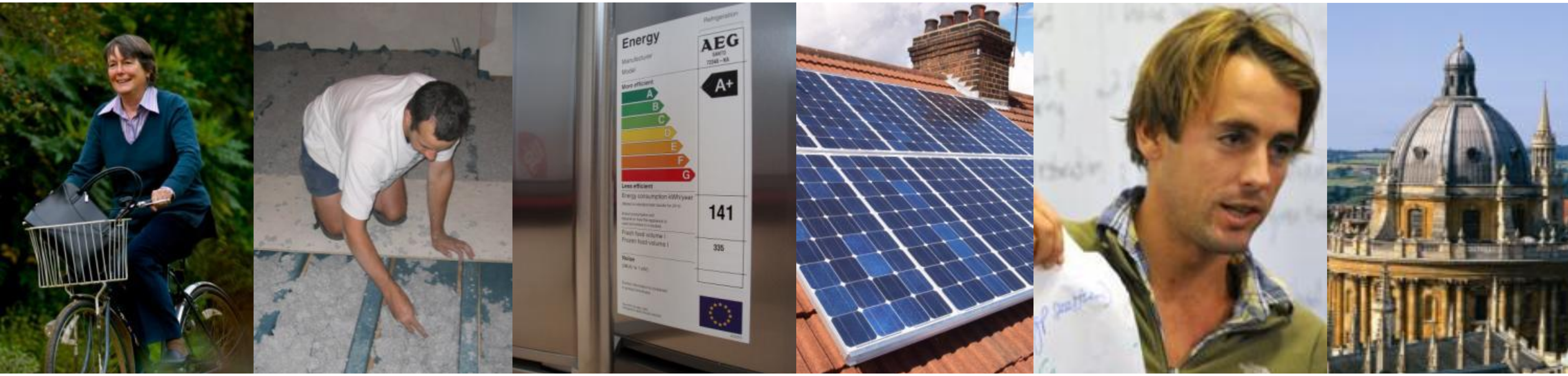
Environmental *Change* Institute

Welcome to the Anthropocene

Energy and carbon in the anthropocene

Nick Eyre



October 13, 2020

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 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

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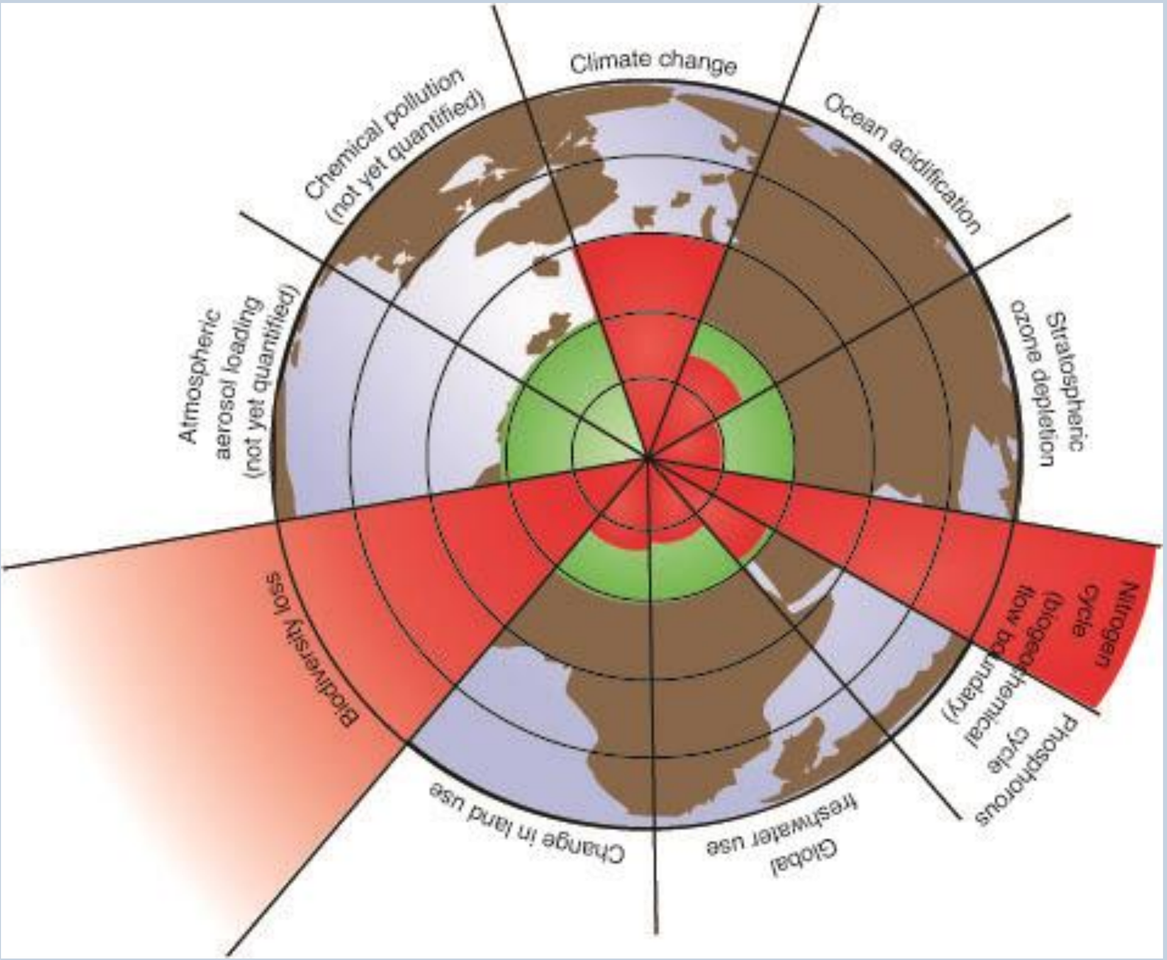
Energy and planetary boundaries



