TOWARDS A CLIMATE-NEUTRAL ENERGY SUPPLY

Pathways for the German energy transition and implications for global developments

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Motivation

Climate Change – Forest fires, extreme wether events, melting glaciers,…

National Geographic, October 10th 2020:
“Climate change is contributing to California's fires”

CNN, November 16th 2019:
„Venedig sees worst floods in 50 years“

CBS News, January 3rd 2020:
„How climate change has intensified the deadly fires in Australia”

The Guardian, March 11th 2020:
“Polar ice caps melting six times faster than in 1990s”

Time, May 22nd 2020:
“The Taste of Bordeaux Is Going to Change”

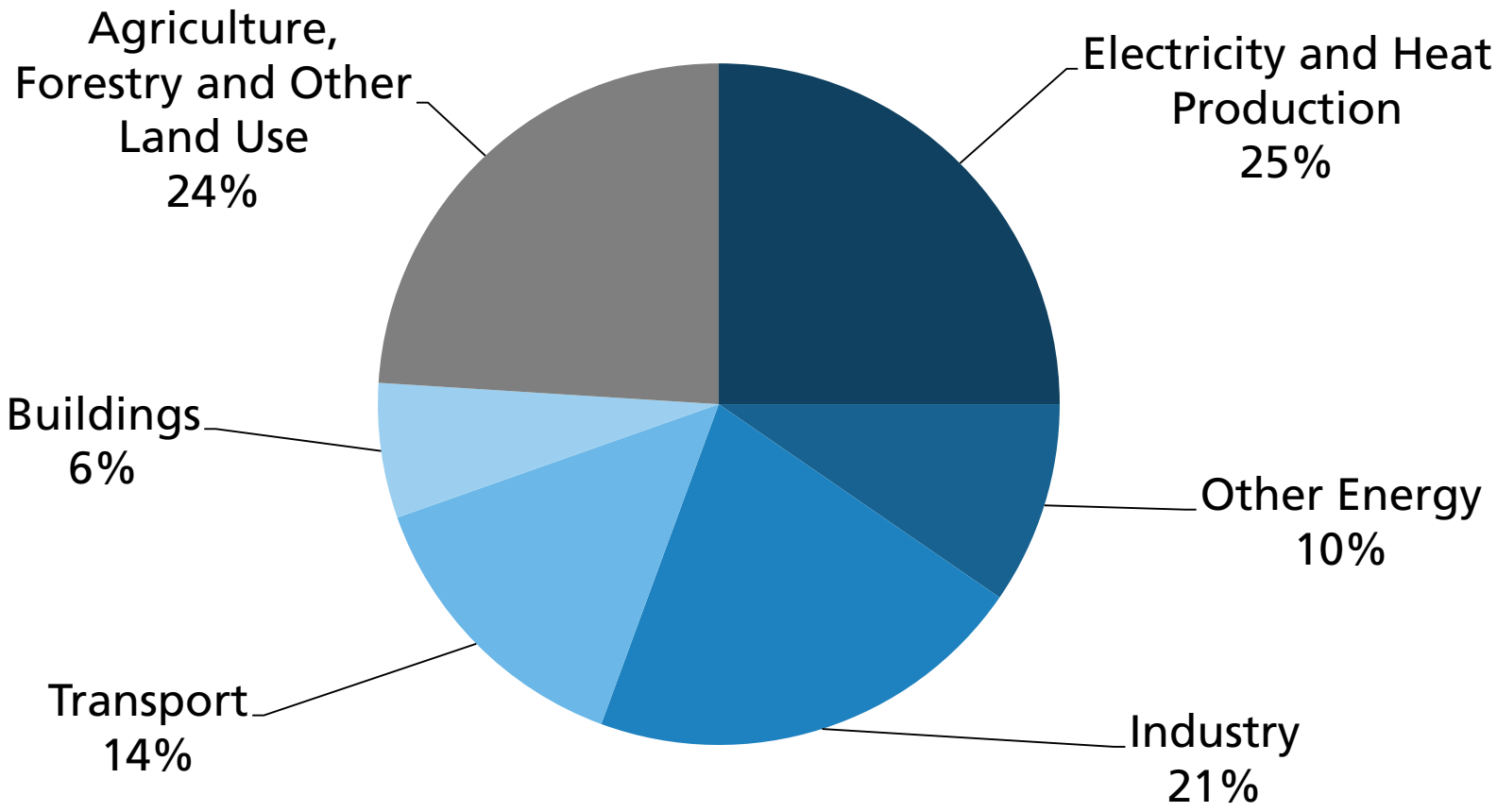
BBC, May, 22nd 2020:
“Cyclone Amphan batters India and Bangladesh”

Motivation

Global Greenhouse Gas Emissions by Economic Sector

- Anthropogenic impact on increased greenhouse effect and resulting climate change obvious
- The energy sector overall contributes more than three quarters to global greenhouse gas emissions

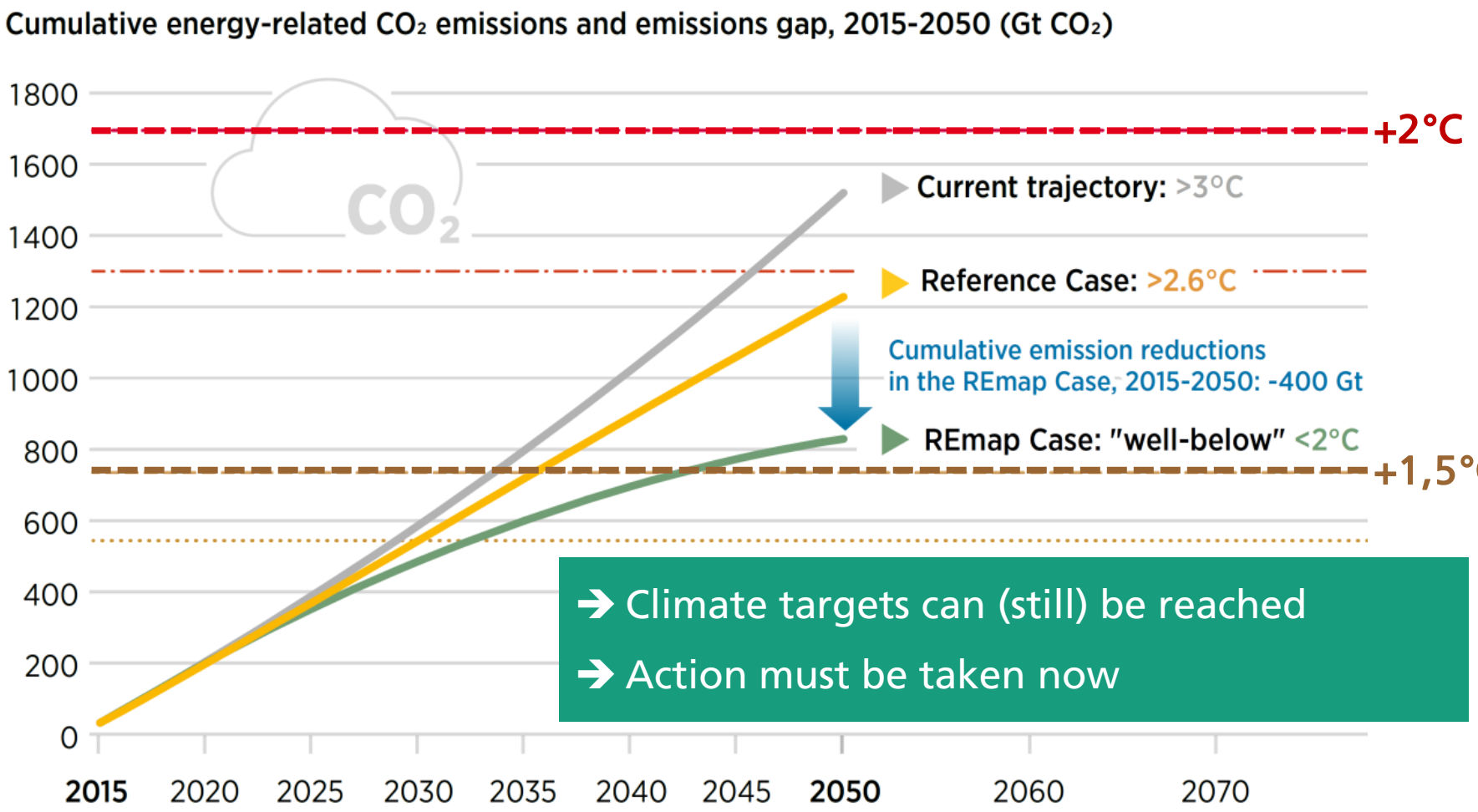
➔ **Clear target: energy systems with drastically reduced CO_2 emissions**



Source: IPCC (2014); based on global emissions from 2010. Details about the sources included in these estimates can be found in the Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.

Motivation

Pathway for a well-below 2°C climate target – Energy related CO_2 emissions



➔ Climate targets can (still) be reached

➔ Action must be taken now

Current trajectory:
Extrapolation of the recent historical trend line of energy-related CO_2 emissions

