SECTOR COUPLING AND SYSTEM INTEGRATION

Key elements of the next phase of the energy system transformation

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Fraunhofer Institute for Solar Energy Systems ISE

Grand Renewable Energy 2018
International Conference and Exhibition

June 17-22, 2018
Pacifico Yokohama, JAPAN

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Business Areas

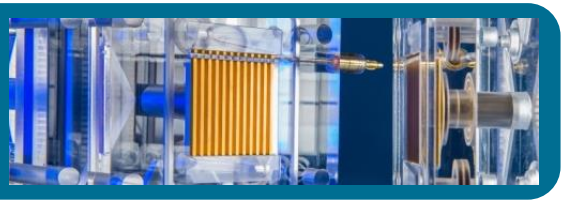
Annual budget 80 Mio €
Approx. 1300 employees

Energy technologies and systems

- Solar Thermal Technology

- Building Energy Technology

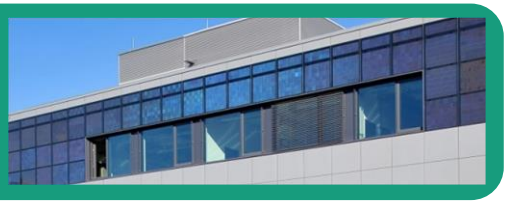
- Hydrogen Technology



- Energy System Technology & Energy Storage

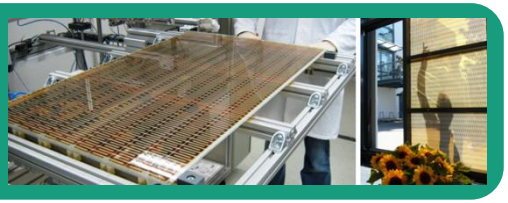
Photovoltaics

- 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 and Europe

Optimization of transformation pathways – methodology

Results

Phases of energy system transformation

Conclusions

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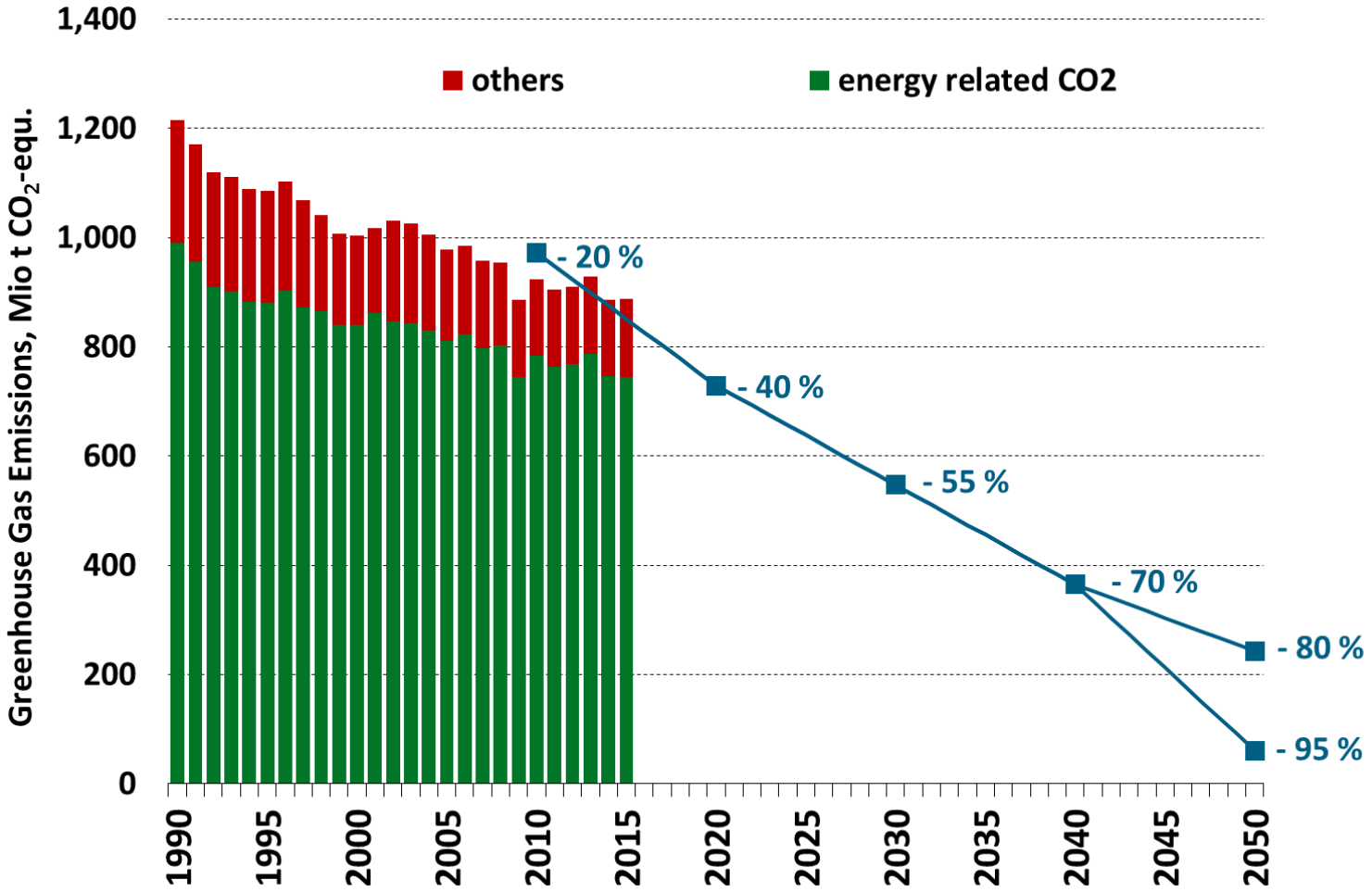
Deep transformation of our energy systems

- 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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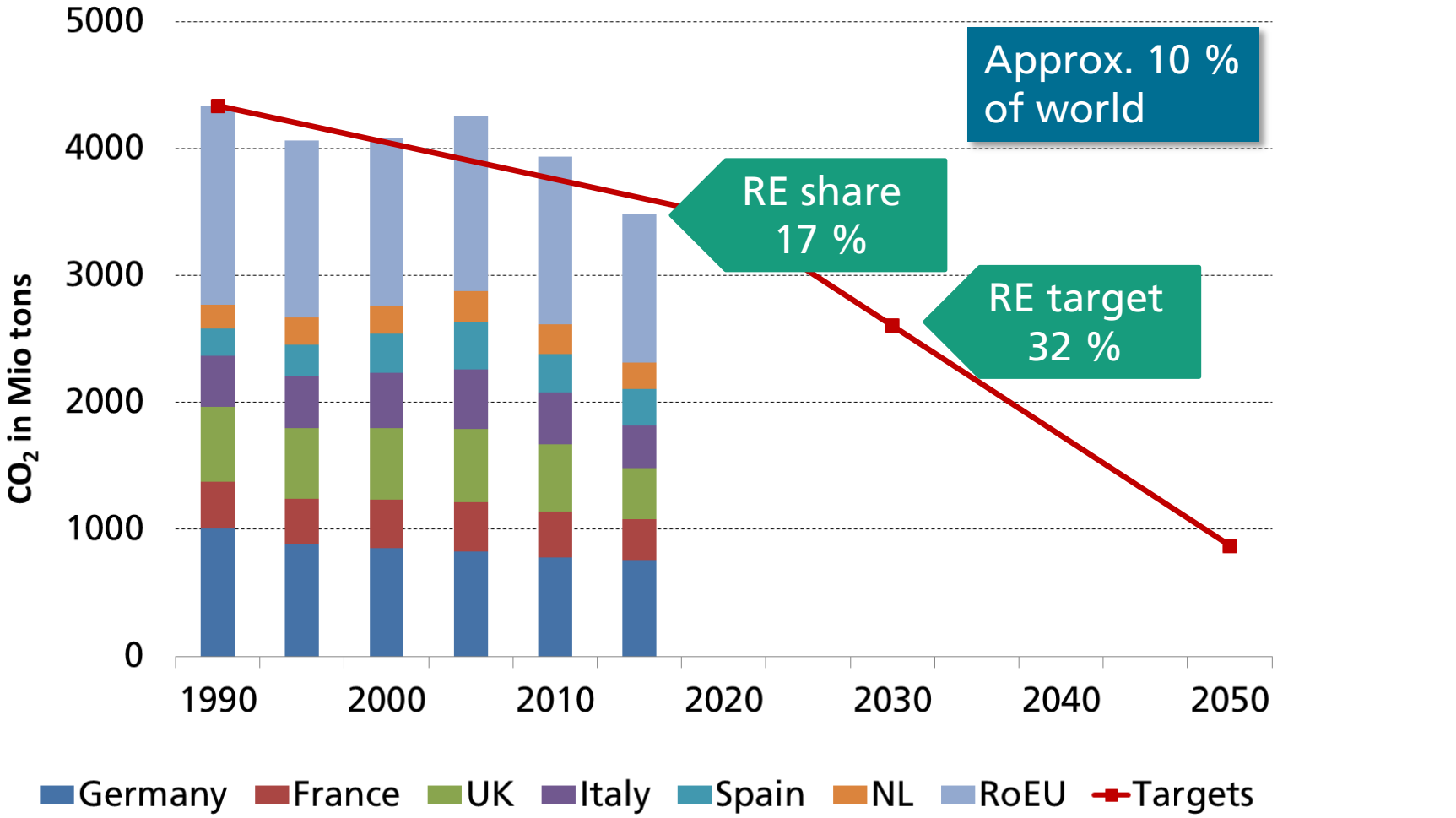
European Union CO_2 emissions

Historical values 1990-2016 and target values until 2050



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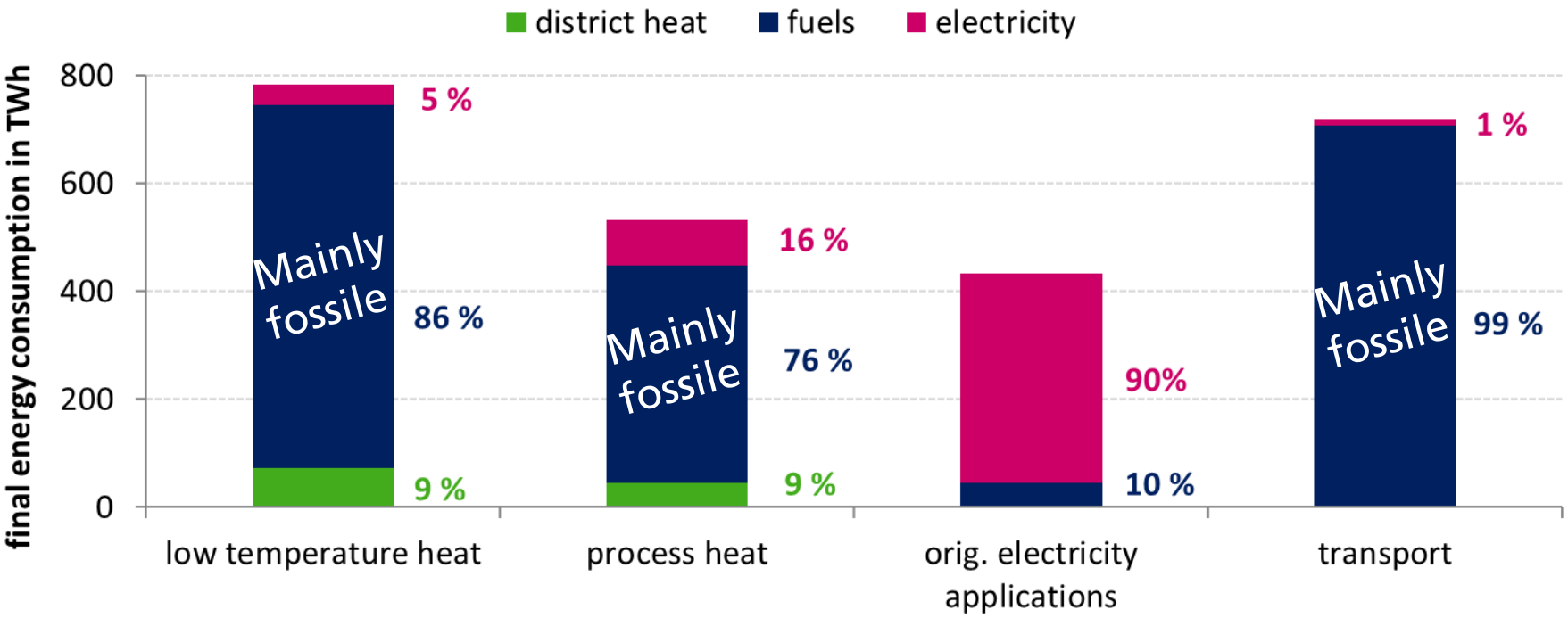
German energy demand of today

Composition of final energy



Source of data: „Energiedaten, Gesamtausgabe“, BMWi, 02/2017

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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 security of supply and at minimal cost?

