PATHWAYS TO TRANSFORM THE ENERGY SYSTEM UNTIL 2050

The German Example and Perspectives for Europe

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Palma (Mallorca), Spain

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Nations Approve Landmark Climate Accord in Paris

New York Times (December 12, 2015)

COP21, Paris
December 2015

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Need for deep transformation of our energy systems

- Climate and sustainability targets are key topics on the global policitical 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
- Transformation of the energy system is more than transformation of electricity supply

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

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Outline

- GHG emissions and targets in Germany and Europe
- Optimization of transformation – methodology
- Results for selected scenarios
- Transfer of results to Europe
- Summary & conclusions

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GHG emissions and targets in Germany and Europe

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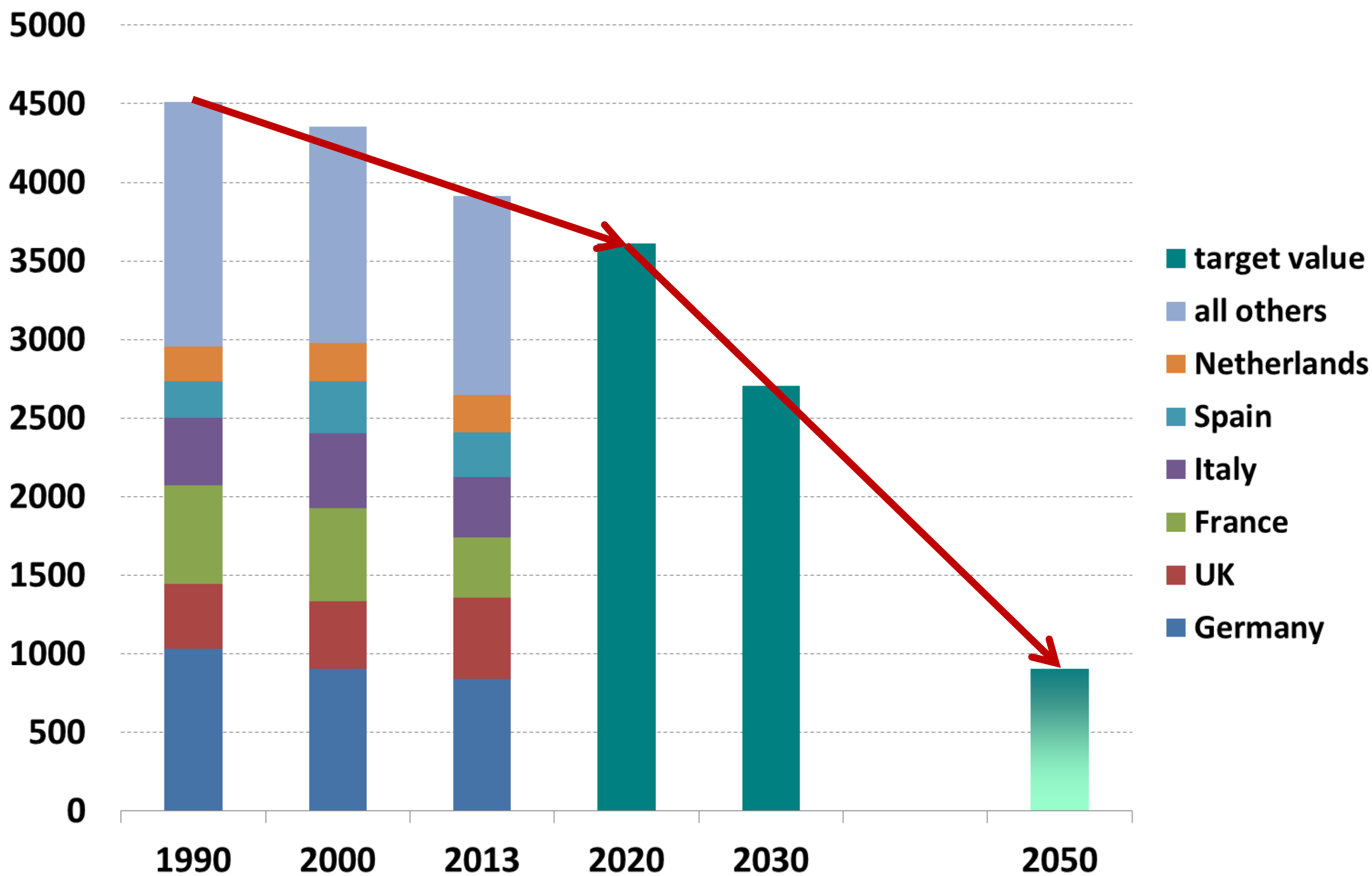
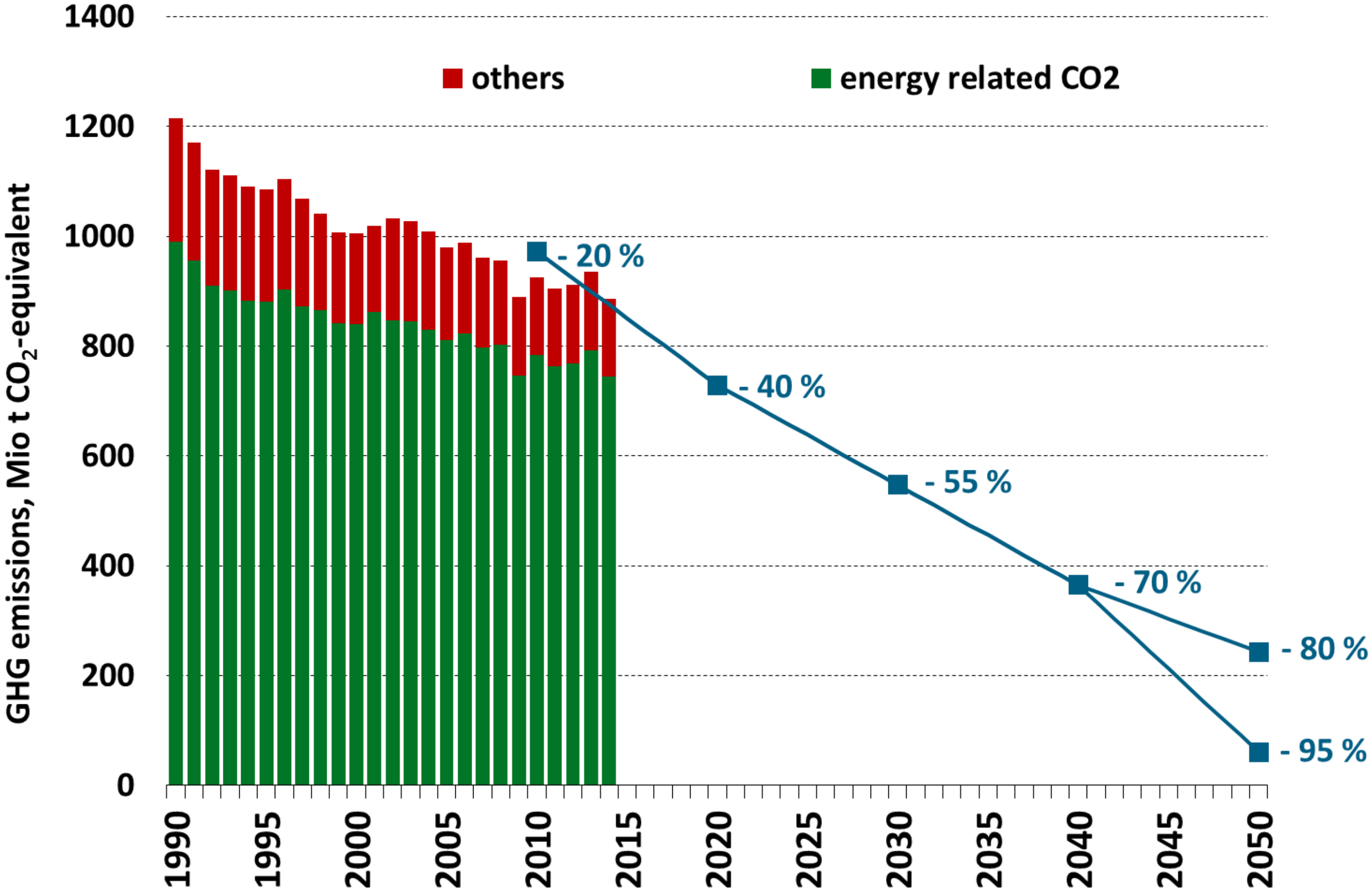
EU energy related CO_2 emissions – history and targets



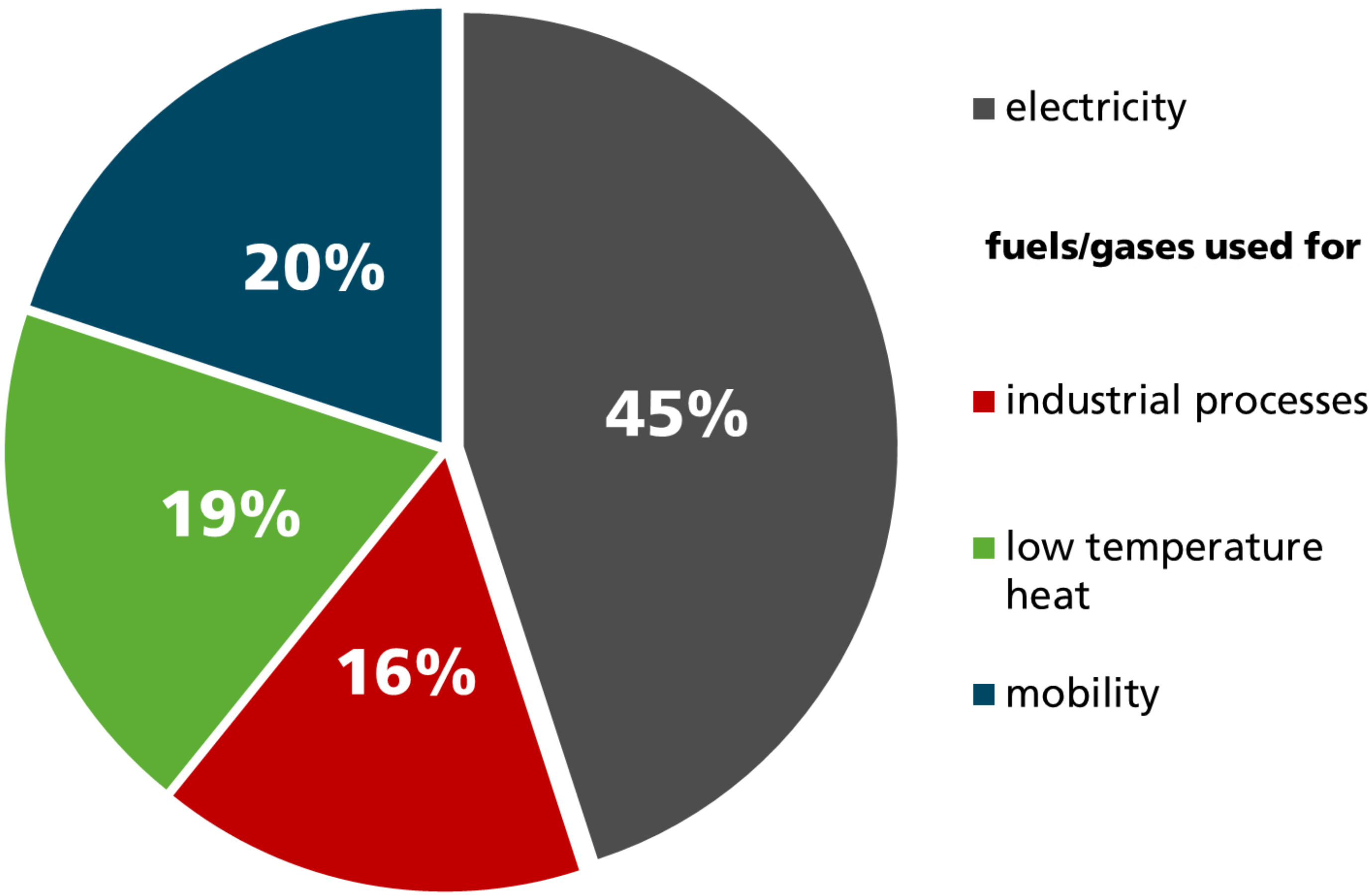
Based on data from: „Zahlen und Fakten. Energiedaten. Nationale und internationale Entwicklung – Überprüfungsdatum 2015-09-22“, BMWi 2015

German GHG emissions: historical values from 1990-2040 and target values until 2050



Based on data from: Nationale Trendtabellen für die deutsche Berichterstattung atmosphärischer Emissionen. Umweltbundesamt (UBA) Dessau, 29.5.2015

Energy related CO_2 emissions – Germany 2013



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Guiding question

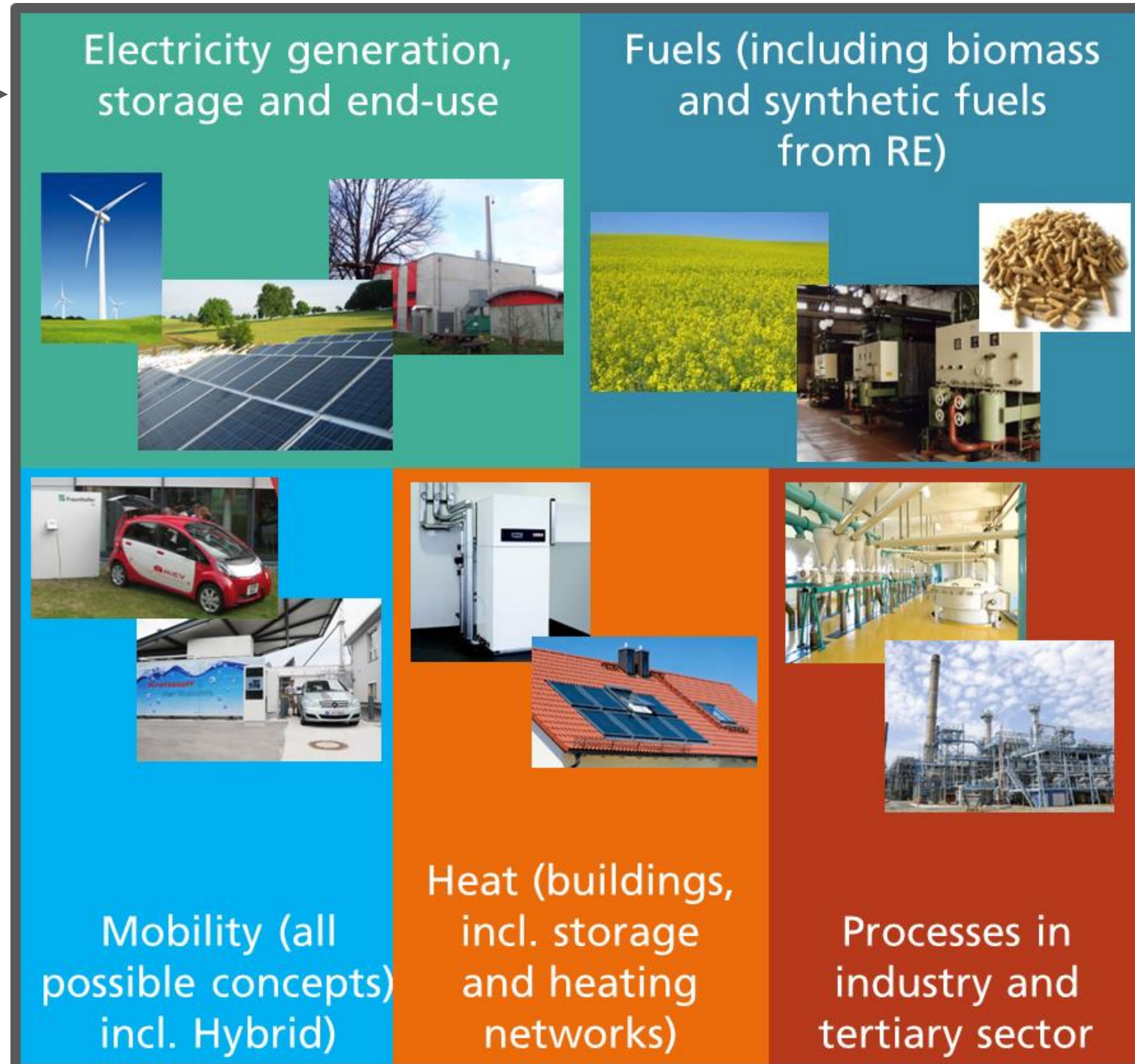
What is the best, i.e. cost-optimized pathway to achieve

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

?

