SECTOR COUPLING AND SYSTEM INTEGRATION

Key elements of the next phase of the energy system transformation and the role of the mobility sector

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»Grid Integration of Electric Mobility«

3rd International ATZ Conference
June 5-6, 2018
Berlin/Germany

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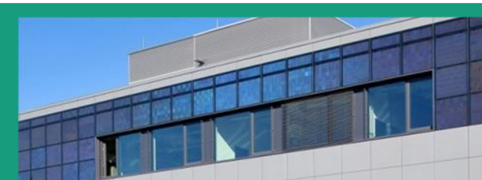
Business Areas

Energy technologies and systems		Photovoltaics	
Solar Thermal Technology		Silicon Photovoltaics	
Building Energy Technology		III-V- and Concentrator Photovoltaics	
Hydrogen Technology		Emerging Photovoltaic technologies	
Energy System Technology & Energy Storage		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

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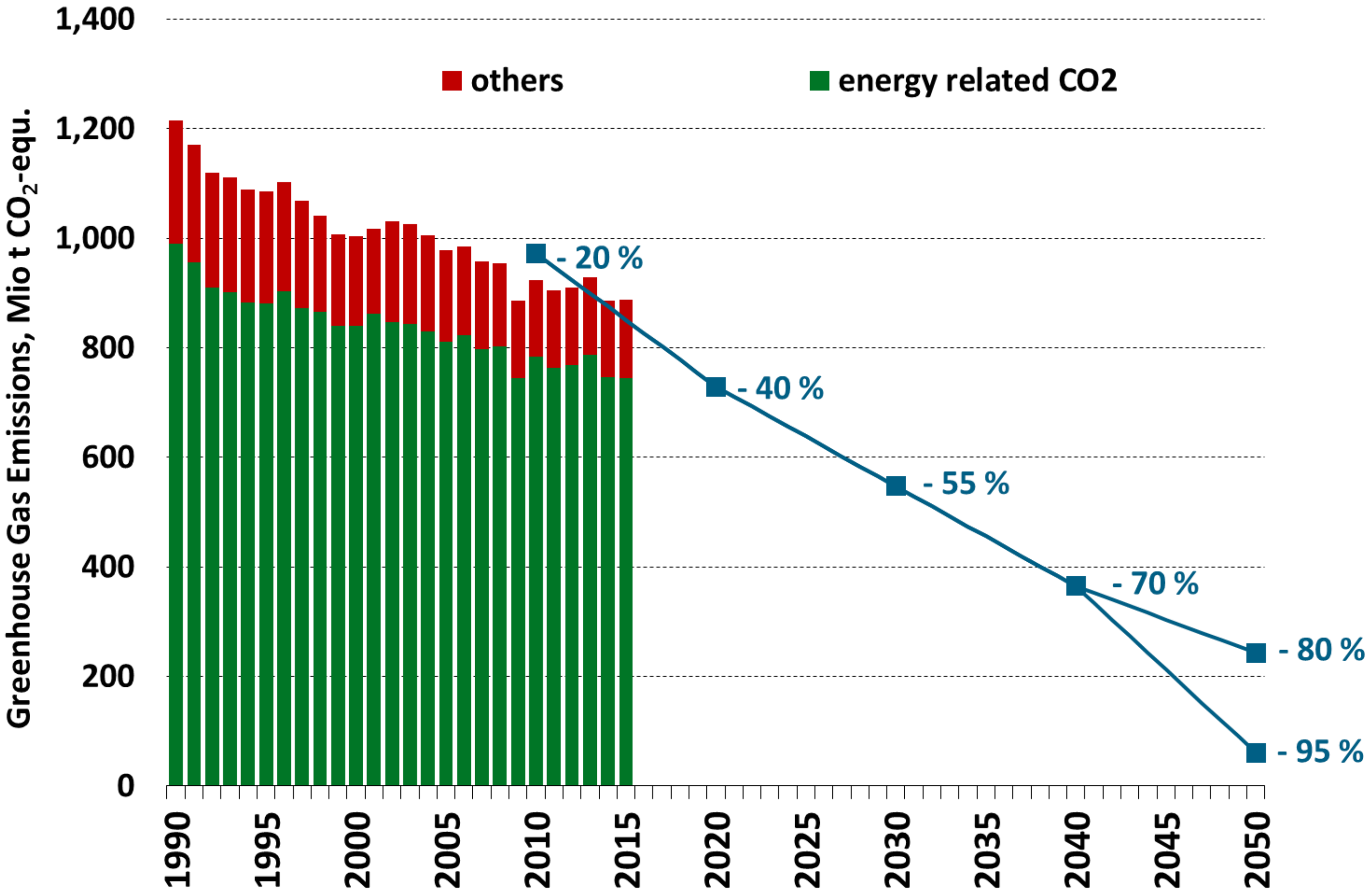
Need for deep transformation of our energy systems

- 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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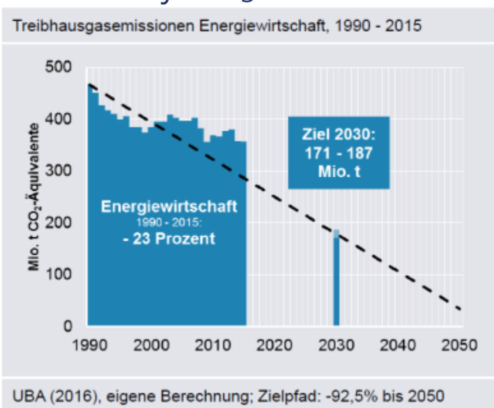
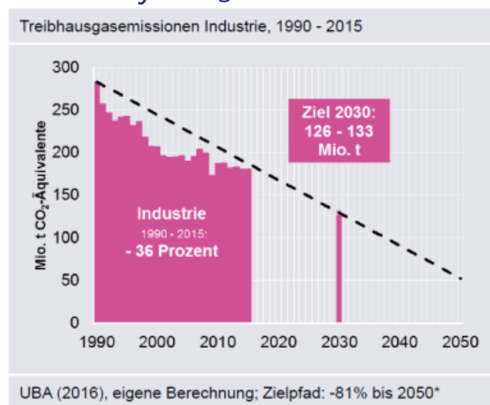
German GHG emissions

Sectorial development and targets

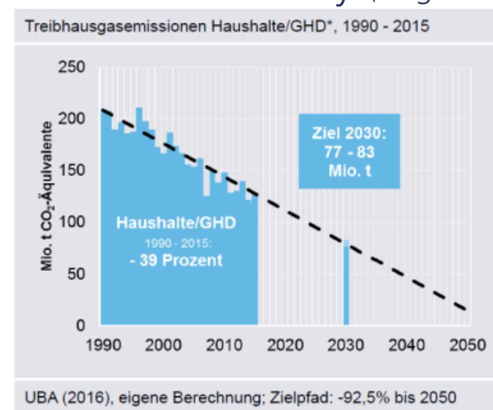
Electricity (Target: -92,5%)



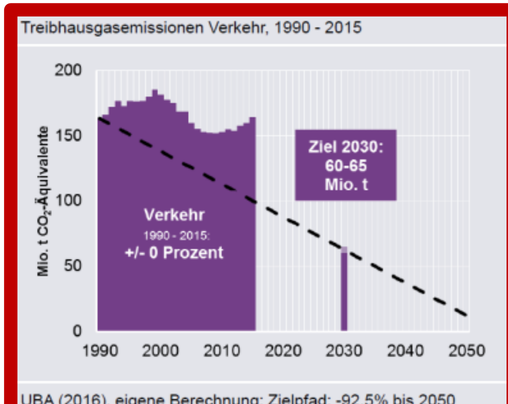
Industry (Target: -81%)



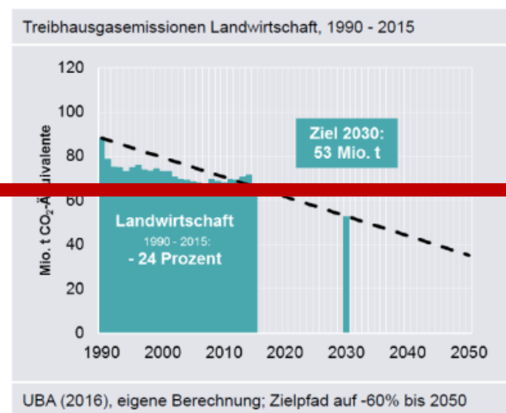
Residential/tertiary (Target: -92,5%)



Transport (Target: -92,5%)



Agriculture (Target: -60%)



Target significantly missed

Graphs: G. Rosenkranz,
Agora Energiewende (2017) & Umweltbundesamt (2016)

