Environmental *Change* Institute

Welcome to the Anthropocene

Energy and carbon in the anthropocene

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October 10, 2018

Energy in human history – the rise of fossil fuels

Society	Key Energy Service	Fuel	Technology
Primitive	Warmth	Human labour Biomass	Fire Hand tools
Agricultural	Agrarian products	Horse power	Wheel Mechanical tools
Industrial	Industrial products	Coal	Boiler Steam engine
Modern	Consumer goods Mobility	Oil Electricity Gas	Engines Electric turbine Electric motor

ANTHROPOCENE

What does this mean for energy in the "late anthropocene"?

Society	Key Services	Fuel	Technologies
Modern	Consumer goods Mobility	Oil Electricity Gas	Combustion engine Electric turbine Electric motor
"Post carbon"	24/7 ICT Universal energy access	Solar Wind Biofuels??	Renewable energy Energy efficiency Energy storage Carbon capture??

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Energy and Carbon Futures

- Global challenges
- Decarbonisation of the global economy
- Energy efficiency
- Low carbon energy supply
- New challenges
- Implications for policy

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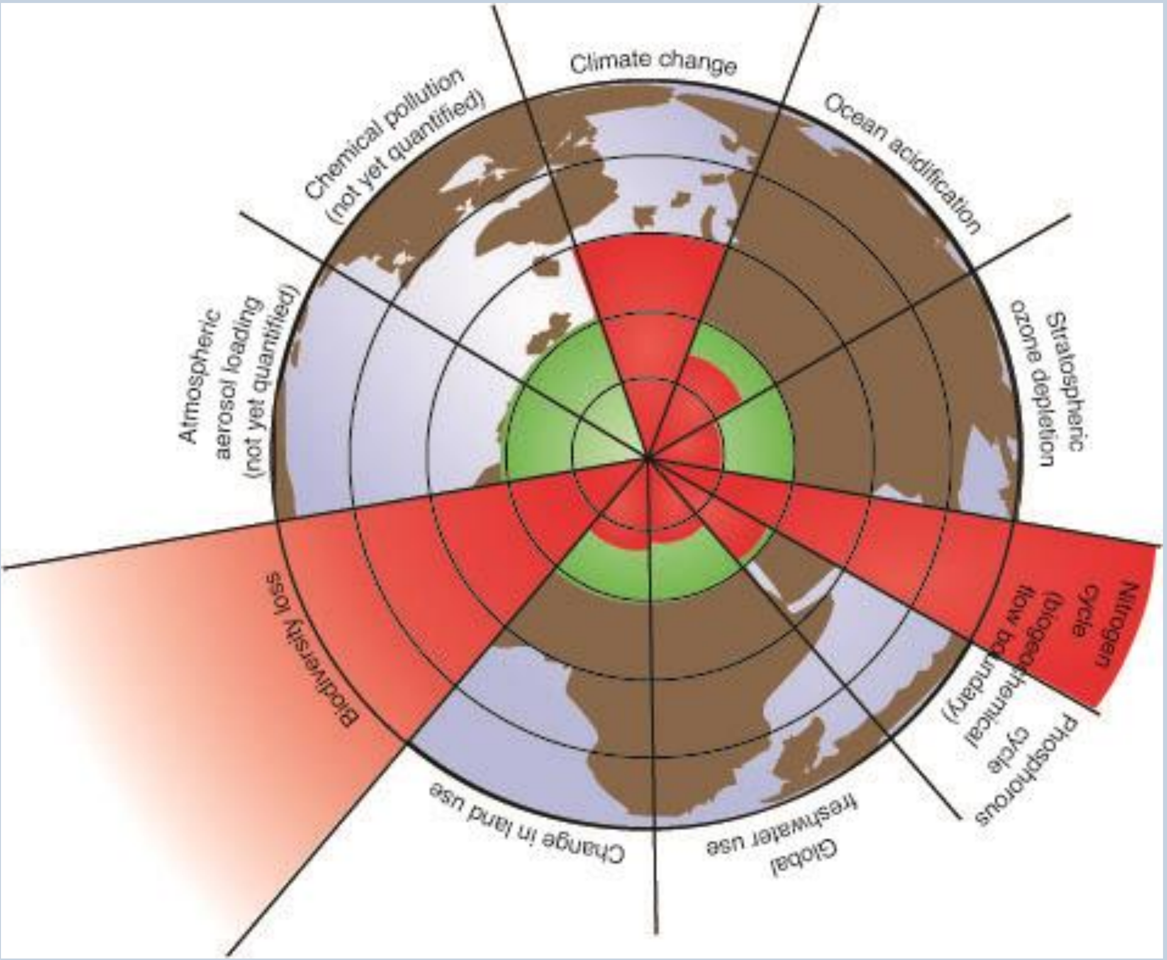
Energy and planetary boundaries



Rockström et al, 2009

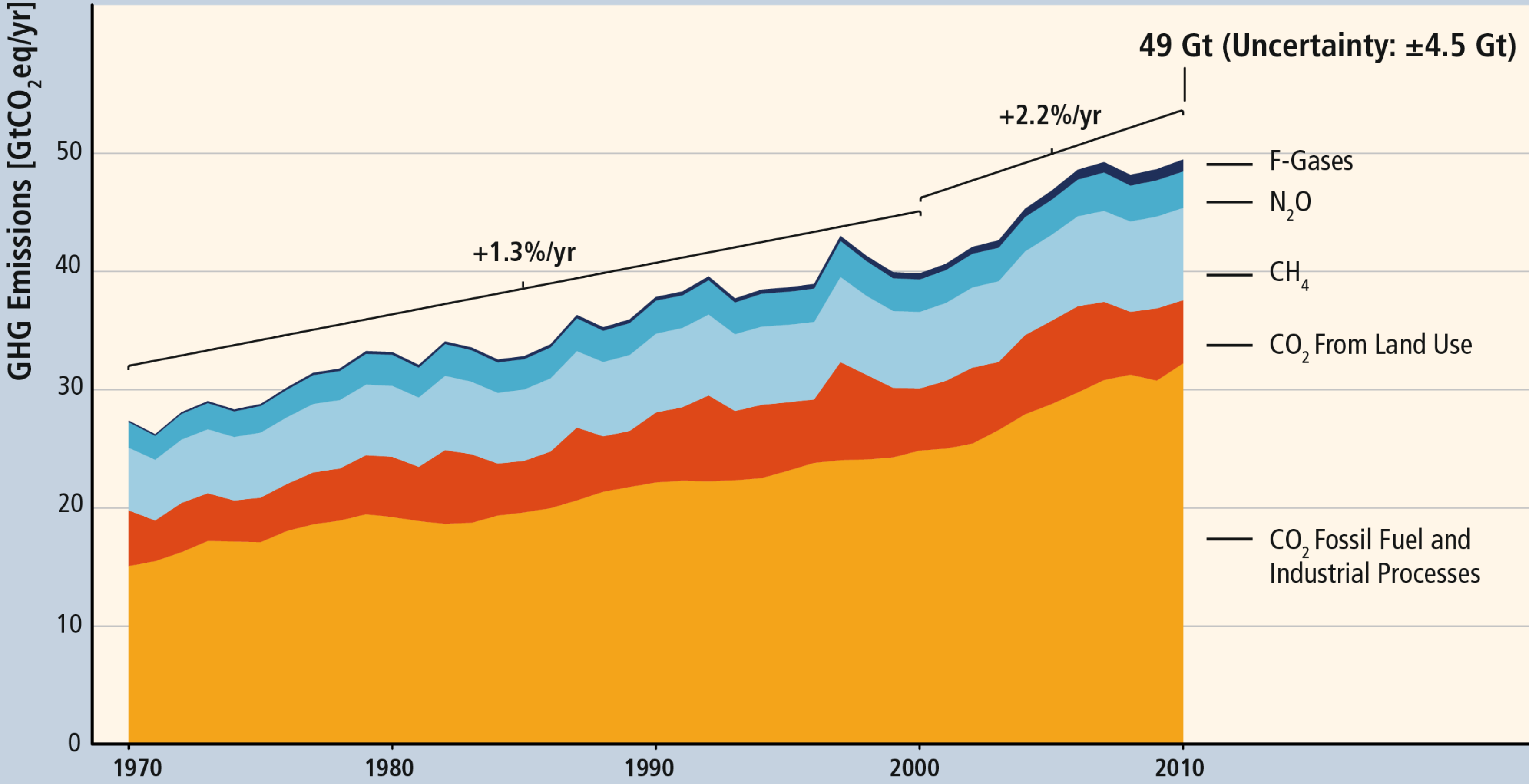
Energy is critical to:

- Climate change
- Ocean acidification

and a major part of:

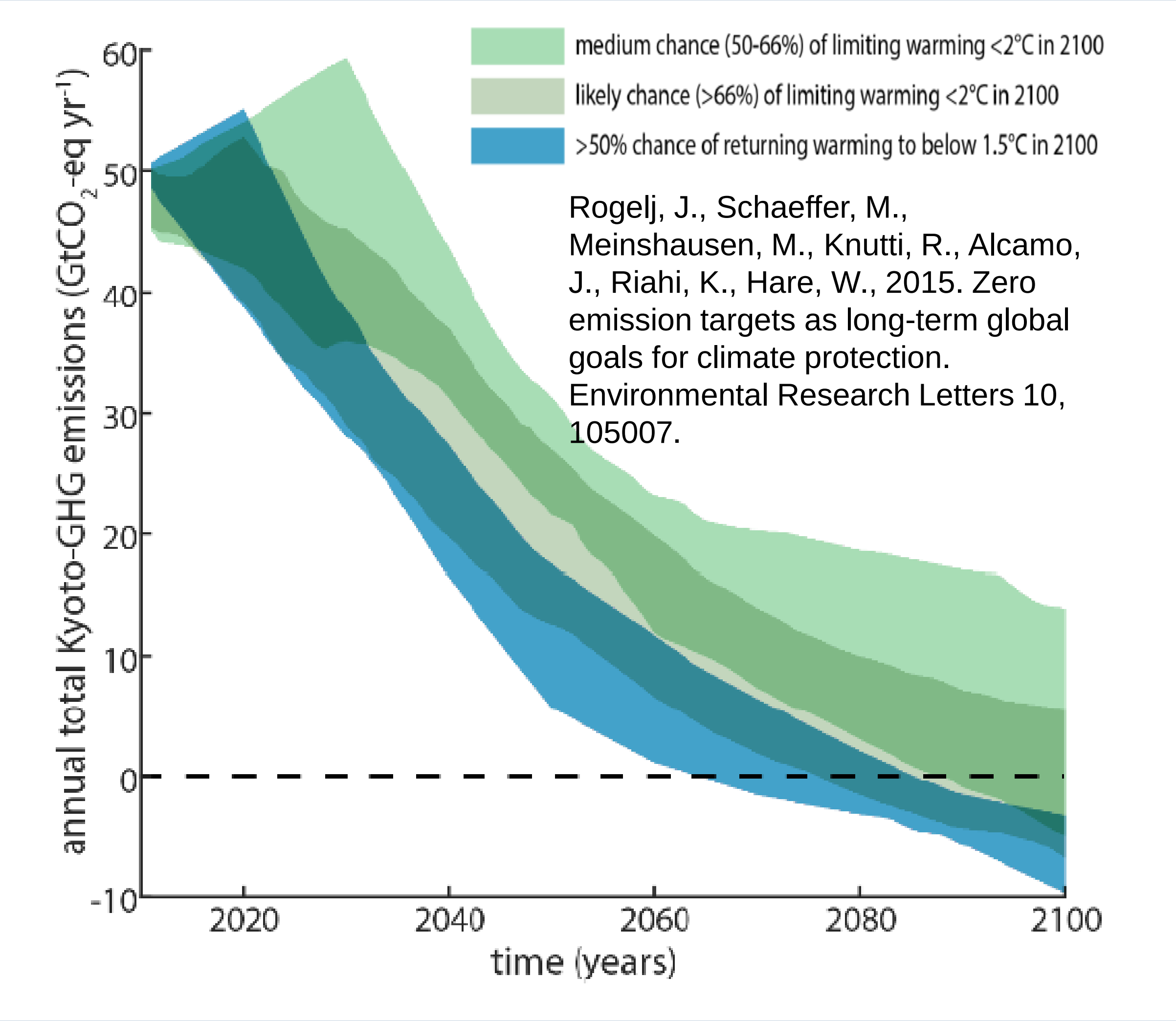
- Nitrogen pollution
- Atmospheric aerosols