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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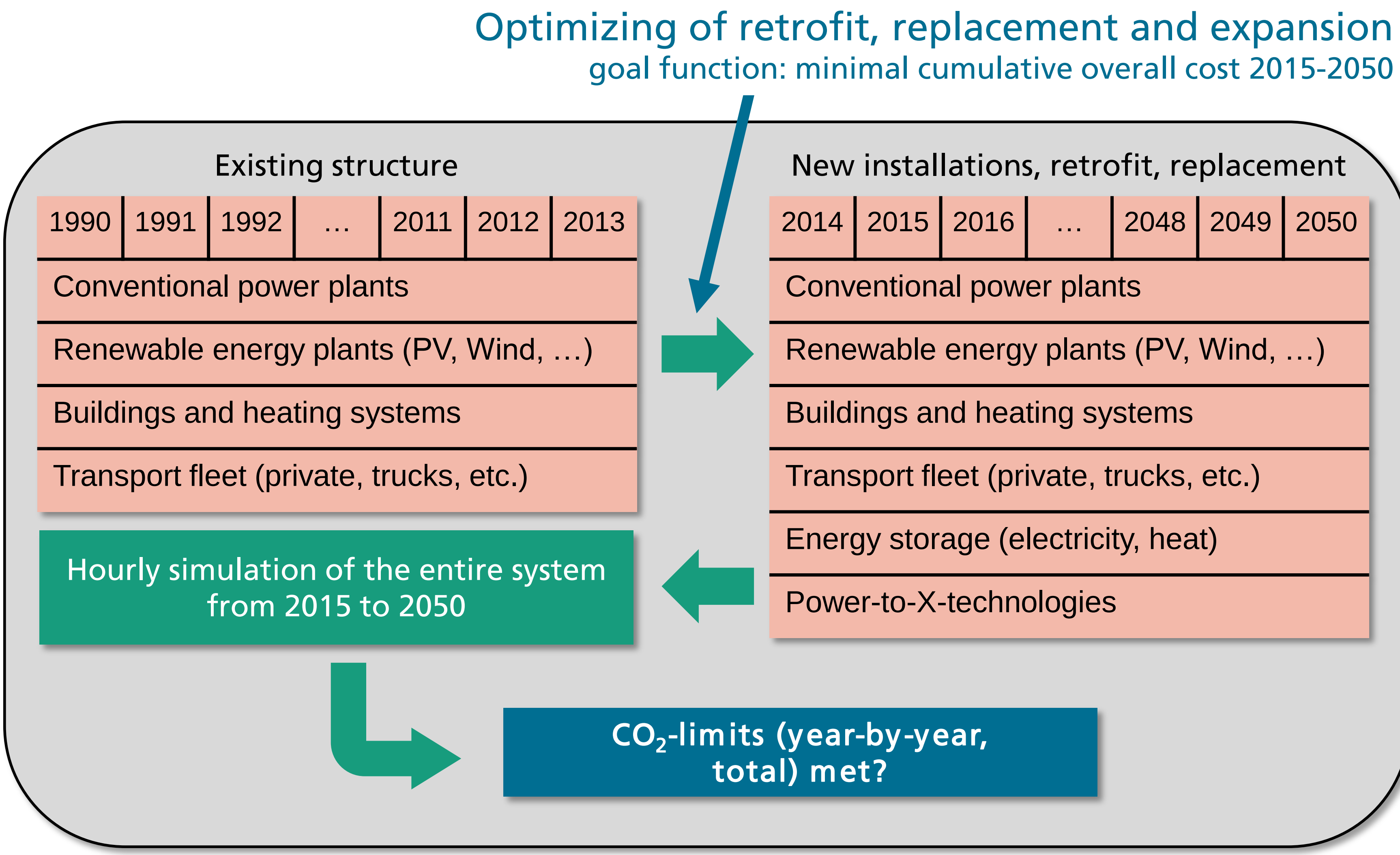
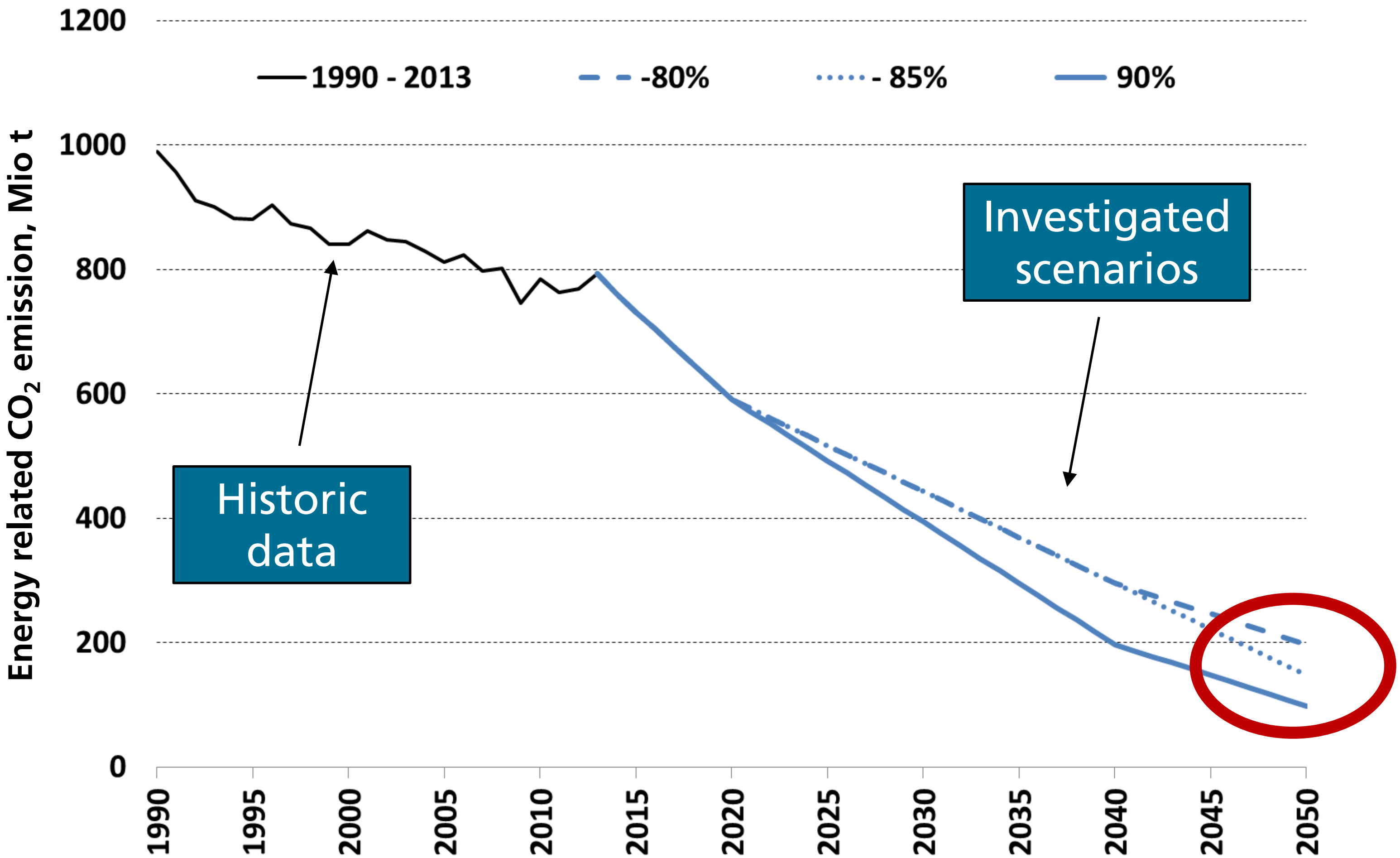
Methodology (1/2)



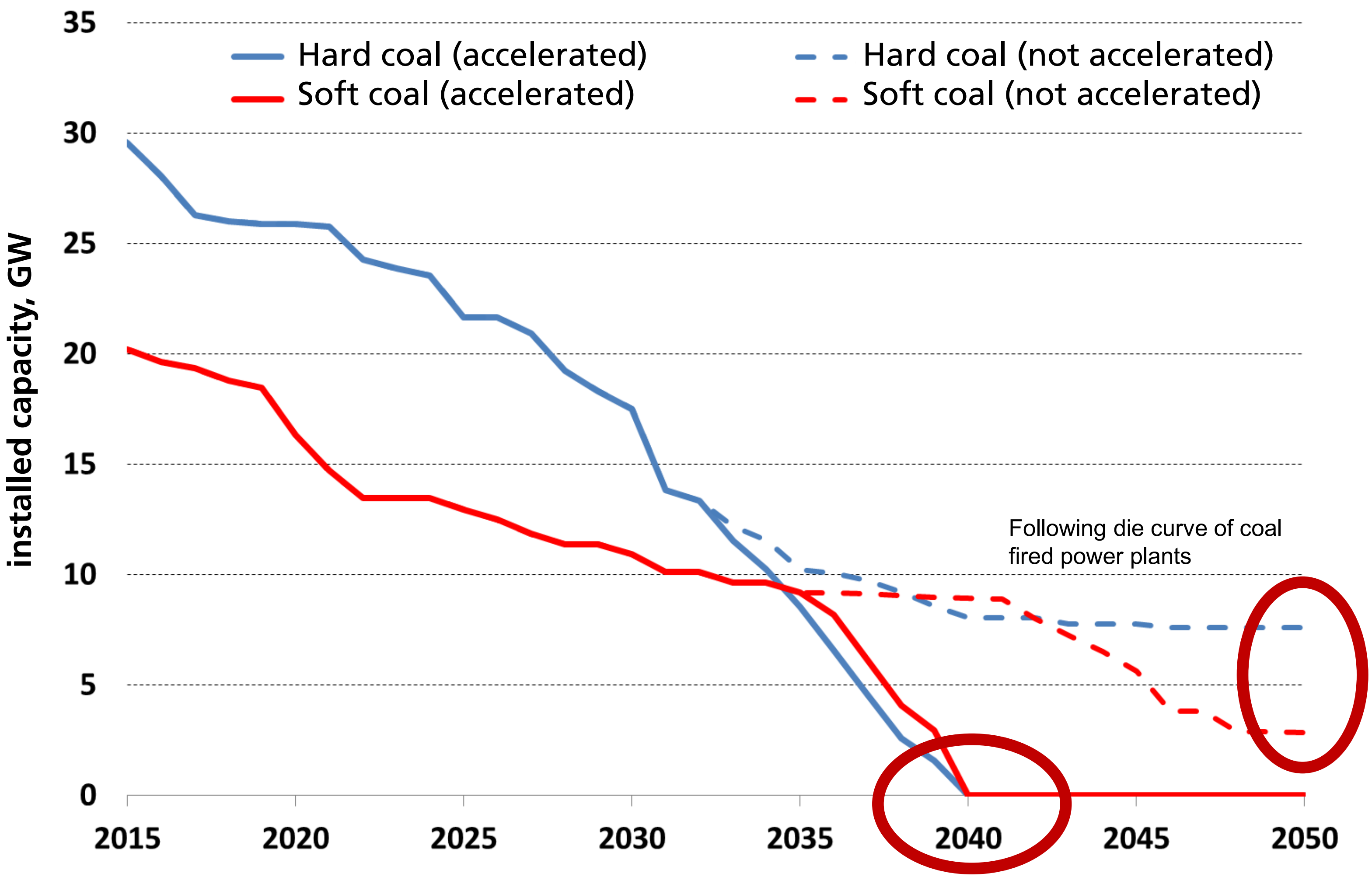
GHG reduction scenarios
Germany



Based on data from: Nationale Trendtabellen für die deutsche Berichterstattung atmosphärischer Emissionen. Umweltbundesamt (UBA) Dessau, 29.5.2015

Phase out of electricity production using coal

Germany



Based on data from: Kraftwerksliste der Bundesnetzagentur. zuletzt aktualisiert am 29.10.2014

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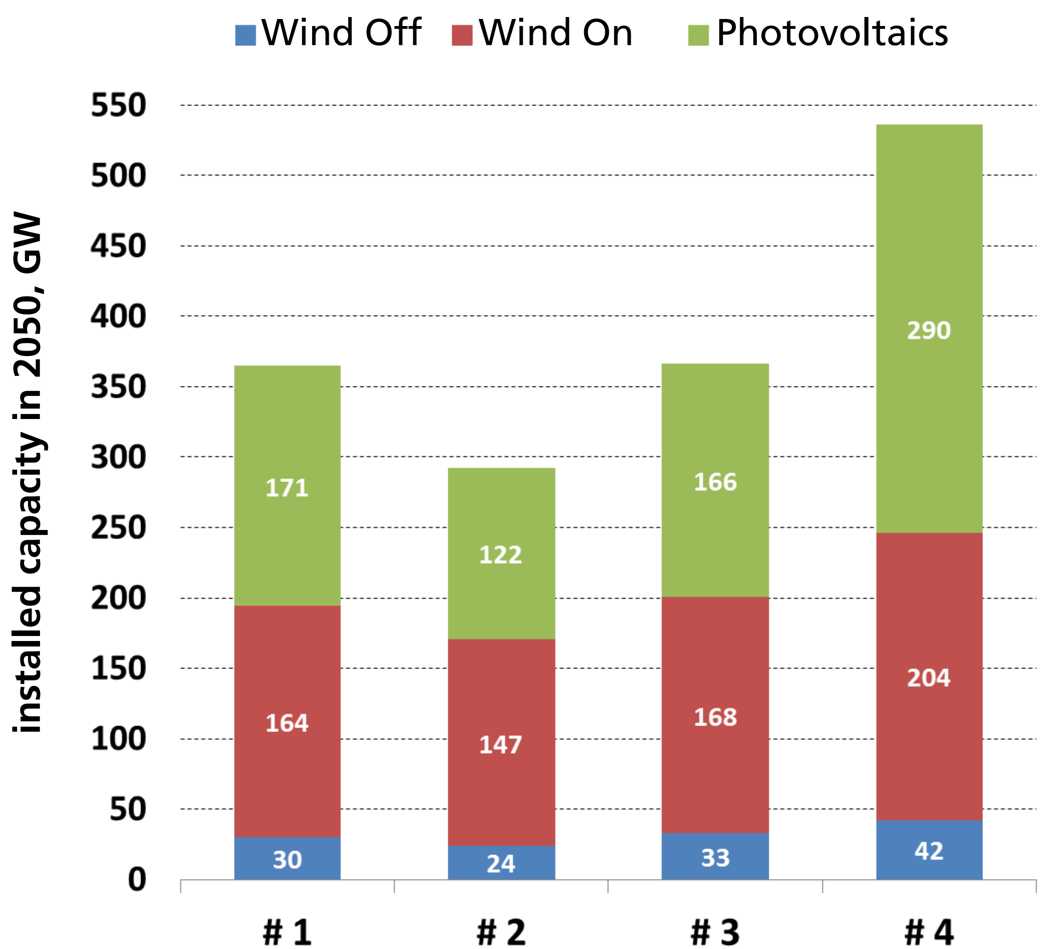
Scenario results (Germany)
Wind and PV in the year 2050