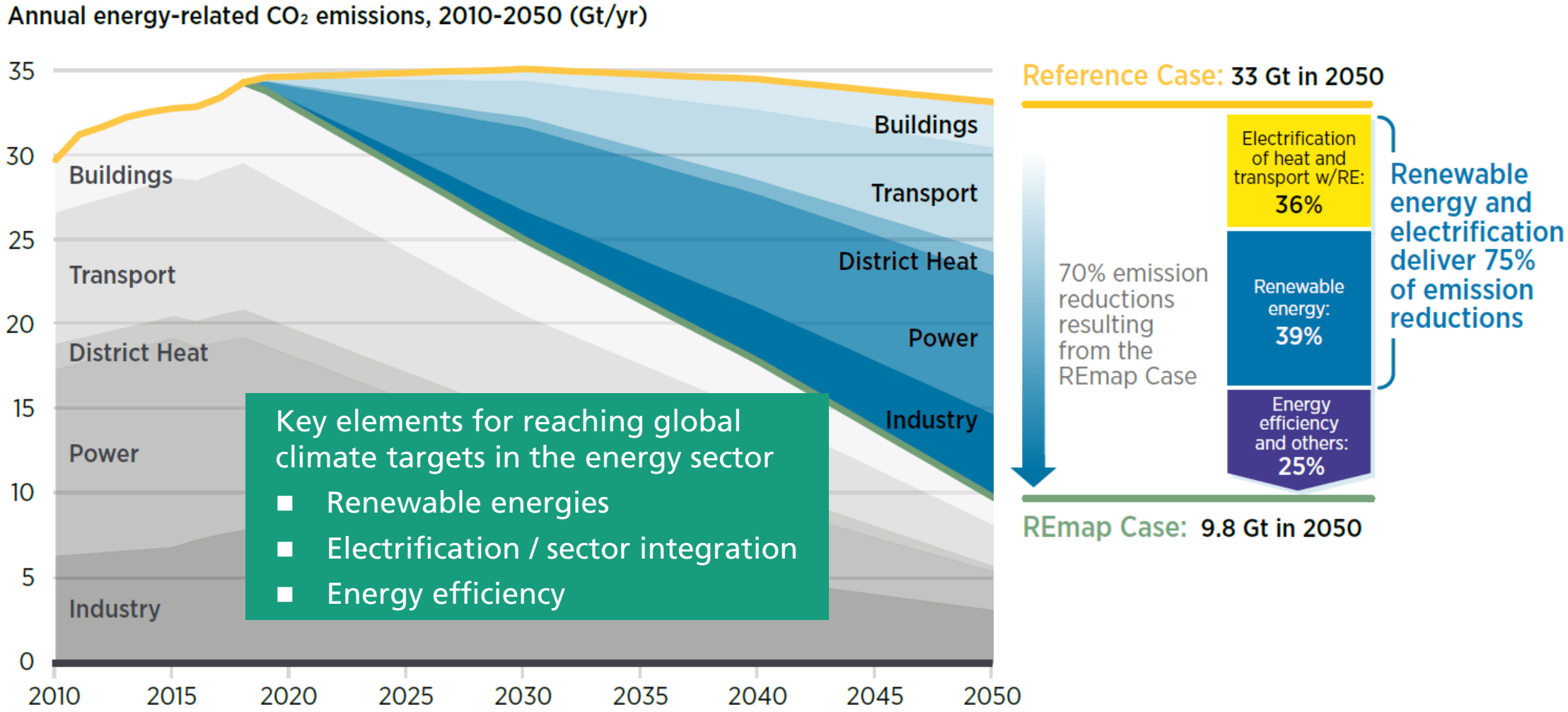
Reference Case:
considering current and planned policies of countries and includes commitments made in Nationally Determined Contributions

REmap Case:
includes the deployment of low-carbon tech-nologies, based largely on renewable energy and energy efficiency

Report: IRENA, Global Energy Transformation – A Roadmap to 2050 (2019 edition), ISBN: 978-92-9260-121-8
https://www.irena.org/publications/2019/Apr/Global-energy-transformation-A-roadmap-to-2050-2019Edition

Motivation

Pathway for a well-below 2°C climate target – IRENA REMap scenario



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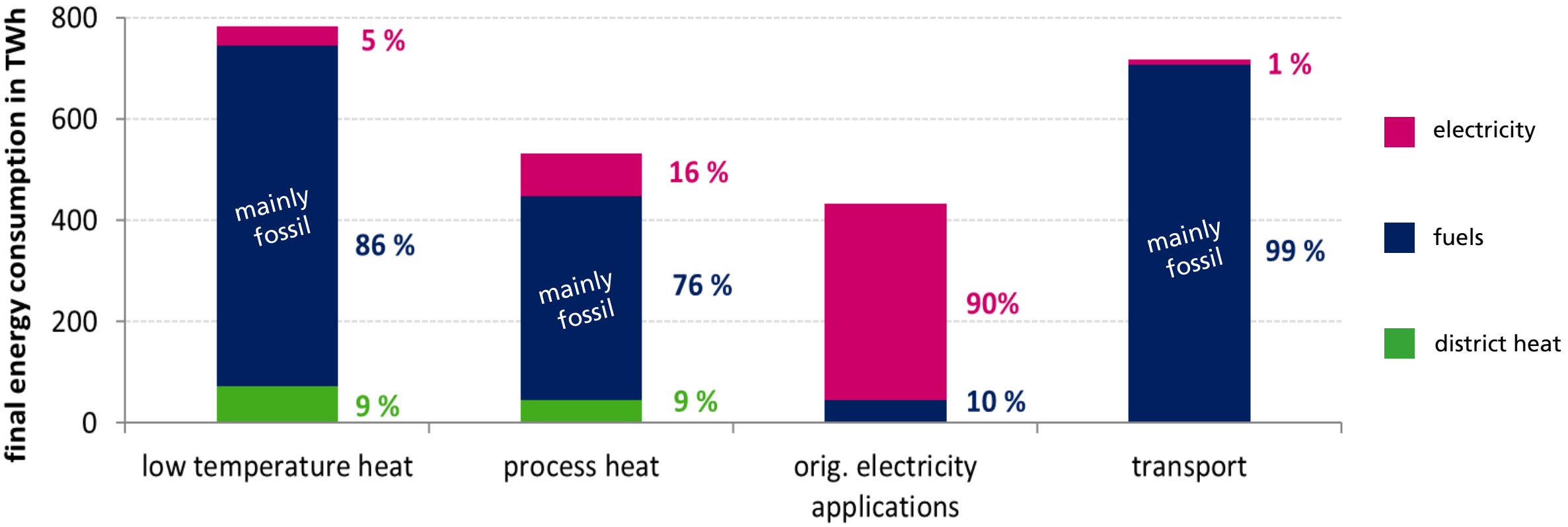
https://www.irena.org/publications/2019/Apr/Global-energy-transformation-A-roadmap-to-2050-2019Edition

Motivation

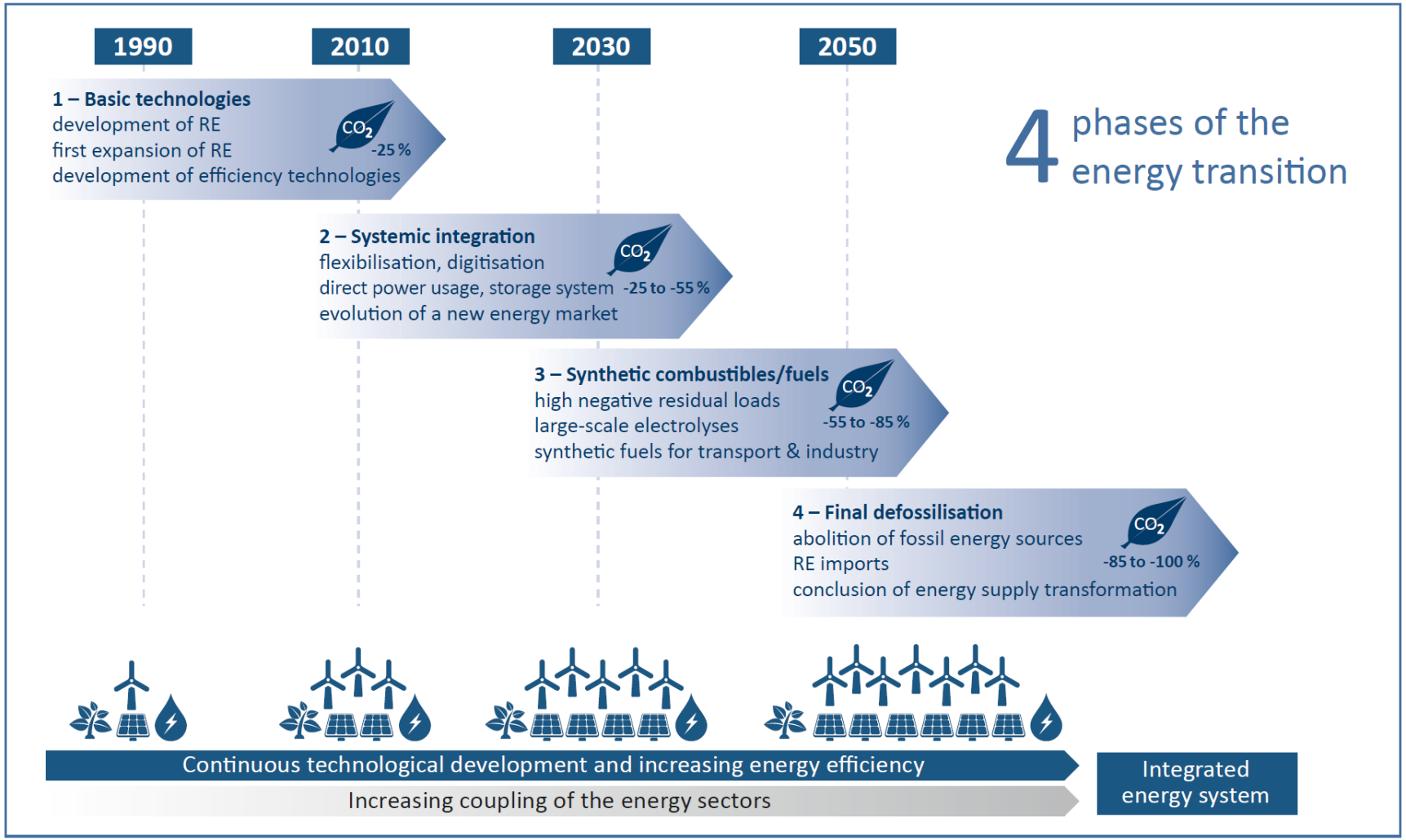
Current status in Germany – Energy consumption today in the four areas of use



Quelle: »Sektorkopplung« – Optionen für die nächste Phase der Energiewende. acatech – Deutsche Akademie der Technikwissenschaften et. al. November 2017. Daten: „Energiedaten, Gesamtausgabe“, BMWi, 02/2017.