Rockström et al, 2009

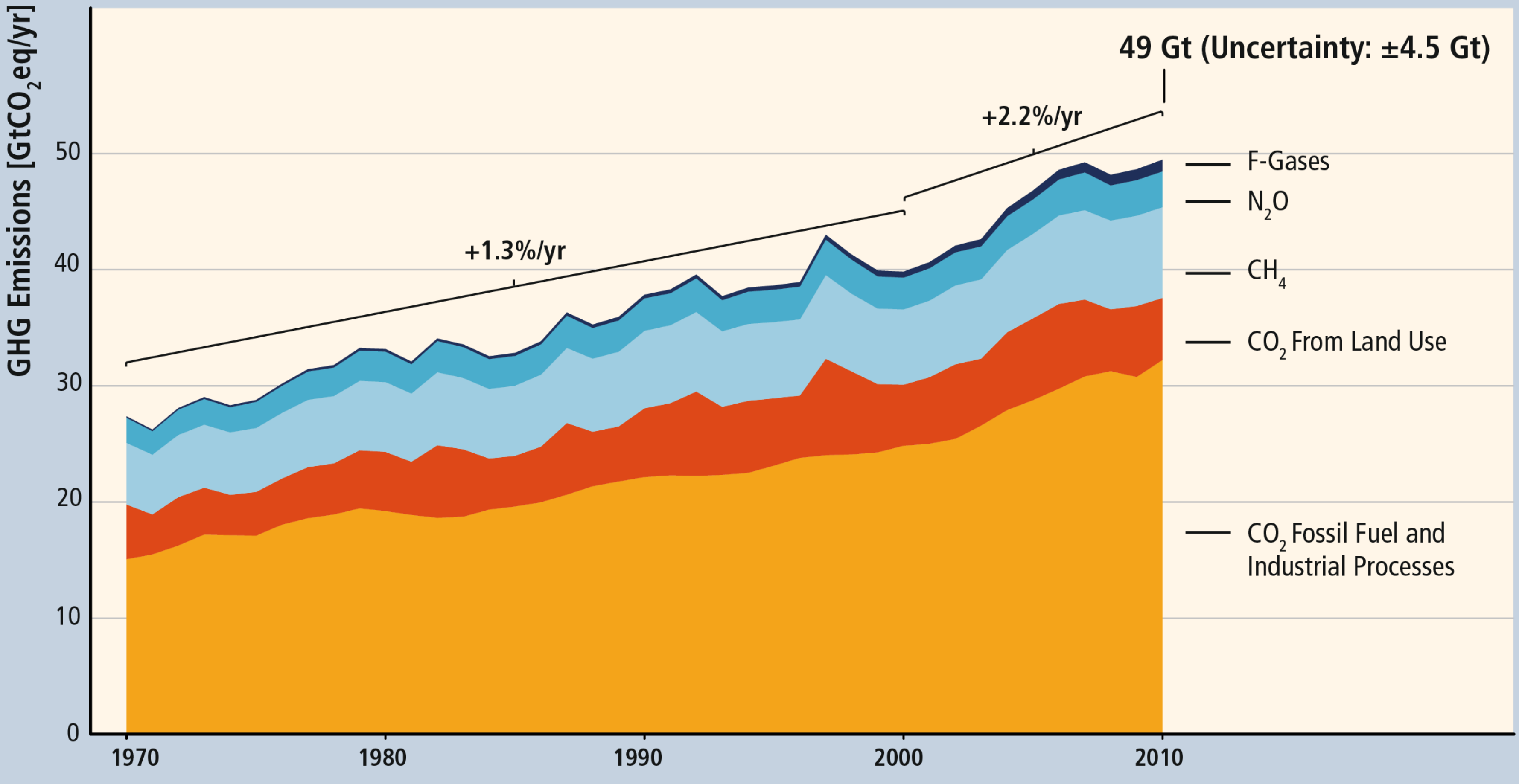
Energy is critical to:

- Climate change
- Ocean acidification

and a major part of:

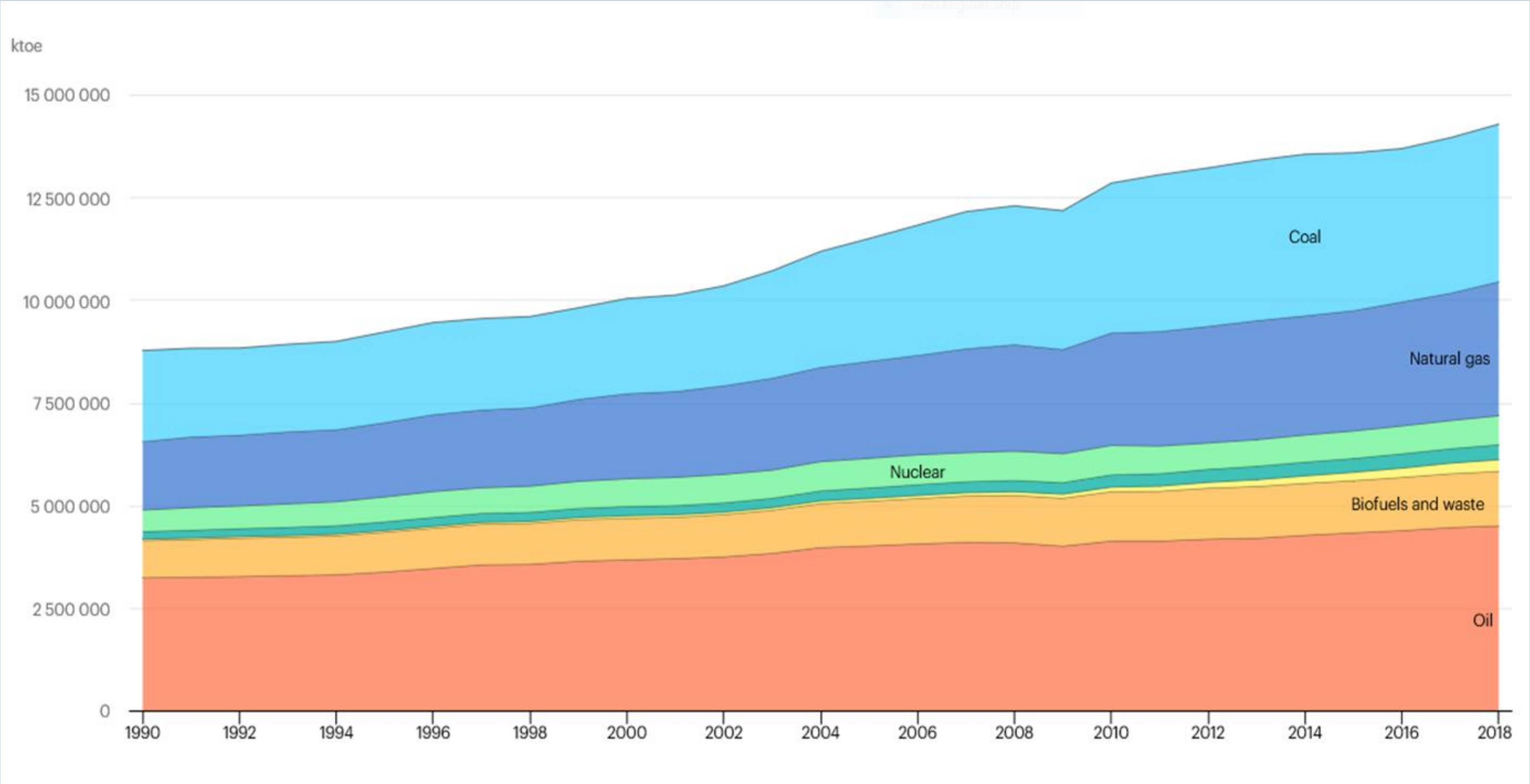
- Nitrogen pollution
- Atmospheric aerosols