#1 -80 % CO_2, phase-out of coal not accelerated

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

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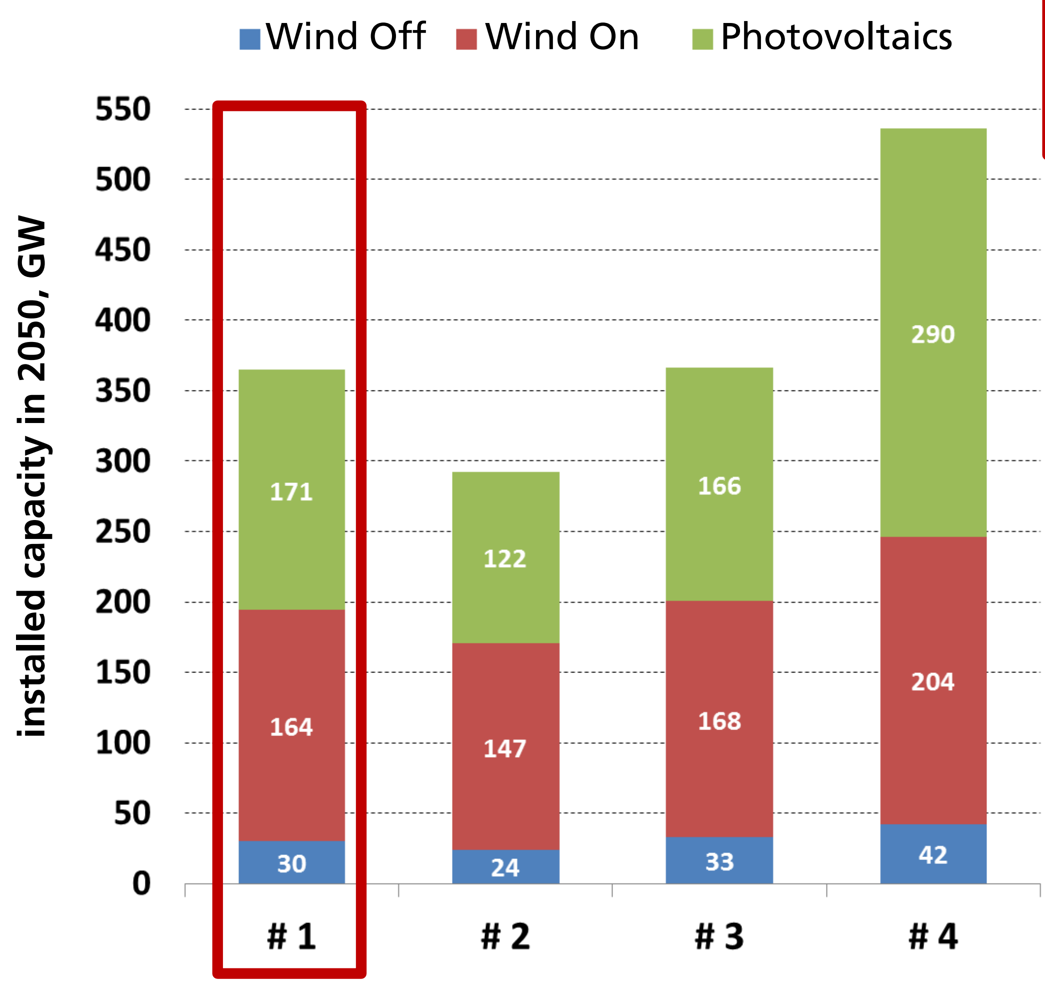

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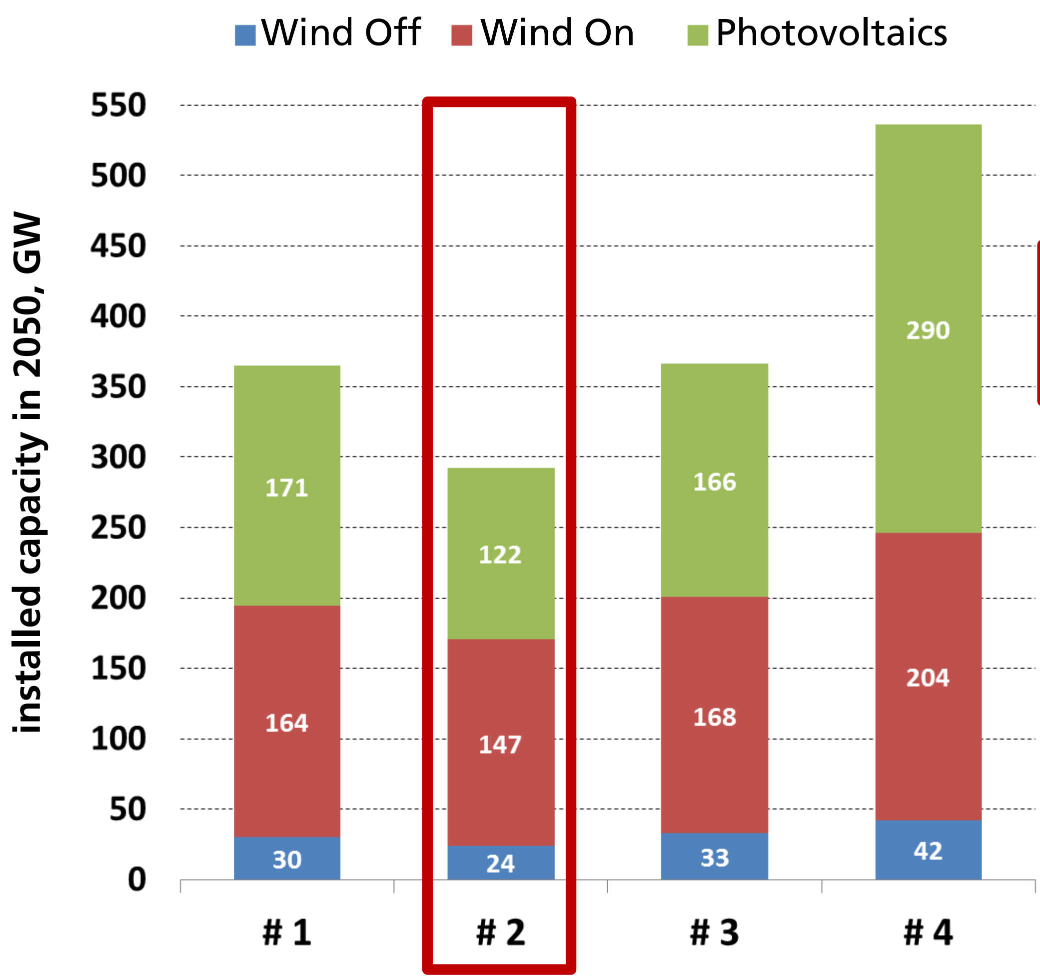

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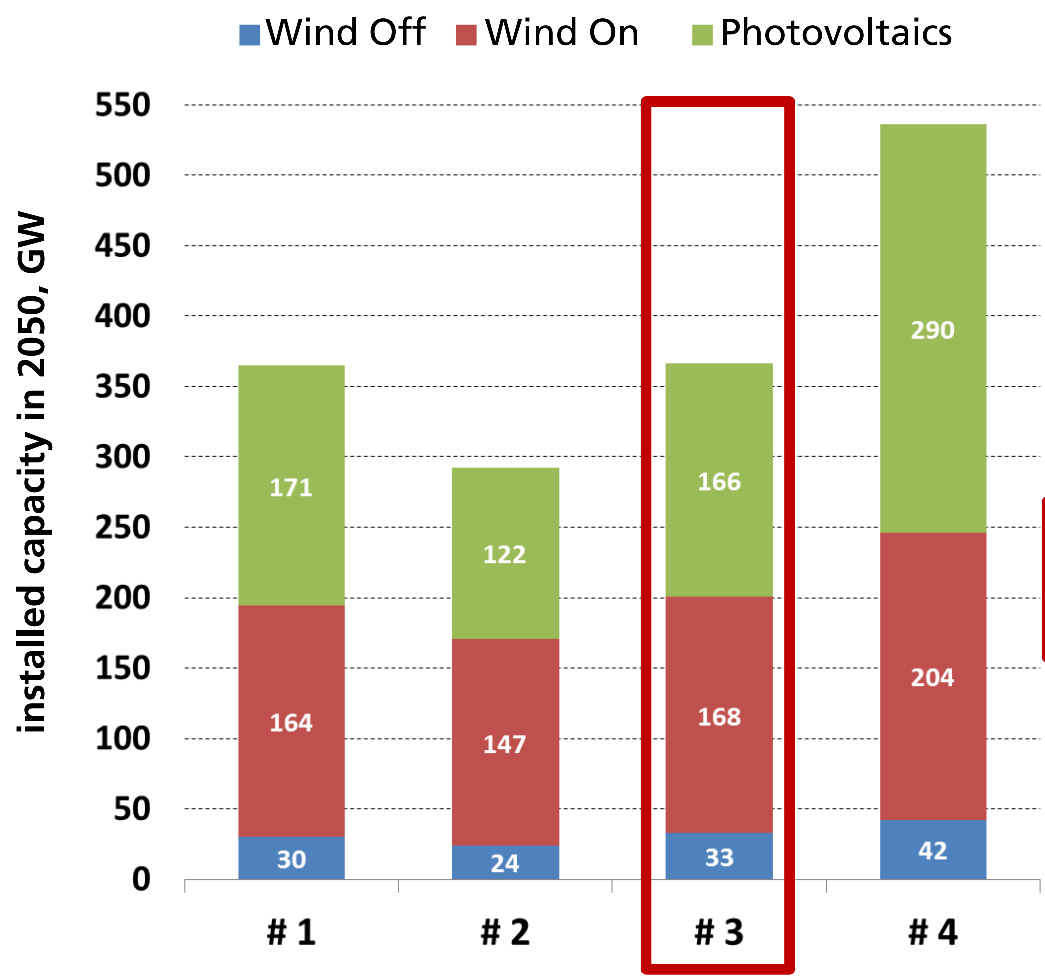

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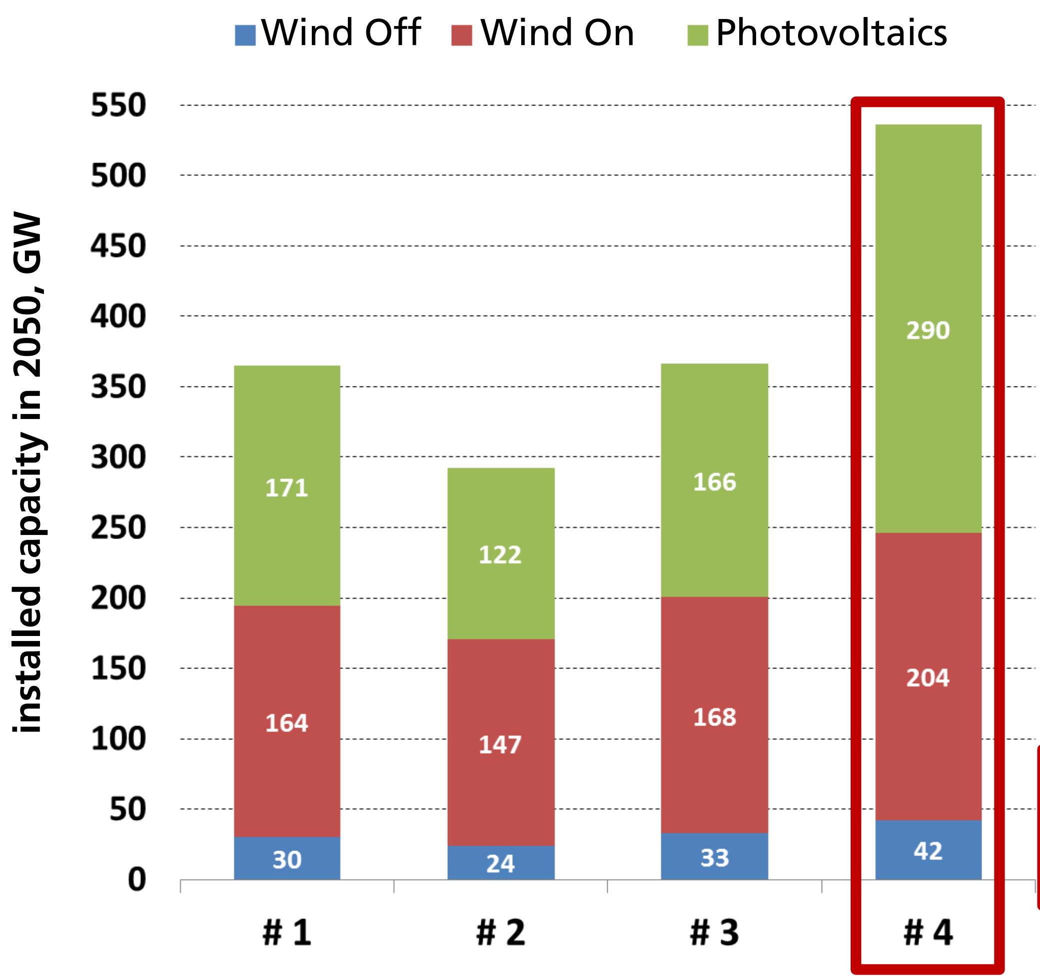

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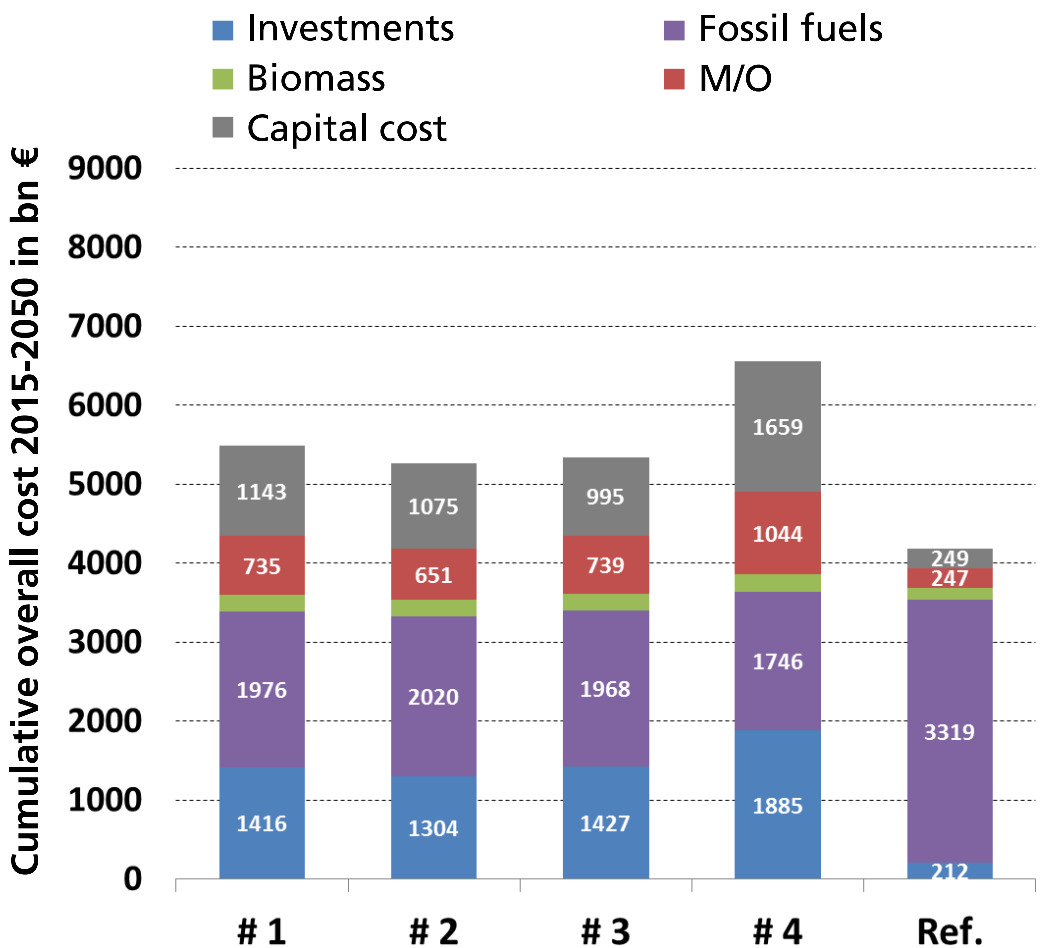
Scenario results (Germany)
Comparison of cumulative overall cost