The challenge – Organise and stimulate the complex transition

Structural phases of the energy system transformation



Leopoldina
Nationale Akademie der Wissenschaften

acatech
DEUTSCHE AKADEMIE DER TECHNIKWISSENSCHAFTEN

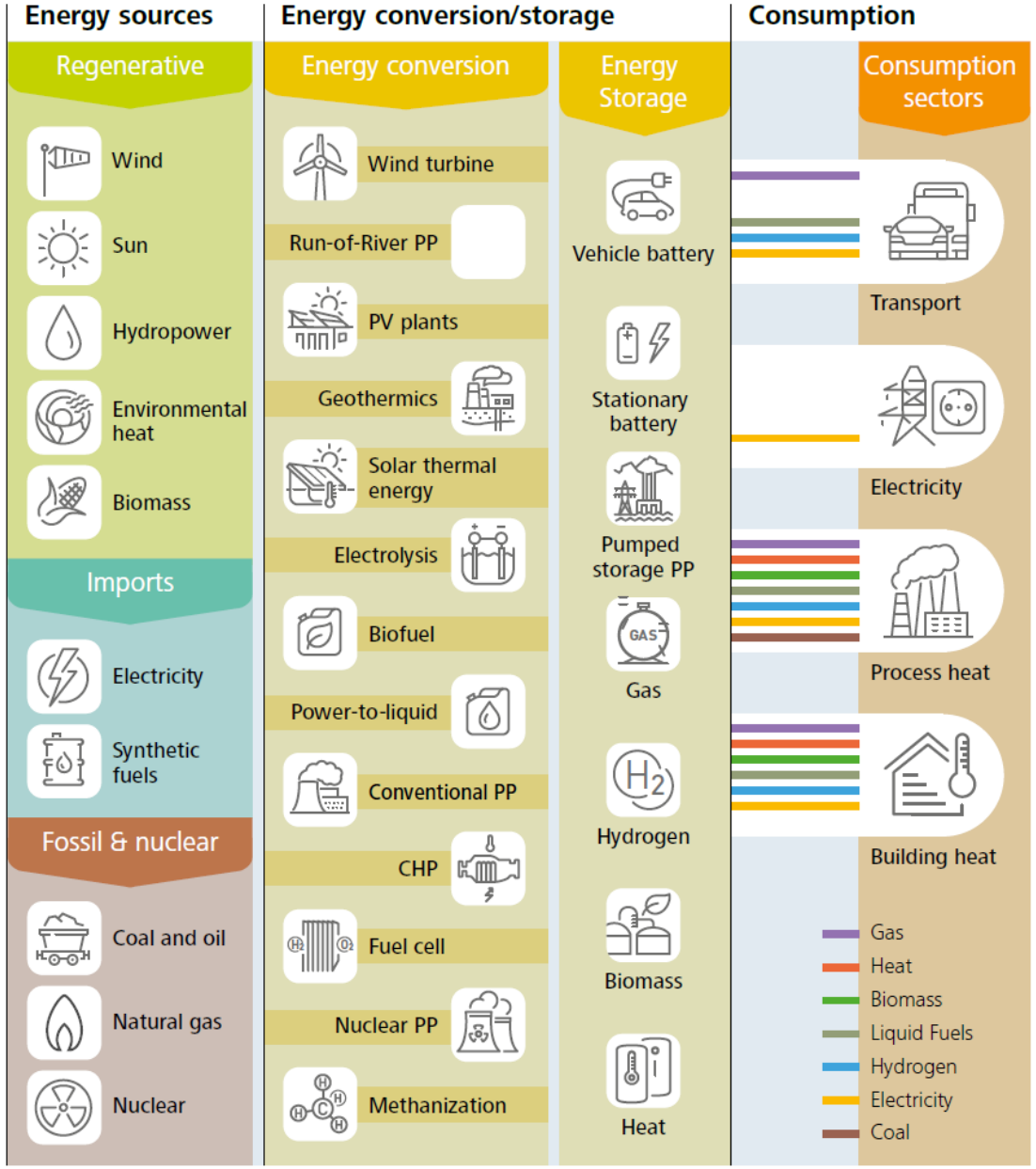
UNION
DER DEUTSCHEN AKADEMIEN DER WISSENSCHAFTEN

Coupling the different energy sectors – options for the next phase of the energy transition. Position paper by the German academies of science. Produced in the framework of »ESYS – Energiesysteme der Zukunft«. https://energiesysteme-zukunft.de/publikationen/stellungnahme-sektorkopplung/

Content

Energy system analysis – Methodology
Renewable Energy Model »REMod«

- **Strictly model-based techno-economic optimization of transformation pathways**
  - Consideration of all sectors and energy sources
  - Comprehensive simulation of energy systems (hourly time scale)
  - Mimimize total transformation cost



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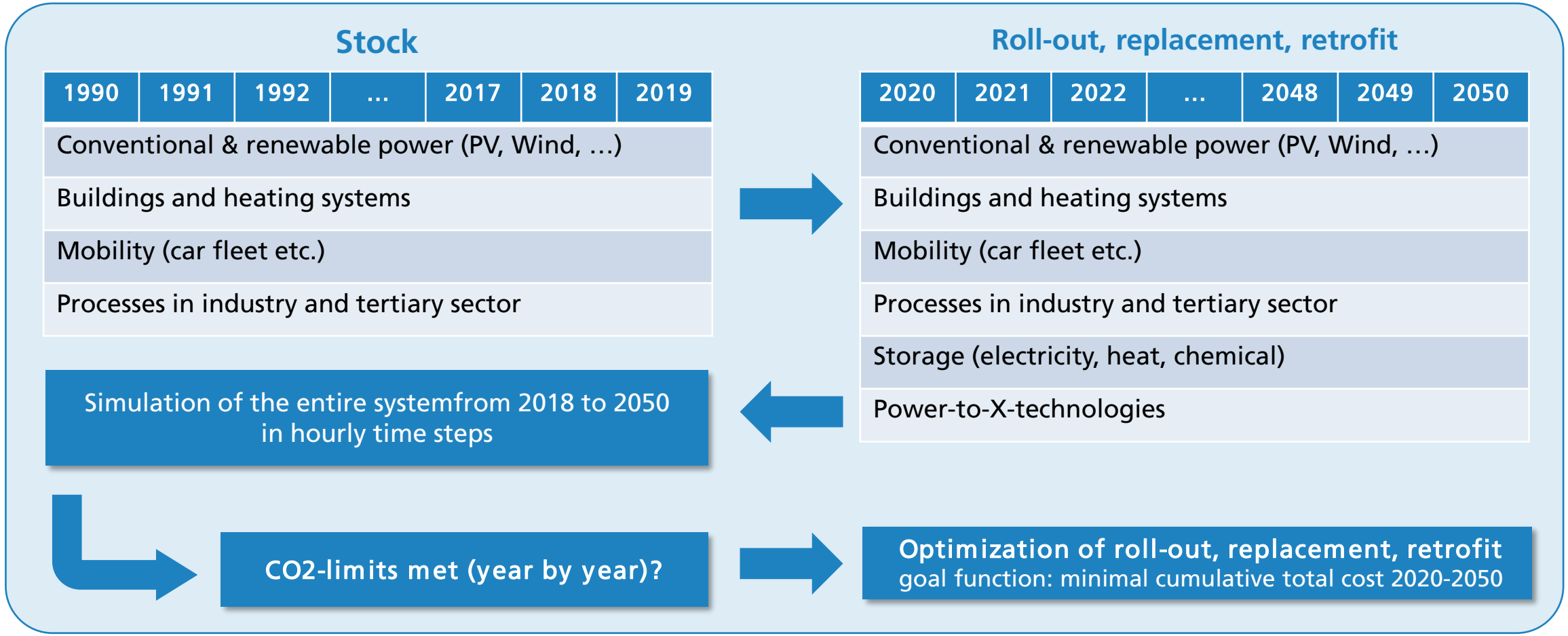
Energy system analysis – Methodology



Energy system analysis – Methodology

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

It can…

…not give answers to the following:

- Forecast of the future
- Describe business models for market participants
- Describe price building on the market

…provide answers to questions such as:

- How can transformation pathways and corresponding overall energy systems look like – based on cost and performance projections for all potentially involved technologies?
- What are overall system costs (incl. investments, capital cost, M&O cost, fuel cost)?

Energy system analysis – Methodology

Assumptions for the four energy worlds/scenarios

Reference

cost-optimal path

- –

Persistance

persistance on conventional technologies

- Transport: higher share of combustion engines in new passenger car registrations
- Buildi… …re gas boilers for new installations, …mps; lower rate of building renovation

All Scenarios:
Reduction of energy-related CO_2 emissions by 95 Percent

Inacceptance

resistance a… large infrastru…

- Reduction of the expansion potential for wind energy
- Less grid expansion for electricity imports
- No use of overhead line trucks

