Energiemodelle – Werkzeuge zur Gestaltung der zukünftigen Energieversorgung

05/12/2018 | **PETER LOPION**, L. KOTZUR, S. RYBERG, M. REUß, K. SYRANIDIS, P. MARKEWITZ, M. ROBINIUS, D. STOLTEN

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IEK-3: Institute of Electrochemical Process Engineering

Handelsblatt

WIRTSCHAFTSPOLITIK

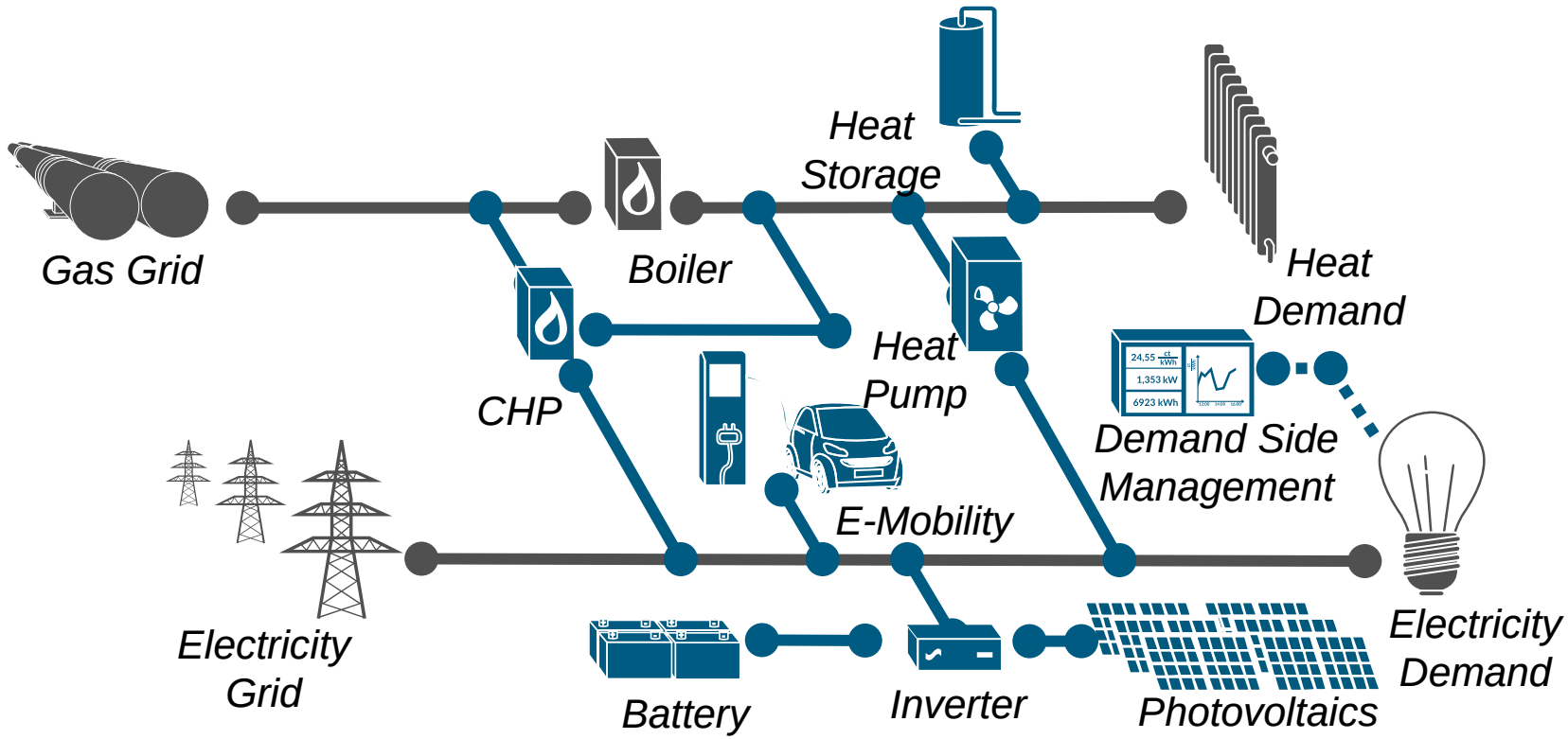
Bundesregierung: Energiewende ist nicht optimierbar

Die Kritik des Bundesrechnungshofes an der Regierung wegen mangelhafter Koordination der Energiewende ist niederschmetternd. Für Berlin jedoch kein Grund, etwas zu verändern.

[1] https://www.handelsblatt.com/politik/deutschland/wirtschaftspolitik-bundesregierung-energiewende-ist-nicht-optimierbar/23674508.html

What are Energy System Models?

'Energy systems models are important methods used to generate a range of insight and analysis on the supply and demand of energy.' [1]



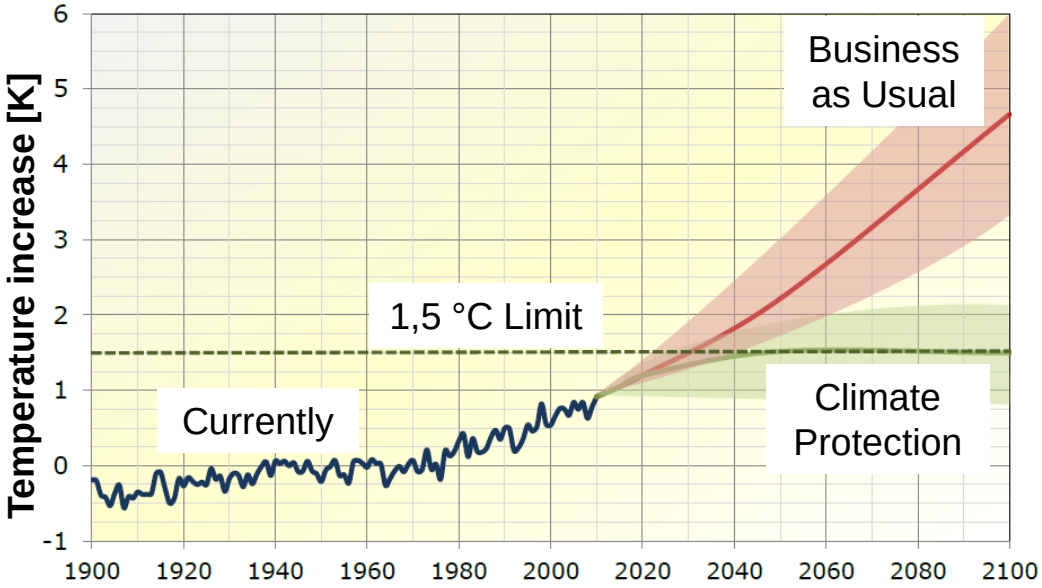
[1] S. Pfenninger, A. Hawkes and J. Keirstead: Energy systems modeling for twenty-first century energy challenges. Renewable and Sustainable Energy Reviews, 33, pp. 74-86. 2014.

Why do we need Energy System Models?

Paris Agreement 12/12/2015

Aim

'Holding the increase in the global average temperature to well below 2 °C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5 °C above pre-industrial levels, recognizing that this would significantly reduce the risks and impacts of climate change' [1]



[1] United Nations Framework Convention on Climate Change, *Paris Agreement (FCCC/CP/2015/L.9/Rev.1), § 2.1(a).* 12/12/2015