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

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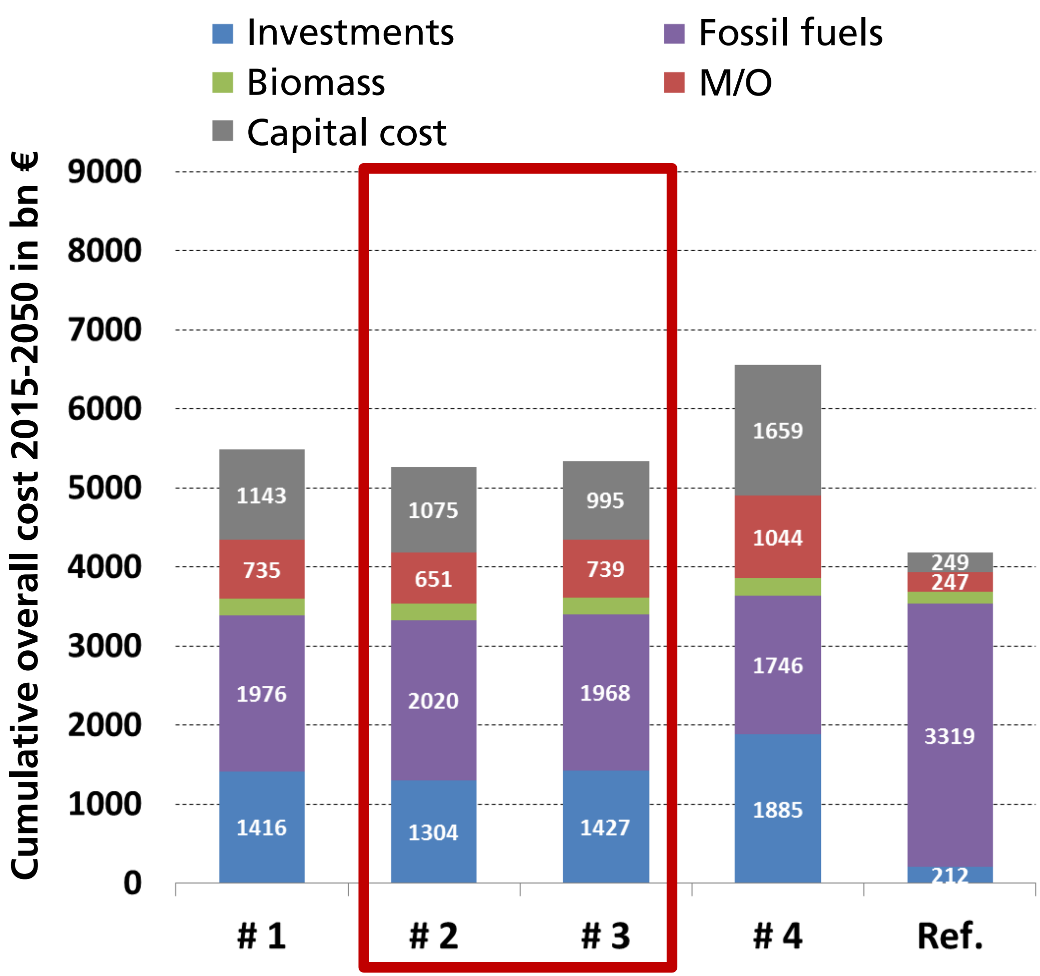
Ref today's system without change

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

Scenario results (Germany)
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

#3 -85 % CO_2, phase-out of coal accelerated

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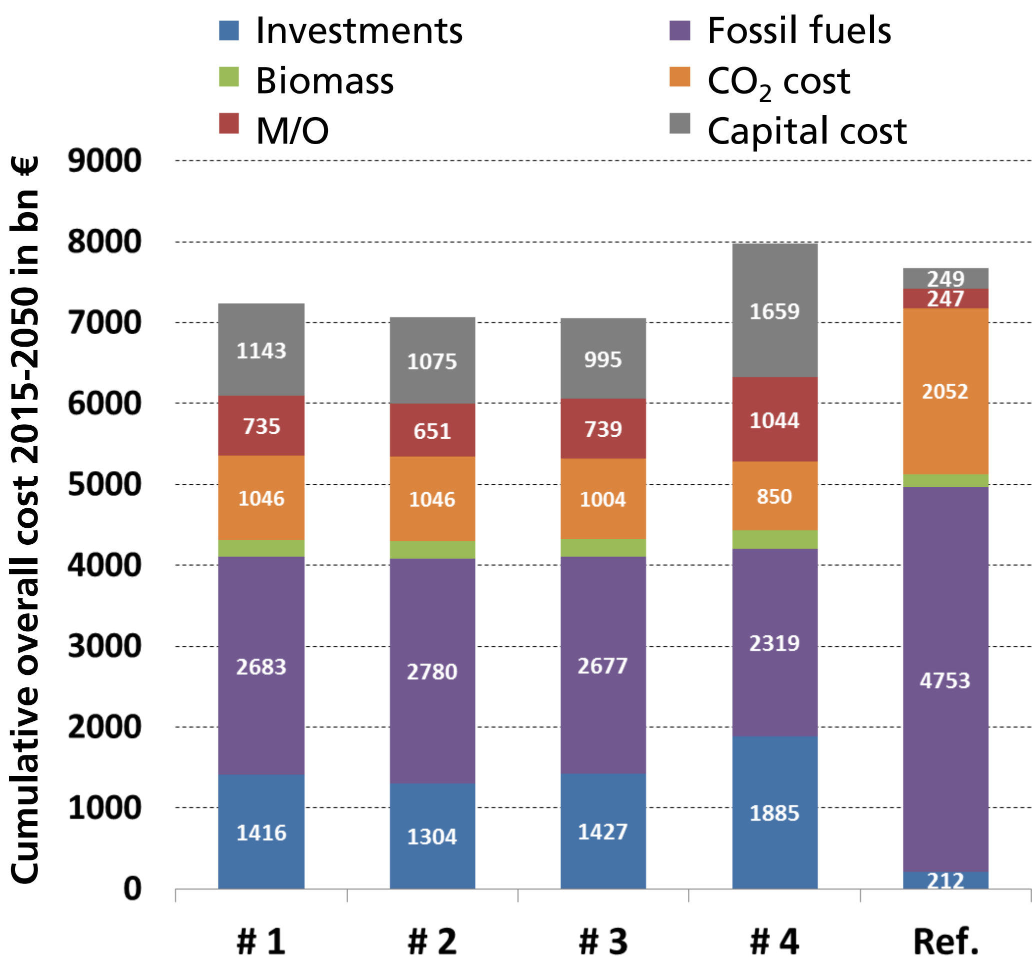

- Increasing cost CO_2 emissions up to 100 € per ton in 2030; then fix value
- Annual price increase of fossil fuels 2%

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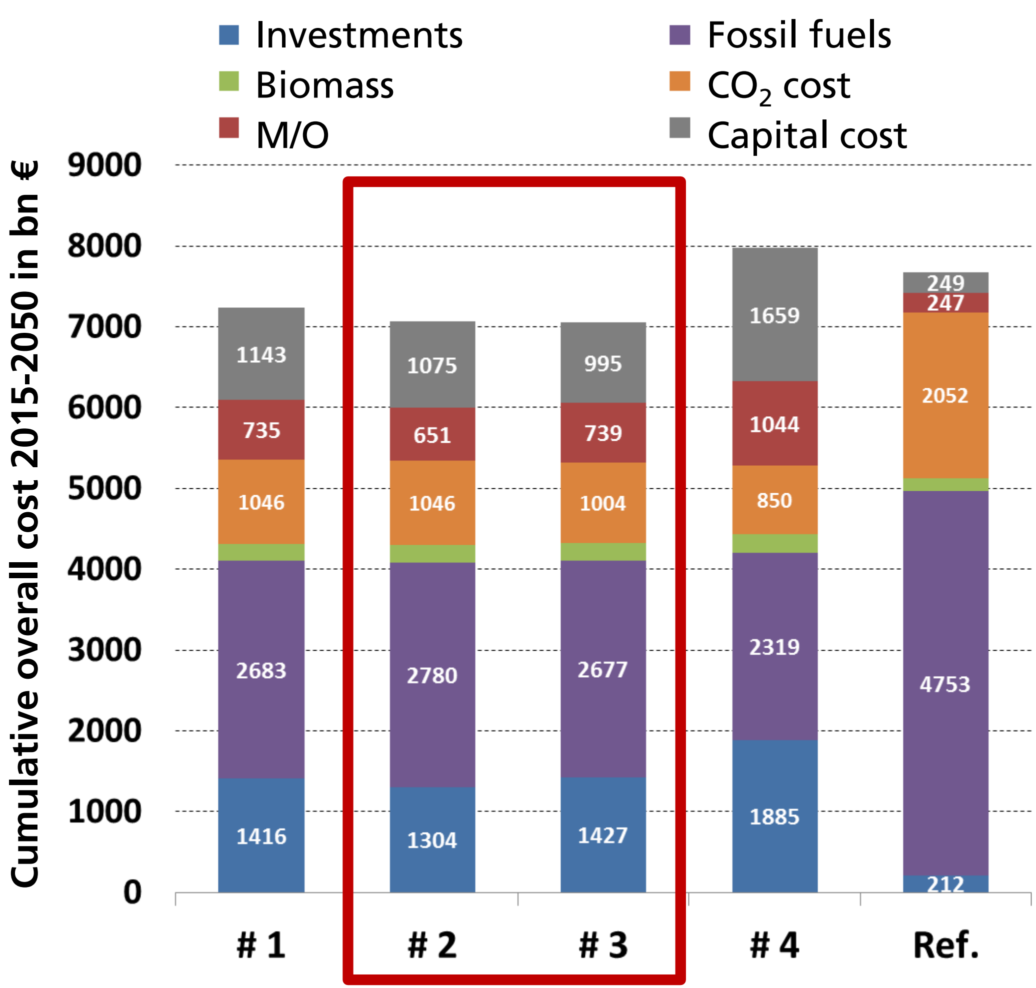

- Increasing cost CO_2 emissions up to 100 € per ton in 2030; then fix value
- Annual price increase of fossil fuels 2%

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

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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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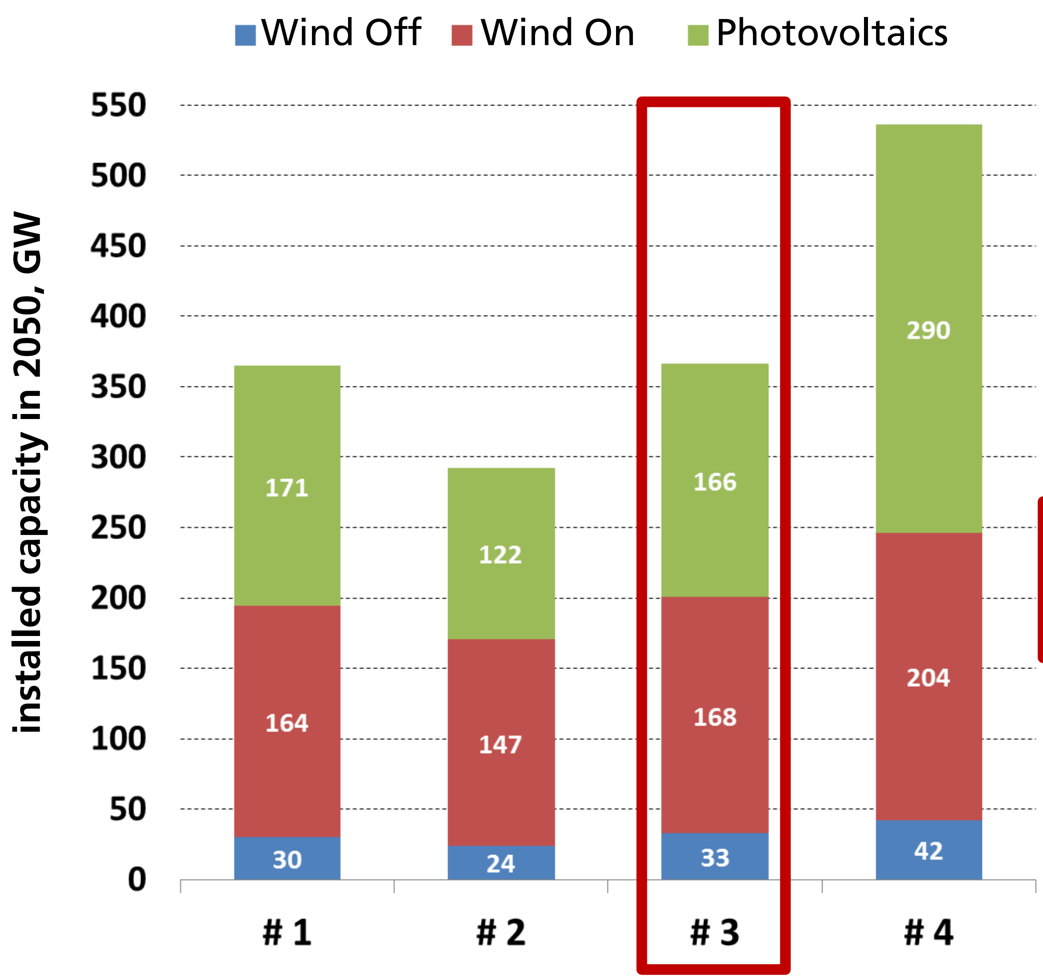
Scenario results (Germany)
Wind and PV in the year 2050



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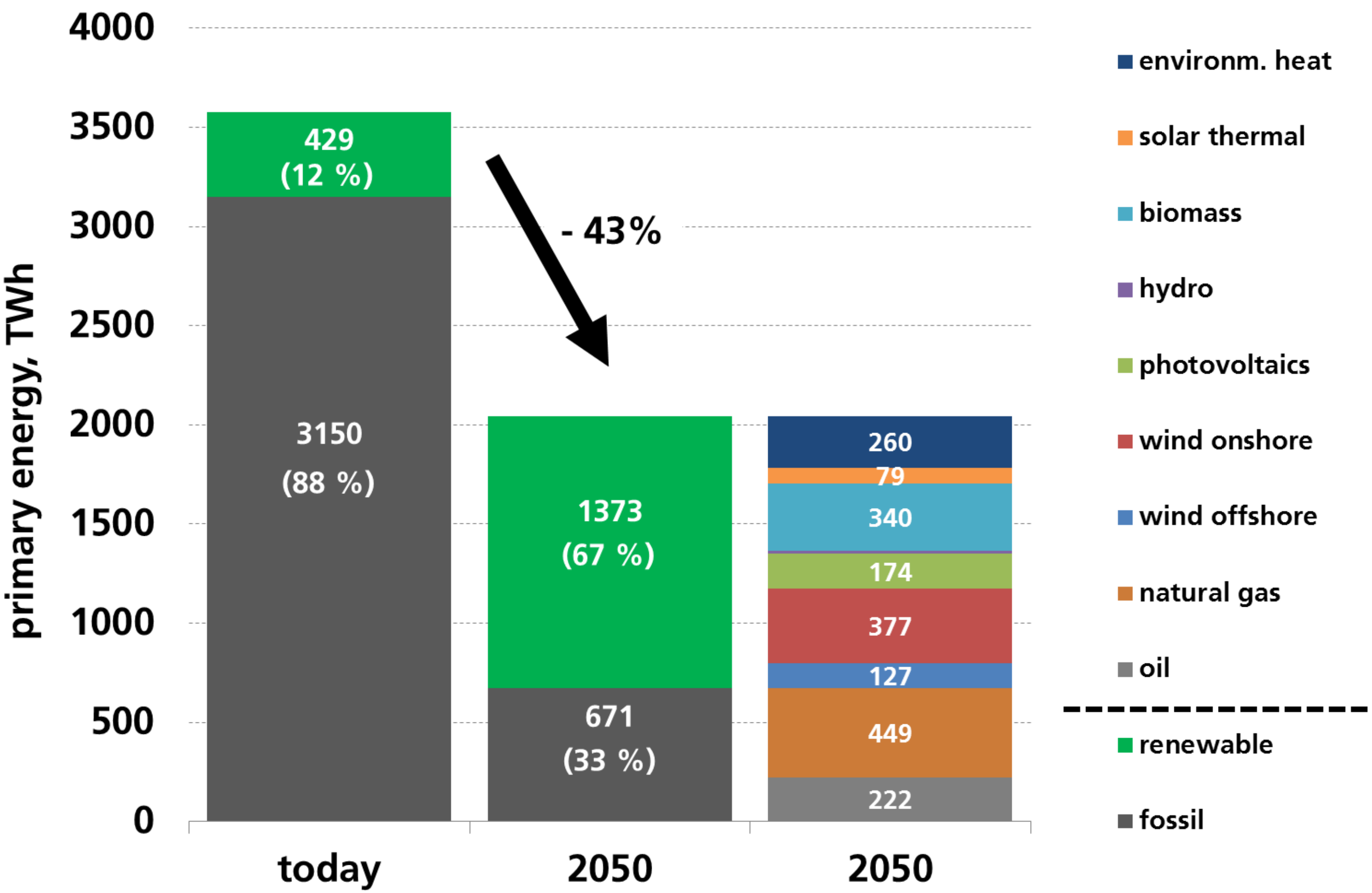
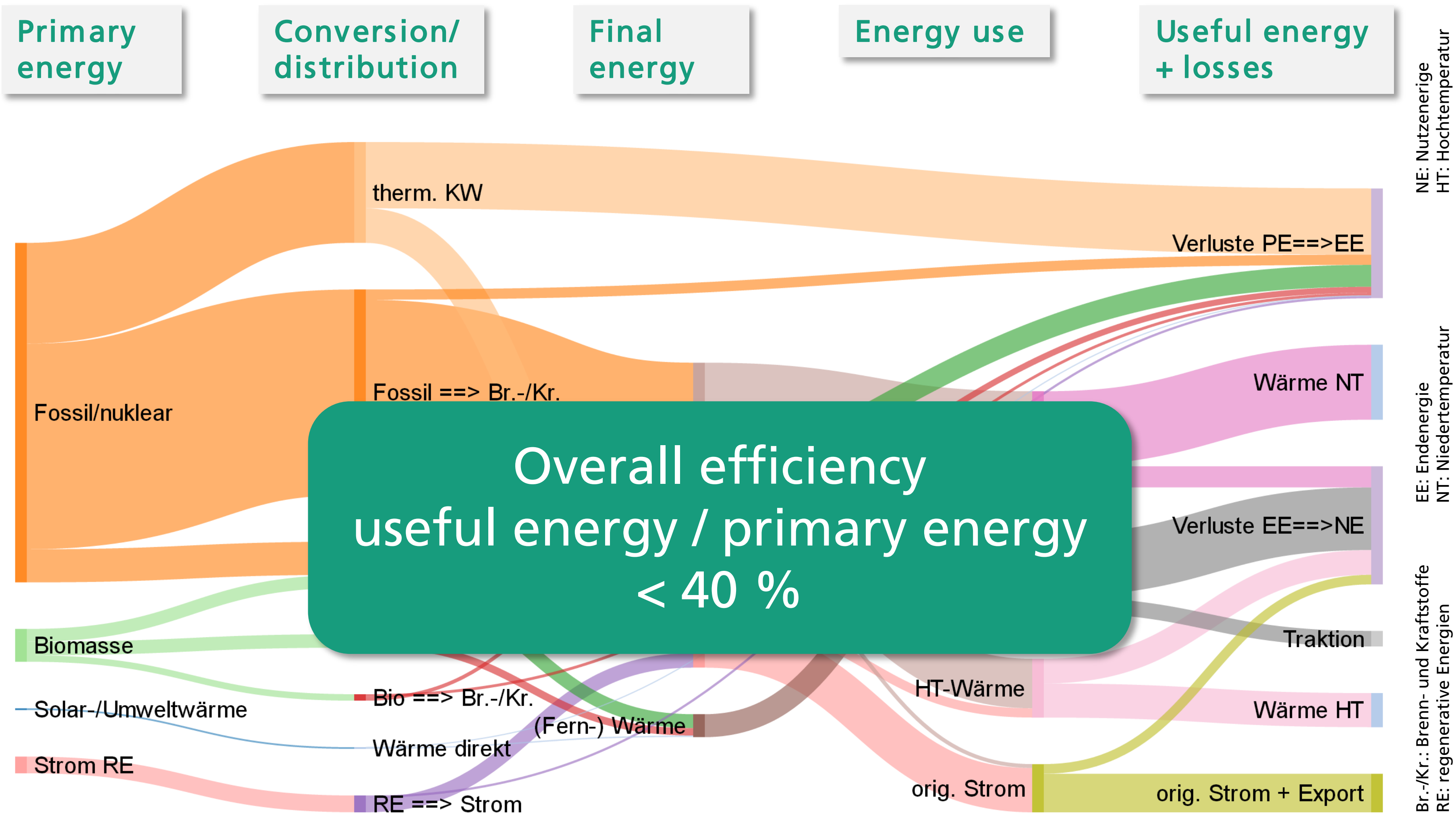
Primary energy 2050 (compared with 2013)
– 85 % - Scenario



