FUTURE ENERGY SYSTEMS WITH HIGH RENEWABLE ENERGY SHARES

Hans-Martin Henning

Fraunhofer Institute for Solar Energy Systems ISE, Freiburg, Germany

Grid Modernization in MA: International Insights to Meet 2050 Carbon Goals

Fraunhofer CSE, April 25, 2018
Boston, MA

www.ise.fraunhofer.de

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Business Areas

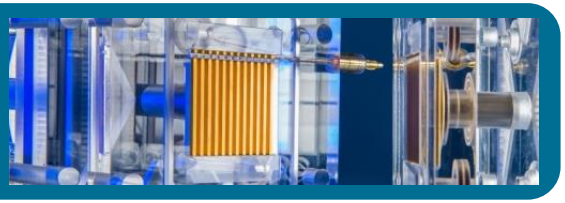
~ 1200 Staff
Operating budget ~ 80 Mio €

Energy technologies and systems
Hans-Martin Henning

Solar Thermal Technology

Building Energy Technology

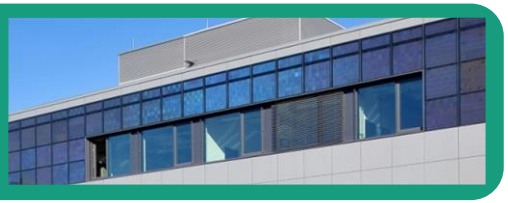
Hydrogen Technology



Energy System Technology

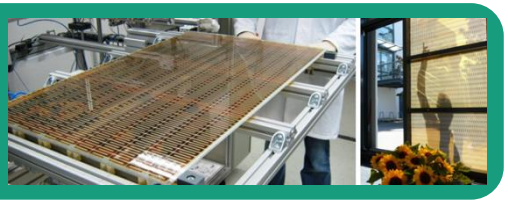
Photovoltaics
Andreas Bett

Silicon Photovoltaics



III-V- and Concentrator Photovoltaics

Emerging Photovoltaic technologies



Photovoltaic Modules and Power Plants

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Outline

GHG emissions and targets in Germany

Optimization of transformation pathways – methodology

Results for selected scenarios

Phases of energy system transformation

Summary, conclusions & outlook

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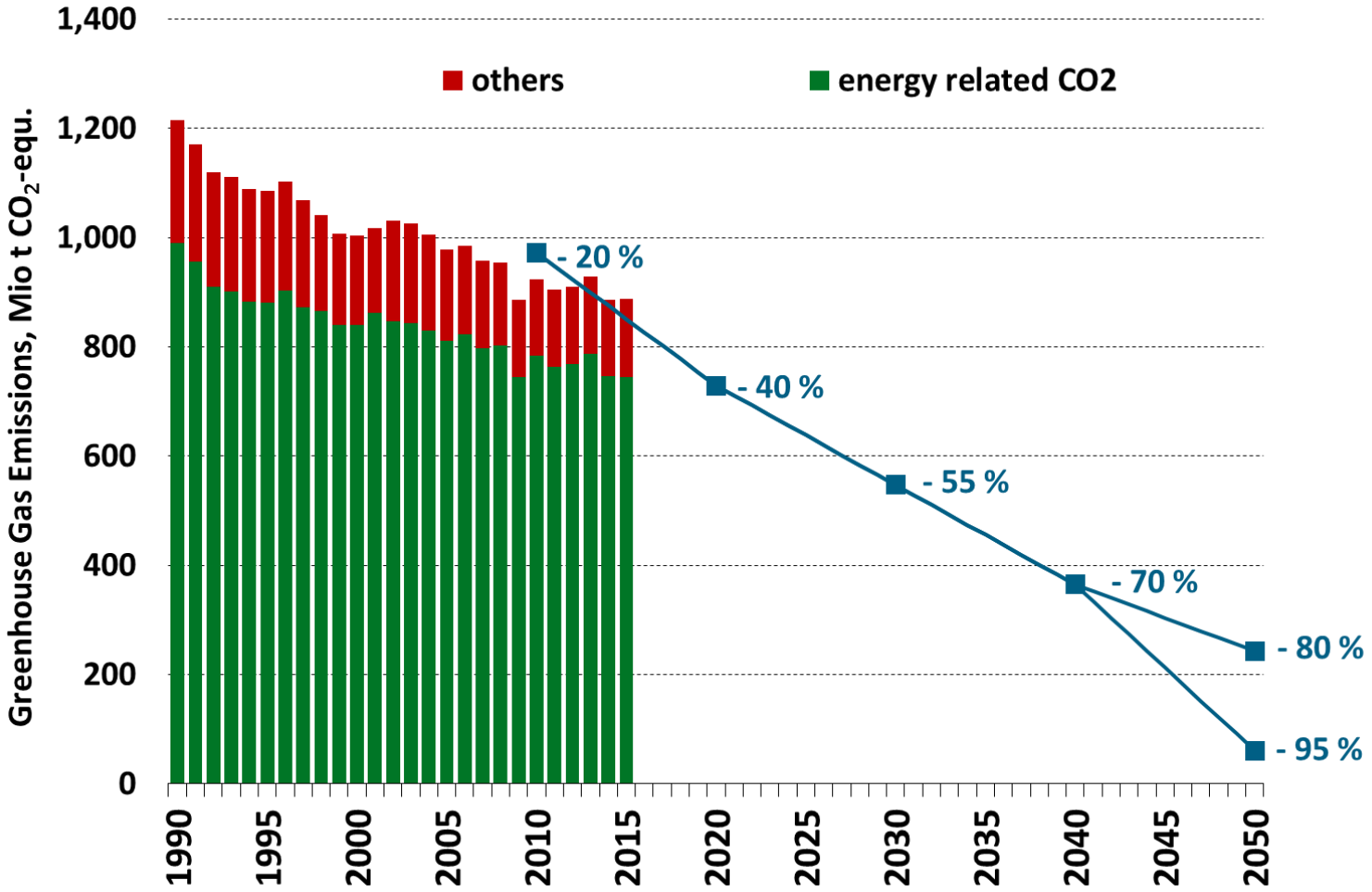
Need for deep transformation of our energy systems

- Climate and sustainability targets are key topics on the global political agenda
- Energy supply causes major parts of anthropogenic climate change
- Clear target ➔ energy systems with drastically reduced CO_2 emissions
- But: the pathway is highly complex

➔ Powerful tools & models needed for comprehensive optimization of energy system transformation pathways

German GHG emissions

Historical values 1990-2015 and target values until 2050



Based on data from: Nationale Trendtabellen für die deutsche Berichterstattung atmosphärischer Emissionen. Umweltbundesamt (UBA) Dessau, 23.1.2017

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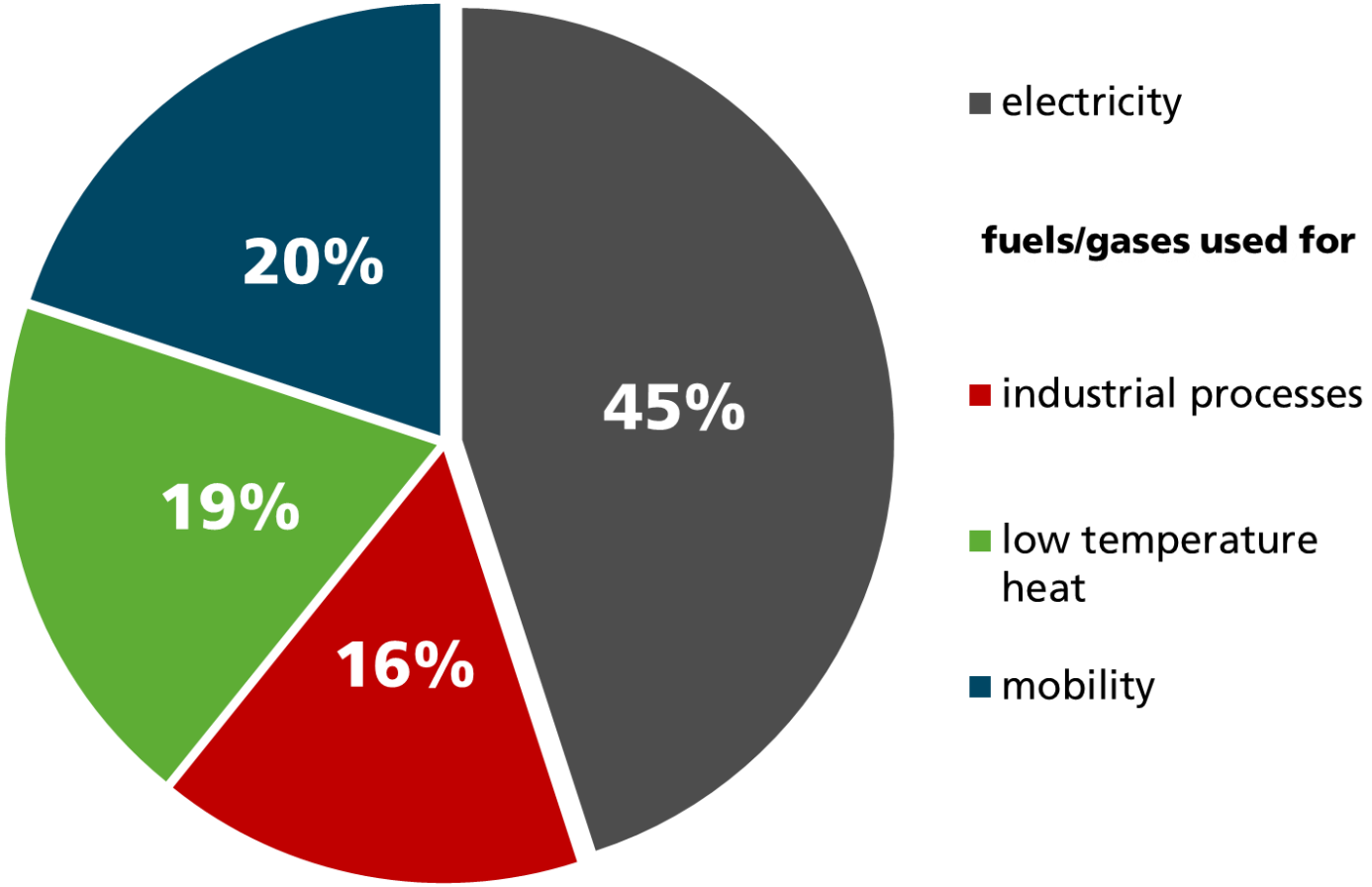
Energy related CO_2 emissions – Germany today



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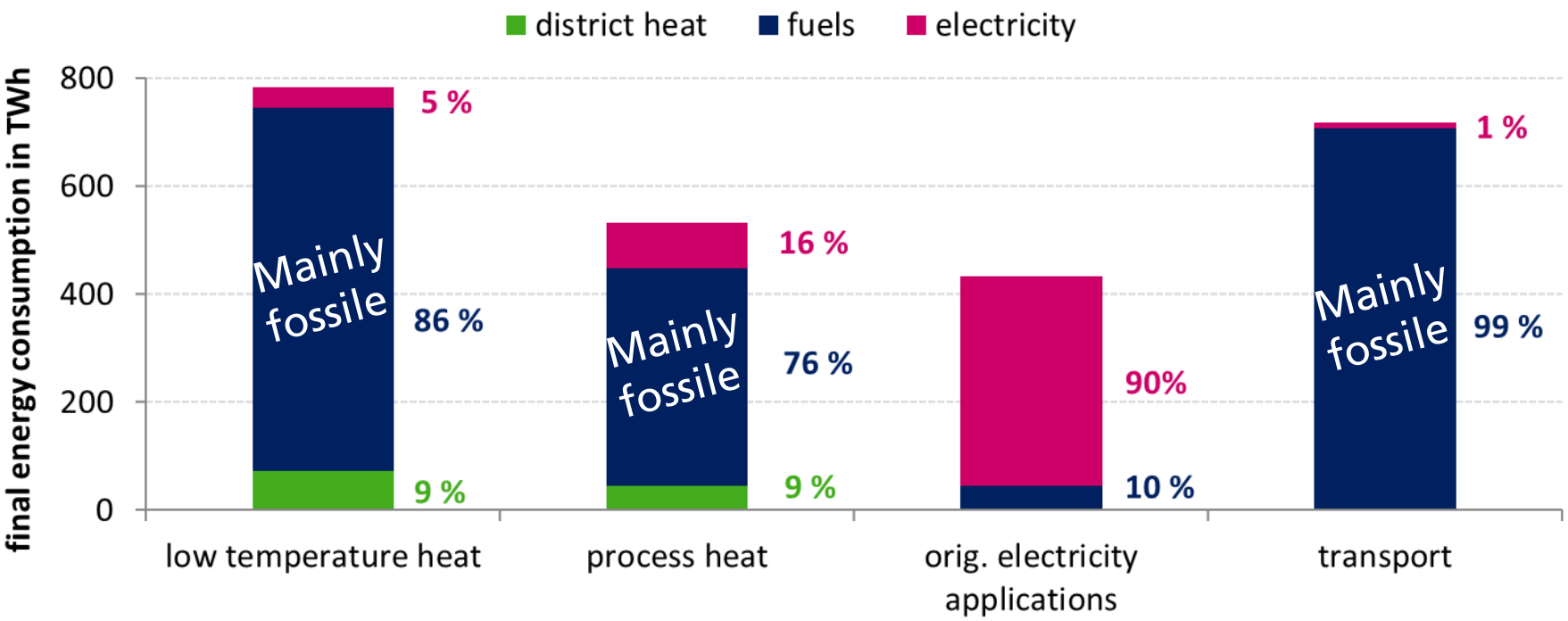
Final energy demand of today



Source of data: „Energiedaten, Gesamtausgabe“, BMWi, february 2017

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Main questions

- How can heat (buildings, industry processes) and mobility sectors become less dependent from fossile energy sources?
- How can the complex overall system be transformed towards achieving climate targets without compromising on energy security and at minimal cost?
- What technologies are necessary at what time?