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



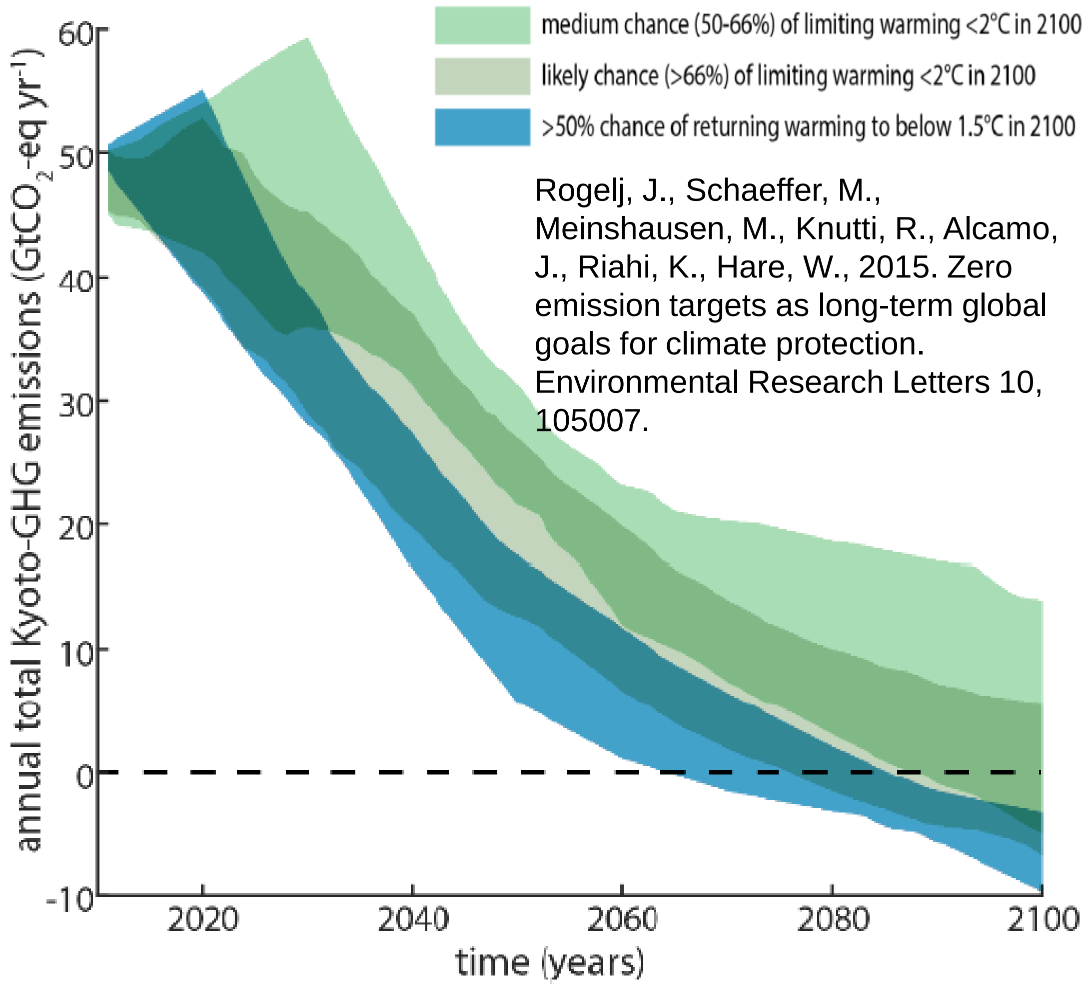
IPCC WGIII, 2014

Global energy systems are currently highly dependent on fossil fuels



IEA World Energy Statistics, 2020

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

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 important everywhere, and therefore can constrain low carbon goals.

This is critical to understanding politically achievable climate policy.

Access: Sustainable Development Goal 7

7 AFFORDABLE AND CLEAN ENERGY

- 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

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

Summary of the Global Challenges for Energy

- Radical reductions in fossil fuel emissio... required to stabilise the climate, h...
  - Energy use is rising, and ... il fuels
  - Fossil fuels dom... ystems that underpin modern li...
  - A... to energy is the priority for ... ent.

A low carbon future requires systemic change in the energy sector – a sustainable industrial revolution.

Just stopping producing fossil fuels is not a viable solution. We need a different energy system.

Questions?

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Energy systems – as a narrative of human history

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Modern	Consumer goods Mobility	Oil Gas	Engines Electric turbine Electric motor
Future	Information Services	Efficiency Renewables	Electrical heat and transportation Hydrogen

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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

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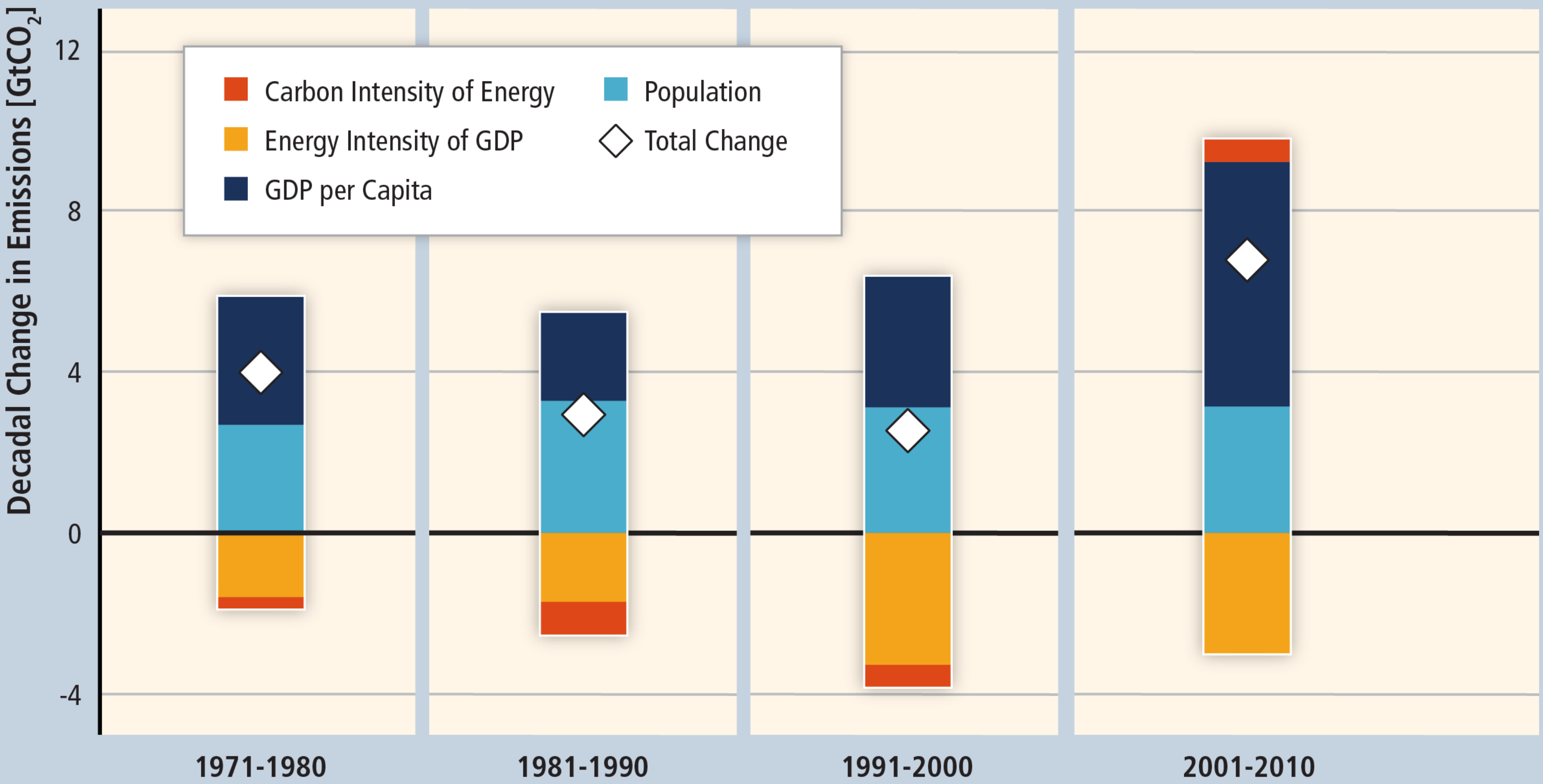
Population and income are driving emissions up: energy efficiency is the dominant mitigating force