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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)

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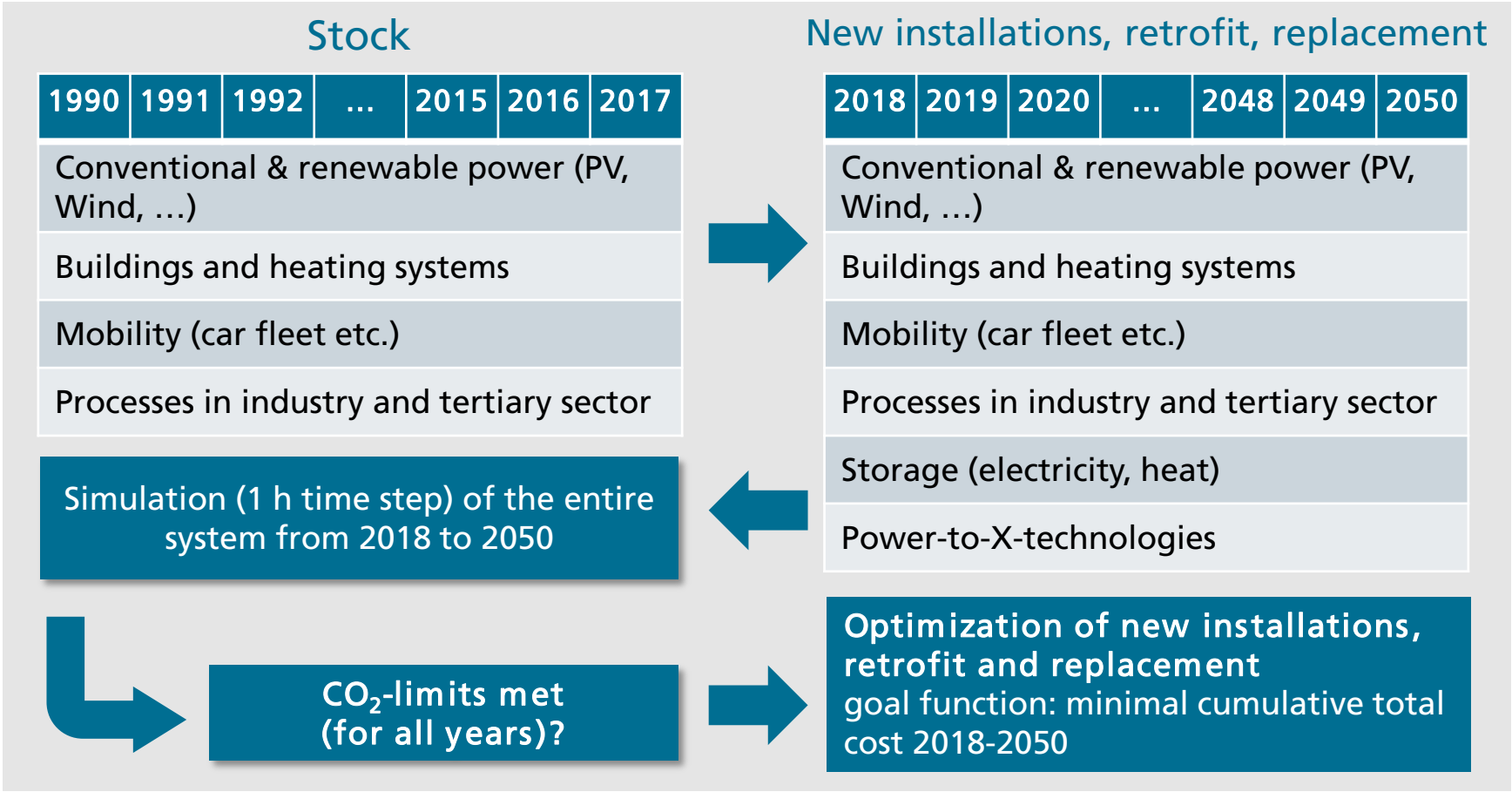
Methodology



Work from the German academies of science

Investigated transformation pathways

Scenario	CO_2 goal	Major characteristics
No restrictions	Minus 85 % in 2050 (compared to 1990)	❑ No limits for direct electricity use (e.g. heat pumps, transportation)
Hydrogen		❑ Transportation with majority of hydrogen / fuel cell drive trains ❑ High fraction of H_2 in gas network
Power-to-Gas Power-to-Liquid (P2G/P2L)		❑ Transportation with majority of fuel/methane based drive trains ❑ Building heating partly based on methane ❑ Good progress in efficiency in industry
High efficiency		❑ No limits for direct electricity use ❑ Good progess in implementing high efficiency technologies ❑ Good progress in reducing energy demand

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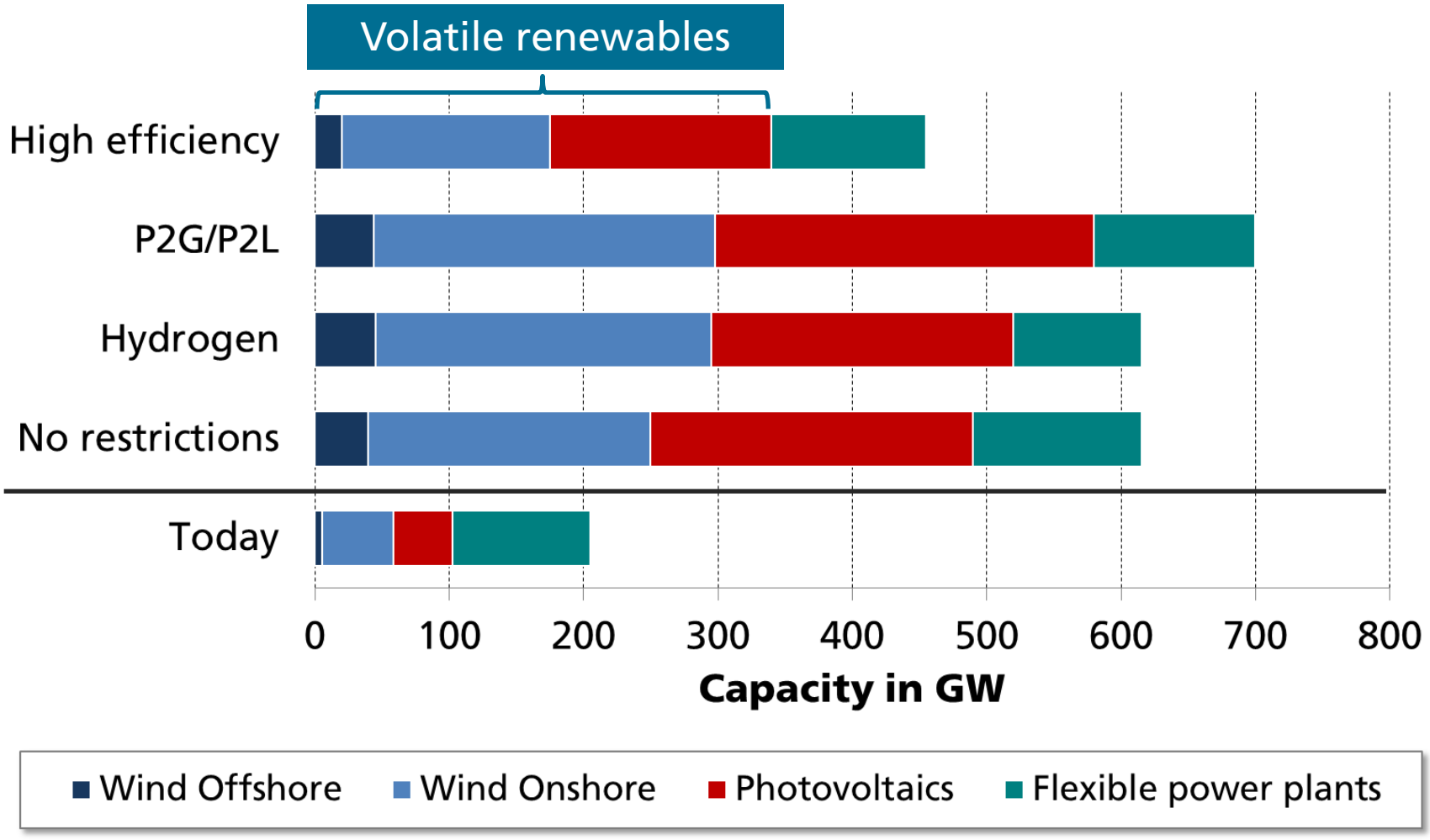
Installed capaity in GW in 2050 and today



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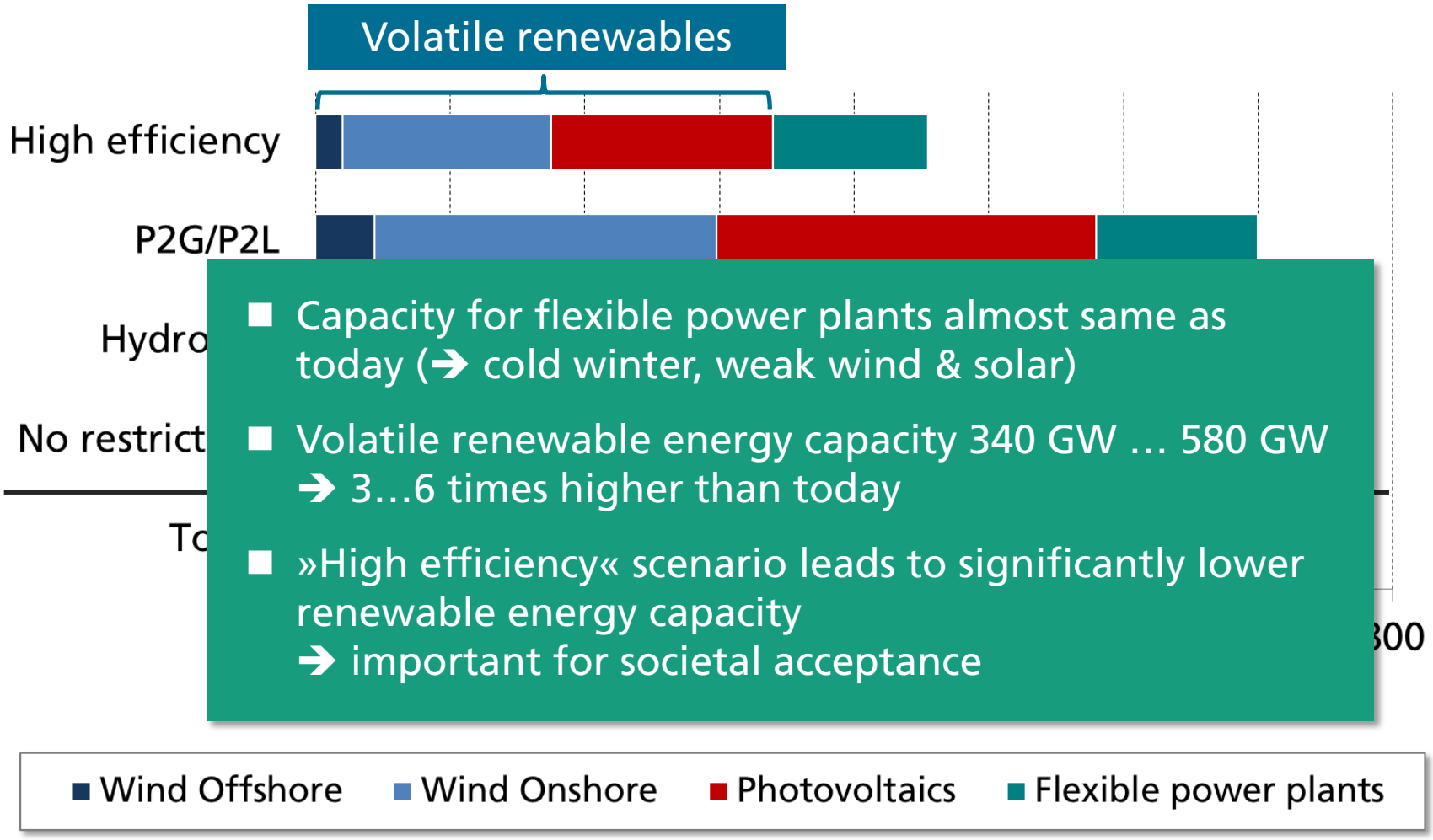

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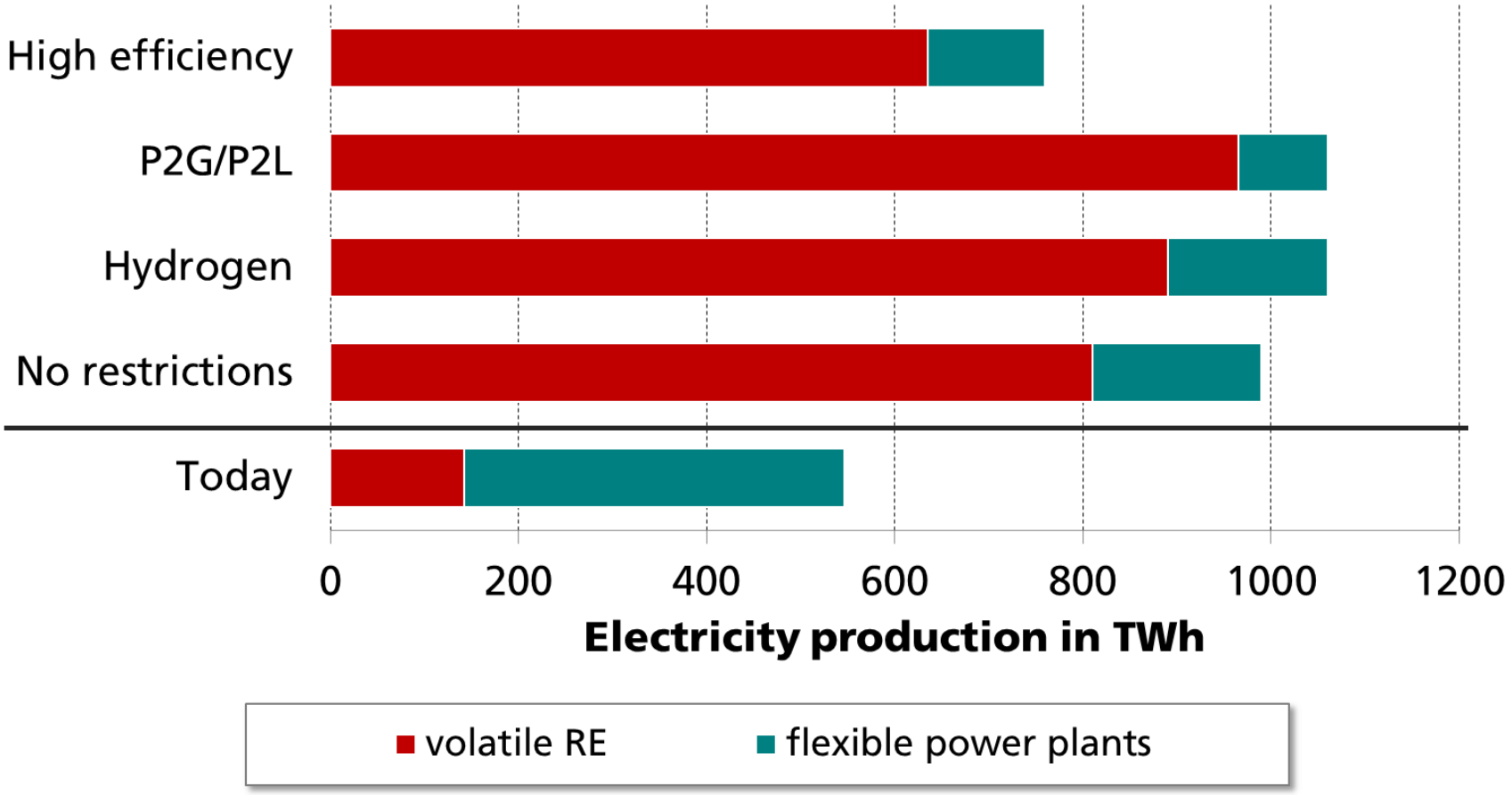
Electricity generation