Sufficiency

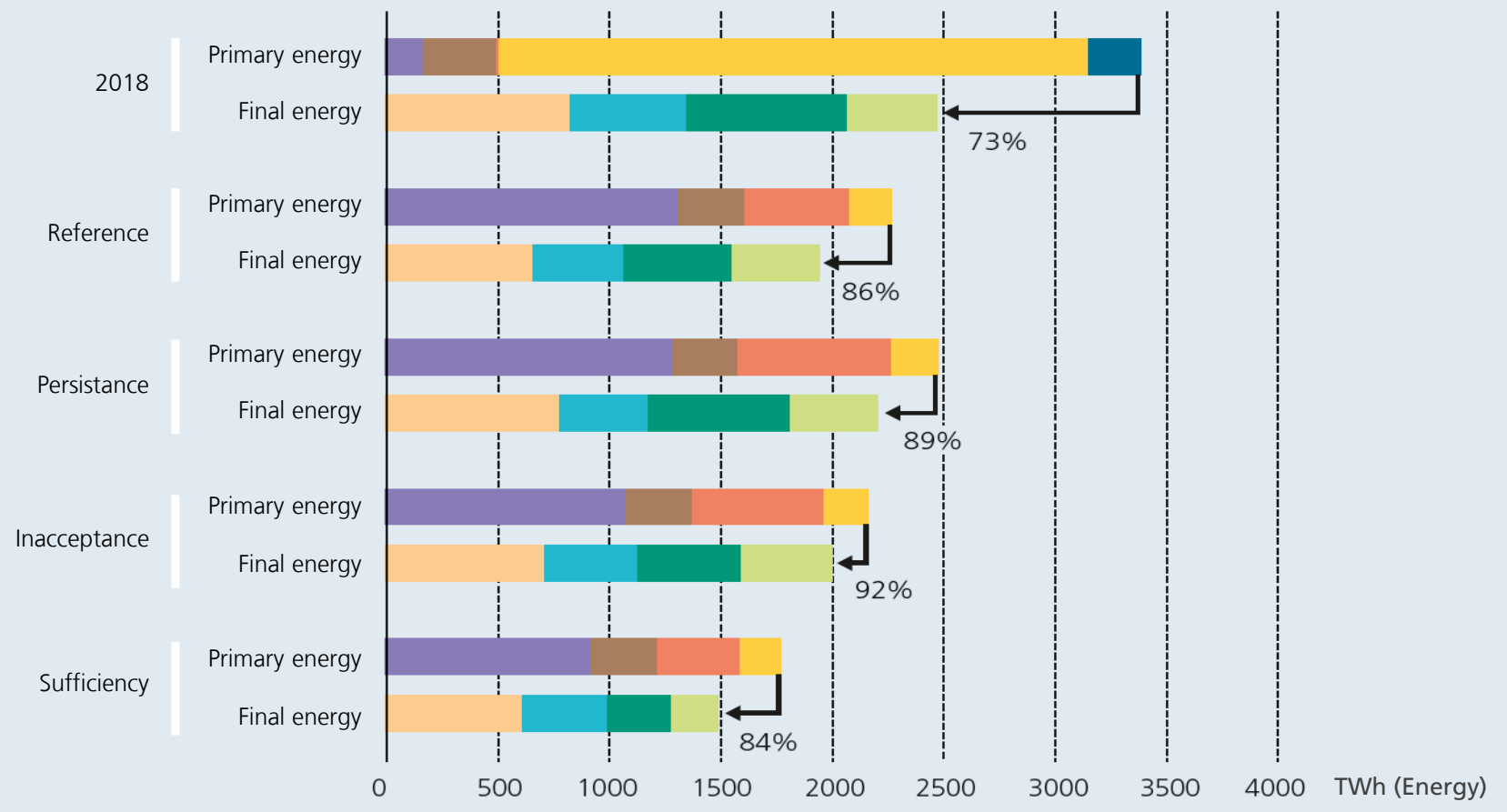
energy savings and changes in behaviour

- Decline in energy consumption in all sectors (e.g. fewer kilometres travelled, reduction in demand for electricity)
- Increased flexibility for car batteries (V2G, G2V)

P. Sterchele et al.: Paths to a Climate-Neutral Energy System, Fraunhofer ISE, Freiburg, February 2020.
https://www.ise.fraunhofer.de/en/publications/studies/paths-to-a-climate-neutral-energy-system.html

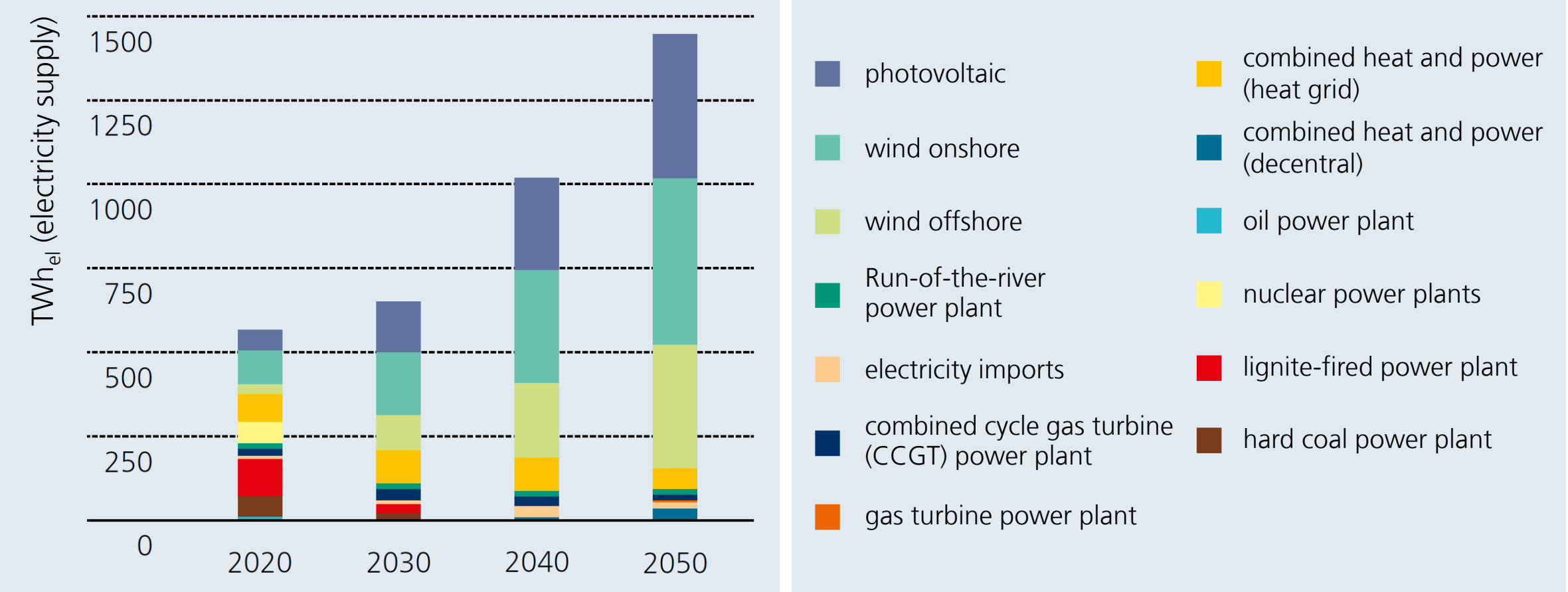
Content

Primary and final energy in 2050



*VRE: Variable renewable energy (sun, wind)

Course of electricity supply (reference scenario)



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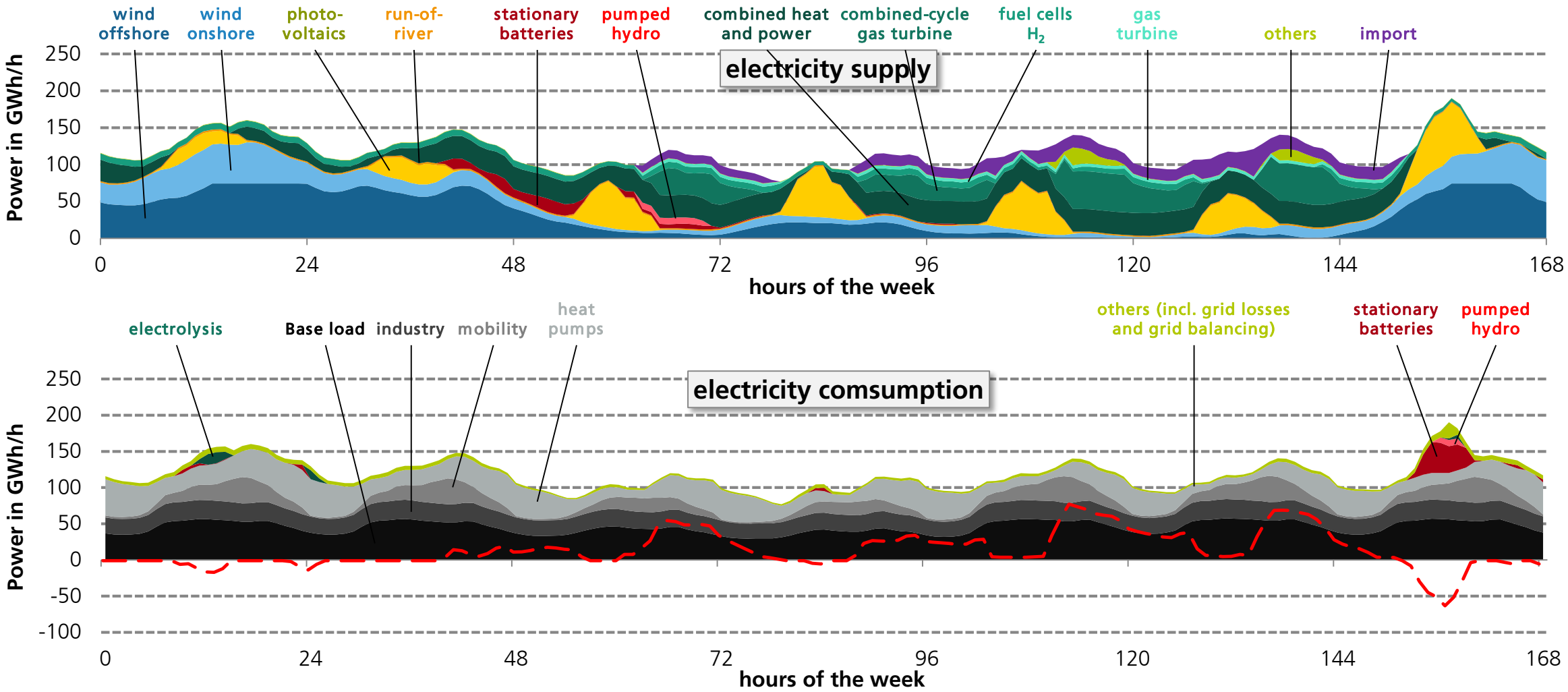
Electricity supply and demand in a winter week (reference scenario, 2050)