Use of fossil fuels for energy is the key driver of climate change



IPCC WGIII, 2014

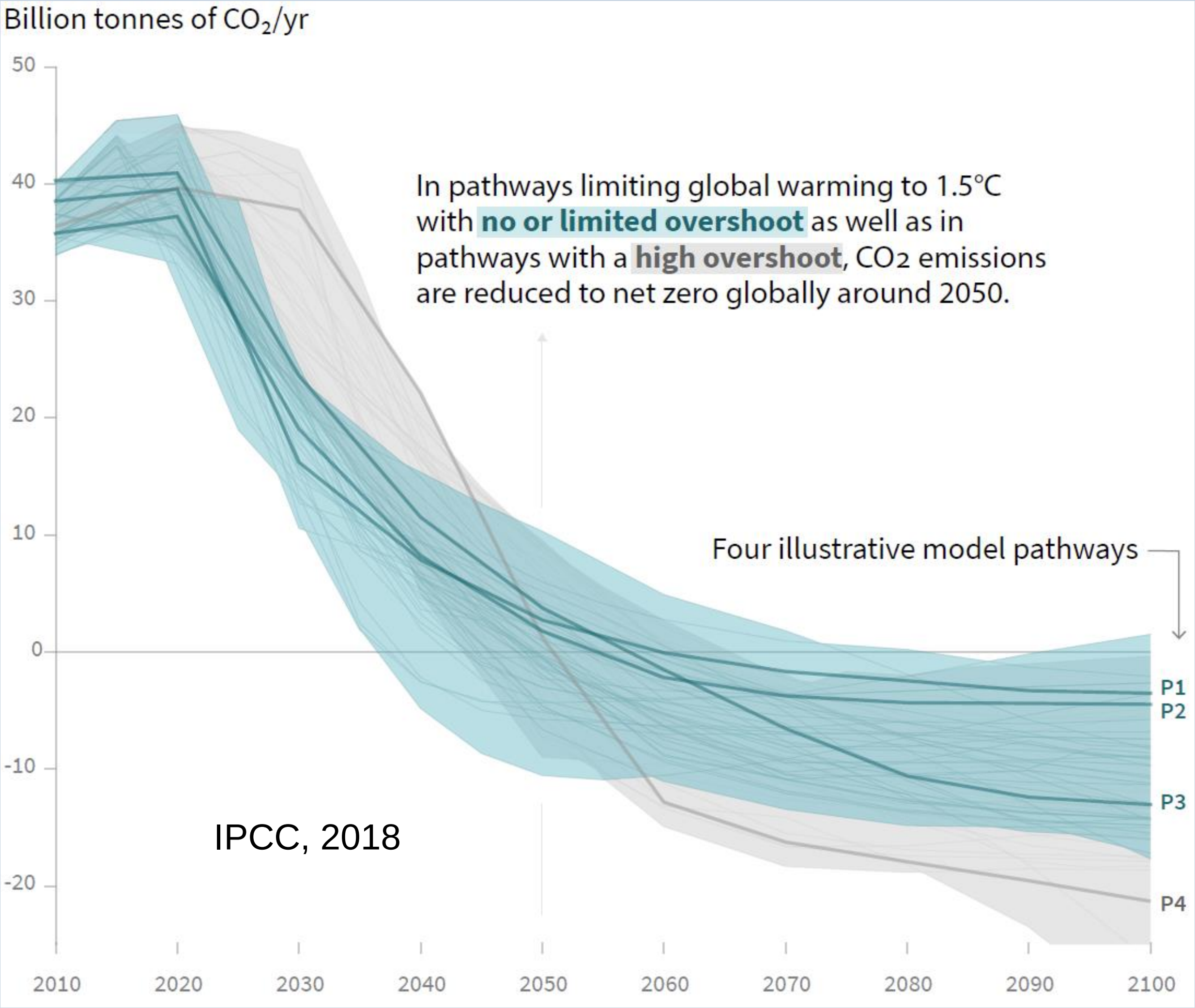
Implications of the Paris Agreement



Rogelj, J., Schaeffer, M., Meinshausen, M., Knutti, R., Alcamo, J., Riahi, K., Hare, W., 2015. Zero emission targets as long-term global goals for climate protection. Environmental Research Letters 10, 105007.

Compliance with the goals of the Paris agreement implies very rapid decarbonisation

Implications of a 1.5 C target



a 1.5C target implies earlier action and an even more rapid energy transition

The Energy Trilemma

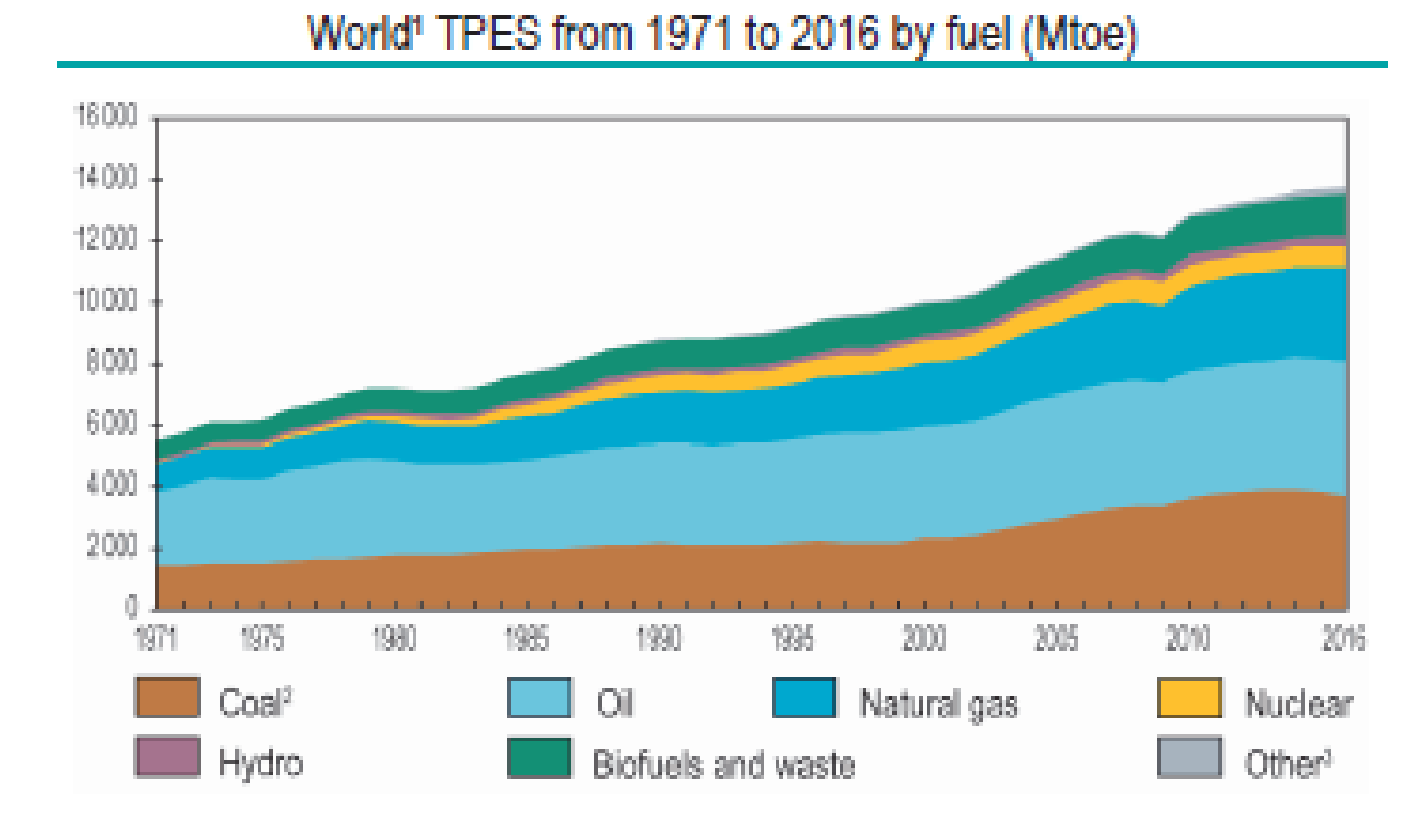
Energy policy usually has 3 types of objective:

- Environmental (climate and others)
- Energy security
- Affordability (including affordable access)

The last two are socially important everywhere, and therefore can constrain low carbon goals.

This is critical to understanding politically achievable climate policy.

Global energy security is currently highly dependent on fossil fuels, i.e. on carbon



IEA World Energy Statistics, 2018

Access: Sustainable Development Goal 7

7 AFFORDABLE AND CLEAN ENERGY

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

- In 2012, more than 1 billion people had no access to electricity.
- In 2014, more than 3 billion people had no access to clean fuels for cooking.

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

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Summary of the Global Challenges for Energy

- Radical reductions in fossil fuel emissions are required to stabilise the climate, but
  - Energy use is rising, and dominated by fossil fuels
  - Fossil fuels provide the energy security that underpins modern life
  - Affordable access to energy is the priority for development.

A low carbon future requires systemic change in the energy sector, promoting energy security, at reasonable cost.