Annual energy in TWh in 2050 and today



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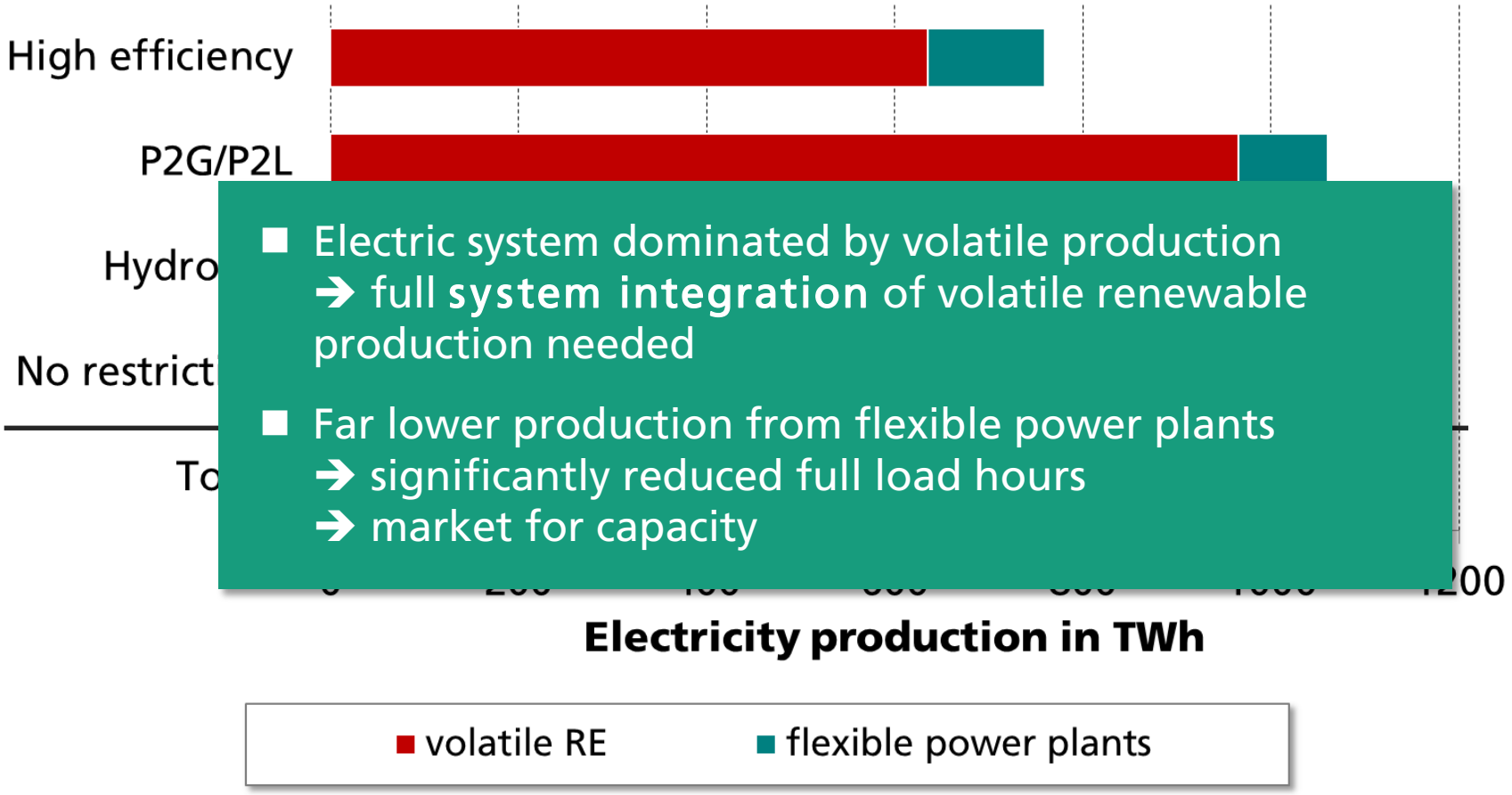

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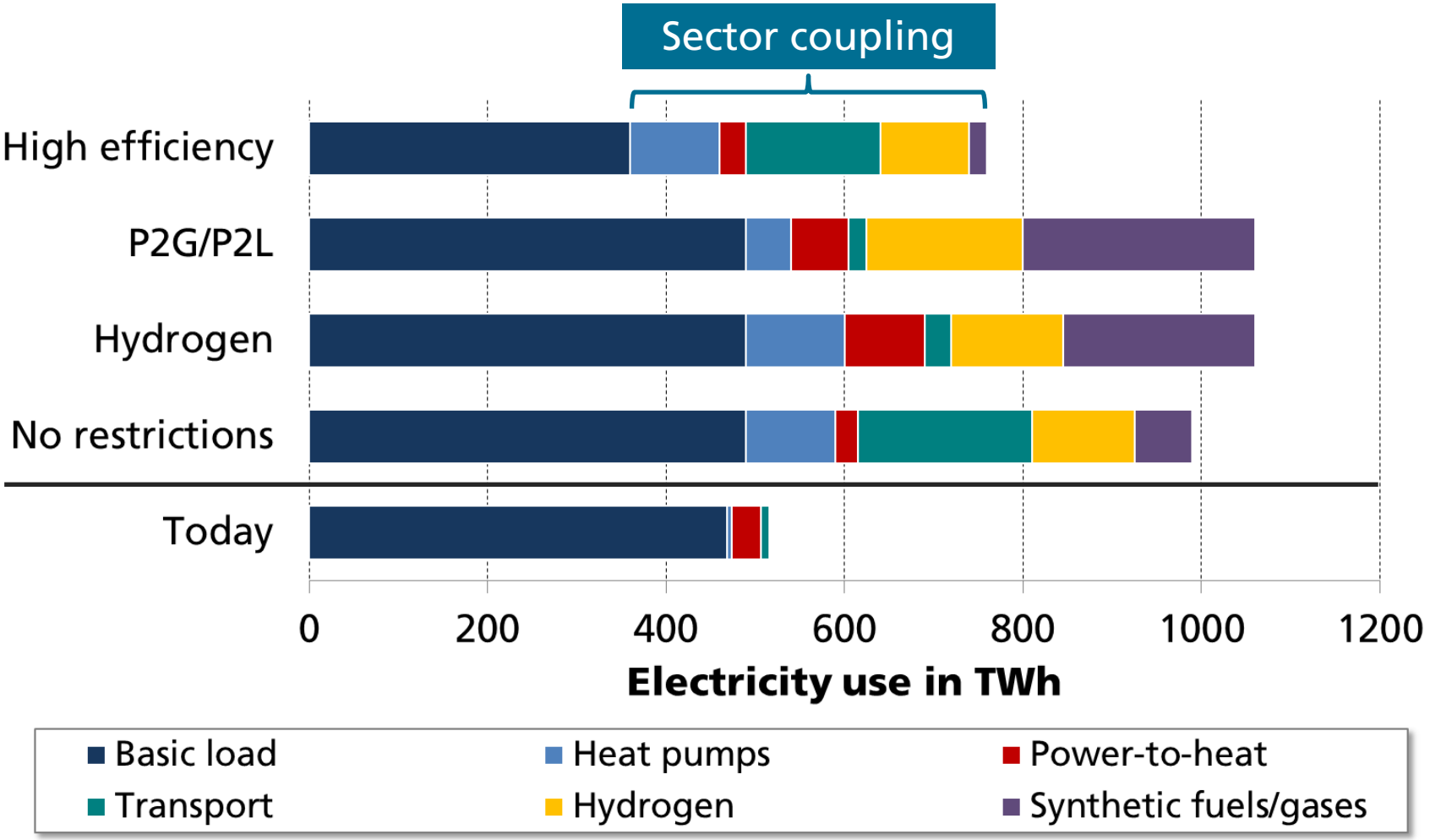
Electricity use

Annual energy in TWh in 2050 and today



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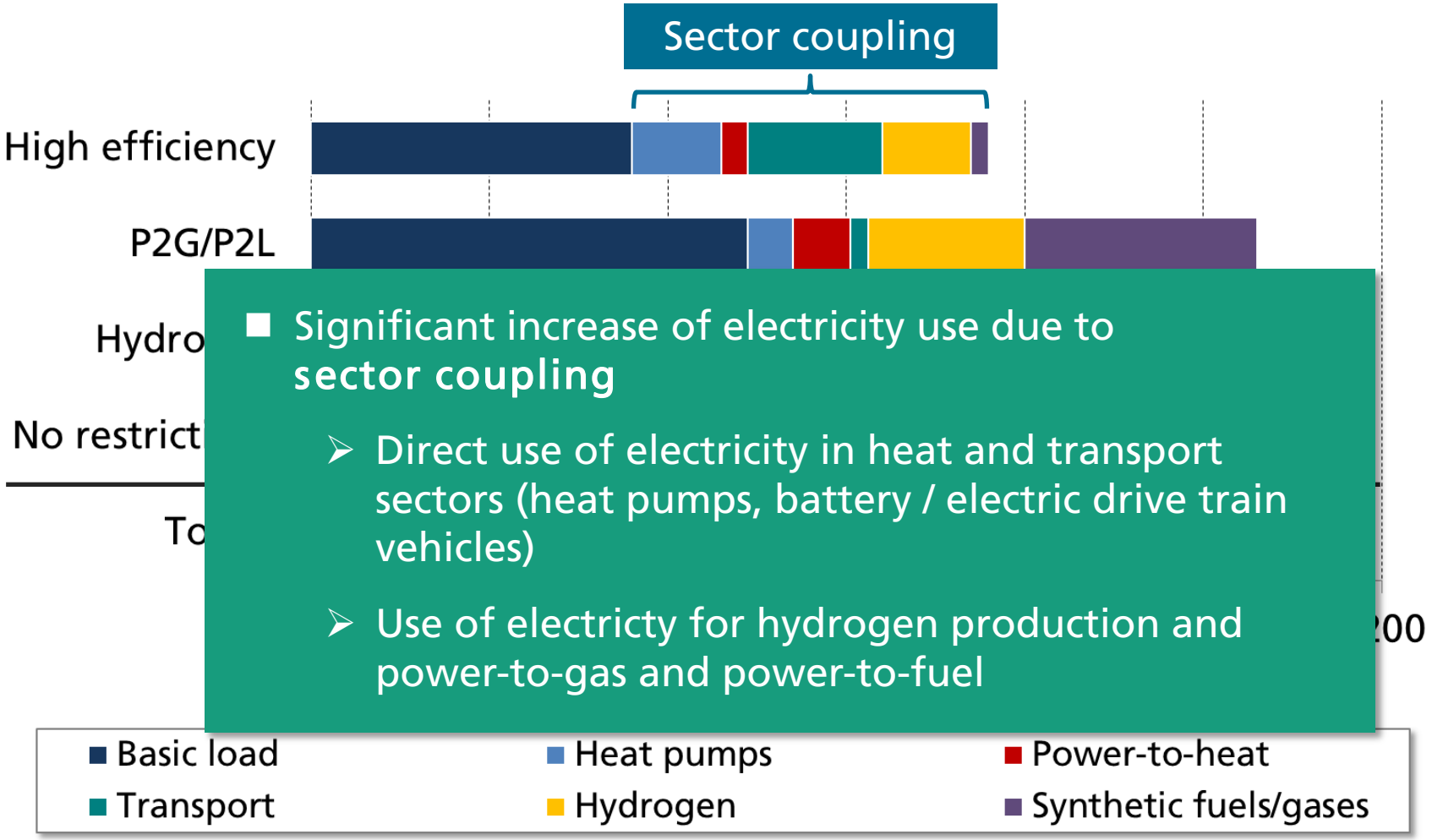

- Significant increase of electricity use due to **sector coupling**
  - Direct use of electricity in heat and transport sectors (heat pumps, battery / electric drive train vehicles)
  - Use of electricty for hydrogen production and power-to-gas and power-to-fuel