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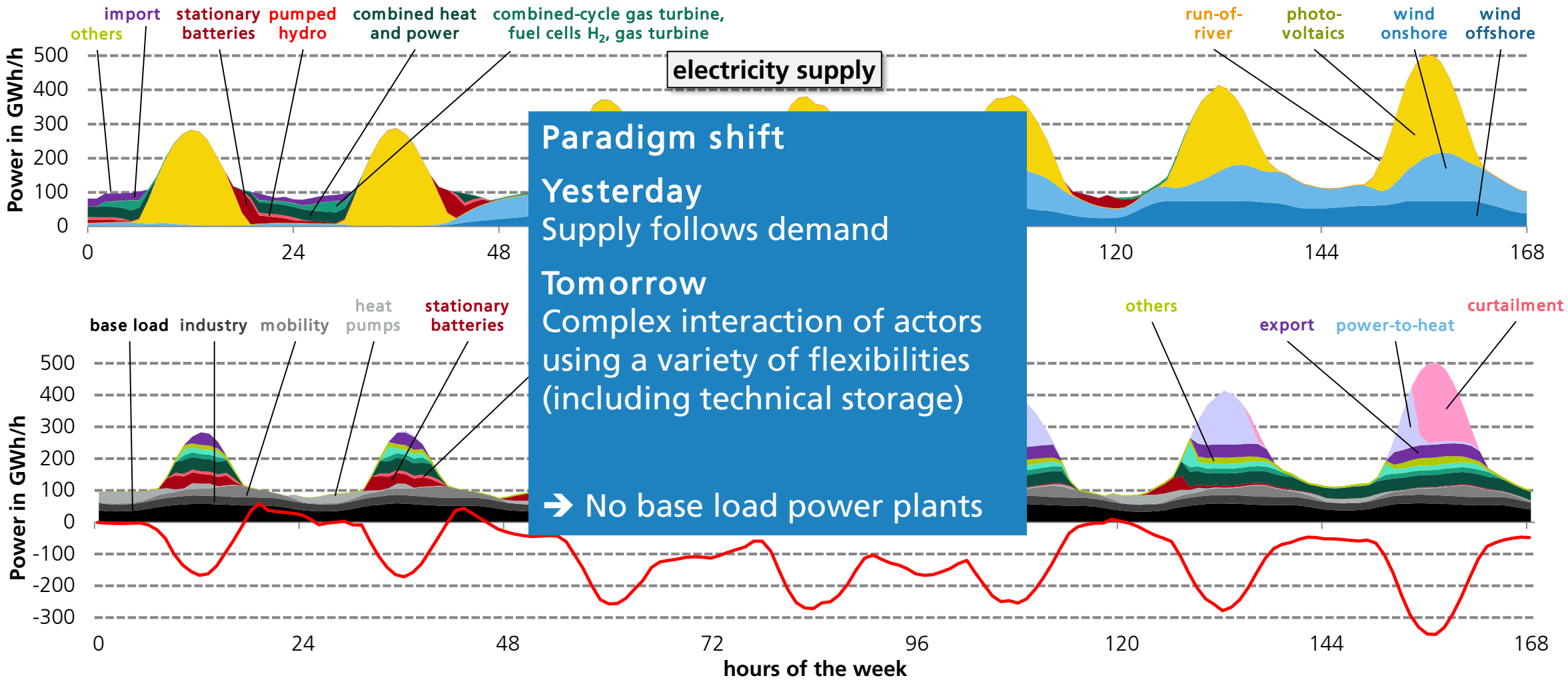
Electricity supply and demand in a summer week (reference scenario, 2050)



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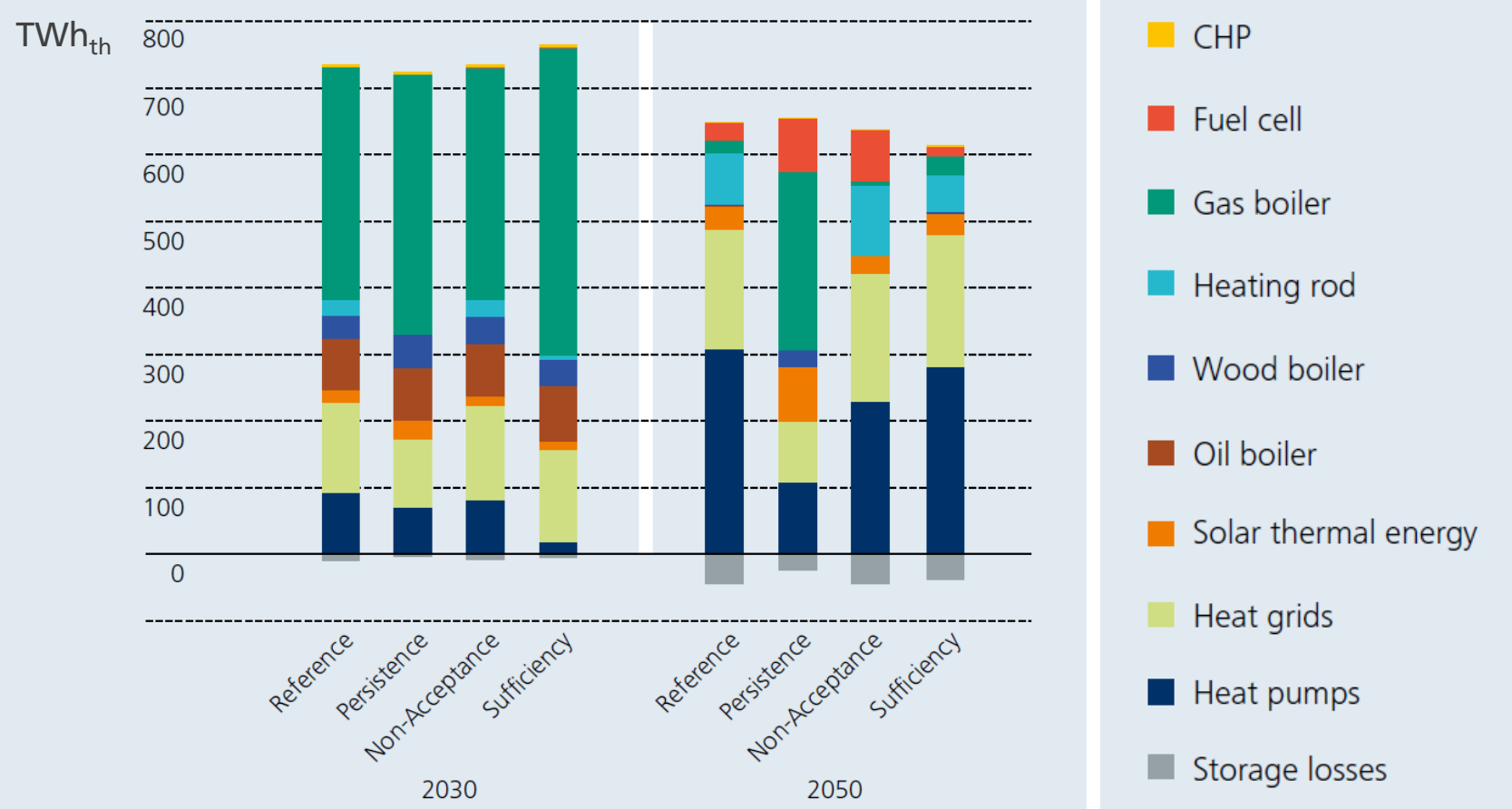
System integration
Heat supply in the building sector



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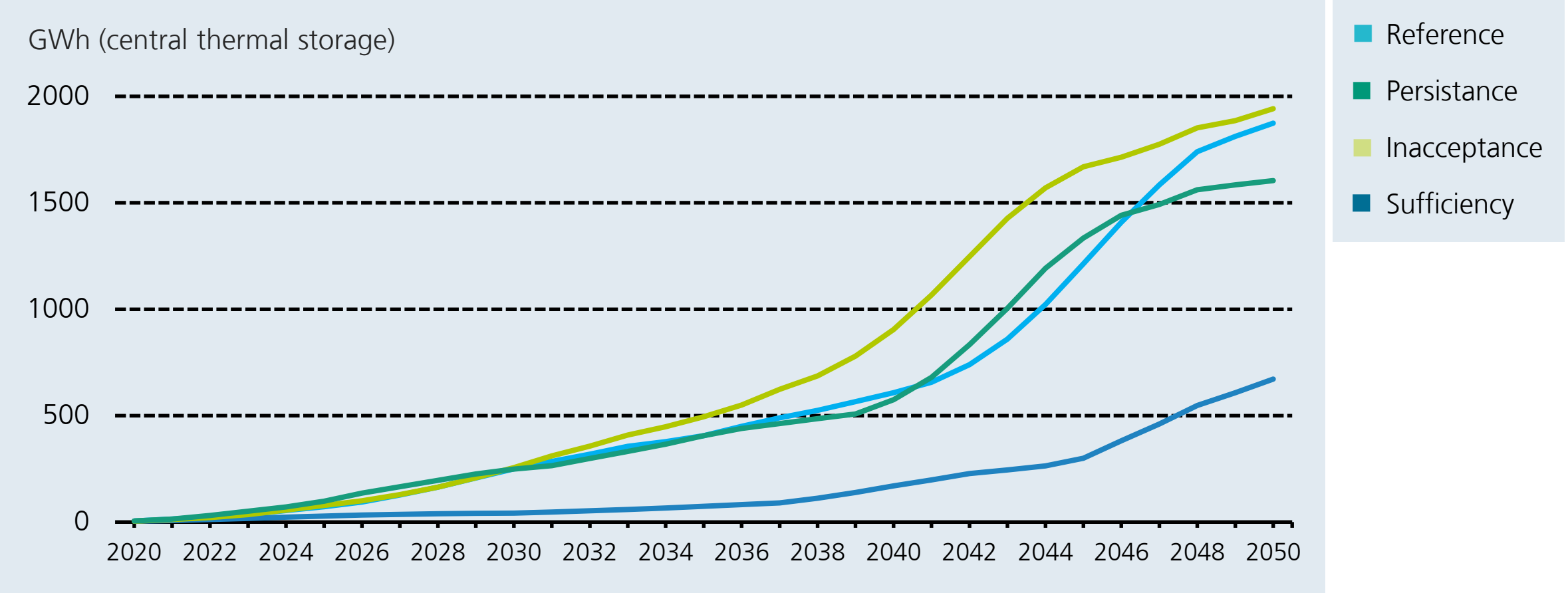
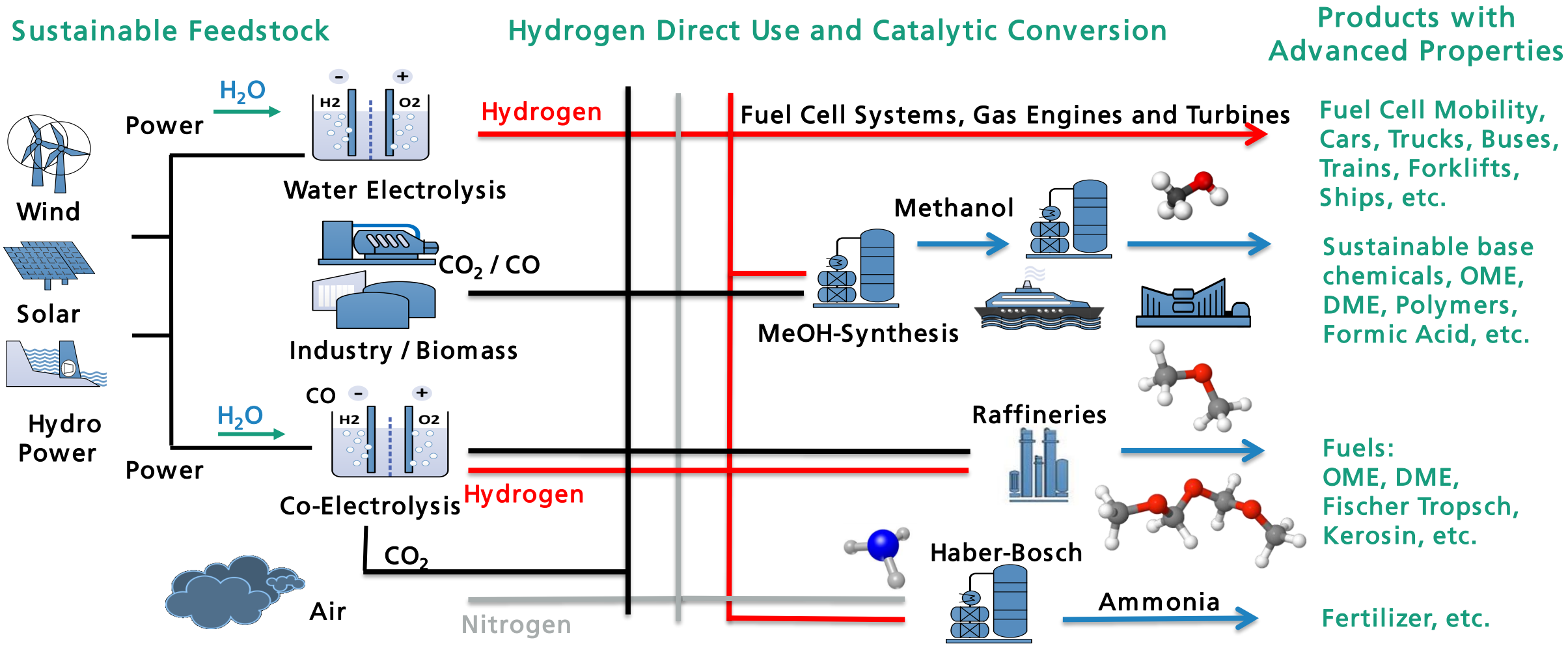
System integration