Energy flux today (2013)



Overall efficiency
useful energy / primary energy
< 40 %

Based on data from: BMWi: „Zahlen und Fakten. Energiedaten. Nationale und internationale Entwicklung – Überprüfungsdatum 2015-09-22“, Daten von Prof. Dr. Eberhard Jochem (IREES) und eigenen Abschätzungen

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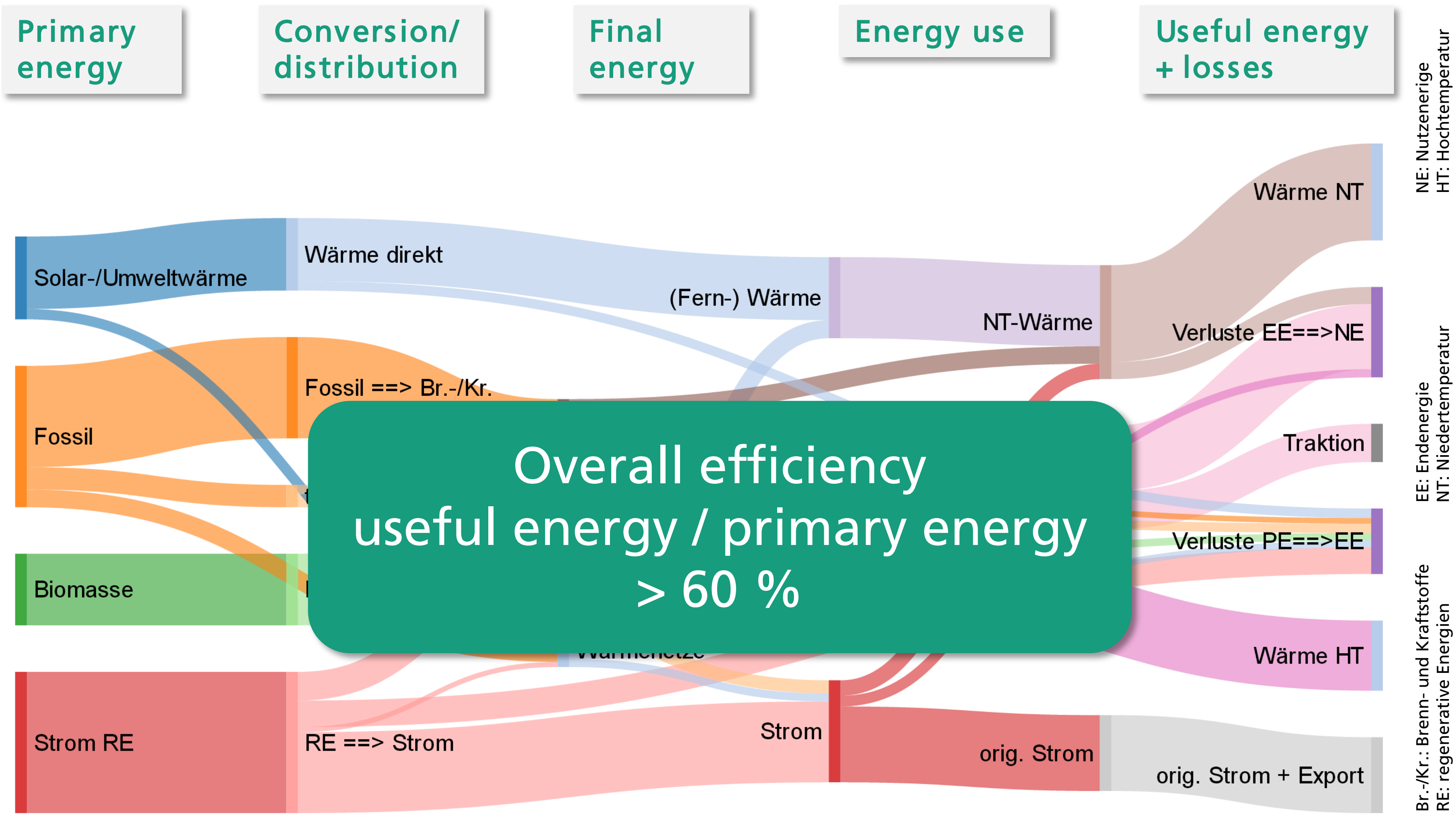
Energy flux 2050 (-85-%-Scenario)



Overall efficiency
useful energy / primary energy
> 60 %

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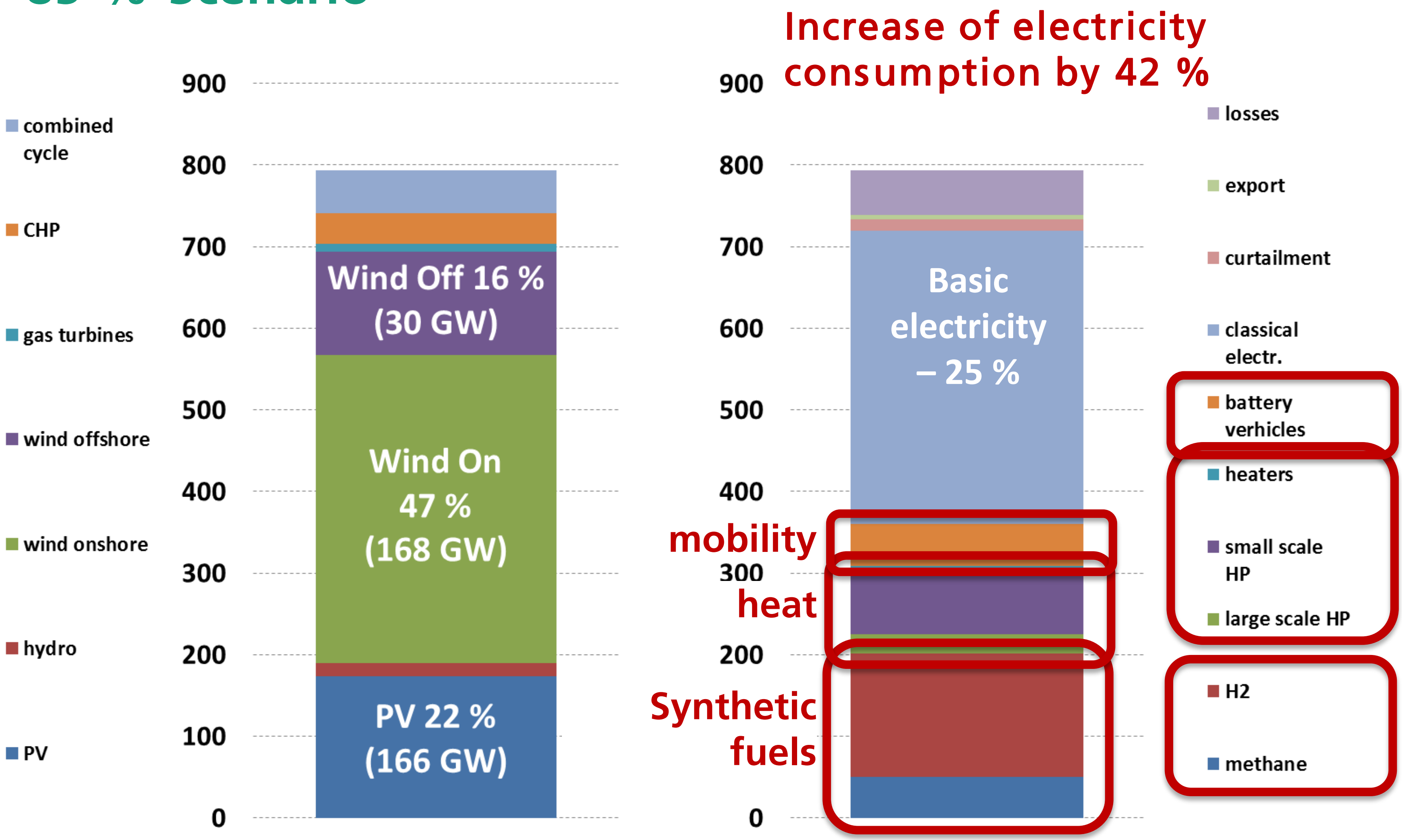
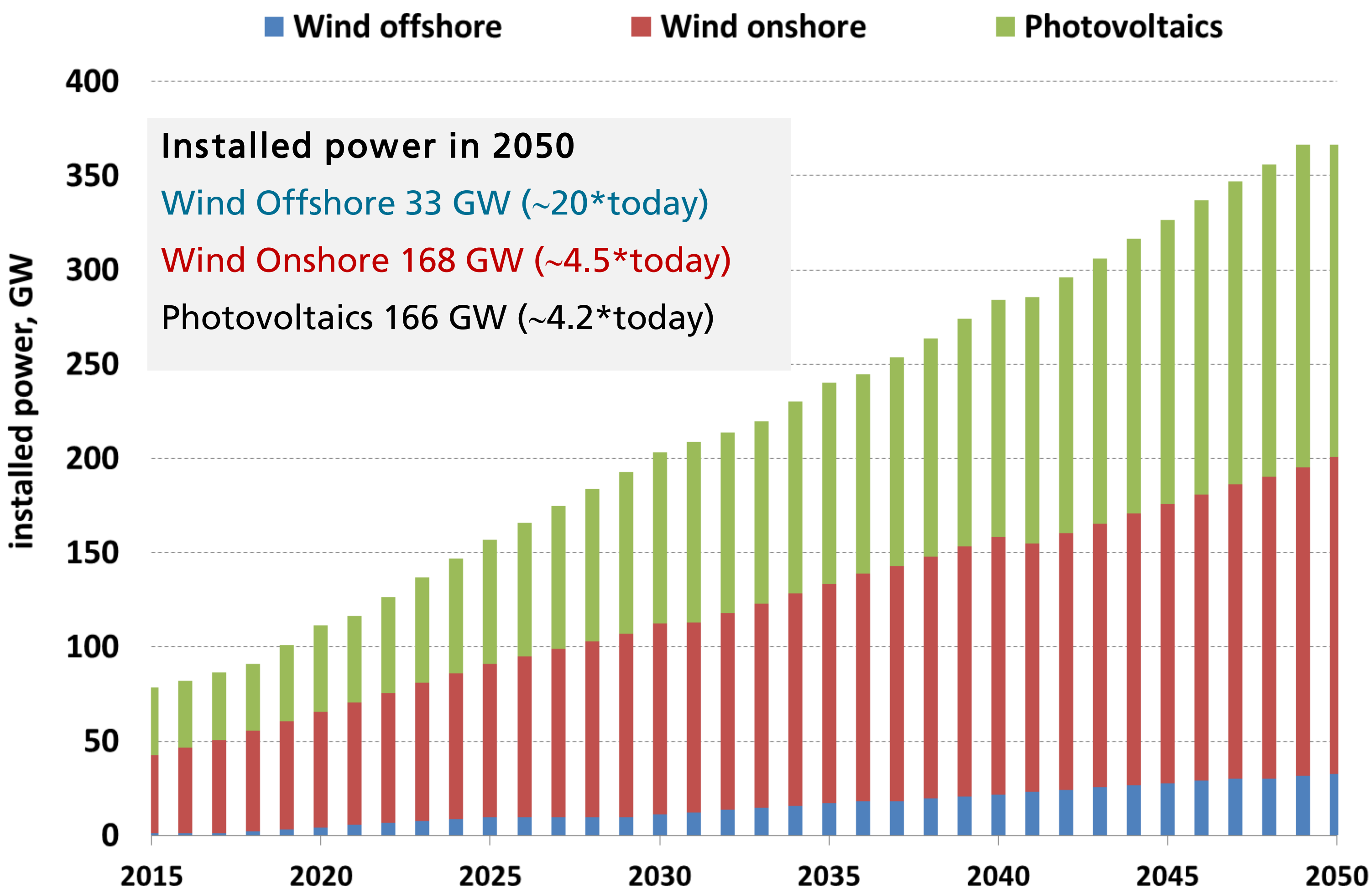
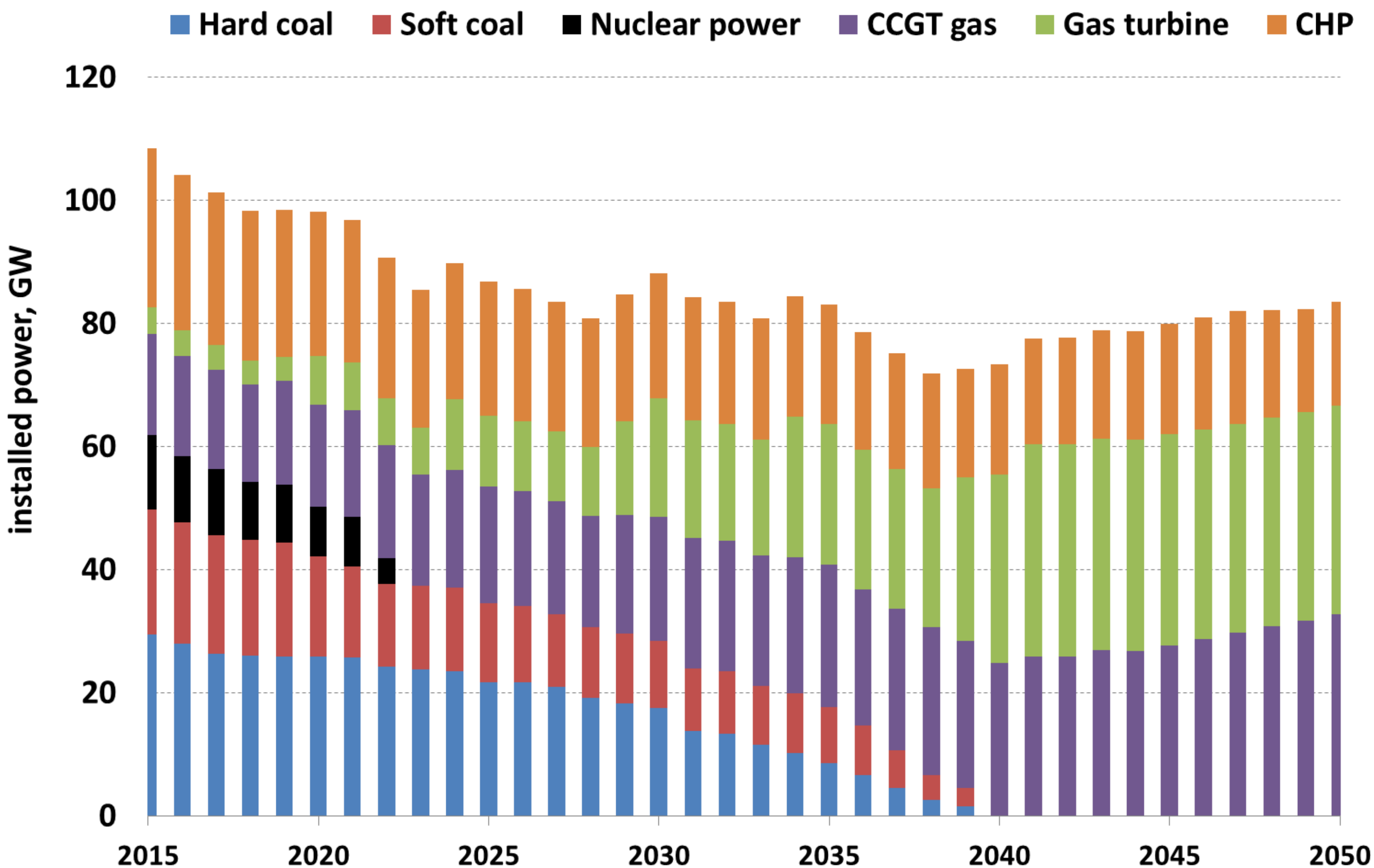
Electricity generation and use
– 85-%-Scenario