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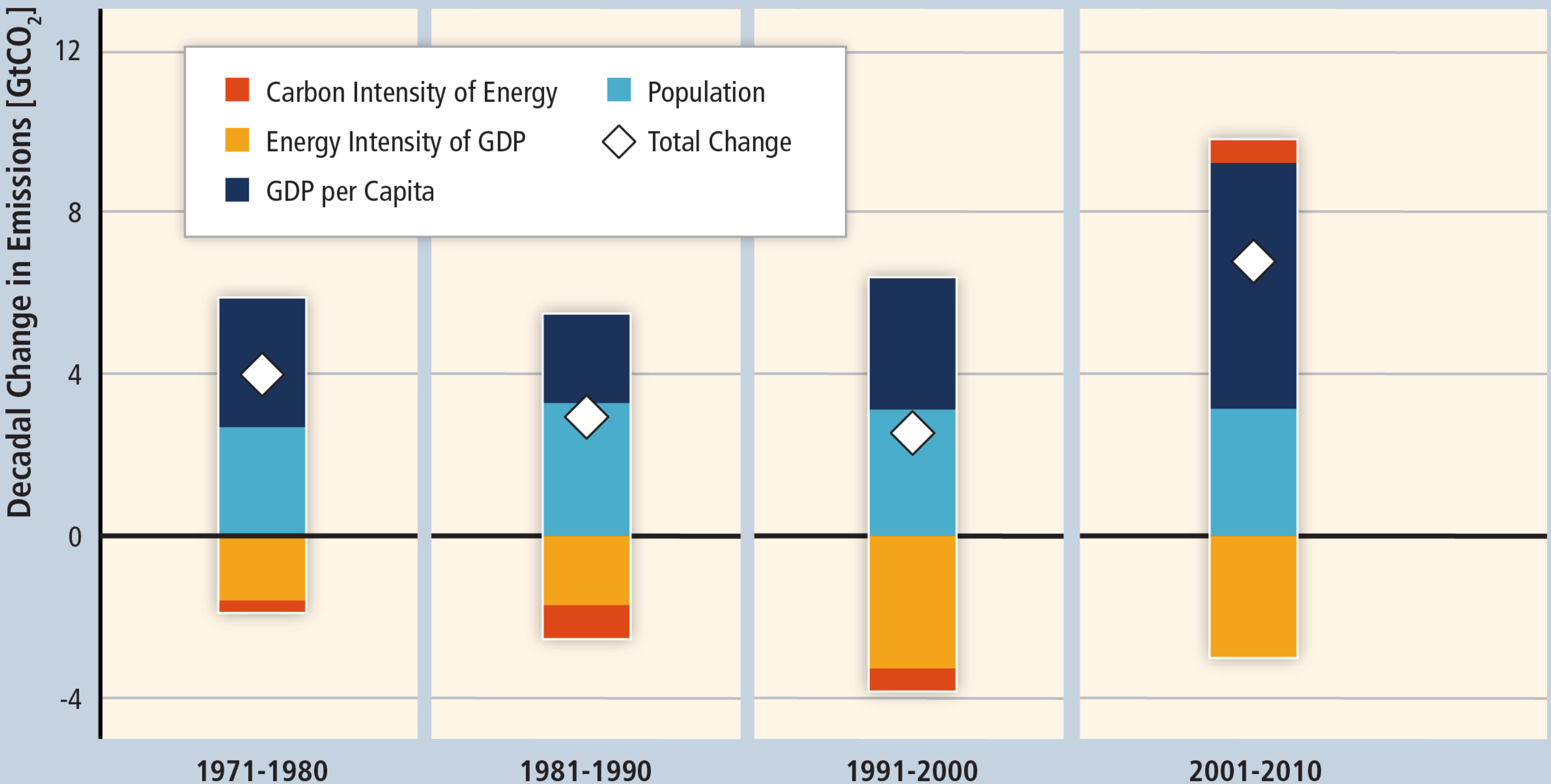
How can we decarbonise an economy?

Emissions of carbon, C, given by the Kaya identity:
$C \equiv (C/E) \times (E/GDP) \times (GDP/P) \times P$
where E = energy use and P = population

If population and wealth rise, **there are only two avenues to decarbonise any economy**

- **Reduce the 'carbon ratio'**, C/E, by changing the energy sources used
- **Reduce the 'energy ratio'**, E/GDP, by improving energy efficiency of the economy

Population and income are driving emissions up; only efficiency is currently mitigating this



IPCC WGIII, 2014

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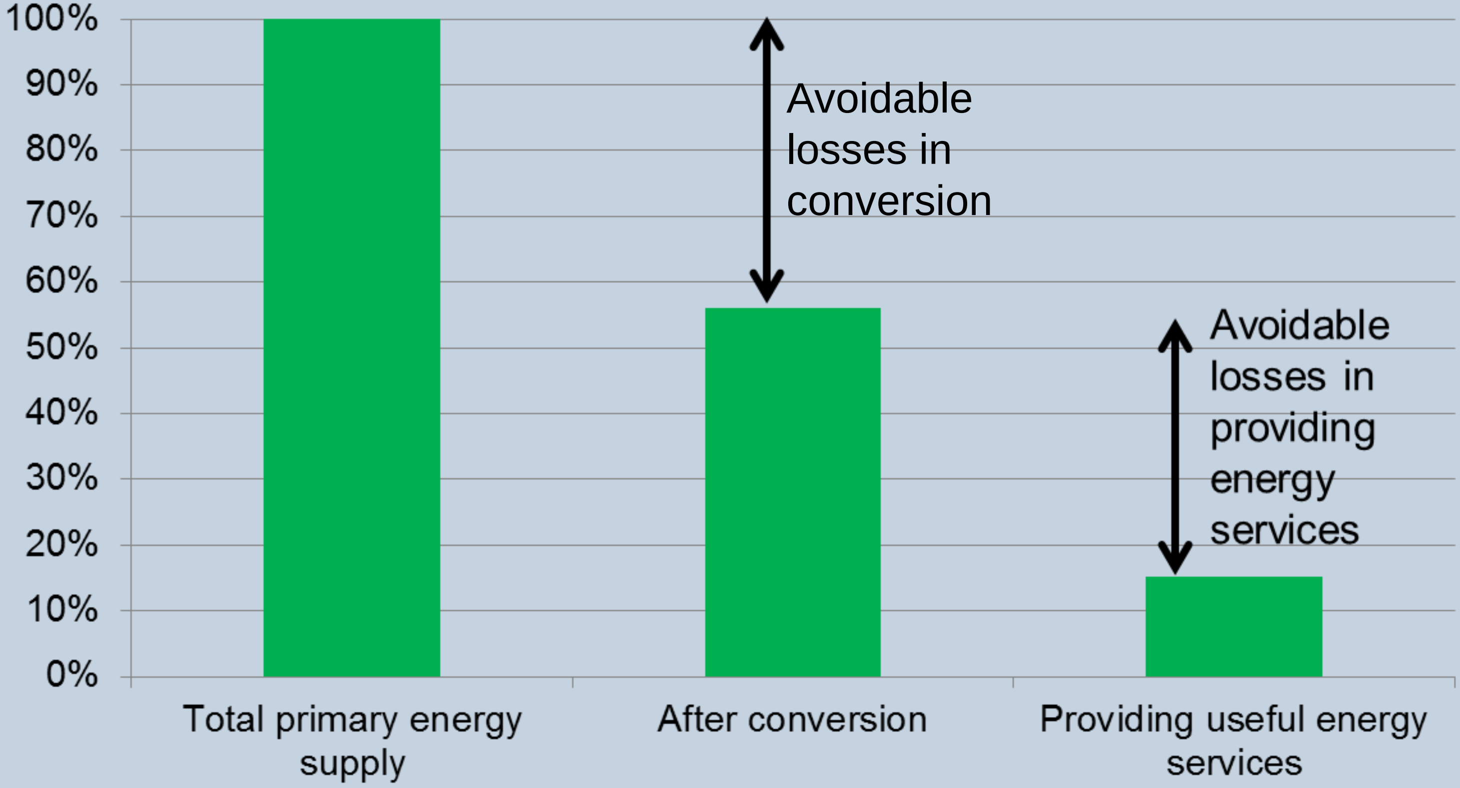
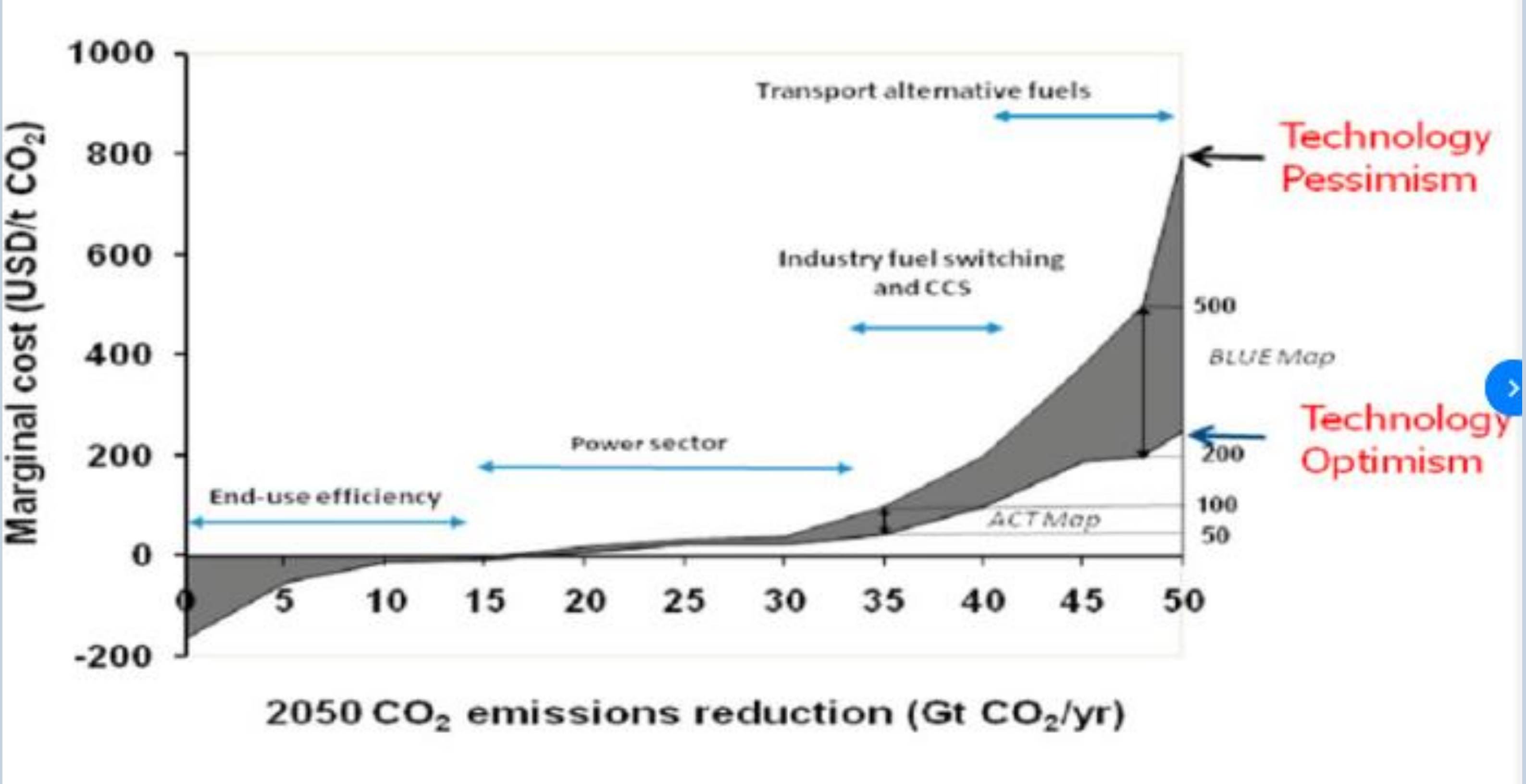
How much more could we improve energy efficiency?