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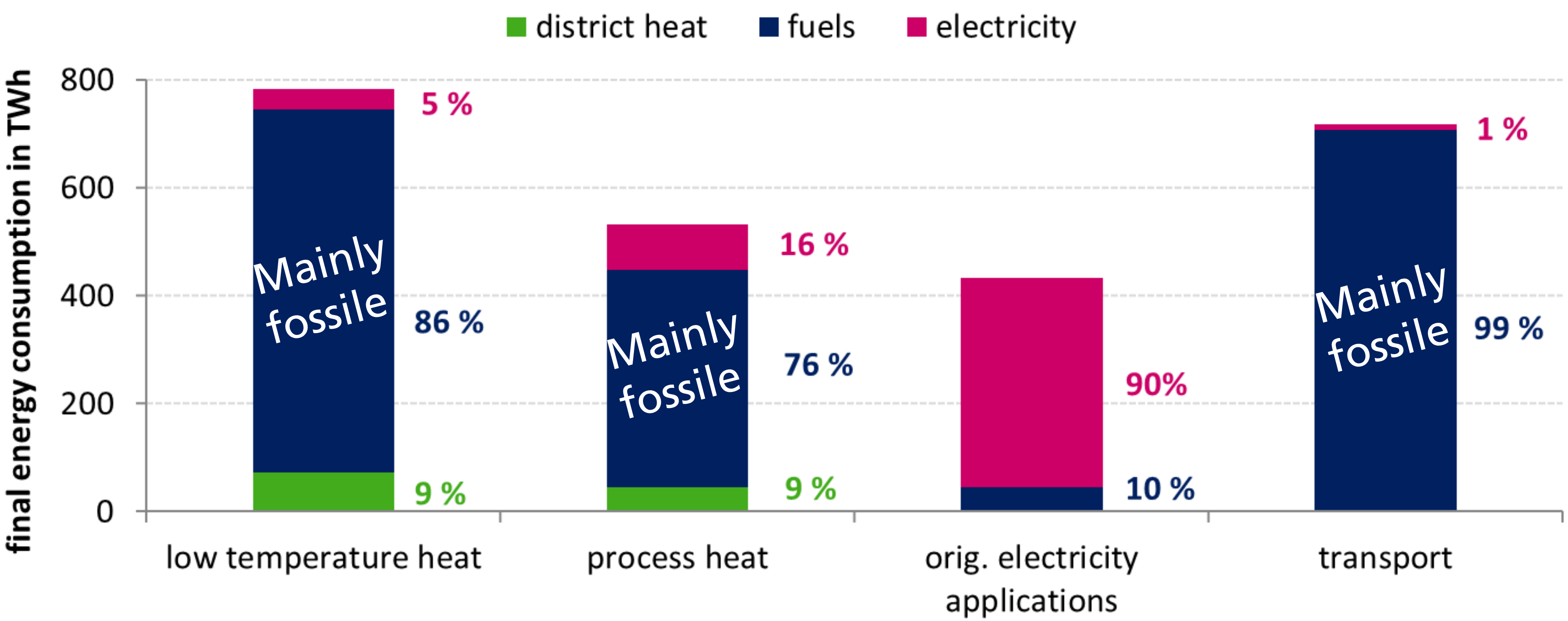
Energy demand of today

Composition of final energy



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

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Major questions

- How can heat (buildings, industry processes) and transportation 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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Renewable Energy Model »REMod«

Mimimize total annual costs

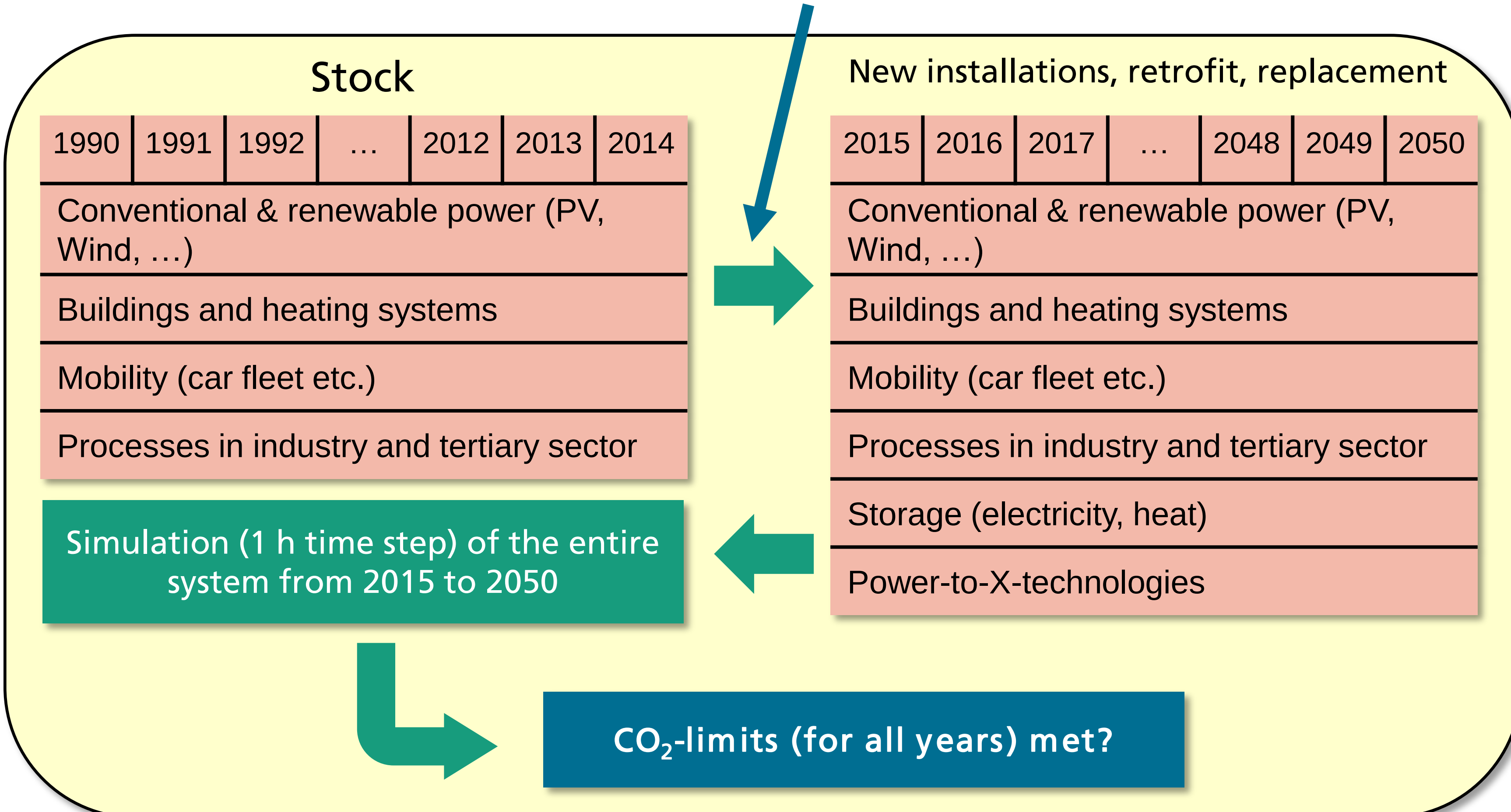
REMod

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

Methodology

Optimization of new installations, retrofit and replacement

goal function: minimal cumulative total cost 2015-2050



What can we expect from such model – and what not?

It can not …

… forecast the future

… describe business models for market participants

… desribe price building on the market

It can …

… draw possible, consistent transformation pathways and corresponding overall energy systems

… provide information on overall system costs (incl. investments, capital cost, M&O cost, fuel cost)
based on cost and performance projections for all potentially used technologies (generation, conversion, distribution, storage, end-use)

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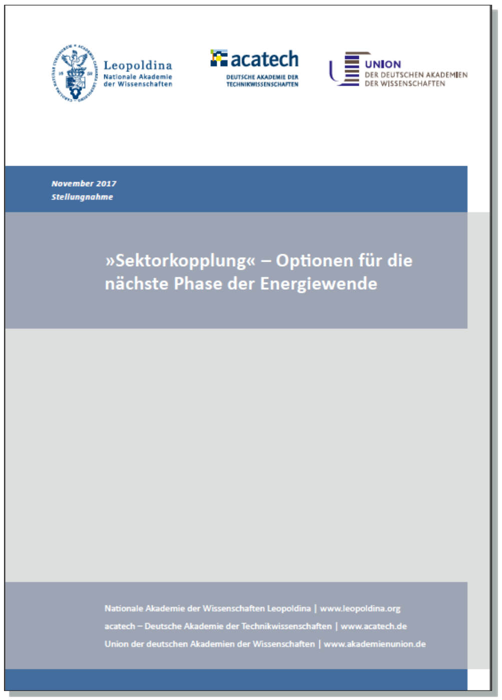
Source



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DER WISSENSCHAFTEN

November 2017
Stellungnahme

»Sektorkopplung« – Optionen für die nächste Phase der Energiewende

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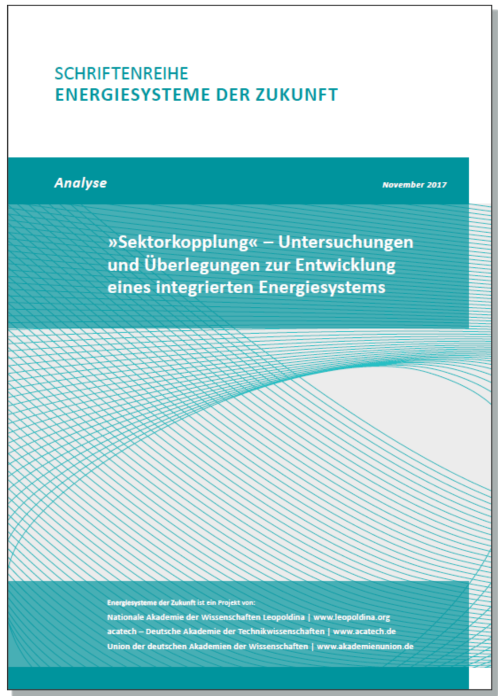

SCHRIFTENREIHE
ENERGIESYSTEME DER ZUKUNFT

Analyse
November 2017

»Sektorkopplung« – Untersuchungen und Überlegungen zur Entwicklung eines integrierten Energiesystems

Energiesysteme der Zukunft ist ein Projekt von:
Nationale Akademie der Wissenschaften Leopoldina | www.leopoldina.org
acatech – Deutsche Akademie der Technikwissenschaften | www.acatech.de
Union der deutschen Akademien der Wissenschaften | www.akademienunion.de

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/

Investigated boundary conditions

Target value for CO_2-emissions, others

Free optimization; no fixed boundary conditions

Predefined boundary conditions

Bezeichnung	60_offen	75_offen	85_offen	90_offen	85_H_2	85_PtG	85_offen+ Aktiv
CO_2-Ziel 2020 2030 2040 2050	-30% -4 -5 -6	-35% - - -	-40% - - -	-40% - - -	-40% - - -	-40% - - -	-40% - - -
Verbrauch originäre Stromanwendungen	wi (ca)	w ((h)	w ((h)	w ((h)	w ((h)	w ((h)	St in 2
Heizungstechnologien	off	o	o	o	o	W p a b	o
Verkehr	off	o	o	o	Pk st re (M e in %)	P B a M b	o
H_2 im Gasnetz in Vol%	5	5	5	5	3	5	5
Prozesswärmenachfrage in TWh	ca	c	c	c	c	Ir -	Ir -
Potenzial PV+Wind in GW	500	500	500	600	600	600	500

