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THE REALITY OF NET ZERO
SEMINAR SERIES

Net Zero: Building Sustainable Solutions

Zero Carbon Energy Systems: The Heavy Lifting for Net Zero

Nick Eyre

Content

- Energy and climate change
- Decarbonising energy supply
- Thinking systemically
- Energy efficiency
- Remaining challenges

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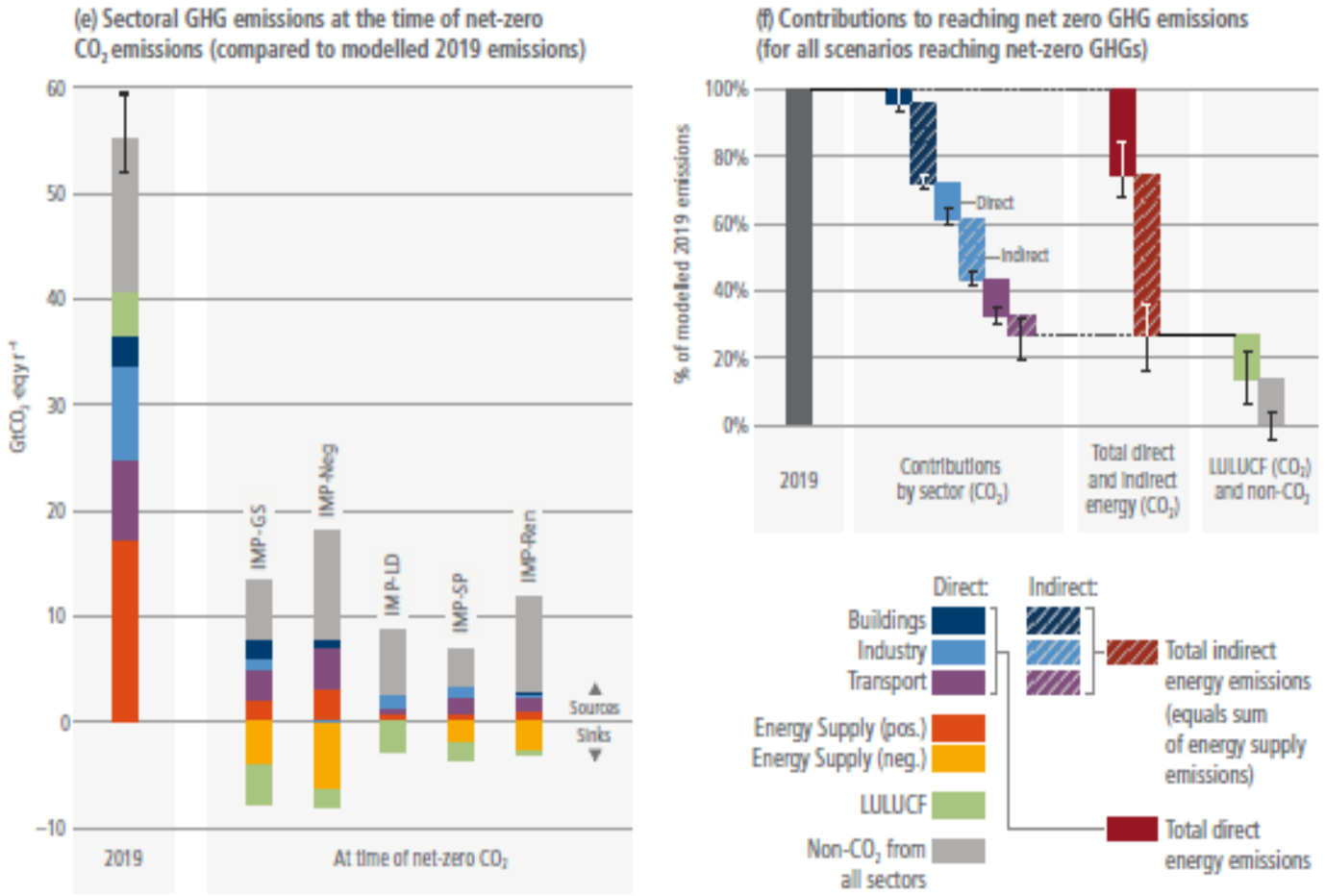
Emissions reductions are the key to delivering net zero

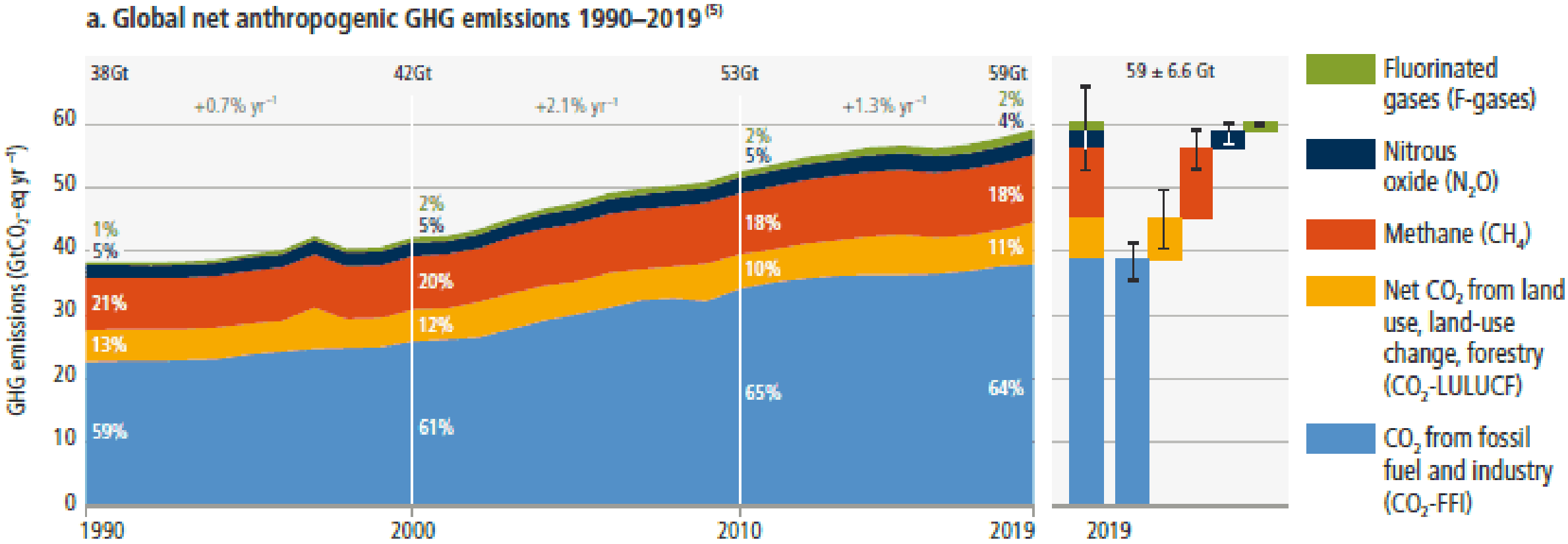
Net zero CO_2 and net zero GHG emissions are possible through different modelled mitigation pathways.



IPCC WG3, Technical Summary, 2022

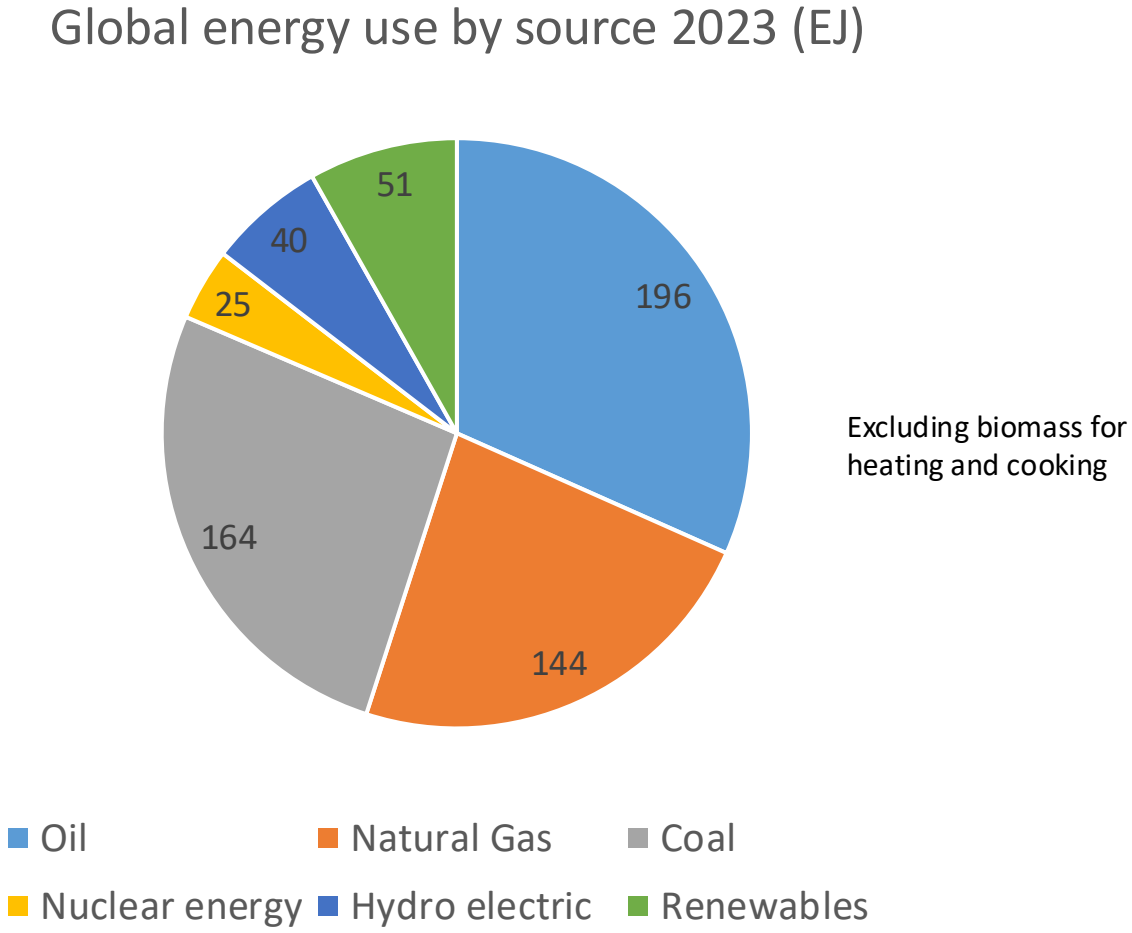
- Net Zero implies that residual emissions are balanced by removals.
- In practice, costs mean that most emissions reductions will do much more than removals.
- This means reducing energy-related emissions by ~90%.
- **Emissions reduction does the heavy lifting of reaching net zero.**