Based on Cullen and Allwood, 2011

…and efficiency is generally the cheapest carbon abatement



IEA, 2008

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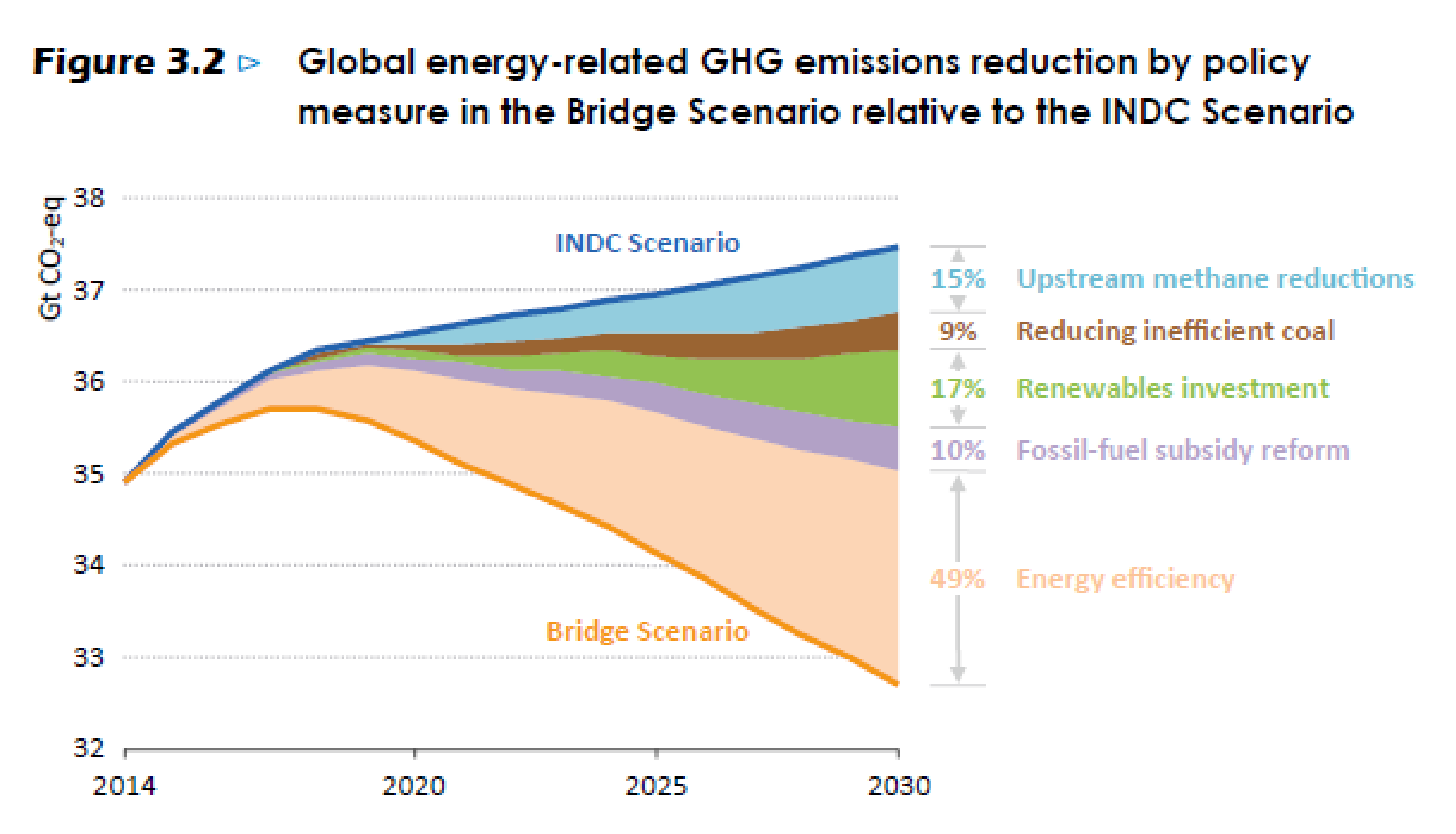
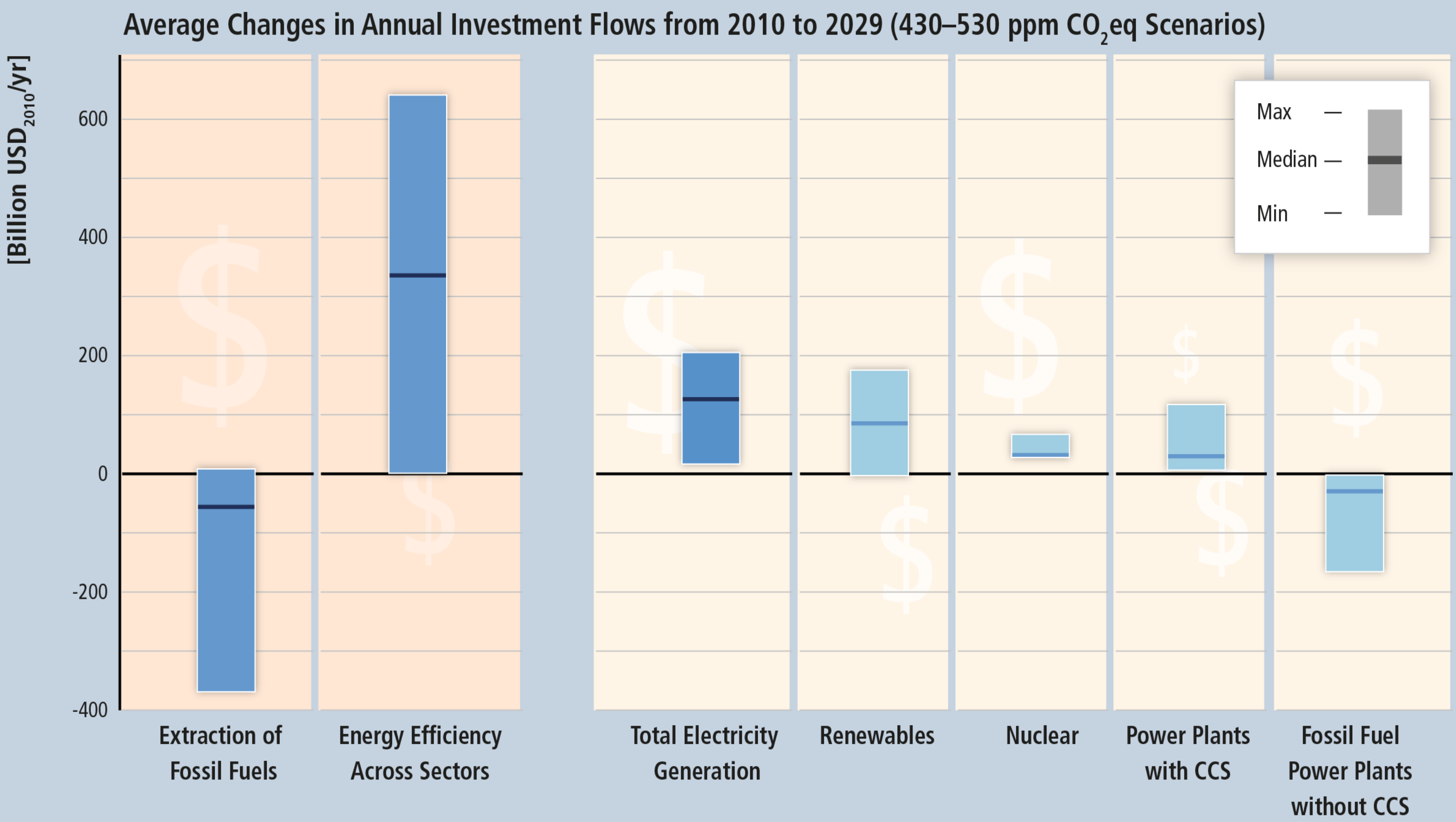
…and likely to be the largest single contributor to stabilising the climate



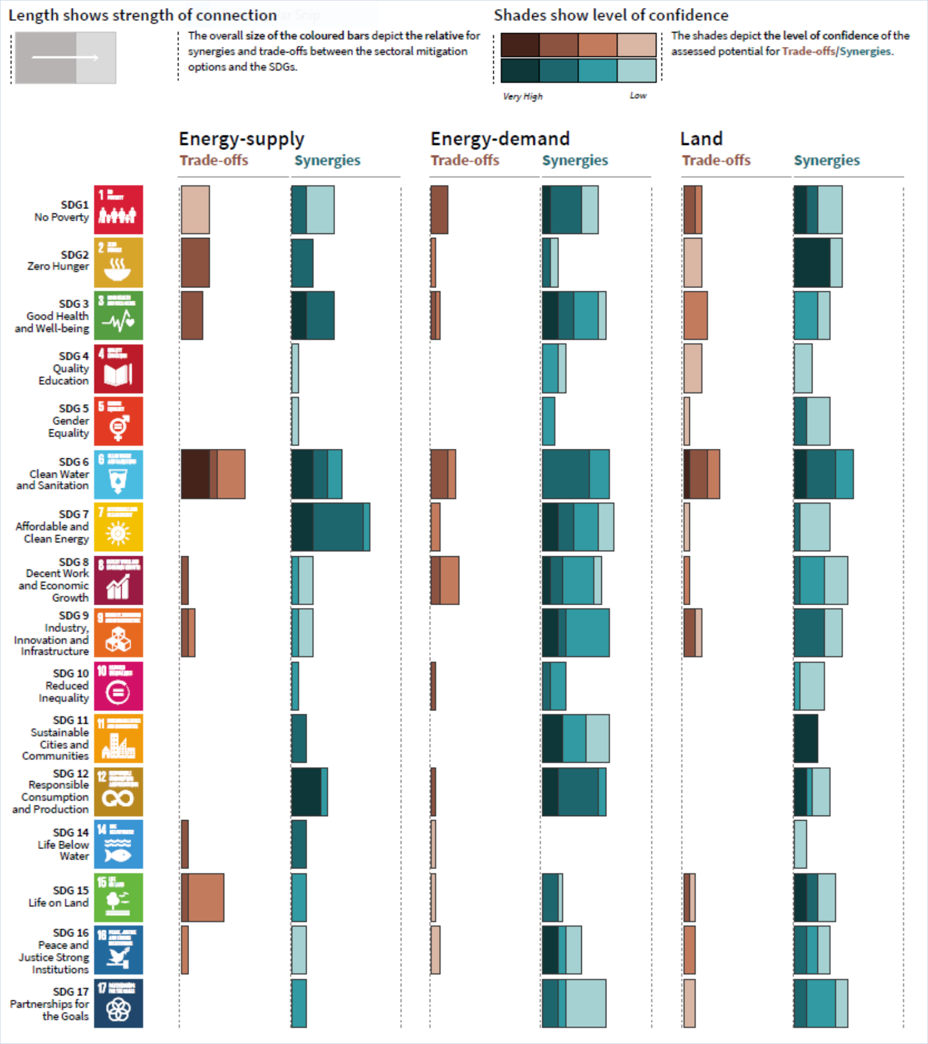
IEA, 2015

…and requires most mitigation investment



IPCC WGIII, 2014

Energy demand and sustainable development



Addressing energy demand issues has stronger benefits for sustainable development than other categories of climate mitigation action

IPCC, 2018

Summary of conclusions for energy efficiency

- Energy efficiency can make a major contribution to energy system decarbonisation, with other benefits.
- The total investment required is very large, but it generally a cheaper option than increased low carbon supply.
- The constraints are social, organisational and institutional, rather than economic

CREDS
CENTRE FOR RESEARCH INTO ENERGY DEMAND SOLUTIONS

…but energy efficiency alone is clearly not sufficient for complete decarbonisation