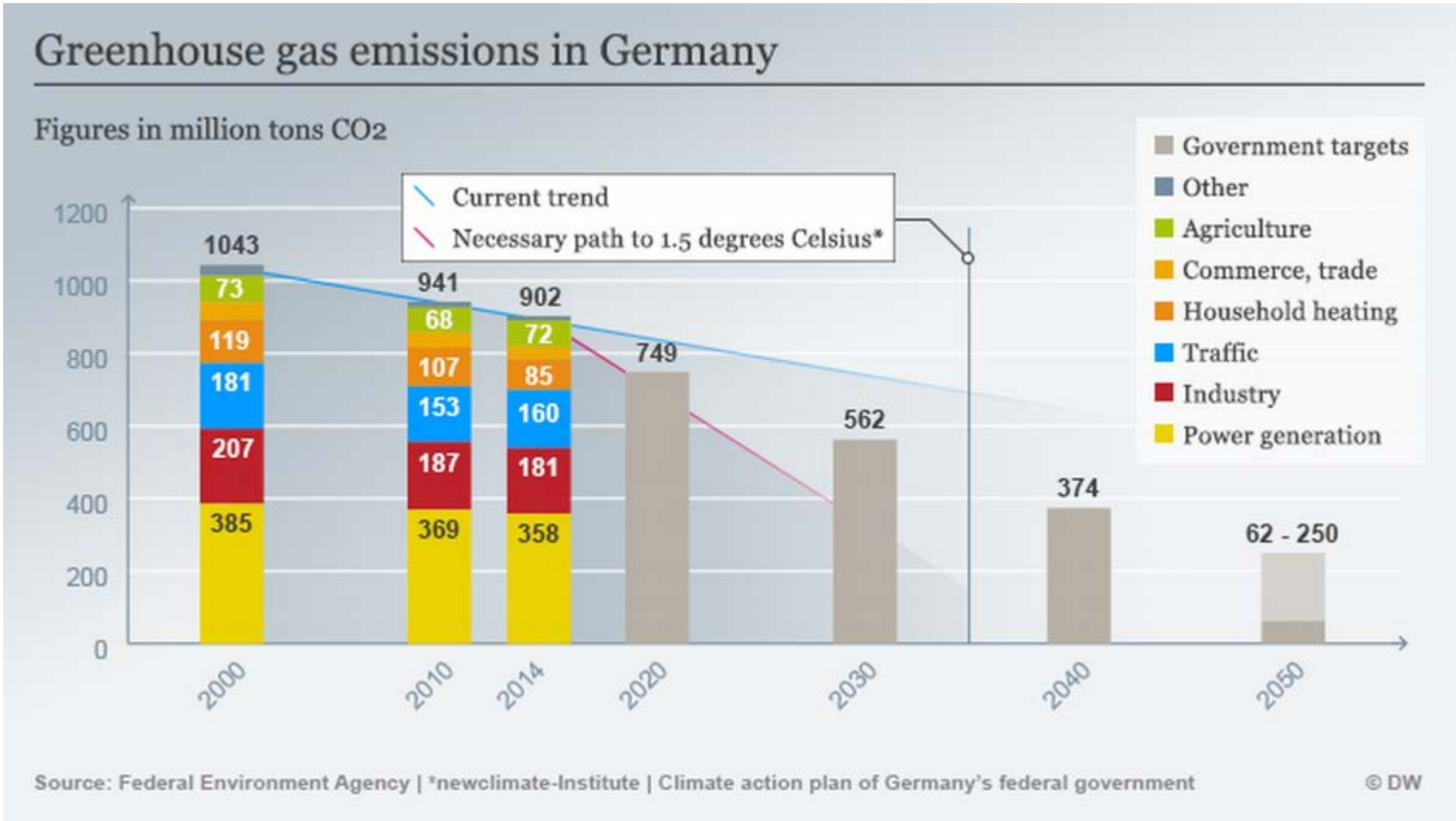
[2] V. Quaschning. *Sektorkopplung durch die Energiewende.* Hochschule für Technik und Wirtschaft HTW Berlin. 2016

Why do we need Energy System Models?

Climate Protection Plan 14/11/2016

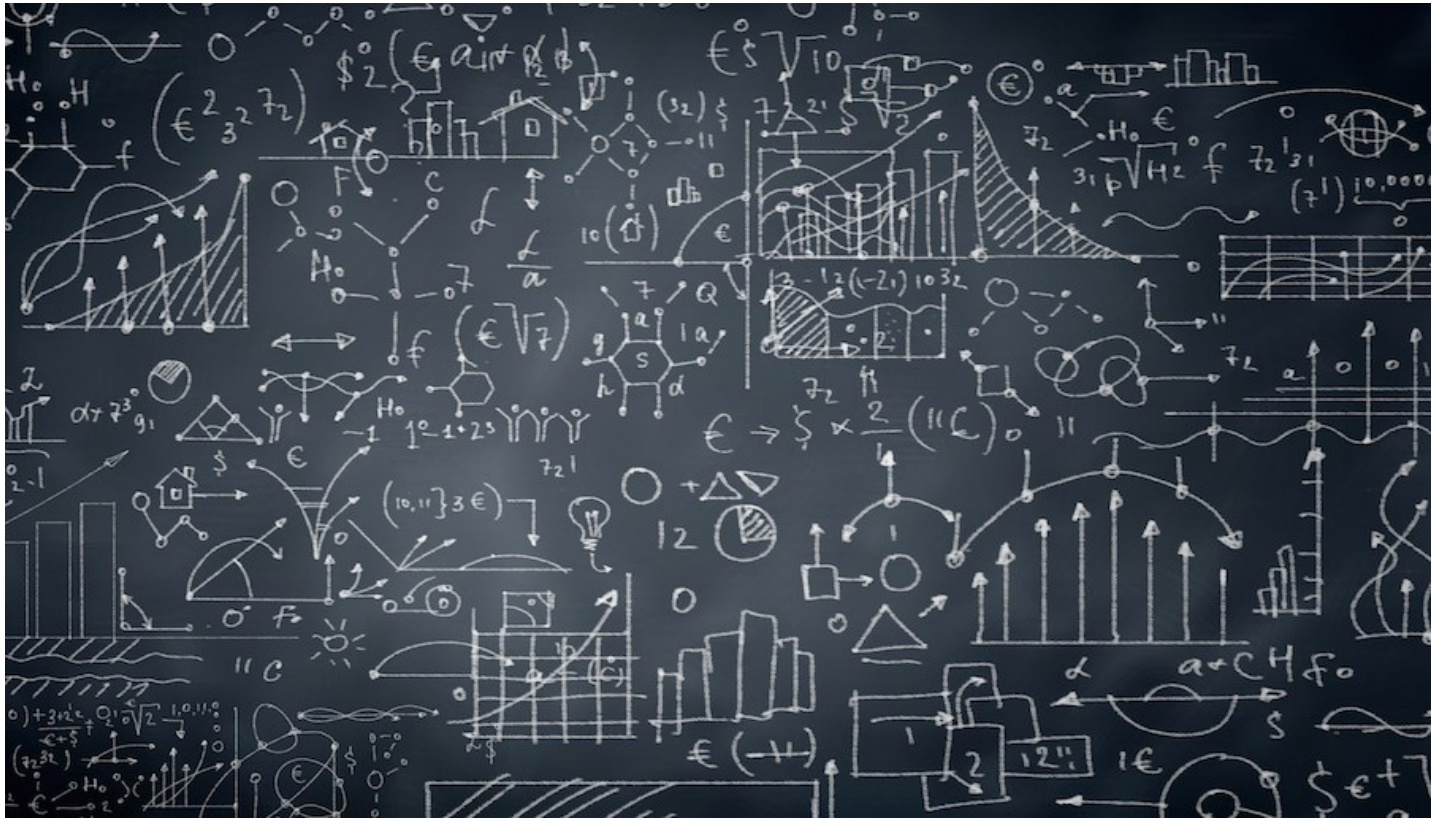
[1] https://www.bmu.de/fileadmin/Daten_BMU/Download_PDF/Klimaschutz/klimaschutzplan_2050_bf.pdf

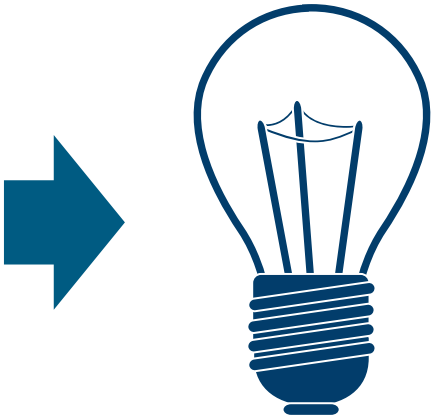
Why do we need Energy System Models?



[1] https://www.dw.com/image/36383612_403.png

Why do we need Energy System Models?





[1] https://s3.amazonaws.com/viking_education/web_development/prep_engineering/complex_problem_small.jpg

Agenda

- Energy System Analysis
- European Models
- German Models
- Summary

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- **Energy System Analysis**
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Institute for Energy and Climate Research – Electrochemical Process Engineering (IEK-3)

Director: **Prof. Dr. D. Stolten**

Employees: **150**

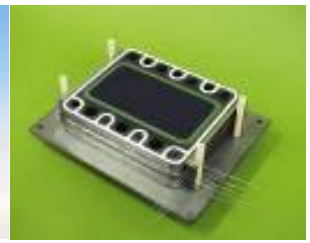
Expertise: **Fuel Cells**

Research fields:

- Process- & system analysis
- Process- & system engineering
- Production technology
- Electrochemistry
- Modeling & simulation
- Catalysis & reaction engineering