…and that implies big reductions in use of fossil fuels



IPCC, WG3, 2022

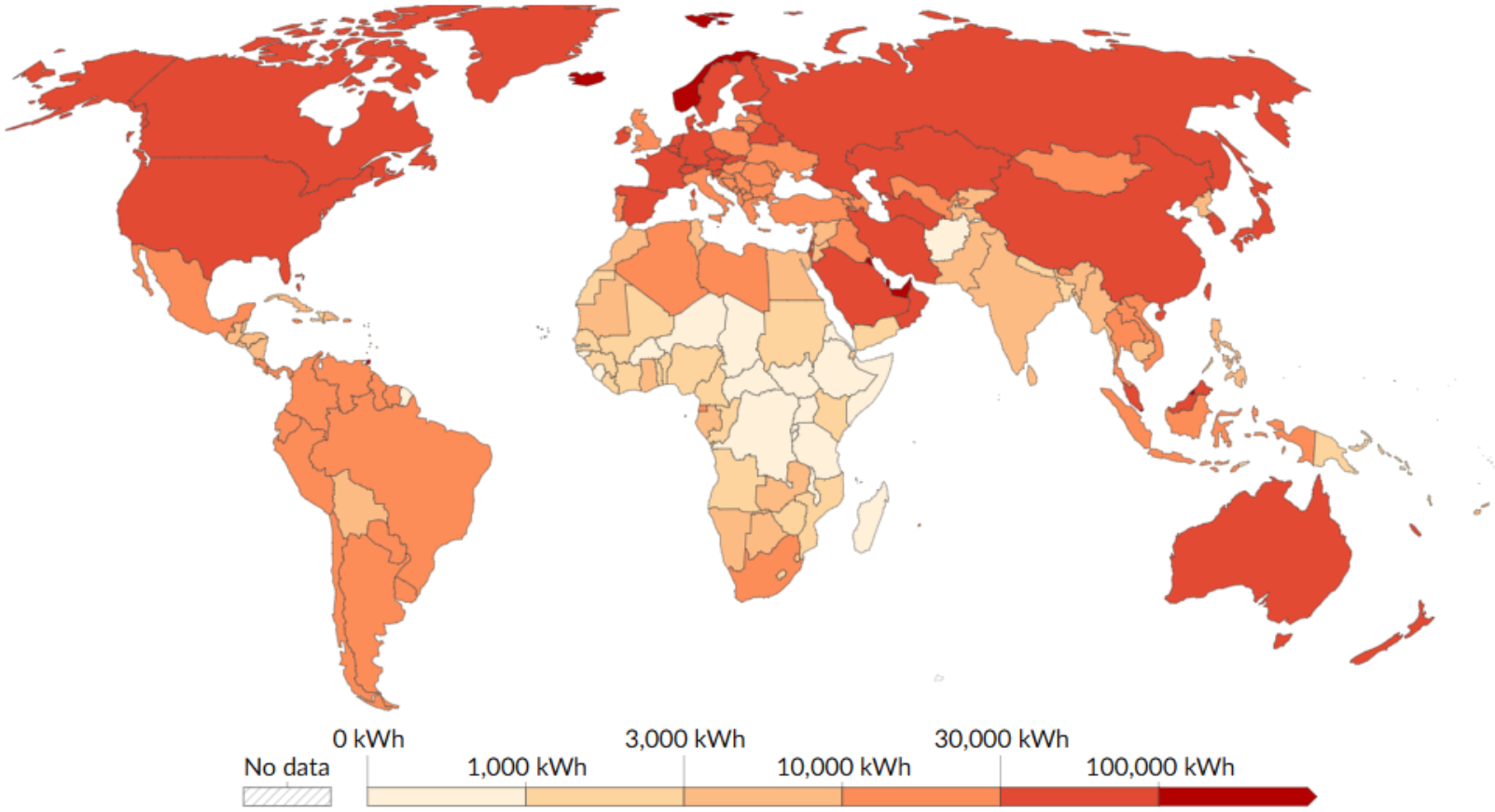
…on which current energy systems are highly dependent



Excluding biomass for heating and cooking

Energy Institute. Statistical Review of World Energy 2024

…and energy use is hugely unequal



Per capita energy use by country. From Our World in Data, based on US Energy Information Administration and Energy Institute Statistical Review of World Energy

…with large numbers of people still unable to access modern energy

By 2030, ensure universal access to affordable, reliable and modern energy services

- In 2022, more than 685 million people had no access to electricity.
- In 2021, 2.1 billion people had no access to clean fuels for cooking.

Source: https://sustainabledevelopment.un.org/sdg7

The Global Energy Challenge

- Radical reductions in fossil fuel emissions are required to stabilise the climate, but
- Fossil fuels dominate the energy systems that underpin modern life and development.

- Just stopping producing fossil fuels is not a viable solution.
- We need a better energy system. One based on decarbonised energy supply, and improved energy efficiency

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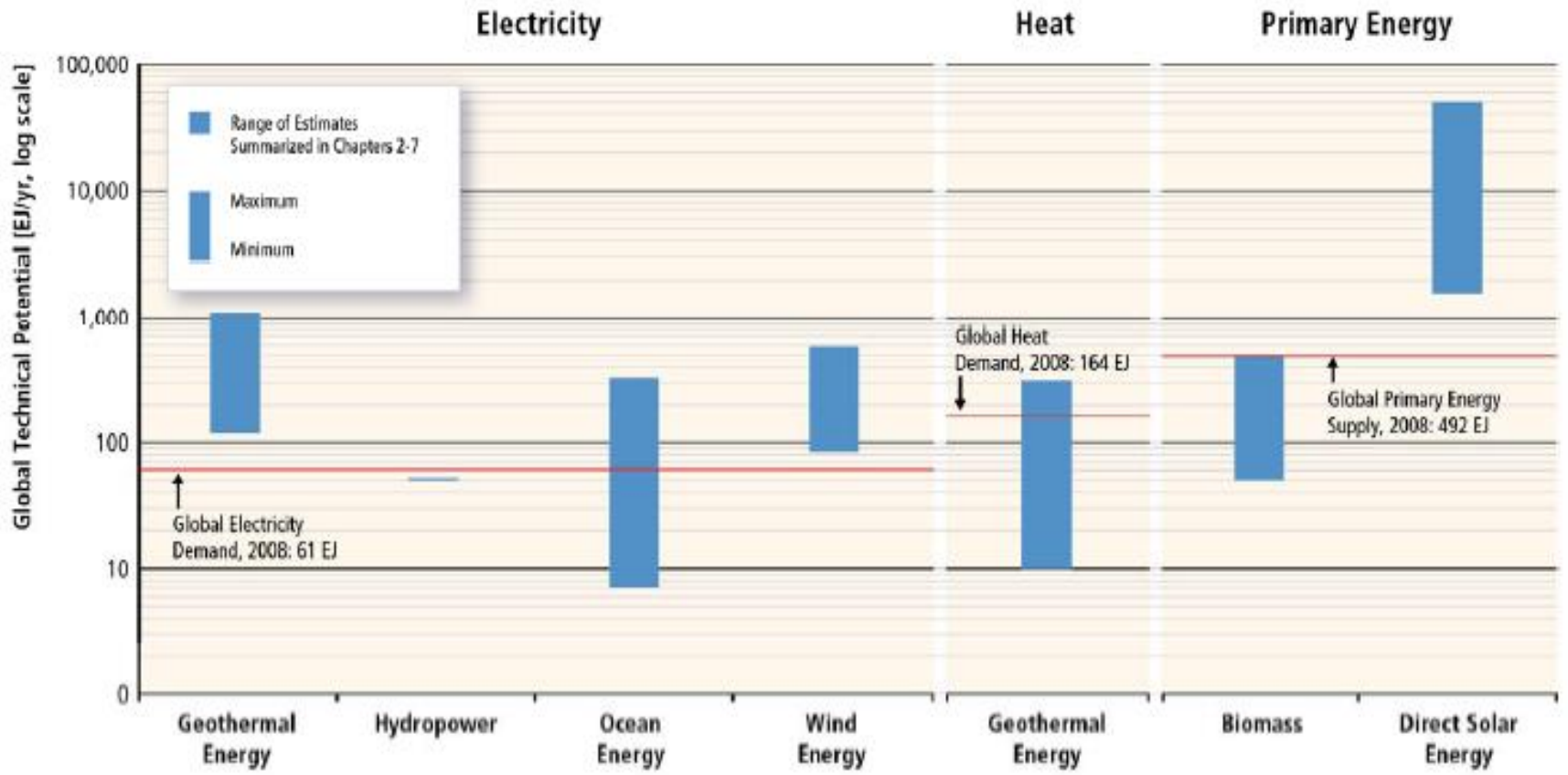
Low carbon energy supply options
What are they?

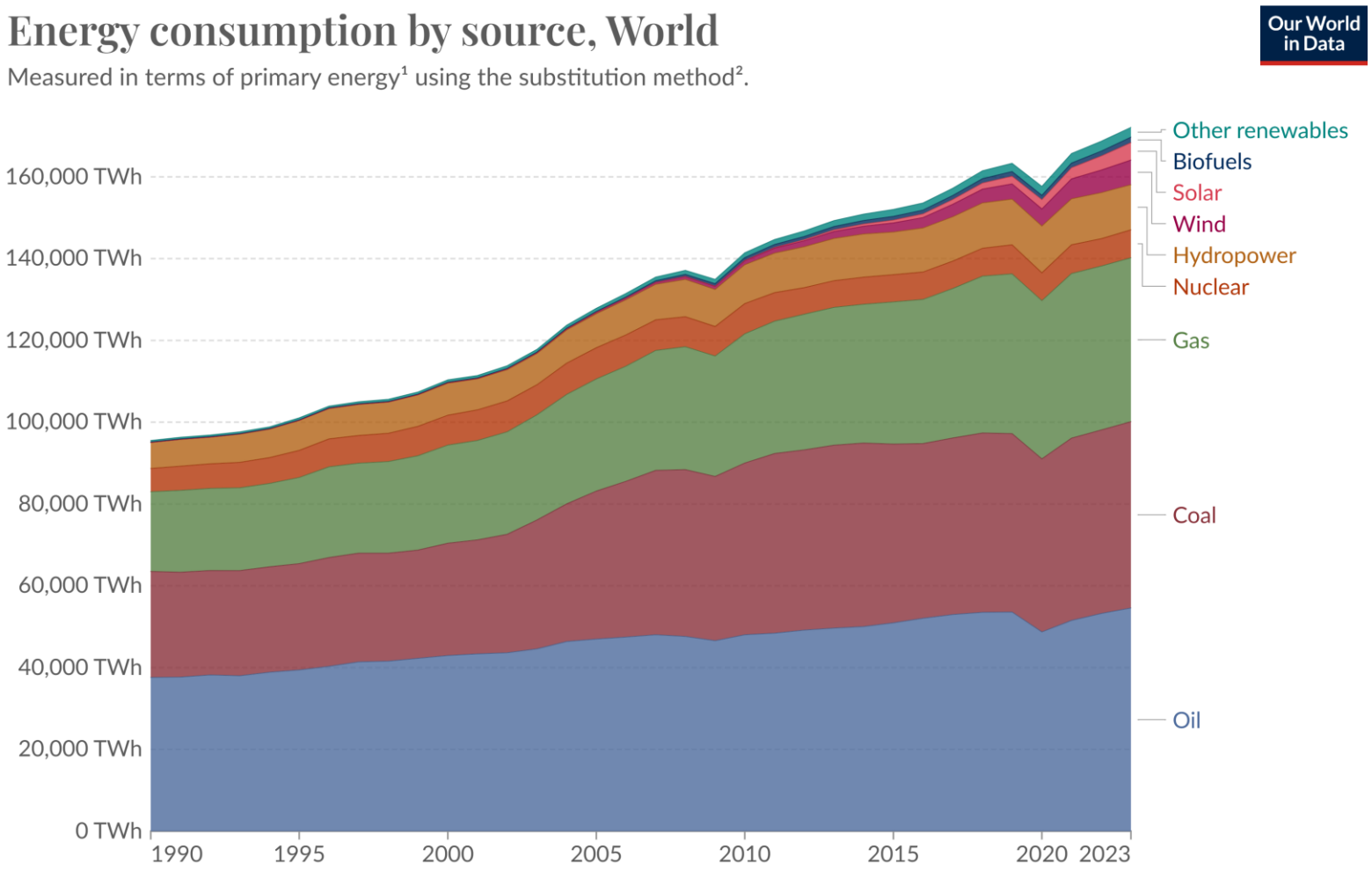
- Renewable energy sources
- Fossil fuels with “carbon capture and storage” (CCS)
- Nuclear power

