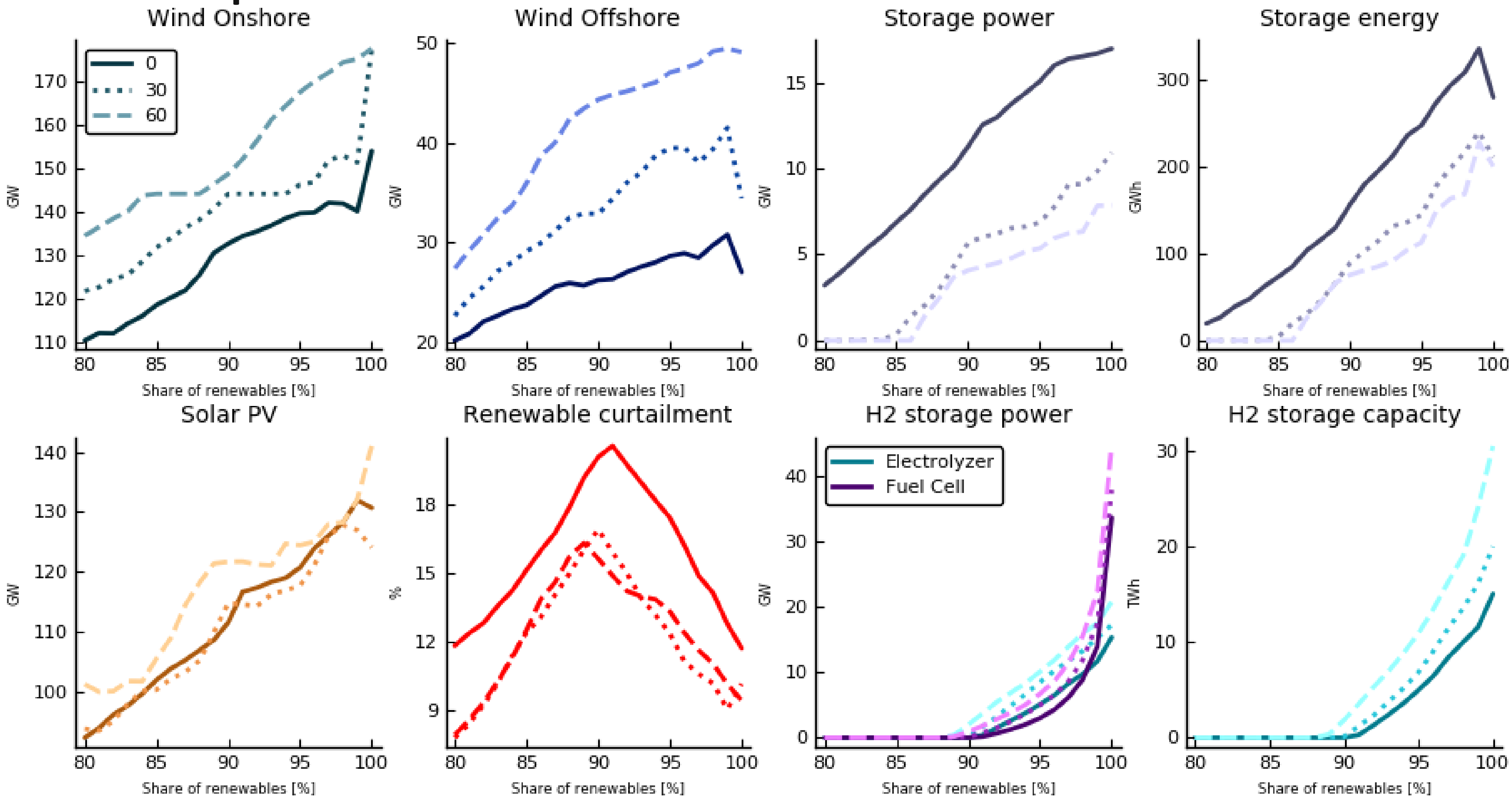
Results: Electric vehicles – 40 mio, 100% RES



→ High power of EV can utilize larger areas on the RHS of the RLDC while also covering peak load hours

Results: Heat pumps (30%, 60% of households equipped with heat pumps)