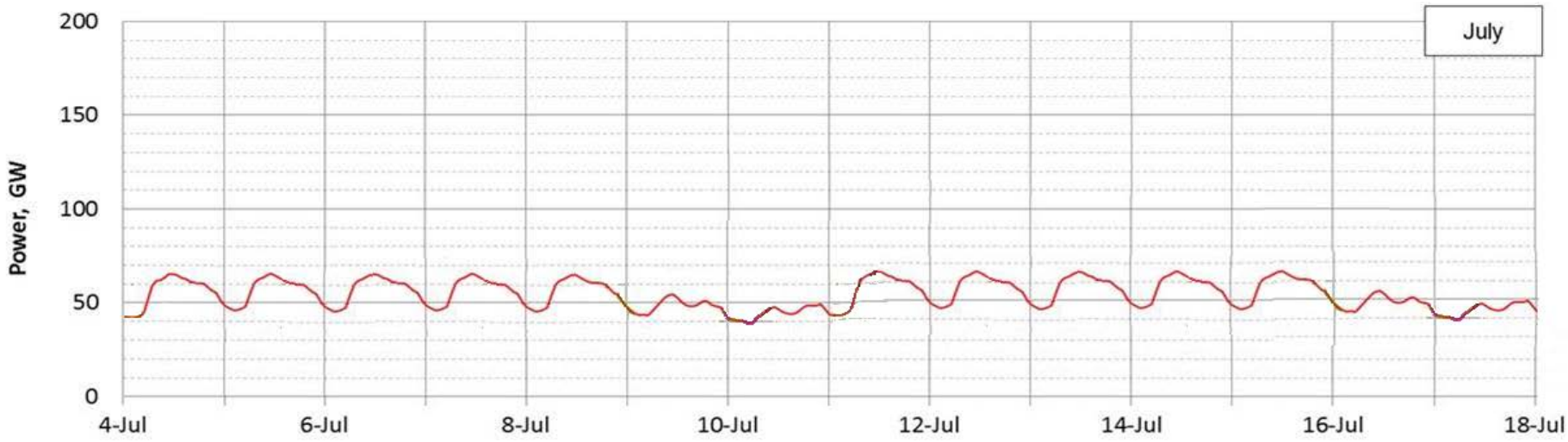




Motivation for the fuel cell technology

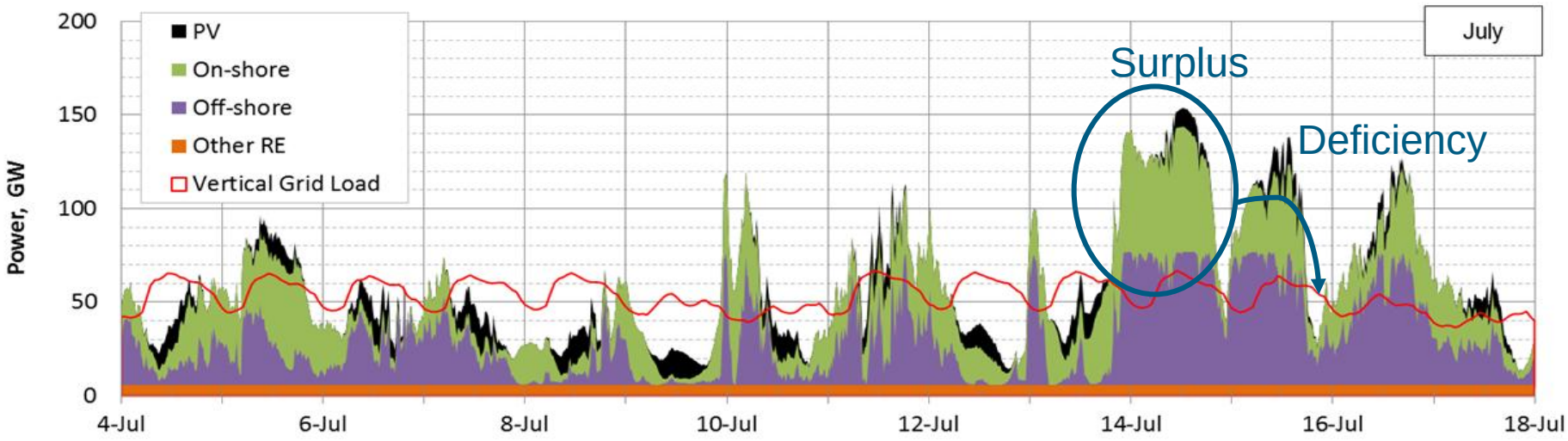
Grid load in Germany in July 2011



[1] D. Stolten et al., 12. Symposium Energieinnovation Graz, 2012

Motivation for the fuel cell technology

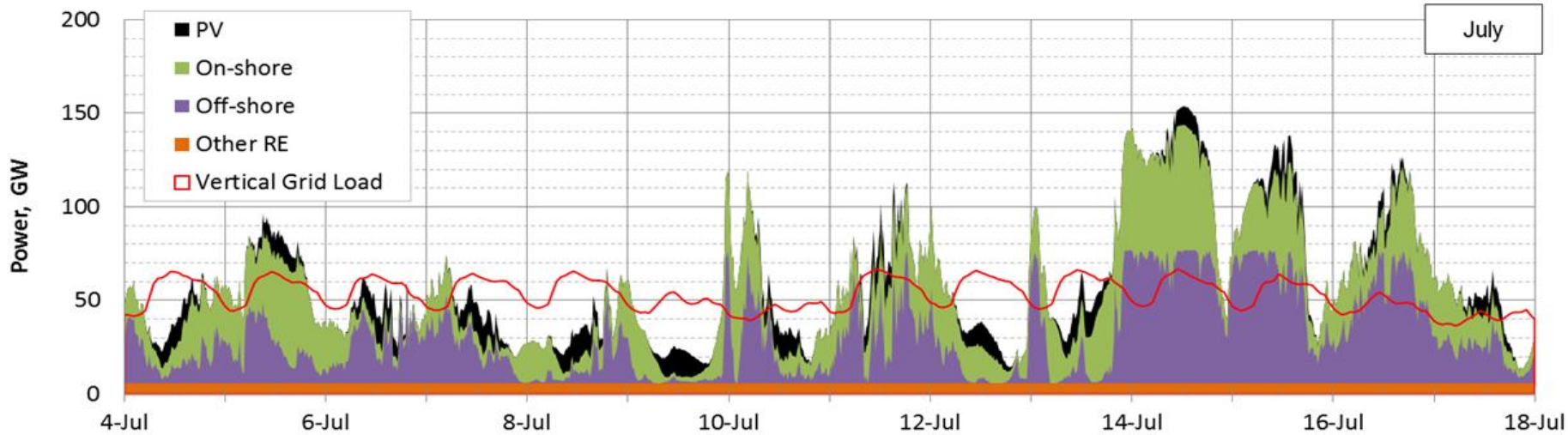
Simulated energy supply with renewable energy sources