Renewable energy: the global potential is huge

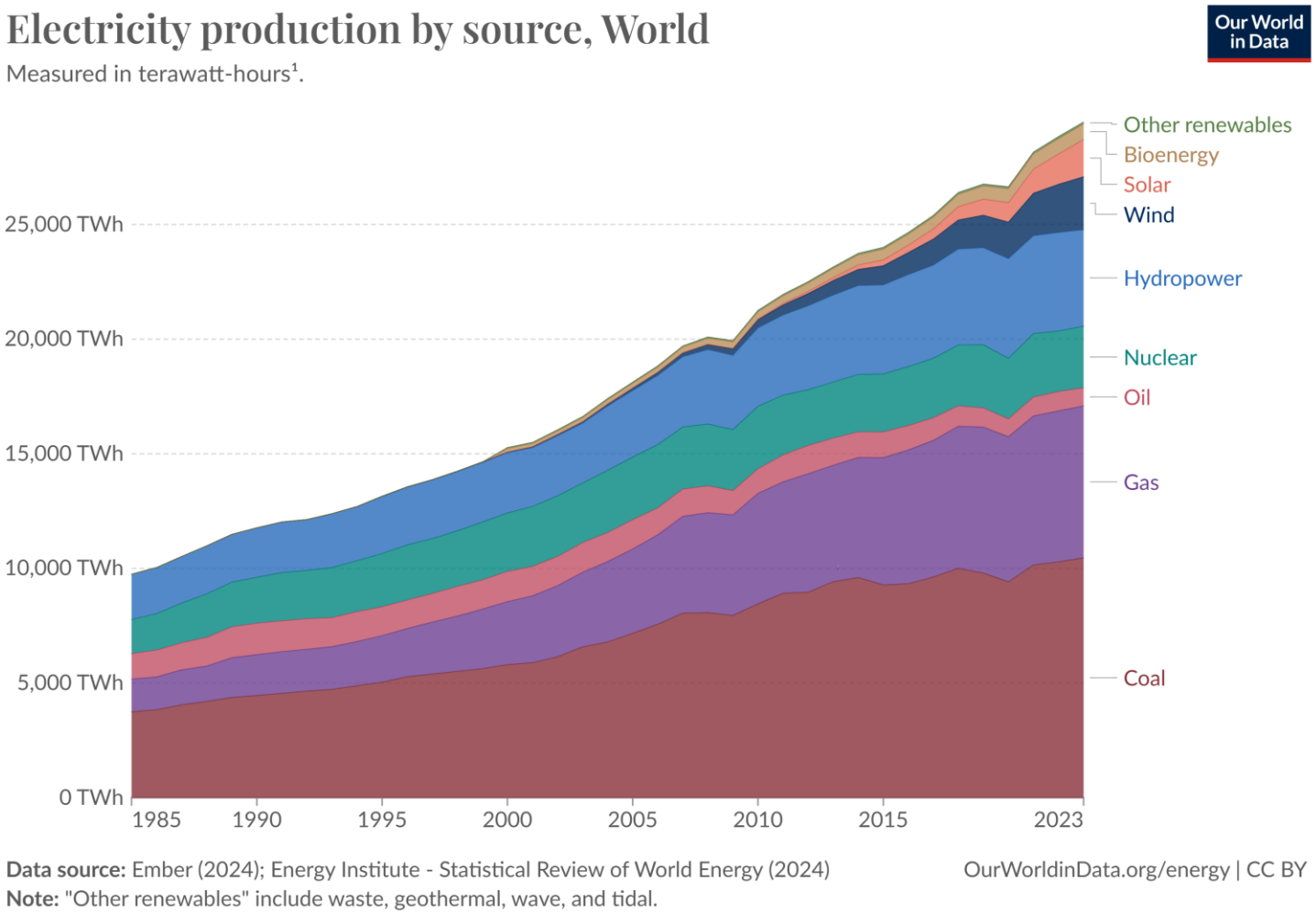


Source: IPCC, Special Report on Renewables, 2011

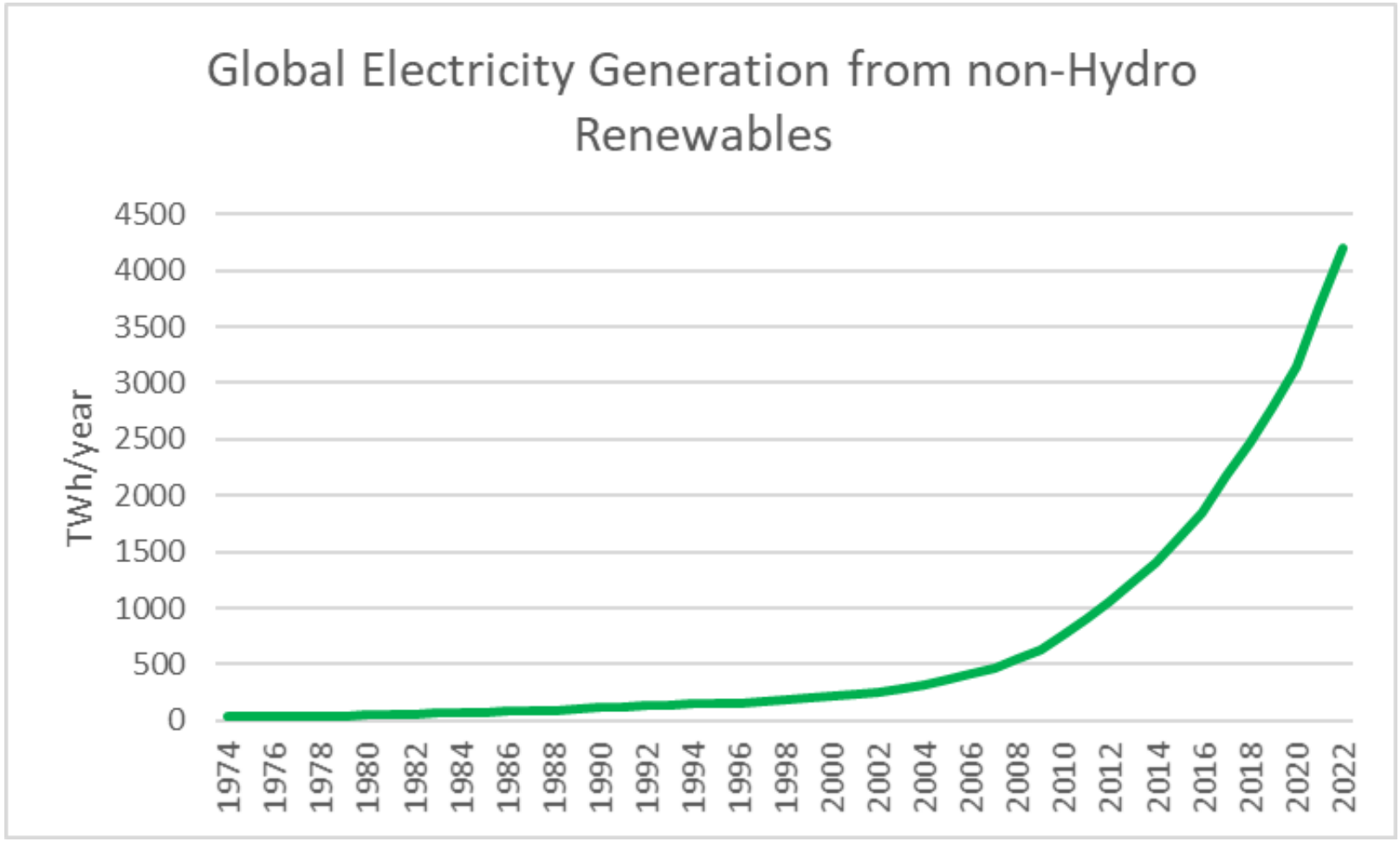
Renewables currently supply only a small share of global energy



