Renewables and sector coupling for the energy transition – A system and cost perspective

Christoph Kost

Head of Group *Energy Systems and Energy Economics*

Fraunhofer Institute for Solar Energy Systems ISE

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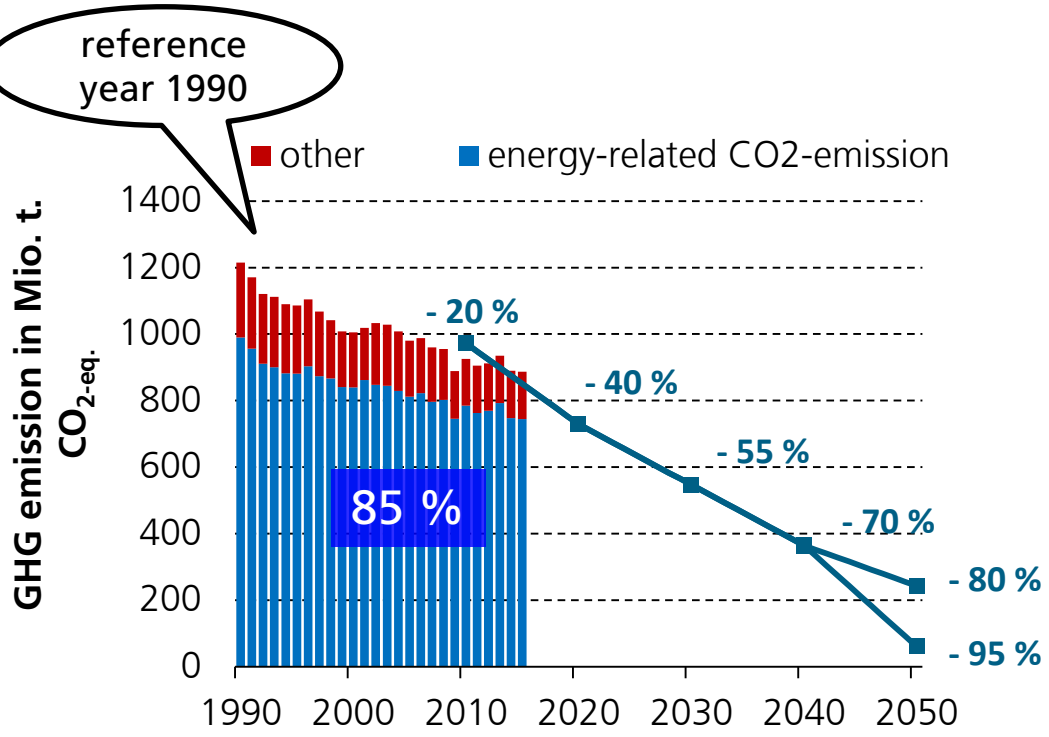
www.ise.fraunhofer.de

Motivation

Objective - Reduction of Greenhouse Gas (GHG) Emissions

<u>Germany:</u>

- Target: -80 % up to - 95 % (referring to 1990)
- Composition of energy-related emissions:
  - 98 % of GHG are CO_2 emissions
- Sectors:
  - Approx. 45 % in the electricity sector
  - Rest: Heat, transport & industry



Substantial reductions are required in all "energy" sectors

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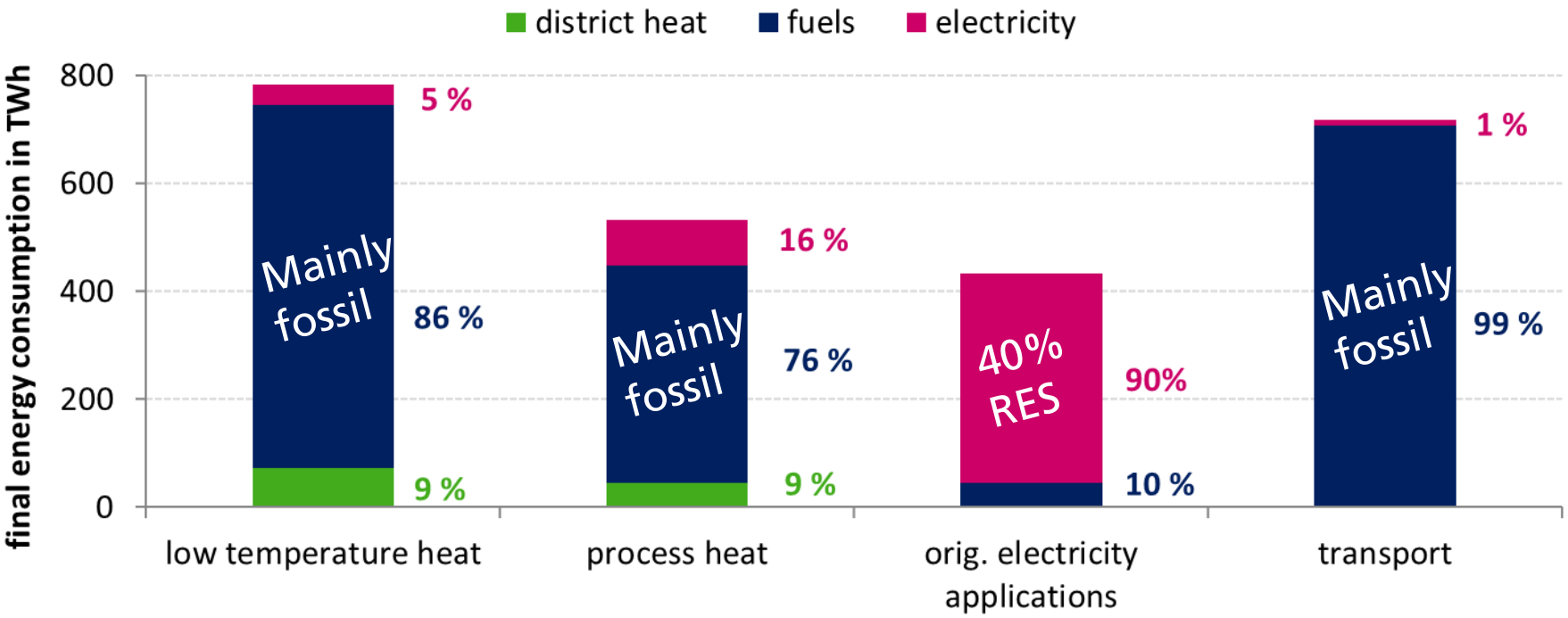
German energy demand of today