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Guiding question

What is the best, i.e. cost-optimized pathway to achieve

- the transformation of the energy system
- with consideration to all energy sources and end-use sectors
- under the condition that the declared climate targets are met in the target year 2050 and in every year until 2050?

Boundary condition in Germany

- No nuclear electricity generation after 2022

Renewable Energy Model »REMod«

Mimimize total annual costs →

REMod

Strictly model-based techno-economic optimization of transformation pathways based on comprehensive simulation of energy systems (hourly time scale)

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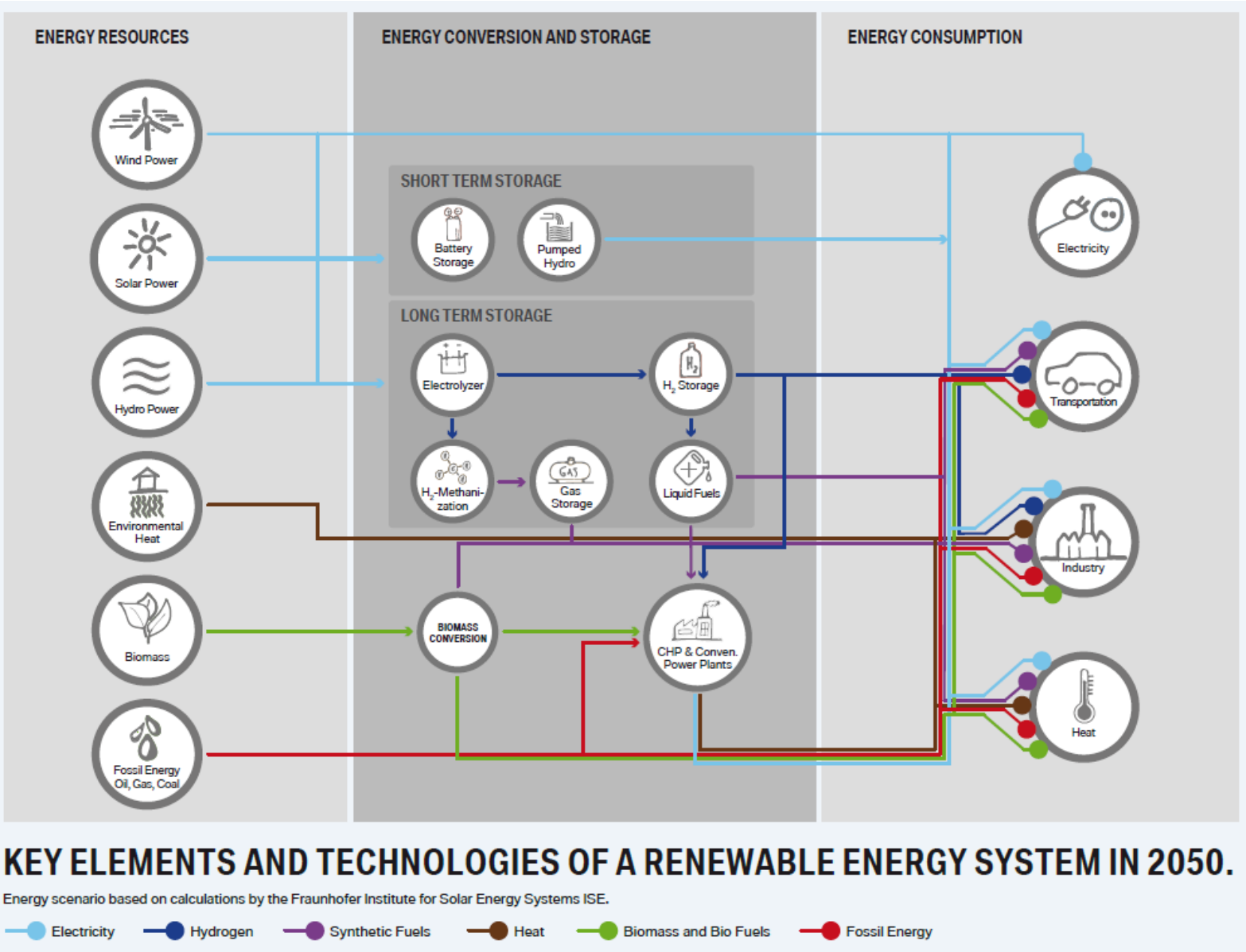
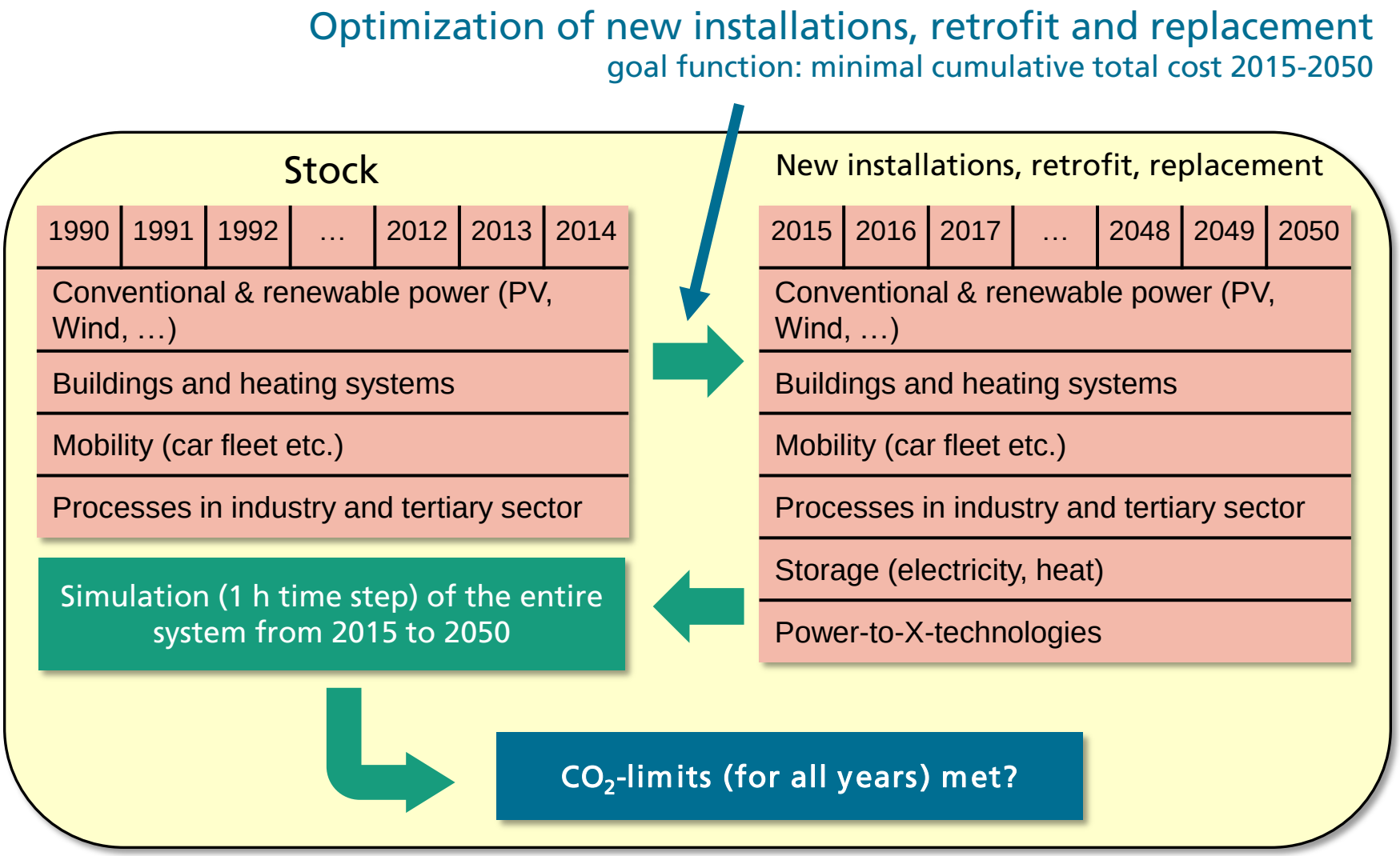


Source:»NEW ENERGY-4-MOBILITY 2050.« presented at Hannover Industry Trade Fair 2017 by BMW based on a study on long term mobility concepts (Fraunhofer ISE)

Methodology



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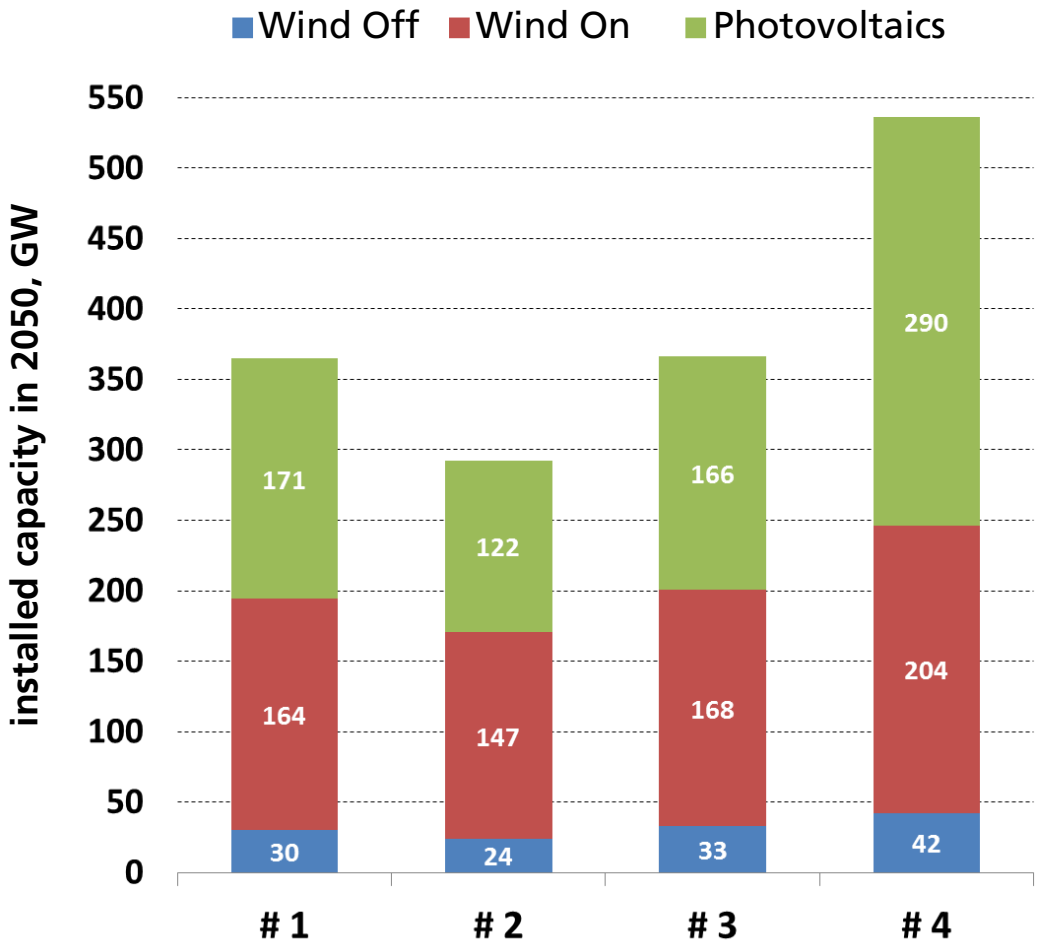
Wind and PV in the year 2050