…but a bigger share of electricity supply

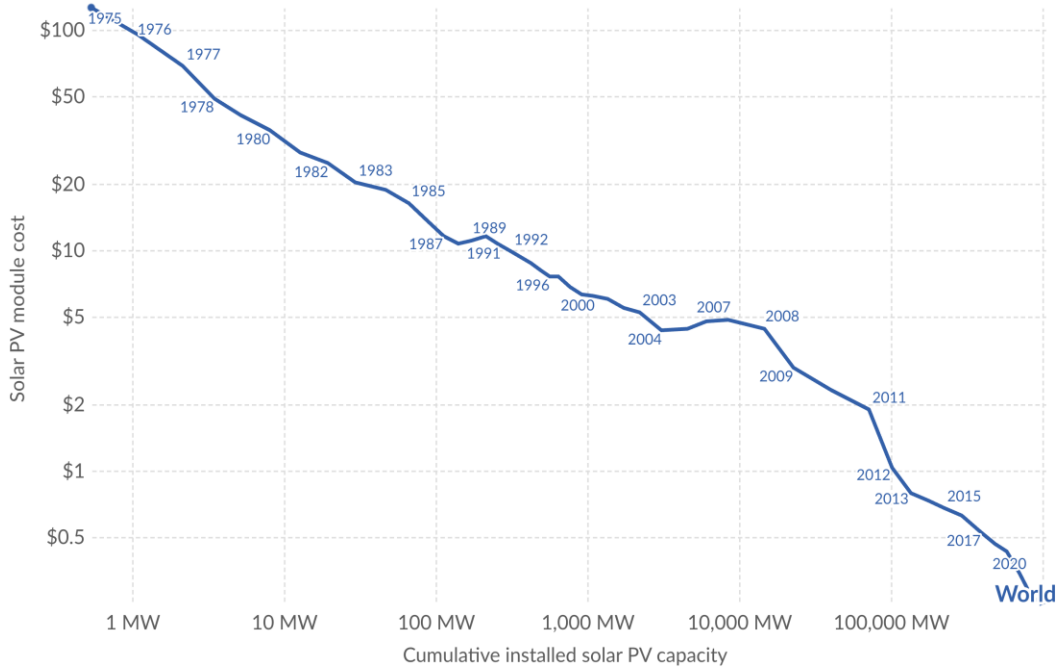


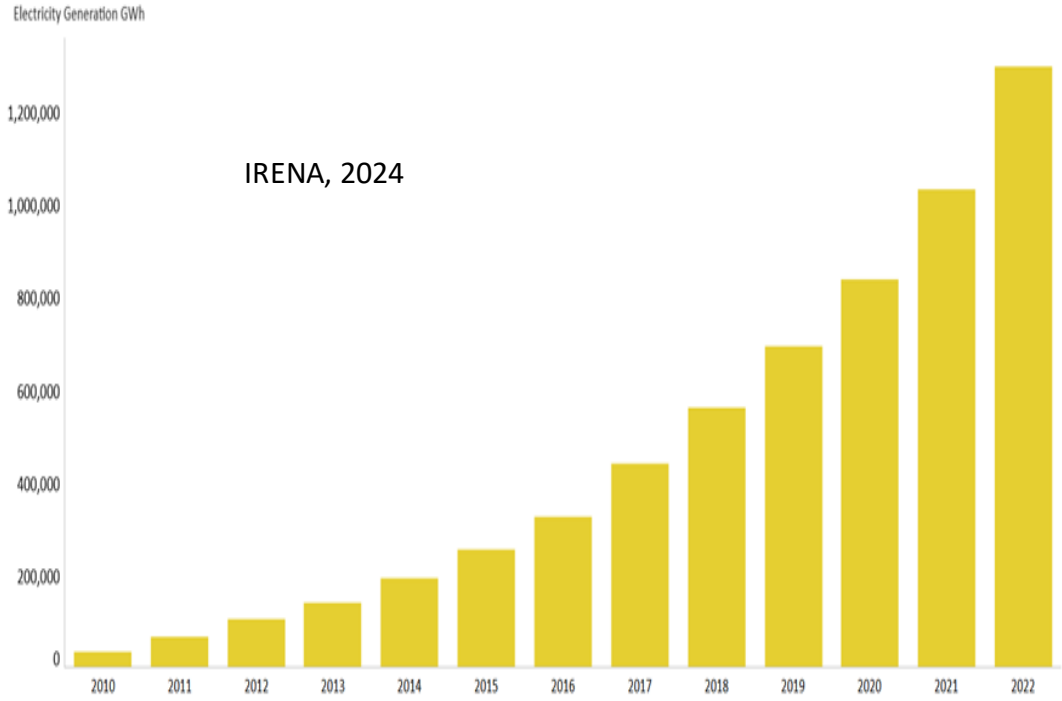
…with that share is rising very rapidly



Energy Institute Statistical Review of World Energy 2024

The growth in renewables is linked to declining costs





IRENA, 2024

Data source: IRENA (2023); Nemet (2009); Farmer and Lafond (2016)

Falling costs drive uptake of solar. And uptake of solar reduce costs. This feedback loop is what leads to system disruption. Solar and wind are the lowest cost electricity almost everywhere, and now the main areas of investment.

Other options, such as nuclear power and fossil fuels with CCS are uncompetitive.

Summary conclusions for decarbonising energy supply

- The current contribution of renewables is small, but growing rapidly.
- Solar and wind now out-compete conventional sources of electricity and dominate investment.
- Future electricity will be very largely from renewables, i.e. sustainable energy flows from the environment.

- …but electricity is only a small part of energy use

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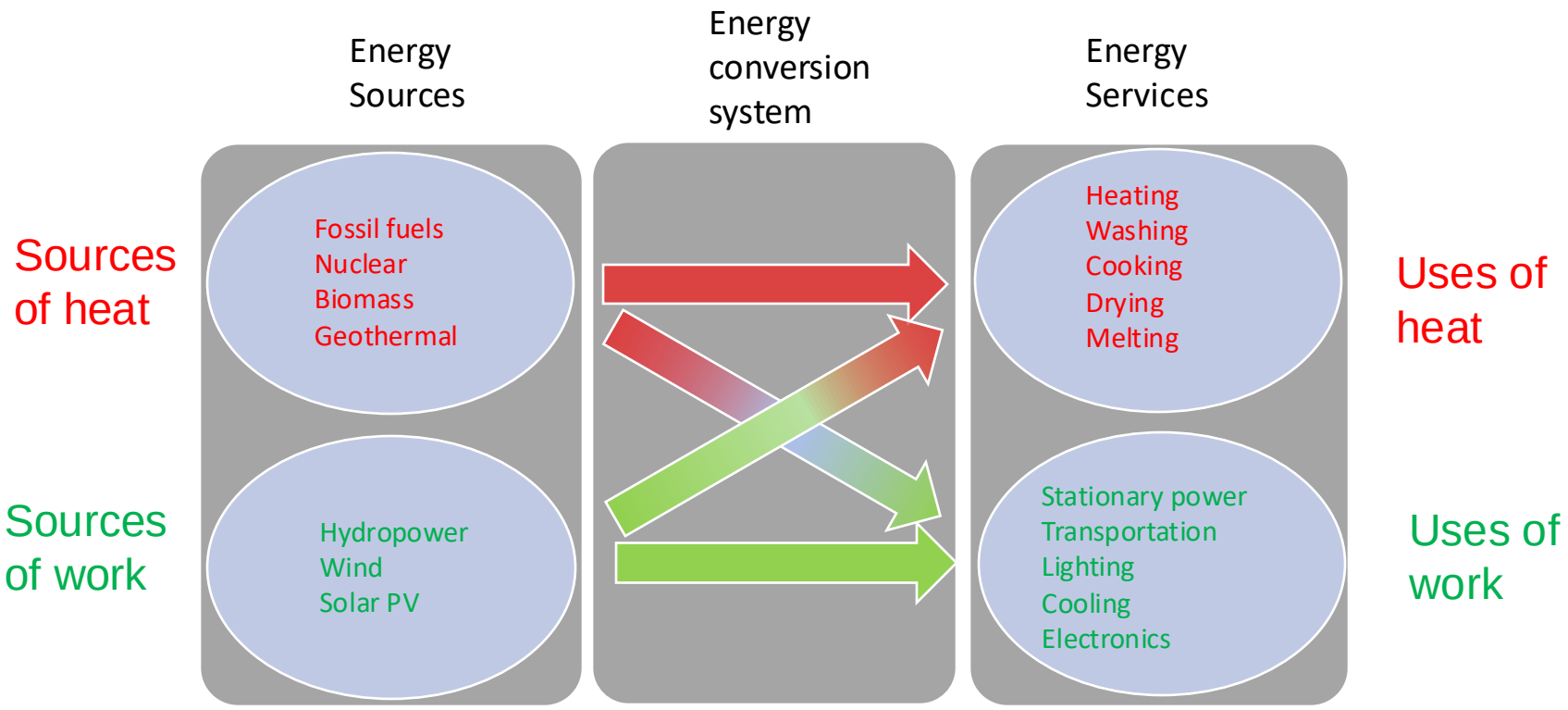
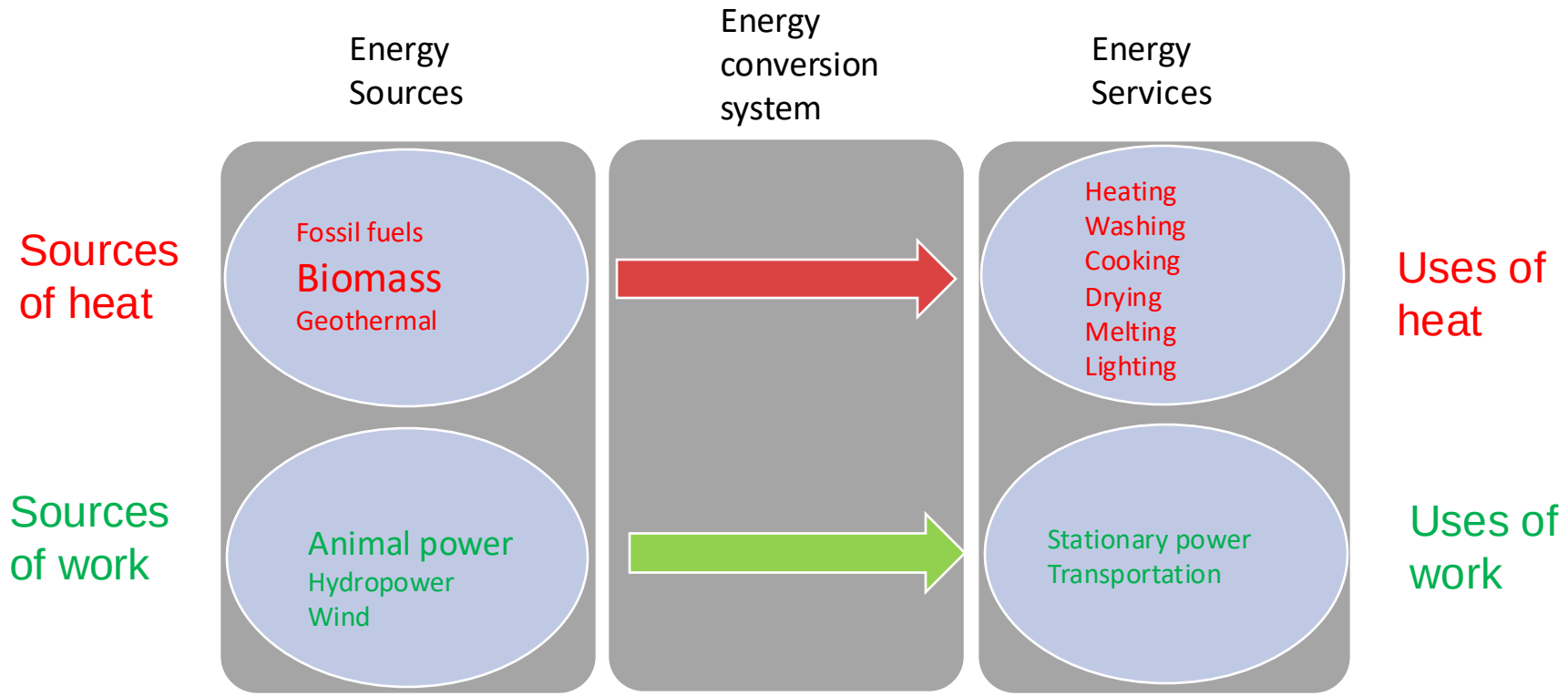
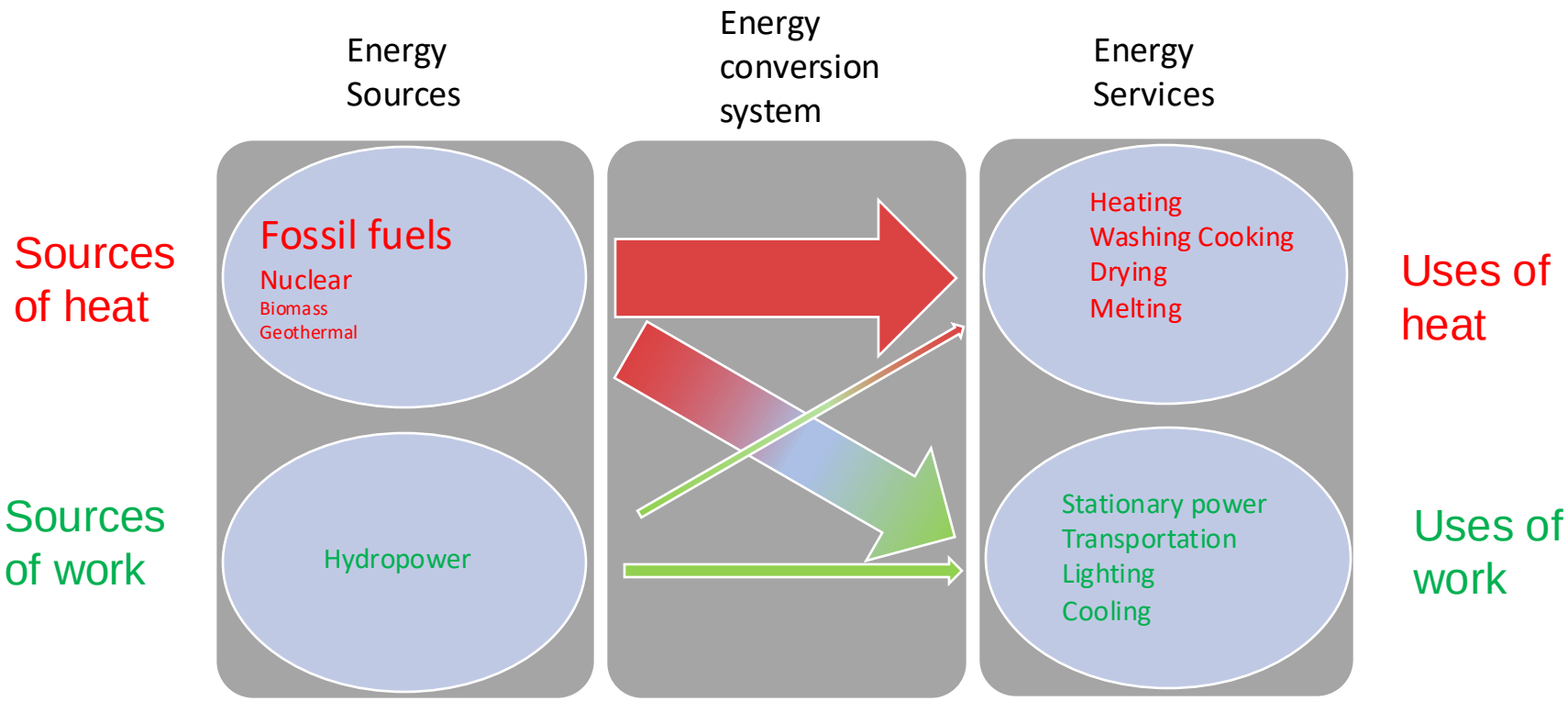
Heat and Work in the energy system