Composition of final energy



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

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Major questions

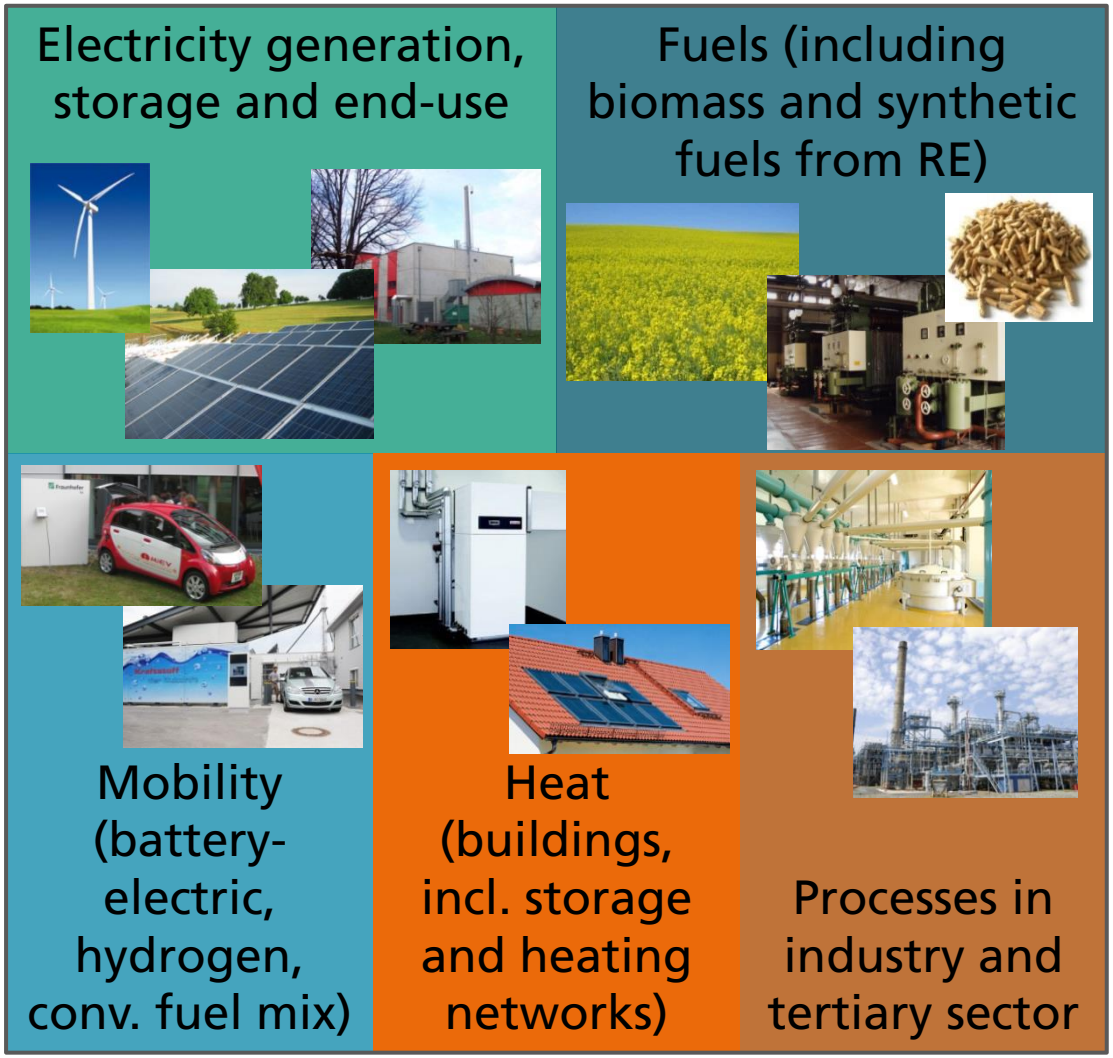
- How can the complex overall system be transformed towards achieving climate targets without compromising on security of supply and at minimal cost?

- How can heat (buildings, industry processes) and transportation sectors become less dependent from fossil energy sources?

Cross-sectoral energy system model REMod

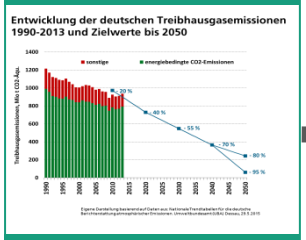
REMod-D
Renewable Energy Model – Deutschland

- Techno-economic optimization
- Based on system simulation
- Hourly time scale 2015-2050
- Objective: **Minimize total annual cost**

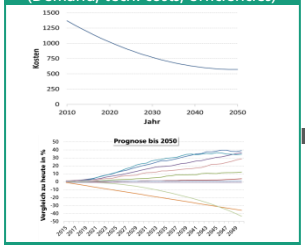


REMod – Cross-sectoral energy system model

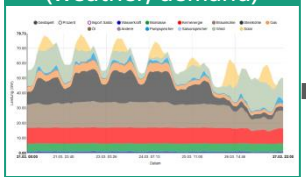
CO_2-target(-80 -95%)



Data input
(Demand, tech. costs, efficiencies)



Hourly profiles
(weather, demand)

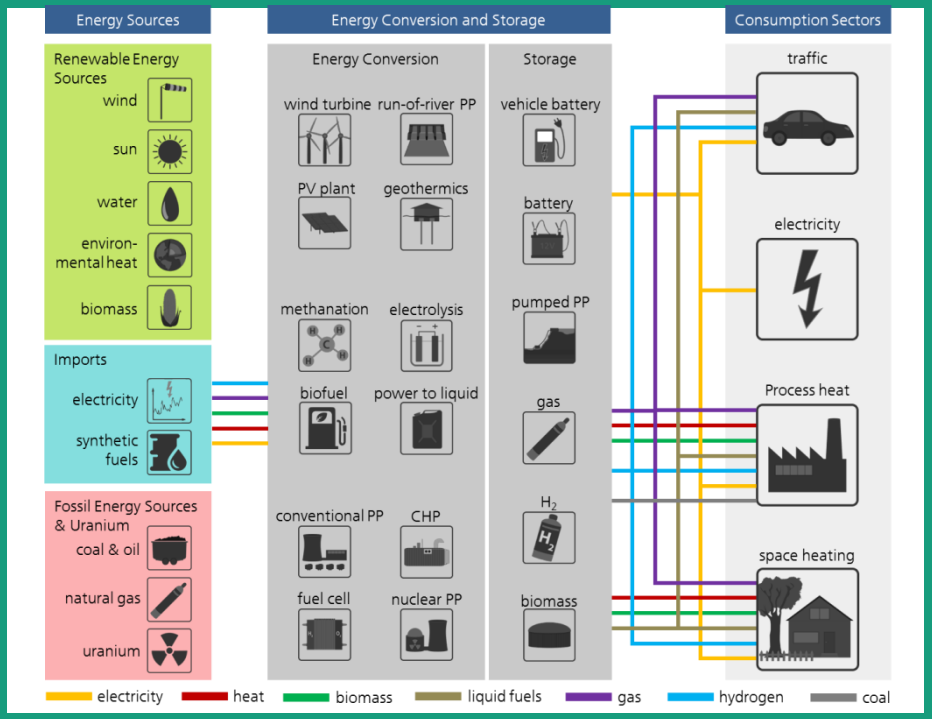


Energy converters today (all sectors)

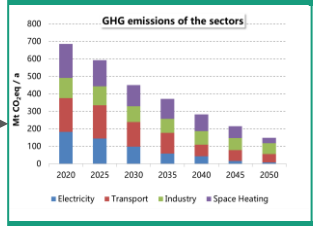
Core of the model

Hourly optimization. Non-linear.
All energy sources, converters, storages and consumption sectors.
Target function: Minimization of total system costs
Boundary conditions: Security of supply and CO_2 emissions

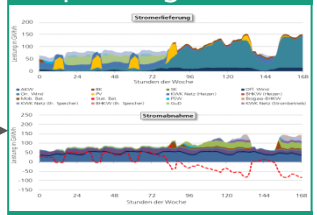
Energy Sources | Energy Conversion and Storage | Consumption Sectors



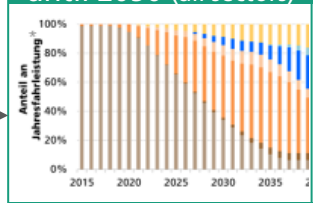
Decarbonisation per sector



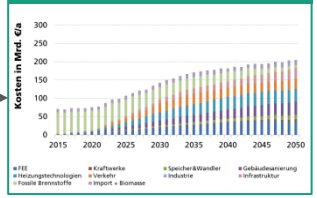
Sector-coupled operating results



Energy converters until 2050 (all sectors)