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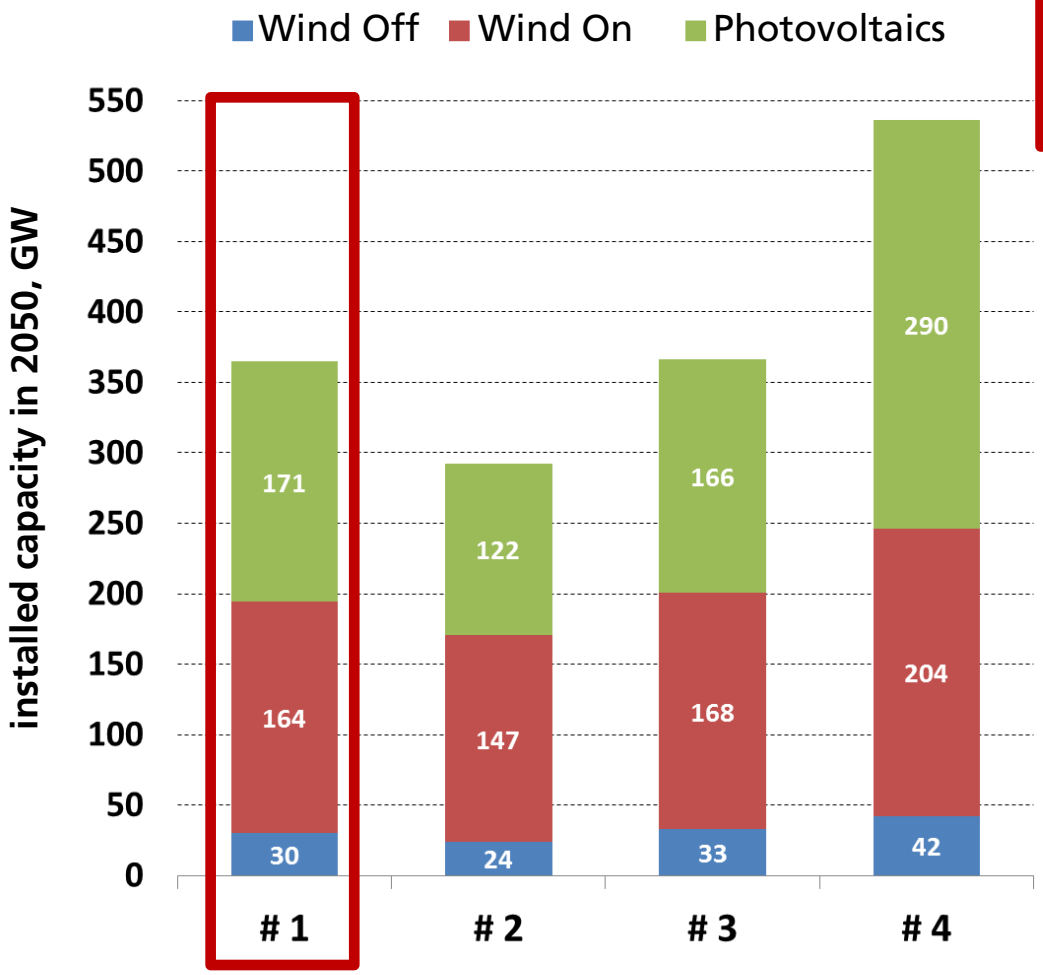

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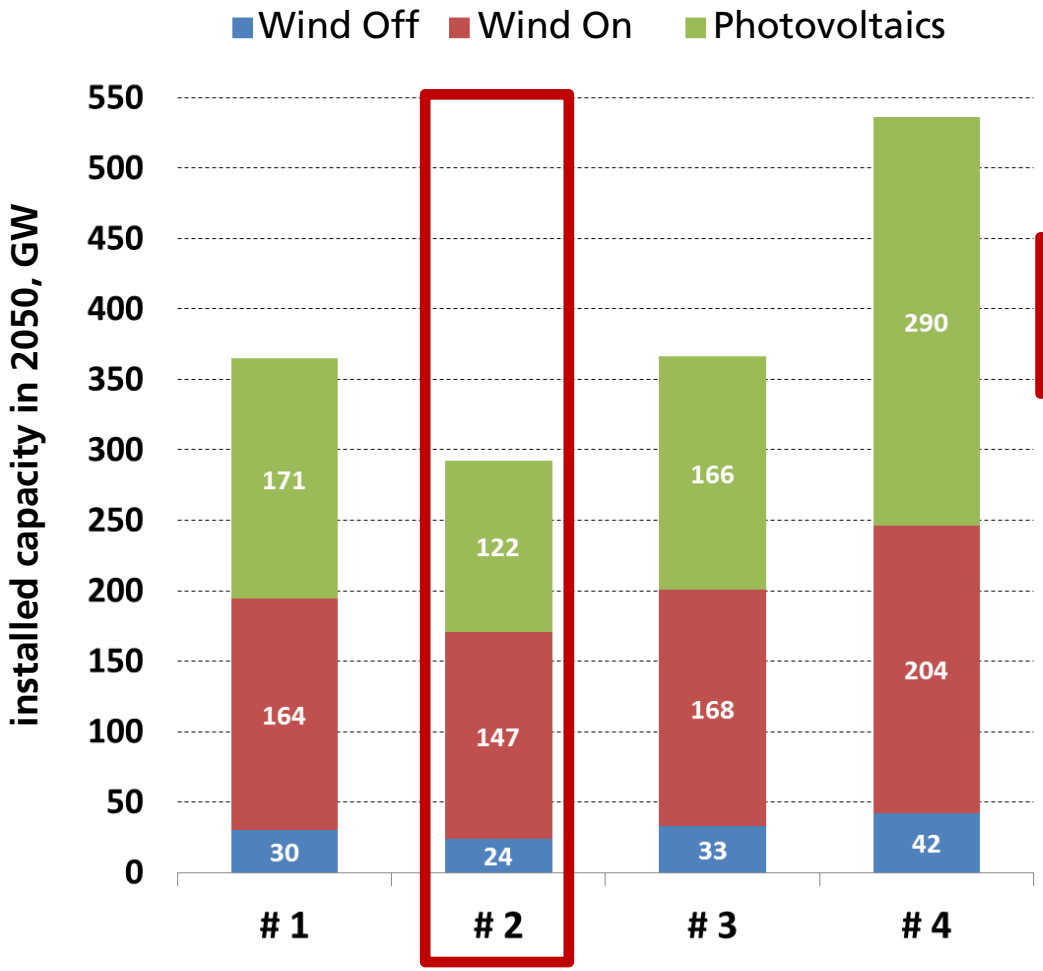

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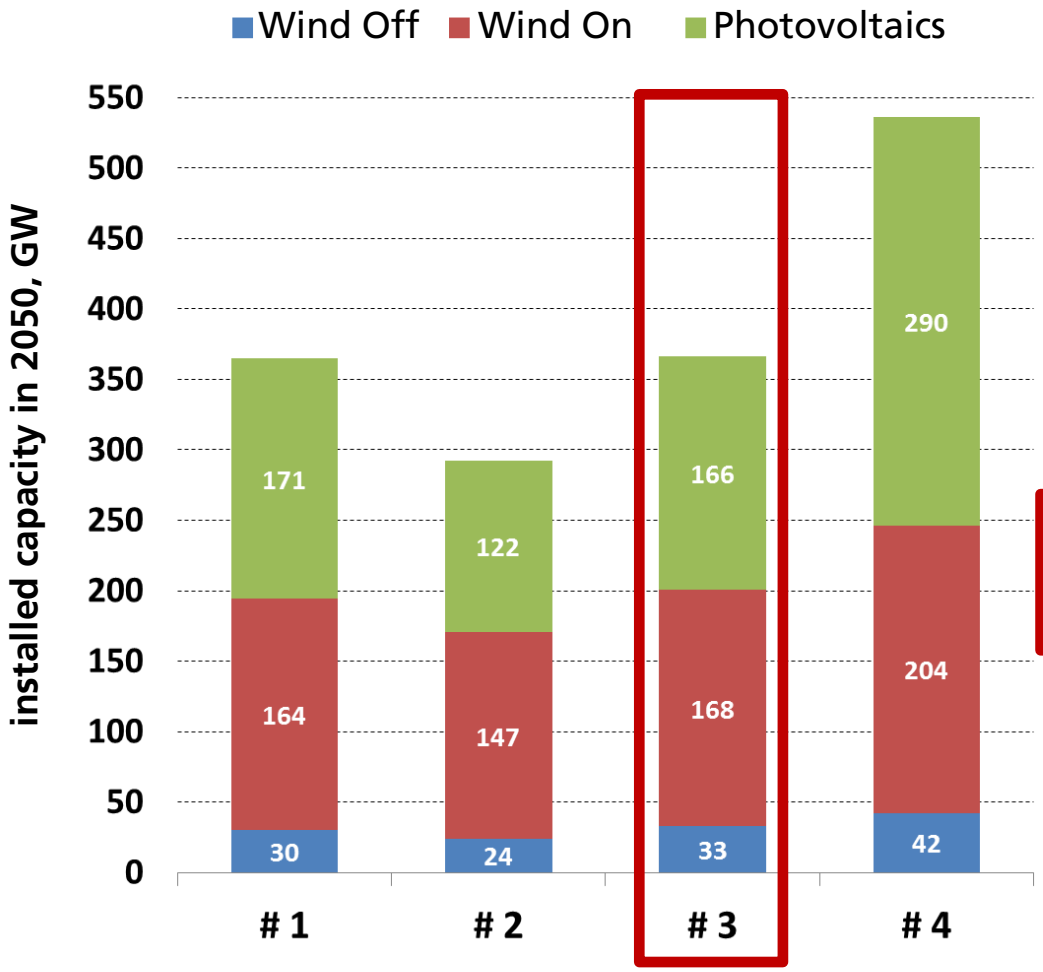

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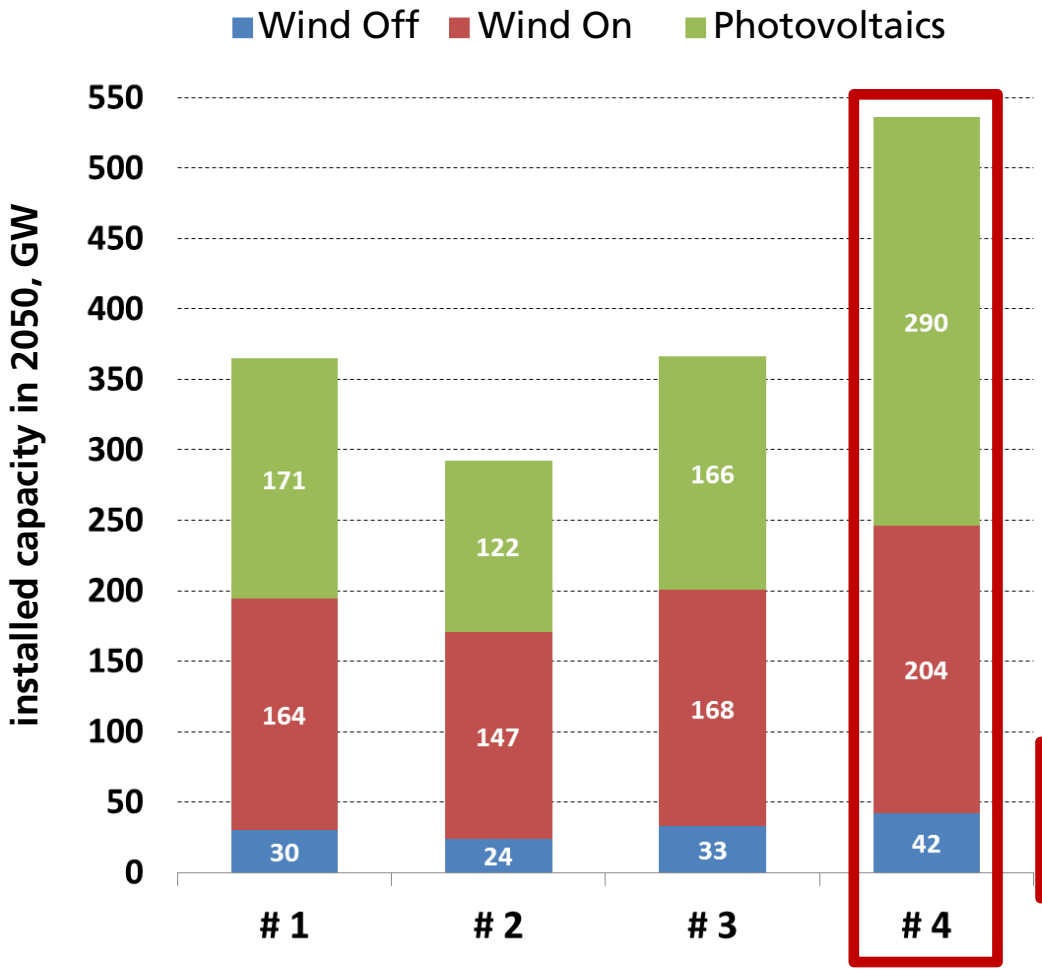