- 60 % CO_2 emissions

- 75 % CO_2 emissions

- 85 % CO_2 emissions

- 90 % CO_2 emissions

- 85 % CO_2; hydrogen

- 85 % CO_2; PtG/PtL

- 85 % CO_2; energy efficiency

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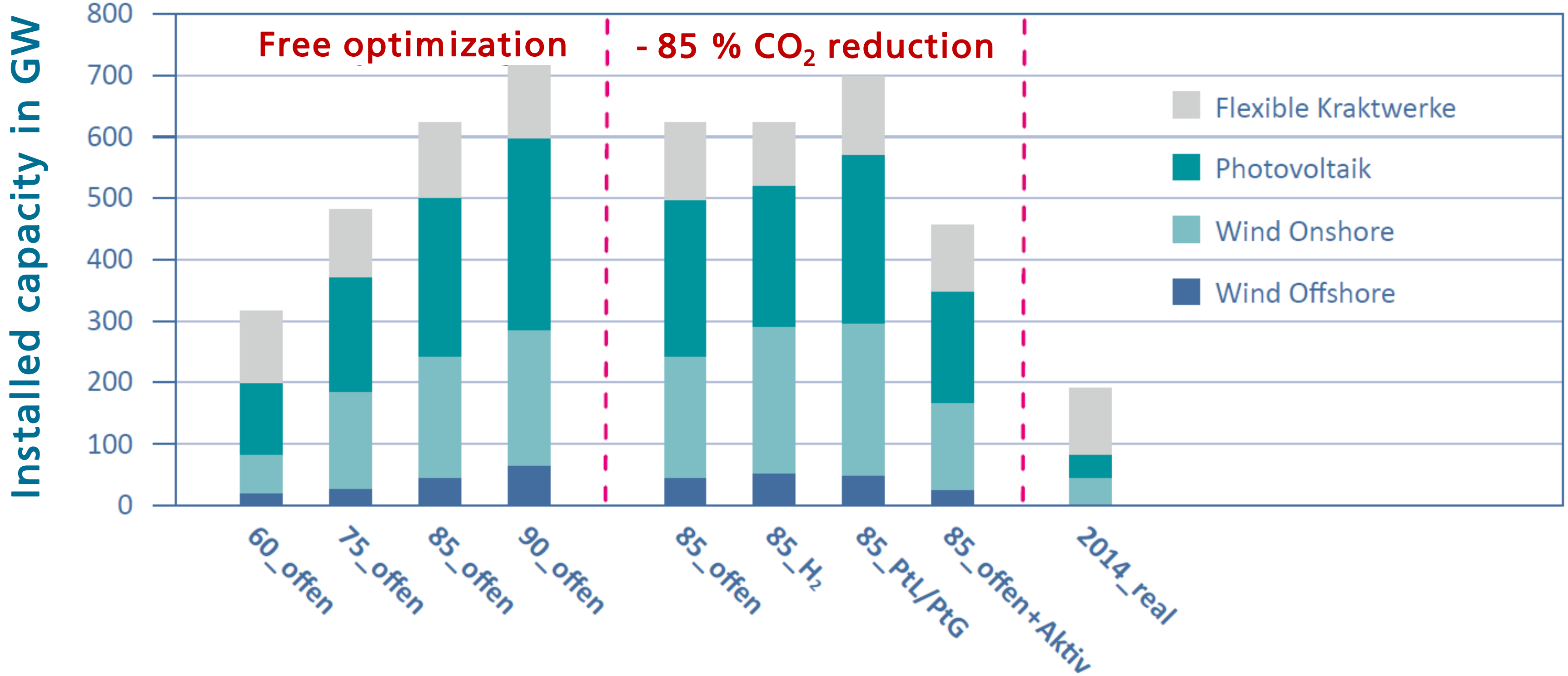
Electricity generation

Installed capaity in GW in 2050



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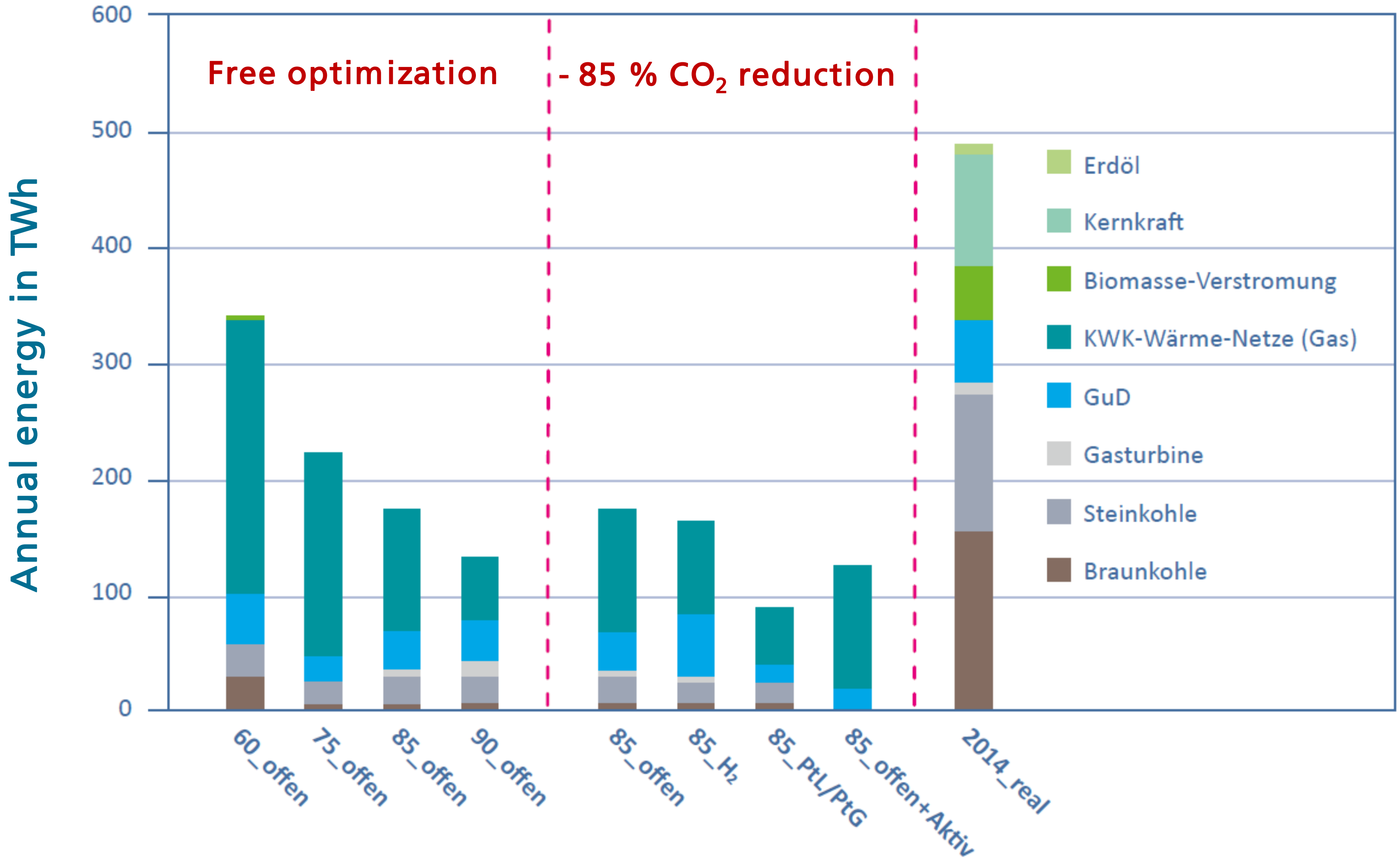
Electricity generation by flexible power plants