System costs of transformation



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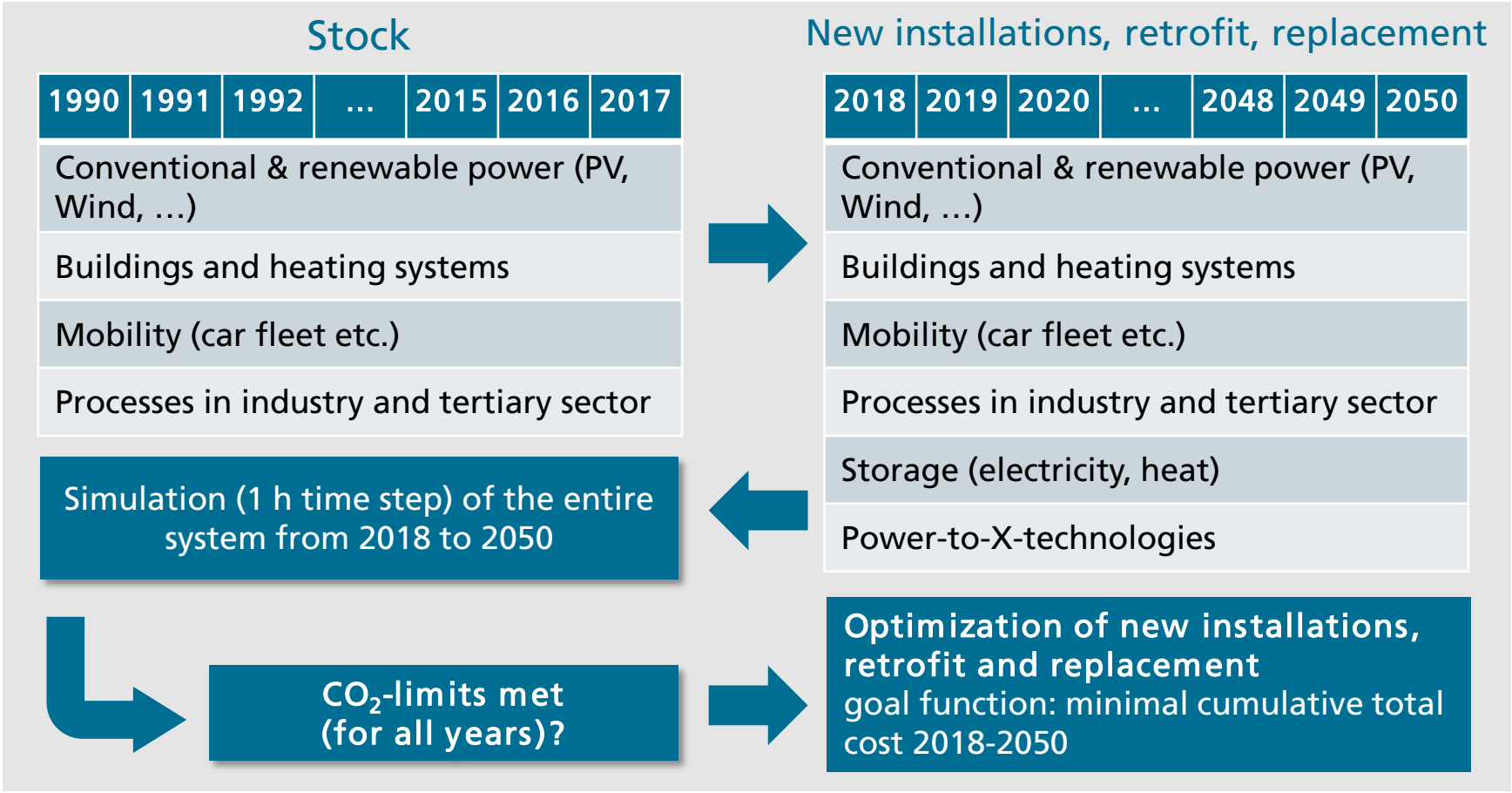
Methodology



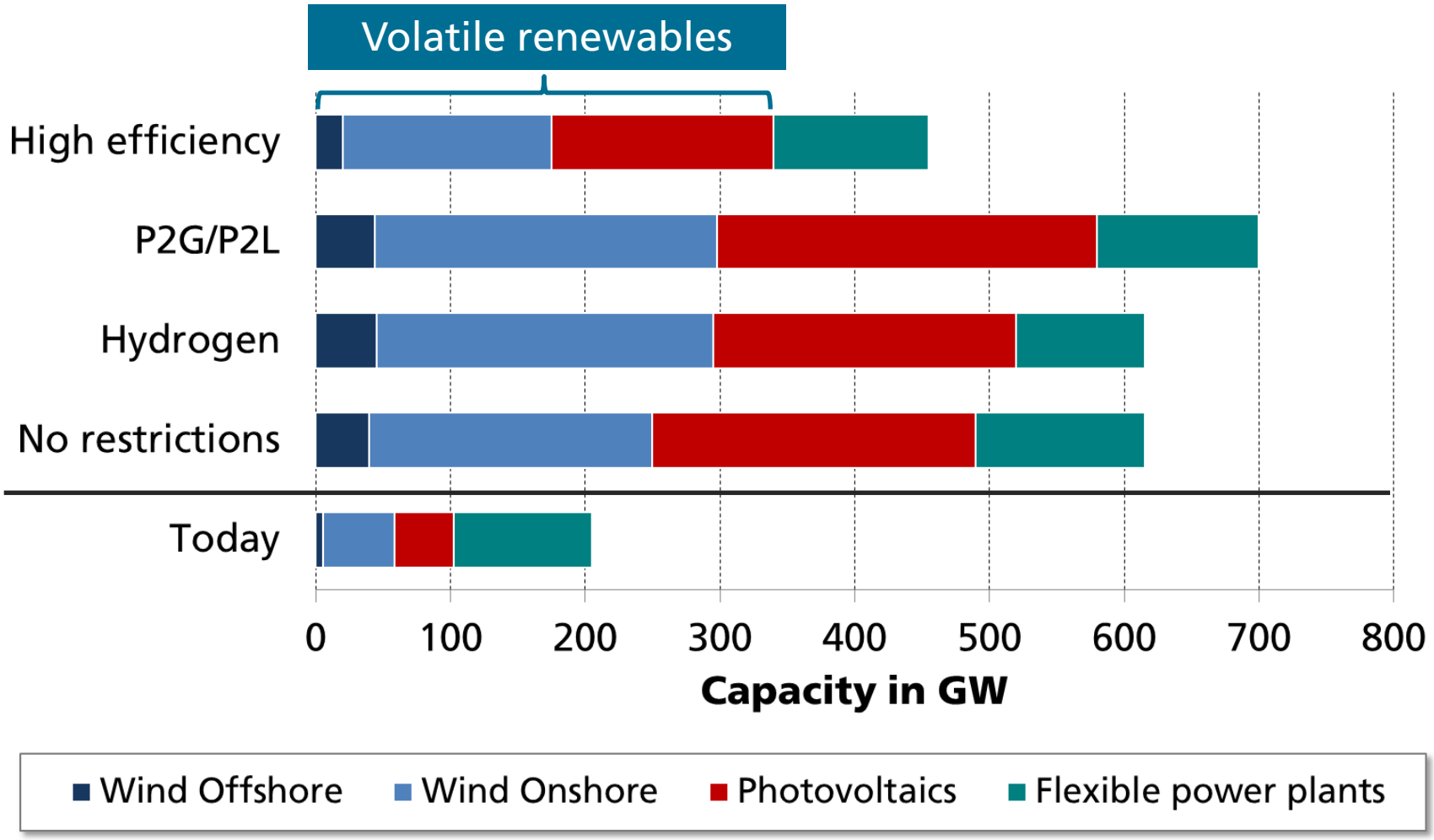
Work from the German academies of science