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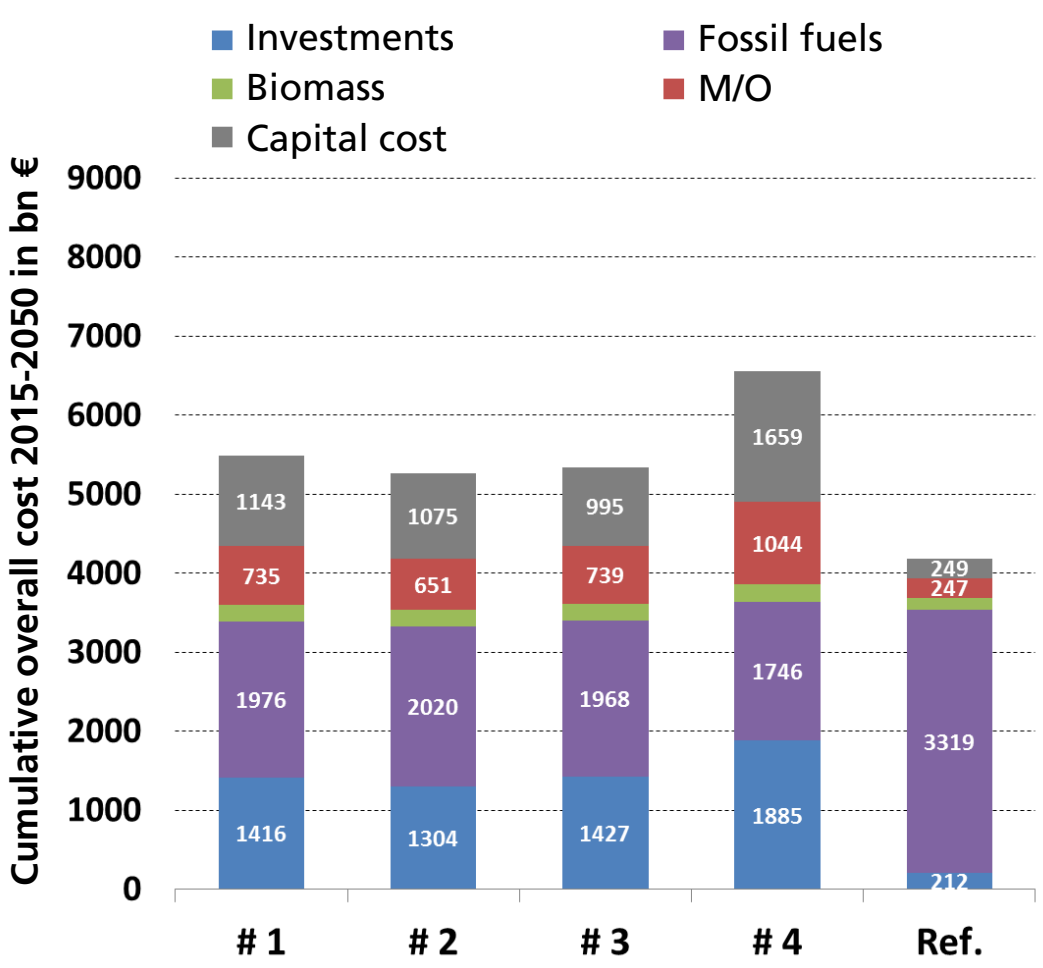
Scenario results (Germany)

Comparison of cumulative overall cost



■ Without cost for CO_2 emissions

■ Prices for fossil fuels constant

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Ref today's system without change

https://www.ise.fraunhofer.de/en/publications/veroeffentlichungen-pdf-dateien-en/studien-und-konzeptpapiere/study-what-will-the-energy-transformation-cost.pdf

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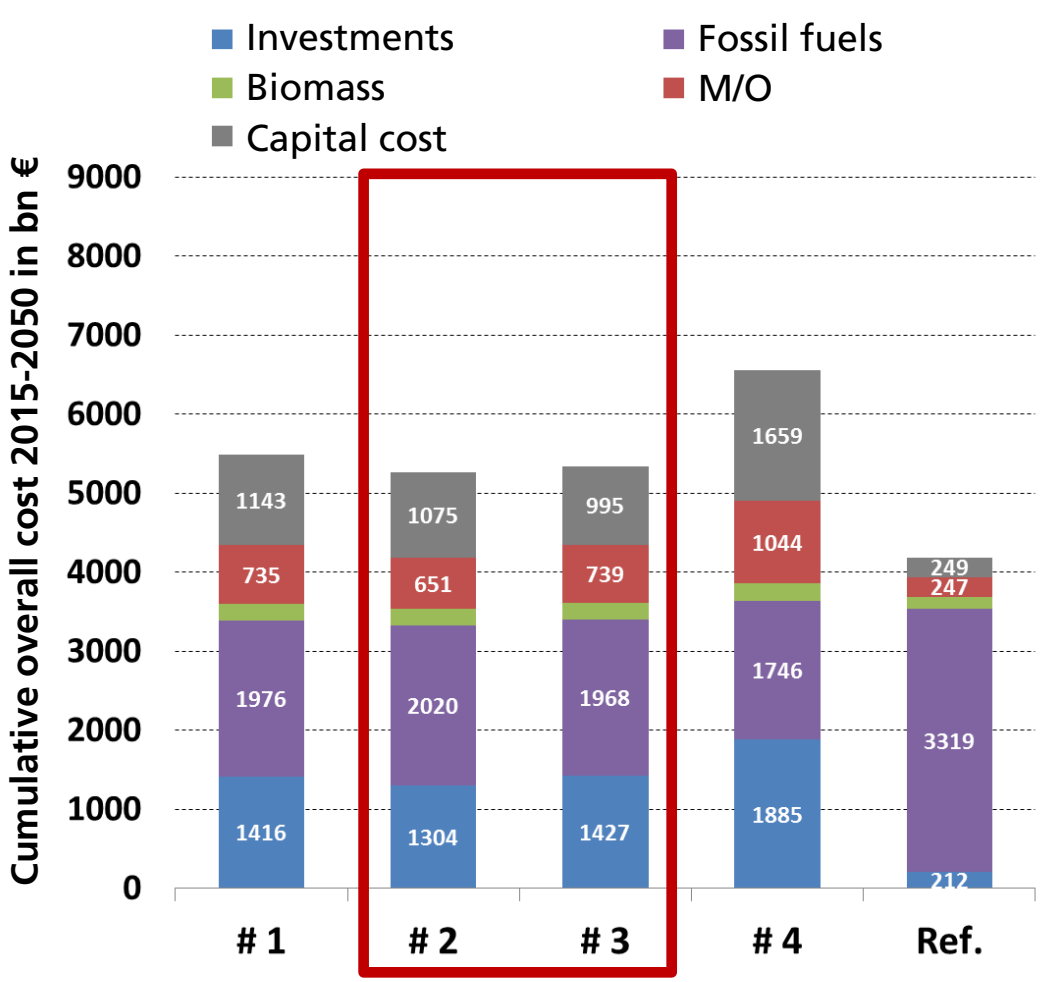
Comparison of cumulative overall cost



- Without cost for CO_2 emissions
- Prices for fossil fuels constant

Cumulative overall extra cost of scenarios # 2 und # 3 approx. 1100 bn € for the period 2015 – 2050 (corresponding to approx. 0.8 % of German GDP)

#2 -80 % CO_2, phase-out of coal accelerated

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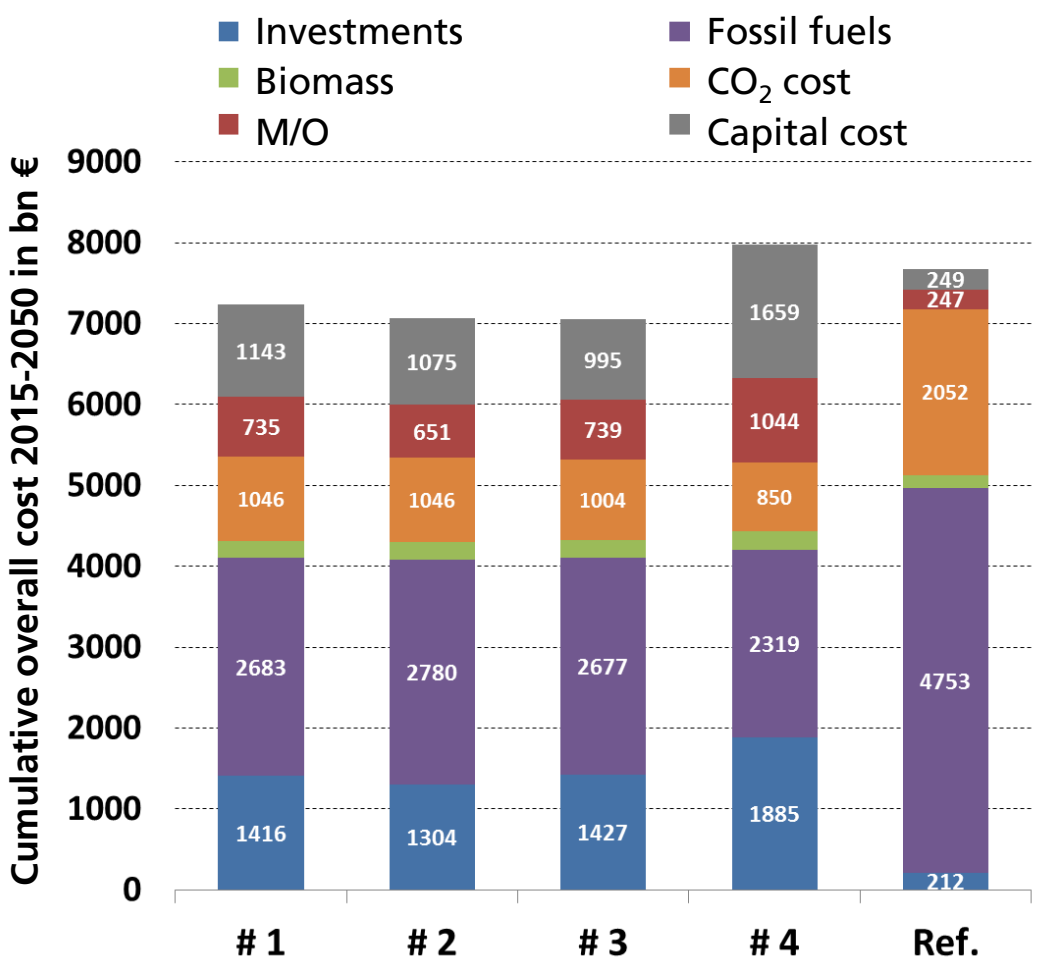

- Increasing cost of CO_2 emissions up to 100 € per ton in 2030; then fix value
- Annual price increase of fossil fuels 2%

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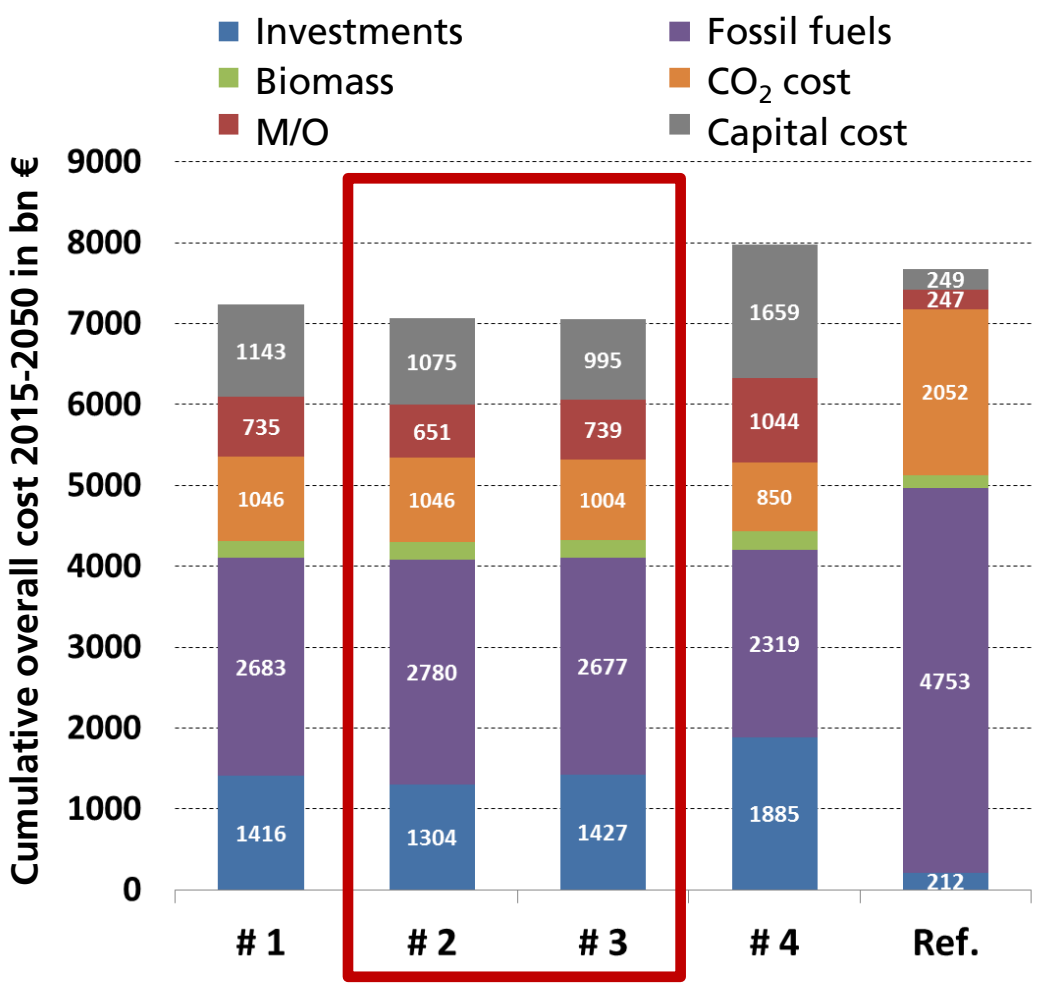