Annual energy in TWh in 2050



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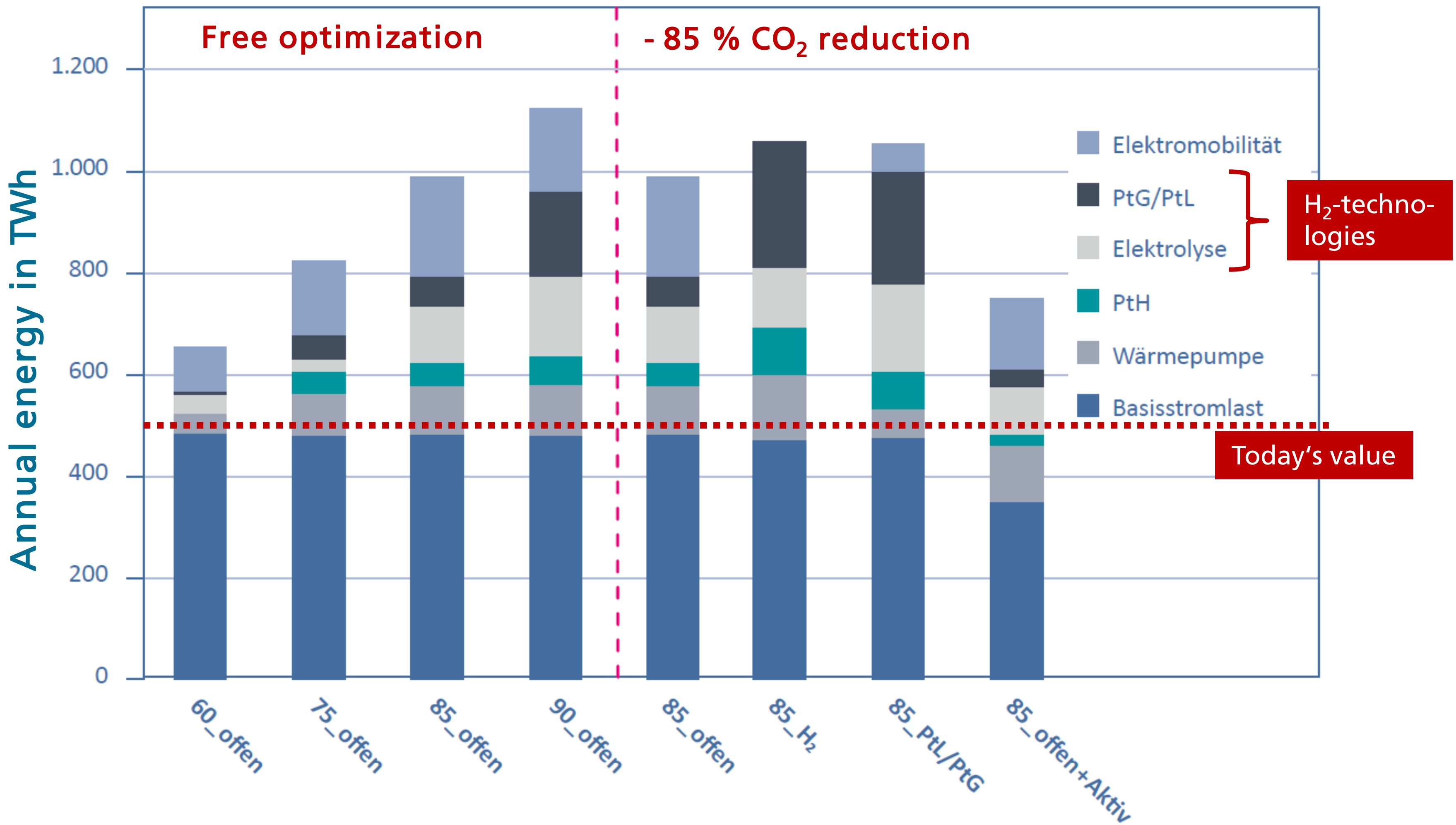
Electricity use

Basic electricity use and electricity for sector coupling in 2050



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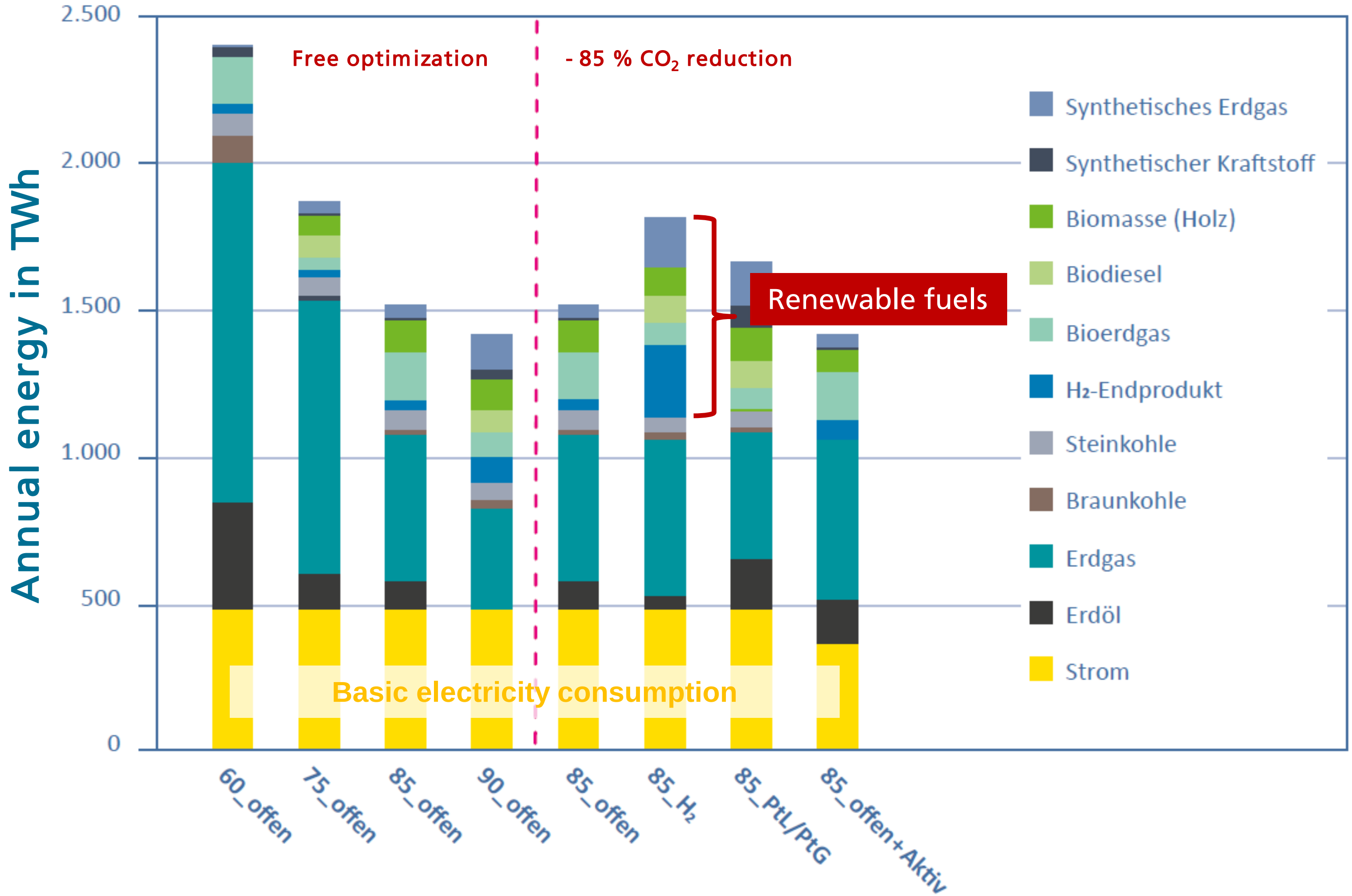
Chemical energy carriers (final energy)

Composition (2050)



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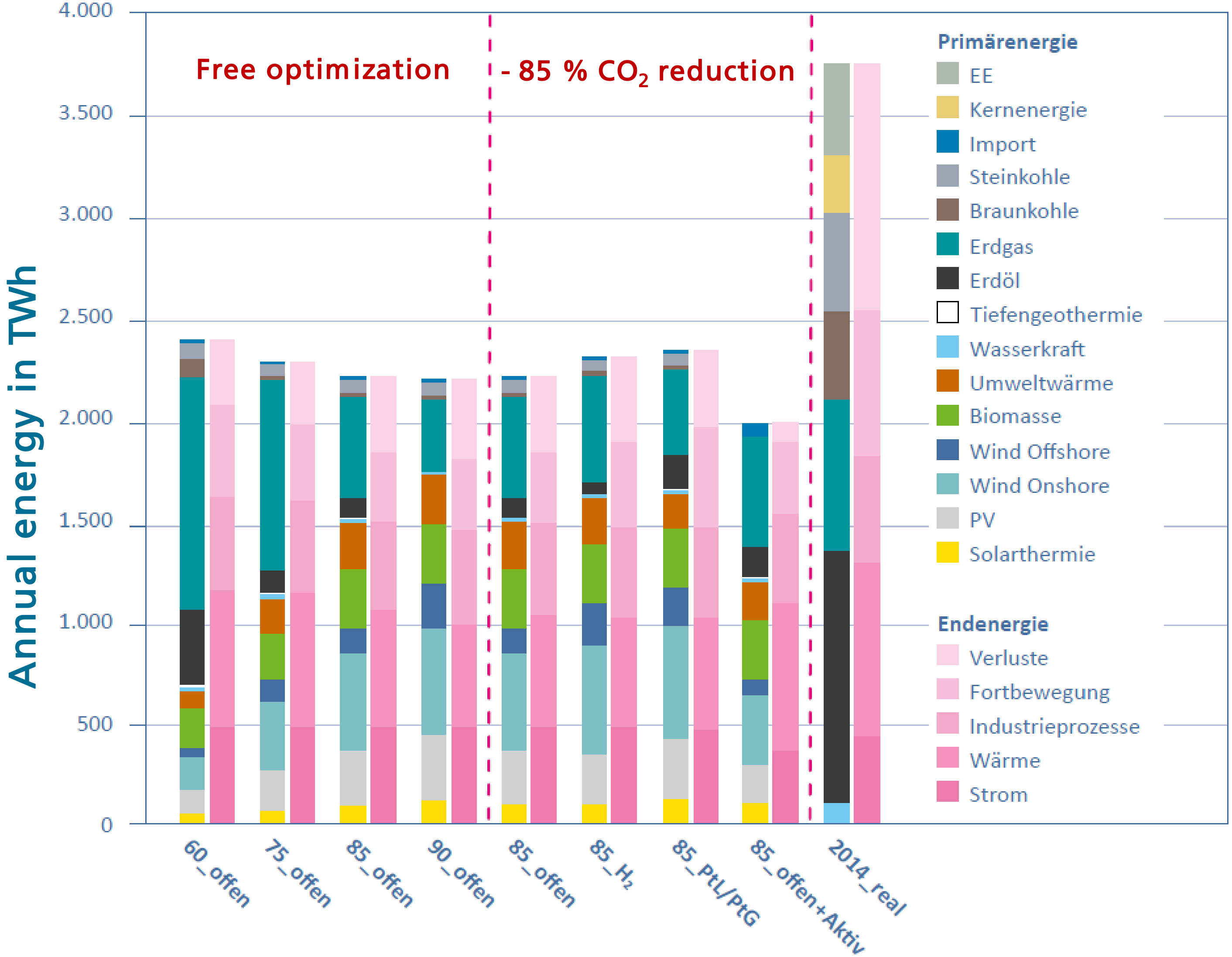
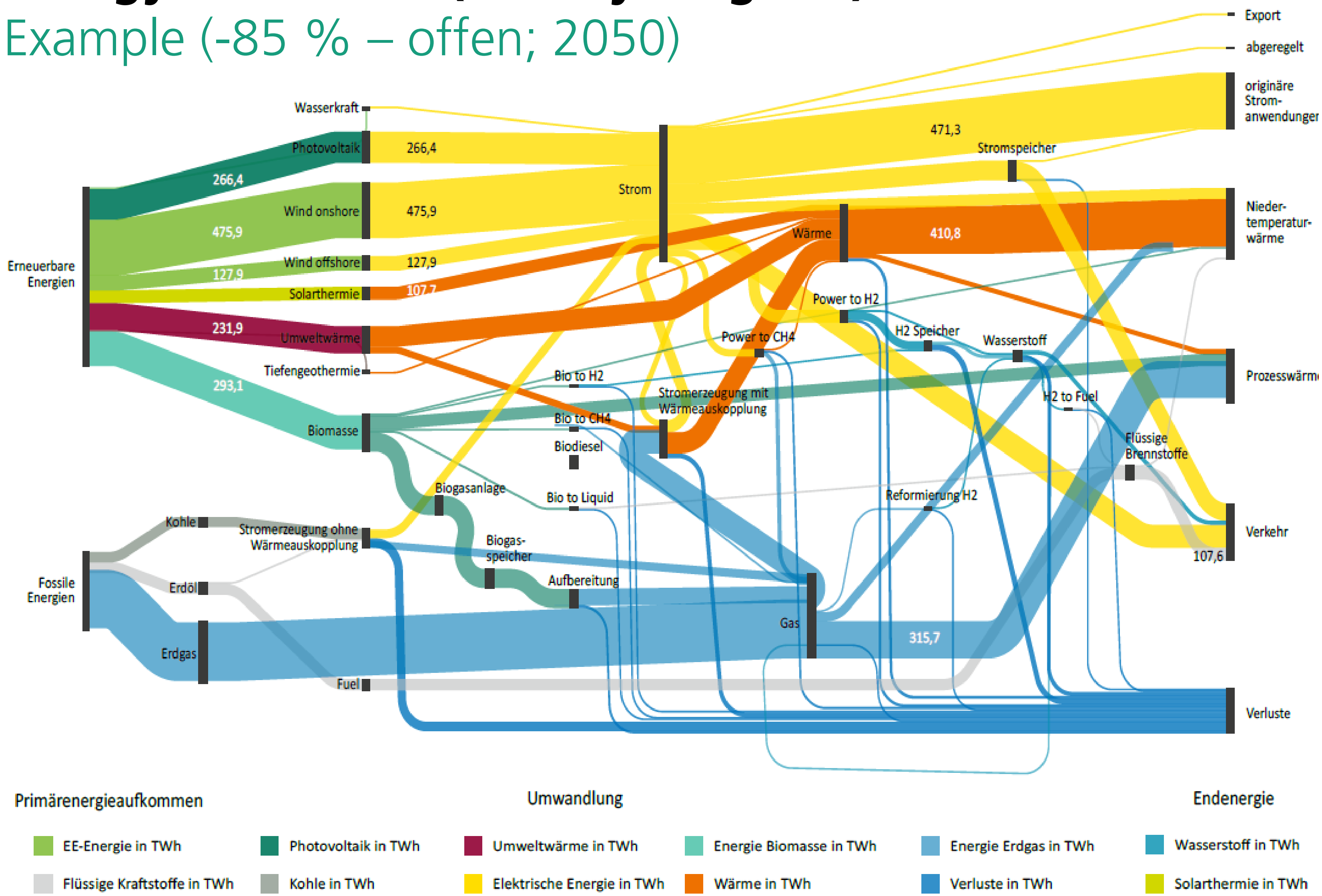
Primary energy (2050)