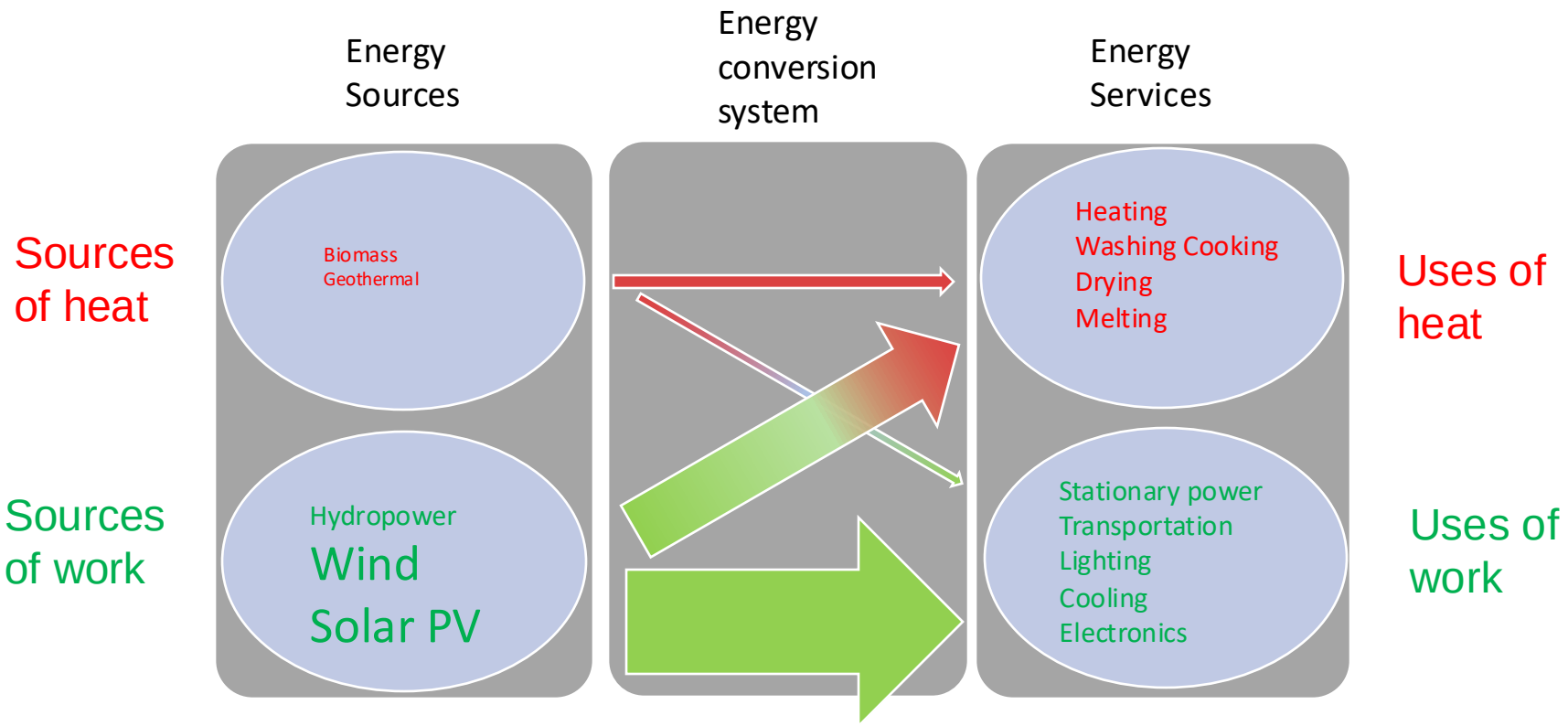
Heat and Work in pre-industrial energy systems



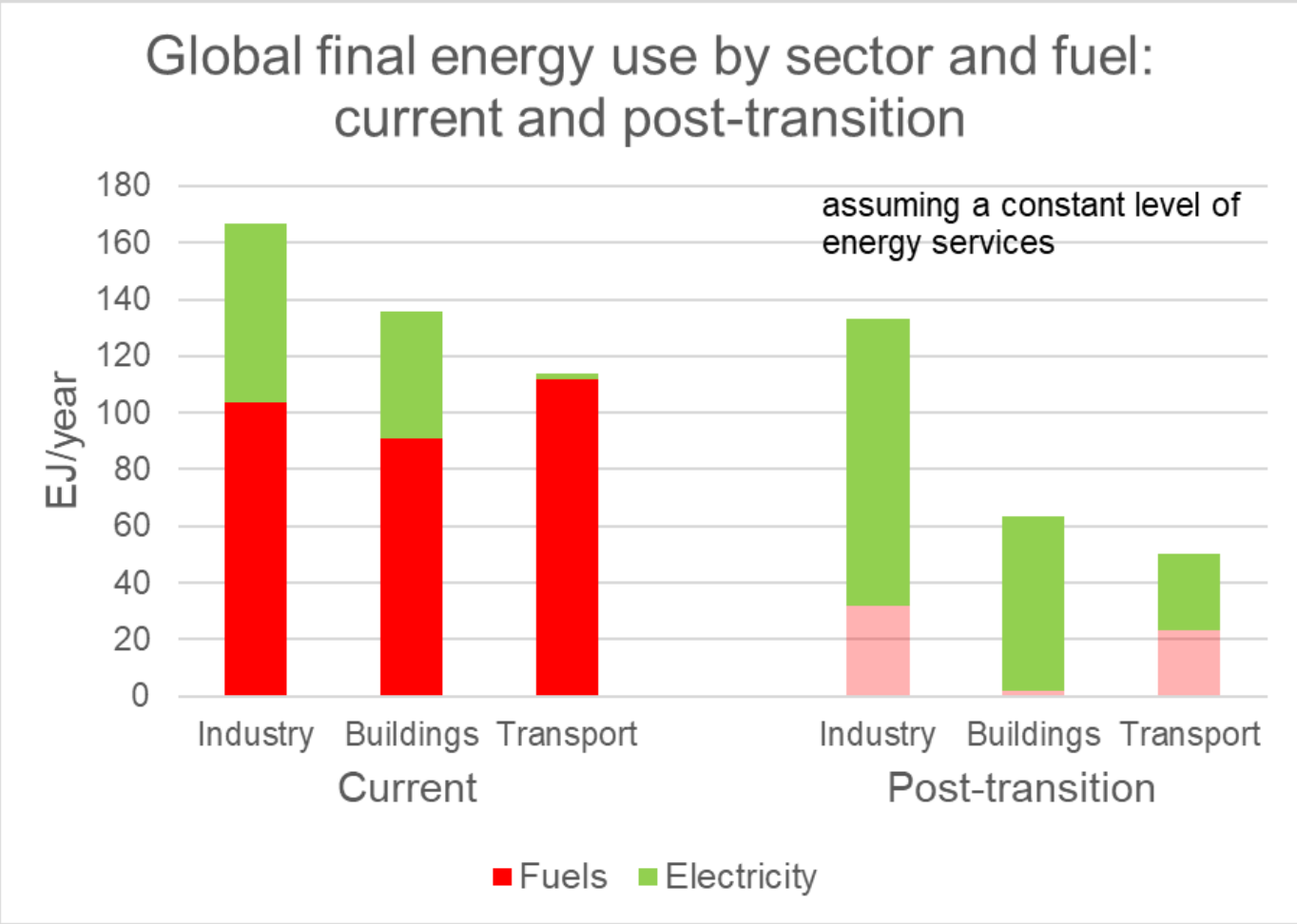
Heat and Work in industrial society energy systems



Heat and Work in renewable energy systems



This has huge implications for energy demand



Eyre, N. (2021). "From using heat to using work: reconceptualising the zero carbon energy transition." Energy Efficiency **14**(7): 77.