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

Electricity generation

Installed capacity in GW in 2050 and today



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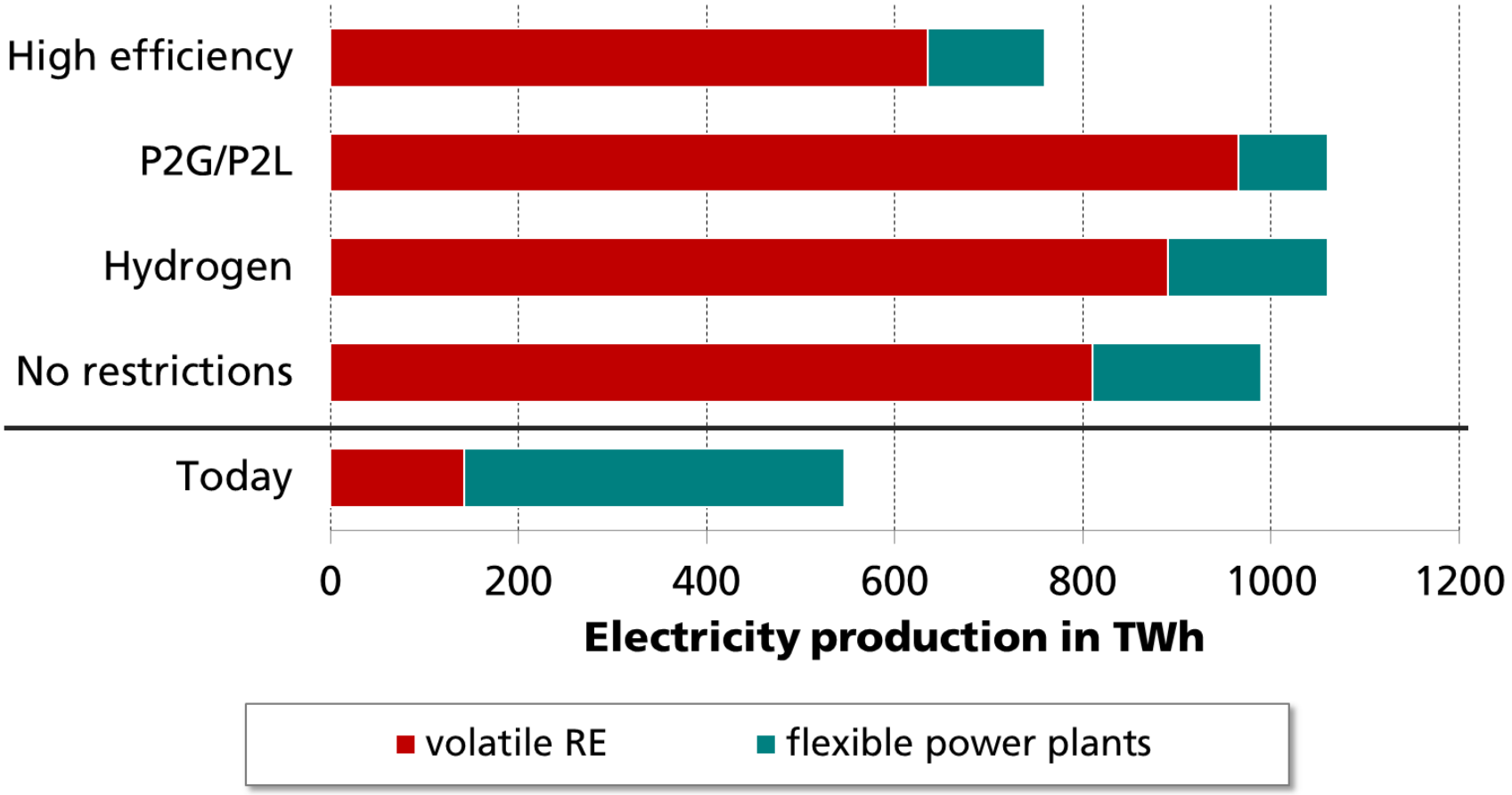
Electricity generation

Annual energy in TWh in 2050 and today



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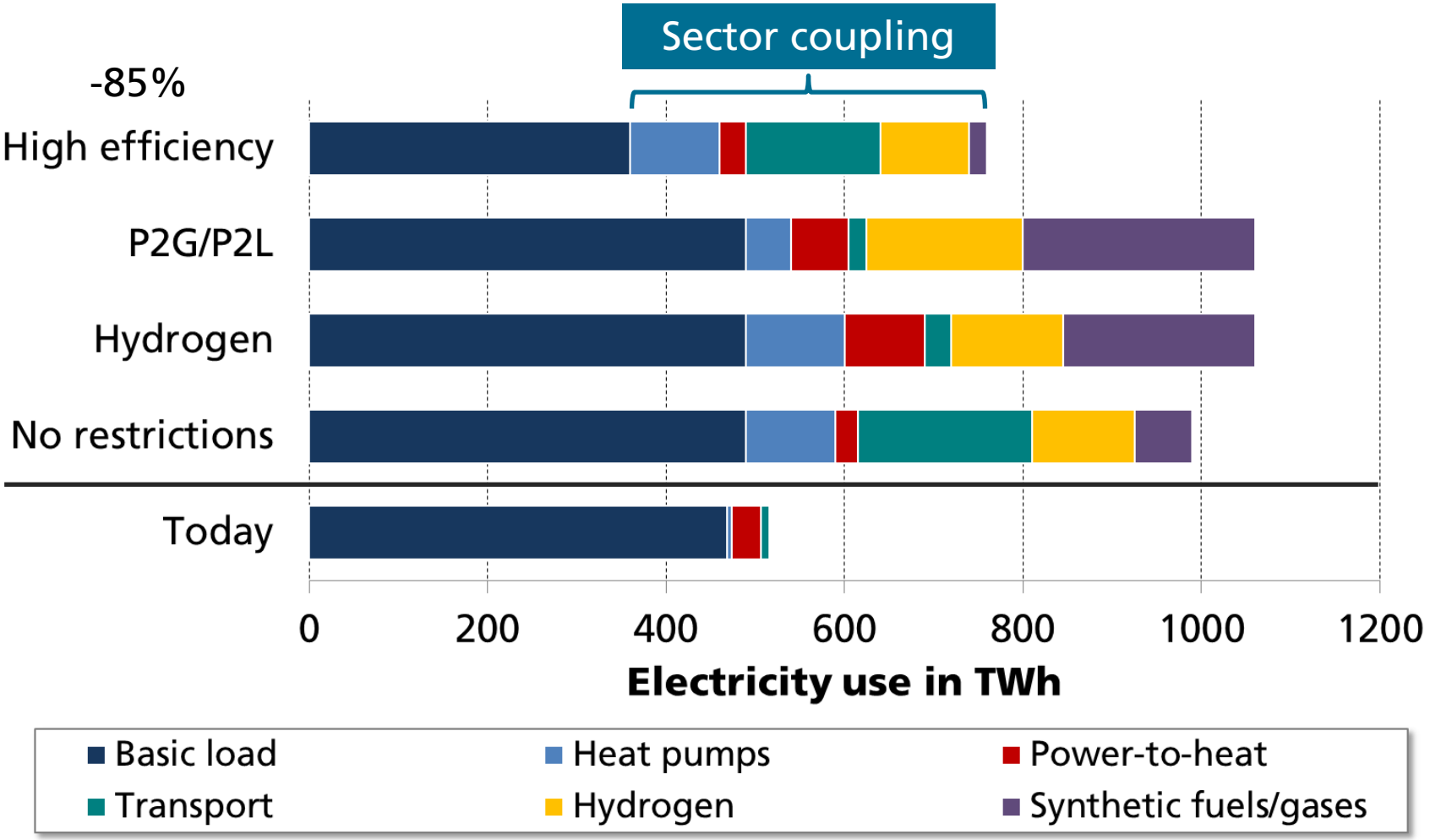
Electricity use