Development of large scale heat storage in heating networks



Synthetic fuels

Power-To-X: Hydrogen Value Chain and Applications



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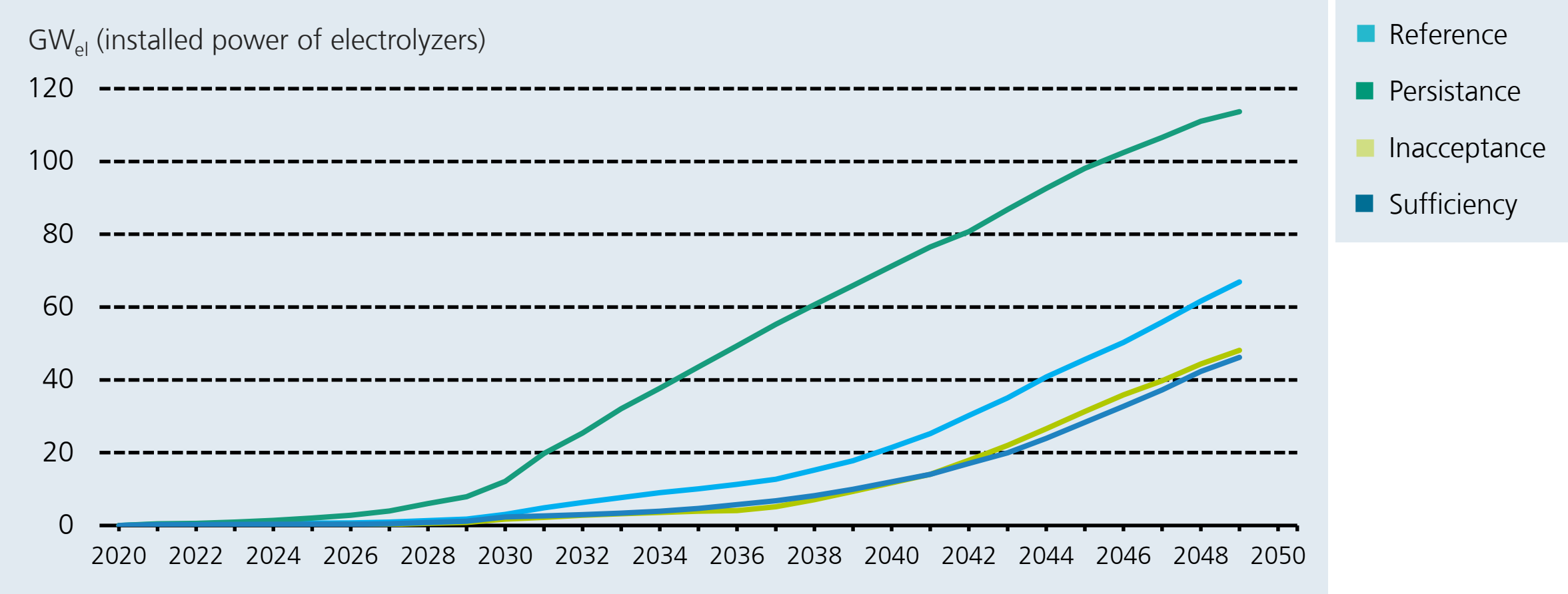
Synthetic fuels

Development of electrolyzer capacity



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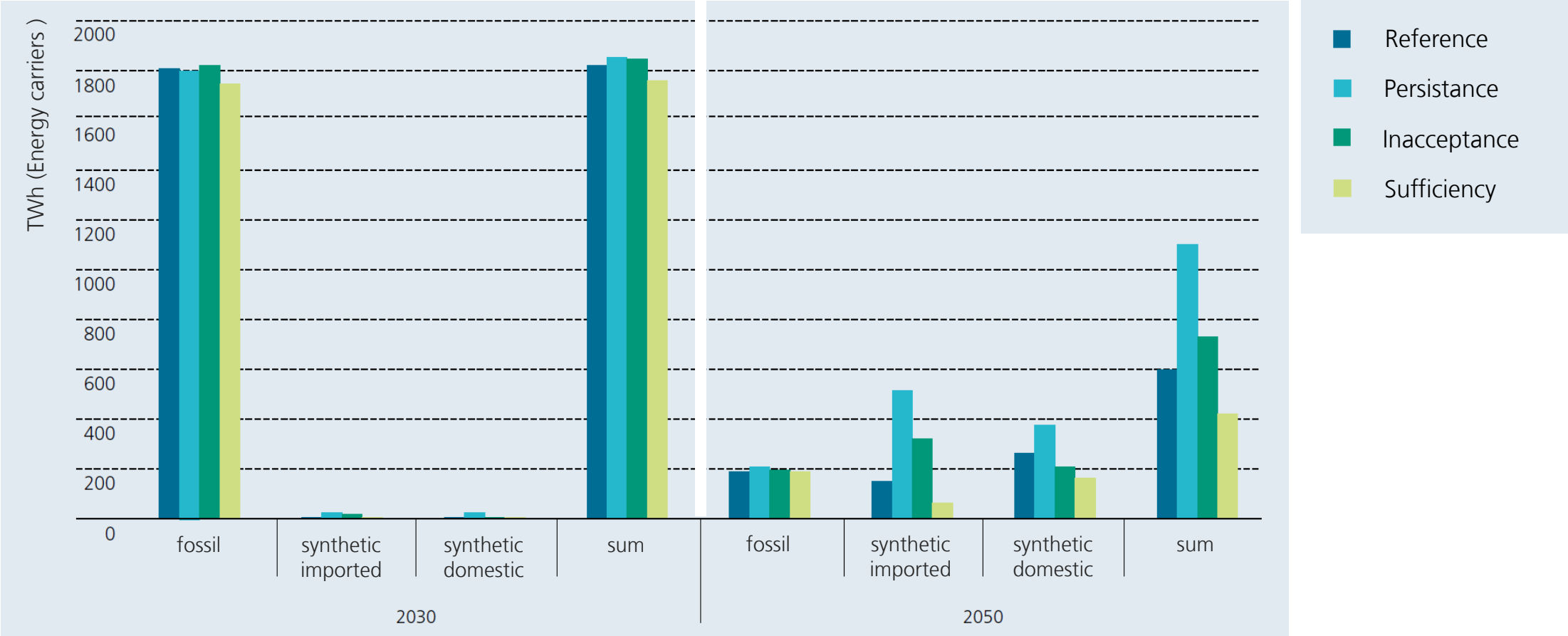
Final de-fossilitation

Composition of fuels (2030, 2050)



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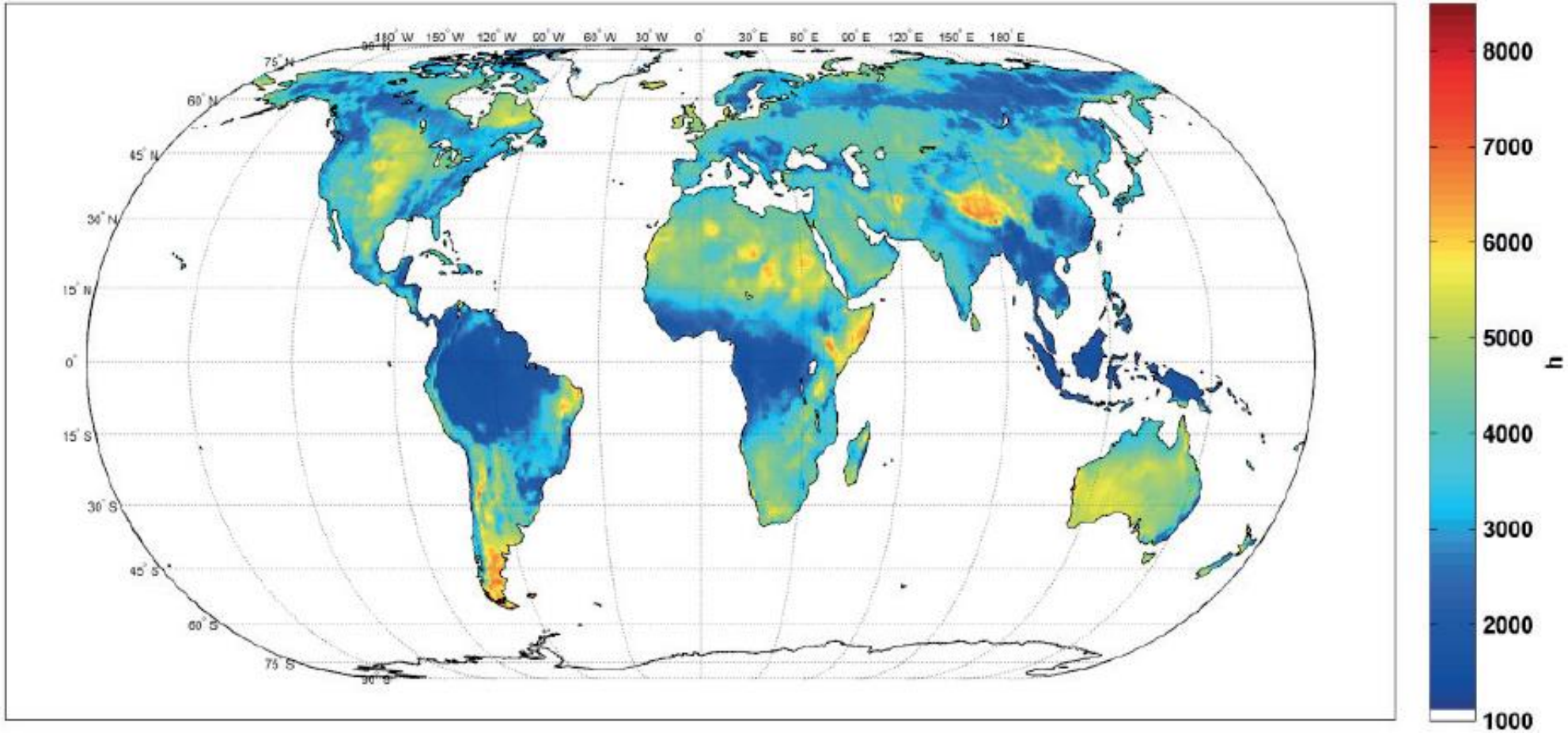
Final de-fossilitation