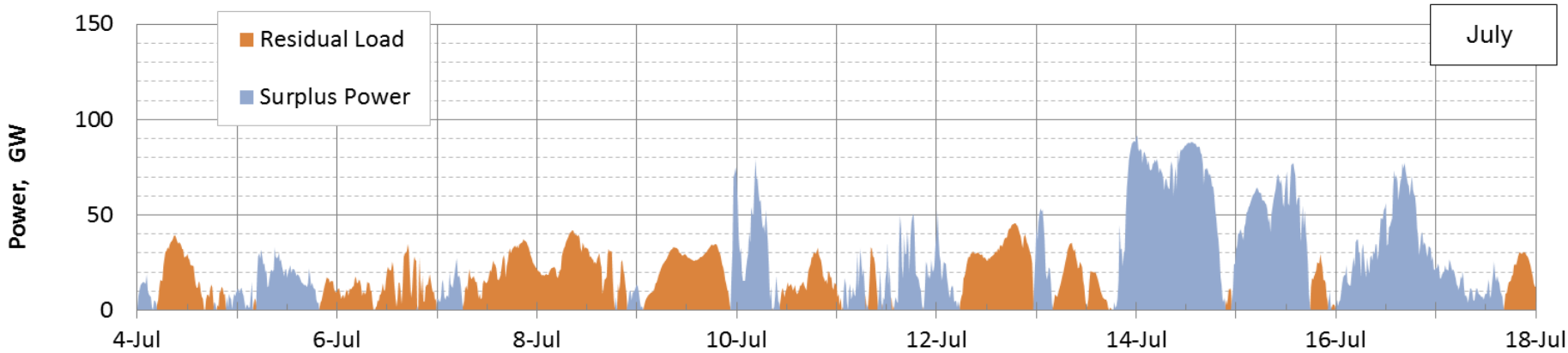


[1] D. Stolten et al., 12. Symposium Energieinnovation Graz, 2012

Motivation for the fuel cell technology

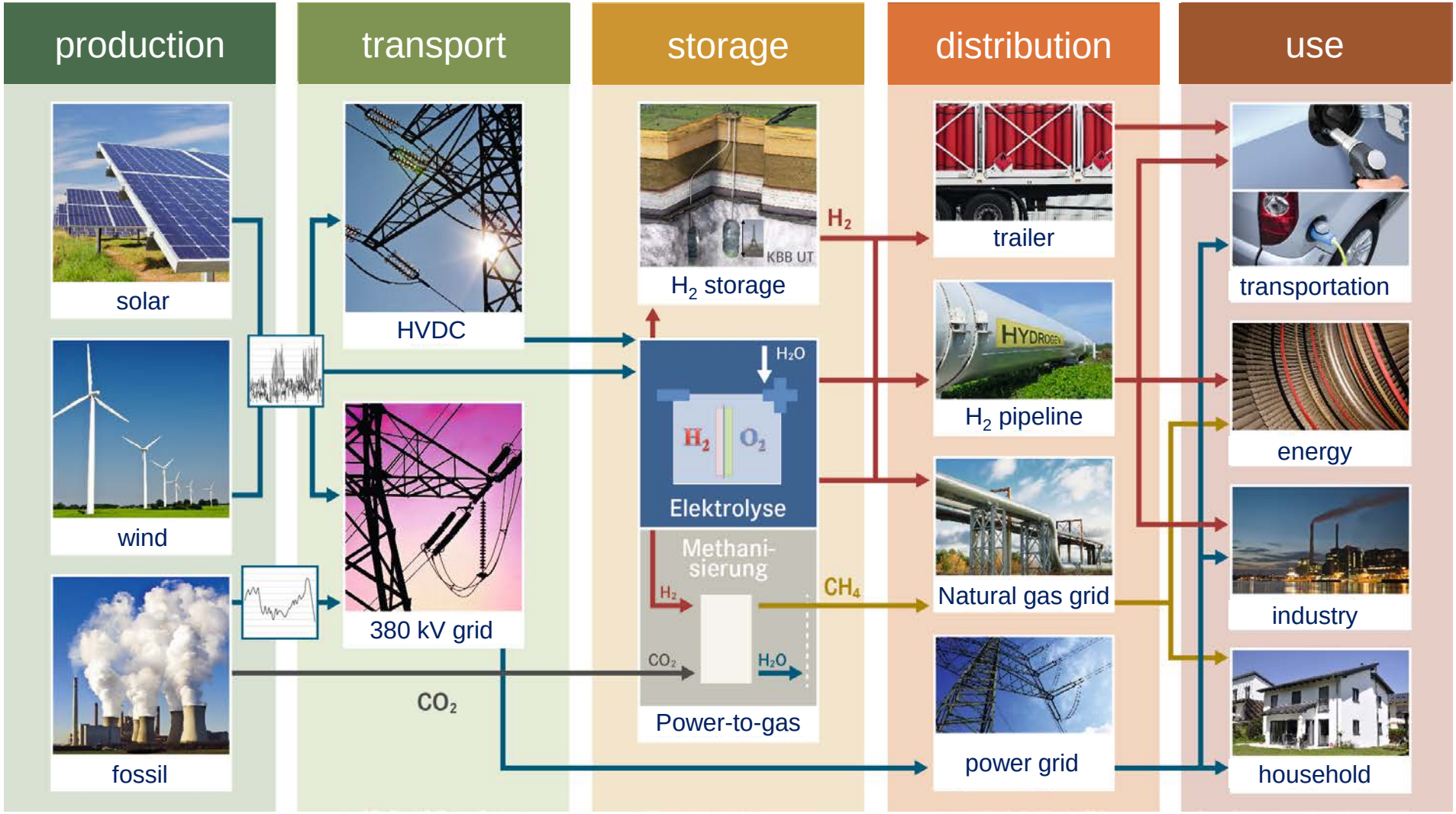
Difference in energy demand and energy supply





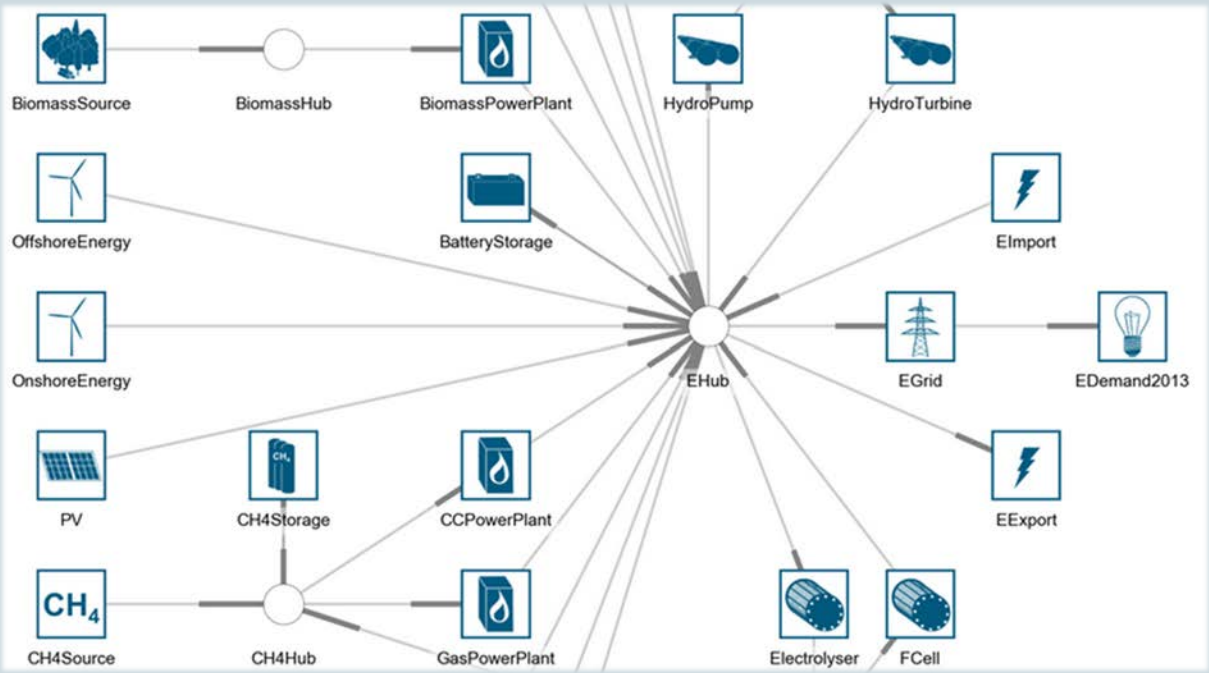
[1] D. Stolten et al., 12. Symposium Energieinnovation Graz, 2012

Energy concept Power-to-Gas



General Approach

Network of defined **nodes**
(sources, sinks, storages, transformers, hubs)
and **edges** (energy and mass flows).
→ **script based**



System of linear equations (LP)