Annual energy in TWh in 2050 and today



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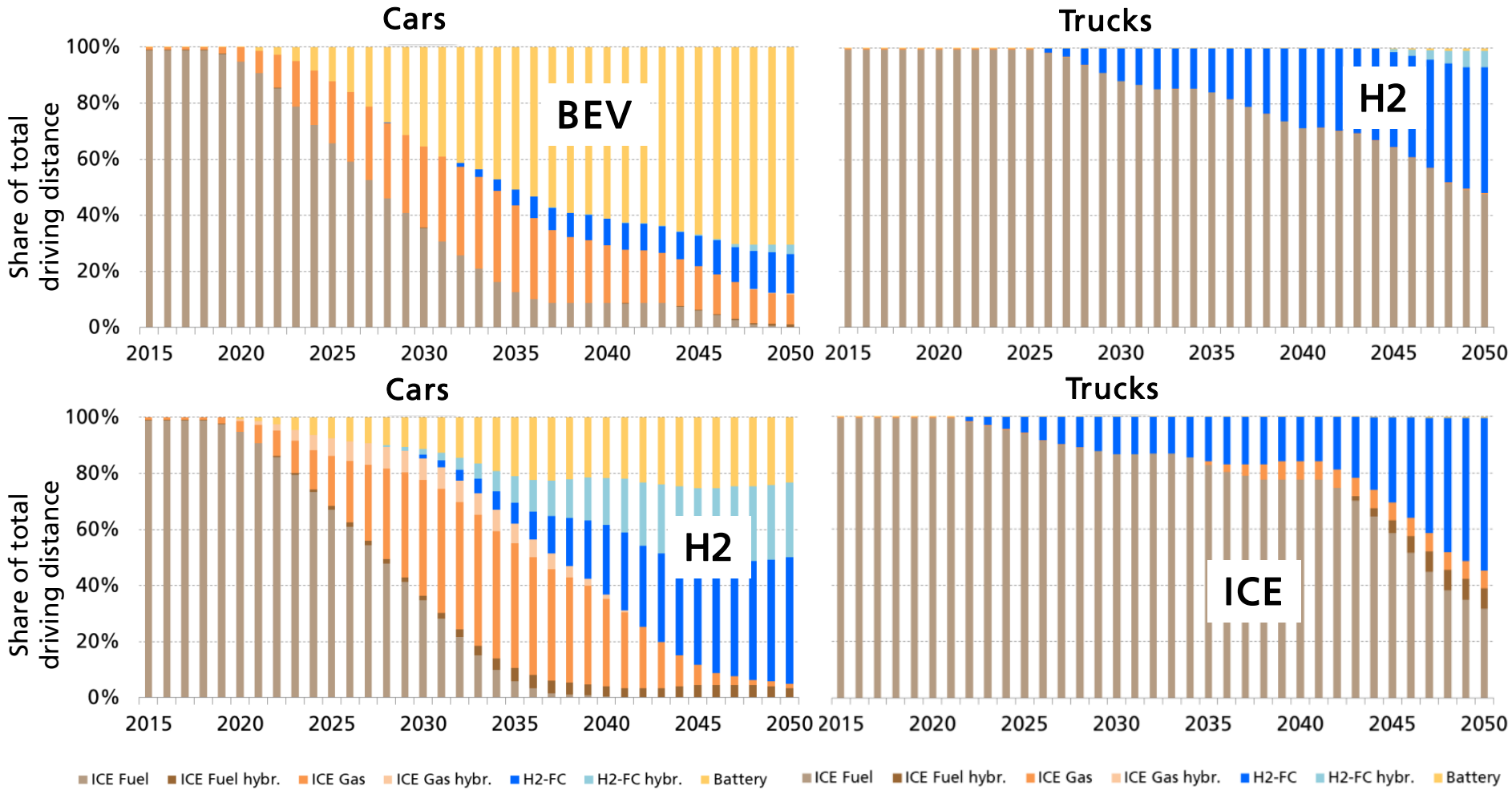
Decarbonization paths in transport sector

Battery electric vehicles – Hydrogen vehicles



ICE = Internal Combustion Engine

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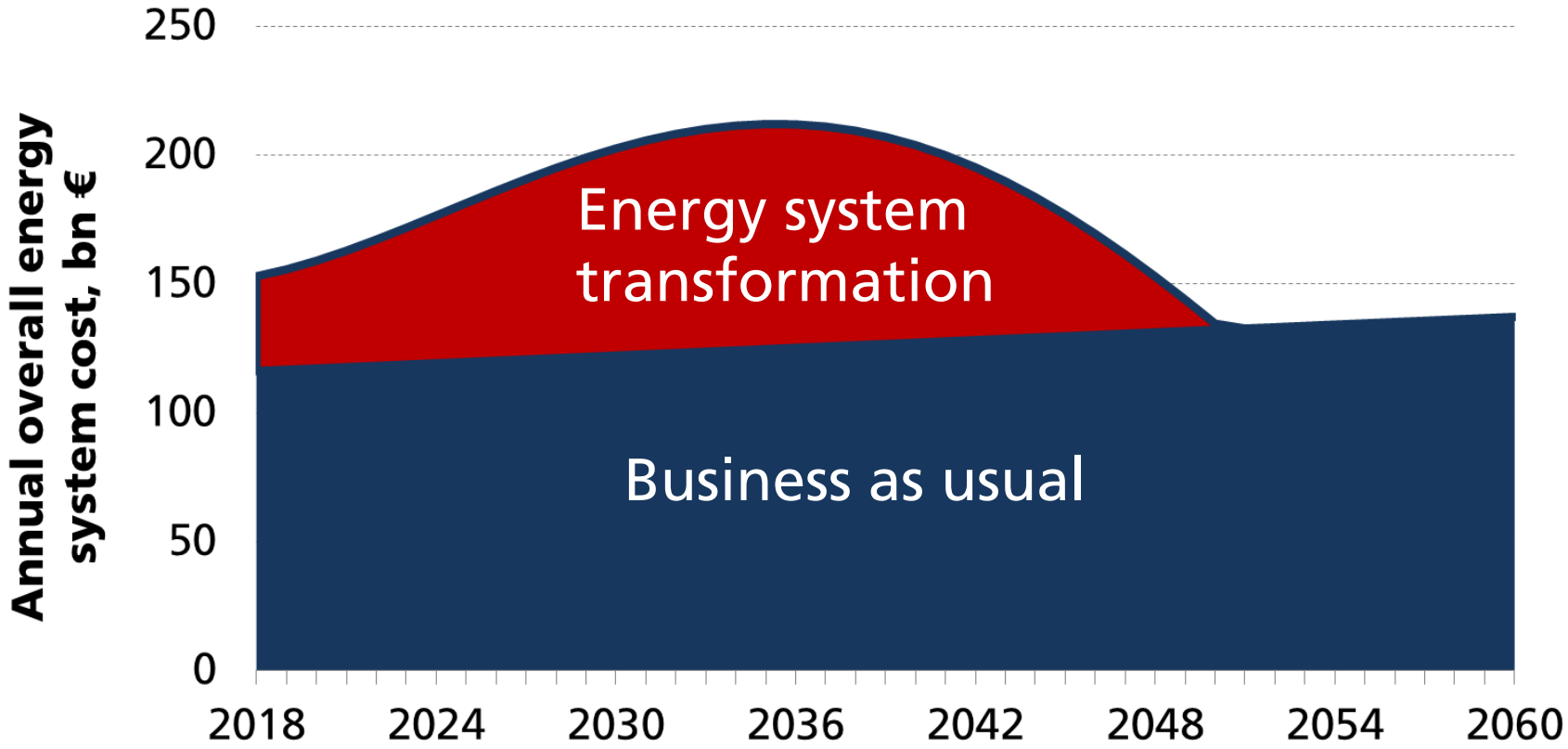
Cost development for »No restriction« scenario