IPCC WGIII, 2014

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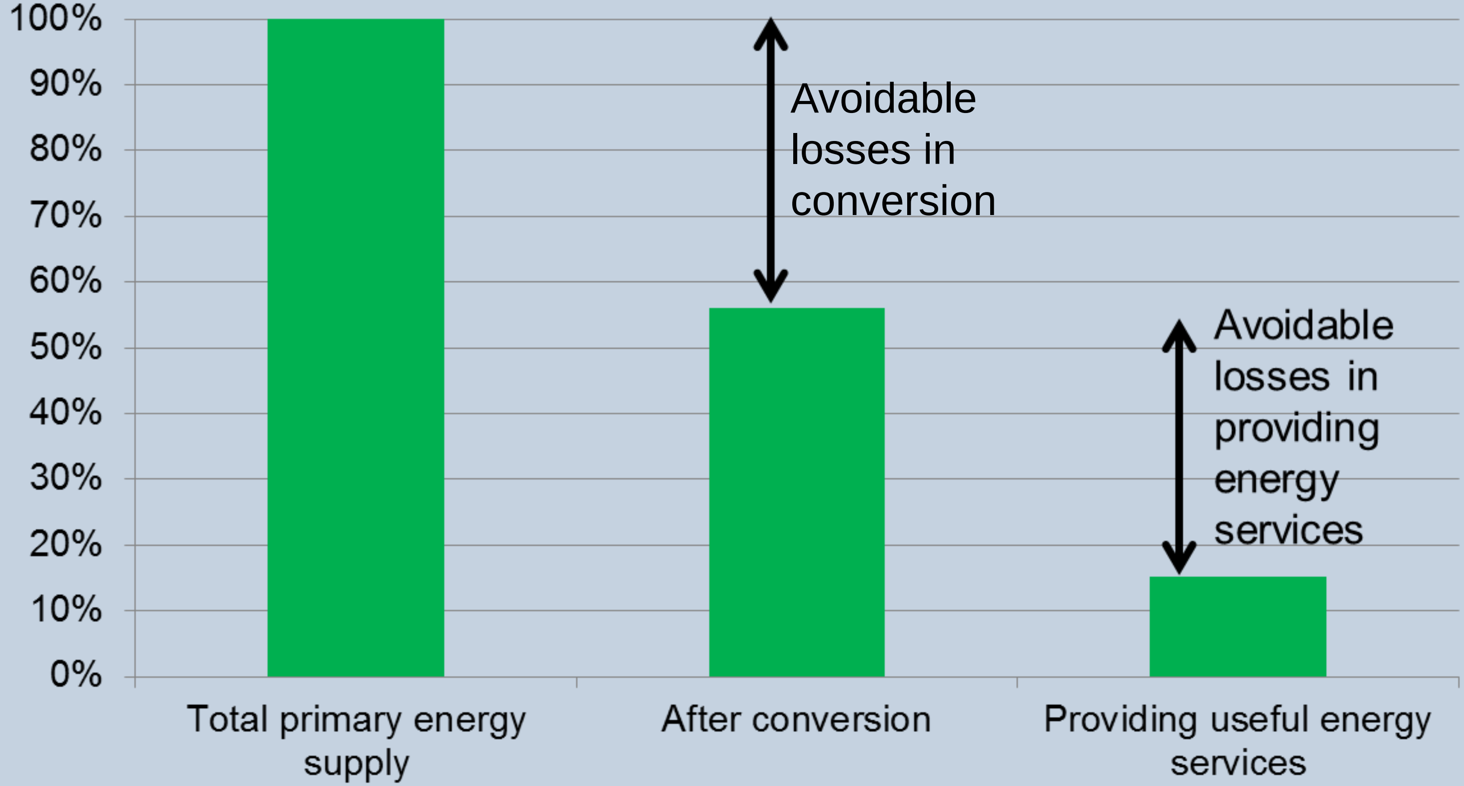
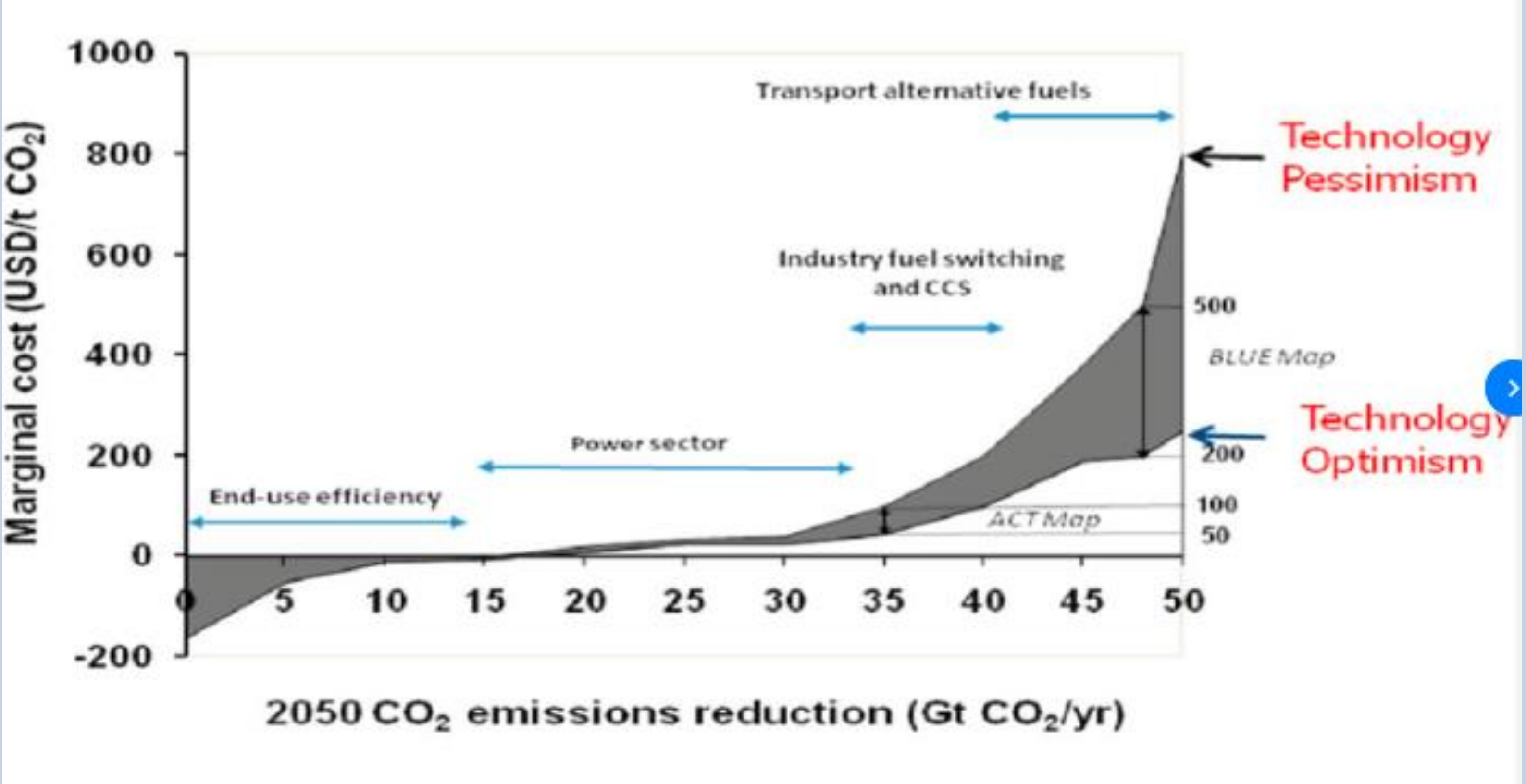
How much more could we improve energy efficiency?