Assumptions

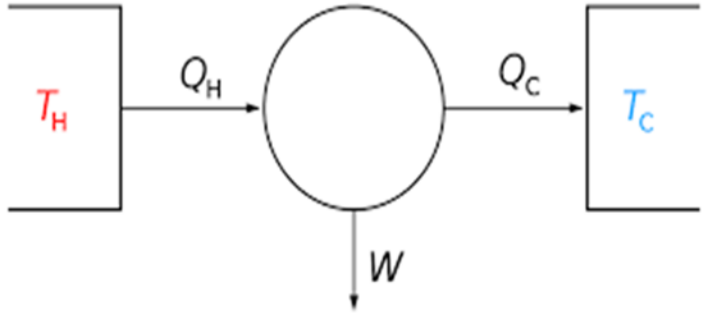
- 100% of post-transition energy comes from hydropower, wind and solar.
- Non-electric final energy is supplied by electrolytic hydrogen.
- Constant energy service demands and no efficiency improvement other than in end use conversion.

Results

- Electricity's share rises from 26% to 77%.
- Final energy demand reduced by 40% (> 50% in buildings and transport)

The synergy of renewables, electrification and efficiency

- The greater efficiency from using electricity is a consequence of the 2nd Law of Thermodynamics: work can be converted into to heat more efficiently than heat can be converted into work.
- One unit of renewable electricity displaces more than one unit of fossil fuel, typically
  - 2 units in power generation
  - 3 units in low temperature heating, and
  - 4 units in vehicles



$$W = Q_H - Q_C$$

$$\frac{Q_H}{T_H} \geq \frac{Q_C}{T_C}$$

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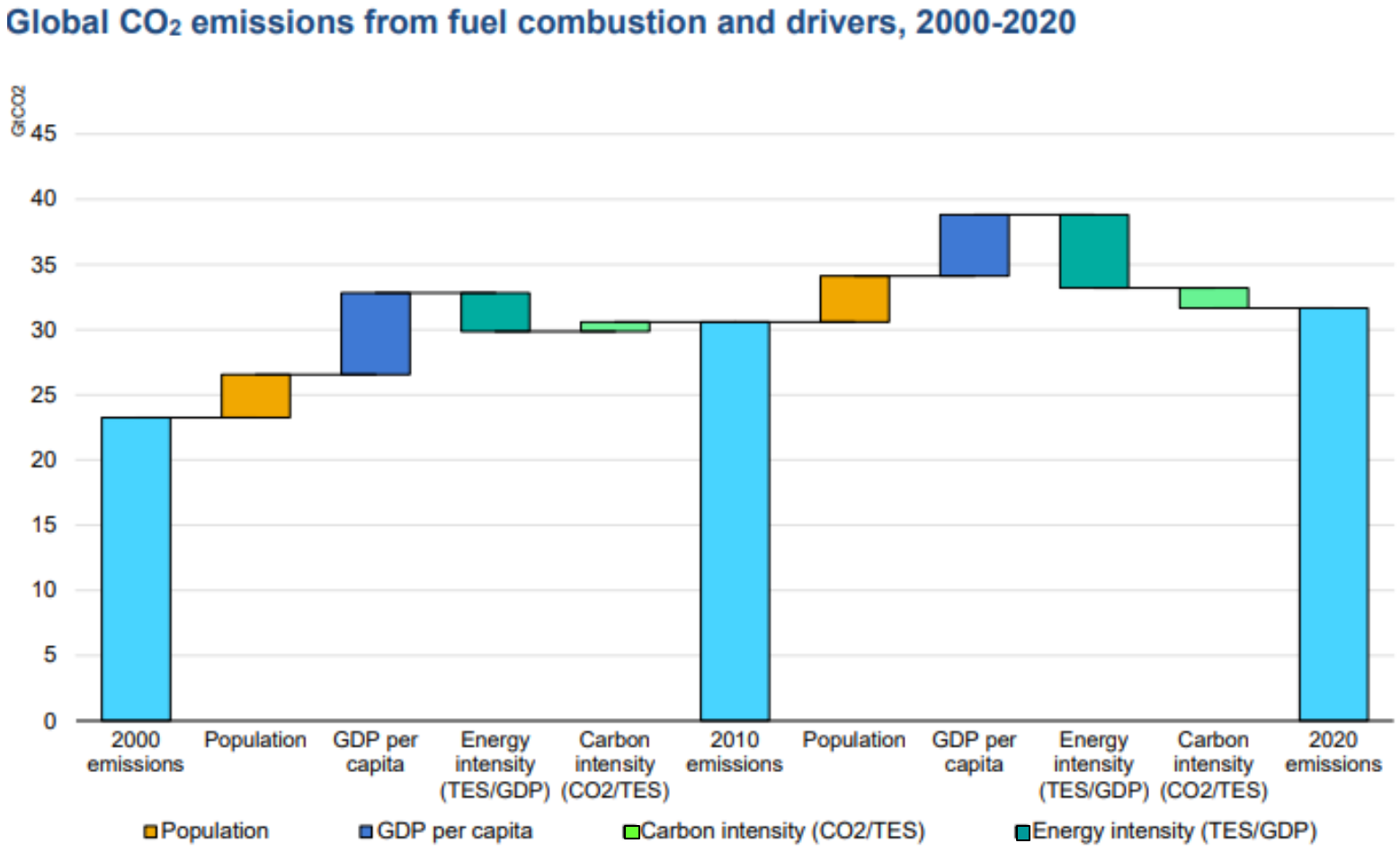
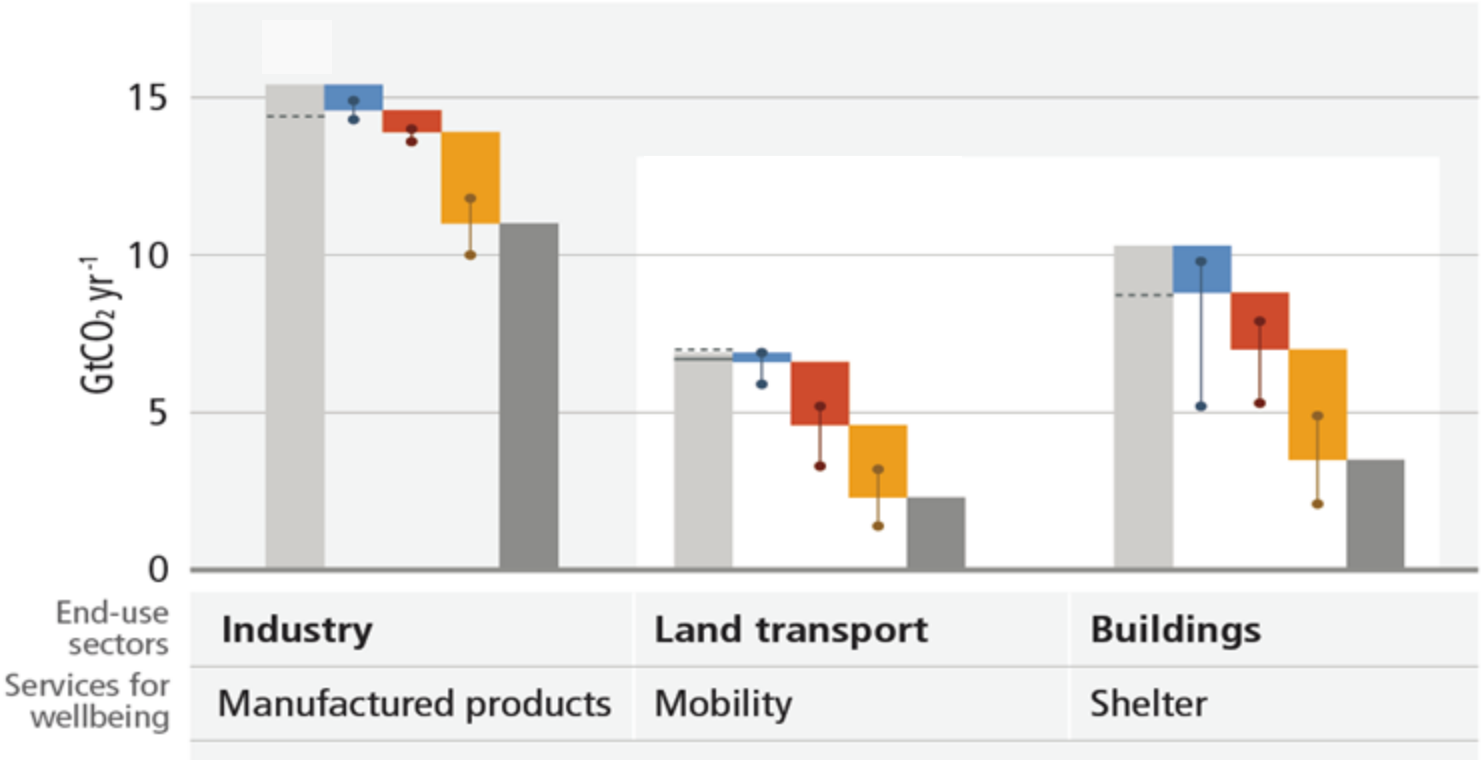
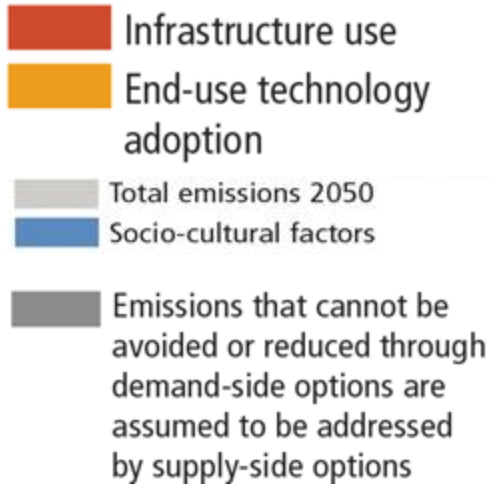
Energy efficiency has historically been the largest contributor to emissions reduction