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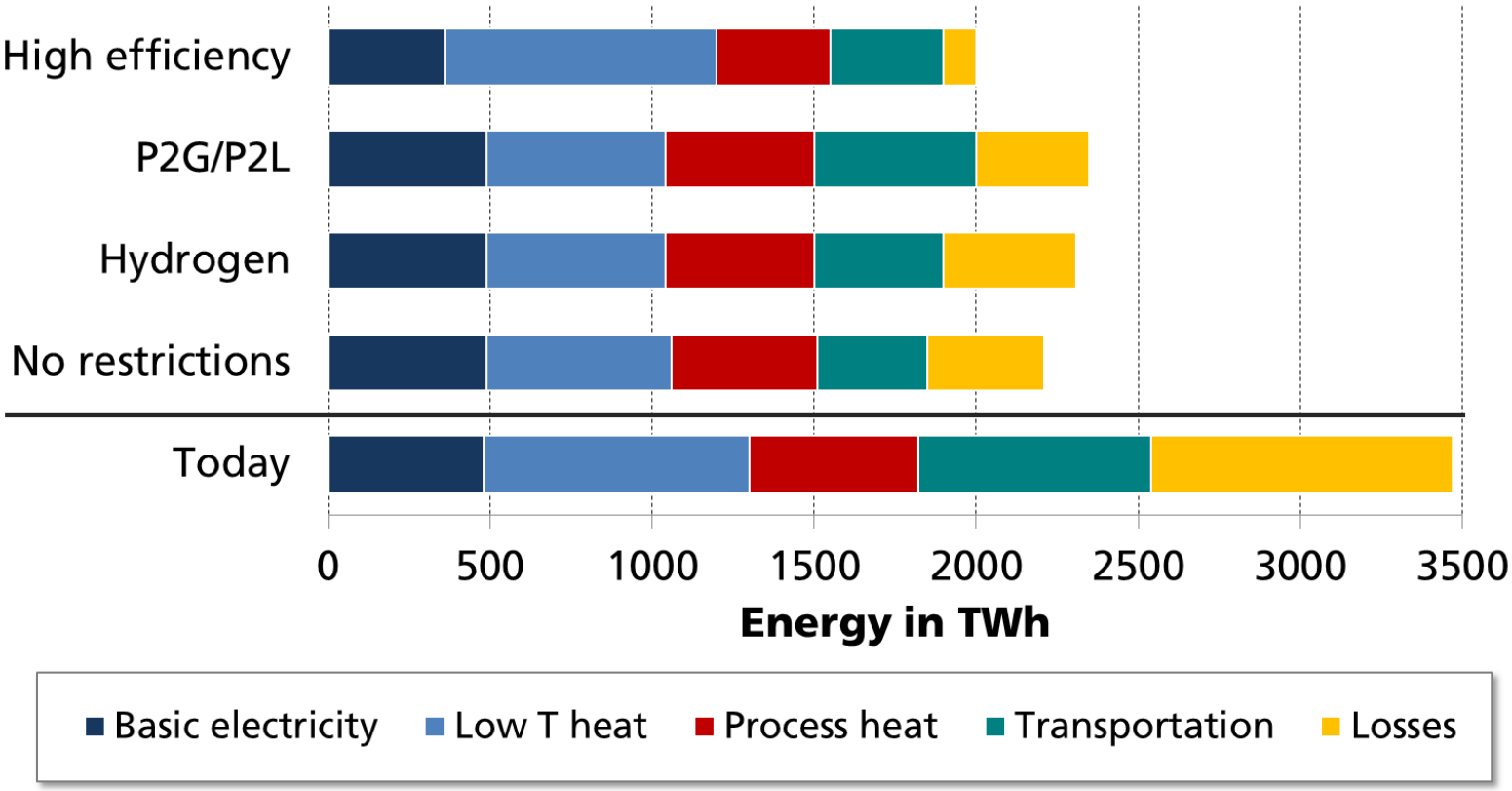
Primary energy and final energy

Annual energy in TWh in 2050 and today



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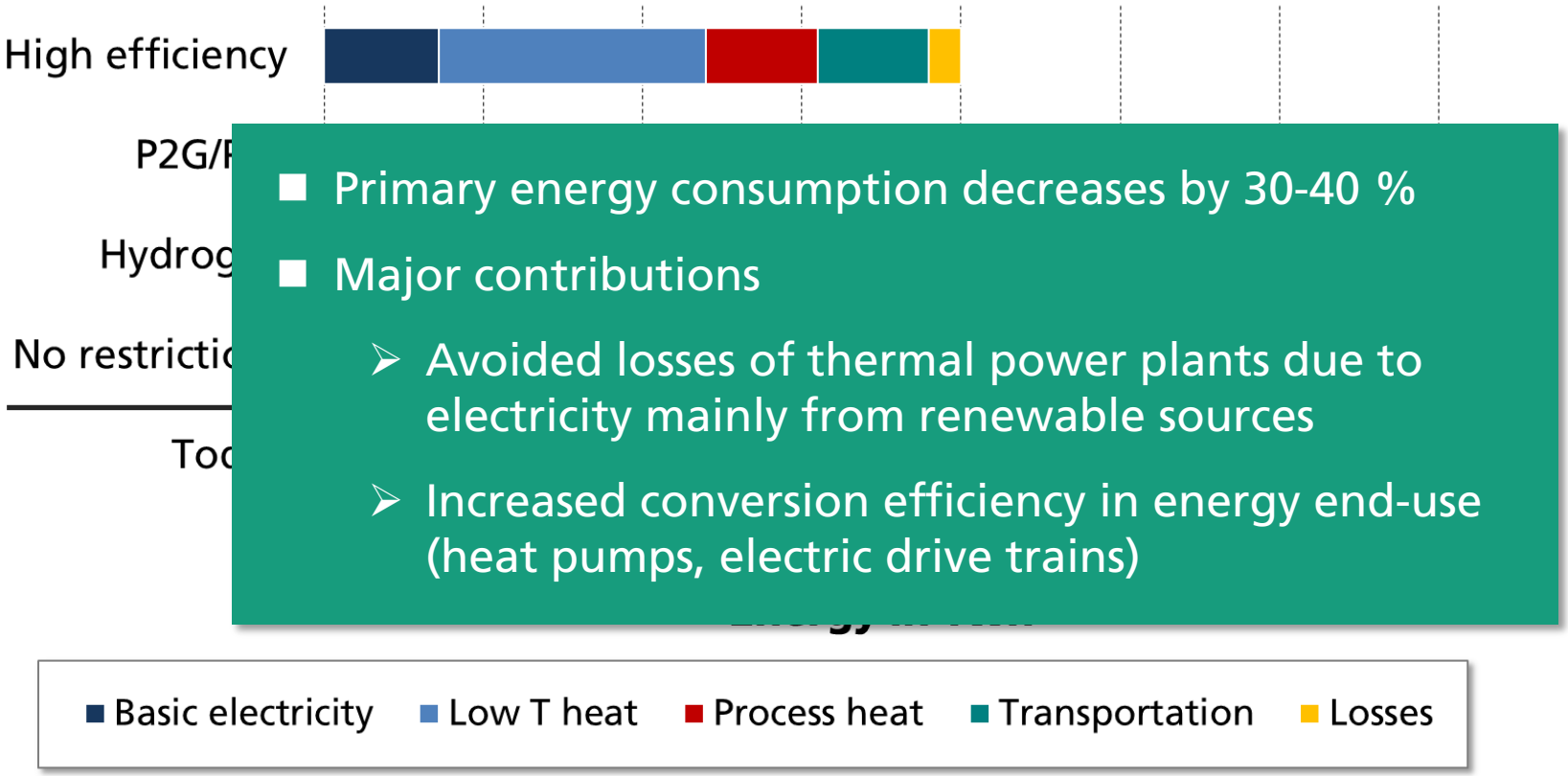
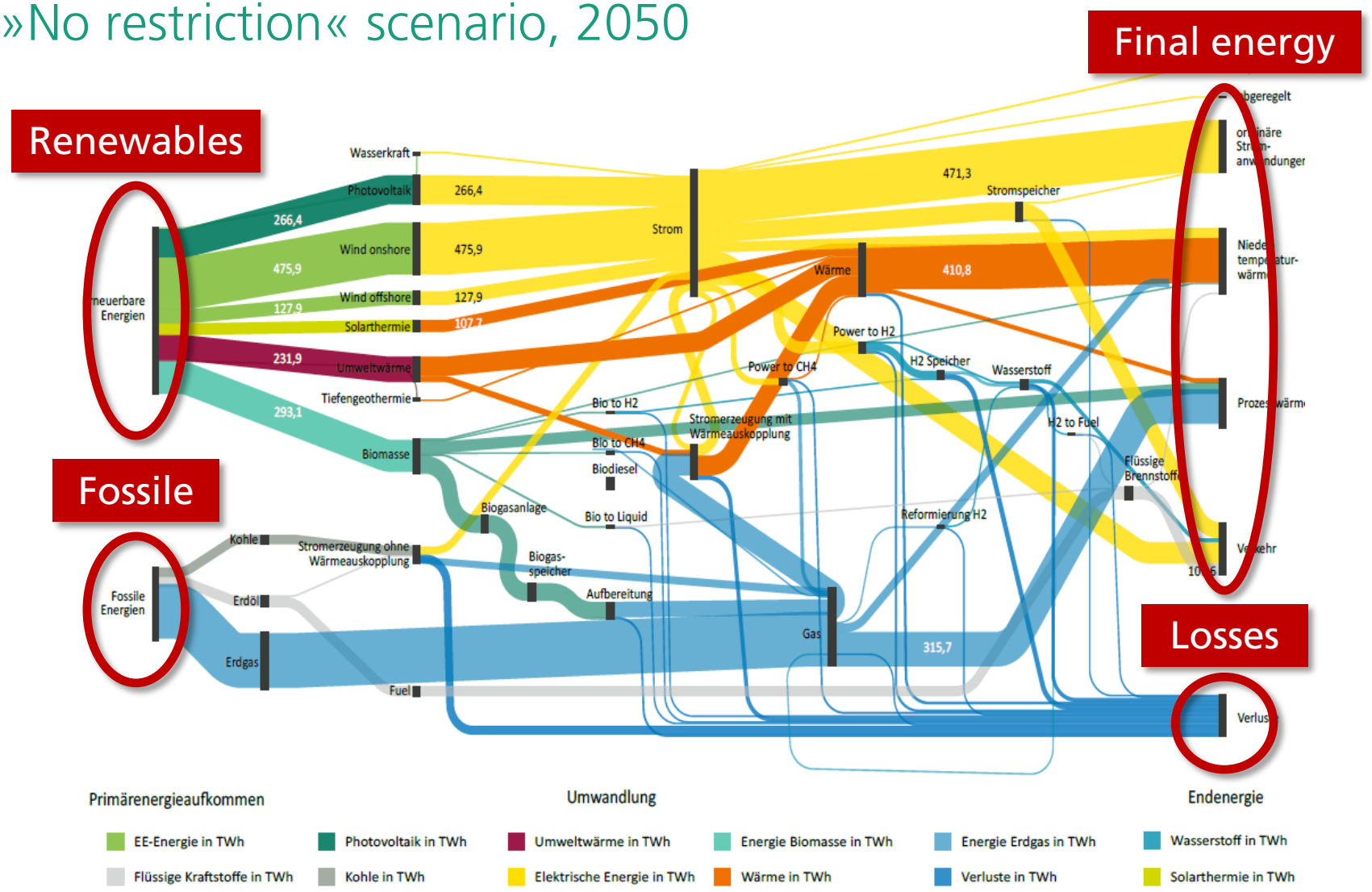


- Primary energy consumption decreases by 30-40 %
- Major contributions
  - Avoided losses of thermal power plants due to electricity mainly from renewable sources
  - Increased conversion efficiency in energy end-use (heat pumps, electric drive trains)