- Data processing
- Objective function
- Constraints
- Visualization

→ **Least-cost energy system**

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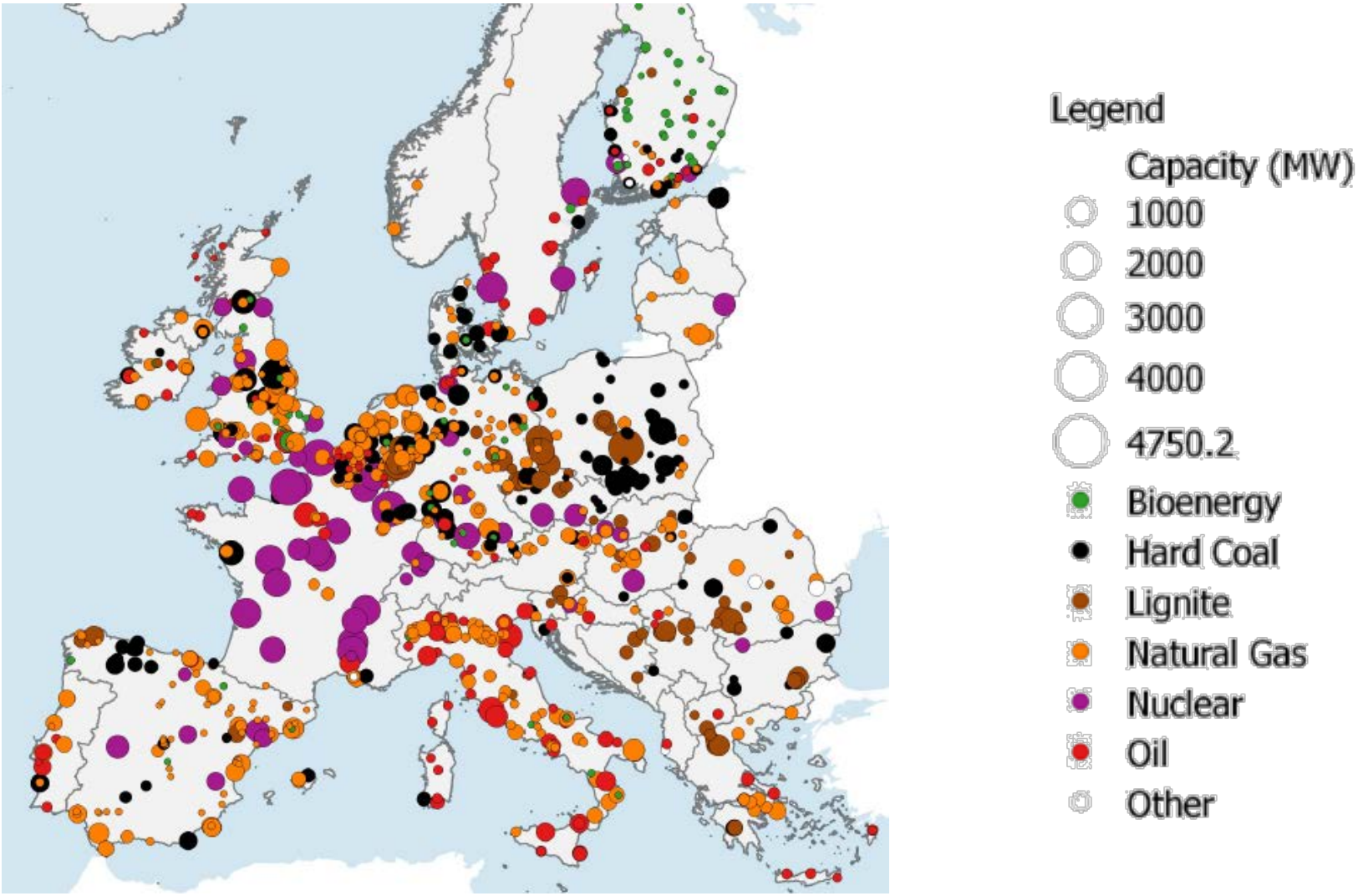
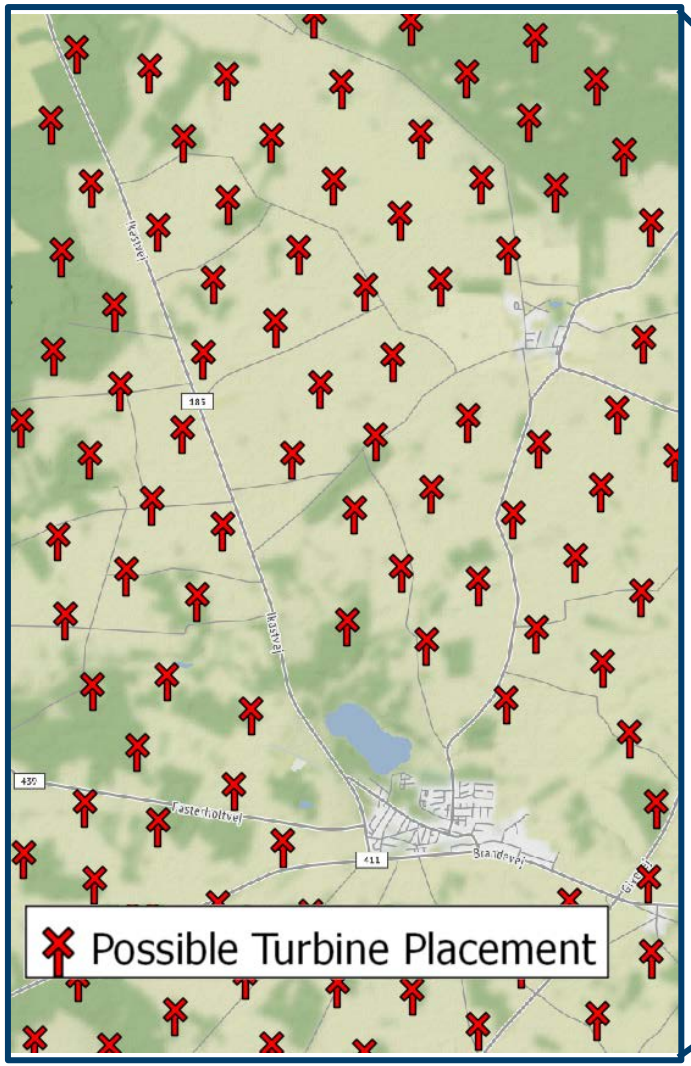
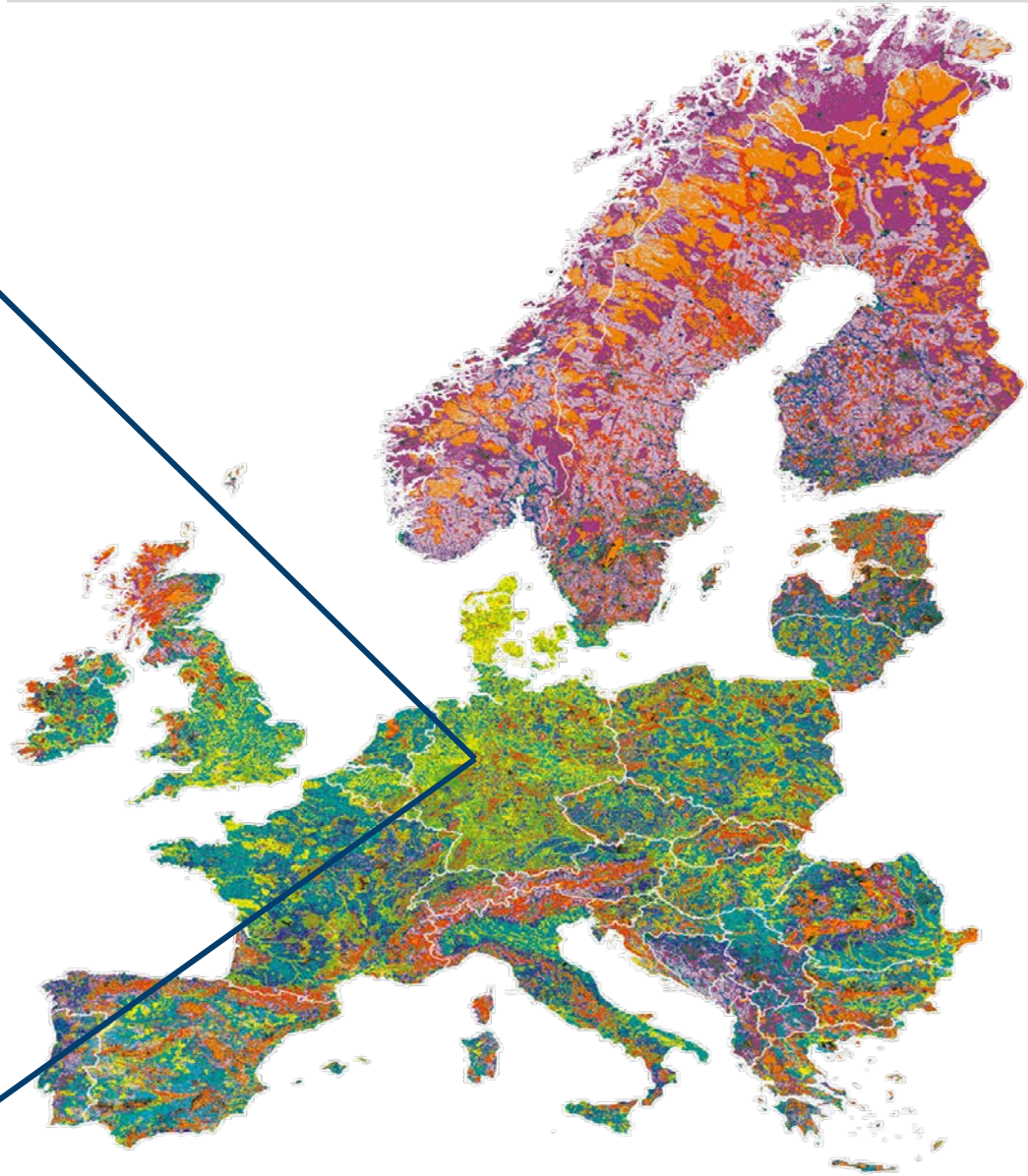
Conventional Power Plants in Europe