Wind and PV
– 85-%-Scenario



Conventional power plants and CHP
– 85-%-Scenario



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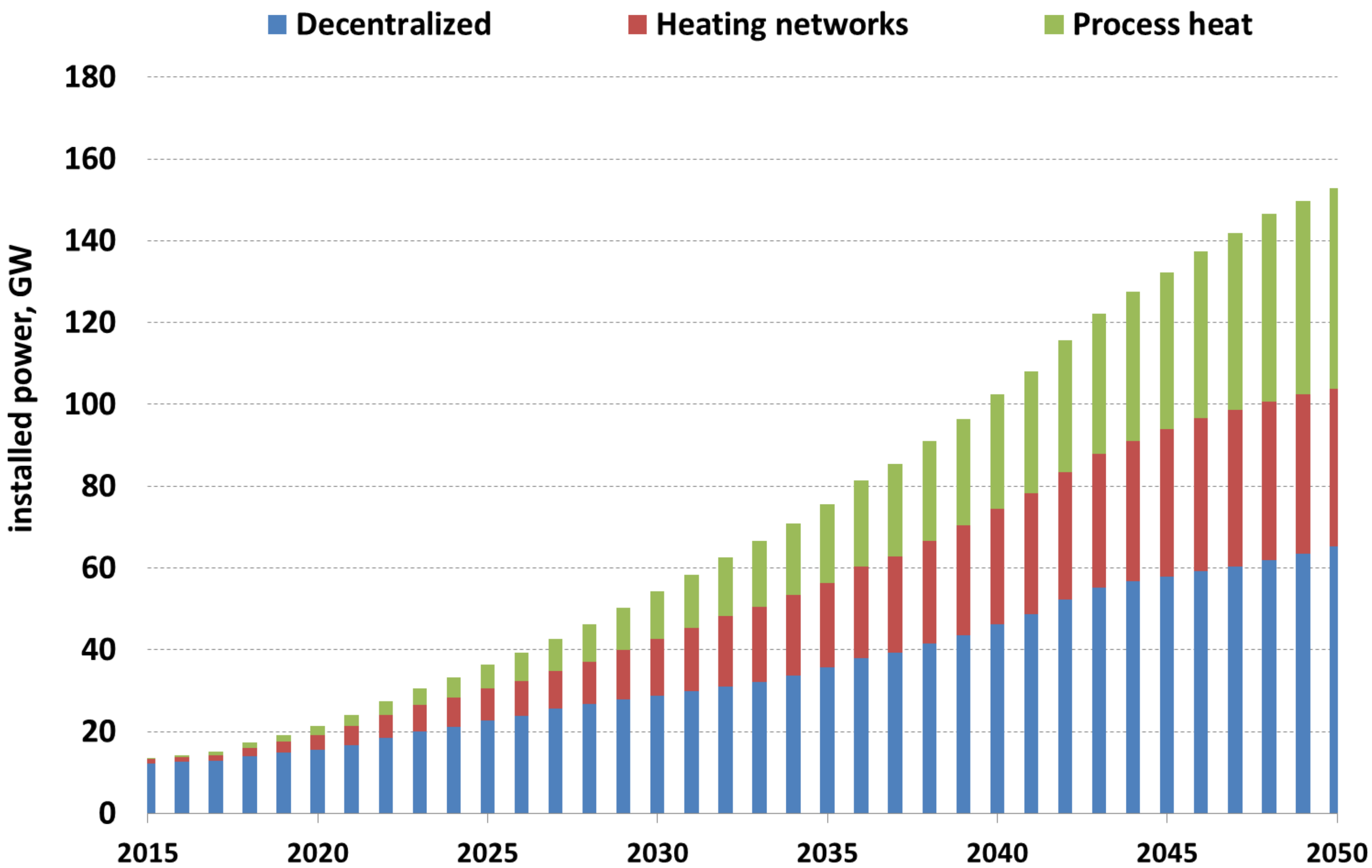
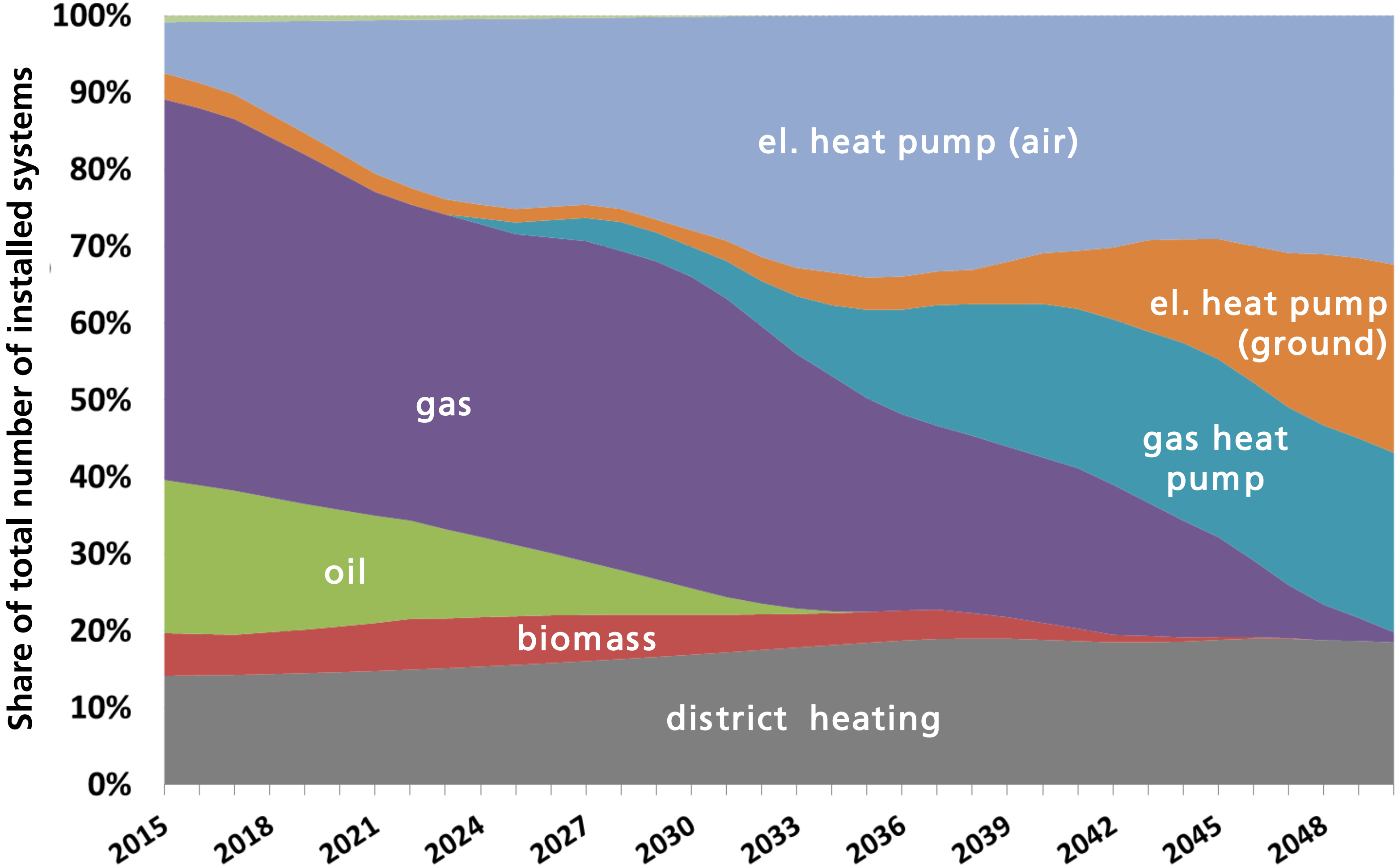
Low temperature solar thermal
– 85-%-Scenario



Heating technologies
– 85-%-Scenario



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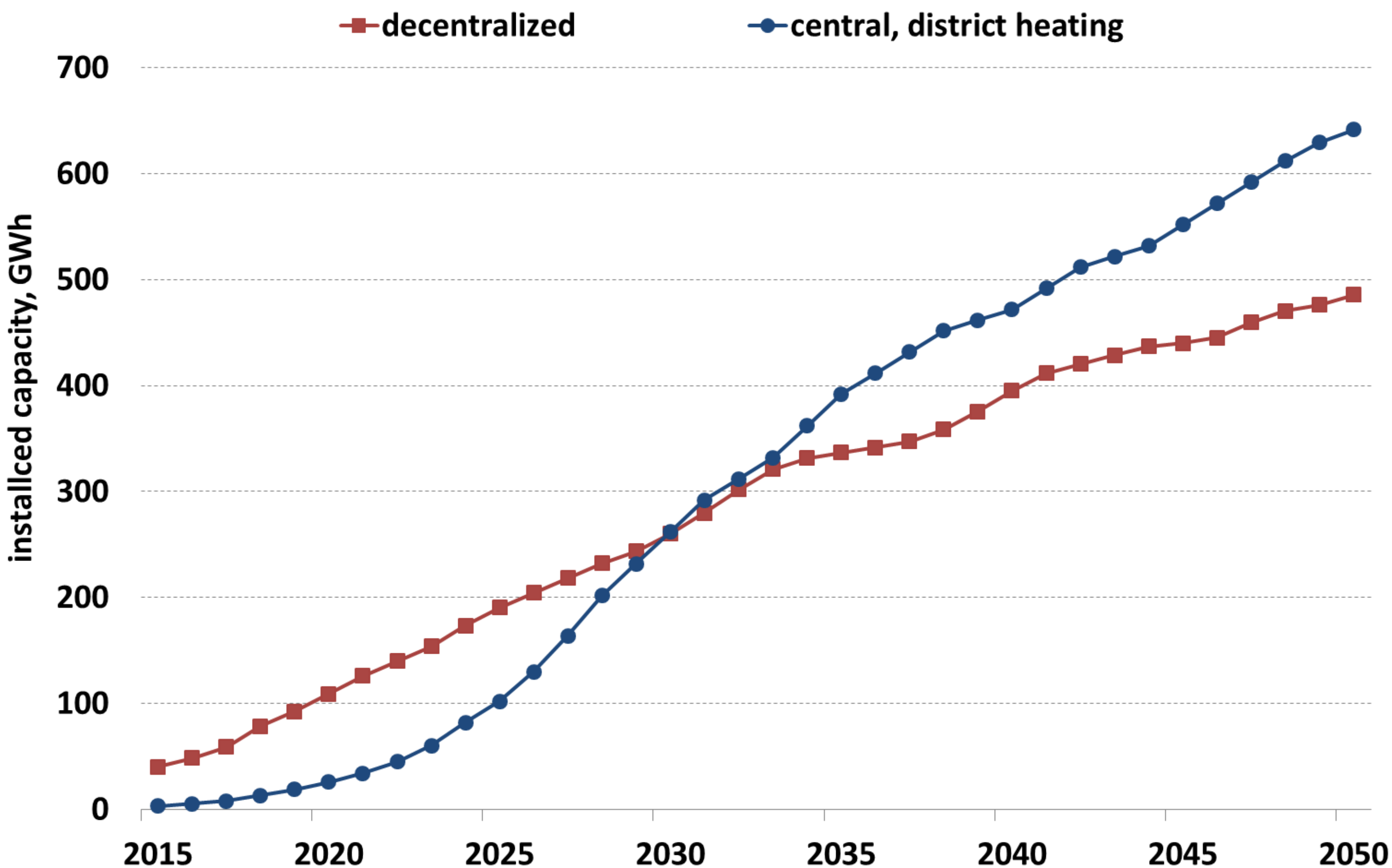
Heat storage
– 85-%-Scenario