Energy flow chart

»No restriction« scenario, 2050



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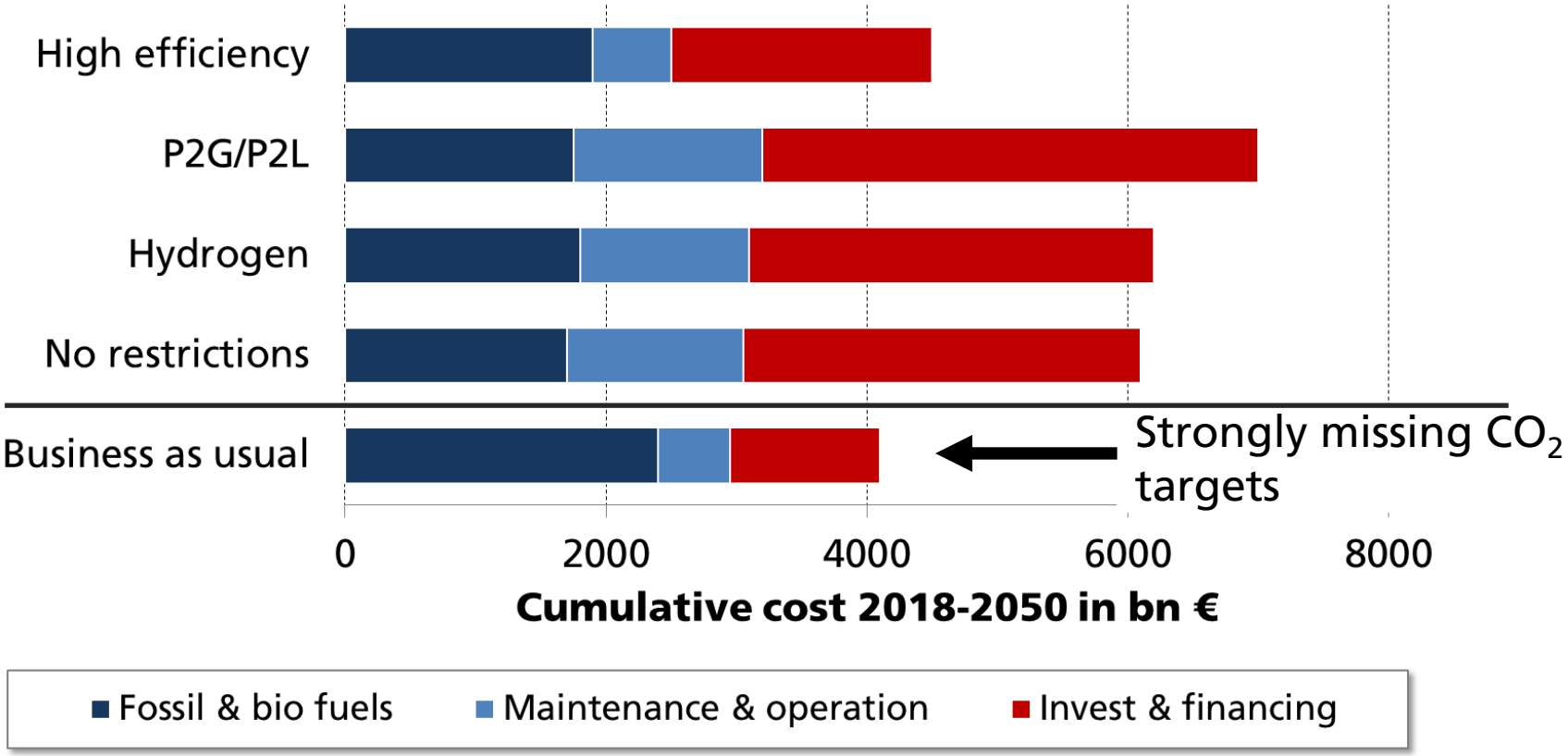
Cost

Cumulative total energy system cost until 2050 in billion €



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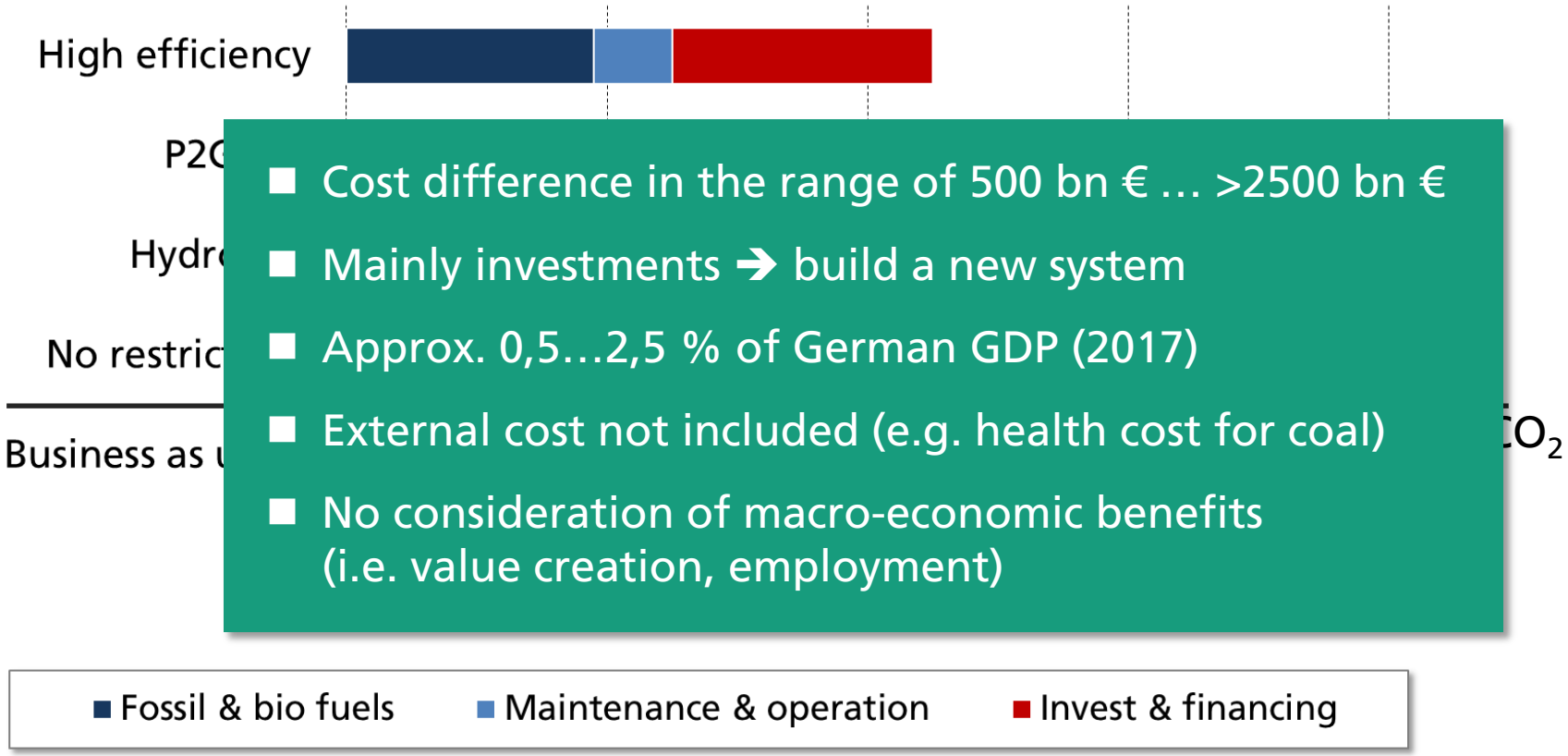

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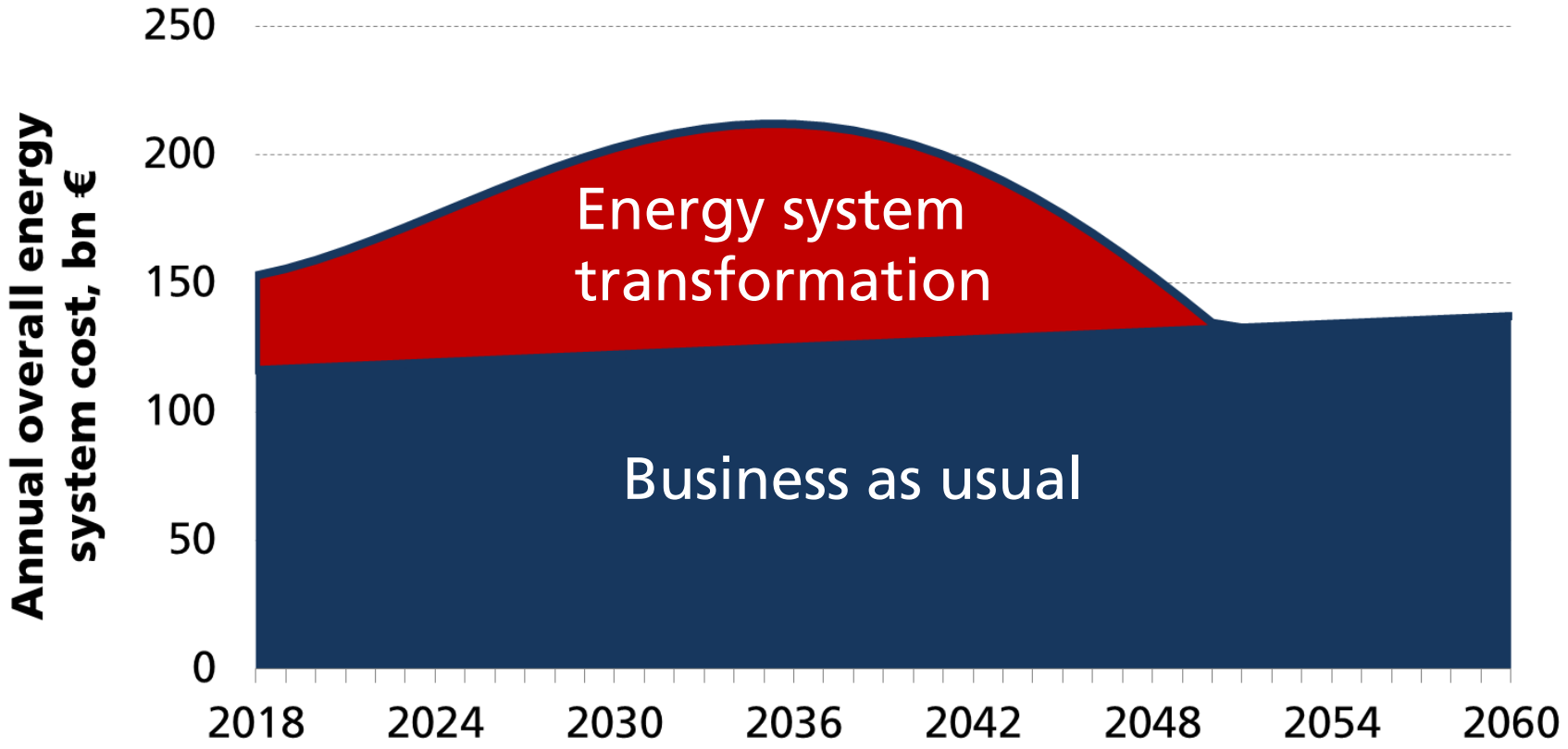
Cost development for »No restriction« scenario

Overall macro-economic energy system cost in bn € per year



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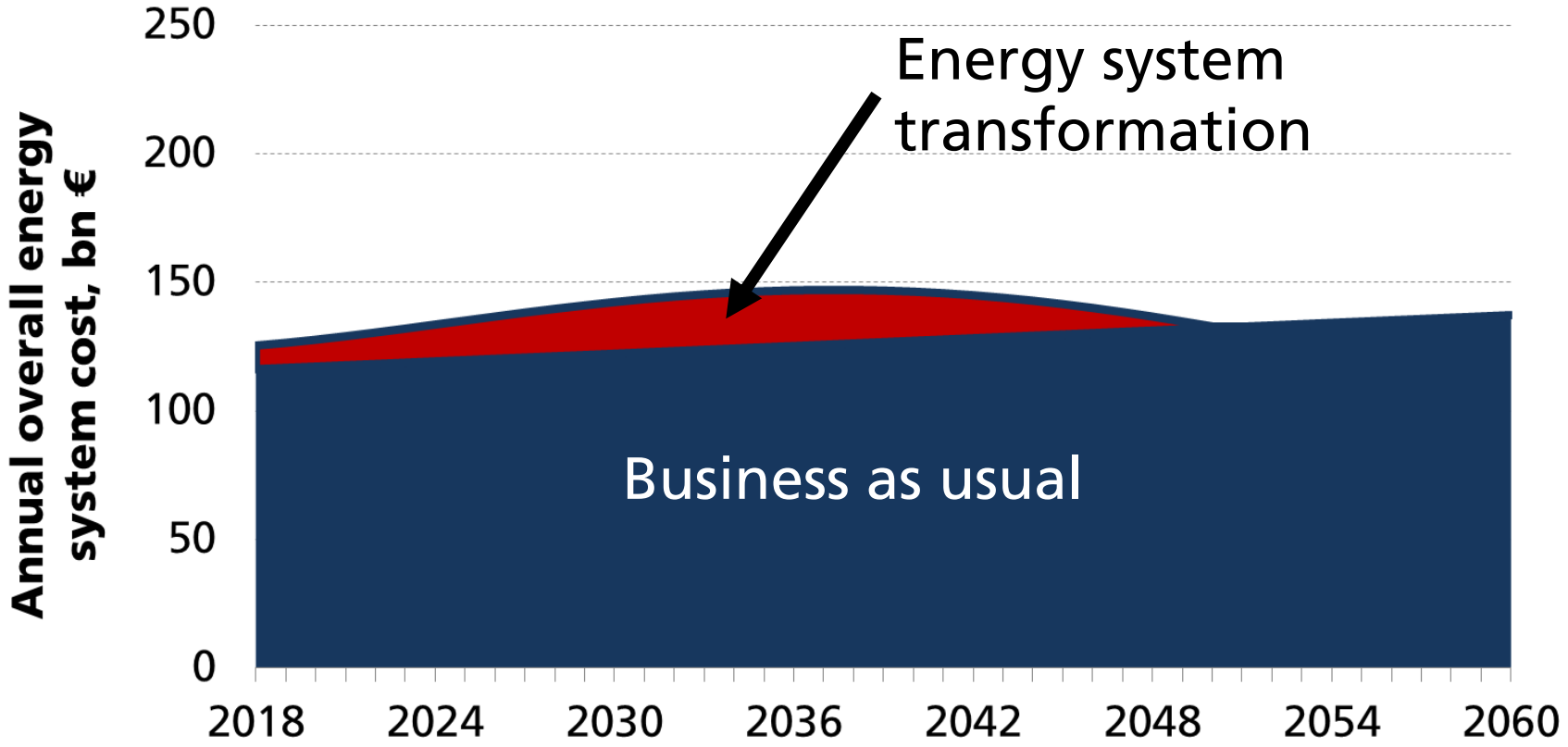
Cost development for »High efficiency« scenario