Energy flow chart (Sankey diagram)

Example (-85 % – offen; 2050)



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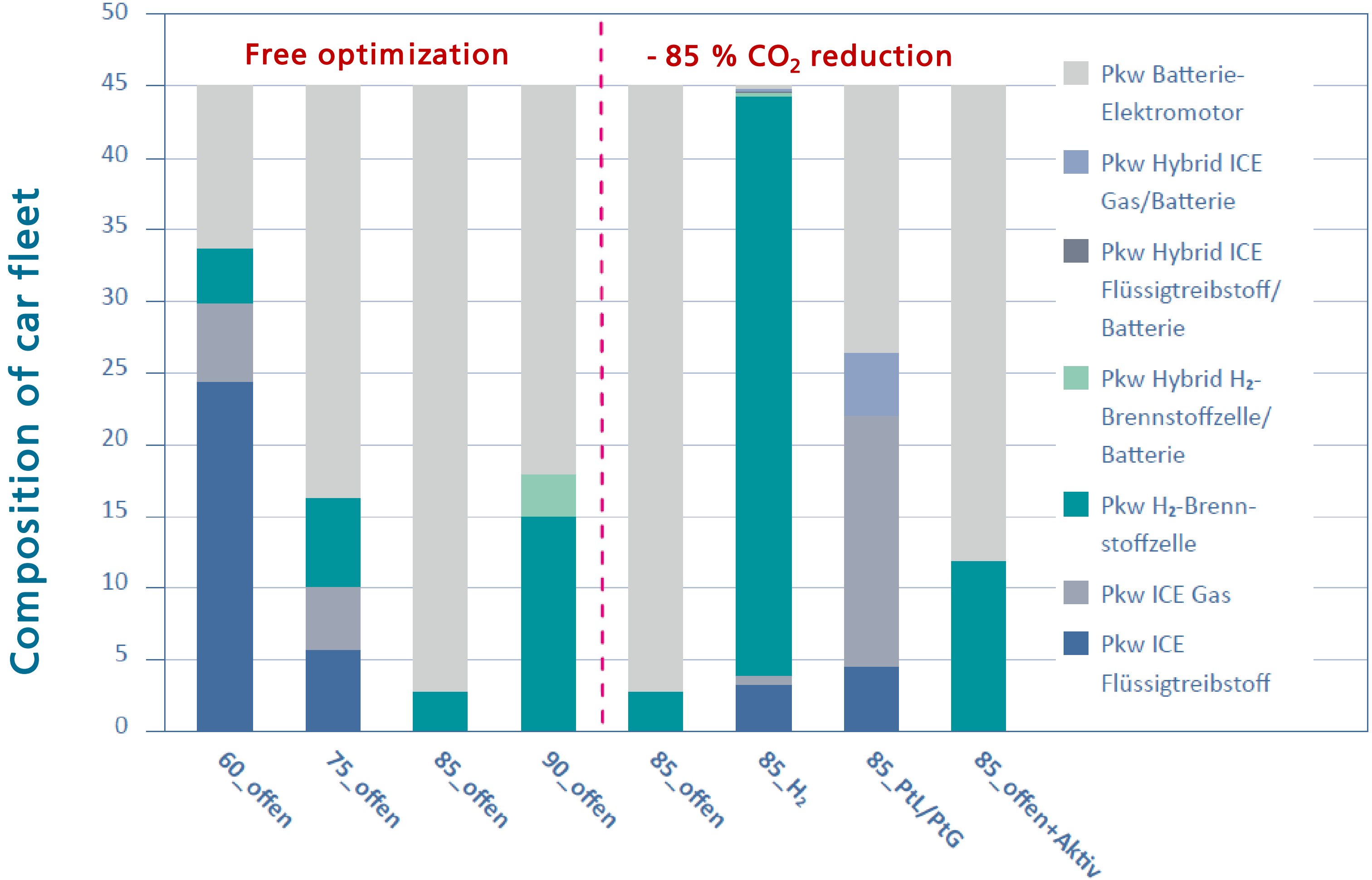
Individual cars

Composition in 2050



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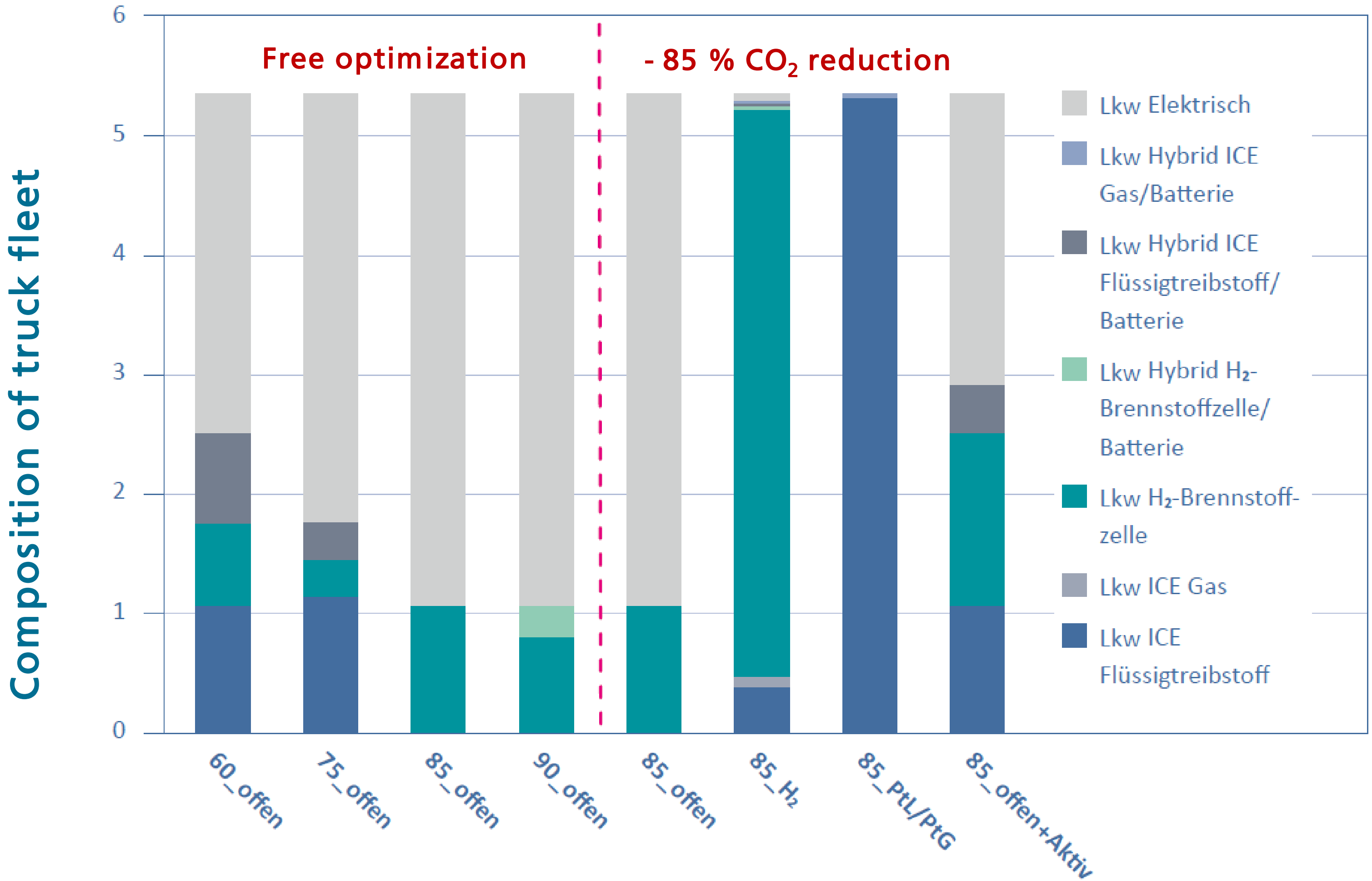
Trucks
Composition in 2050