Land Eligibility





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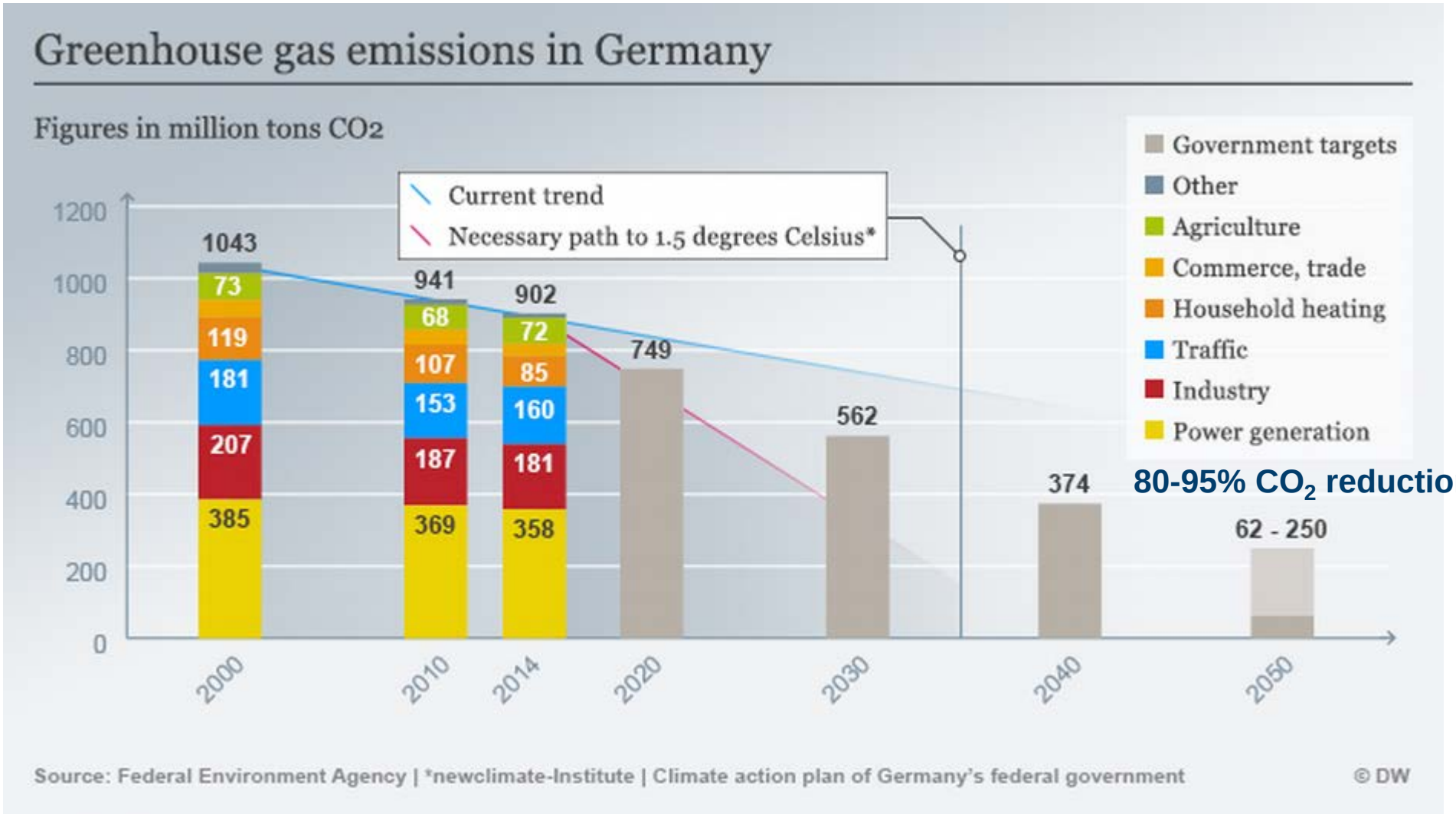
Why do we need Energy System Models?



80-95% CO_2 reduction

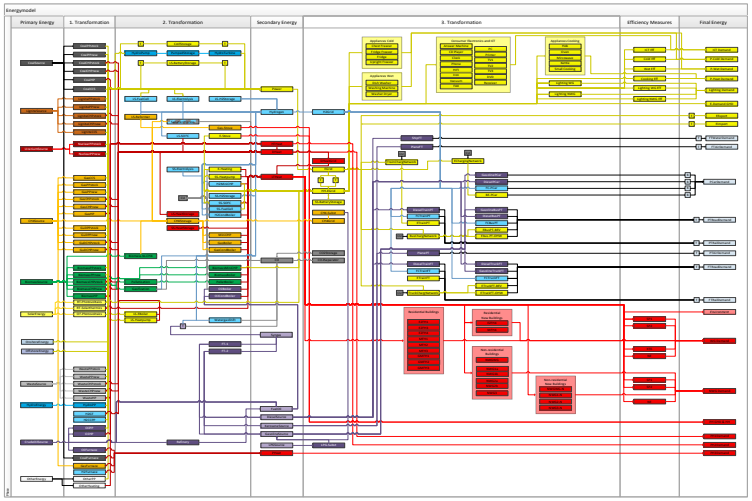
[1] https://www.dw.com/image/36383612_403.png

Model Overview

Model Structure

MACRO-ECONOMIC INPUT DATA
(fuel prices, population, stocks, etc.)

ENERGY SYSTEM MODEL



DEMAND

→ Electricity demand
- Residential sector / Households (HH)
- Industry (IND)
- Trade & Commerce (T&C)

→ Heat demand
- Room heating
- Water heating
- Process heat (HH, IND, T&C)

→ Transport demand

→ Demand for industrial goods

Macro-economic assumptions based on [1]

today 2020 2030 2040 2050

Myopic Transformation Path Analysis

[1] Klimapfade für Deutschland 2050 (BDI, 2018)

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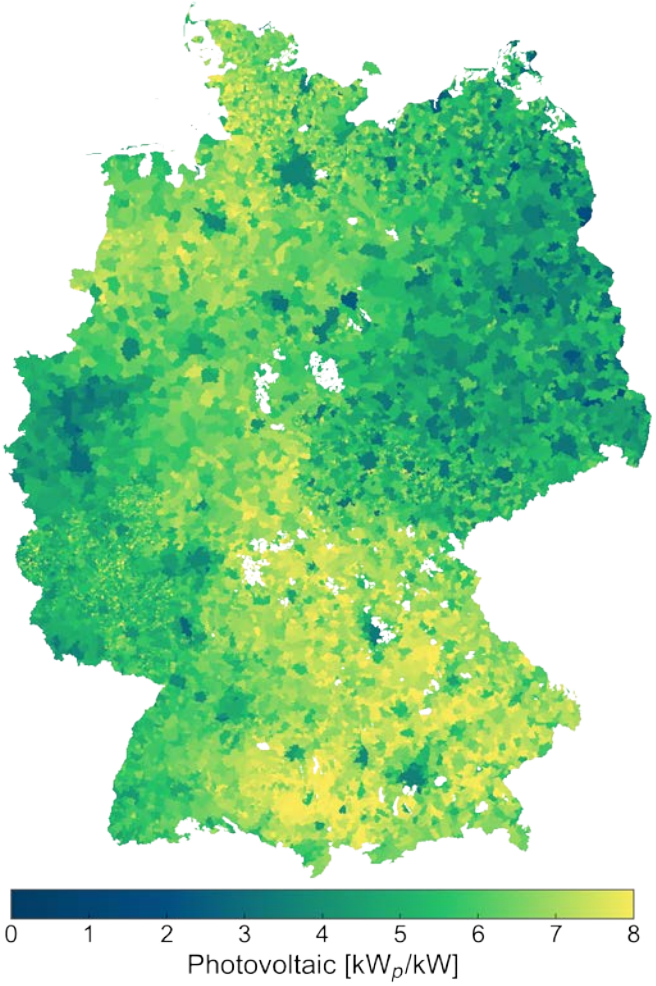
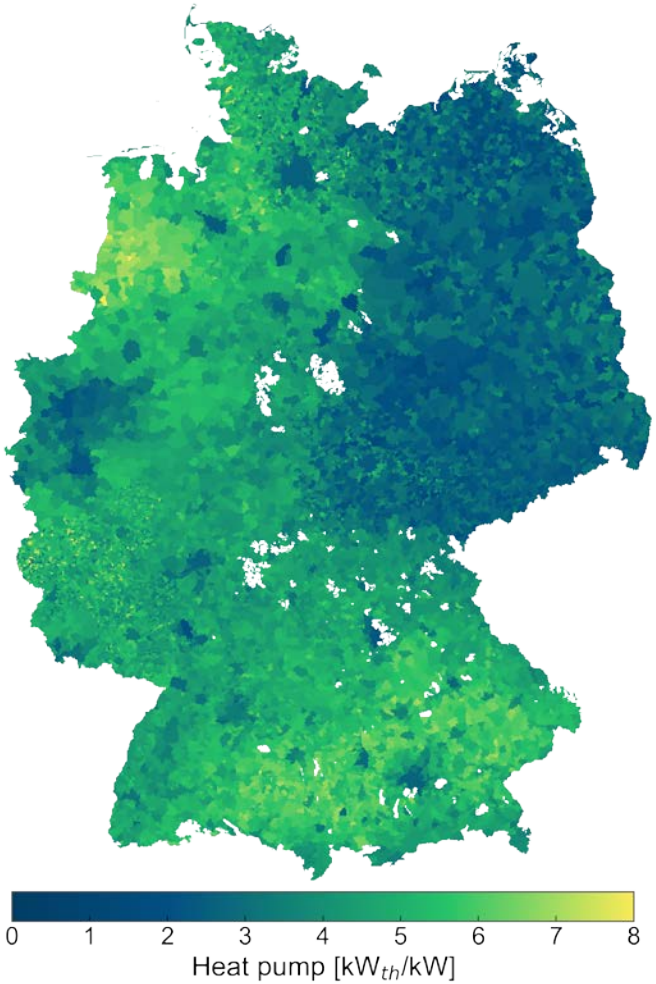
Installed Technologies Future Scenario