- Increasing cost CO_2 emissions up to 100 € per ton in 2030; then fix value
- Annual price increase of fossil fuels 2%

Cumulative overall cost of scenarios # 2 und # 3 approx. 600 bn € lower than reference for the period 2015 – 2050

#2 -80 % CO_2, phase-out of coal accelerated

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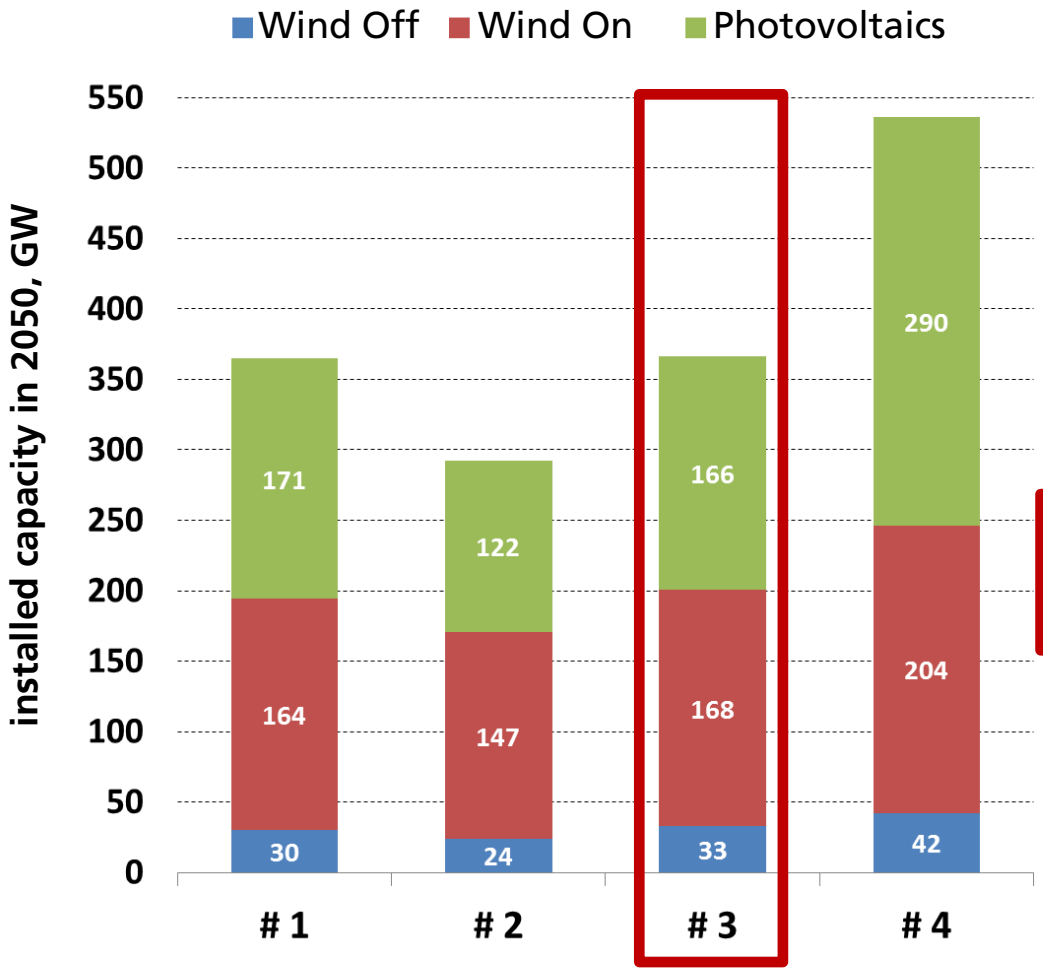

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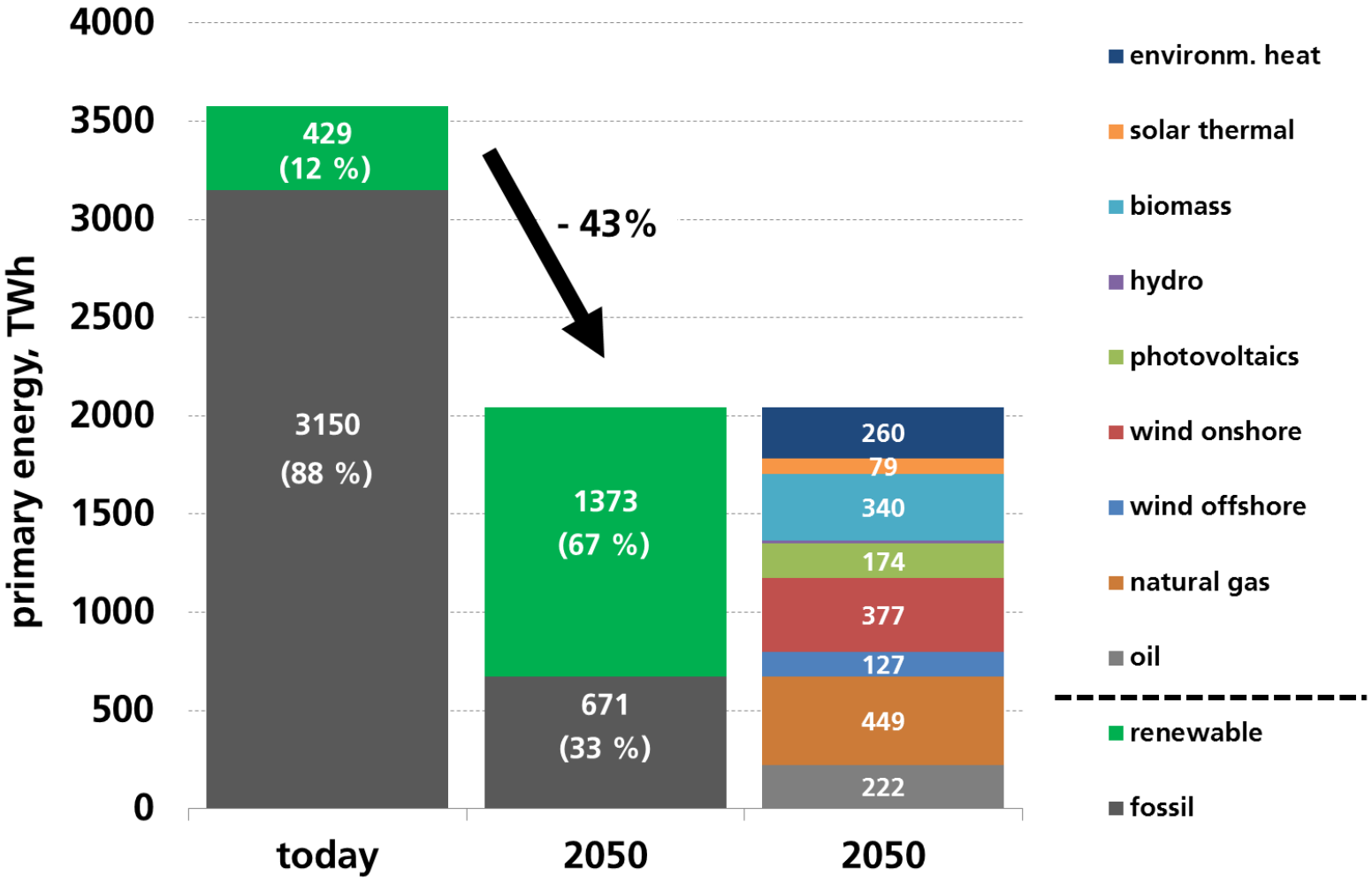
Primary energy 2050 (compared with 2013)
– 85 % - Scenario



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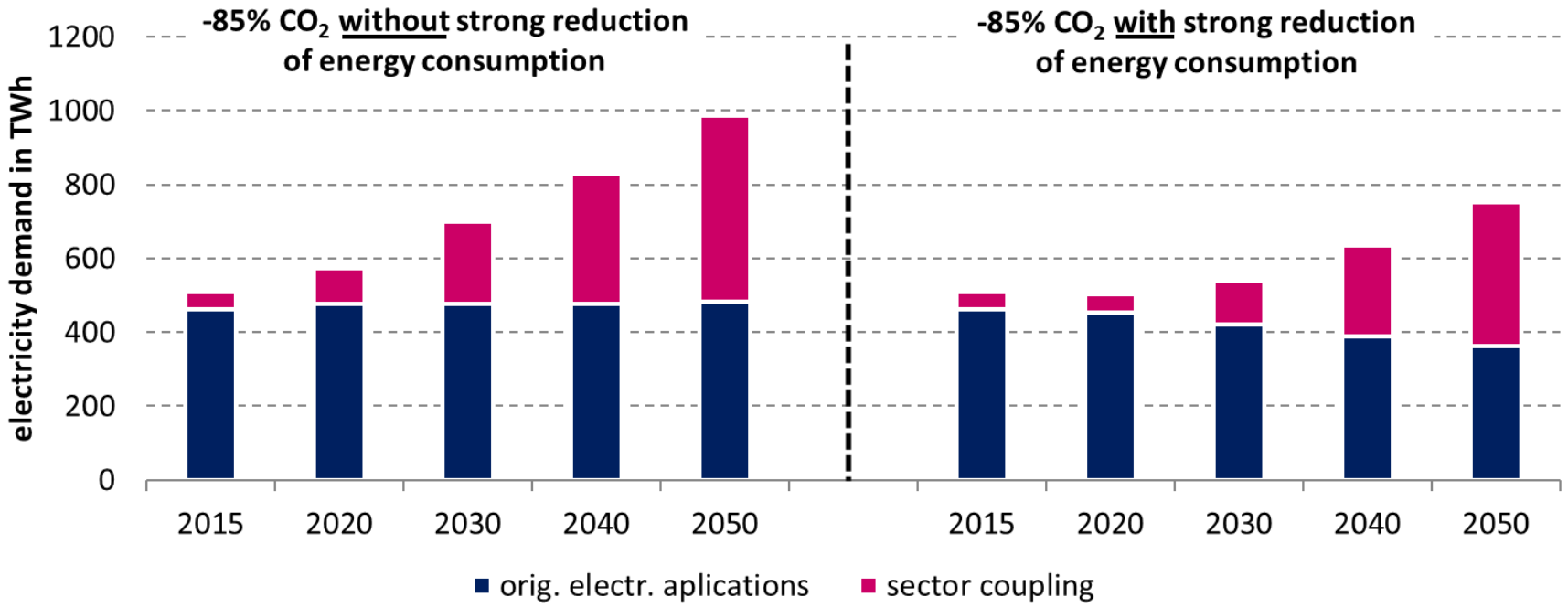
Development of electricity demand
-85 % - scenarios



- Growing electricity demand due to sector coupling
- Today: ~500 TWh ➔ 2050: 800…1000 TWh