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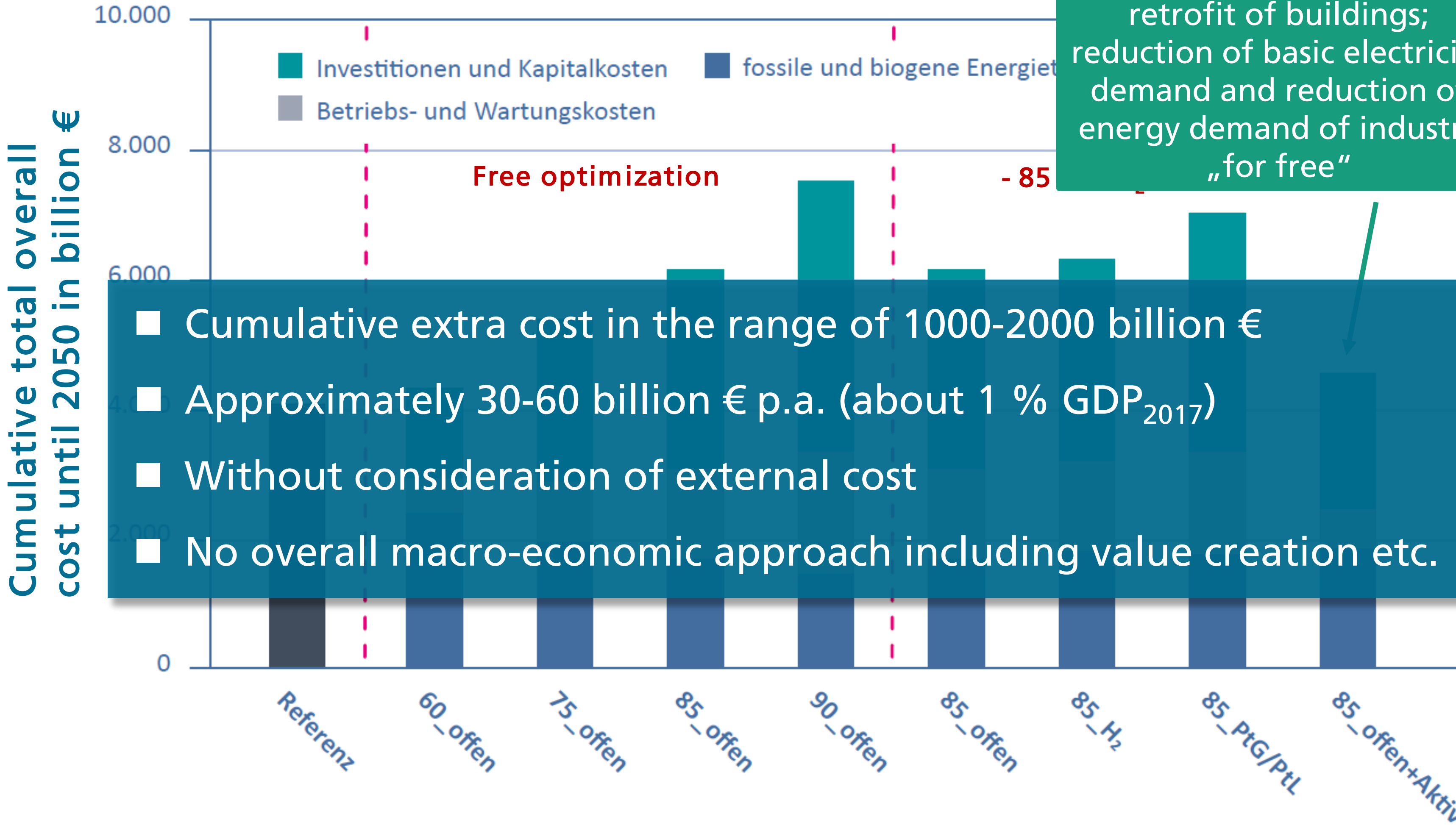
Cost

Cumulative total system cost until 2050 in billion €



Including cost for energy retrofit of buildings; reduction of basic electricity demand and reduction of energy demand of industry „for free“

- Cumulative extra cost in the range of 1000-2000 billion €
- Approximately 30-60 billion € p.a. (about 1 % GDP_{2017})
- Without consideration of external cost
- No overall macro-economic approach including value creation etc.

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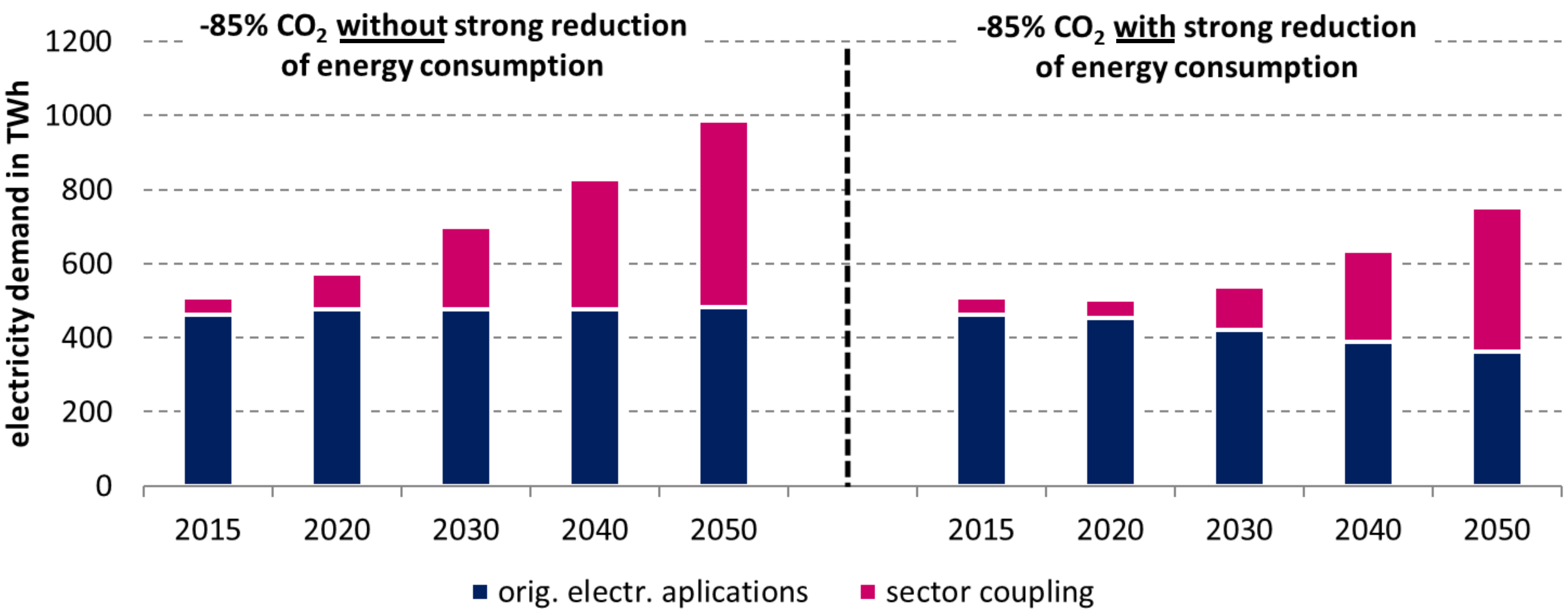
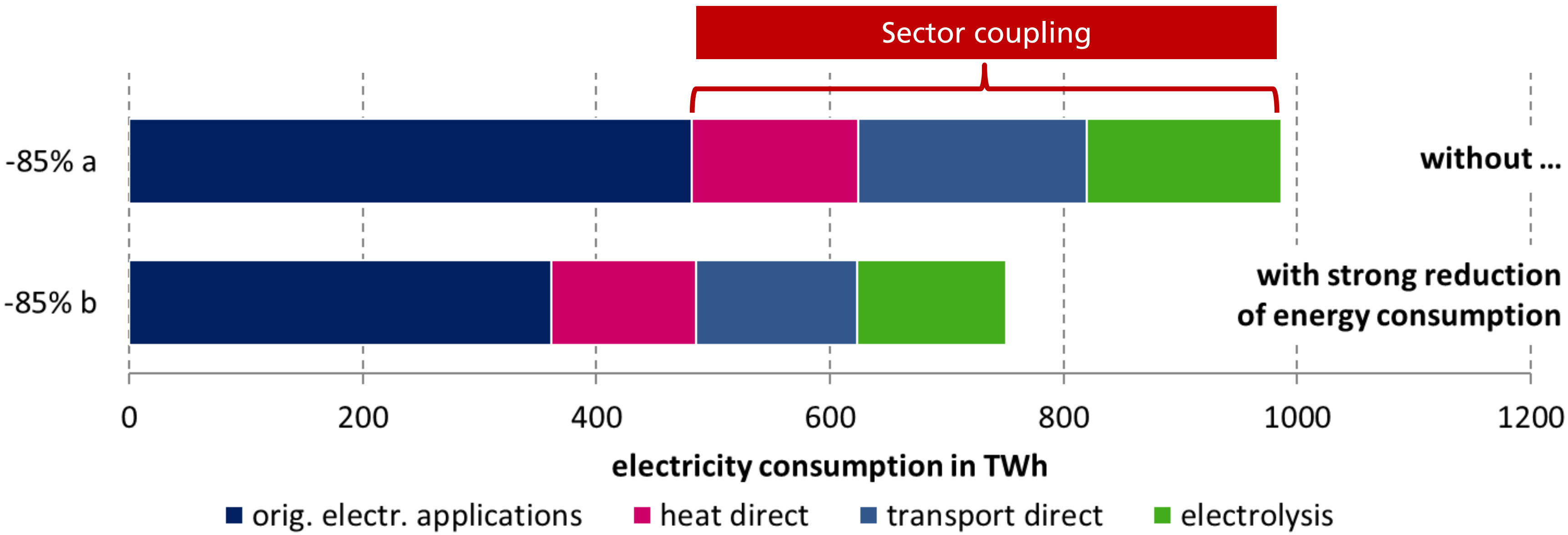
Development of electricity demand