Based on IEA Energy Efficiency Market Report, 2022

..and the potential for future demand-side reductions is large





Based on IPCC 6th assessment report WG3, Chapter 5, 2022

..and the energy transition opens huge new energy efficiency opportunities

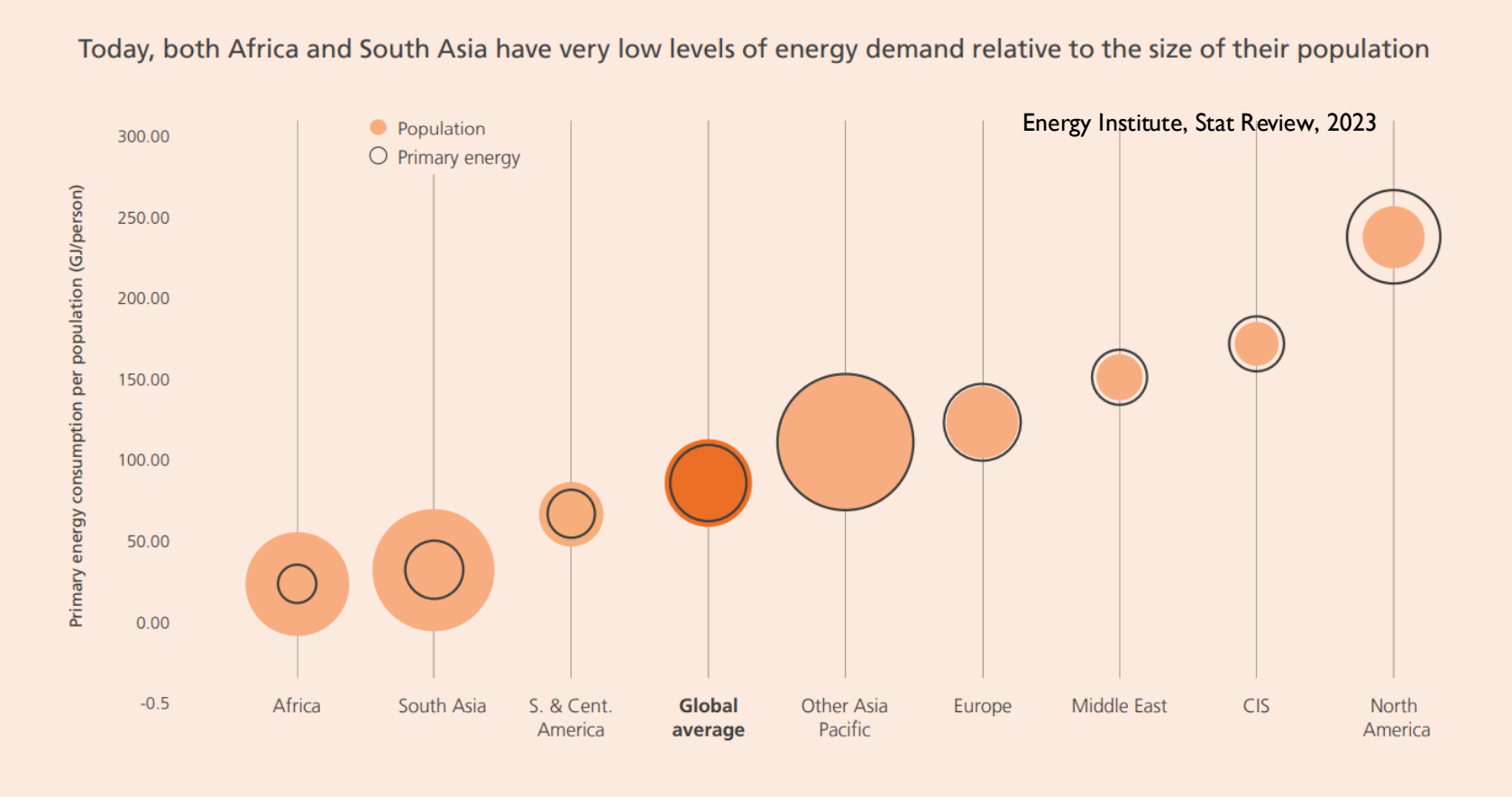
There are essentially three components:

- Traditional energy efficiency measures, e.g. insulation, heat recovery.
- New efficiency options enabled by electrification - EVs, heat pumps etc.
- Changes in the systems in which energy is used, notably
  - In mobility – modal shift,
  - In materials – circular economy
  - In diet – local, less-processed and plant-based diets

A typical developed economy can halve its energy use, whilst increasing welfare

UK energy saving potential by sector, from Barrett et al (2022). "Energy demand reduction options for meeting national zero-emission targets in the United Kingdom." Nature Energy.

…which has huge potential distributional consequences



If European energy use can be halved, global energy demand can be decreased with everyone reaching European living standards

Summary conclusions for energy demand

- Energy efficiency will make a major contribution to energy system decarbonisation.
- Zero-carbon energy will not be able to decarbonise the global economy quickly without efficiency improvements.
- Efficiency is often a cheaper option and has other benefits.
- The constraints are often political, social and organisational, rather than economic.

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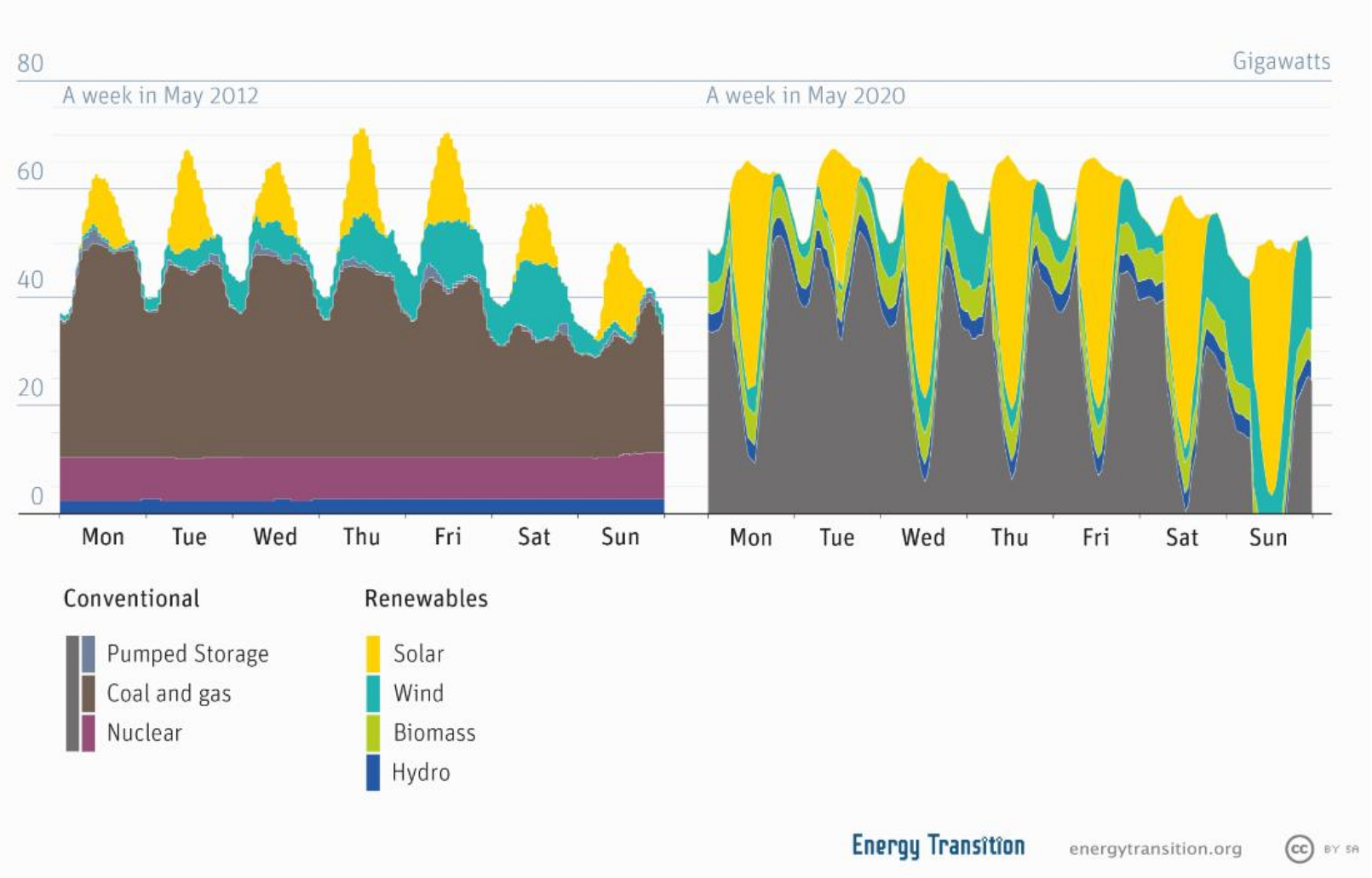
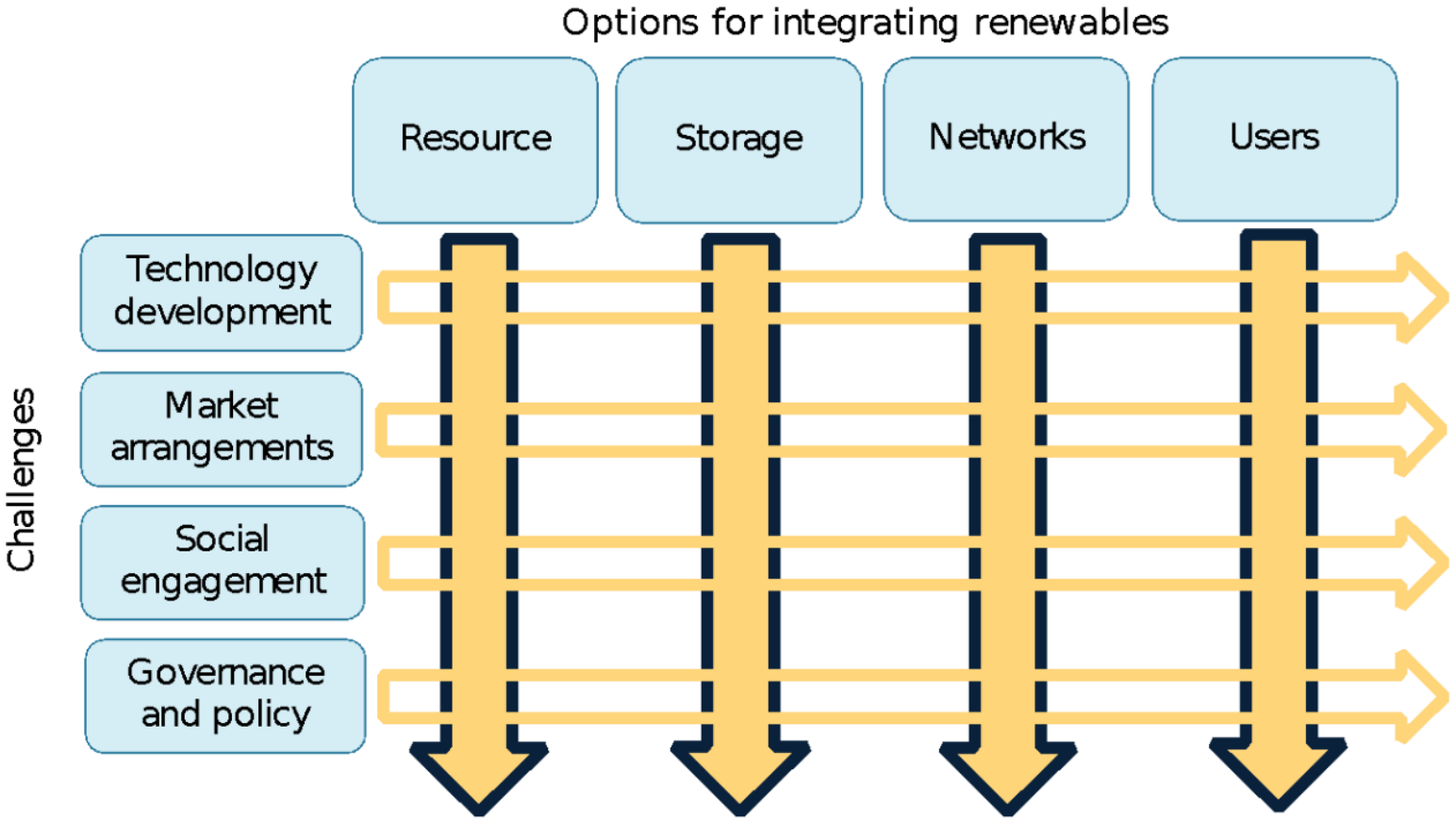
1. The challenge of variability



The dominant renewables will be solar and wind. They are variable and increase the need for flexibility in the electricity system.