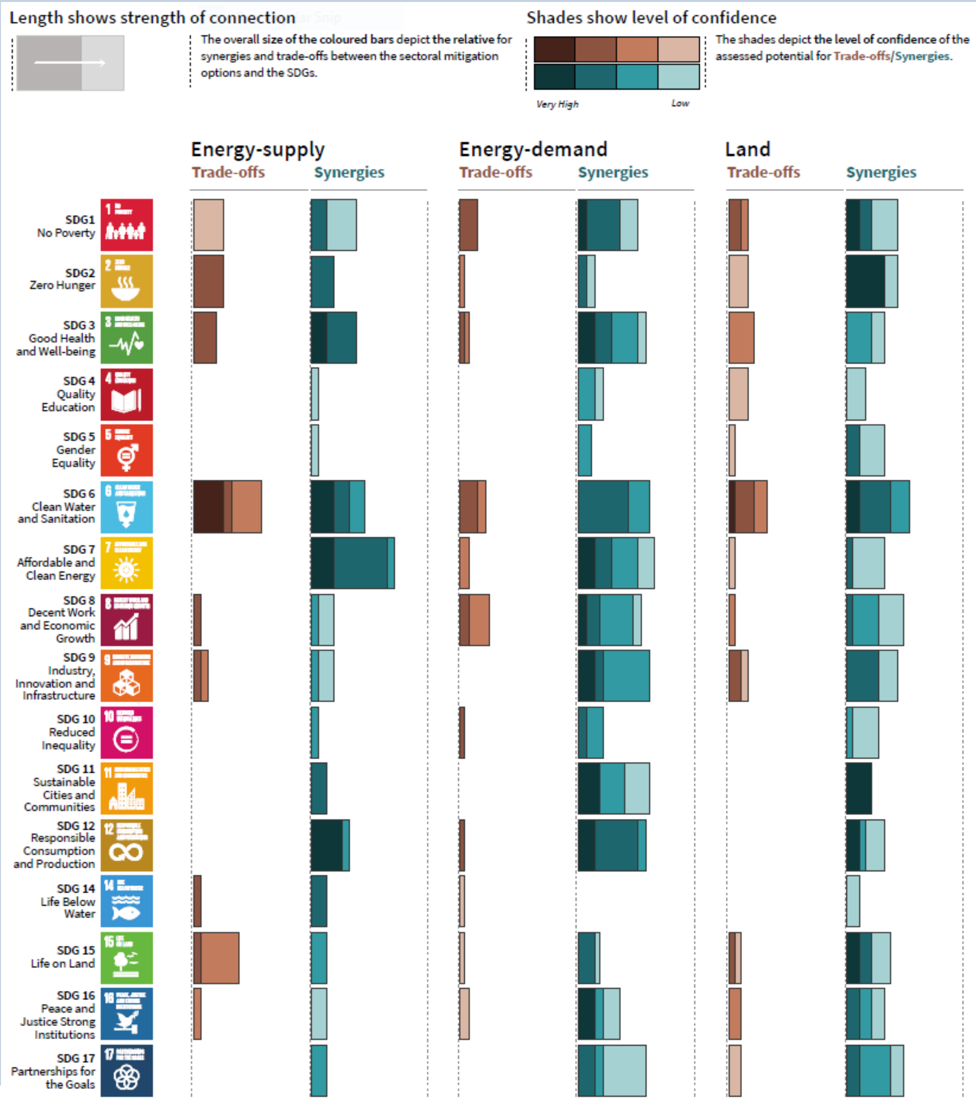
Based on Cullen and Allwood, 2011

…and efficiency is generally the cheapest carbon abatement



IEA, 2008

Energy demand and sustainable development



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

IPCC, 2018

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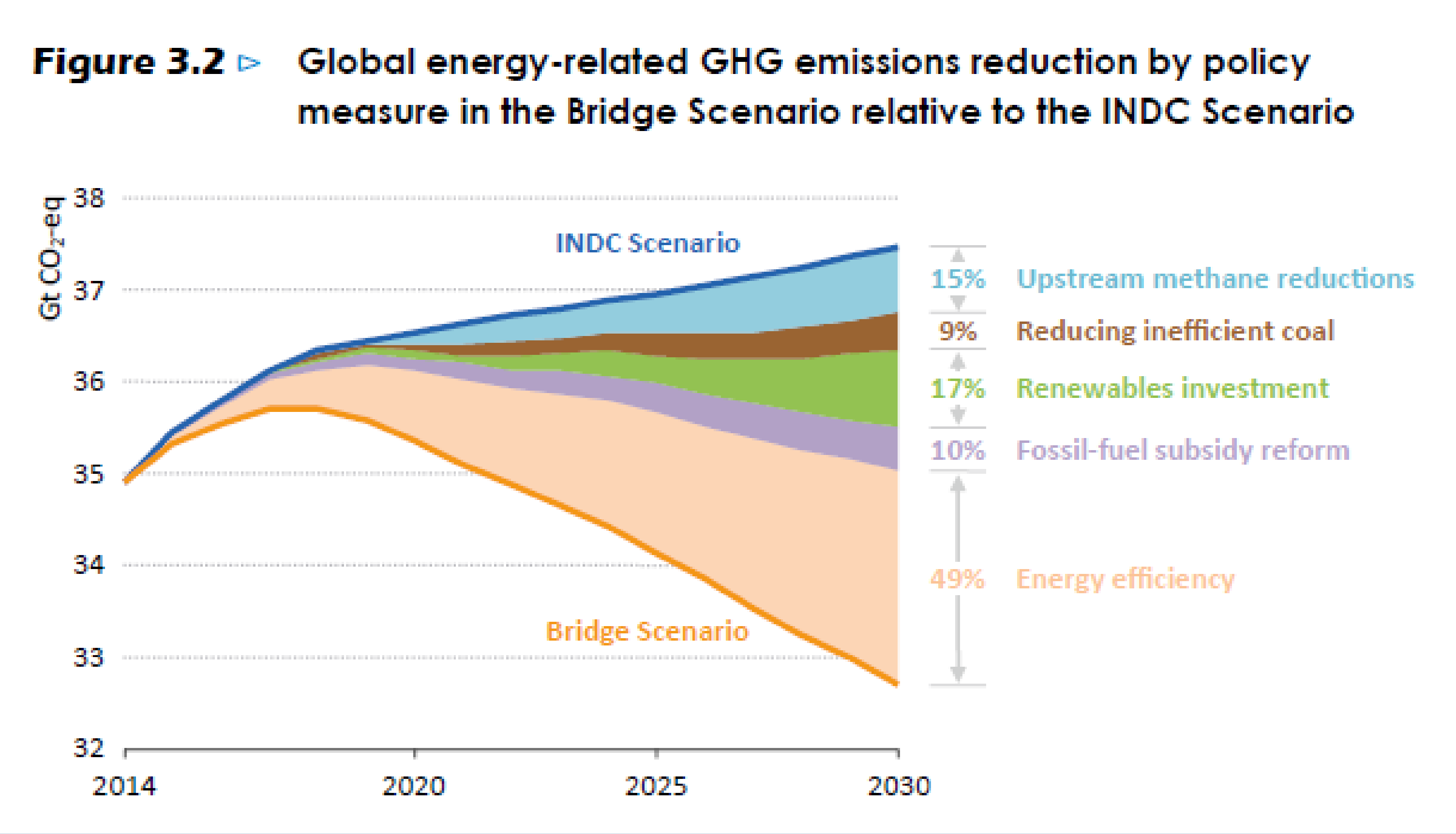
…improved efficiency is likely to be the largest single contributor to stabilising the climate



IEA, 2015