-85 % - Scenarios



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

Composition of electricity use
-85 % - Scenarios: results for 2050



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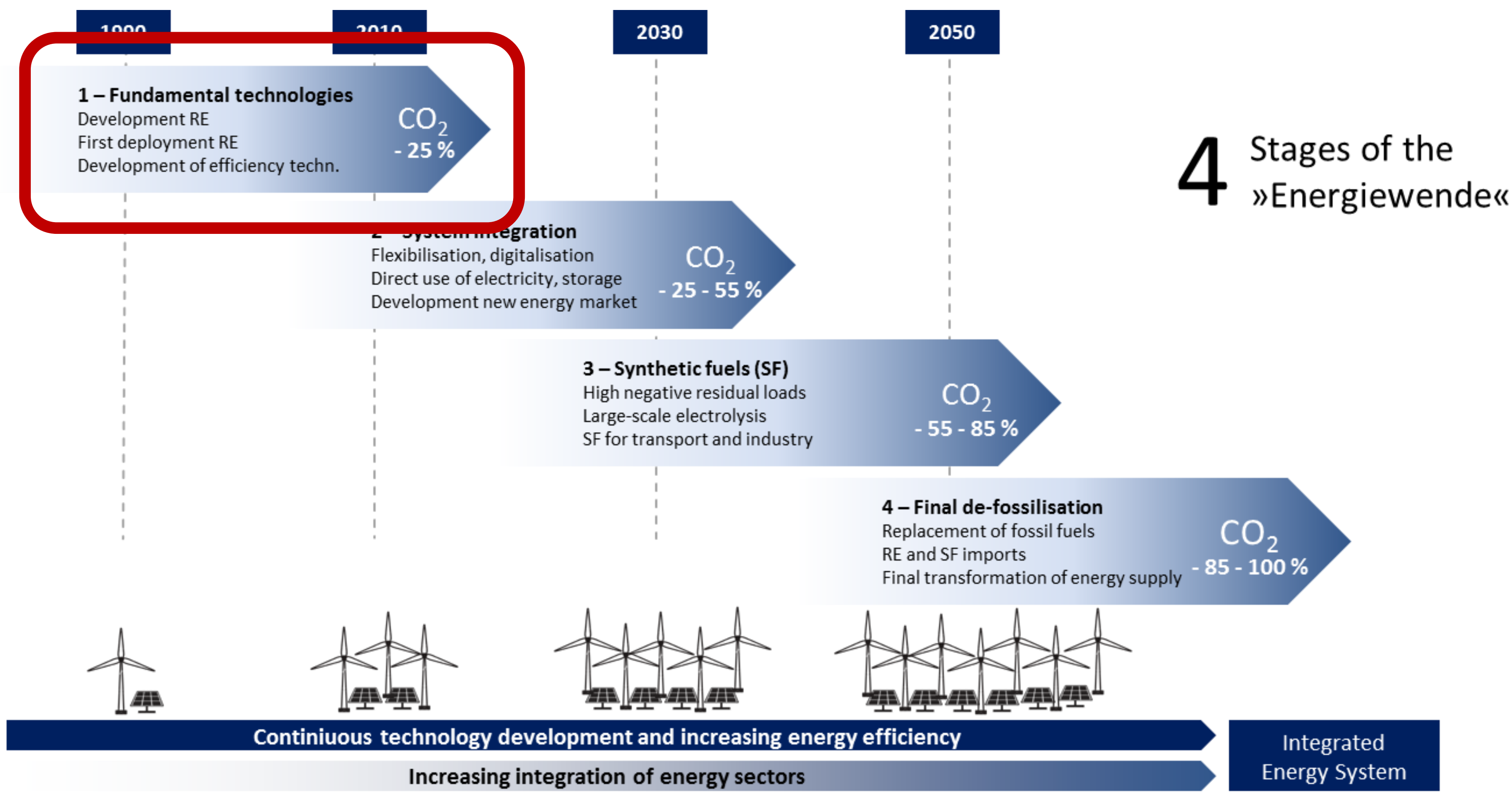

Source: »Sektorkopplung« - Optionen für die nächste Phase der Energiewende. Published by acatech, November 2017

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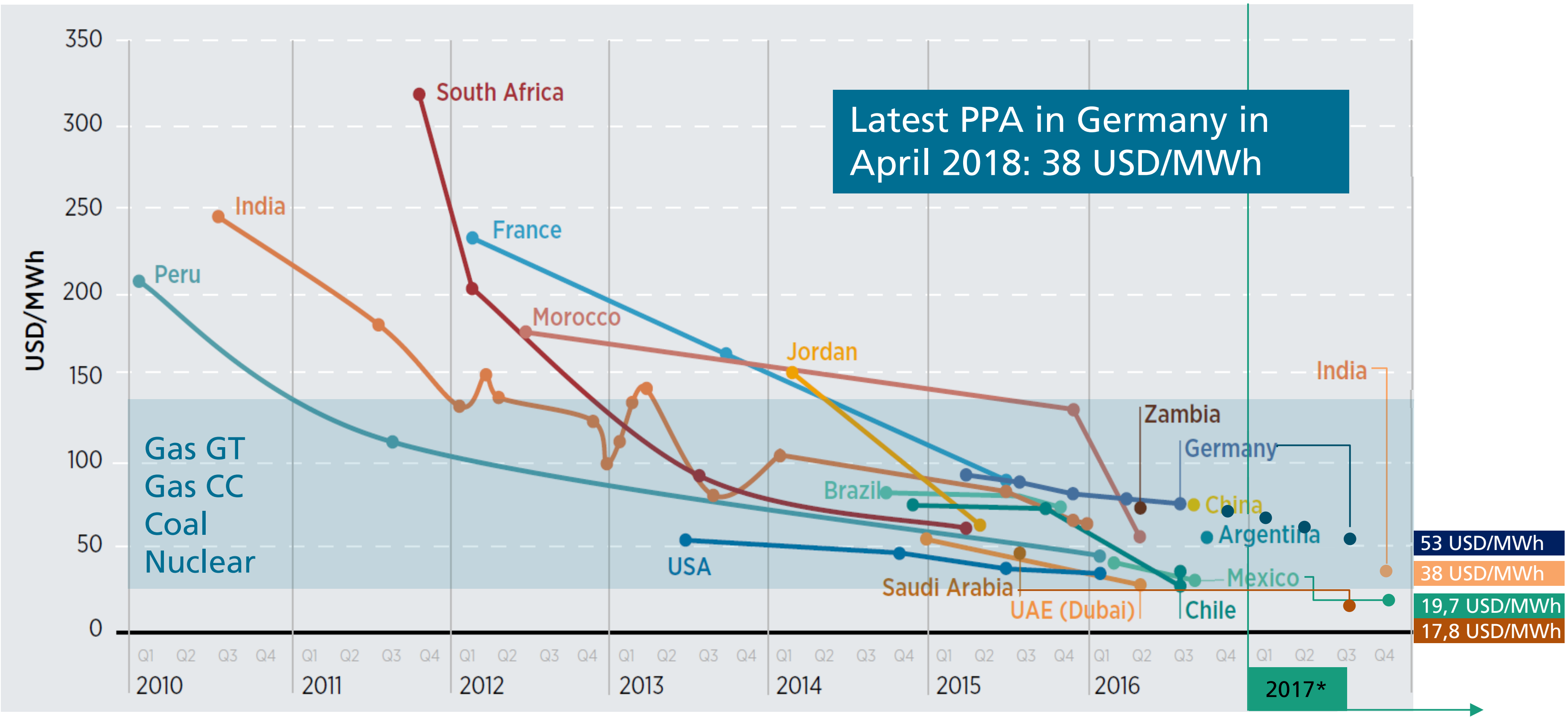
Average prices for PV electricity in PPAs