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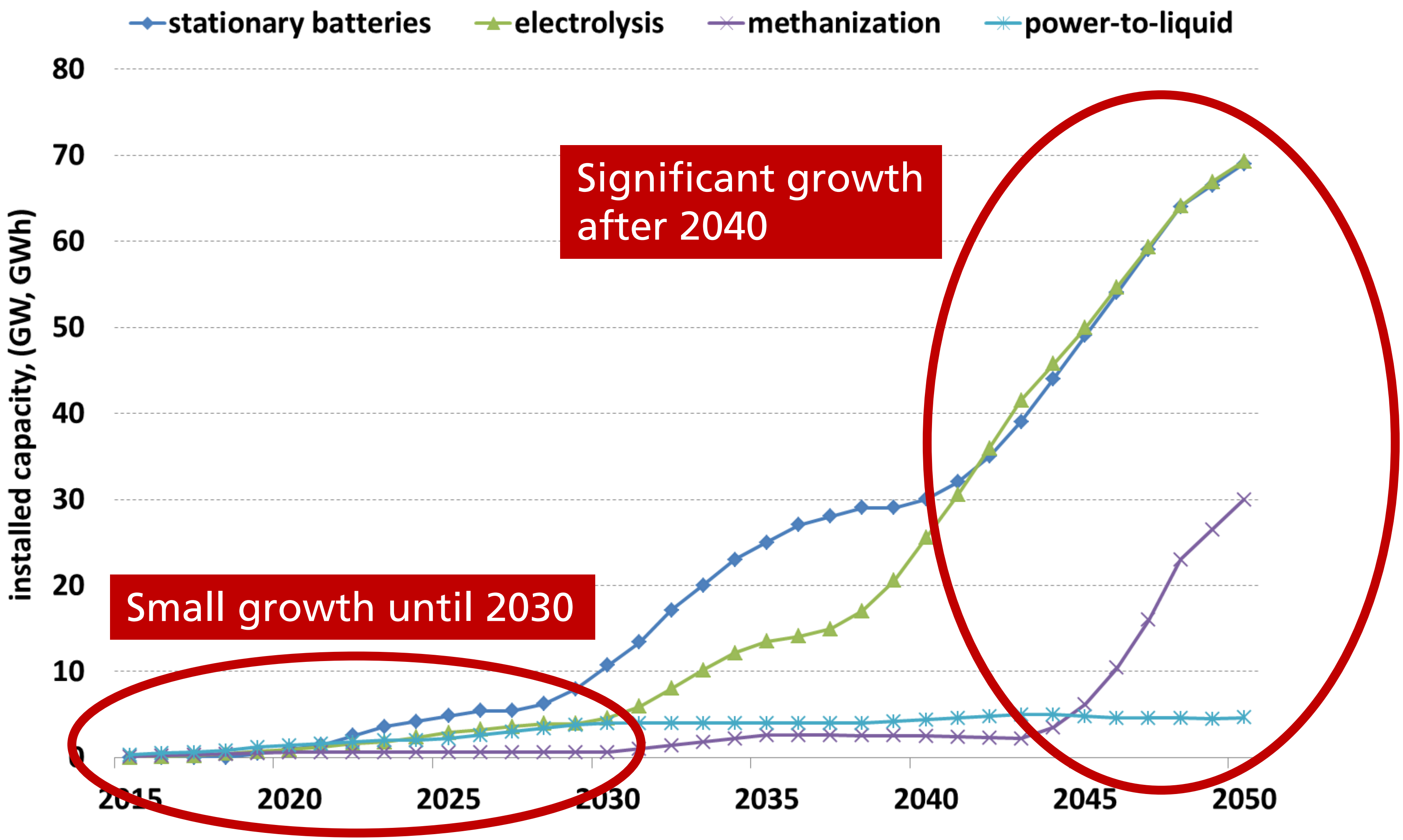
Stationary batteries and power-to-fuel converters
-85% Scenario



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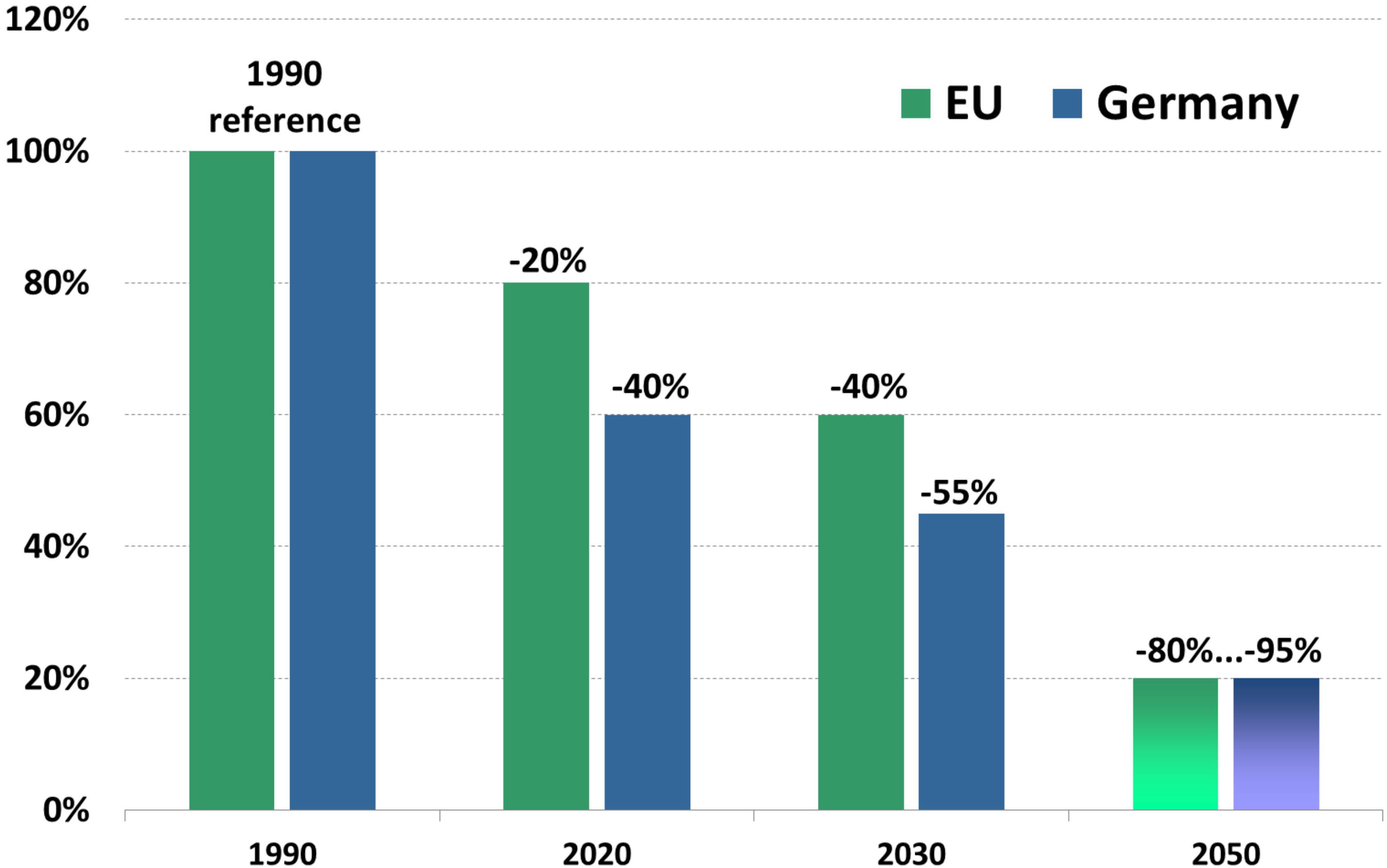
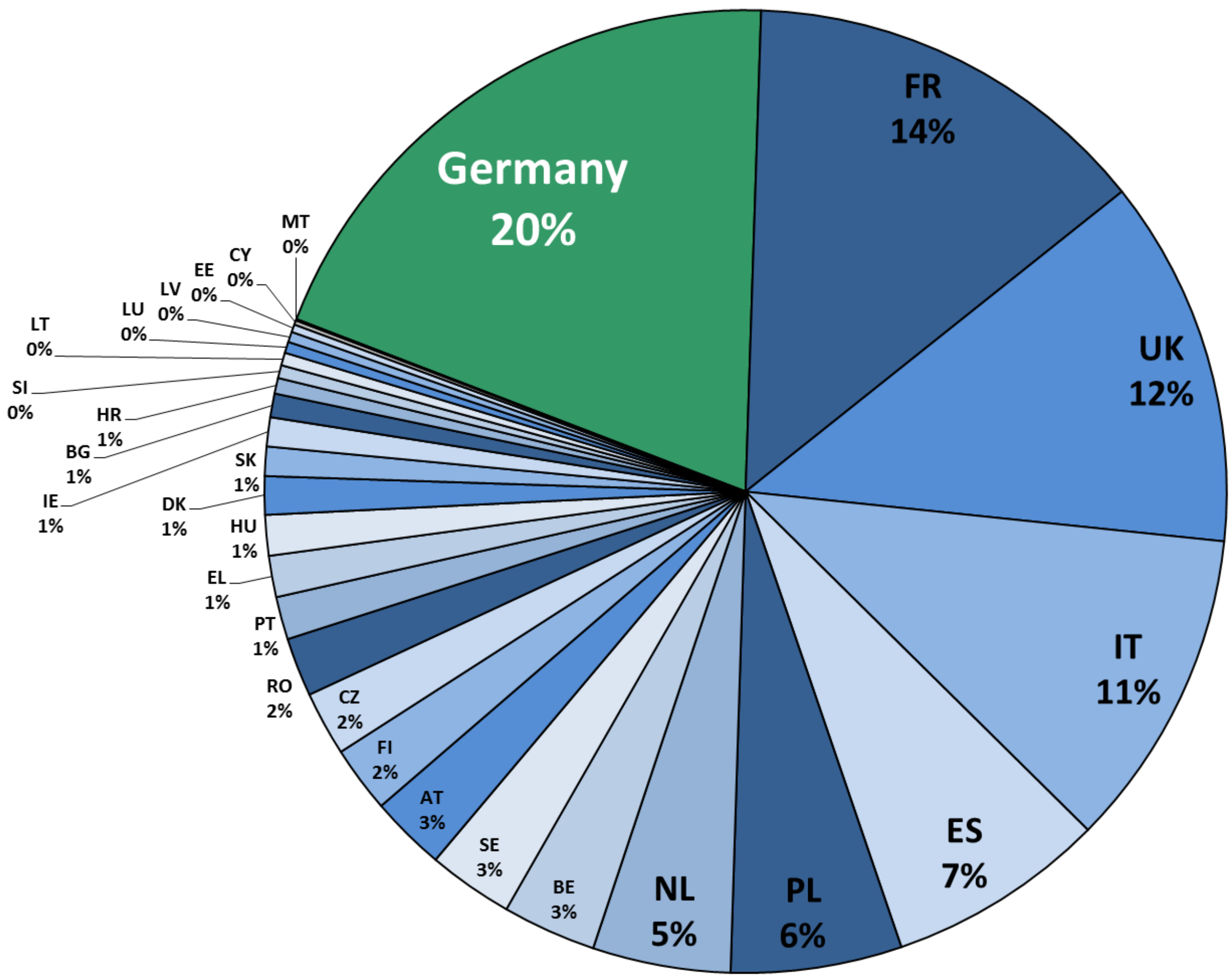
Outline

GHG target values



Final energy
Europe vs. Germany



Based on data from: EU energy in figures. Statistical pocket book 2015.

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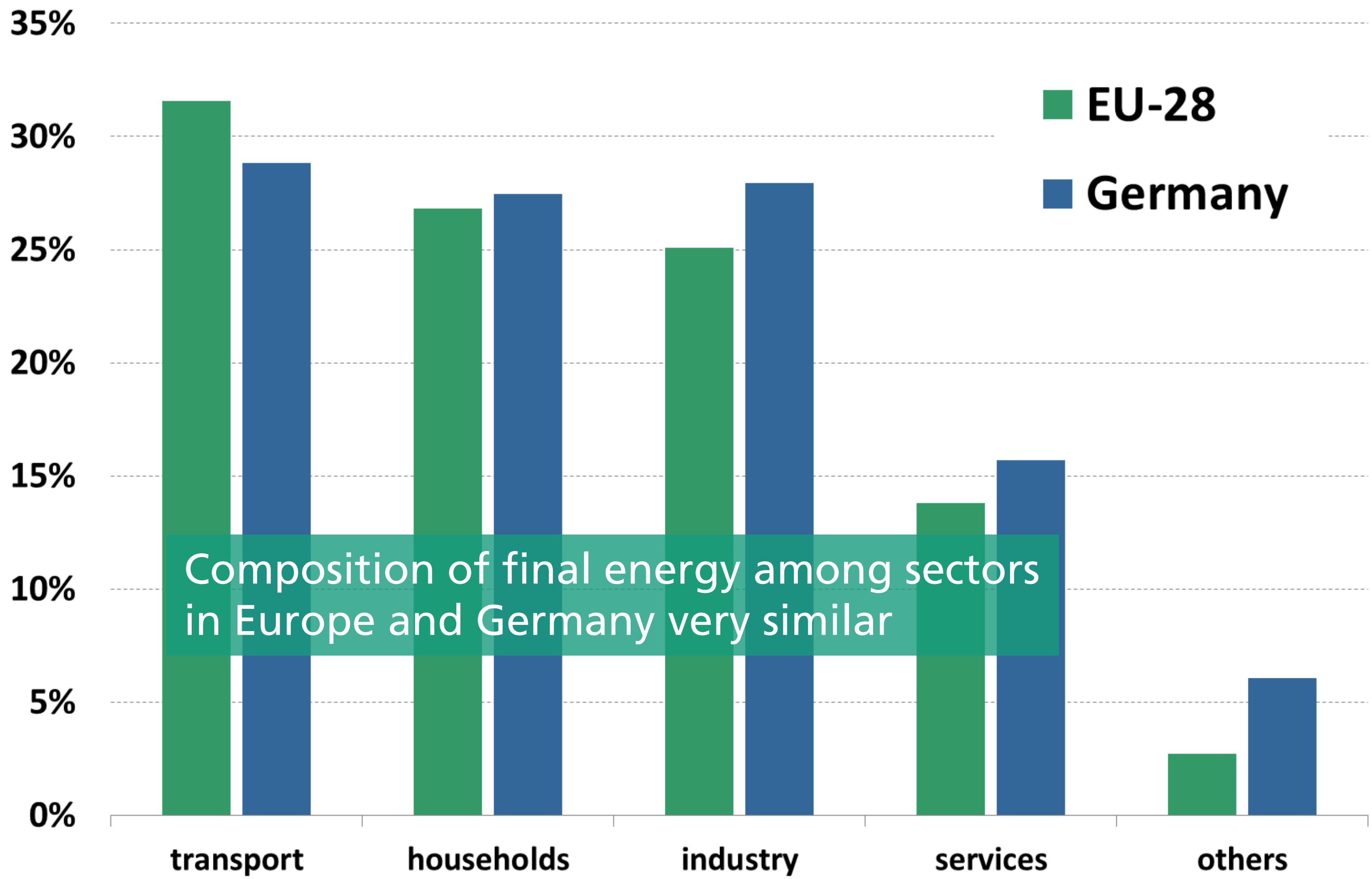
Final energy distribution among sectors
Europe vs. Germany



Based on data from: EU energy in figures. Statistical pocket book 2015.

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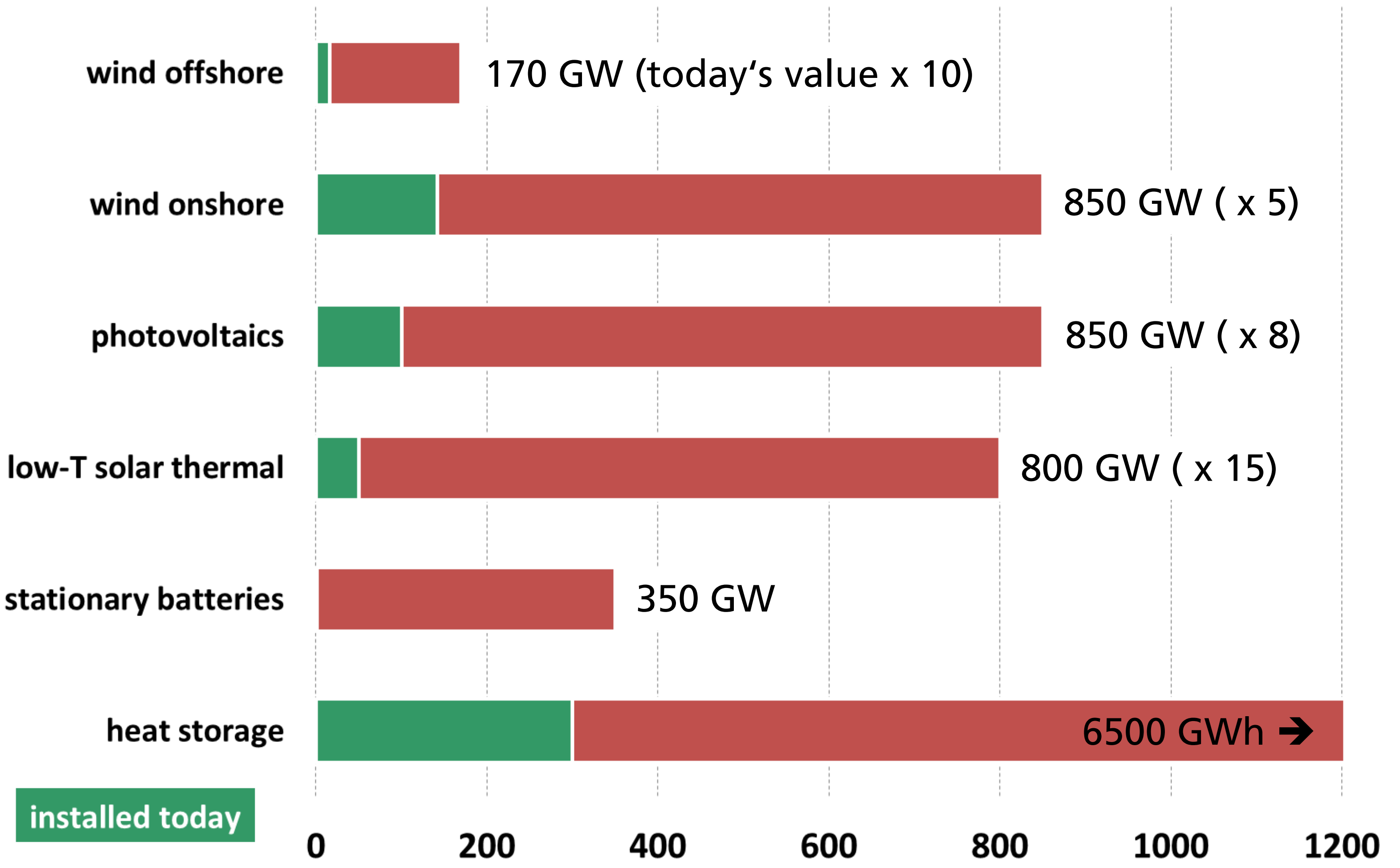
Extrapolating optimization results to Europe
Needed capacities