Summary of conclusions for energy efficiency

- Energy efficiency will have to make a major contribution to decarbonisation
- Doing this has significant ‘co-benefits’.
- It is often more cost effective than increased low carbon supply.
- The constraints are often social, organisational and institutional

CREDS
CENTRE FOR RESEARCH INTO ENERGY DEMAND SOLUTIONS

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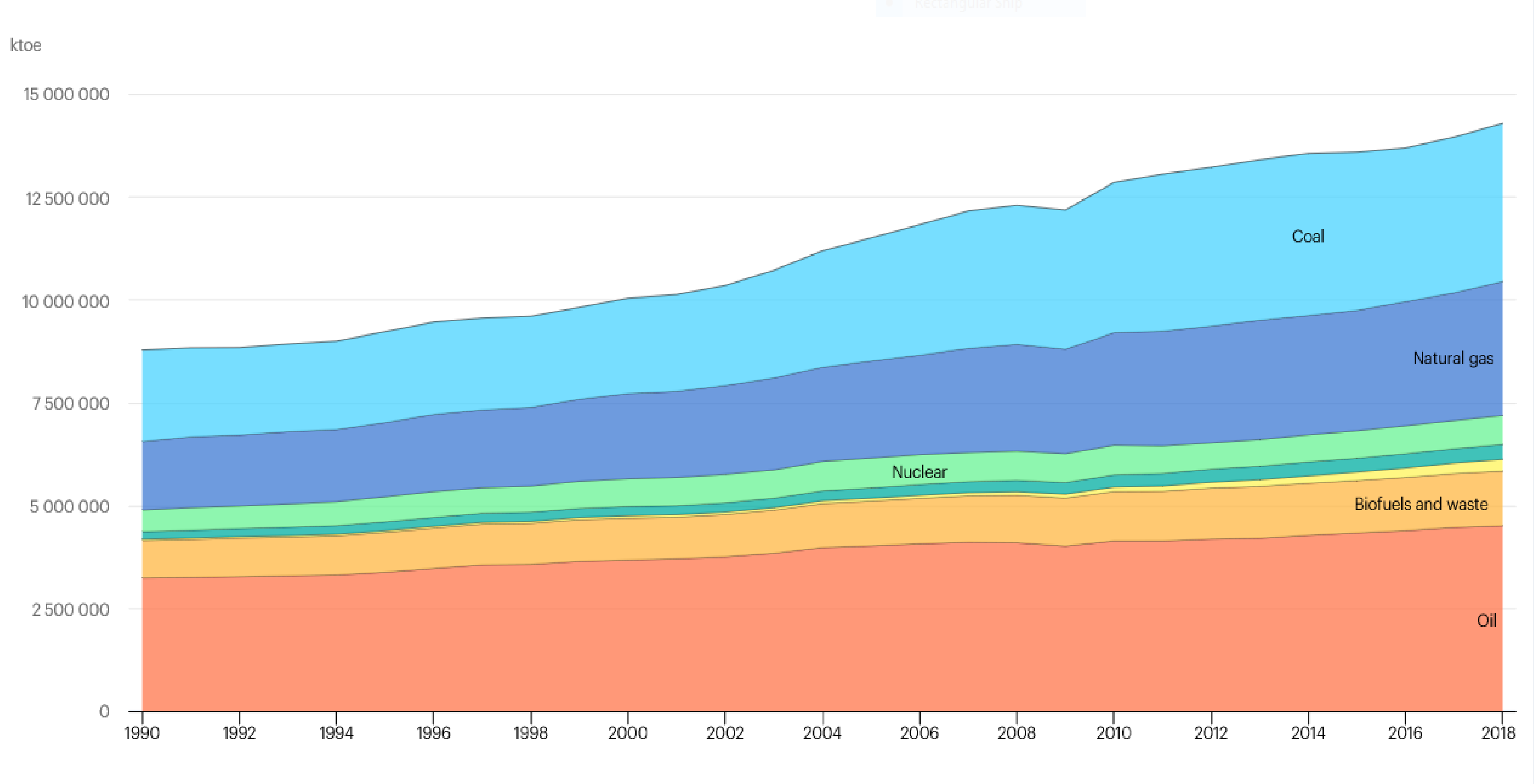
Low carbon energy supply options
What are they?