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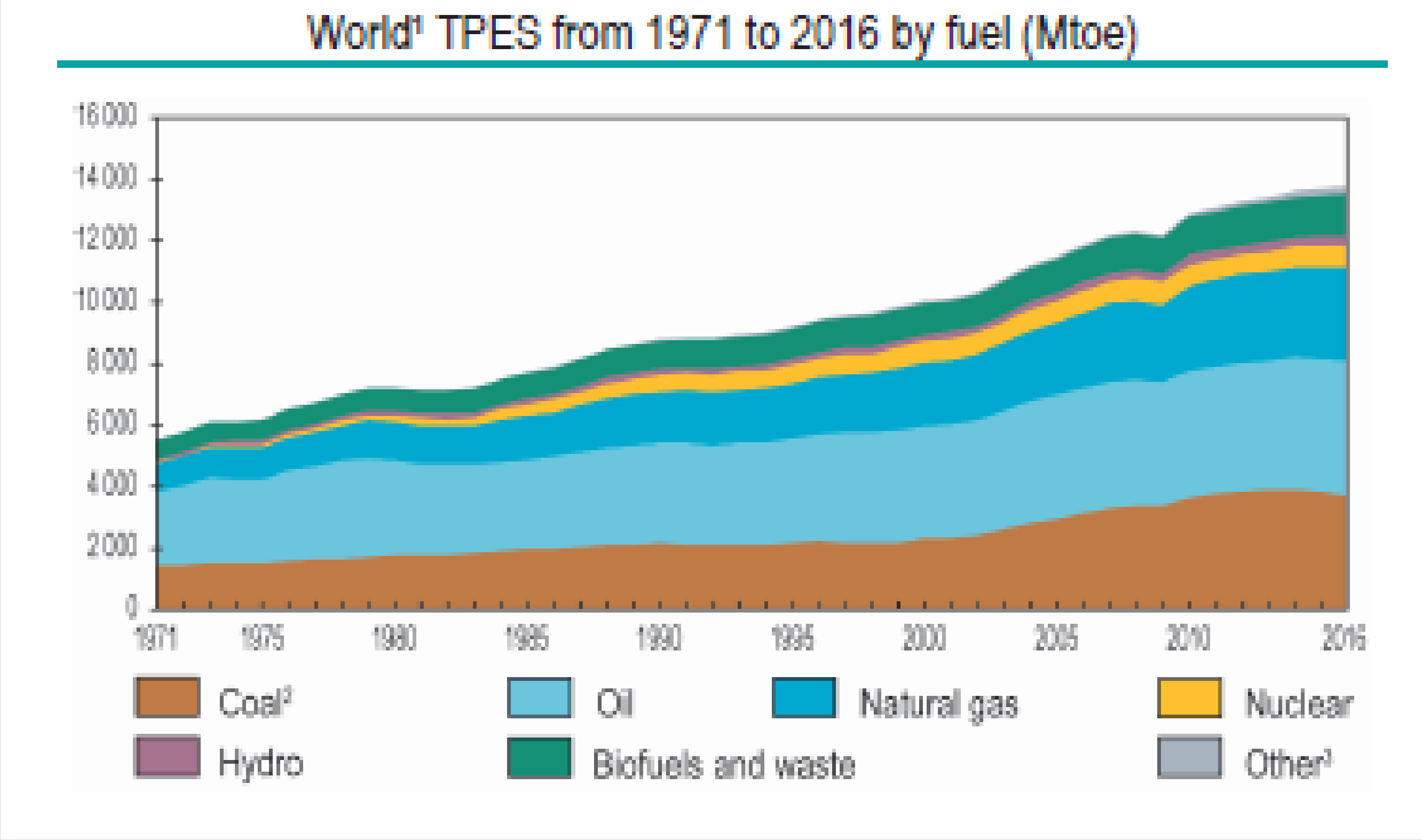
Low carbon energy supply options
What are they?

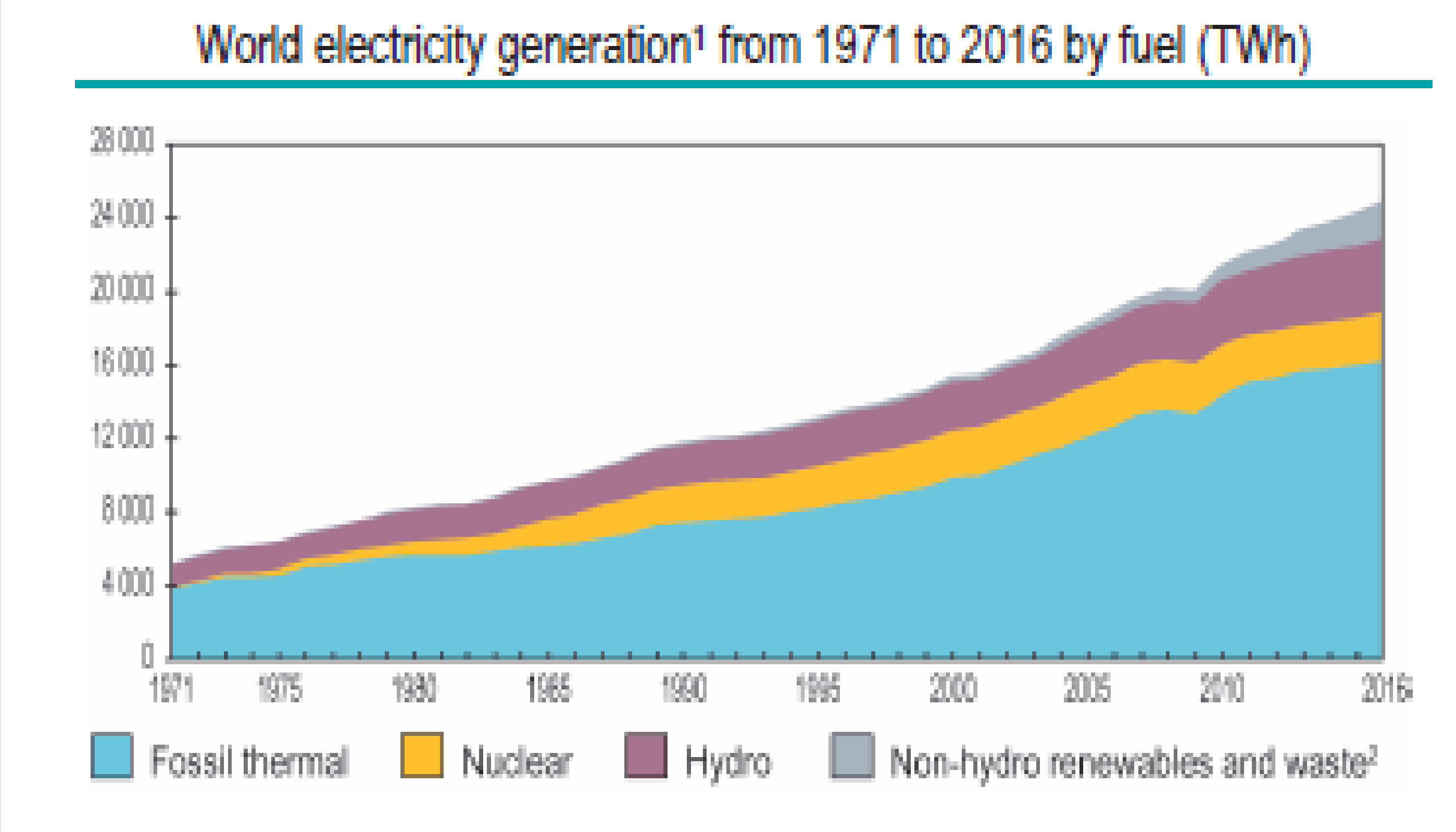
- Renewable energy sources (RES)
- Fossil fuels with “carbon capture and storage” (CCS)
- Nuclear power