Power-To-X: Full Load Hours of PV and Wind Power Plants Combined



Source: IEA (2017) Renewables

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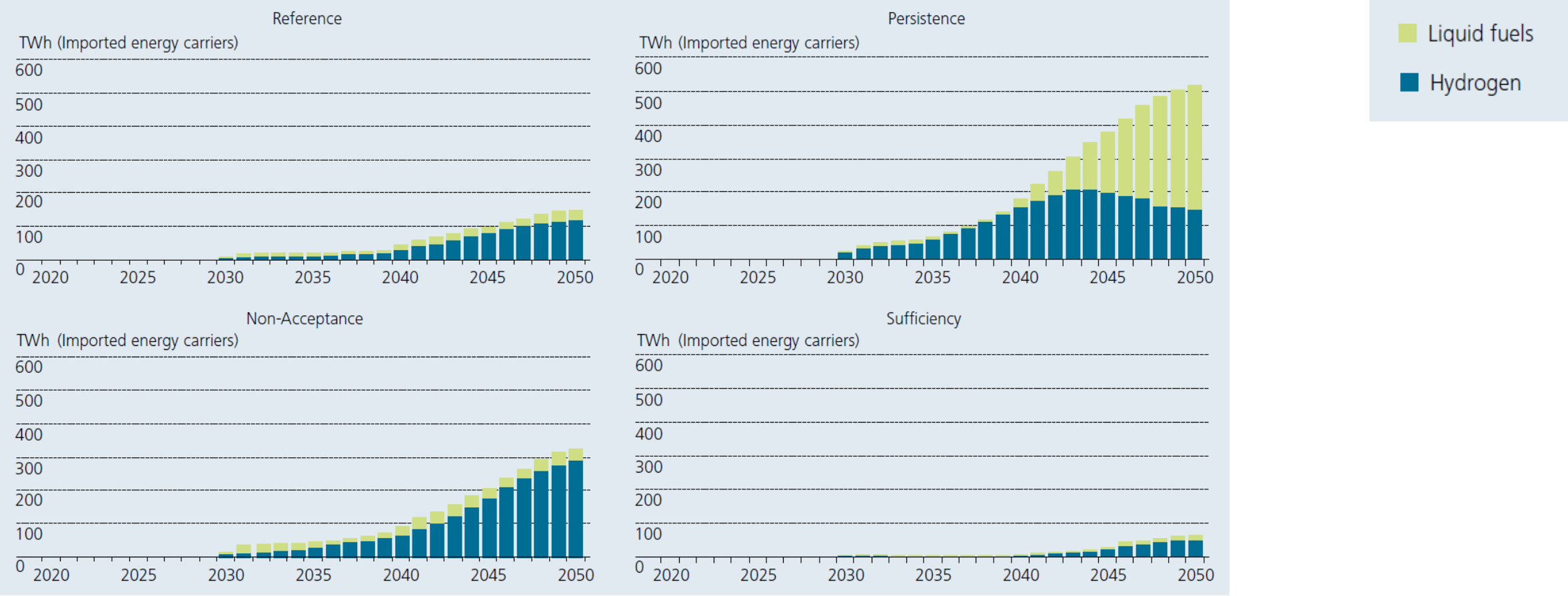
Final de-fossilitation

Imported synthetic energy carriers produced abroad by electrolysis and converted to hydrogen with renewables



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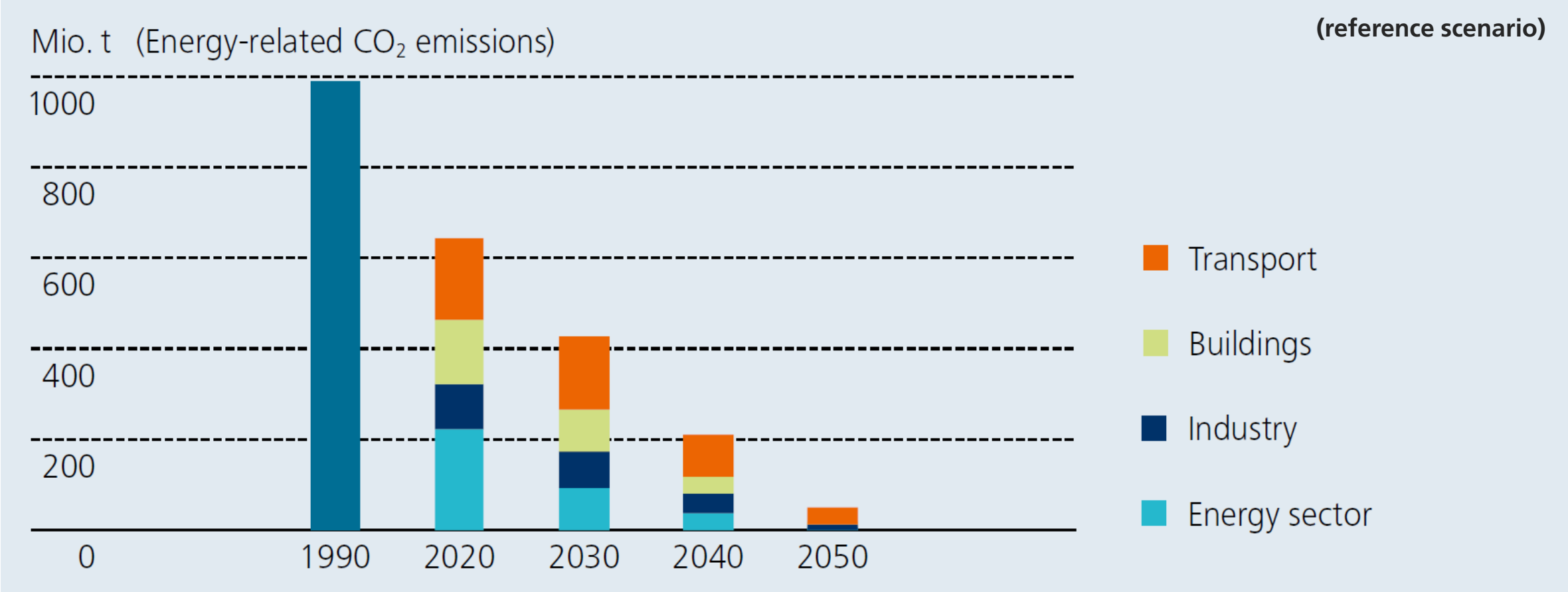
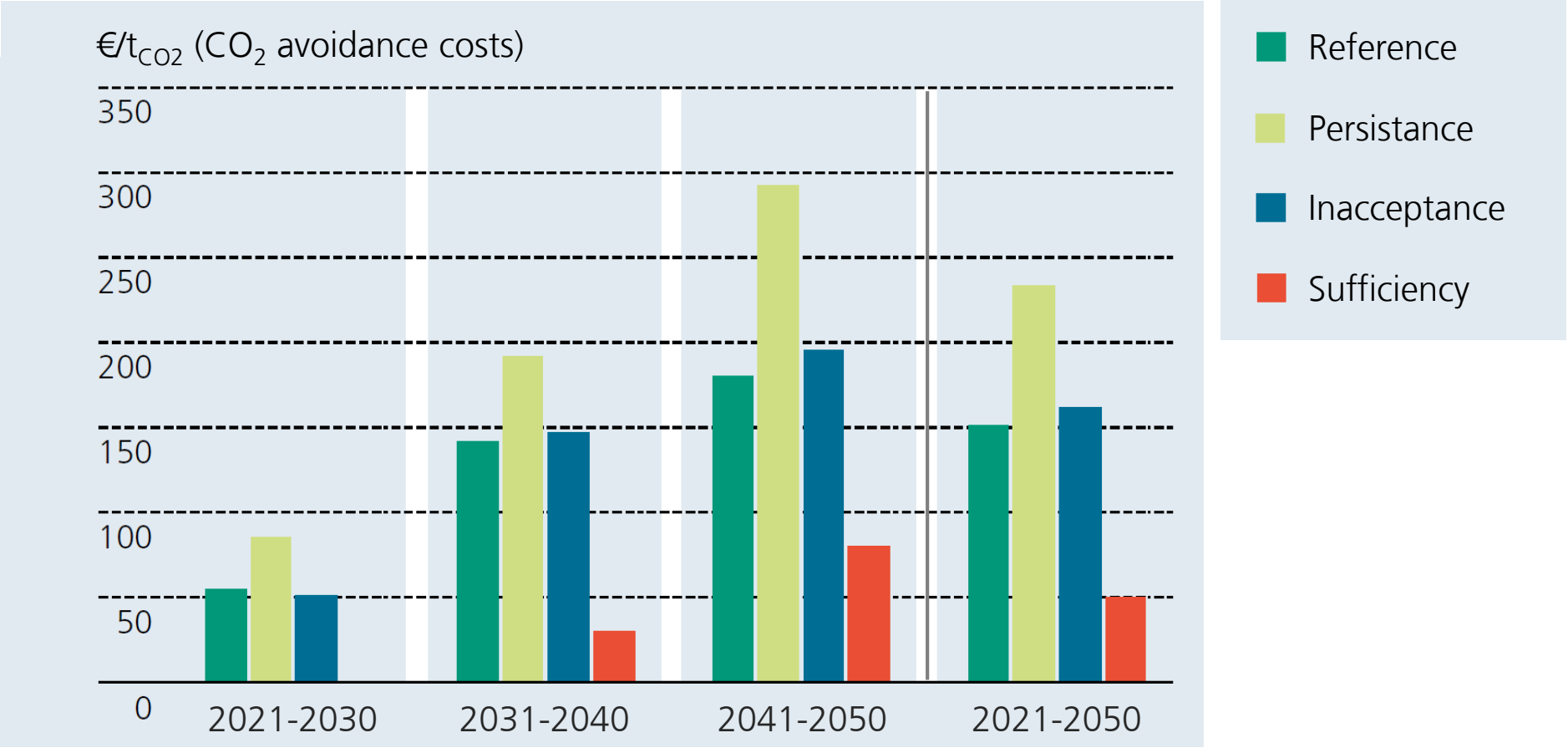
Energy-related CO_2 emissions after breakdown into the sectors