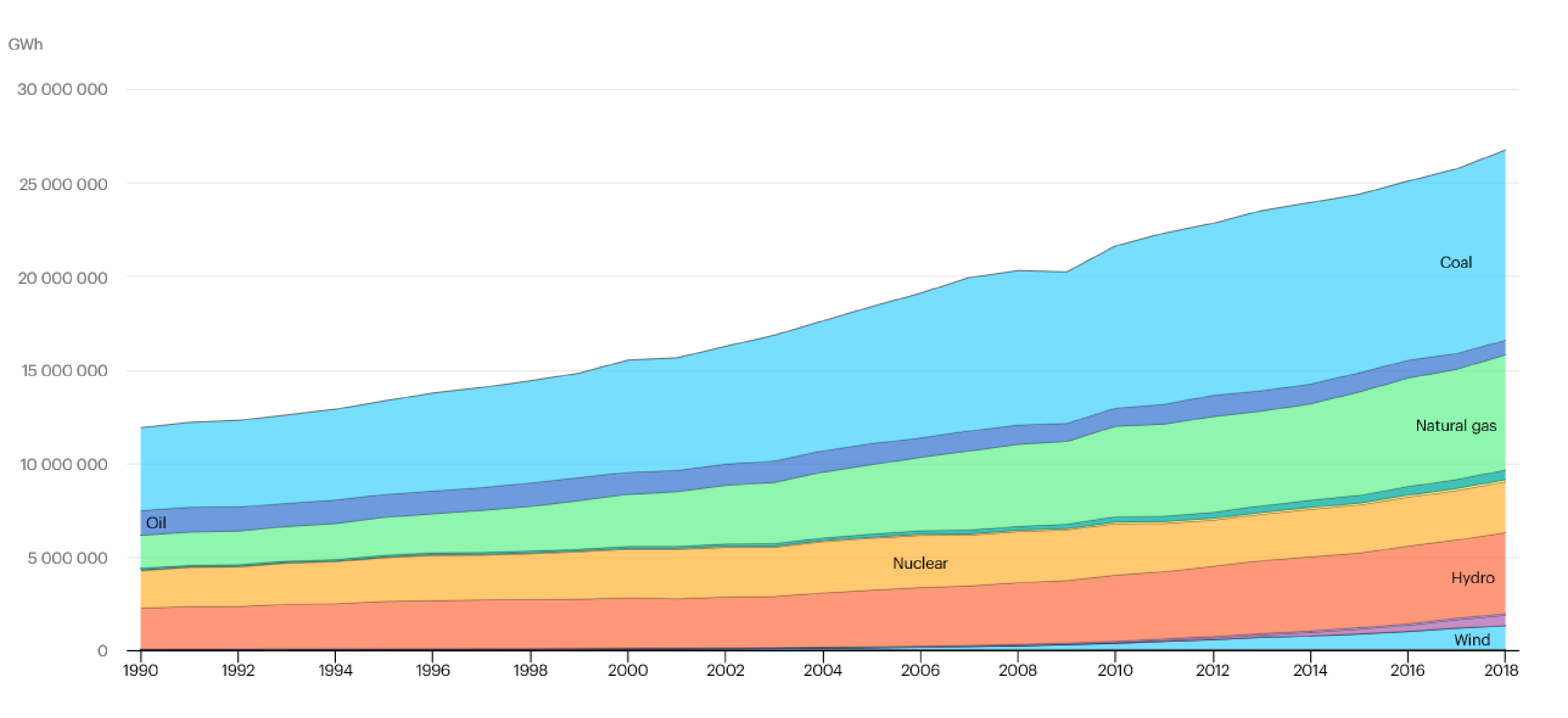
- Renewable energy sources (RES)
- Fossil fuels with "carbon capture and storage" (CCS)
- Nuclear power

Trends in Global Energy Supply



IEA World Energy Statistics, 2018

Trends in global electricity generation



IEA World Energy Statistics, 2018

The key renewables

- **Wind** – very large untapped potential at low cost.
- **Solar** – historically expensive, but recent dramatic cost reductions.
- **Hydro** – historically the most important, but limited new potential
- **Biomass** – potentially important and can be stored, but raises questions about impacts on terrestrial biosphere and the ‘food v fuel’ debate.