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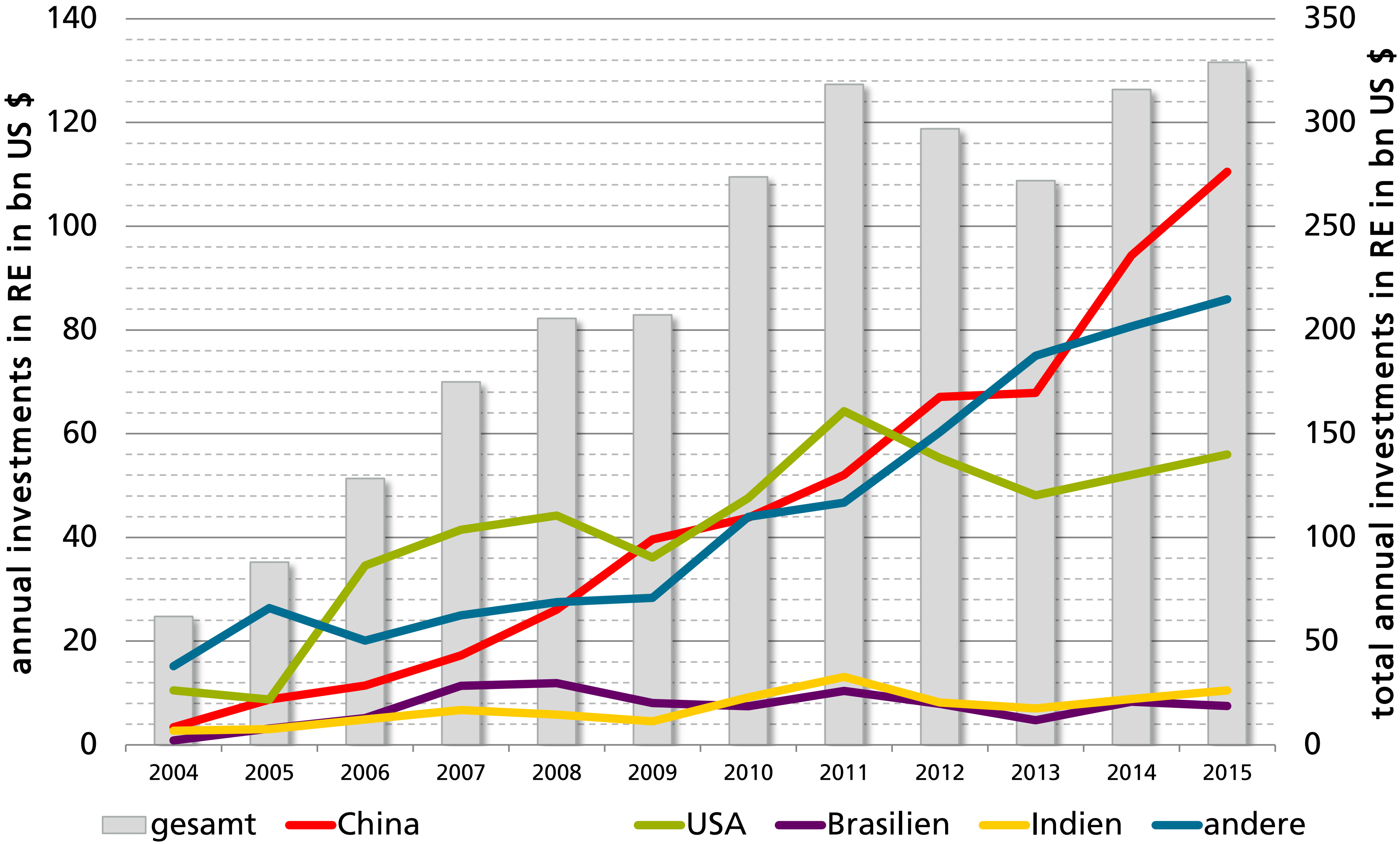
However… global investments in renewable energies



Based on data from: Bloomberg, Clean Energy Investment in Numbers, 2016 (Figure from Hans-Josef Fell)

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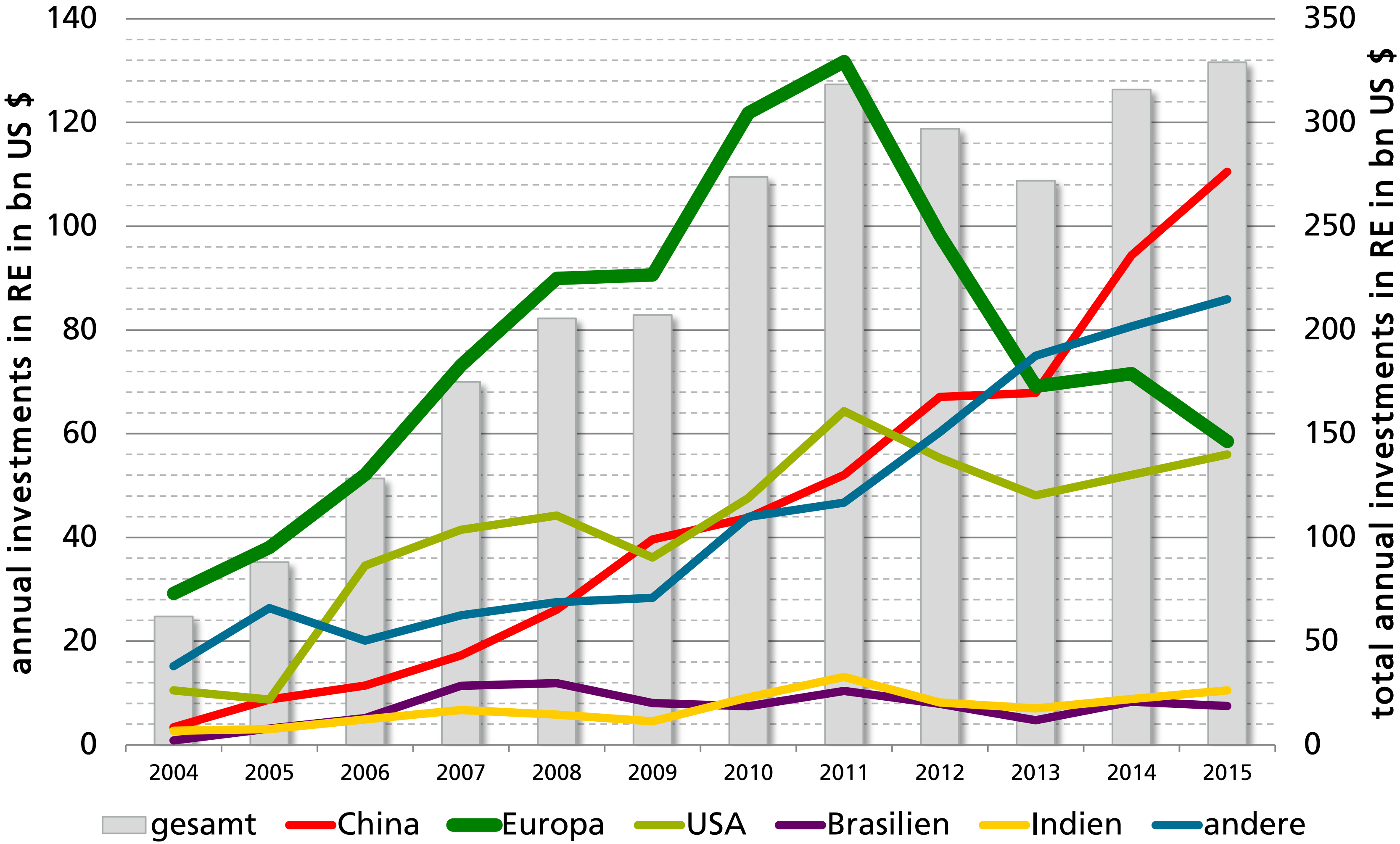
… and recent developments in Europe



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Phases of the energy system transformation

Phase 1 „RE development“

CO_2-reduction ~ 0-20%

- Development of basic RE technologies (wind, solar)
- Significant cost reductions
- Market introduction and extension without significant implications for the overall system

Phases of the energy system transformation

Phase 1 „RE development“	Phase 2 „system integration“
CO_2-reduction ~ 0-20%	CO_2-reduction ~ 20-60%
■ Development of basic RE technologies (wind, solar) ■ Significant cost reductions ■ Market introduction and extension without significant implications for the overall system	■ Activation of flexibilities: residual electricity generation and electricity use ■ Convergence of electricity and heat sector ■ Demand side management ■ Short term storage

Phases of the energy system transformation

Phase 1 „RE development“	Phase 2 „system integration“	Phase 3 „synthetic fuels“
CO_2-reduction ~ 0-20%	CO_2-reduction ~ 20-60%	CO_2-reduction ~ 60-80%
■ Development of basic RE technologies (wind, solar) ■ Significant cost reductions ■ Market introduction and extension without significant implications for the overall system	■ Activation of flexibilities: residual electricity generation and electricity use ■ Convergence of electricity and heat sector ■ Demand side management ■ Short term storage	■ Significant negative residual loads ■ Use of renewable electricity for production of synthetic fuels ■ Increased use of synthetic fuels for mobility sector

Phases of the energy system transformation

Phase 1 „RE development“	Phase 2 „system integration“	Phase 3 „synthetic fuels“	Phase 4 „RE import“
CO_2-reduction ~ 0-20%	CO_2-reduction ~ 20-60%	CO_2-reduction ~ 60-80%	CO_2-reduction ~ 80-100 %
■ Development of basic RE technologies (wind, solar) ■ Significant cost reductions ■ Market introduction and extension without significant implications for the overall system	■ Activation of flexibilities: residual electricity generation and electricity use ■ Convergence of electricity and heat sector ■ Demand side management ■ Short term storage	■ Significant negative residual loads ■ Use of renewable electricity for production of synthetic fuels ■ Increased use of synthetic fuels for mobility sector	■ Final displacement of fossil fuels in all end-use sectors ■ Import of renewable fuels, e.g. from regions in the sun belt (e.g. north africa)

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Phases of the energy system transformation

Phase 1 „RE development“	Phase 2 „system integration“	Phase 3 „synthetic fuels“	Phase 4 „RE import“
CO_2-reduction ~ 0-20%	CO_2-reduction ~ 20-60%	CO_2-reduction ~ 60-80%	CO_2-reduction ~ 80-100 %
■ Development of basic RE technologies (wind, solar) ■ Significant cost reductions ■ Market introduction and extension without significant implications for the overall system	■ Activation of flexibilities: residual electricity generation and electricity use ■ Convergence of electricity and heat sector ■ Demand side management ■ Short term storage	■ Significant negative residual loads ■ Use of renewable electricity for production of synthetic fuels ■ Increased use of synthetic fuels for mobility sector	■ Final displacement of fossil fuels in all end-use sectors ■ Import of renewable fuels, e.g. from regions in the sun belt (e.g. north africa)

- Continuous increase of efficiency in end-use sectors
  - Energetic refurbishment (building stock)
  - Reduction of electricity use in classical end-use applications (e.g. artificial lighting, pumps and drives, …)
- Continuous expansion of renewable energy converters (solar, wind, geothermal)

see also: Hans-Martin Henning, Andreas Palzer, Carsten Pape, Frieder Borggrefe, Henning Jachmann und Manfred Fischedick; Phasen der Transformation des Energiesystems. Energiewirtschaftliche Tagesfragen, Februar 2015

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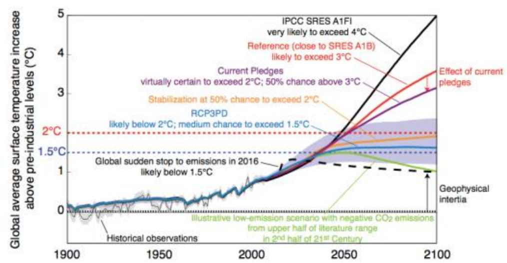
Summary

- Transformation of energy systems in line with GHG emission reduction targets technically feasible
- Renewable energies (solar, wind) become dominant
- Importance of electric energy increases
- Short term storage starts to become important in the years 2020 to 2030
  - Heat storage (decentralized, connected to district heating networks)
  - Electricity storage: stationary batteries + pumped hydro
- Large scale conversion of renewable electricity into synthetic chemicals (hydrogen, methane, liquids) is in particular needed for CO_2 reduction rates > 65 % (target for 2035 and beyond) ➔ in particular needed for transportation
- Cost competitive once CO_2 emissions appropriately penalized

Win

Meeting GHG reduction targets



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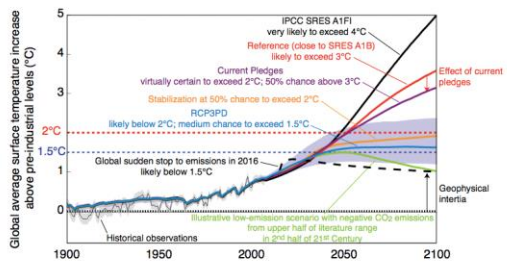
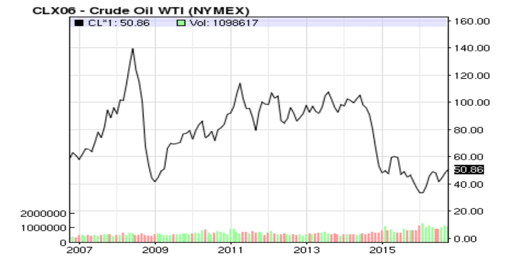
Win – Win

Meeting GHG reduction targets



Reduced dependence from imports of energy resources and their volatile price developments



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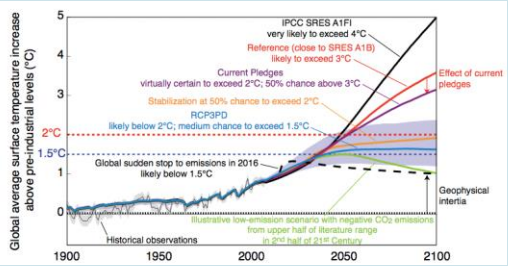
Win – Win – Win

Meeting GHG reduction targets



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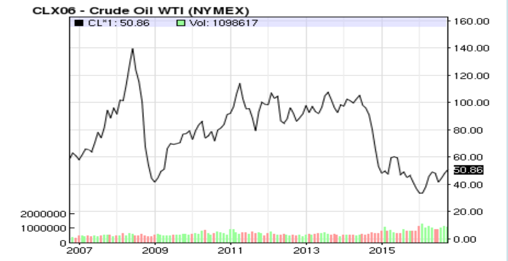

Create local value and employment by implementation of RE plants and RE technology production facilities

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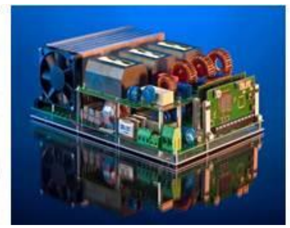
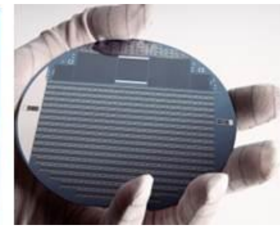
Many thanks for your attention…

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