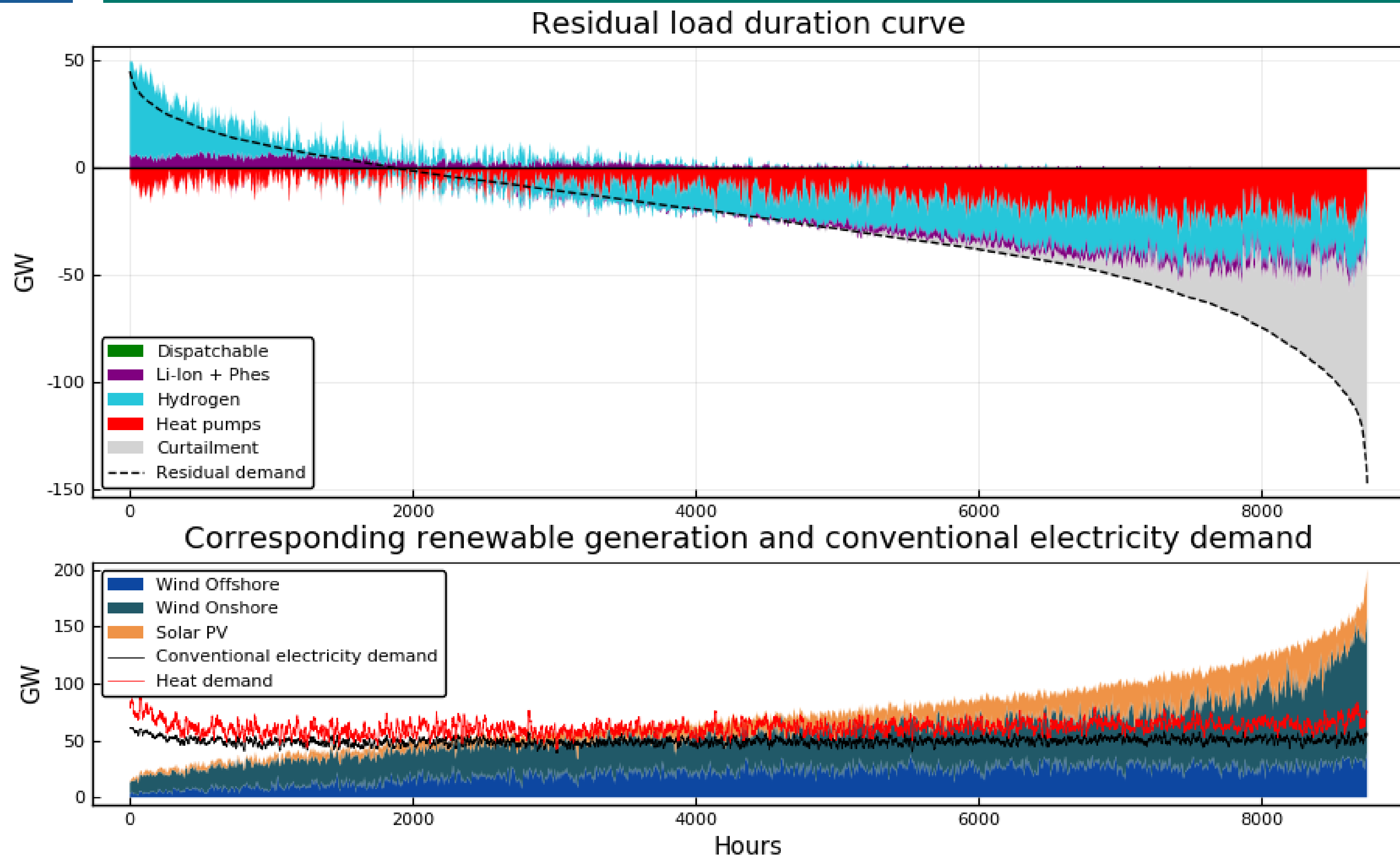
Installed capacities



→ Seasonality and missing re-electrification:
smaller effect on Li-Ion and pumped hydro, but more need for seasonal storage