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



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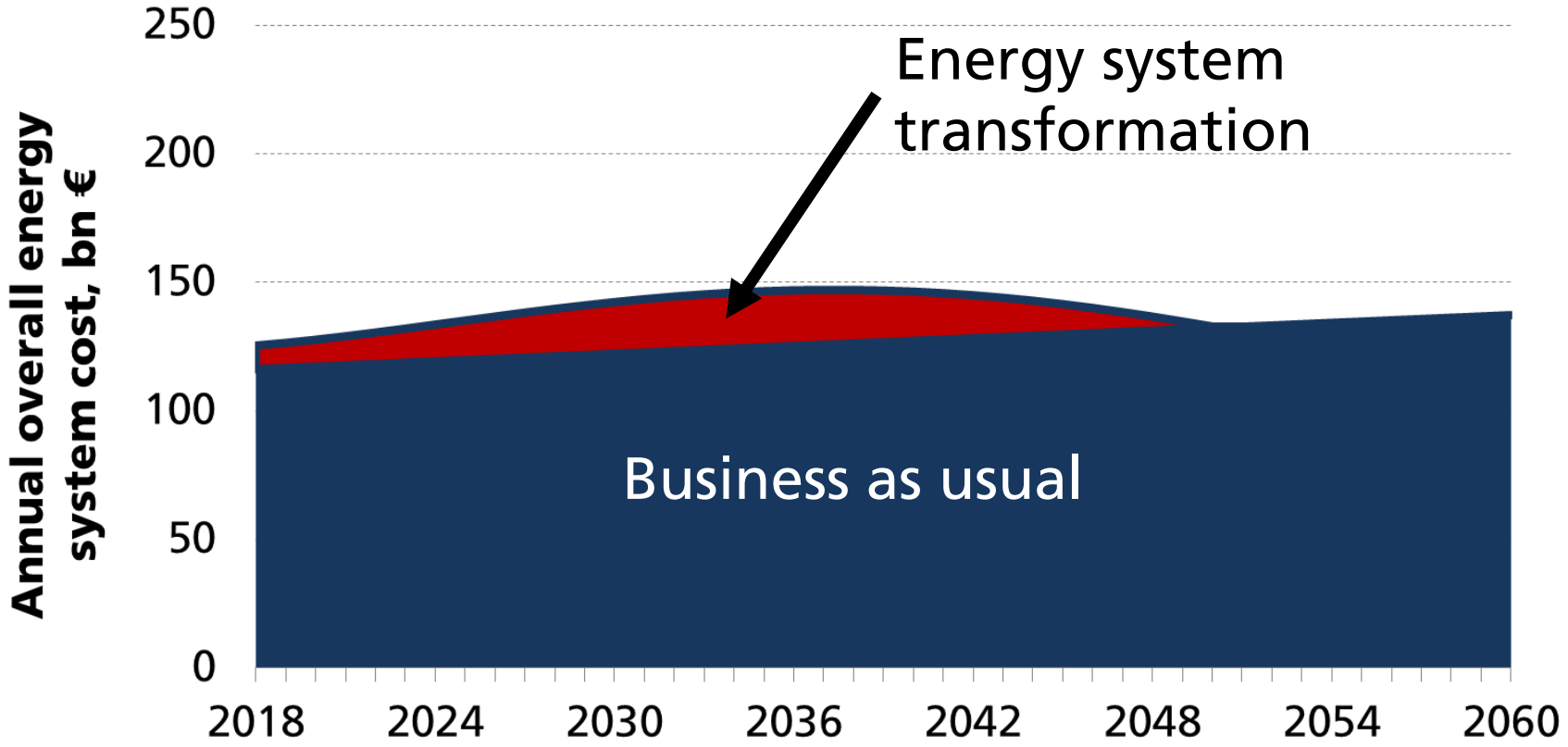
Cost development for »High efficiency« scenario

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



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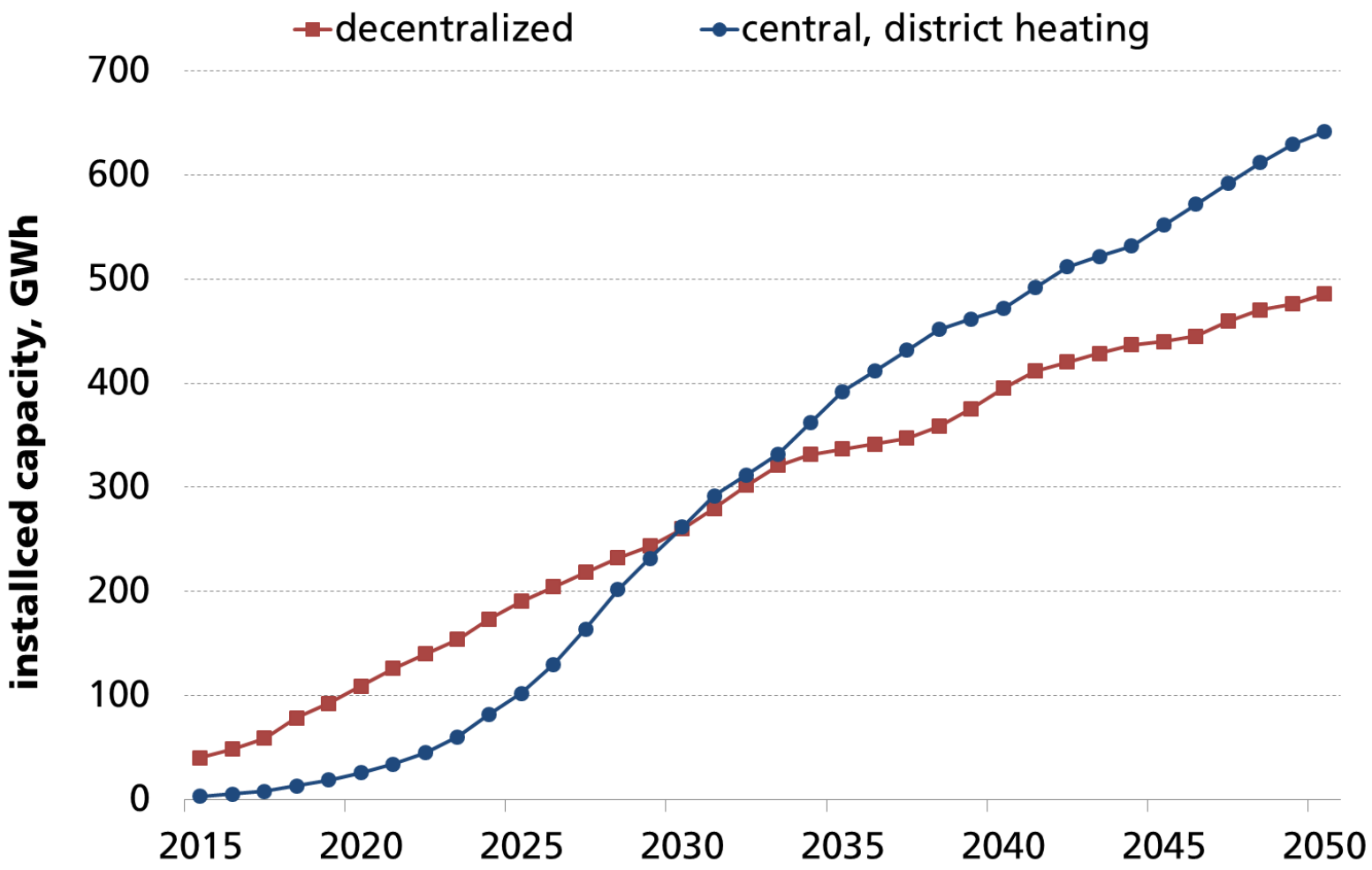
Sector coupling and power demand

- A much **stronger coupling of sectors** (integrated energy system) is a key element in achieving the climate goals.
- **New applications**, especially in the heating and transport sectors, are expected to increase power demand in the future (up to 1,000 TWh).
- **Wind and photovoltaic systems must be greatly expanded** in order to meet this demand in a climate-neutral manner. A five to seven times higher capacity of renewables than today could be necessary (400 - 600 GW).
- **Measures for the efficient use of energy** are playing a decisive role, i.a. also to limit this expansion.
- At the same time - in spite of **short-term storages** and measures for the **flexible use of electricity** - a stand-by reserve power of the same size as today's power plants is required ("cold dark doldrums").