Trends in Global Energy Supply



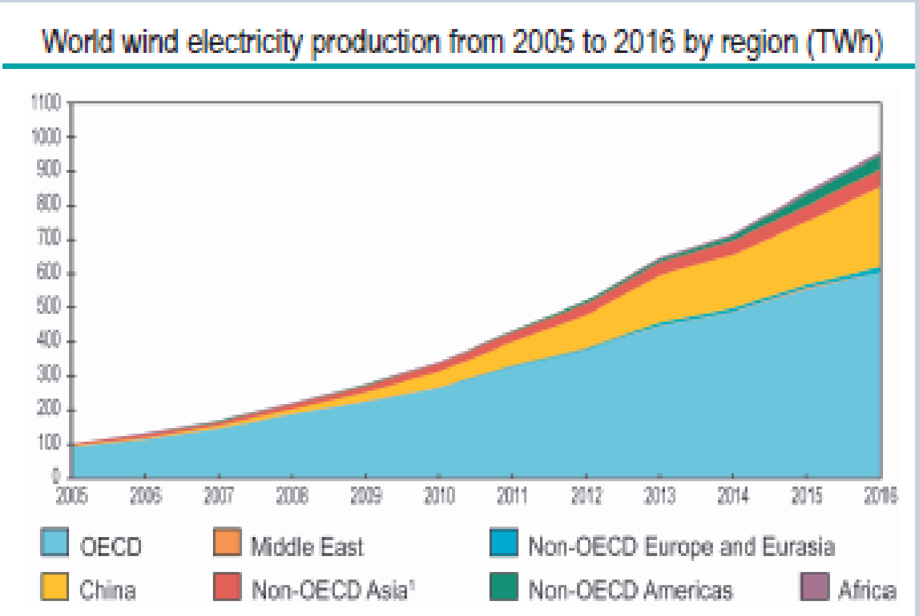
IEA World Energy Statistics, 2018

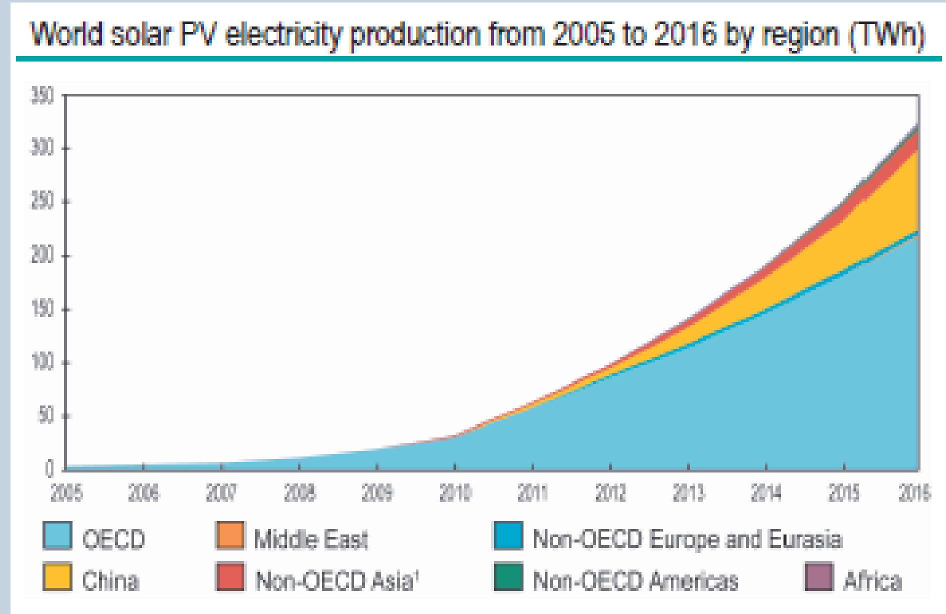
Trends in global electricity generation



IEA World Energy Statistics, 2018

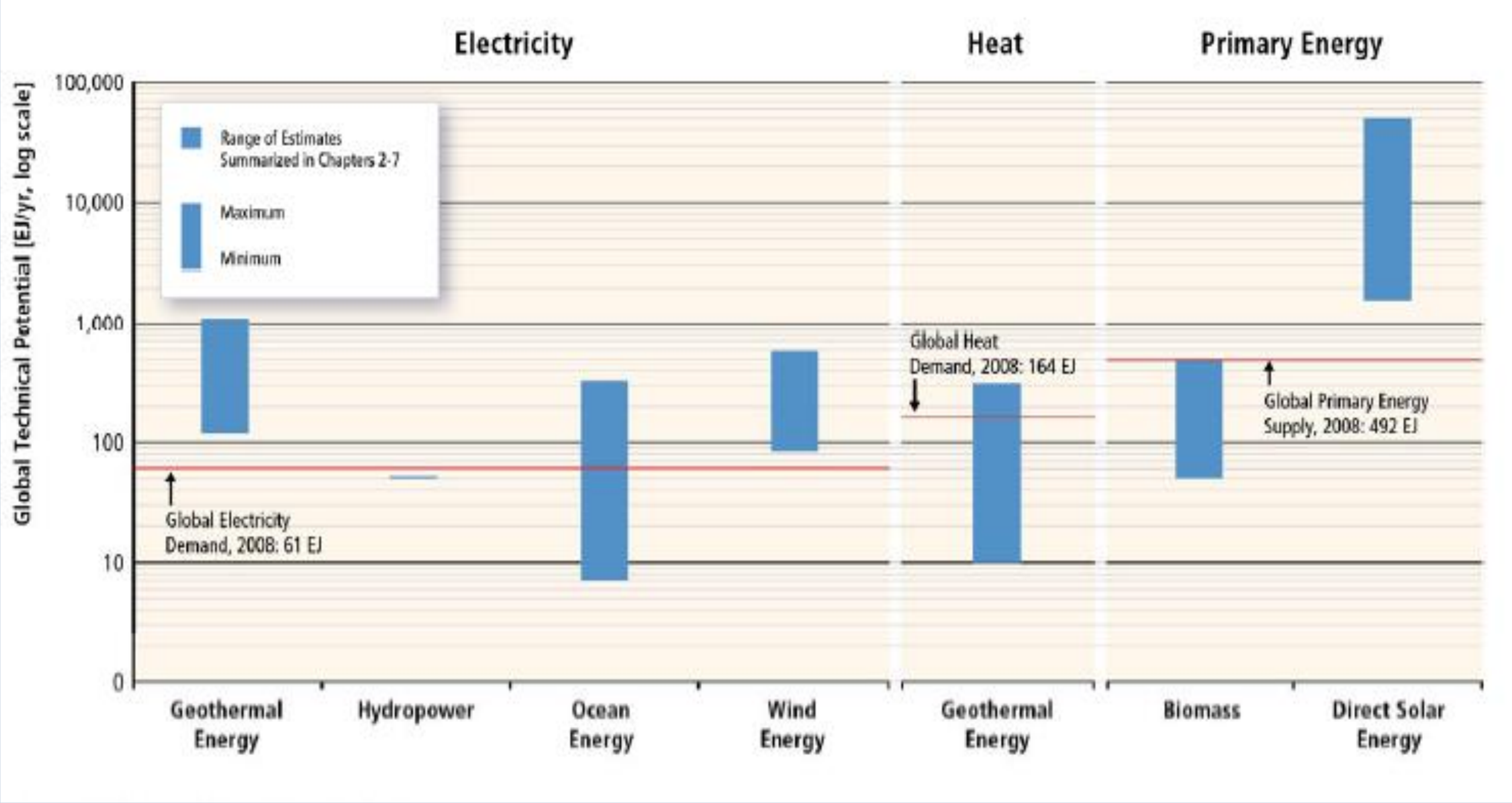
Renewable electricity – current trends





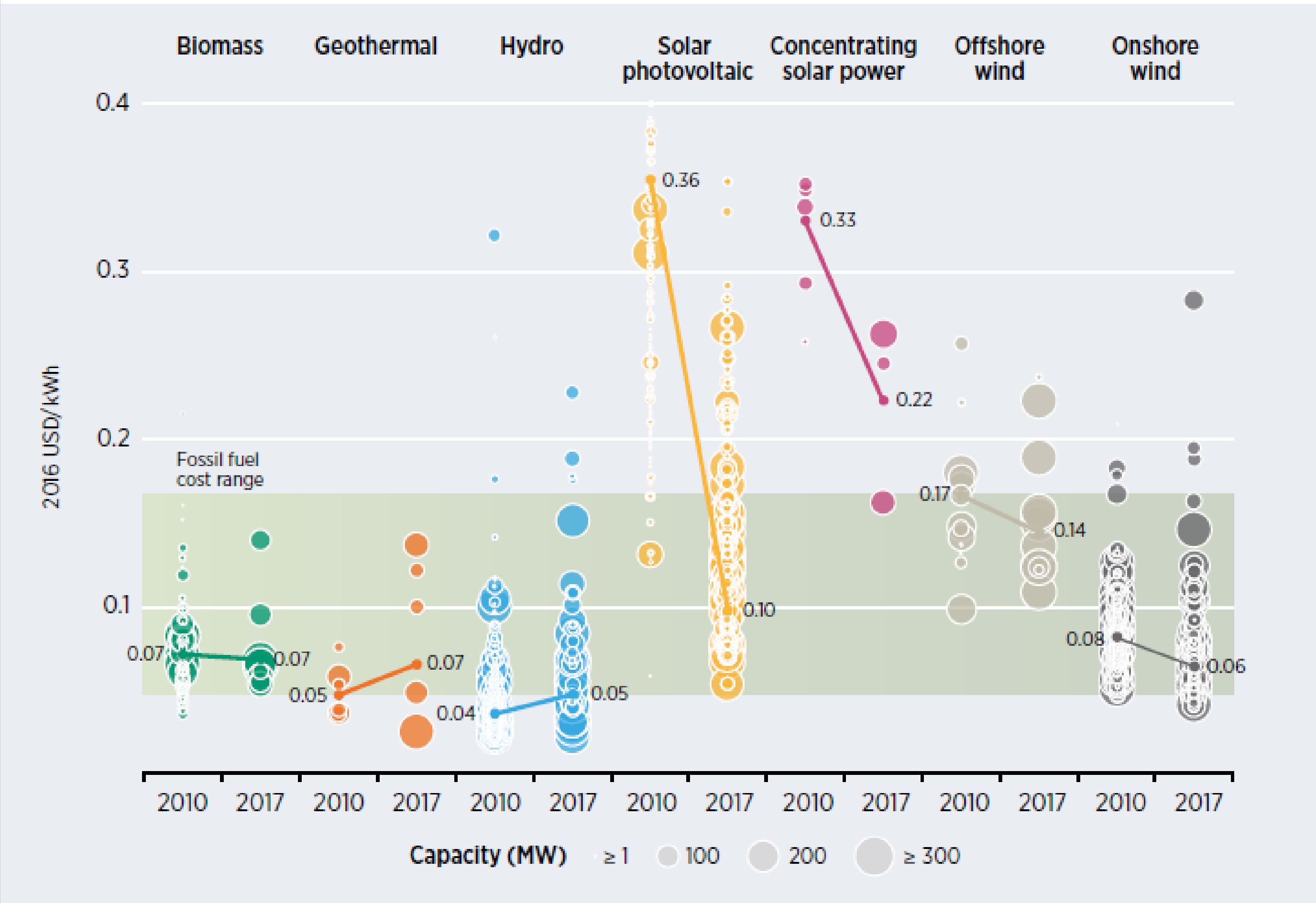
Source IEA World Energy Statistics, 2108

Renewable energy: estimated global technical potential



Source: IPCC, 2011

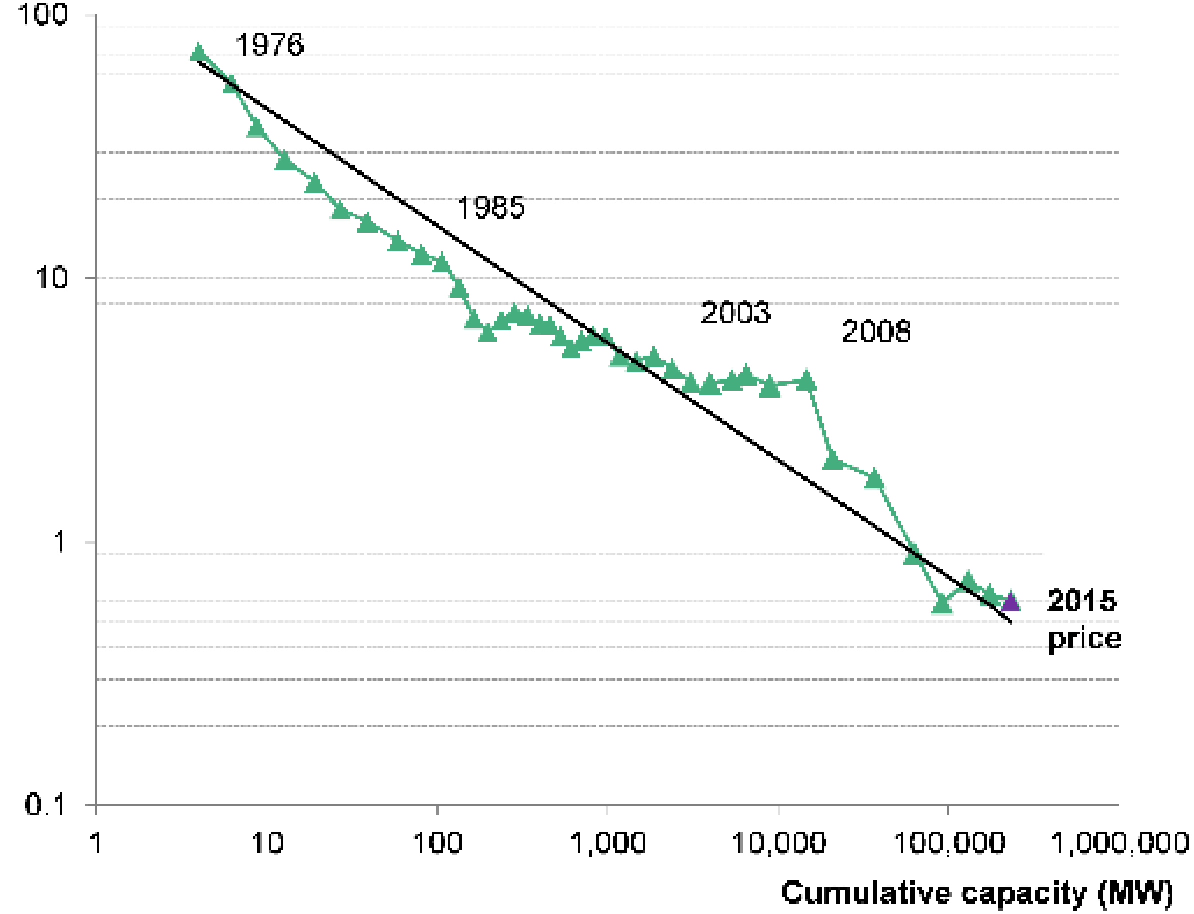
Renewable electricity costs 2010-2017



Source: IRENA Renewable Cost Database.