4

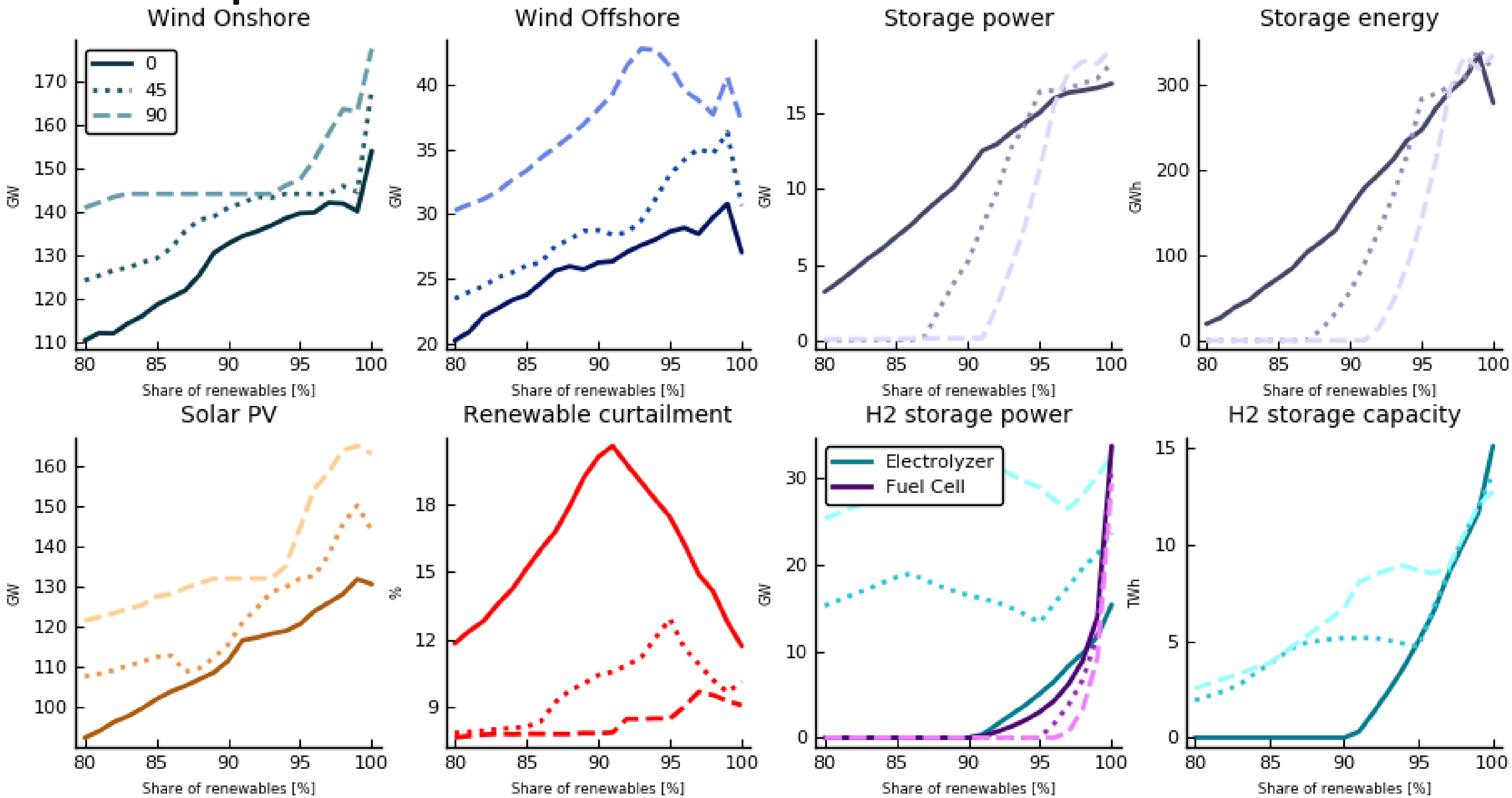
Results: Heat pumps – 60% of households, 100% RES