Relative to the conventional mean load of the Reference scenario

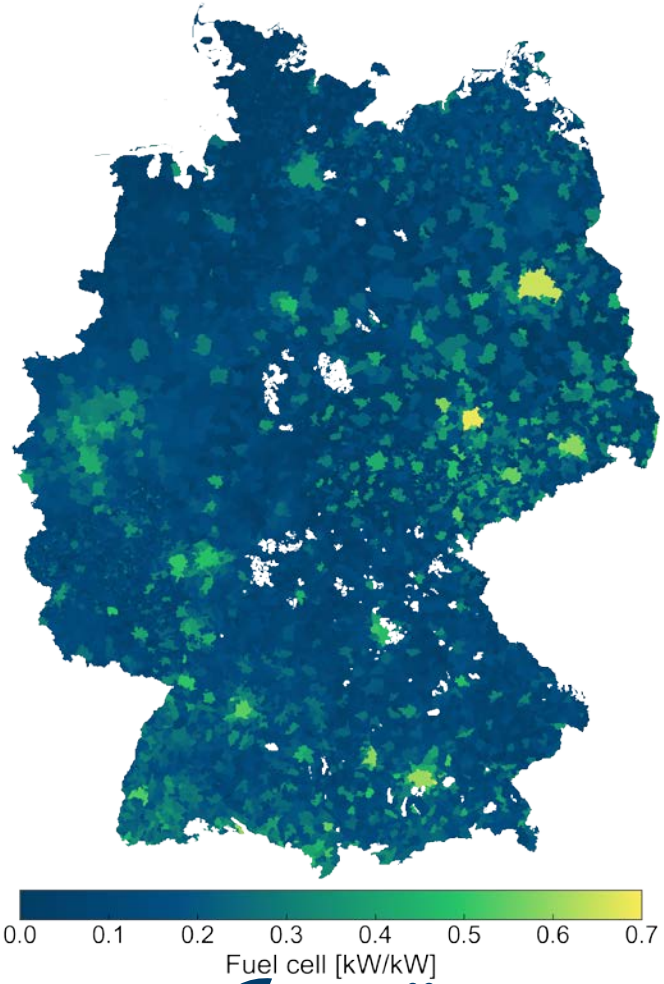
Photovoltaic (roof top)



Heat pumps



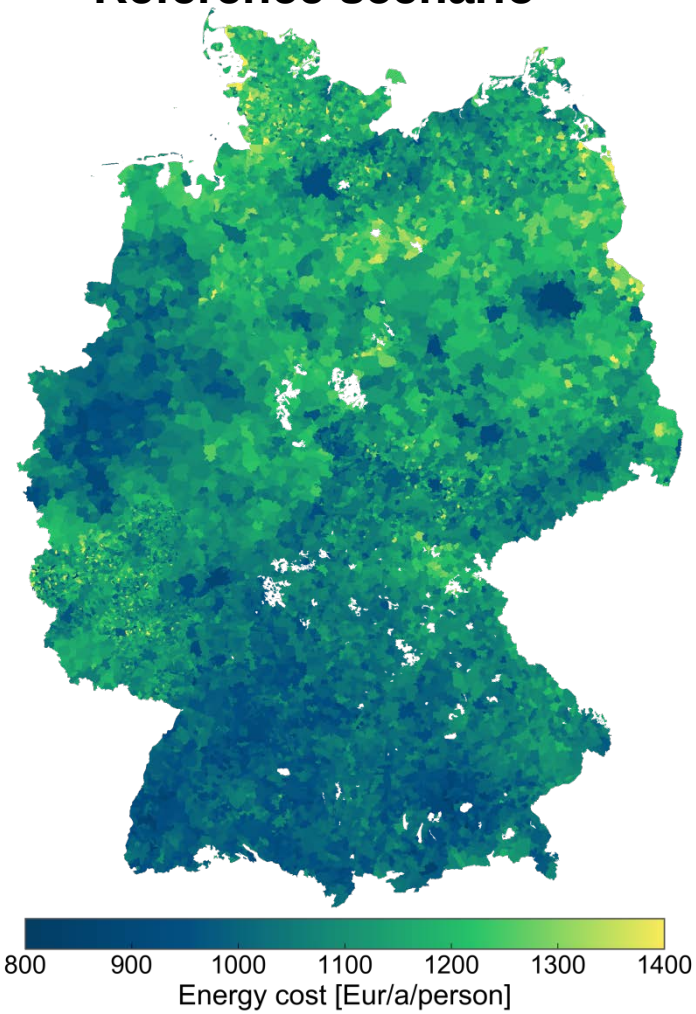
Fuel cells



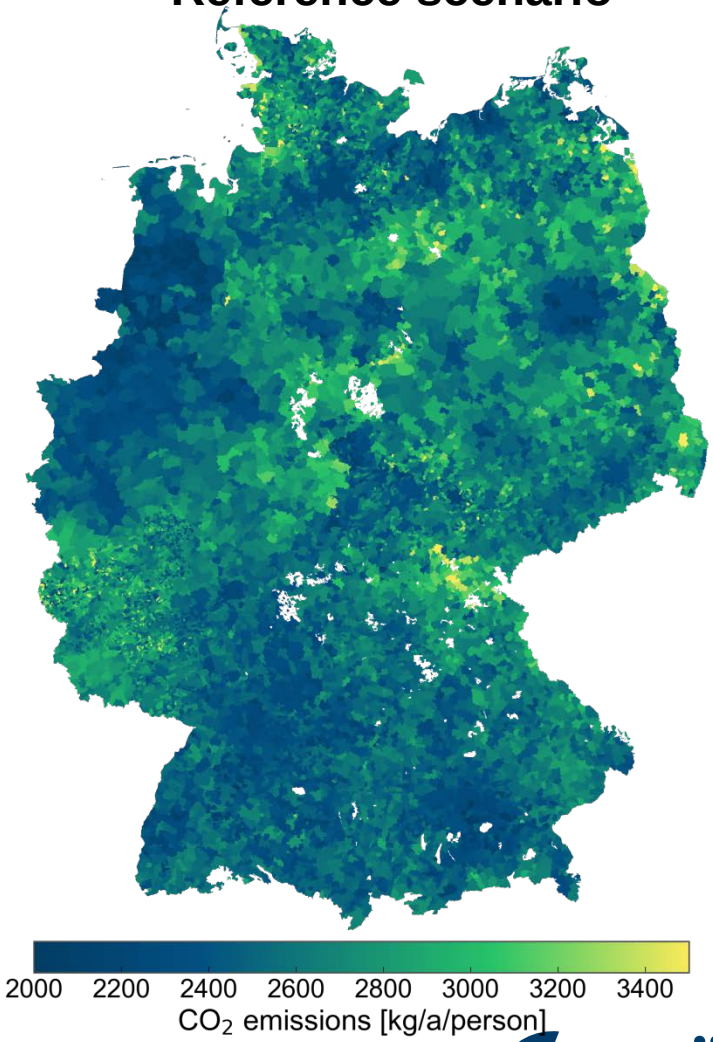
[1] L. Kotzur et al.: Future Residential Grid Load in Germany. 25. Workshop des GEE-Studentchapters. 2018.