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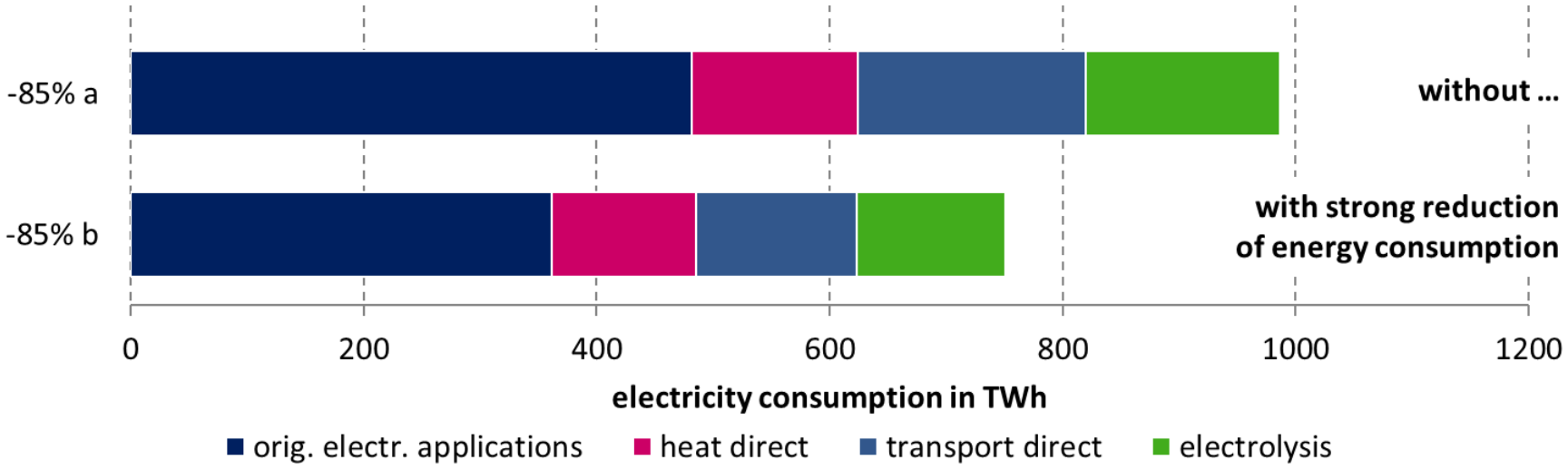
Composition of electricity use

Results for 2050



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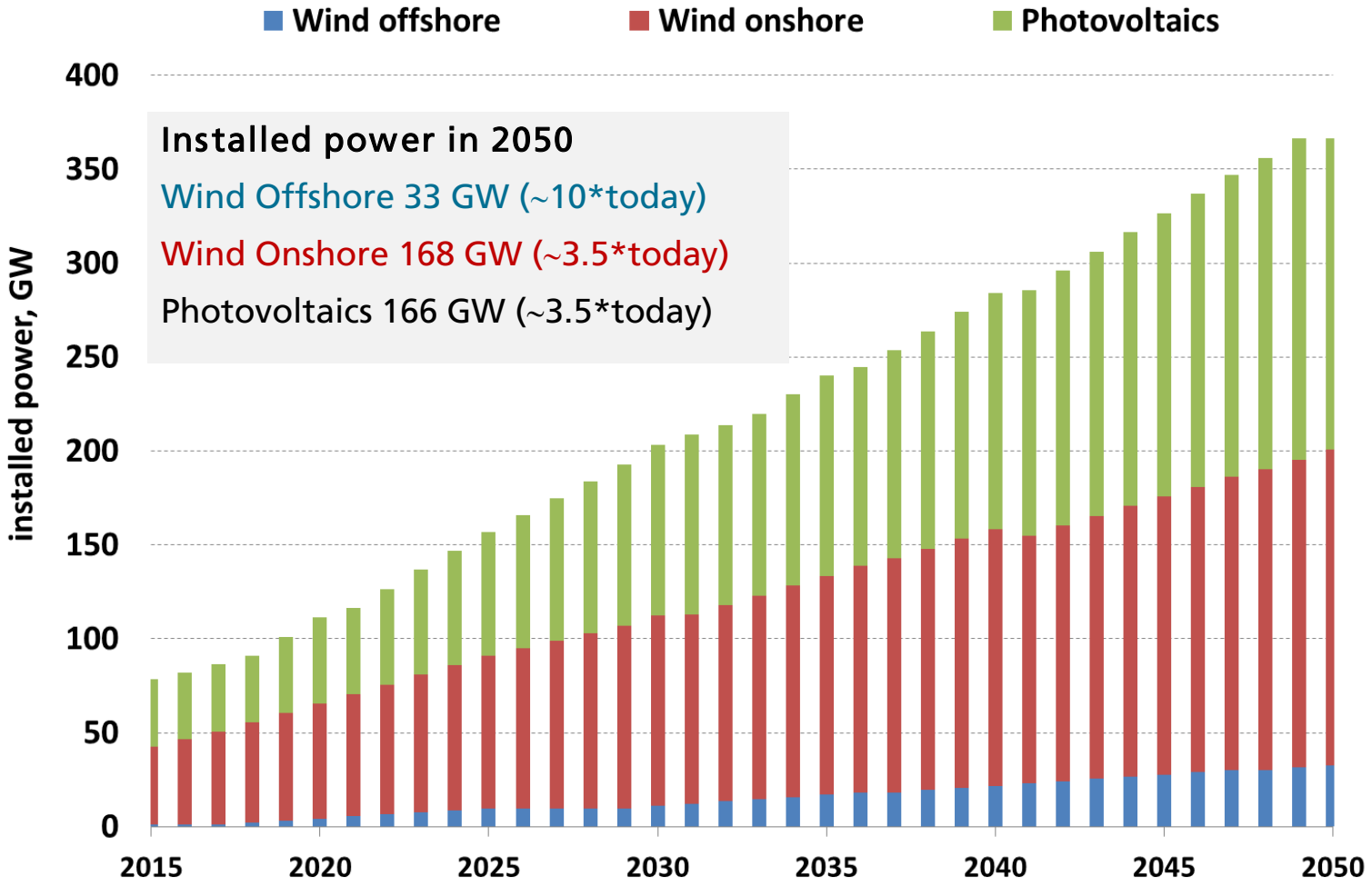
Wind and PV
– 85 % Scenario



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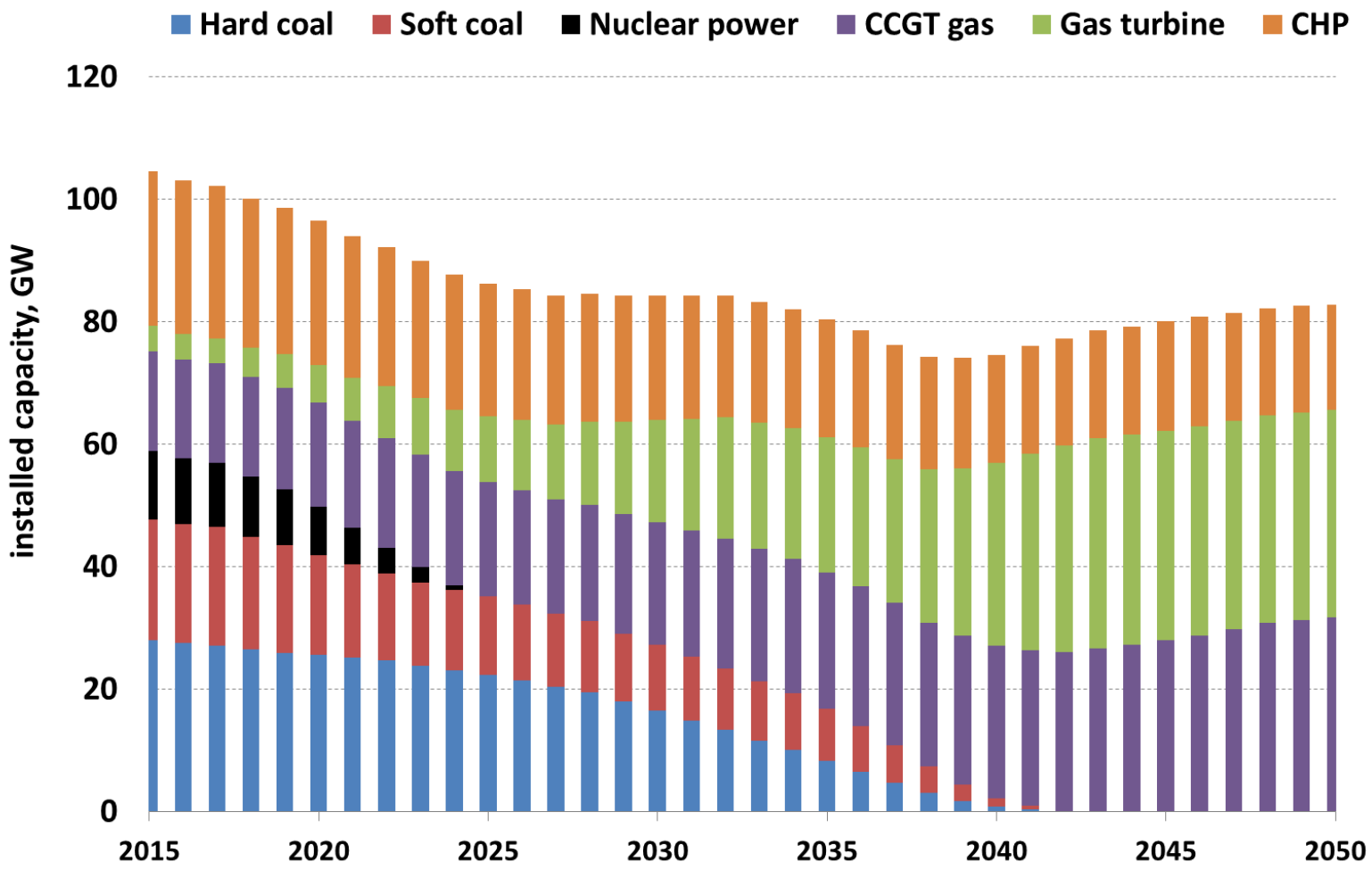
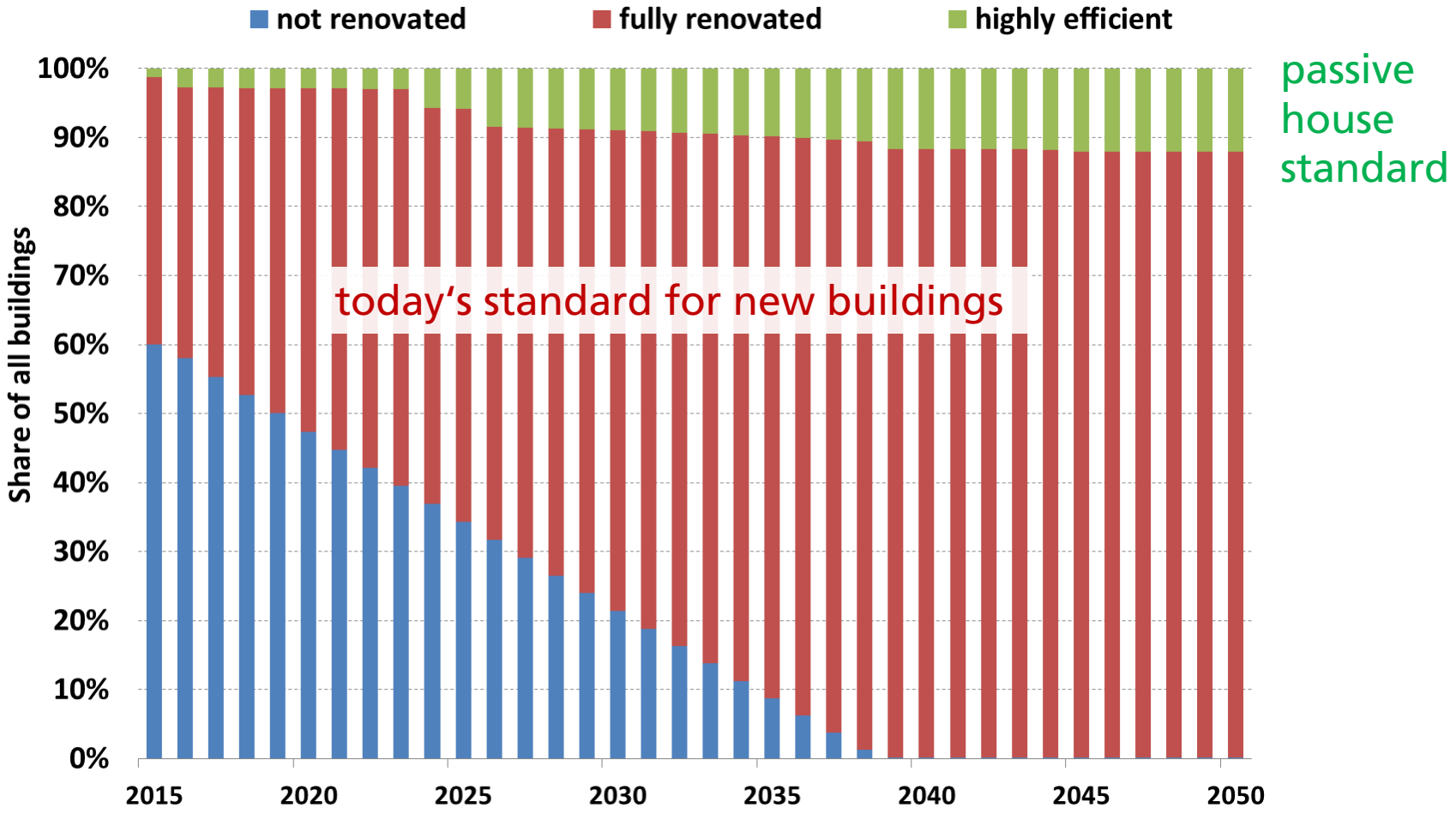
Conventional power plants and large scale CHP
– 85 % Scenario