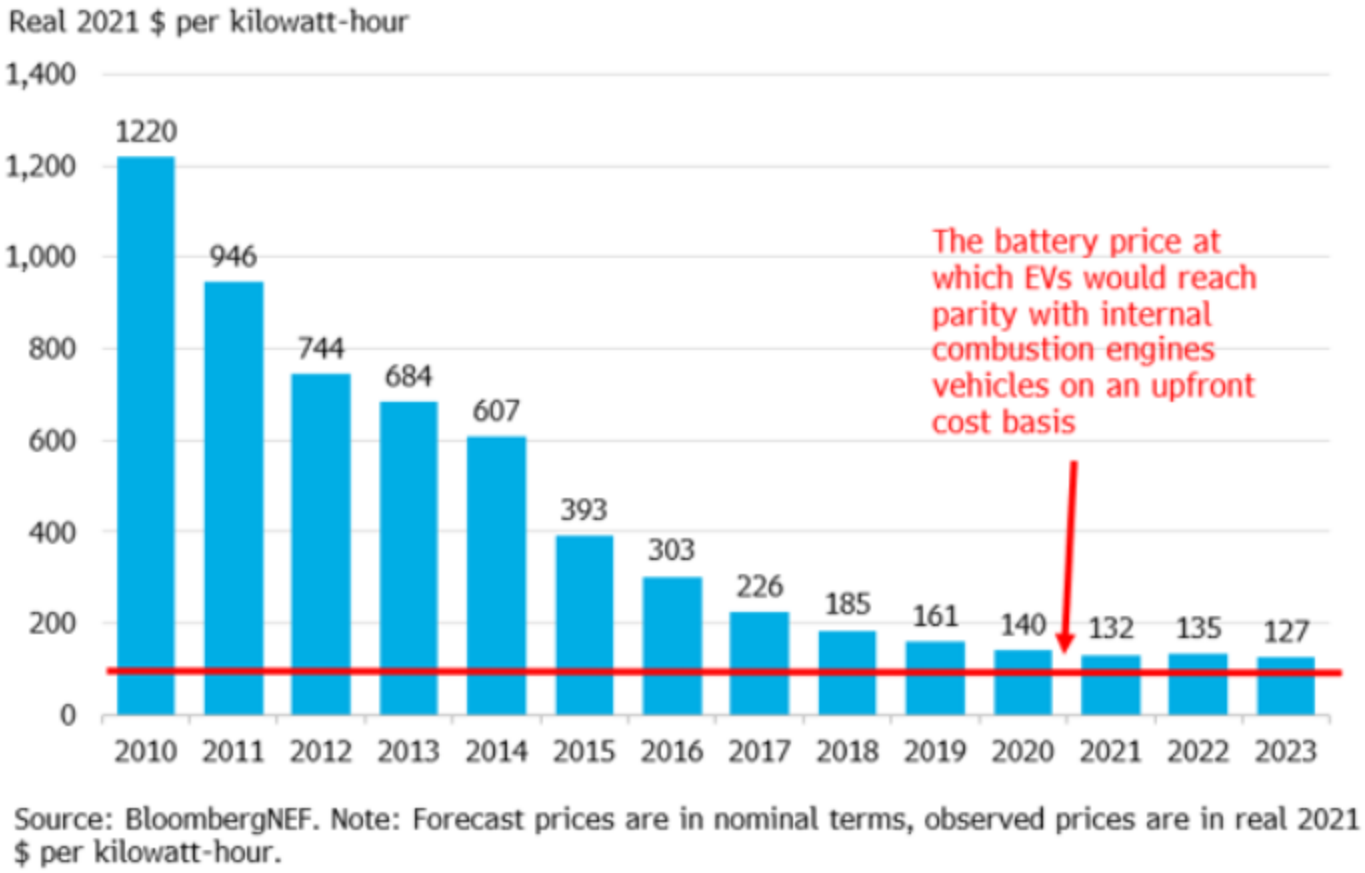
…has a mix of potential solutions



Integrate project, 2015

Electricity system balancing requires some combination of flexible generation (resources), storage, interconnection (networks) and demand side response (users)

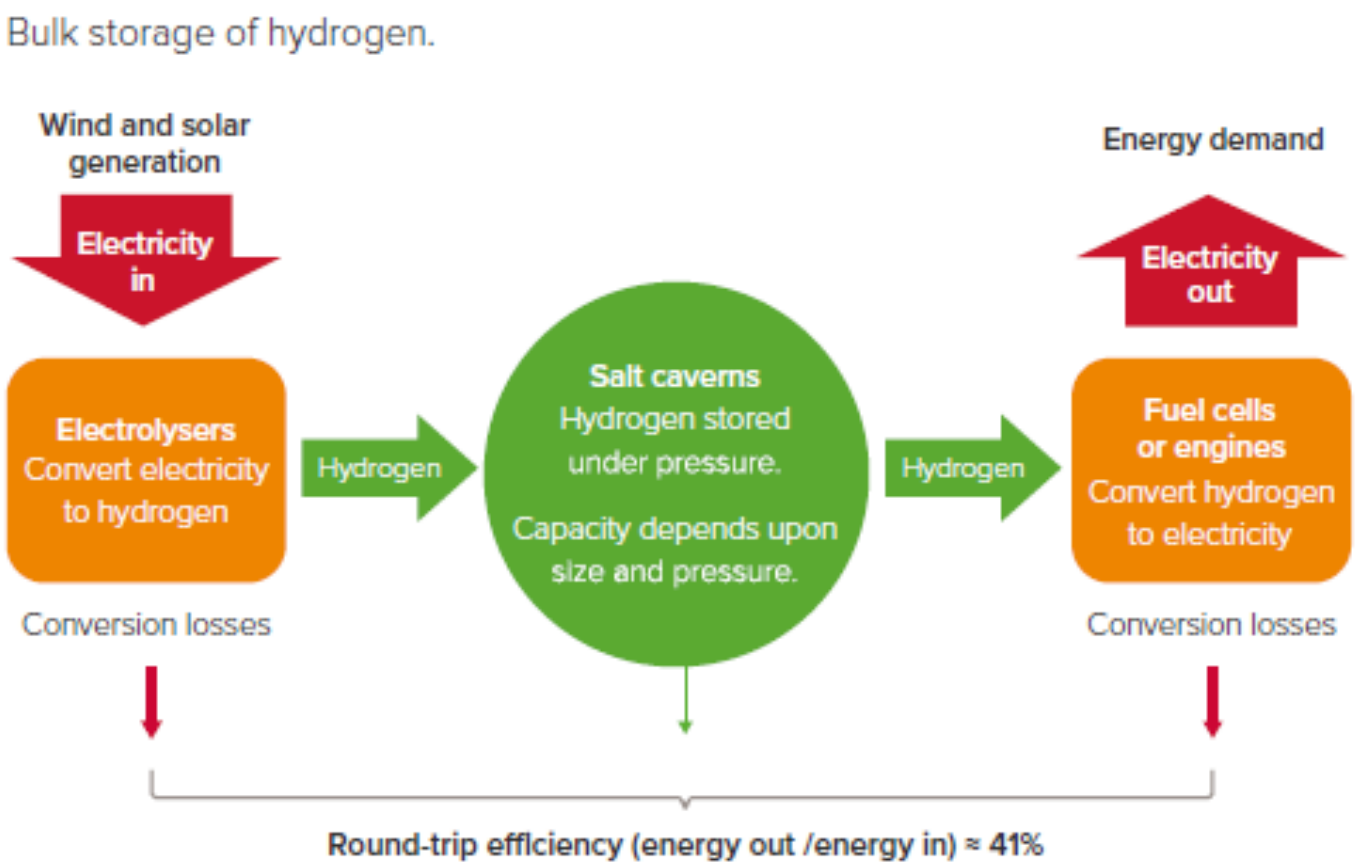
Electricity storage – short term



Source: BloombergNEF. Note: Forecast prices are in nominal terms, observed prices are in real 2021 $ per kilowatt-hour.

Battery cost reductions to $100/kWh look feasible, making batteries a game-changing technology for diurnal storage.

Electricity storage – long term



From Llewellyn Smith et al (2022) Large-scale electricity storage. Royal Society Policy briefing

- Storage to deal with long term variability must be very low cost
- Hydrogen in salt caverns looks the most feasible option
- The conversion cycle is inefficient, and adds 20-30% to the cost of electricity
- 100% renewable supply systems are still the lowest cost option

2. The challenge of ‘hard to decarbonise’ sectors

A large number of sectors and end uses have traditionally been seen as ‘hard to decarbonise’. These include:

- Poorly insulated buildings
- Heavy goods vehicles
- Marine transport
- Aviation
- Steel-making
- Fertilisers
- Petrochemicals
- Cement

In all these cases there are certainly challenges.

...but advances in electrification are making them easier

Sector	Traditional thinking	Current thinking
Lighting, appliances and cooling	Electricity	Electricity
Building heating	Electricity or hydrogen	Electricity
Light vehicles	Biomass or hydrogen	Electricity
Heavy vehicles	Biomass or hydrogen	Electricity
Marine short haul	Biomass or hydrogen	Electricity
Marine long haul	Biomass or hydrogen	Hydrogen based fuels
Aviation short haul	Biomass	Electricity
Aviation long haul	Biomass	Biomass or hydrogen
Industrial heating	Hydrogen	Electricity
Primary steelmaking	Hydrogen	Hydrogen
Ammonia	Hydrogen	Hydrogen

Key messages

- **We can't** stabilise the climate without huge reductions in fossil fuel use
- **We can't** get huge reductions in fossil fuel use without a radically different energy system
- Renewable energy, electrification and improved energy efficiency are the central elements of the solution
- And they have major synergies
- They need investment, and
- There are still some challenges to address, but
- **We can** get to a zero-carbon energy system.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