January 2010 - December 2017



Source: Renewable Energy Auctions 2016, IRENA
* Source: Fraunhofer ISE

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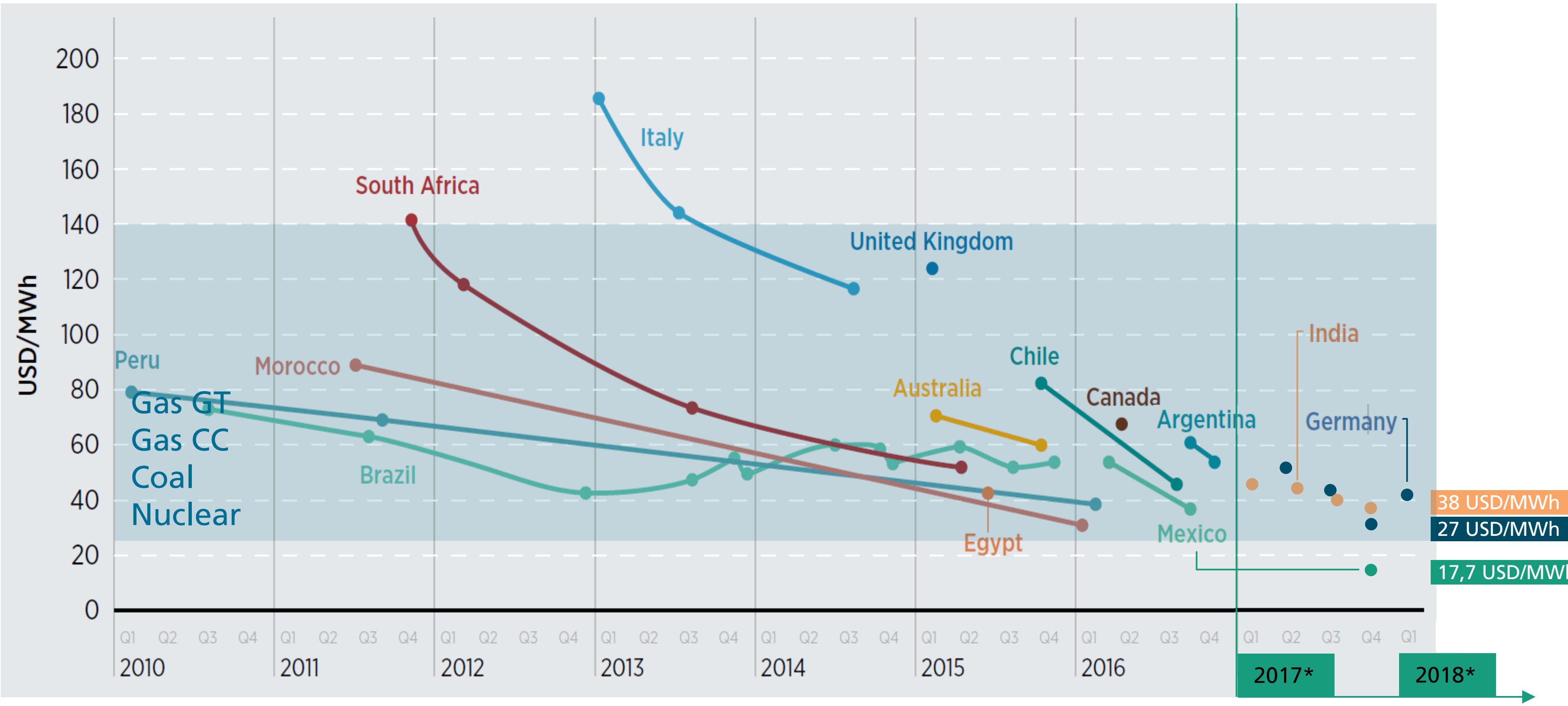
Average prices for Onshore-Wind electricity in PPAs
January 2010 - December 2017



Source: Renewable Energy Auctions 2016, IRENA
* Source: Fraunhofer ISE

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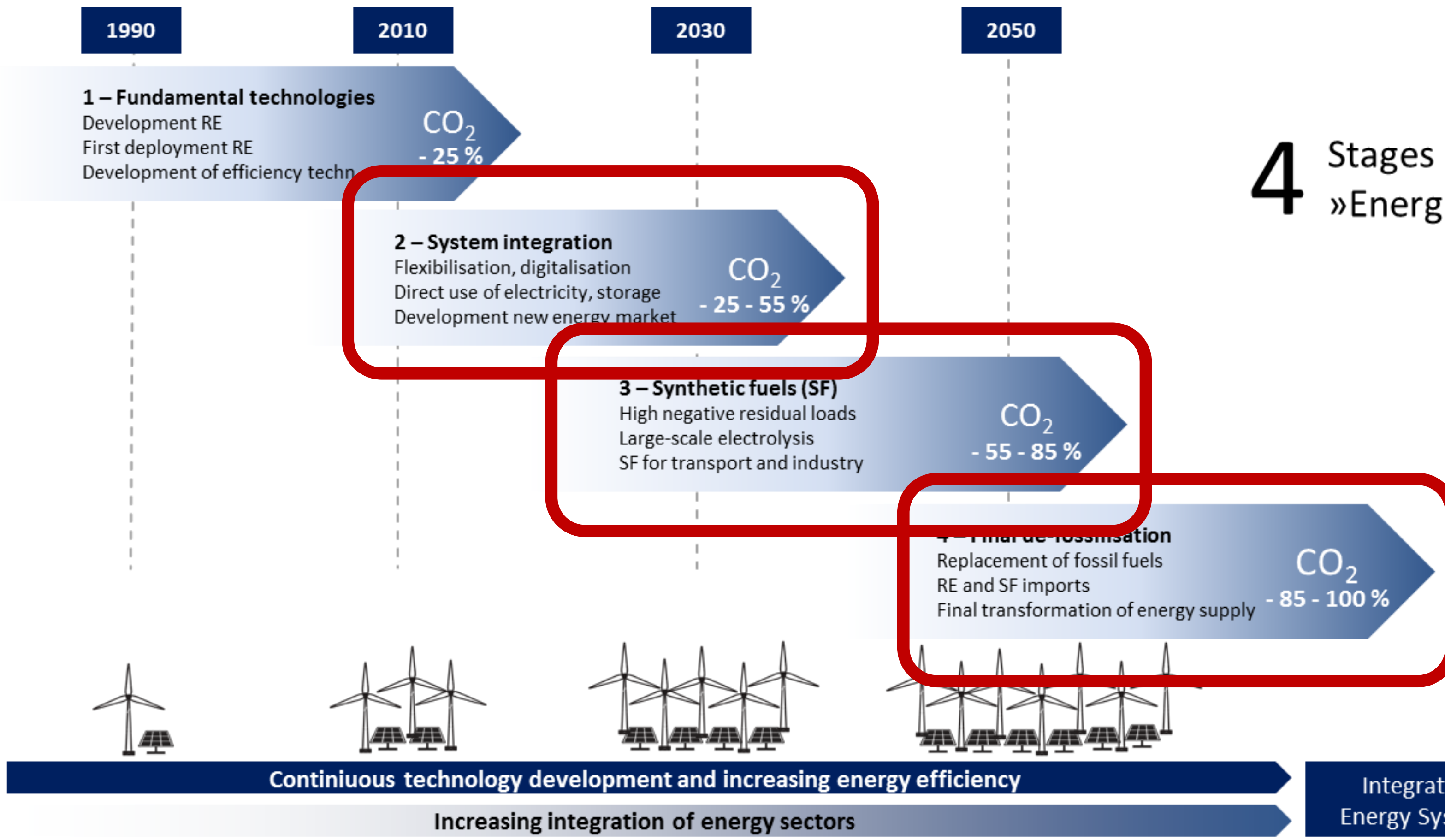
Phases of the energy system transformation



4 Stages of the »Energiewende«

Source: »Sektorkopplung« - Optionen für die nächste Phase der Energiewende. Published by acatech, November 2017

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- Transformation of energy systems in line with GHG emission reduction targets seems in principle technically feasible
- Renewable energies (solar, wind) become dominant and importance of electric energy increases
- Increased conversion efficiencies and consumption reduction important
- Coupling of sectors essential ➔ electricity use (directly, indirectly) for heat and mobility
- Short term storage and use of short term flexibilization options (e.g. load shifting, demand response)
- Large scale conversion of renewable electricity into synthetic energy carriers (hydrogen, liquids, chemicals, methane)
- Transformation cost competitive if CO_2 emissions appropriately penalized
- Anyhow cost competitive on the long run, i.e. once major investments have been made and the system transformation has been completed

Conclusions
General

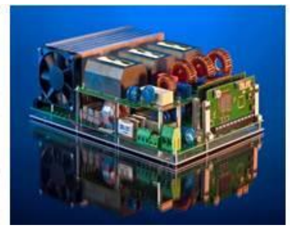
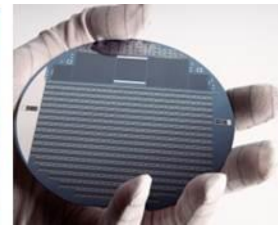
- A large scale direct use of electricity is indicated from a system perspective
- Electricity should be used directly where it is possible without major efforts
  - ➔ Electrical heat pumps in buildings with low temperature heating systems
  - ➔ Urban mobility concepts (public, individual, light trucks)
- Some kind of long term storage needed from a system perspective
  - ➔ Production of hydrogen by electrolysis with RE becomes a key technology
  - ➔ Hydrogen can be used in various applications such as re-electrification in fuel cells (mobile, stationary), chemistry or for production of synthetic fuels (liquid, gas)
- Most critical: needed capacity of renewable energy converters, in particular onshore wind ➔ societal acceptance

Conclusions
Mobility

- From a system perspective a large scale use of direct electricity is indicated
- However, also system developments with large scale use of hydrogen or large scale use of synthetic fuels and gases produced with RE are possible
  - More RE converters needed
  - Higher – but not substantially higher – overall cost
- Most probably other criteria will be decisive which drive concepts will be used for which application
- All technology options should be further developed
- An effective CO_2 pricing mechanism would be most helpful

Many thanks for your attention…

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