→ Heat pumps need electricity also in times of positive residual load

4 Results: Additional hydrogen demand (45 TWh, 90 TWh)

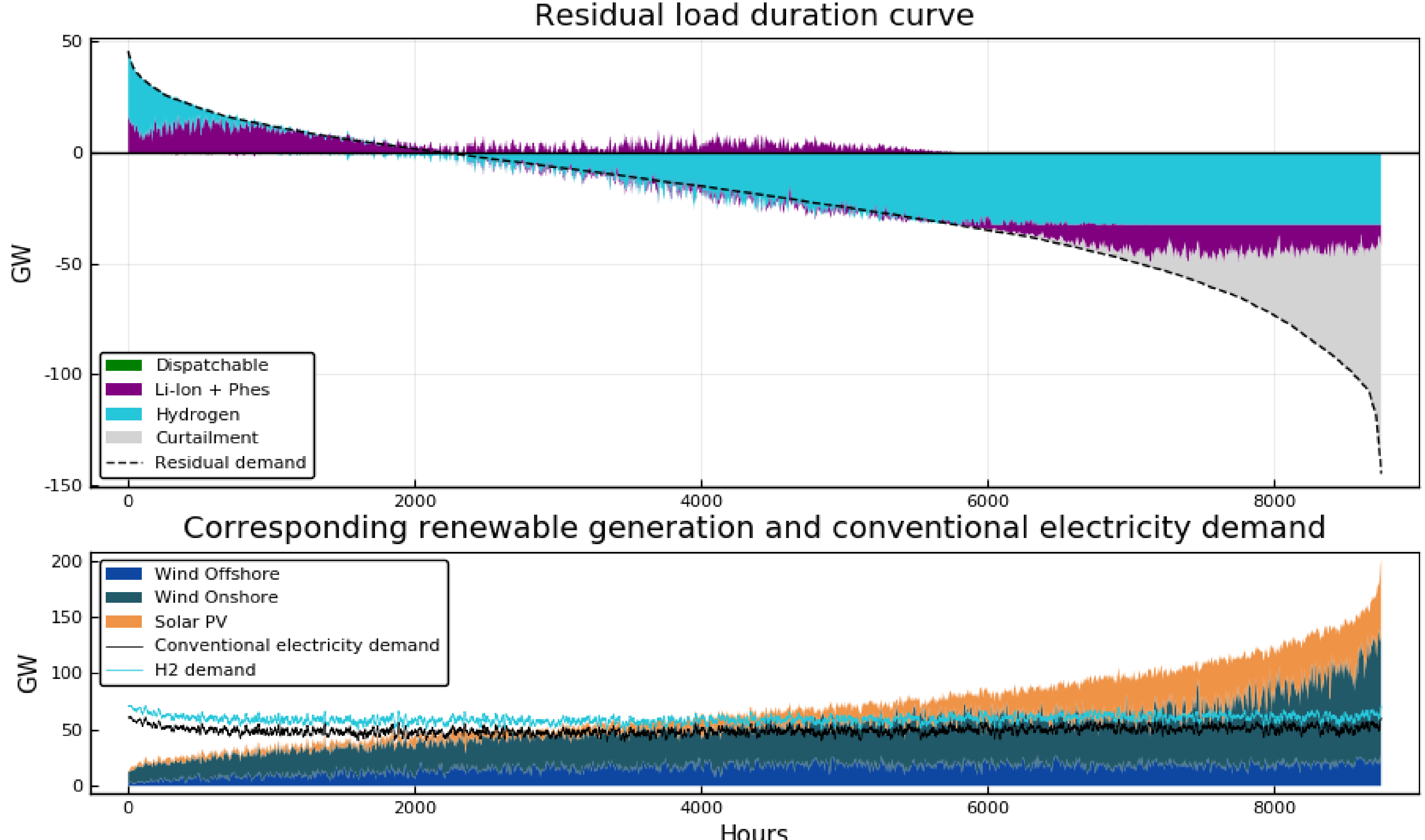
Installed capacities



→ „Early“ investments in hydrogen infrastructure below 90% RES share

→ But no substitution of other storage technologies in 100% case

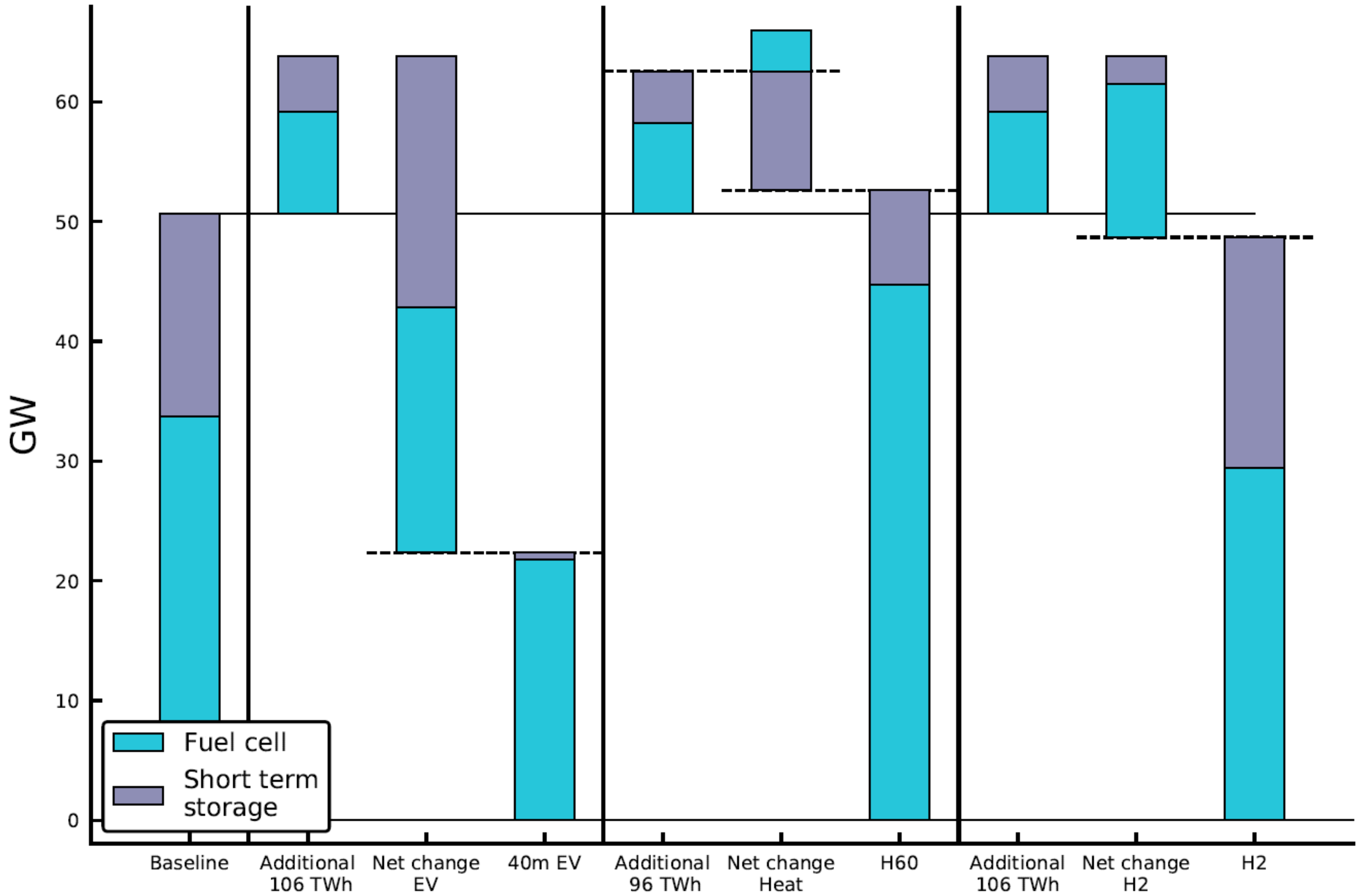
4 Results: Additional hydrogen demand – 90 TWh, 100% RES