Buildings
– 85 % Scenario



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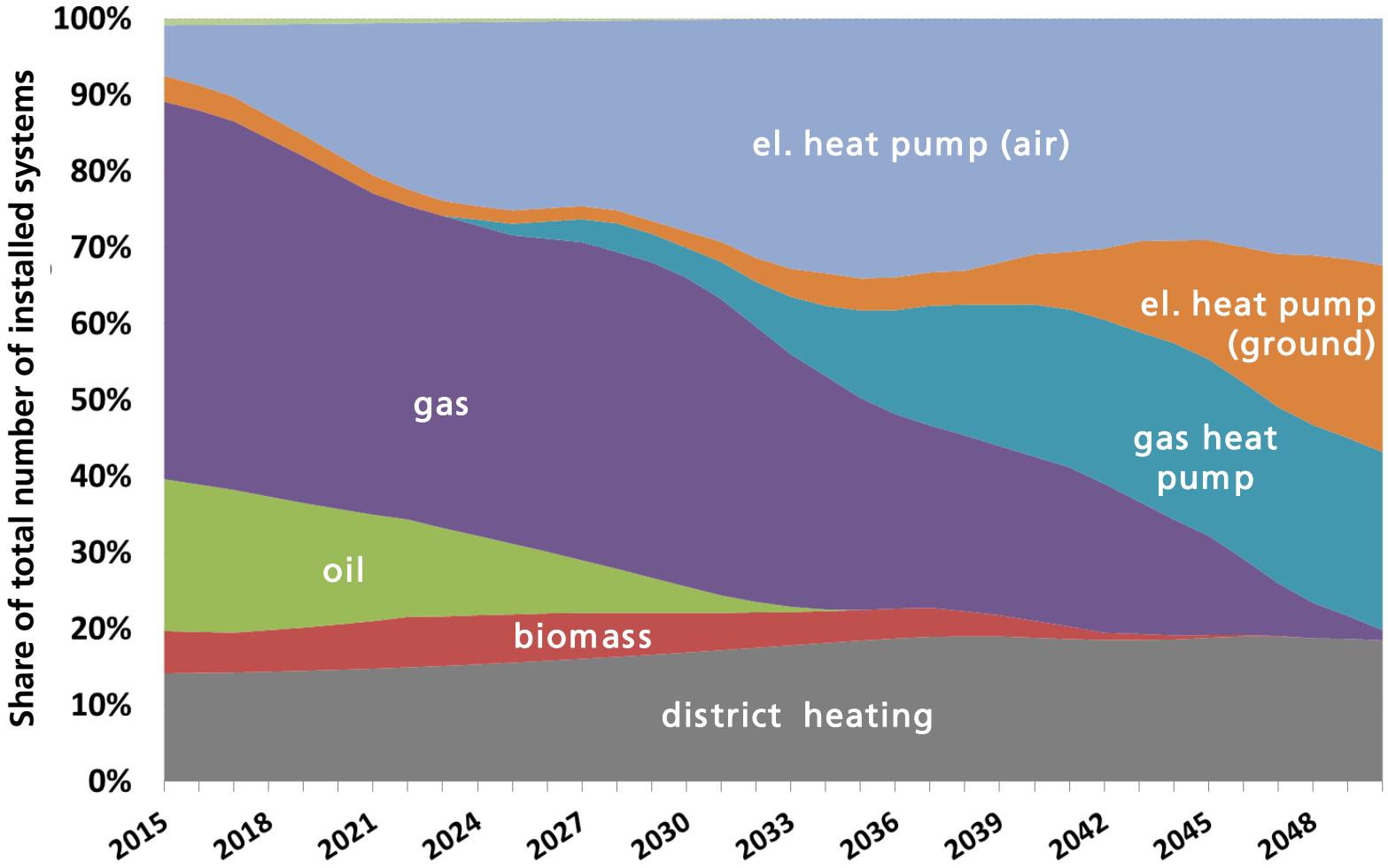
Heating technologies
– 85 % Scenario



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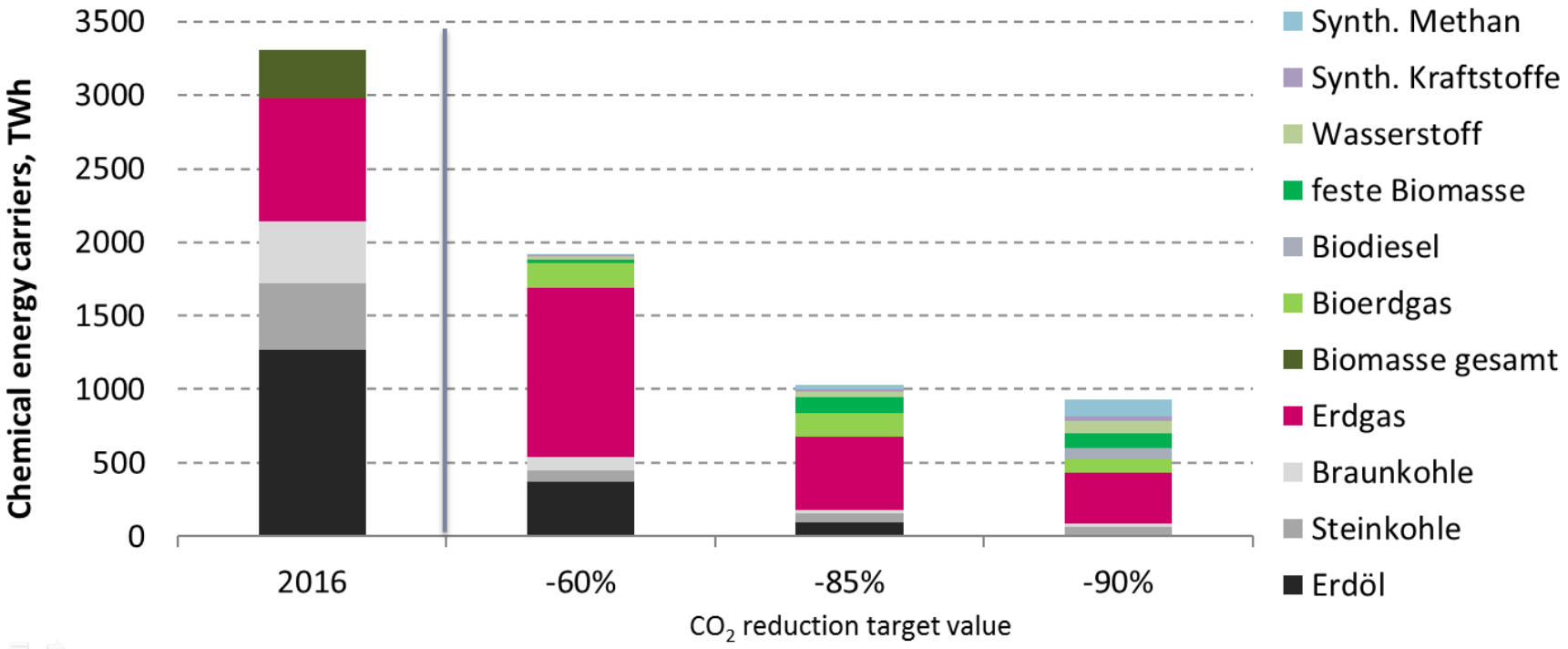
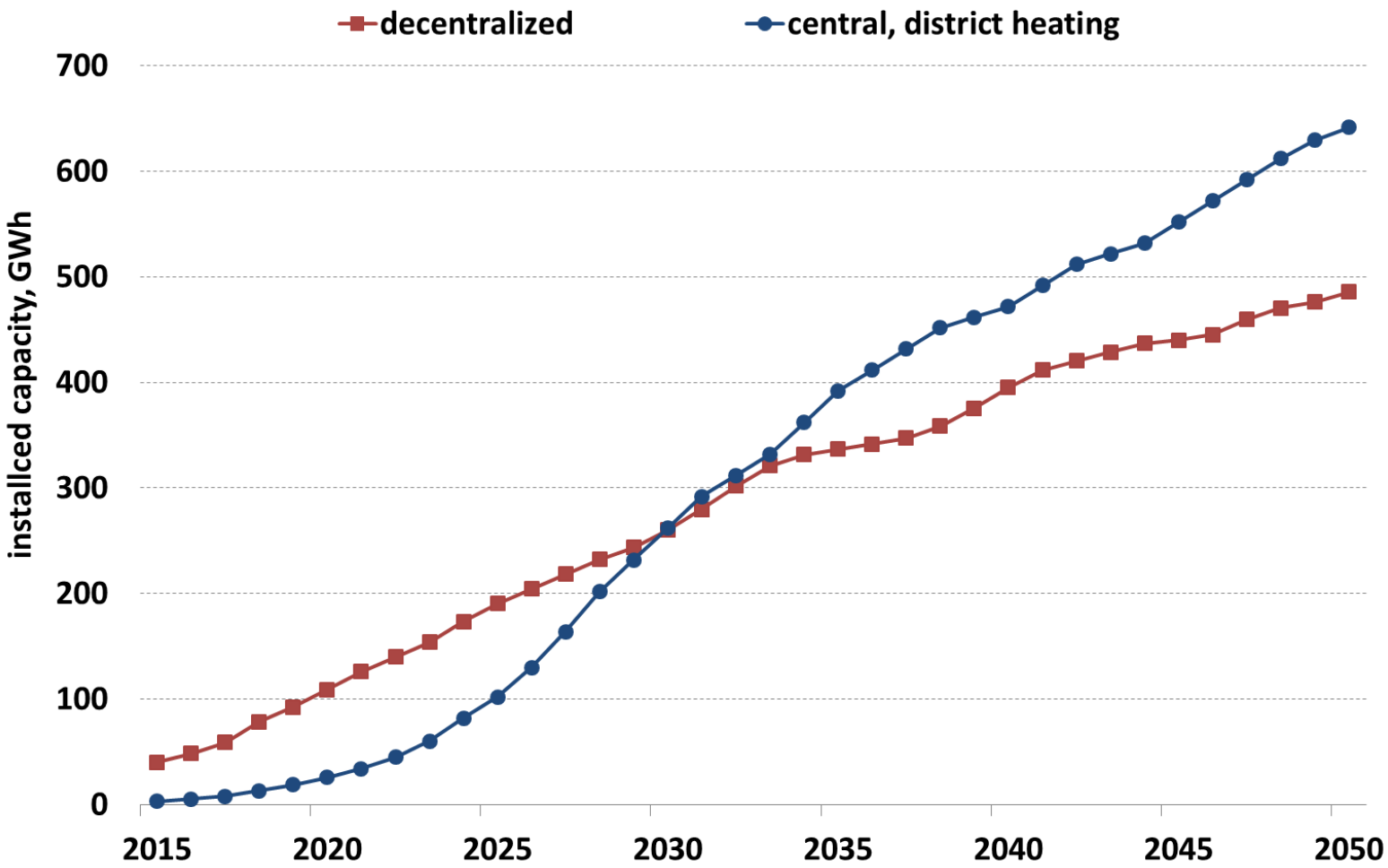
Chemical energy carriers