Overall macro-economic energy system cost in bn € per year



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Intermediate conclusions

- Transformation of energy systems in line with GHG emission reduction targets seems in principle technically feasible
- Renewable energies (in particular solar and wind) become dominant
- Importance of electric energy increases ➔ two times more
- Coupling of sectors ➔ electricity use (directly, indirectly) for heat and mobility
- Short term storage and use of flexibilization options (e.g. load shifting)
- Large scale conversion of renewable electricity into synthetic energy carriers (hydrogen, liquids, chemicals, methane)
- Efficiency and limitation of consumption essential: far lower cost and lower needed capacity for wind and solar ➔ societal acceptance
- New system cost competitive on the long run, i.e. once major investments have been made and the system transformation has been completed

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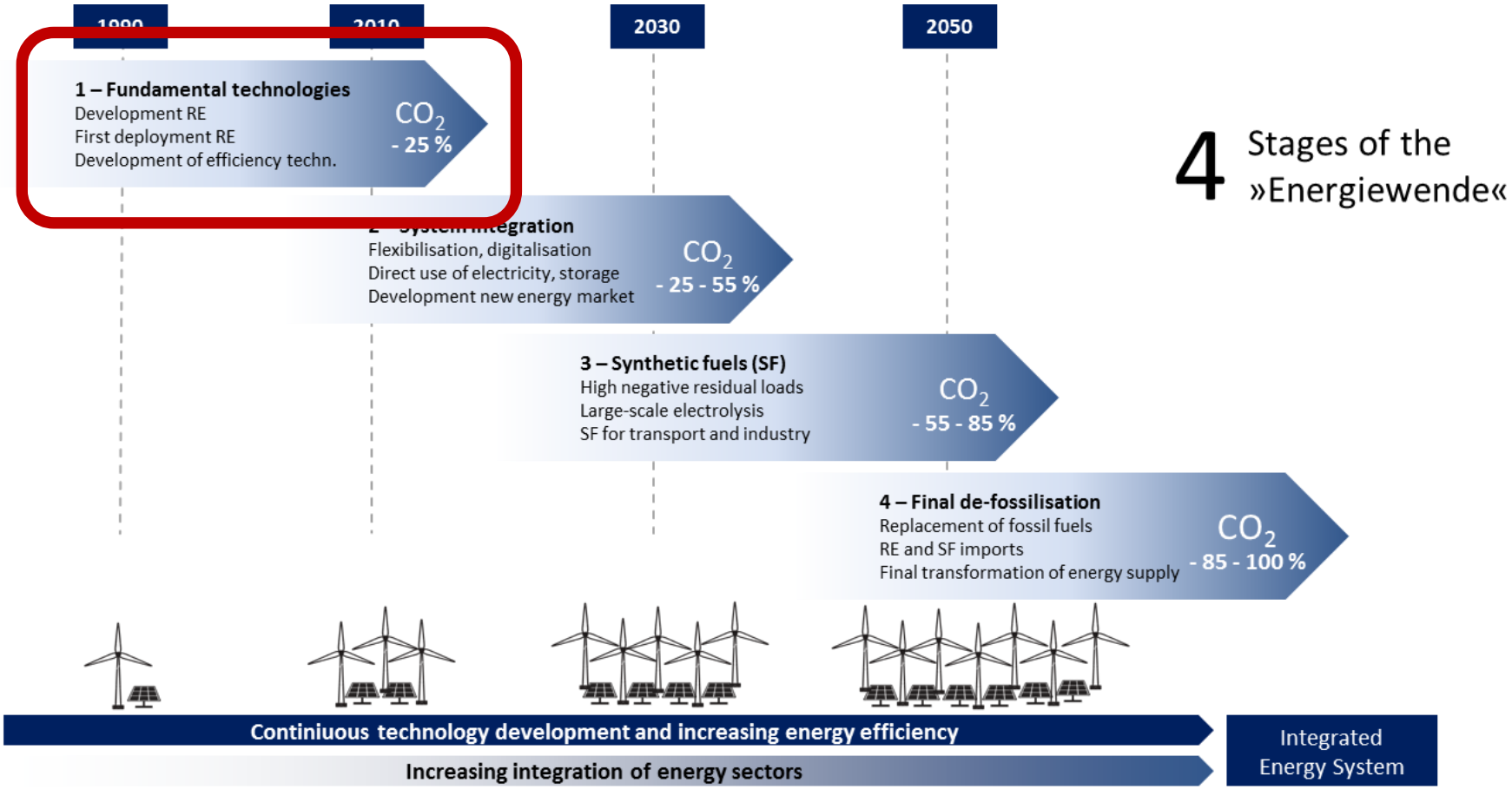

4 Stages of the »Energiewende«

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

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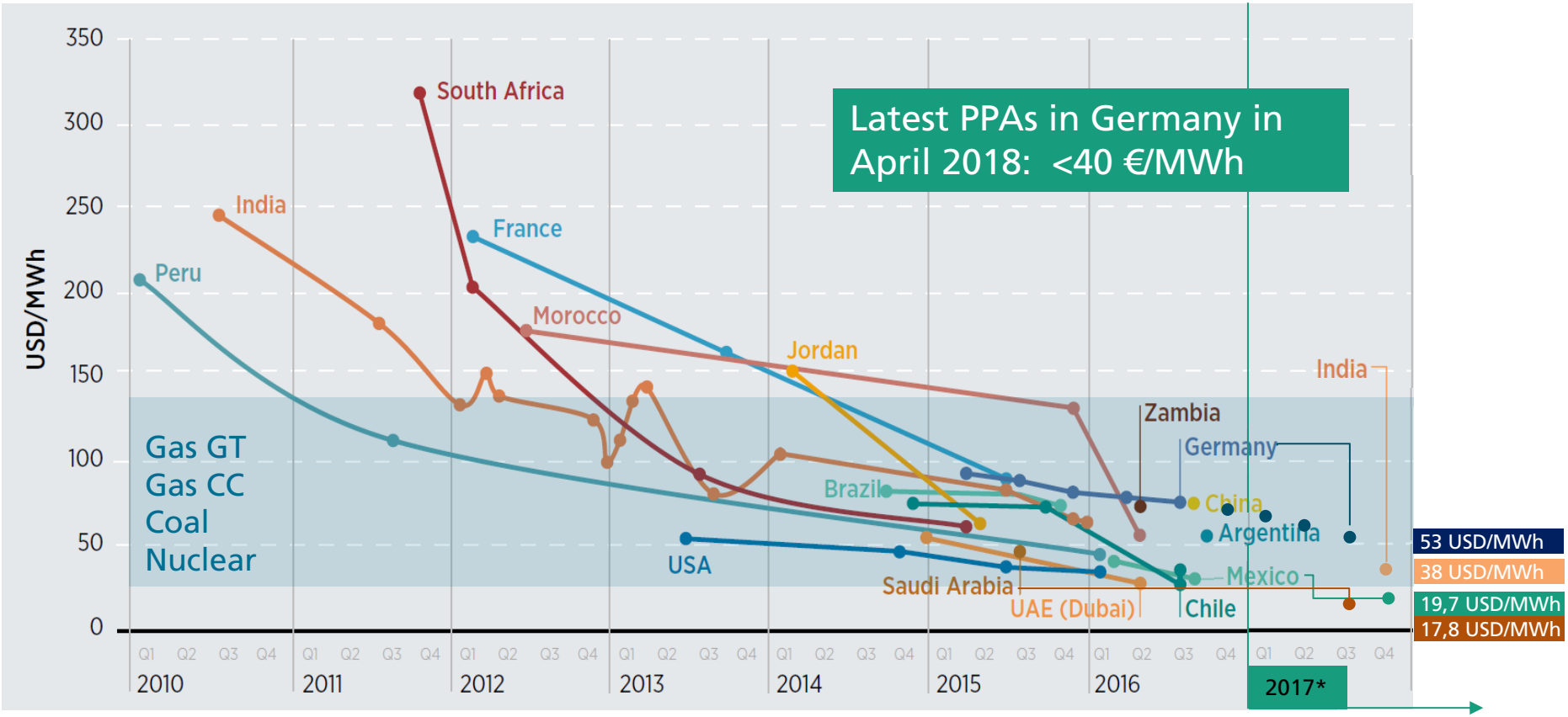
Average prices for PV electricity in PPAs

January 2010 - December 2017



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

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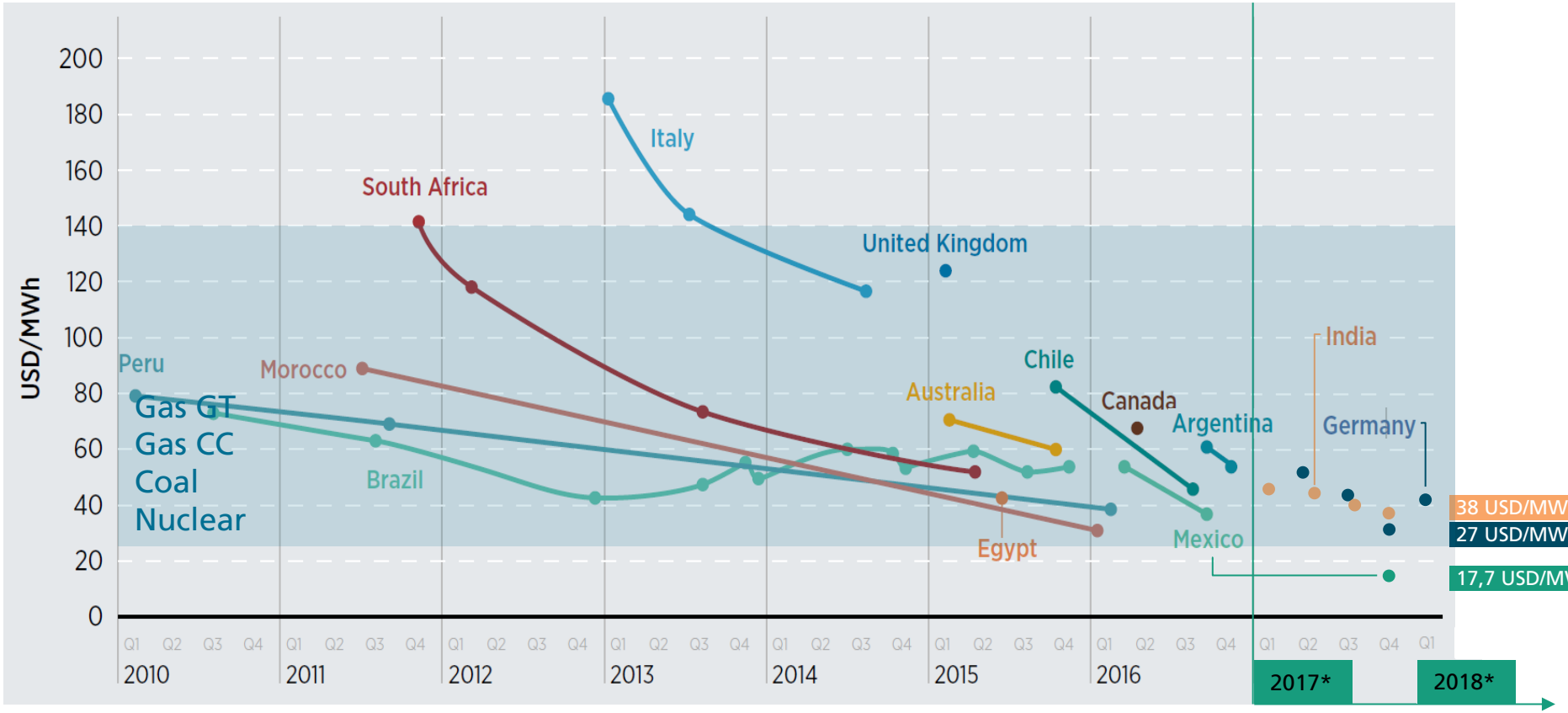
Average prices for Onshore-Wind electricity in PPAs

January 2010 - December 2017



Source: Renewable Energy Auctions 2016, IRENA
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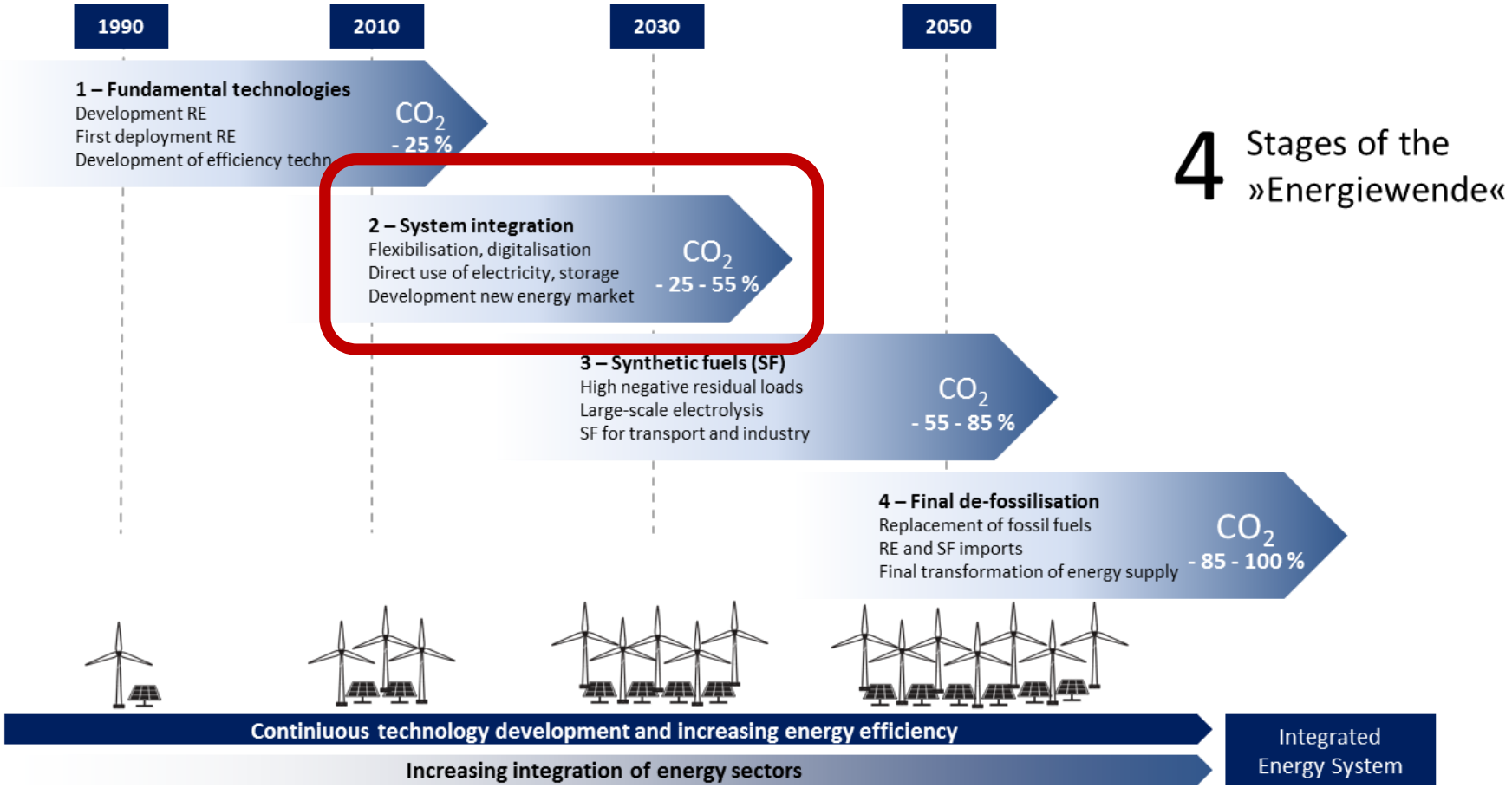
Phases of the energy system transformation