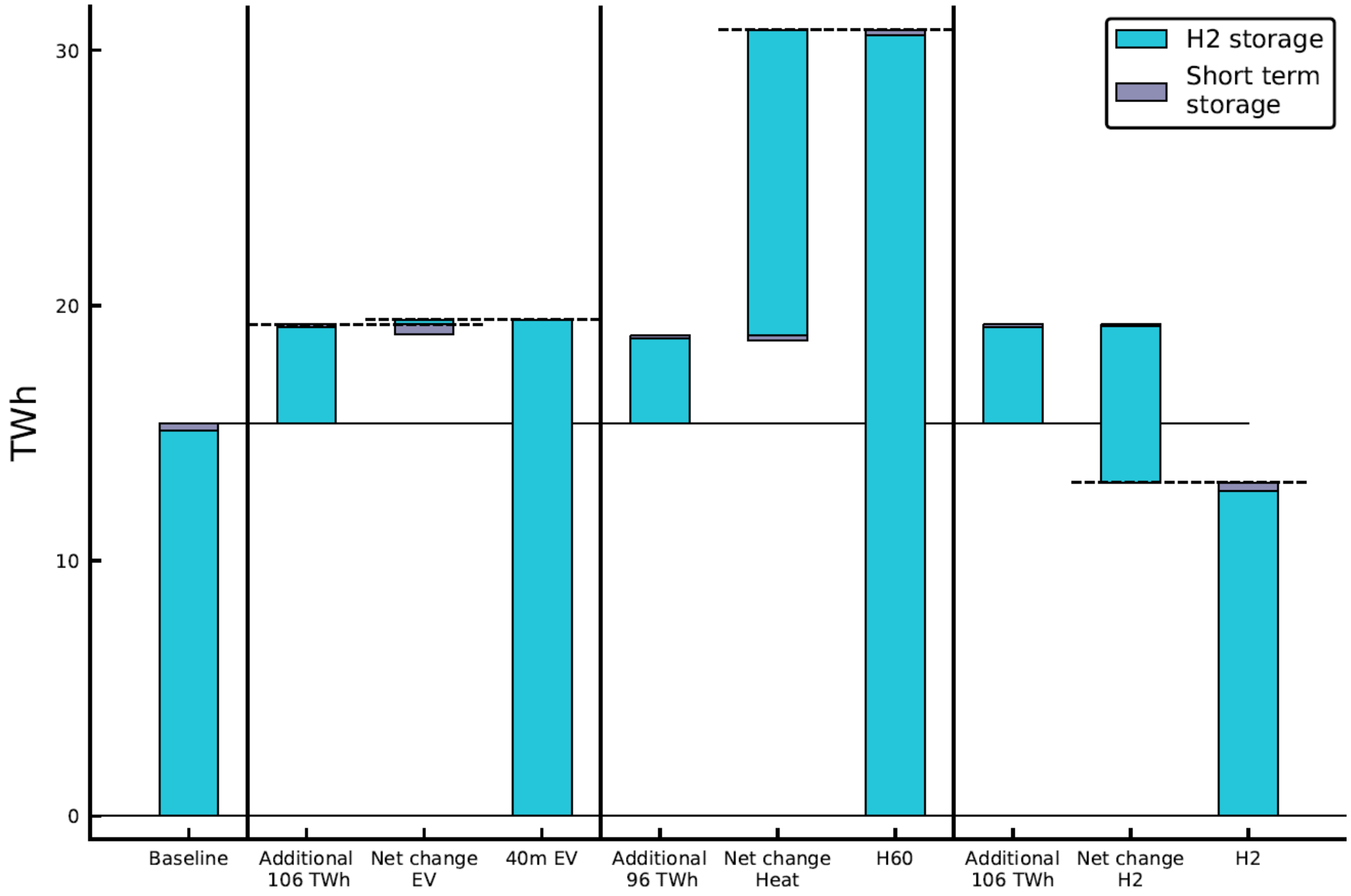
→ RHS of RLDC larger and flatter than in other scenarios to increase the full load hours of electrolyzer