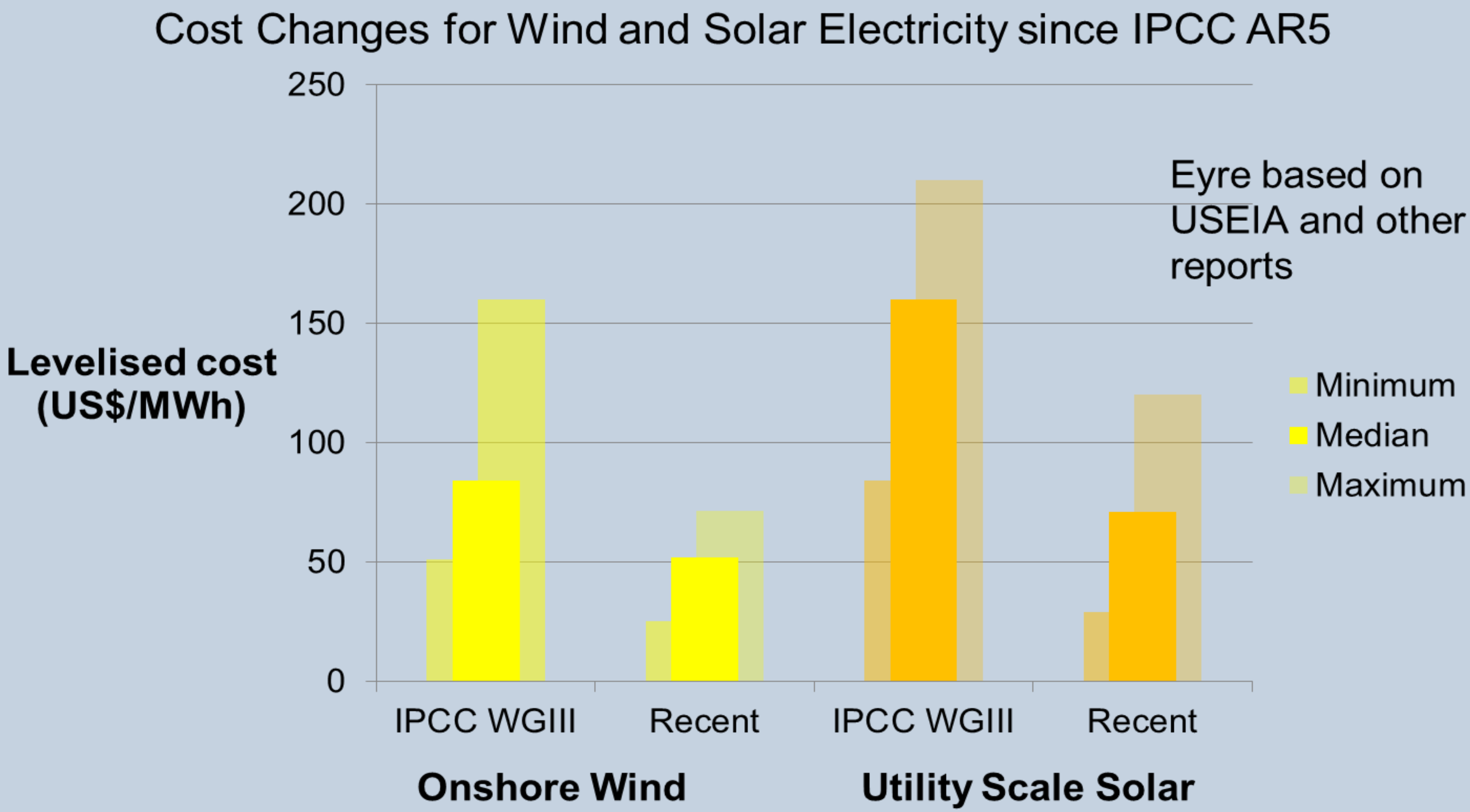
Source IRENA, 2017

Long term costs of solar have fallen dramatically



Source: Bloomberg New Energy Finance, 2016

International analysis that underpins climate policy does not recent progress



The key renewables

- **Wind** – very large untapped potential in some regions at low cost.
- **Solar** – useful contributions from solar heat, but solar electricity is the major prize. Historically expensive, but recent dramatic cost reductions.
- **Biomass** – potentially important and can be stored, but raises questions about impacts on terrestrial biosphere and the ‘food v fuel’ debate.

Wind and solar are now the cheapest low carbon options and increasingly the cheapest of all electricity generation options

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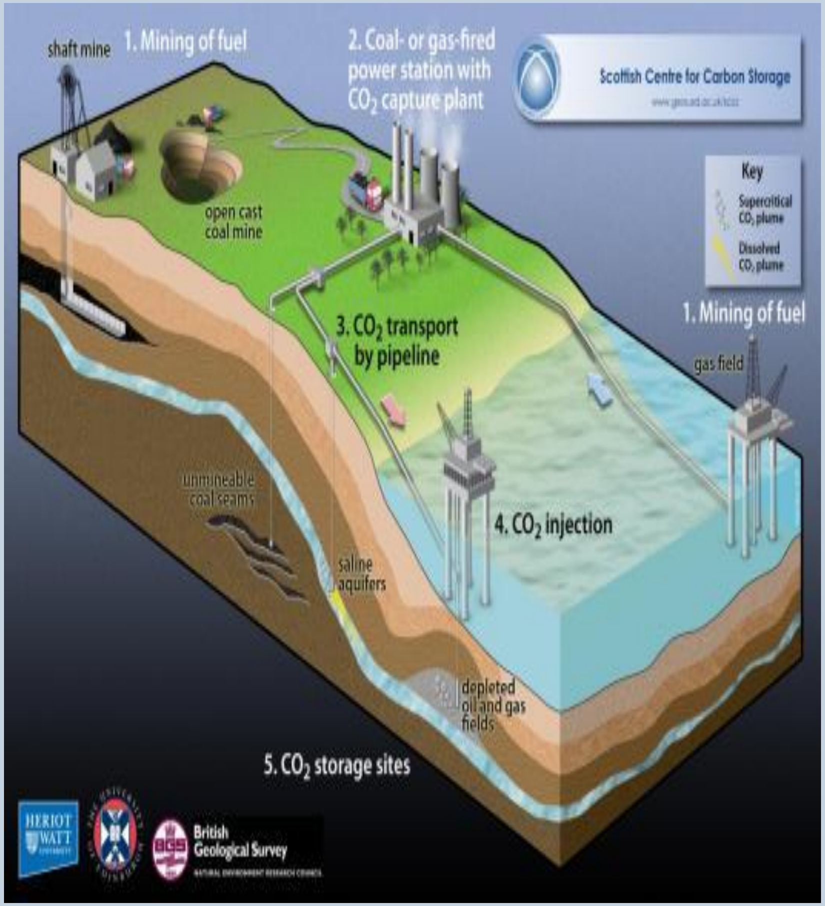
Carbon capture and storage (CCS) - benefits

- CCS allows use of fossil fuels, protecting fossil investment
- All stages (from extracting CO_2 to disposal) are technically proven
- Can be used with any fossil fuel or biomass



CCS – the risks

- CCS is unproven at commercial scale
- Costs are therefore uncertain, but currently high
- 100% CO_2 capture not possible
- Possible risks associated with CO_2 transport and disposal in large volumes
- Social acceptability is already a problem

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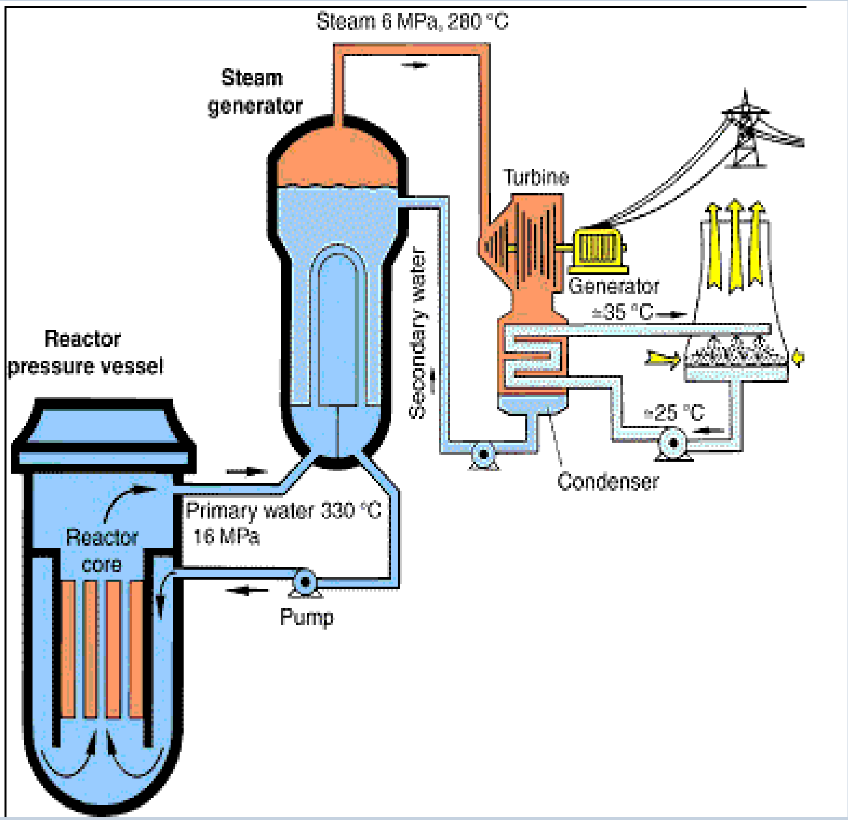
CCS – conclusions

- Significant deployment is unlikely before 2030.
- Increasingly unattractive as an electricity generation option, as it cannot compete with renewables
- More likely to be useful in “hard to decarbonise” sectors, e.g. industrial processes, hydrogen, aviation fuels.
- Potential negative emissions via biomass with CCS (BECCS), but large scale feasibility unlikely.

Nuclear – the technology

- Large resource base of uranium and thorium
- Proven technology – 50 years operational experience
- Large and replicable – ~1000 MW typical scale
- Smaller options under development



Nuclear – the risks

- Wastes: radioactive and long-lived
- Weapons links: particularly for plutonium reprocessing
- Accidents: high consequences and variable public acceptability.
- Affordability: capital costs are very high. Build time: ~10 years
- New technologies have not been commercially deployed

Nuclear – conclusions

- Costs are rising
- Risks are too high for private investment
- Not credible that nuclear will ever compete economically with renewables.
- Fukushima revived concerns about accidents

- Interest now largely in countries with nuclear weapons programmes or aspirations

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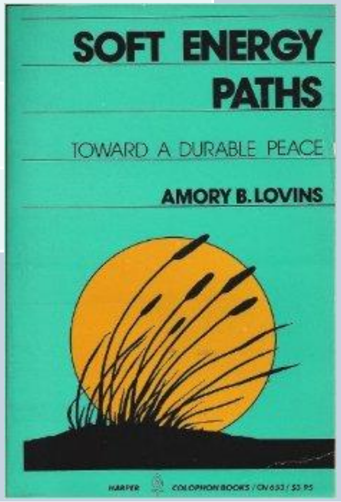
Summary of conclusions for low carbon energy

- The current contribution of renewables is small, but growing rapidly
- Renewables, especially solar and wind, now compete with conventional sources in electricity generation.
- CCS and nuclear are unlikely to be important, at least in electricity generation, for purely economic reasons.
- The low carbon economy will be fuelled by very largely by flows of energy from the natural environment.
- The variability of wind and solar resources is the major constraint on future market penetration

Competing paradigms for energy

	Hard pathway	**Soft pathway**
Key energy sources	Energy stocks	Natural energy flows
Technologies	Fossil, CCS, nuclear	Solar, wind, efficiency
Number and scale	Few and big	Many and small
Environmental protection strategy	Capture and bury wastes	Avoid wastes
Distribution	Centralised	Distributed
Innovation rates	Low	High
Capital intensity	High	High

Based on Lovins, Soft Energy Paths, 1976



In the last 6 years, the soft pathway has become much more economic.