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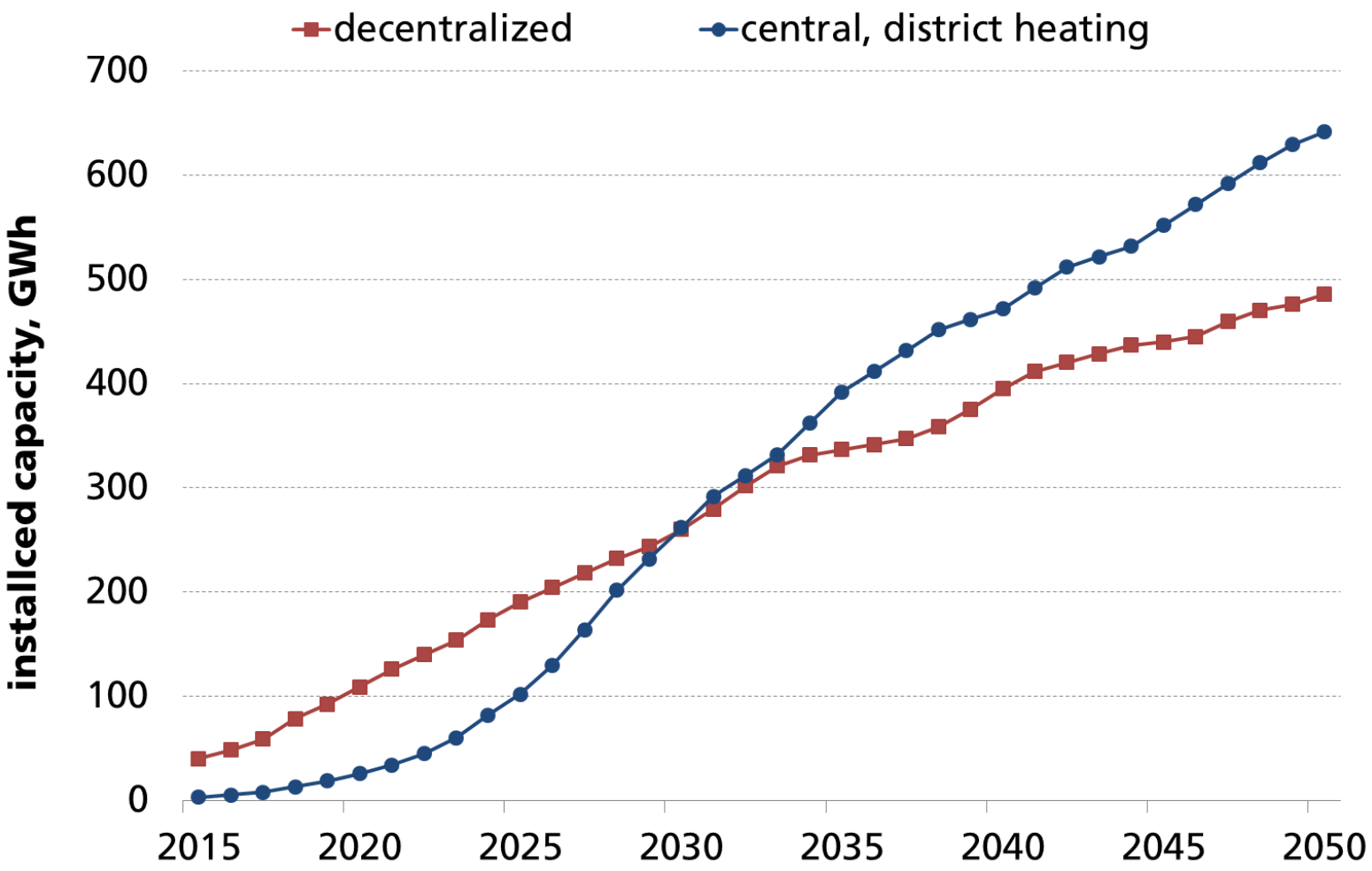
Heat storage

»No restriction« scenario



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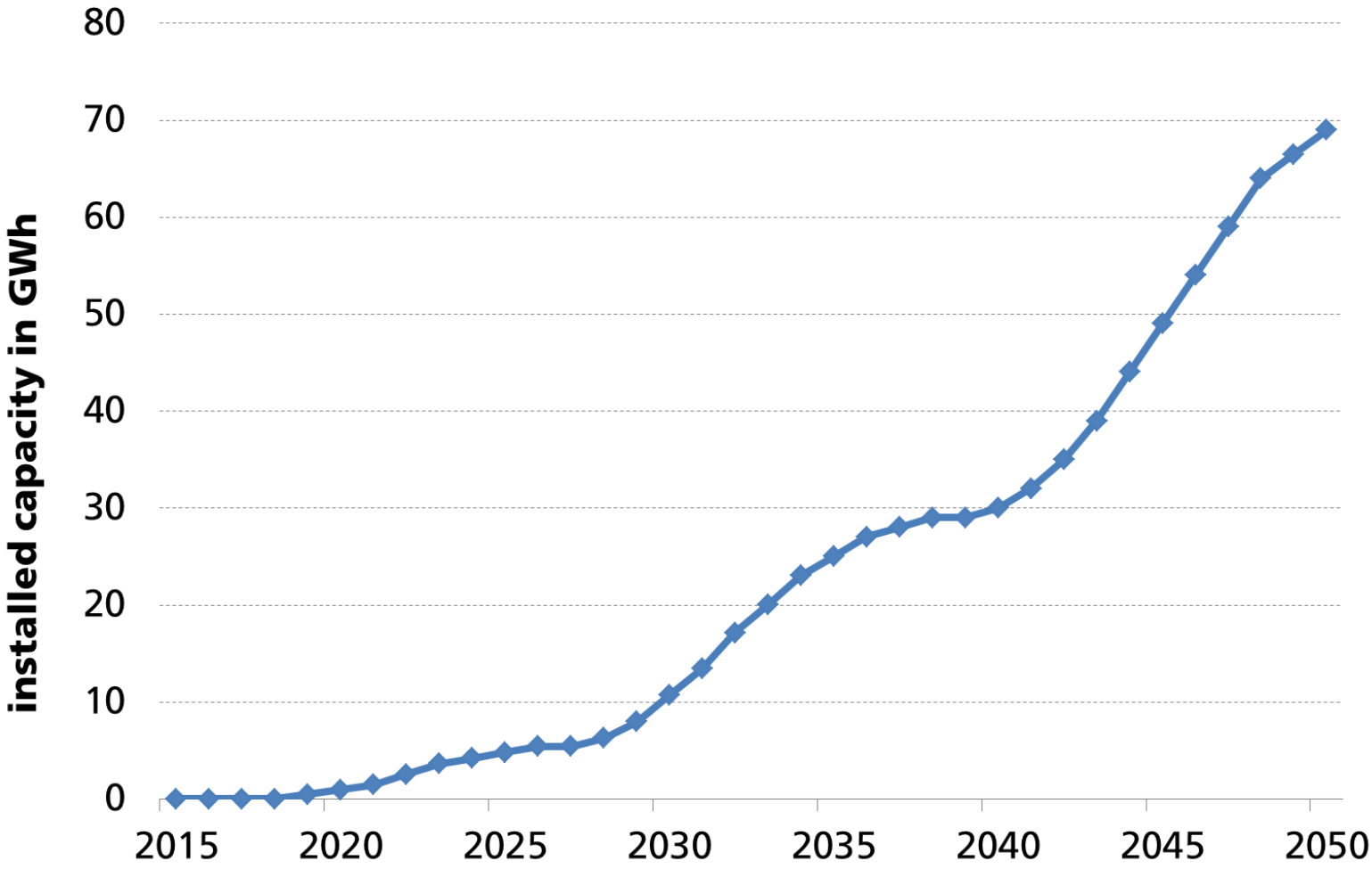
Stationary battery storage

»No restriction« scenario



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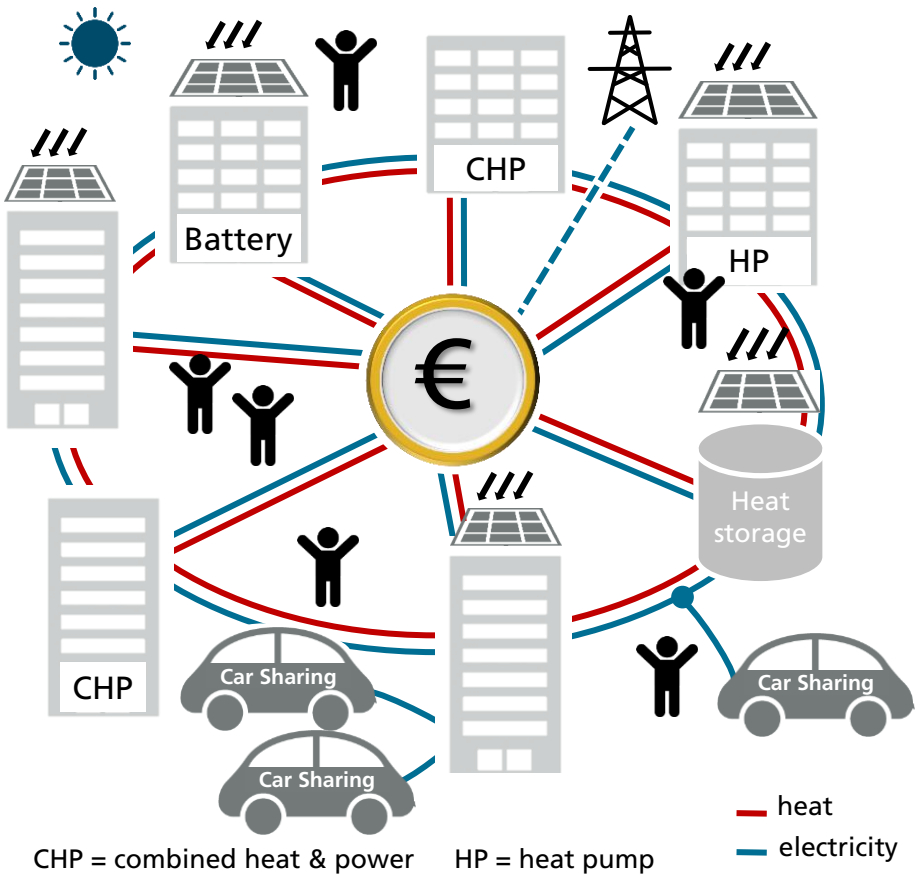
New markets and new market design