4

Results: installed power, 100% renewable share
Separation of additional energy demand and flexibility



Results: installed storage energy capacity, 100% renewable share
Separation of additional energy demand and flexibility



Impact of sector coupling in case with

< 100 % RES share

- Sector coupling lowers electrical storage needs
- Peak load partly covered by dispatchable technologies
    - ➢ storage size determined by RHS of the RLDC

100 % RES share:

- Storage-mitigating effect only for electric vehicles since they contribute to the LHS of the RLDC
- Seasonal storage needs *increase* in case of heat pumps due to seasonality of heat demand while heat pumps do not offer any long term storage option
- Limited storage synergies with additional hydrogen demand

Sensitivities with alternative flexibility assumptions

- Cap on pumped hydro energy storage potential
- Restricted EV flexibility
- Larger short term heat storage
- Seasonal heat storage options
- Lack of caverns for hydrogen storage
- Comparison with P2X fuels for heating (e.g. synthetic methane)

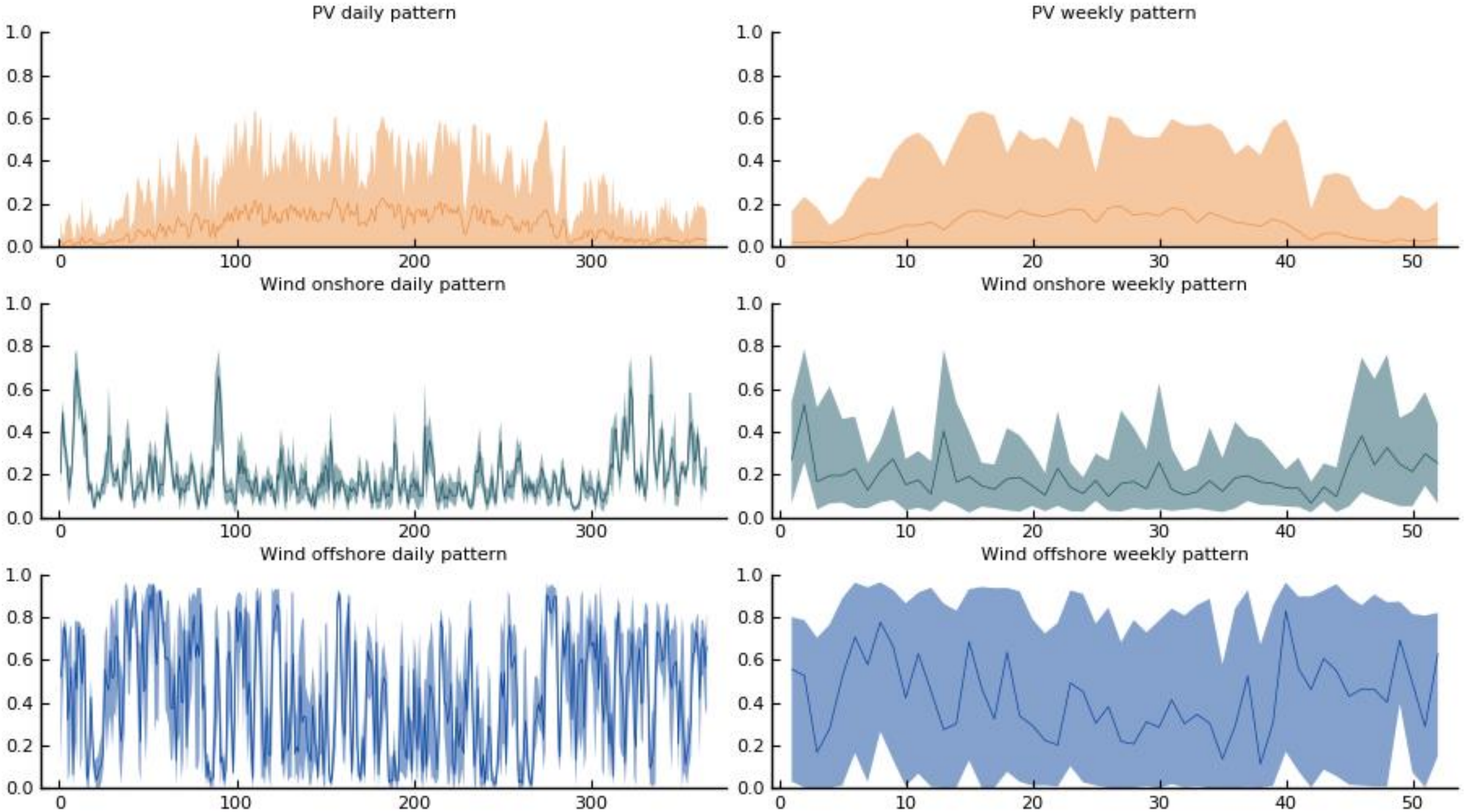
Thank you for listening

DIW Berlin — Deutsches Institut für Wirtschaftsforschung e.V.
Mohrenstraße 58, 10117 Berlin
www.diw.de

Contact
Wolf-Peter Schill | wschill@diw.de

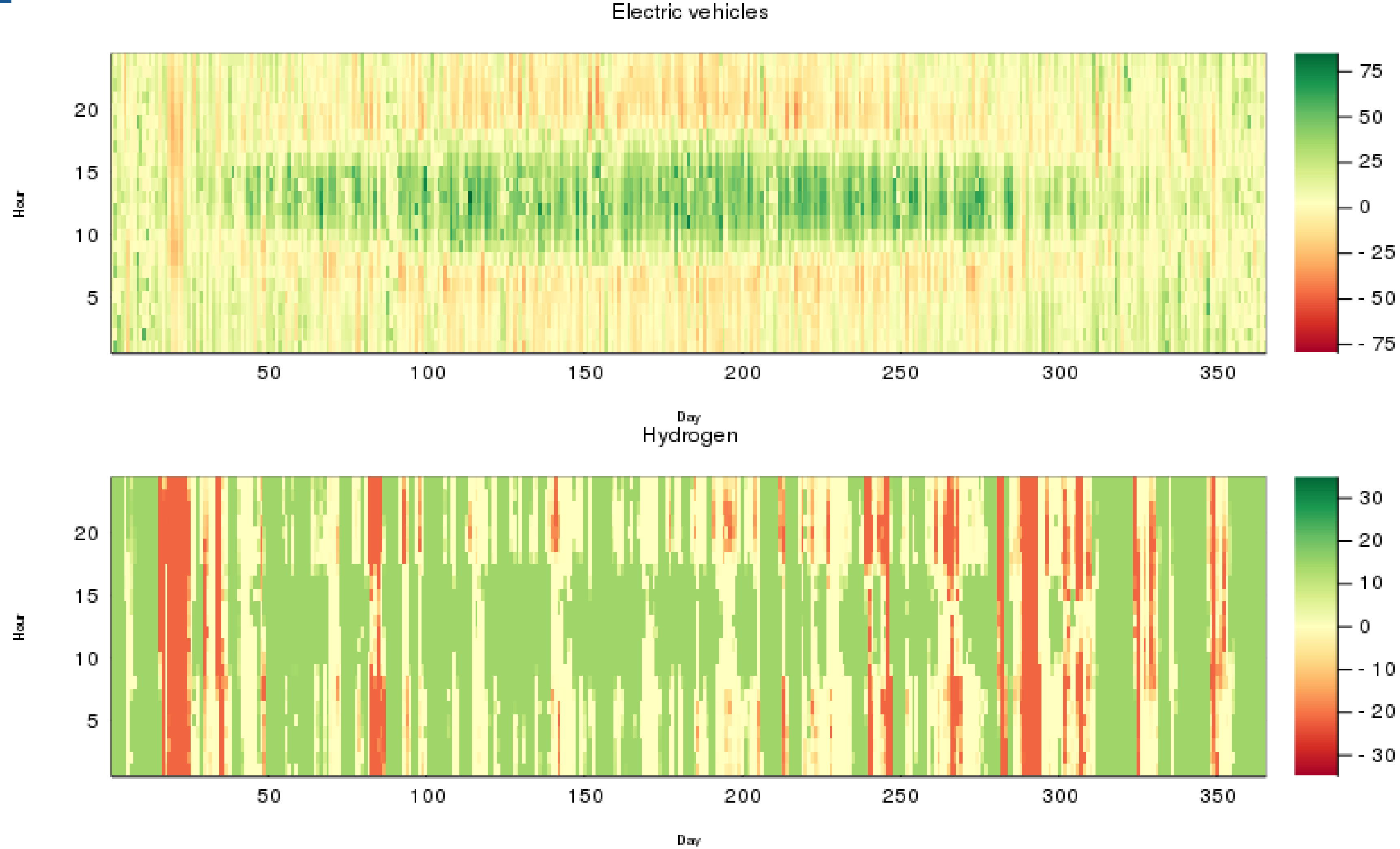
Mario Kendziorski | mkendziorski@diw.de

Patterns of hourly variable renewable generation (average, min, max)