CO_2 avoidance costs for the next three decades and total until 2050



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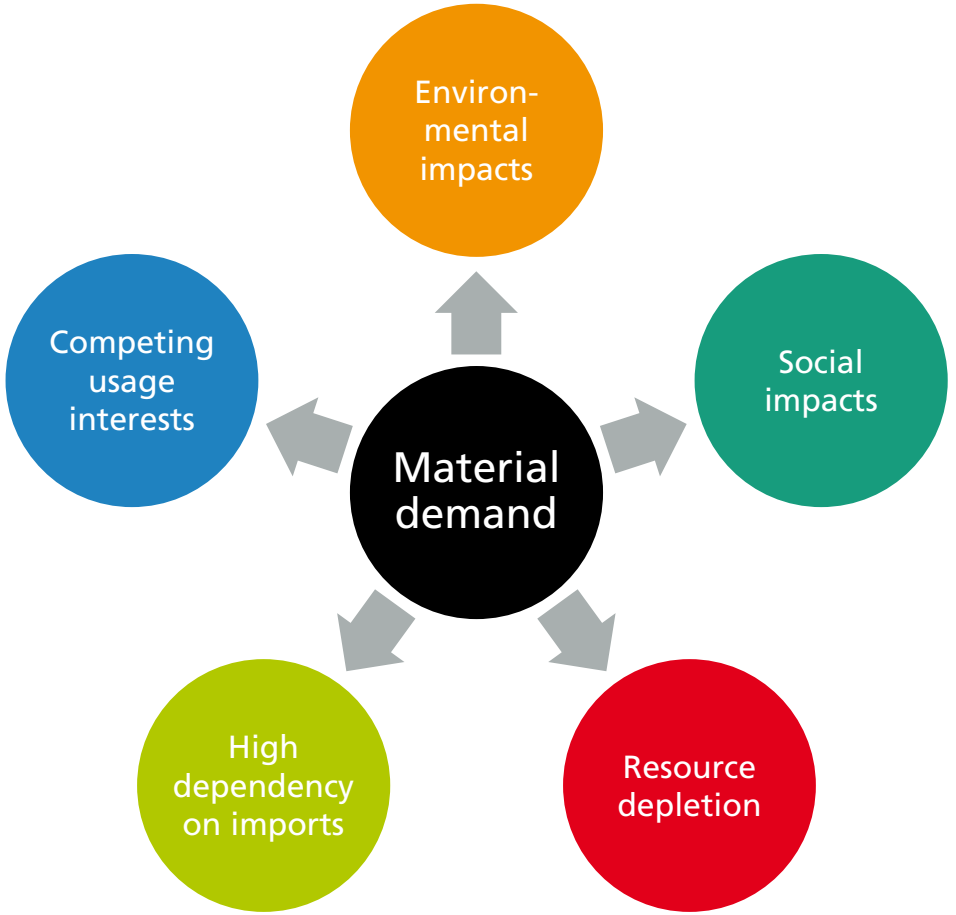
Resource efficiency and circular economy
Example: Metals

- From 1970 to 2017, the annual global extraction of metal ores grew from 2.6 billion tons to 9.1 billion tons



Resource efficiency and circular economy
Important factor for a cost-efficient transformation

- Classic energy supply system is based on fossil but finite energy sources – all other materials in power plants and facilities play a secondary role from a resource perspective
- Future energy system is based primarily on renewable energies (inexhaustible according to human judgement) and will consist of many millions of energy conversion and storage plants

➔ **Massively increased use of a variety of materials** (semiconductors, composite materials, polymers, copper, steel, concrete, rare earth metals,…)

➔ **Share of material costs will be dominant** for many technologies of the future energy system

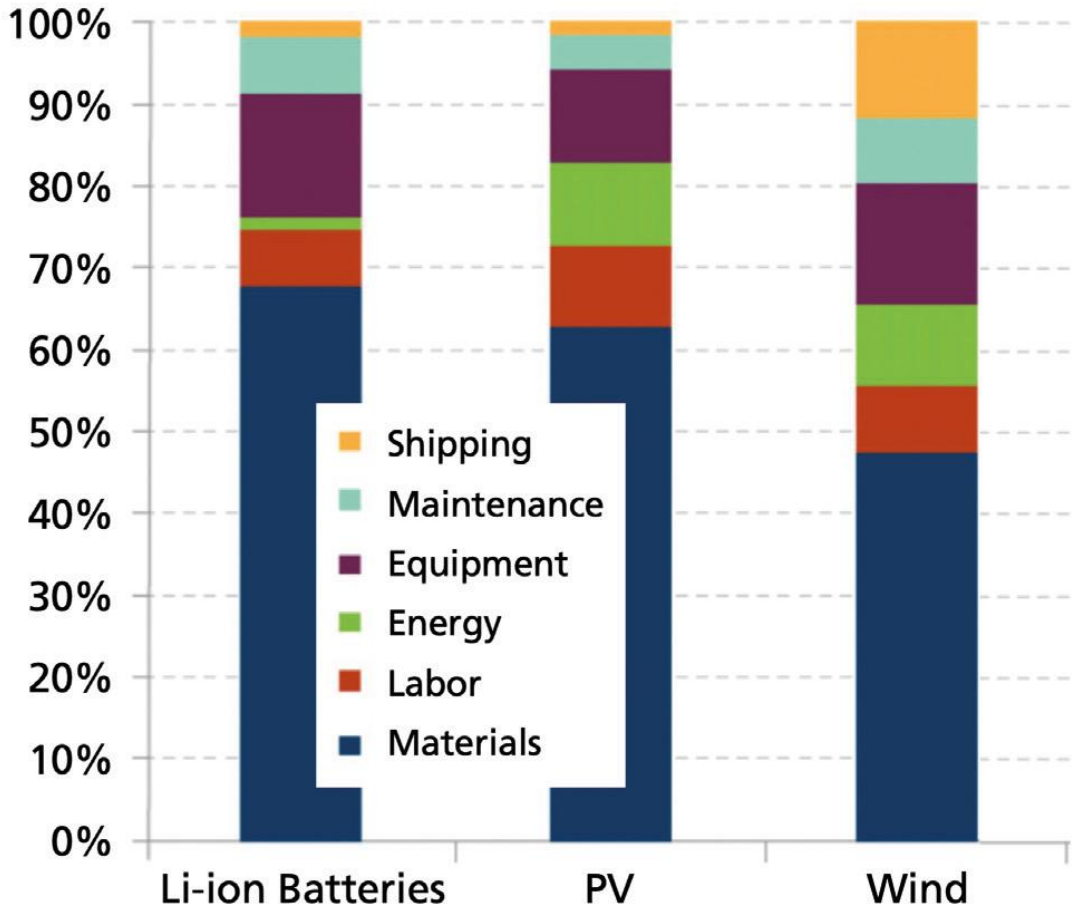


Figure: EMIRI Technology Roadmap, Sept. 2019.

Resource efficiency and circular economy
Approaches

1. **Energy efficiency:** reduction of the needed number of components
2. **Material efficiency:** reduction of the use of raw material or substitution of critical materials
3. **Reuse:** e.g. second life of car batteries
4. **Recycling:**
   - Secondary production of metals via recycling to reduce the amount of needed raw material
   - Design for recycling: products that are easy to dismantle and that indicate constituent materials on components, allowing for easier material separation

Figure: EIT Raw Materials, https://eitrawmaterials.eu/events/spring-school-on-circular-economy/

Content

Motivation

Energy system analysis – Methodology

Results for Germany

Conclusions

Conclusion
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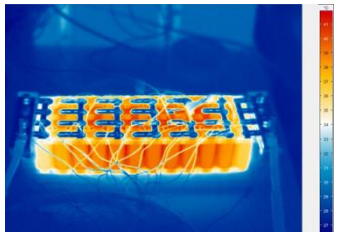
- Transformation of energy systems in line with GHG emission reduction targets seems in principle technically feasible
- Renewable energies (in particular solar and wind) become dominant – in Germany and worldwide
- Efficiency and reduction of consumption essential (costs, acceptance)
- Sector coupling:
  - Use of electricity (direct, indirect) for heating, transport and industry
  - Importance of electricity rises ➔ increase up to 100 %





Conclusion
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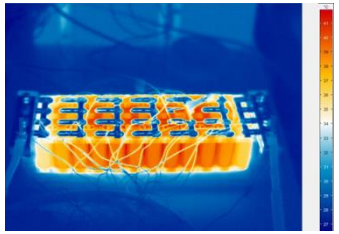
- System integration of (volatile) renewable energies
  - Flexible power generation: controllable power plants
    ➔ CHP (thermal power plants, fuel cells), CCPP, gas turbines
  - Flexible use of electricity ➔ load management
  - Storage technologies (batteries, heat storage, hydrogen)

- Challenges:
  - Further development of the market framework is necessary
  - Social acceptance of the transition is mandatory
  - High importance of resource efficiency and circular economy for key materials (from copper and concrete to rare earth materials)





Thank You for Your Attention!

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