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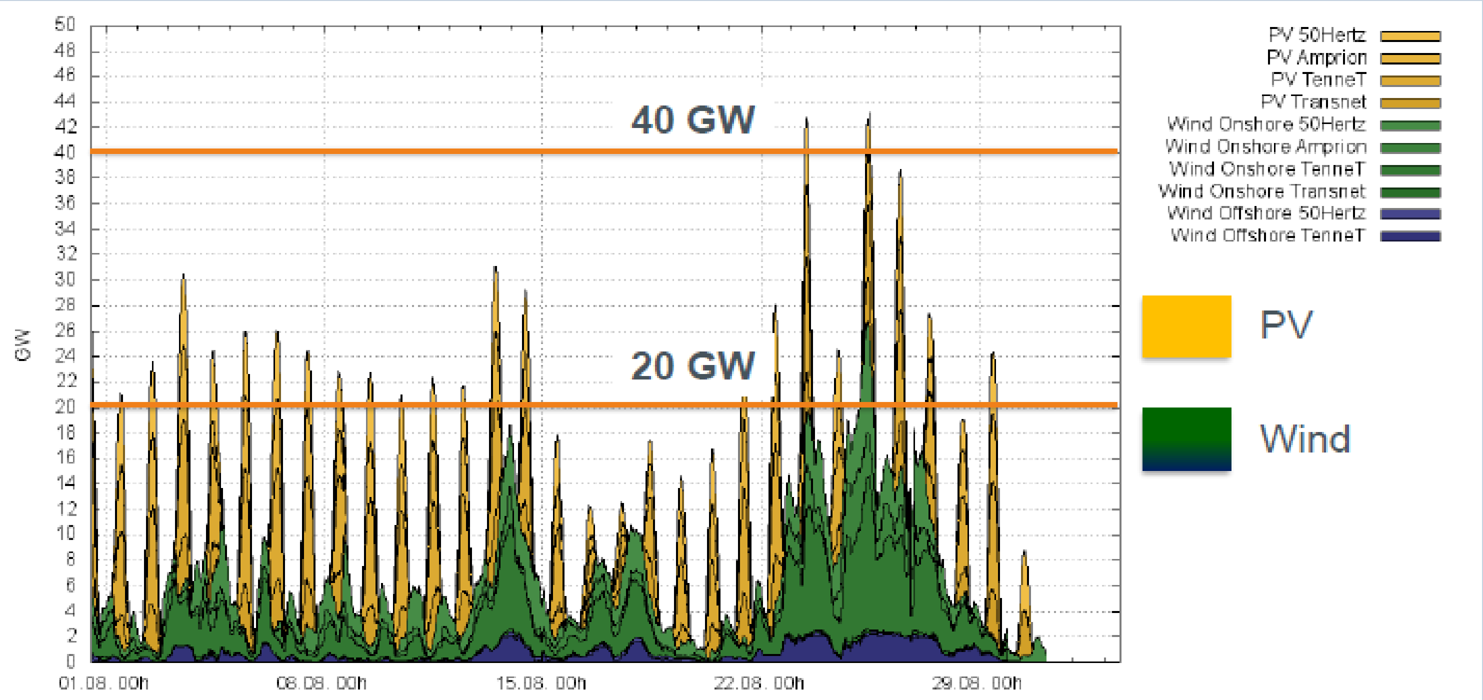
1. The challenge of variability

- The dominant renewables are expected to be solar and wind, which are variable, and increase the need for flexibility in the electricity system.
- Electricity system balancing will require some combination of
    - flexible generation,
    - demand side response (DSR),
    - storage,
    - interconnection.

The balancing problem



Solar and wind supply in Germany, August 2015, Ehlers, 50 Hz

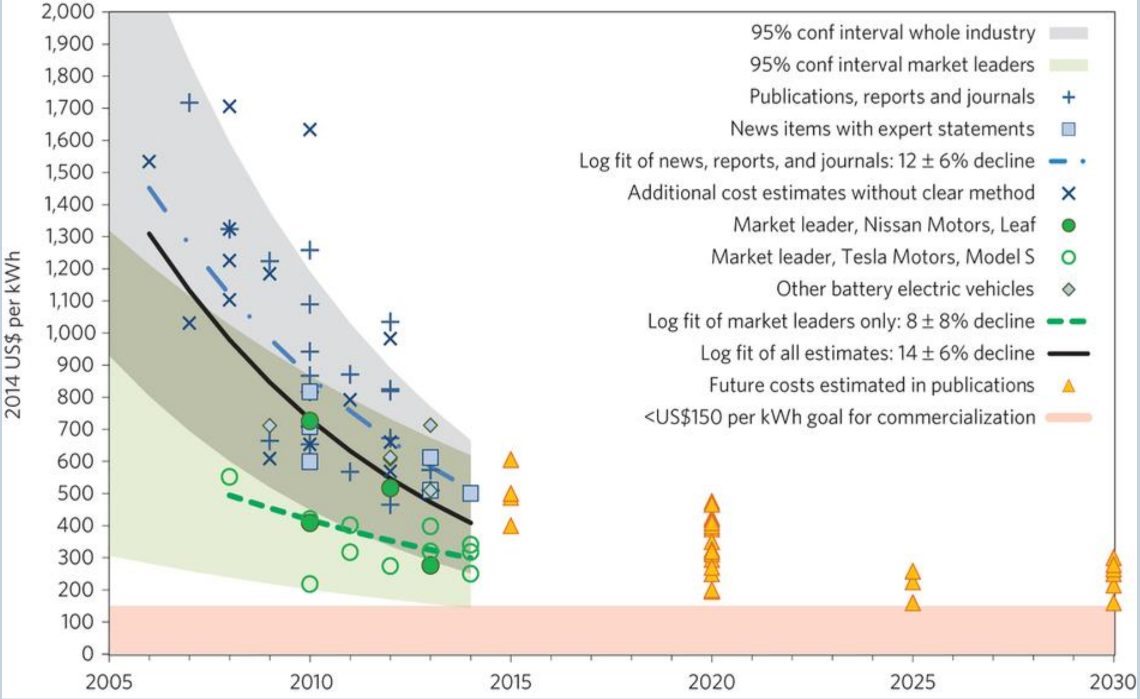
The share of wind & solar varies from 2% to 70% of 60 GW demand. This requires other generation to be flexible

Demand Side Response (DSR)

- It involves re-timing an energy service (e.g. washing) or storing the energy for later use (e.g. hot water)
- The technical potential is large and the economic potential is being increased by smart technology
- It requires:
  - Energy users to respond to price signal; and/or
  - Energy users to agree to allow others (e.g. suppliers) to control some of their energy uses.

Electricity storage

- Historically expensive and mainly pumped hydropower
- Battery costs falling rapidly



Nykvist, B.& Nilsson, M.Nature Climate Change, 2015

Cost reductions to $100/kWh look feasible, which makes batteries a game-changing technology for diurnal storage

2. The challenge of non-electric demand

- 80% of final energy demand is for transport and heating.
- Decarbonisation needs electrification or other zero carbon vectors.
- Electric vehicles add to electricity demand, but also provide a huge increase in storage.
- Heating has less associated storage, and the demand is strongly peaked in winter.

Options for low carbon heating

Options are:

- Reduced demand through passive design and construction, i.e. radically improved efficiency.
- Biomass (naturally stored solar energy), limited by land use trade-offs in many places.
- Massive increases in electricity capacity.
- Inter-seasonal storage of renewable energy, e.g. thermal or chemical, e.g. hydrogen.

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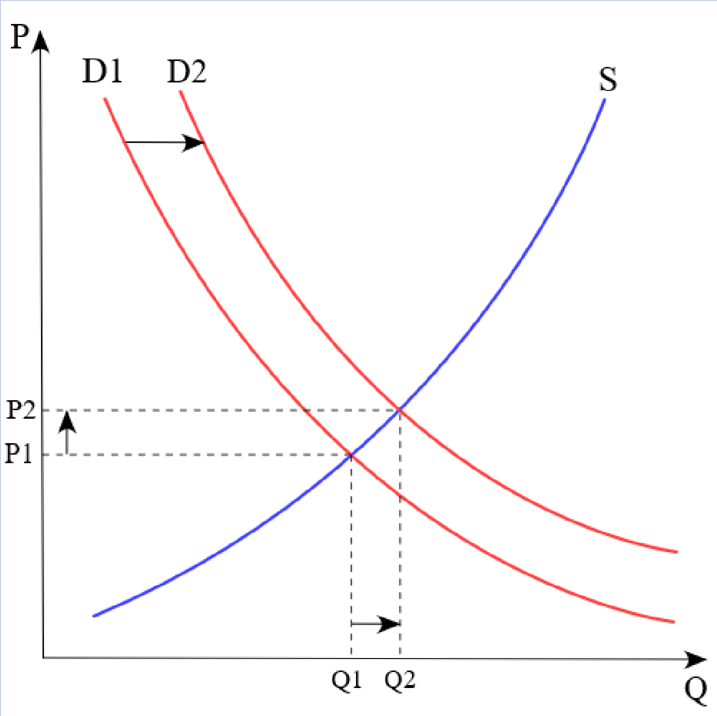
Carbon markets

- A key component of global policy in the Kyoto Protocol (driven by US concerns to limit costs)
- Most used in the EU Emissions Trading Scheme
- But some benefits to developing countries through the Clean Development Mechanism (CDM)



Often considered the 'centrepiece' of climate policy, but

- of limited effectiveness at carbon prices so far experienced
- not essential to the 'bottom-up', 'promise and review' approach of the Paris Agreement

Multiple market failures requires multiple policy instruments

Market failure	Intervention required
Free use of the atmosphere	Pricing carbon
Unpriced benefits of technological innovation	Support for innovation through R&D and ‘learning by doing’
Social and political barriers to the use of technologies	Regulation, incentives and engagement

Based on Stern, 2006; Grubb, 2014

The key to climate mitigation is effective policy at multiple scales

- International climate agreements provide a context for change, but are only a part of effective climate policy.
- Policy needs to support innovation in, and adoption of, low carbon technologies.
- So action is also needed within the framework of national energy policies.
- Many actions are at a ‘human scale’, and difficult to influence remotely, so local actors will also be key.

- Effective “climate policy” is not just international.

Final Conclusions

- Energy efficiency (EE) and renewable energy sources (RES) will be the major solutions for a sustainable energy system.
- Energy demand can be reduced and some of this is the lowest cost carbon abatement.
- The costs of renewables are falling dramatically.
- Strategies that focus on RE and EE constitute a paradigm shift in energy markets and policy.
- Active public policy is needed to support investment, innovation and engagement.

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