Heat storage

»No restriction« scenario



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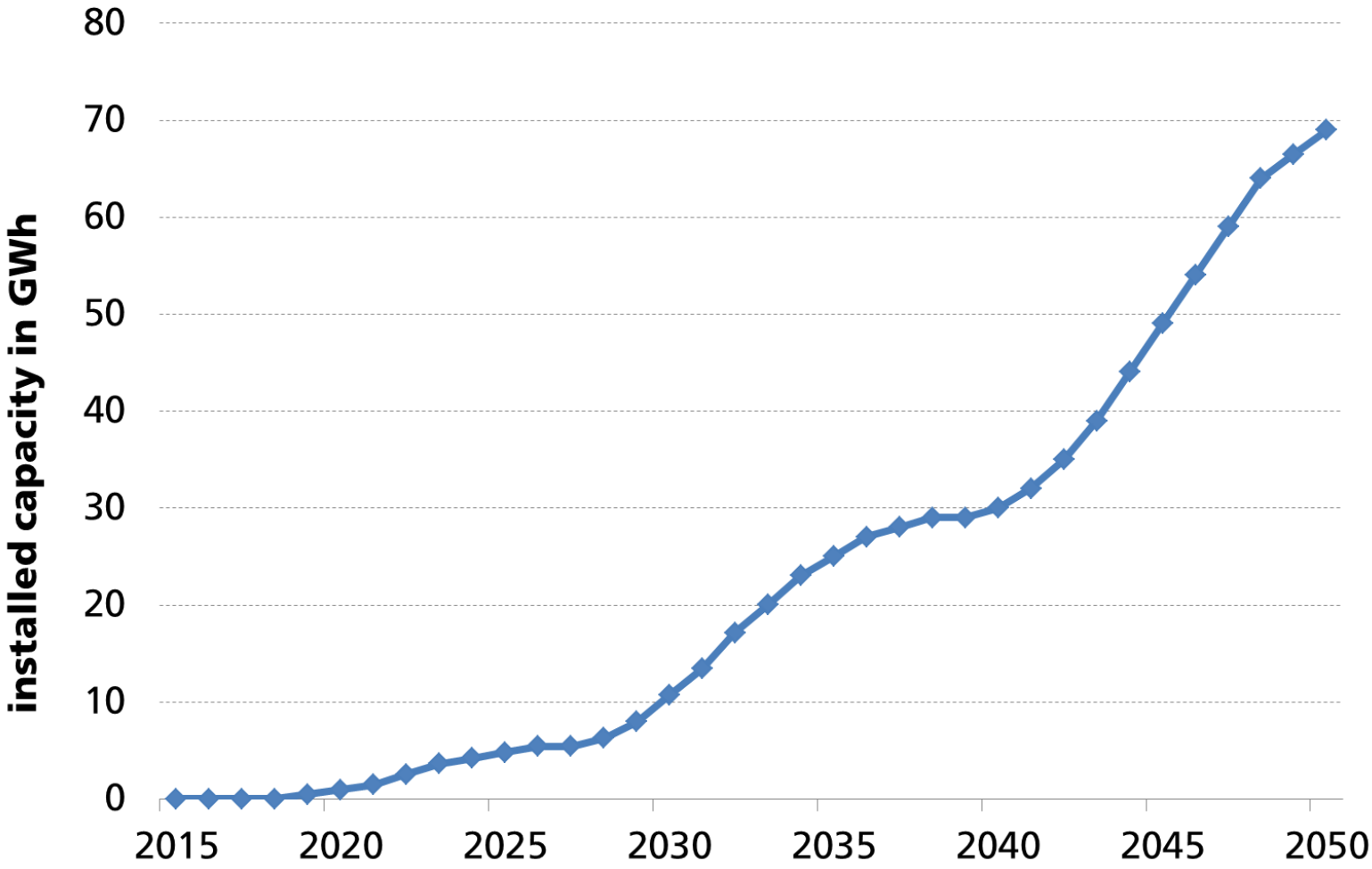
Stationary battery storage

»No restriction« scenario



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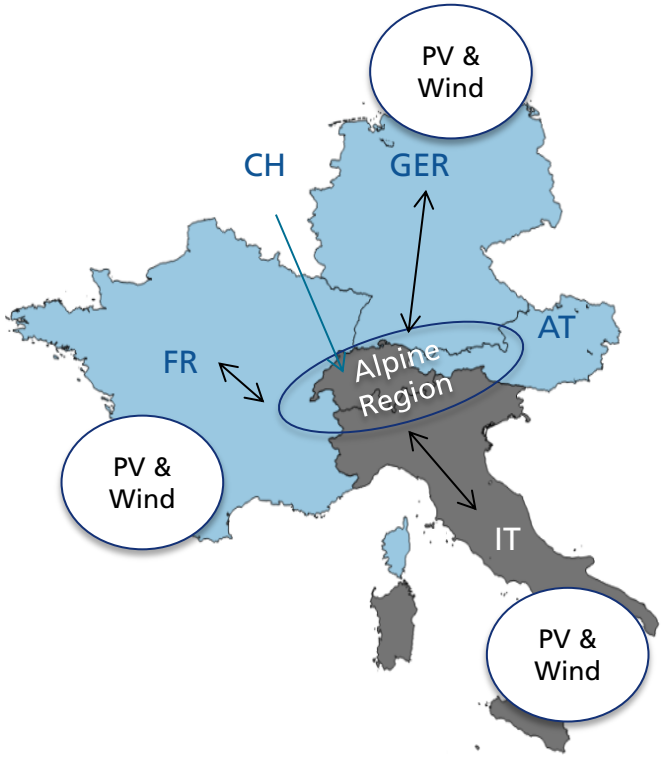
Role of the Alps in electricity balancing in Europe

Research Question

- What are effects on electricity generation, prices and new power plants between the Alpine region (Switzerland and Italy) with high share of hydropower power plants and the neighboring countries?



Methodology

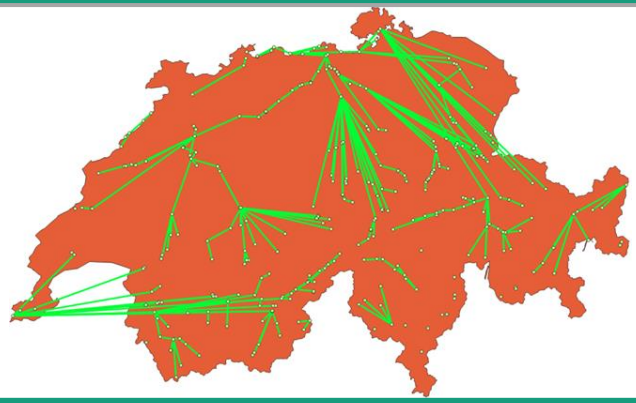
- Power sector analysis with focus on Switzerland and Italy, but including the power sector of Southern Germany, France, Austria

Role of the Alps in electricity balancing in Europe
Analysis of hydro power potentials

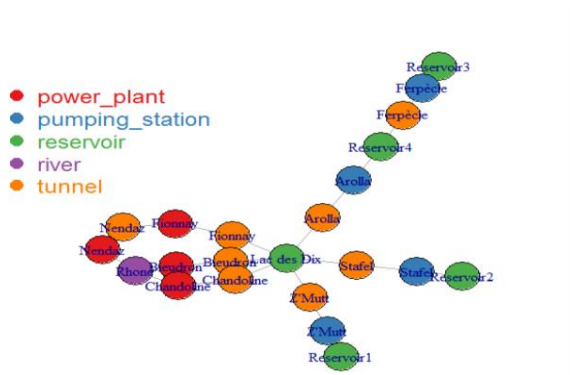
Key aspects of analysis

- Water potential and seasonal effects in combination with PV and wind
- Insights on the difficulties to obtain optimal generation strategies of energy storages (cascade effects)
- Long-term impact of climate change on water availabilities (seasonal effects, glaciers)