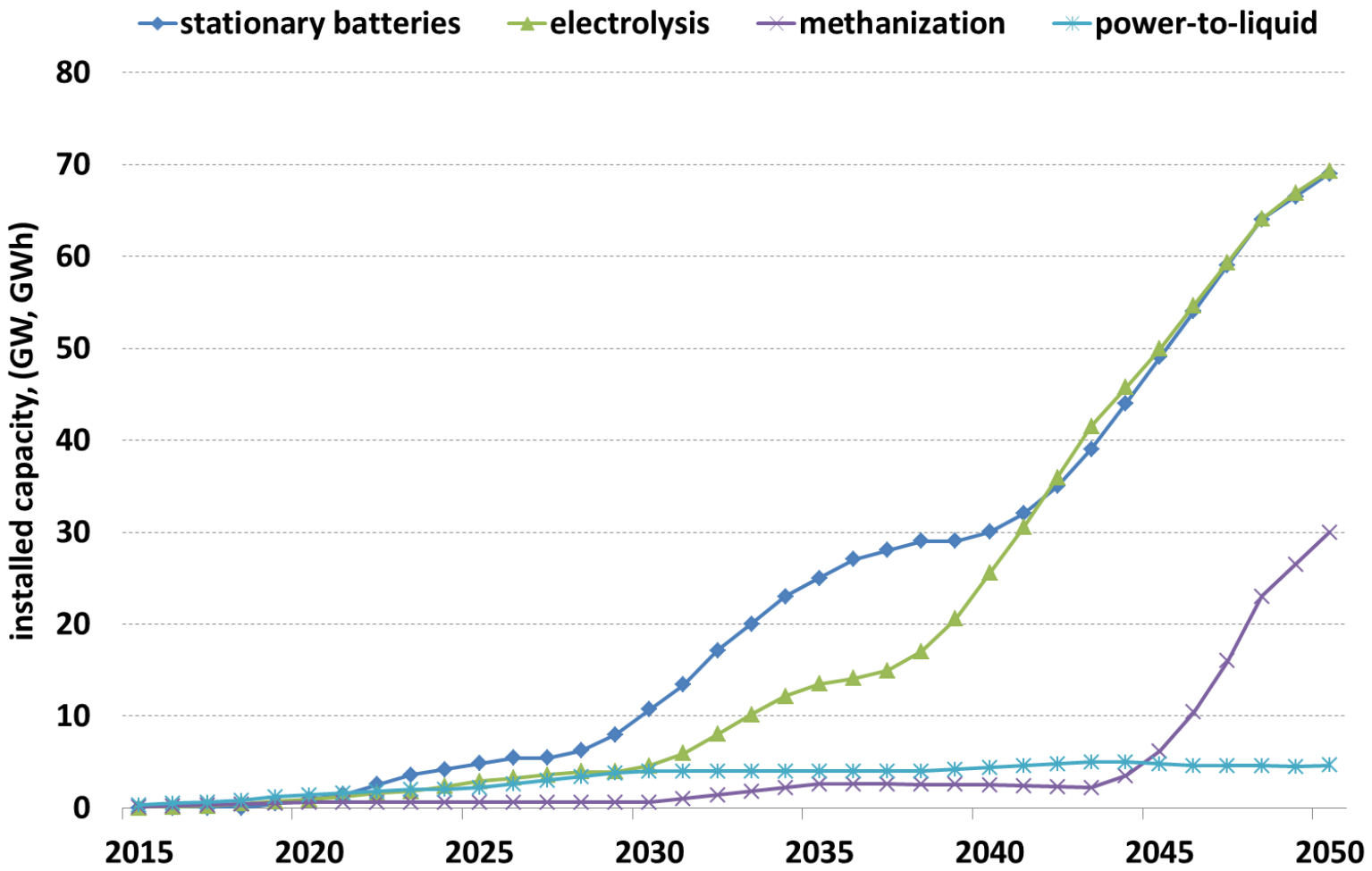


➔ The more ambitious GHG targets the lower the amount of chemical energy, but increasing share of renewables

Heat storage
– 85 %-Scenario



Stationary batteries and power-to-fuel converters
-85 % Scenario



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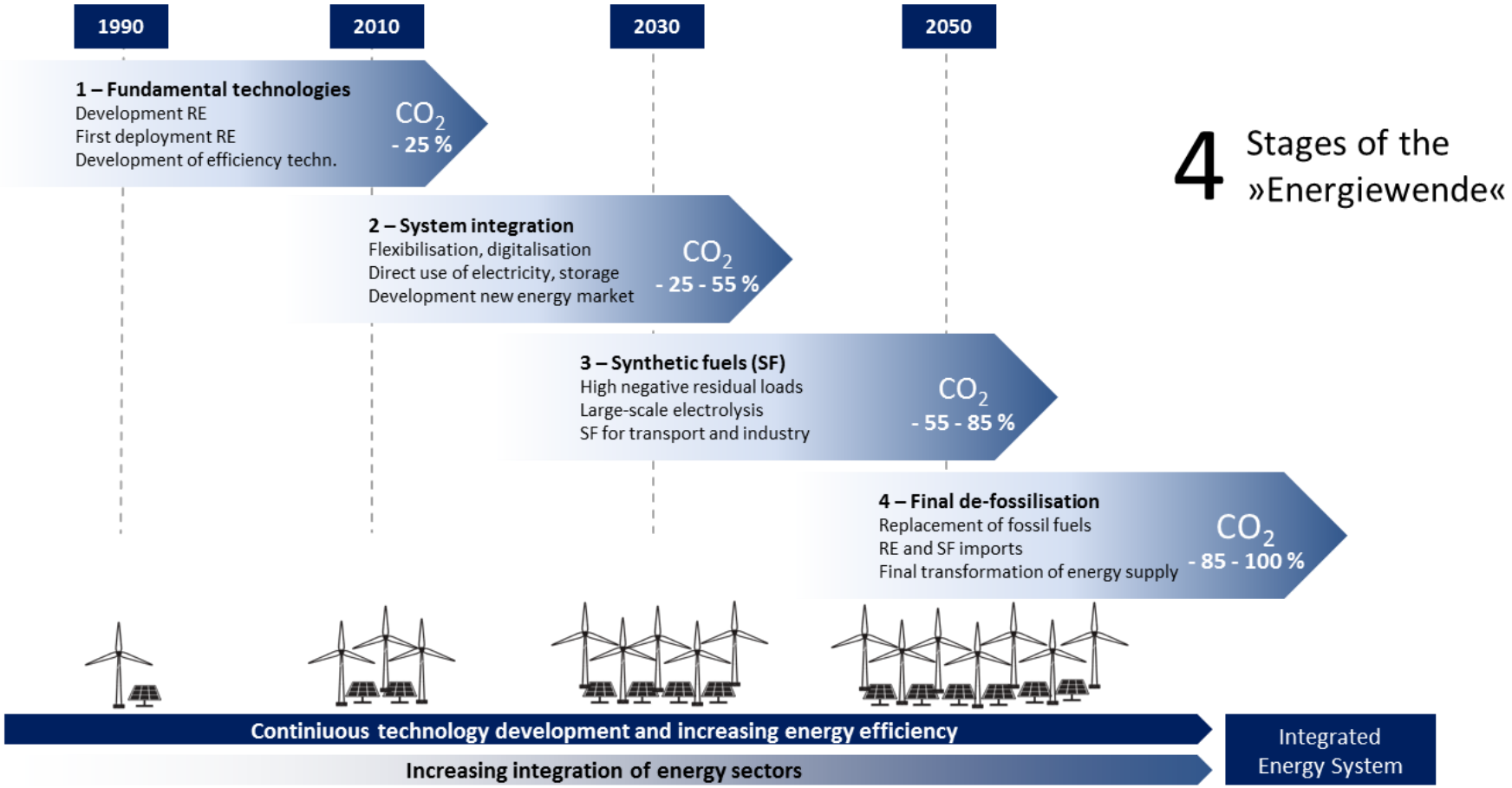

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Summary & conclusions

- Transformation of energy systems in line with GHG emission reduction targets seems technically feasible
- Renewable energies (solar, wind) become dominant and importance of electric energy increases
- Increased conversion efficiencies and reduced consumption important
- Coupling of sectors ➔ electricity use for heating and mobility
- Short term storage starts to become important in the years 2020 to 2030
- Large scale conversion of renewable electricity into synthetic chemicals (hydrogen, methane, liquids) is in particular needed for CO_2 reduction rates > 60 % ➔ in particular used for transportation
- Cost competitive if CO_2 emissions appropriately penalized (≈ 100 € / ton)
- Anyhow cost competitive on the long run, i.e. once major investments have been made and the system transformation has been completed

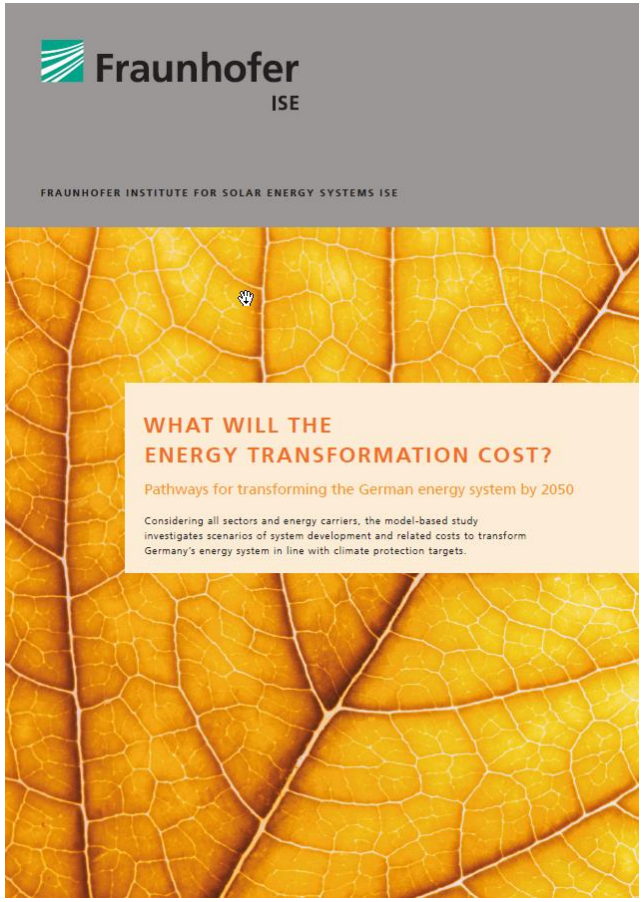
Some major needs

- CO_2 pricing
- Flexible electricity prices
- Separate pricing for energy and power
- Policies supporting home markets

Outlook

- Comprehensive, powerful model for optimization of energy system transformation pathways that
  - includes all end-use sectors and energy carriers and
  - includes security of supply, i.e. all loads are matched in each hour through the period of transforming the energy system
- Recent further work mainly focuses on industry (electrification, flexibilization) and mobility (long term mobility scenarios)
- Model widely used
  - for studies produced for e.g. utilities, car manufacturers, HVAC manufacturers, policy decision makers, ….
  - and applicable to other regions or countries

Sources



Study from Fraunhofer ISE »What will the energy transformation cost? – Pathways for transforming the German energy system by 2050«

November 2015

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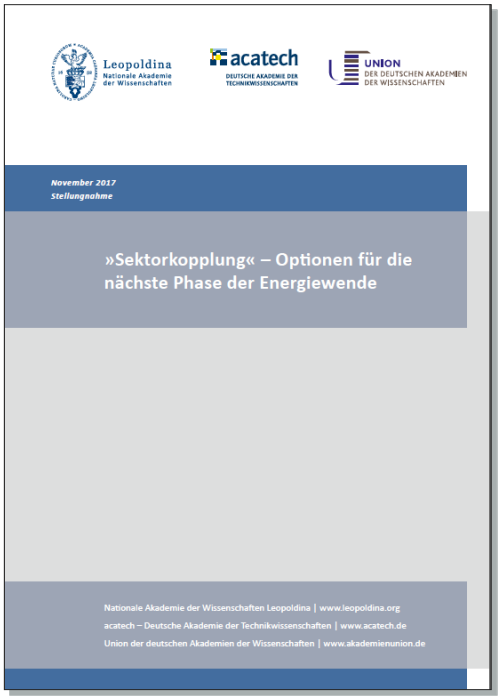
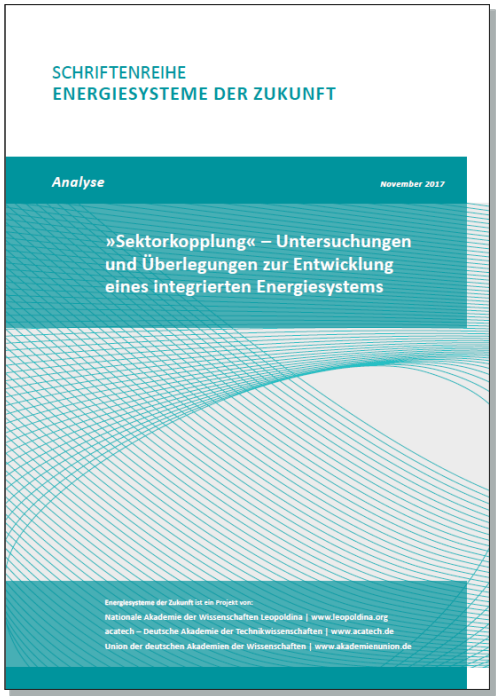
Sources





Working group »Sector Coupling« within the BMBF funded project »Energy systems of the future«, carried out by the German academies of science

(Working group leaders: Prof. Eberhard Umbach, Prof. Hans-Martin Henning)

November 2017

Download
http://energiesysteme-zukunft.de/ themen/sektorkopplung/

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Many thanks for your attention…

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