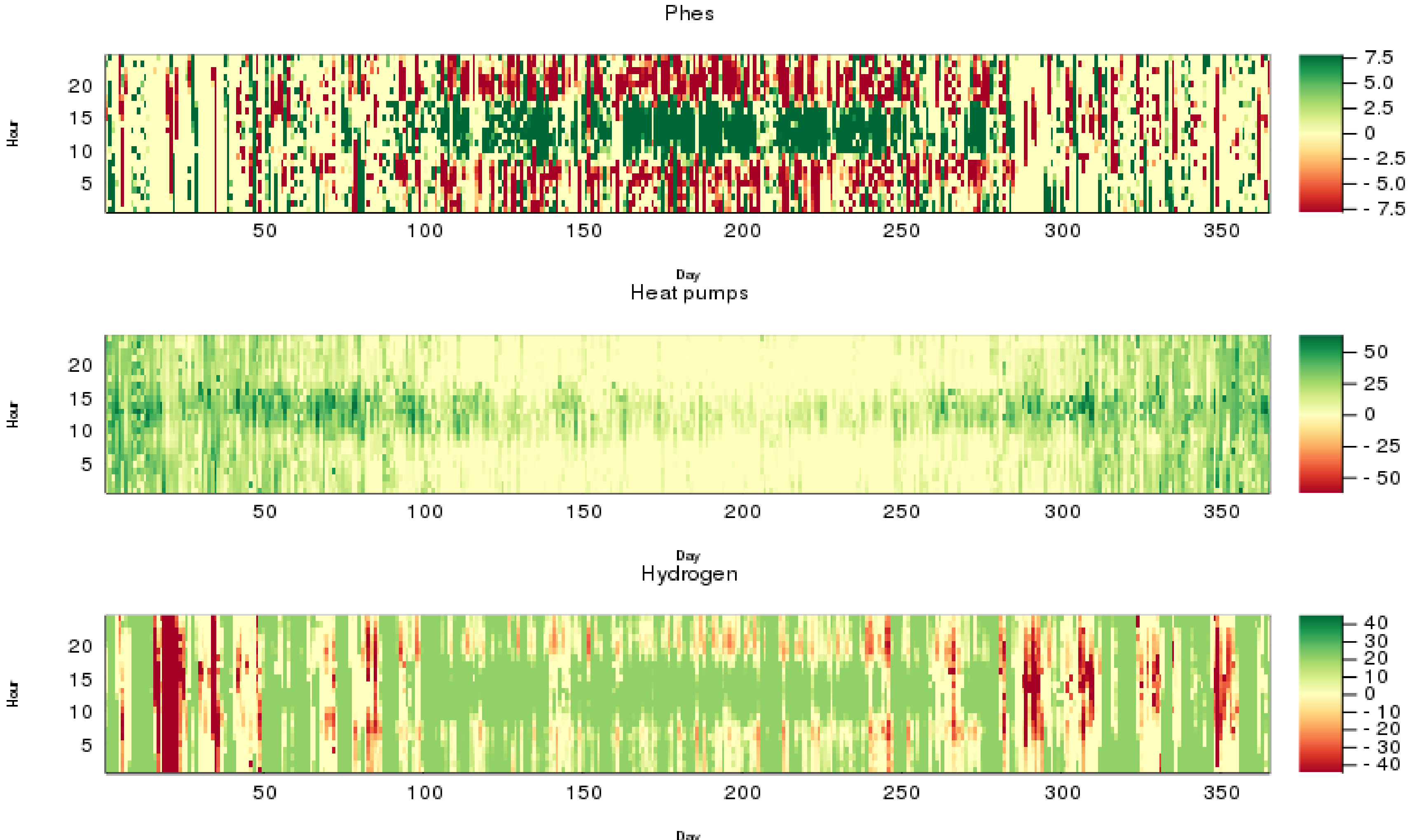
→ Again: substantial differences of short- and long-term fluctuations

Results: Electric vehicles – 40 mio, 100% RES



→ Electric vehicles provide a lot of (short-term) flexibility and replace Phes/Li-Ion

4 Results: Heat pumps – 60% of households, 100% RES



→ Heat pumps mainly active during winter time

→ Phes stronger focusses on summer surplus generation