Configuration of basins



Linkages between hydro power plants



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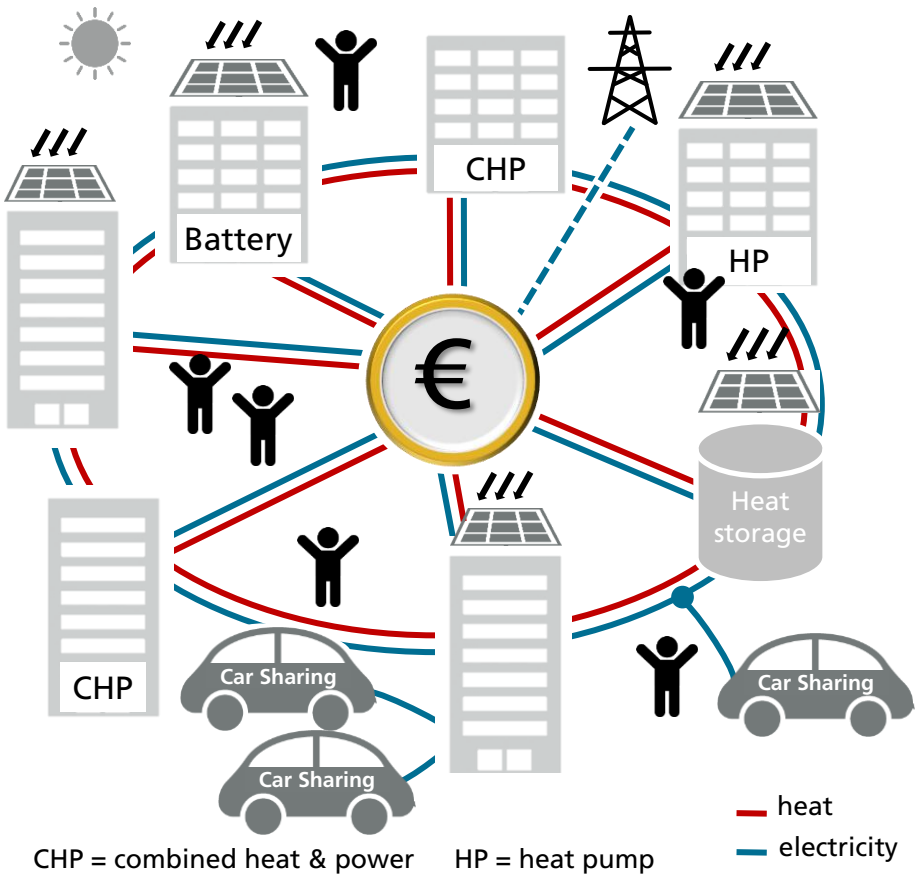
New markets and new market design

New market actors and digital services

Description



CHP = combined heat & power HP = heat pump

Elements

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

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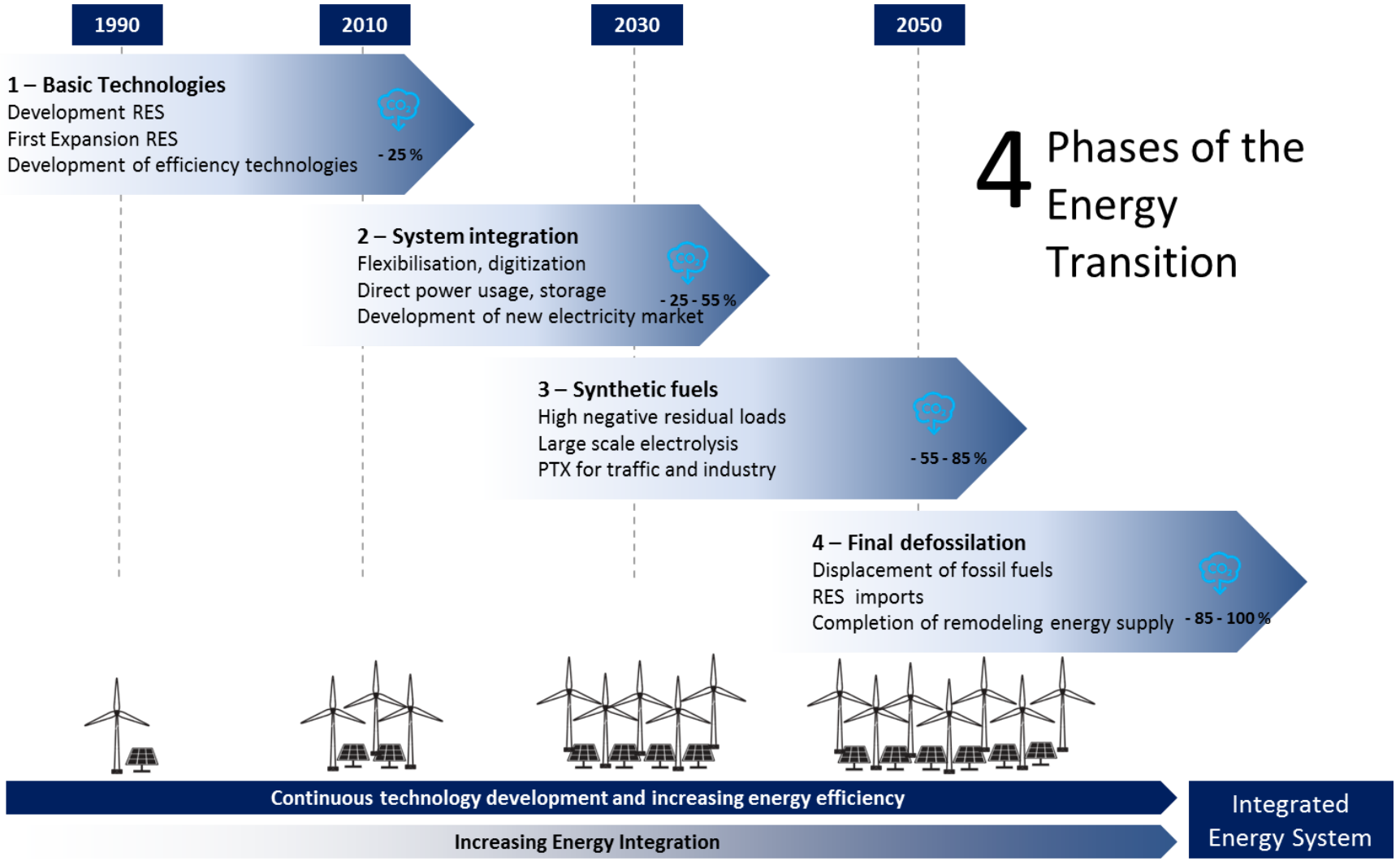
4 Key Phases of the Energy Transition



Results from https://energiesysteme-zukunft.de/themen/sektorkopplung/

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Conclusion

Technology and market development needs

- Cross sectoral perspective necessary to decarbonize all sectors.
- Large capacities for wind and solar plus large scale storage (batteries, pumped hydro, heat in district heating networks)
- Large scale hydrogen production starting in the mid of the 2030s
- New market frameworks to stimulate flexible load and generation

- Continuing with „Business as Usual“, will lead to failing to reach the climate protection targets -> **coal phase out is a first mandatory step**.
- **Comprehensive, effective CO_2 pricing covering all energy sectors** PLUS specific measurements in each sector and for each technologies needed.
- **“Social agreement between sectors”** to prioritize the goal of drastically reducing greenhouse gas emissions in order to avoid climate change with dramatic consequences

Thank you for kind attention!

Fraunhofer Institute for Solar Energy Systems ISE

Christoph Kost

Christoph.Kost@ise.fraunhofer.de

www.ise.fraunhofer.de

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Fraunhofer Institute for Solar Energy Systems ISE
At a Glance

Institute Directors:
Prof. Dr. Hans-Martin Henning
Dr. Andreas Bett

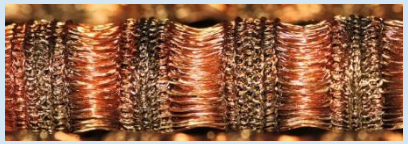
Staff: ca. 1200

Budget 2017: €89.2 million

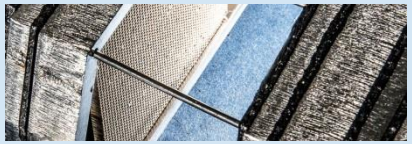
Established: 1981

Photovoltaics

Solar Thermal Technology



Building Energy Technology



Hydrogen Technologies

Energy System Technology

Group Energy Systems and Energy Economics