Change of Energy Supply Cost per Person

Annual cost per person in the Reference scenario



Emissions per person in the Reference scenario



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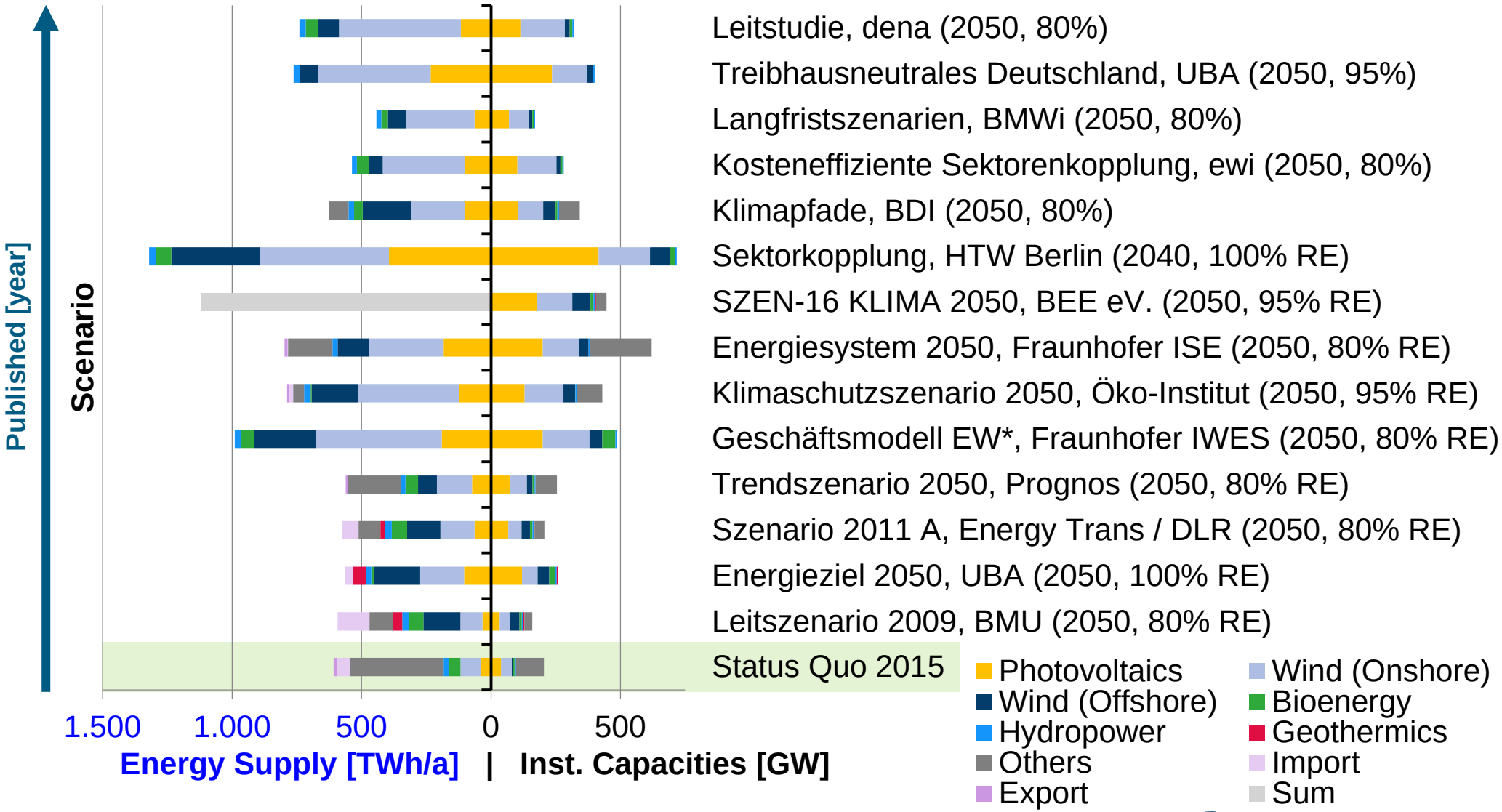
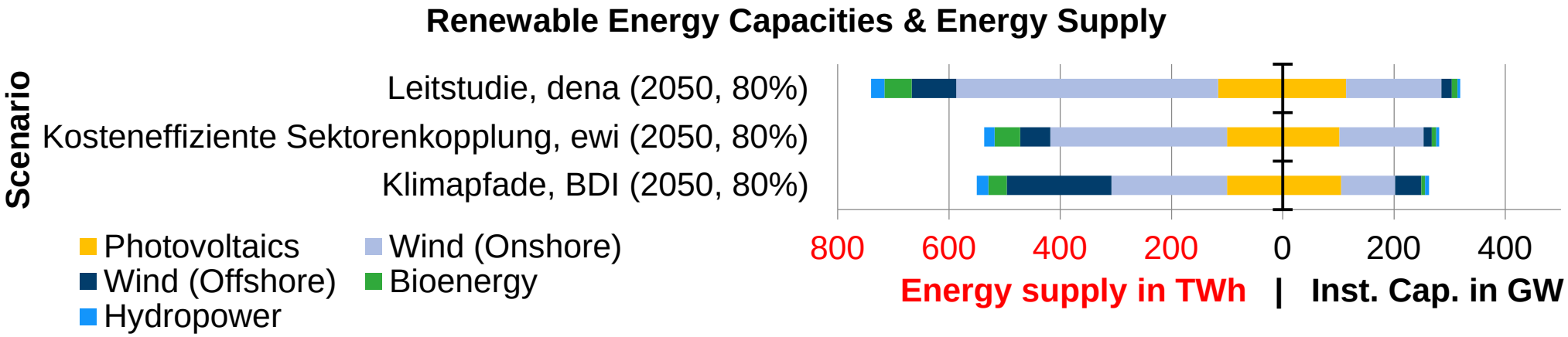
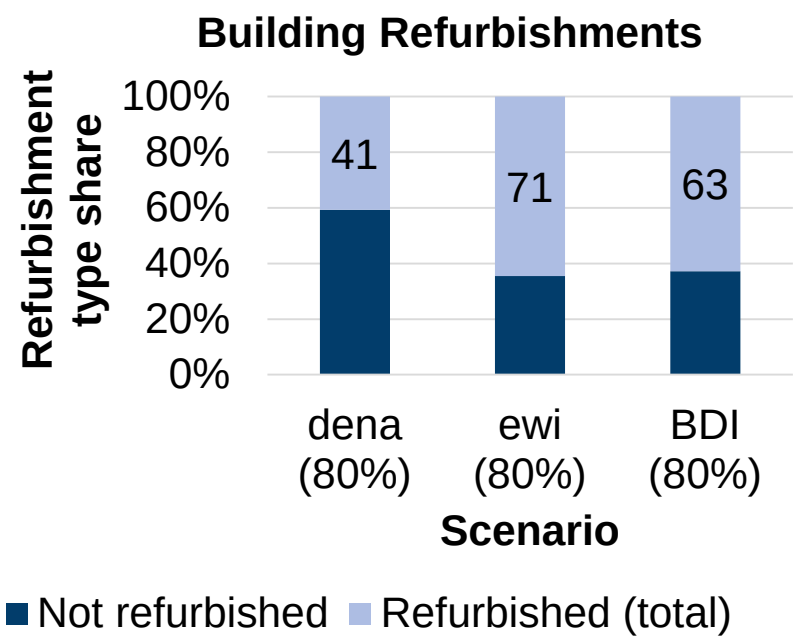
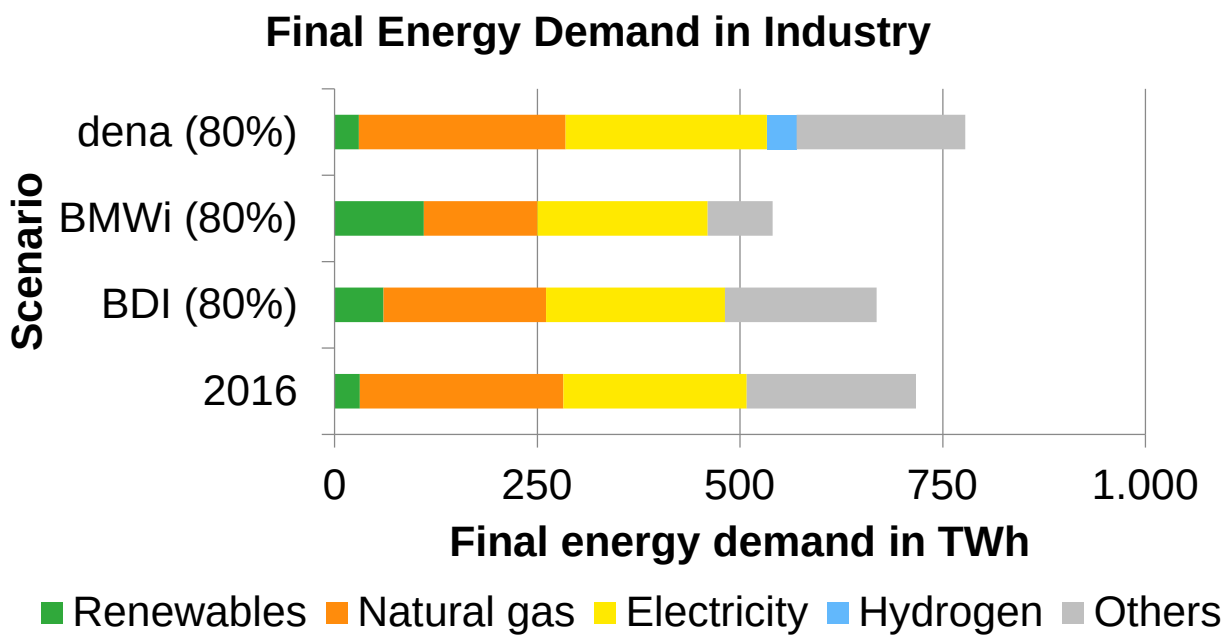
Installed Capacities and Electricity Supply of Renewable Energies [1-15]



Comparison of Energy Scenarios for Germany [1-4]







Summary

Energy System Models

‘Energy systems models are important methods used to generate a range of insight and analysis on the supply and demand of energy.’ [1]

→ **Necessary tools to support planning processes of the ‘Energiewende’**

→ **Wide range of potential areas of application**

Results

- Energy efficiency plays an important role in future energy scenarios
- Energy storage options are one crucial factor for the future energy supply
- Isolated solutions for 95% CO_2 reduction scenarios are not tenable

[1] S. Pfenninger, A. Hawkes and J. Keirstead: Energy systems modeling for twenty-first century energy challenges. Renewable and Sustainable Energy Reviews, 33, pp. 74-86. 2014.

THANK YOU FOR YOUR ATTENTION