New market actors and digital services

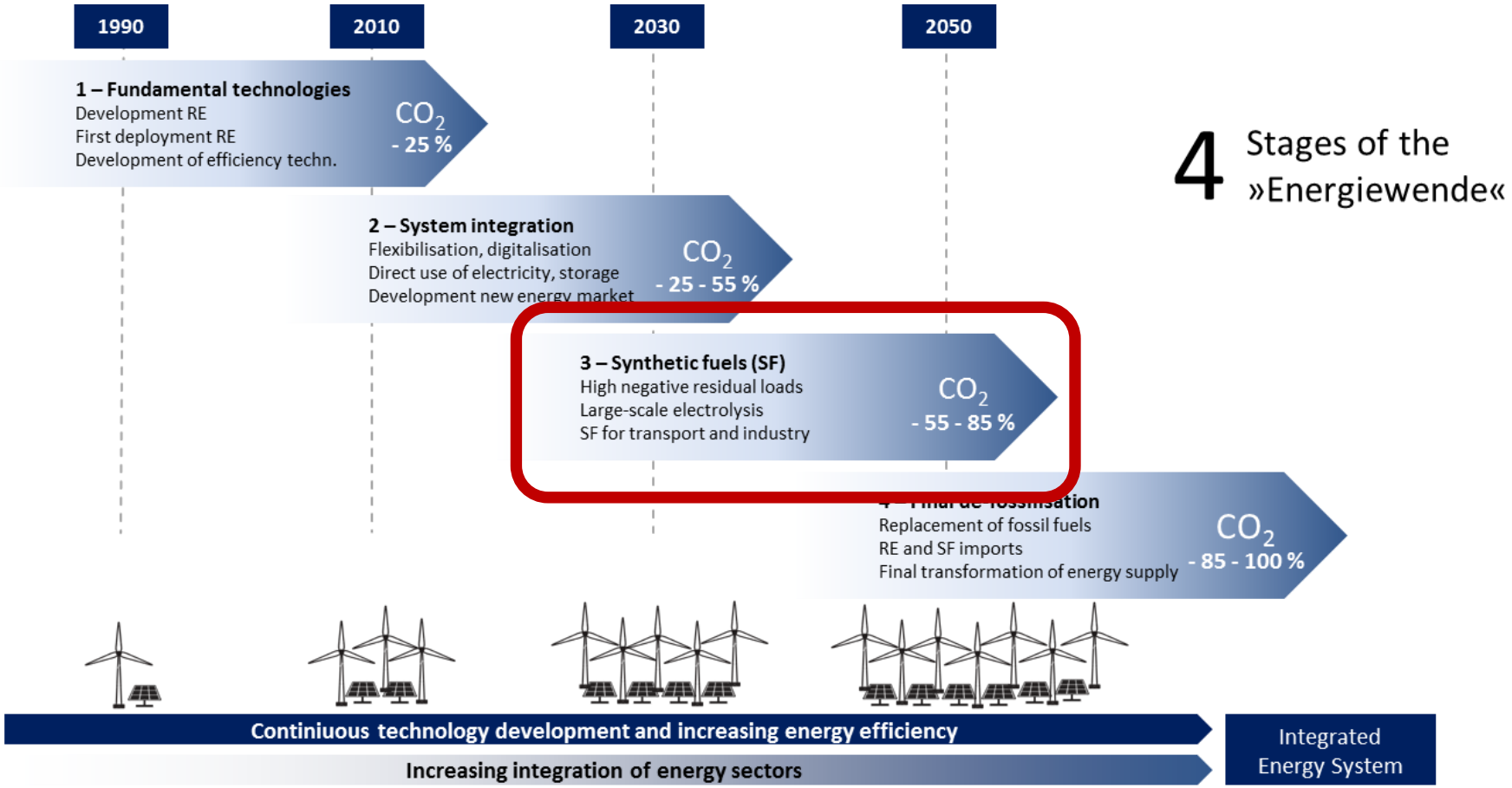
Description



Elements

Digital market place	▪ Fully automated execution and accounting of EMS transactions
Self-learning EMS	▪ Smart contracts ▪ Conformity to energy market design
Cyber-Security	▪ Fully integrated load management ▪ Artificial iIntelligence for prognosis and control
Planning tools	▪ Resiliency of decentralized energy and IT structure ▪ Powerful tools for design and planning

Phases of the energy system transformation



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

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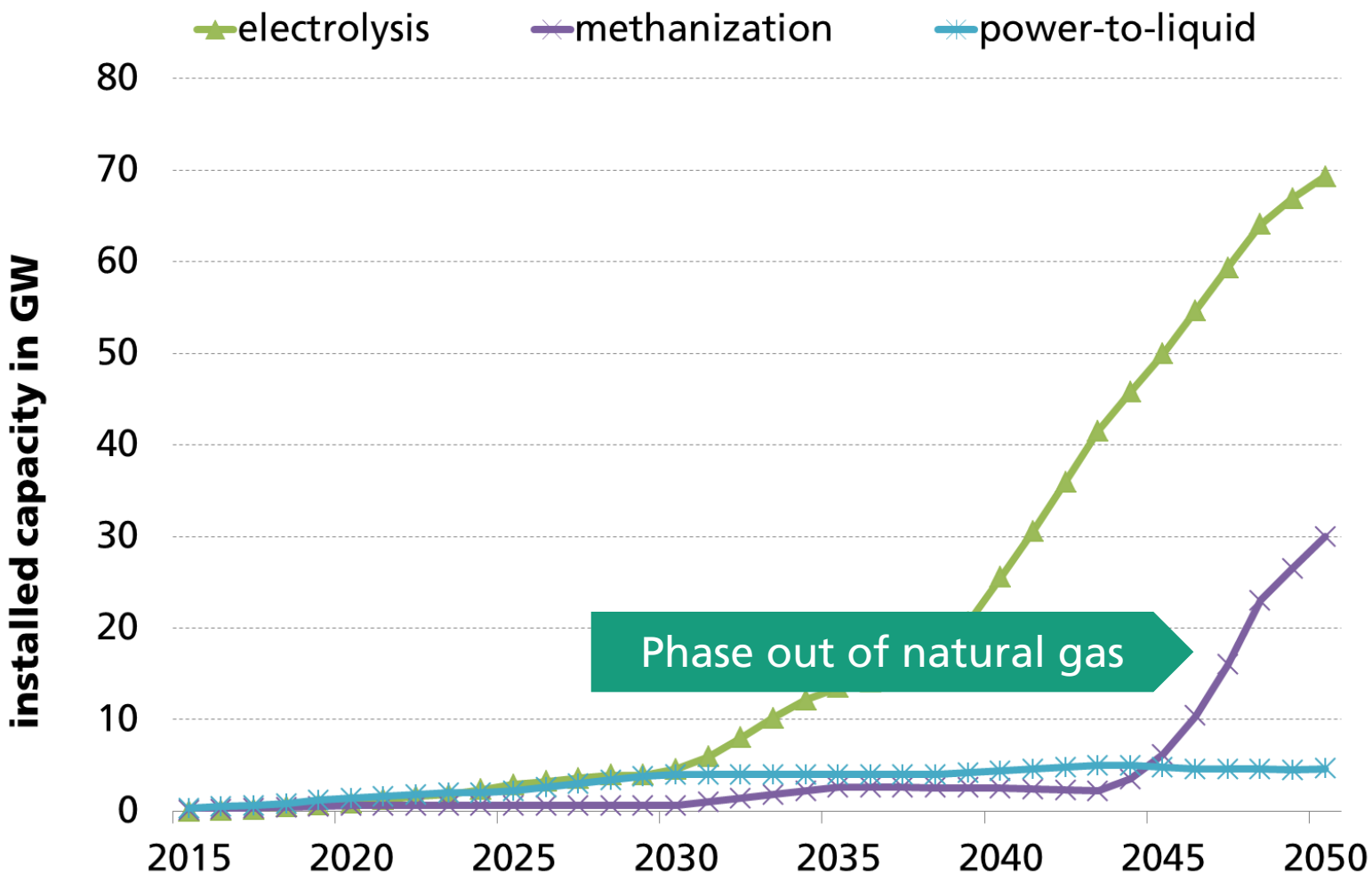
Multi-GW scale electrolysis and P2G/P2L converters

»No restriction« scenario



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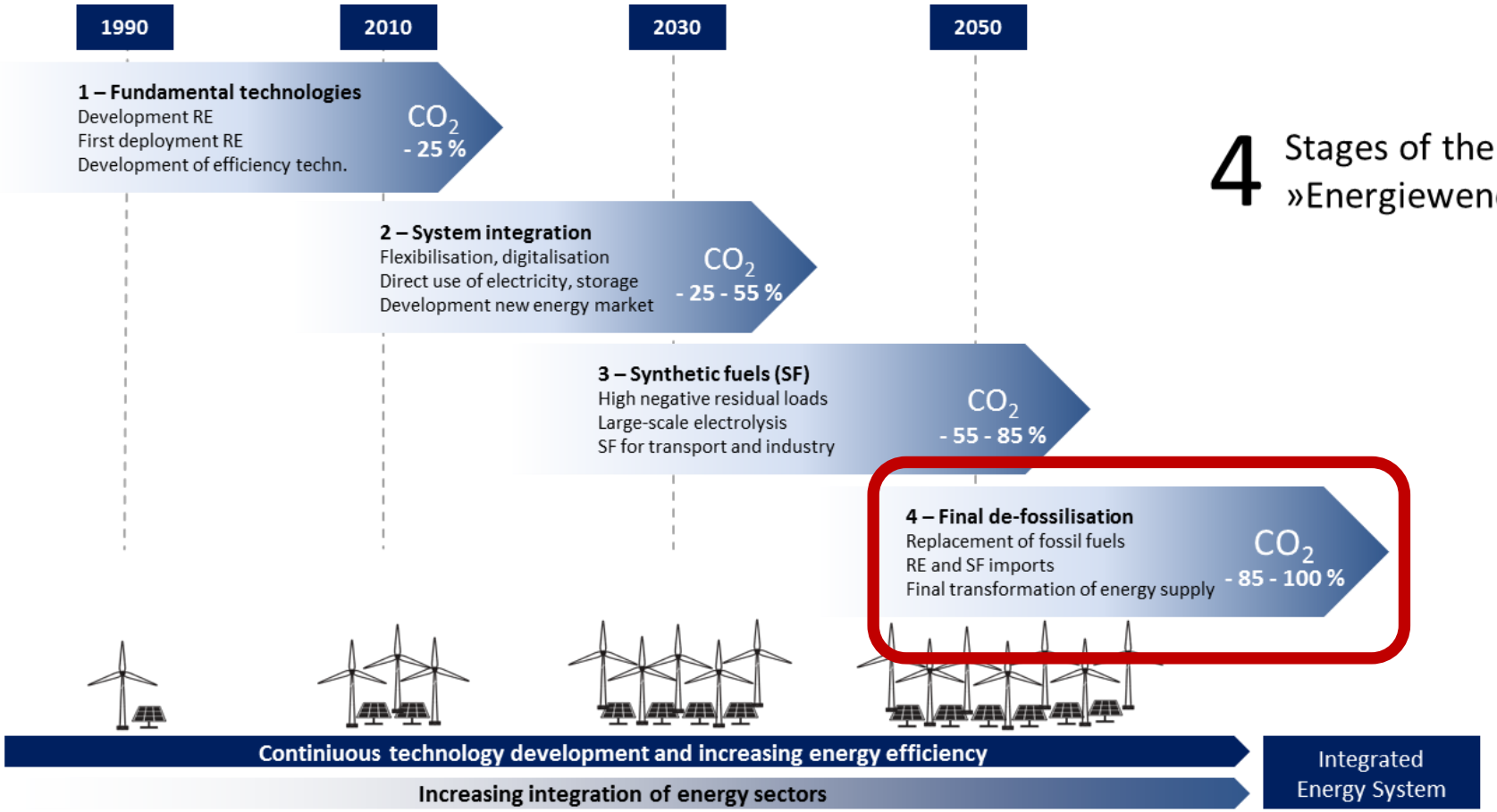

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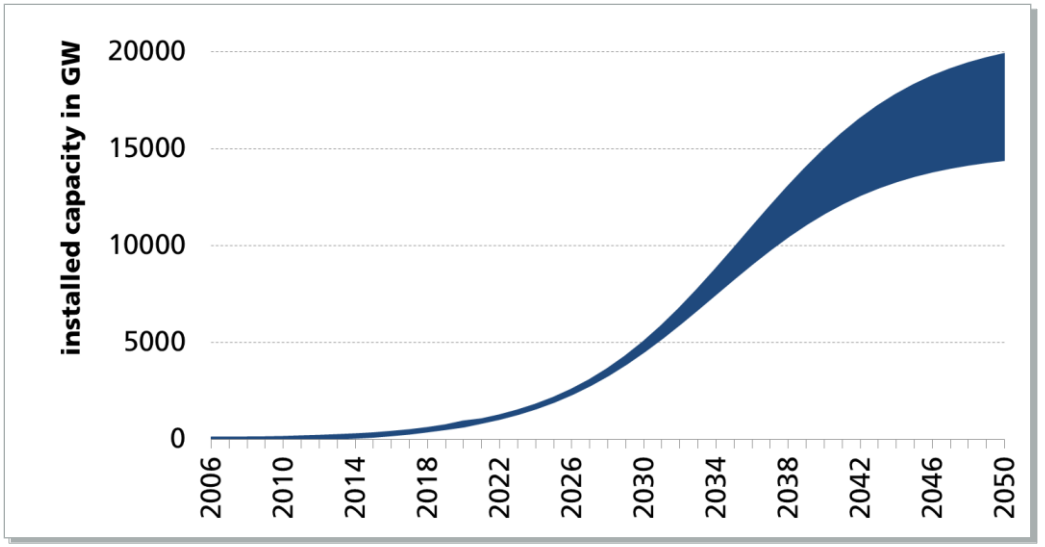
Solar electricity generation needs (PV, solar thermal)

- Needed global solar electricity capacity of 15…20 TW in 2050
- Production capacity for many 100 GW per year
- Product diversification for various applications
  - Utility scale (PV, solar thermal) for various climatic conditions (e.g. desert)
  - Solutions for buildings (factory buildings; office & residential buildings)
  - Integration in built environment (e.g. parking spaces)
  - Multi purpose solutions (e.g. agro-photovoltaics, BIPV)



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Conclusions

Technology and market development needs

- Similar large capacities for wind and other renewables
- Large scale storage (batteries, pumped hydro, heat for district heating networks)
- Large scale hydrogen production starting in the mid of the 2030s
- Power-to-gas and power-to-liquid technologies
- Compact and high efficient power electronics for stationary and mobile applications
- Powerful load and grid management technologies based on self-learning energy management systems using artificial intelligence
- New market frameworks to stimulate flexible load and generation
- Comprehensive, effective CO_2 pricing covering all energy sectors

Think big !

Many thanks for your attention…

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