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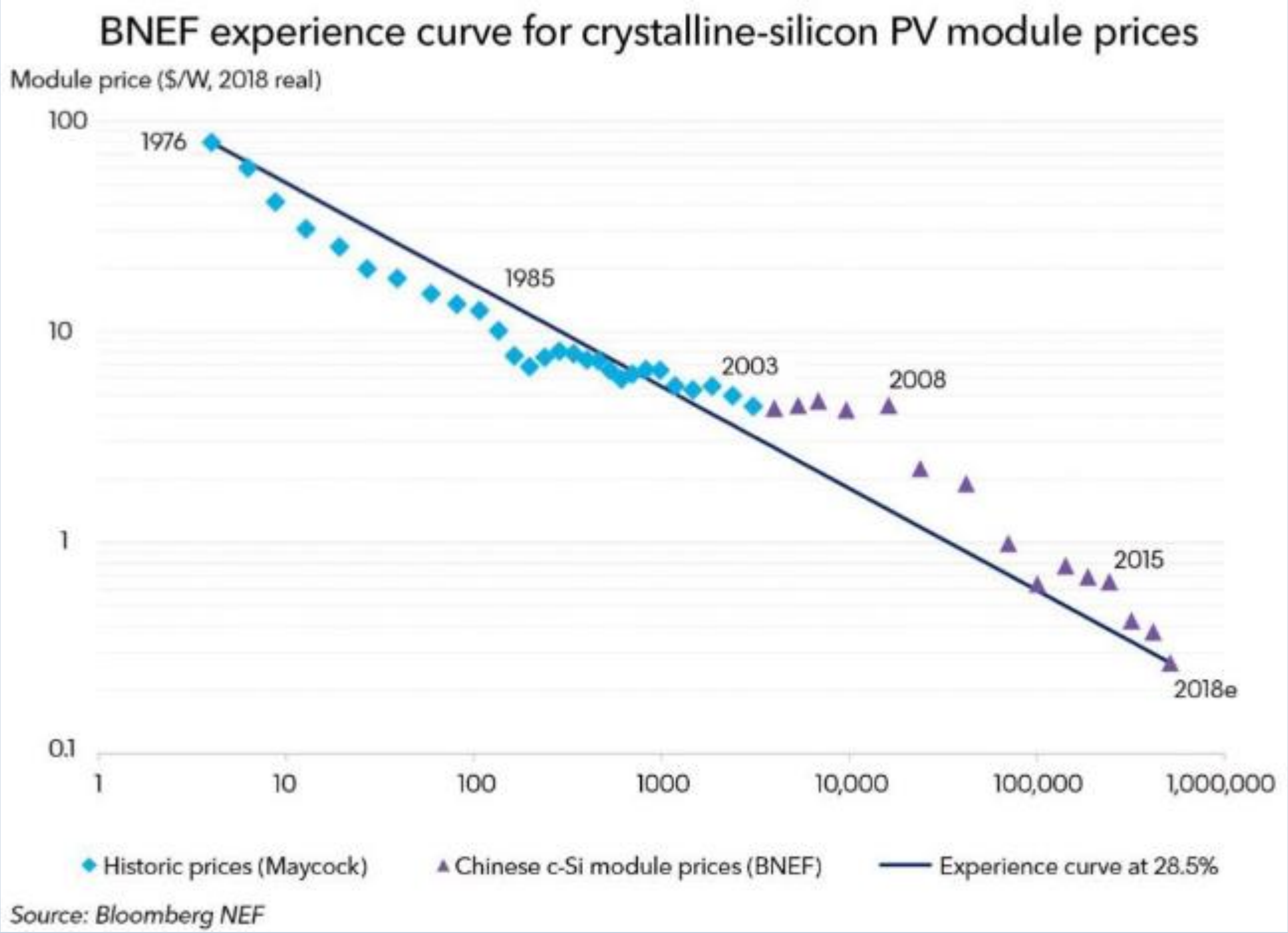
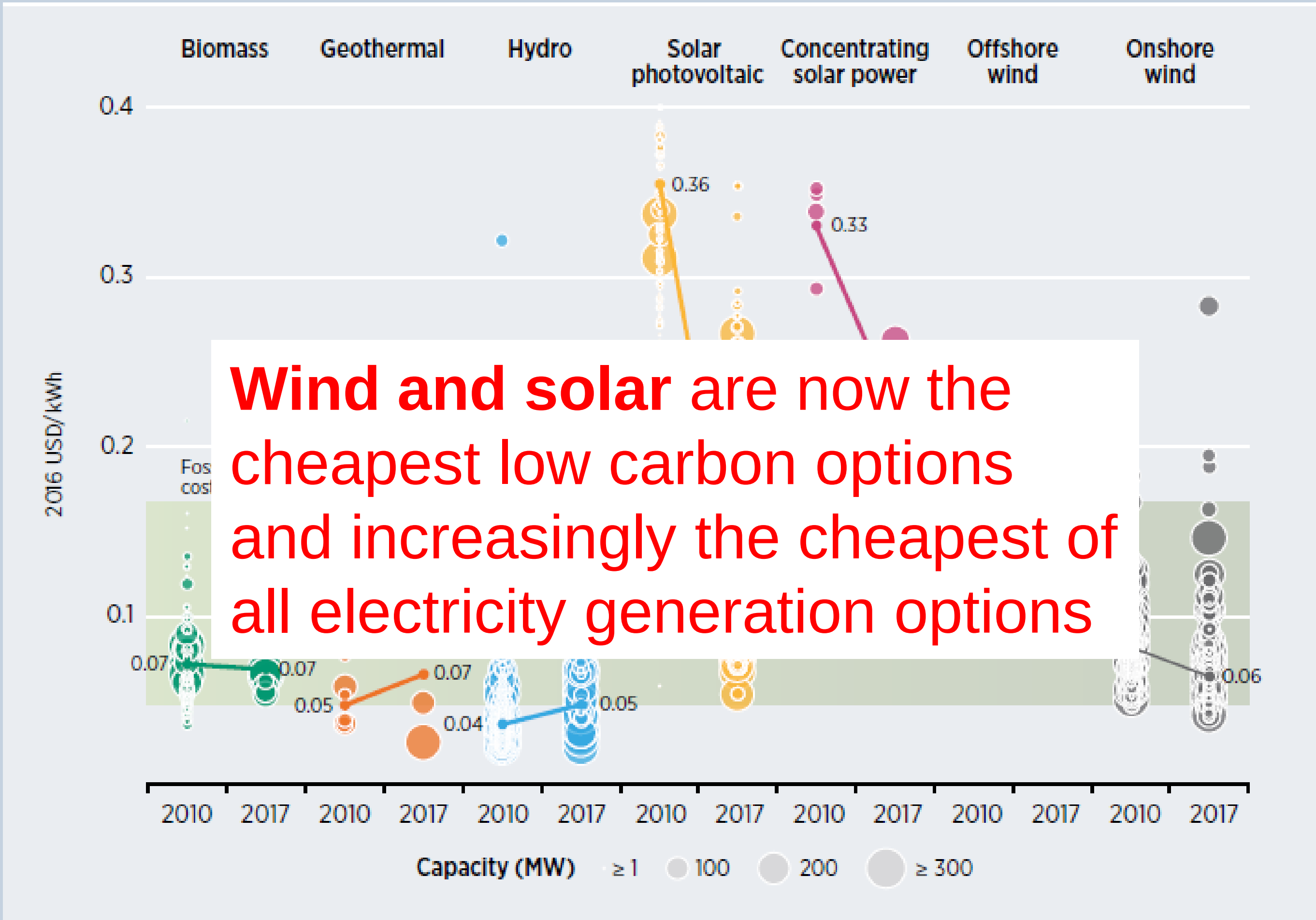
Long term costs of solar have fallen dramatically



Renewable electricity costs 2010-2017

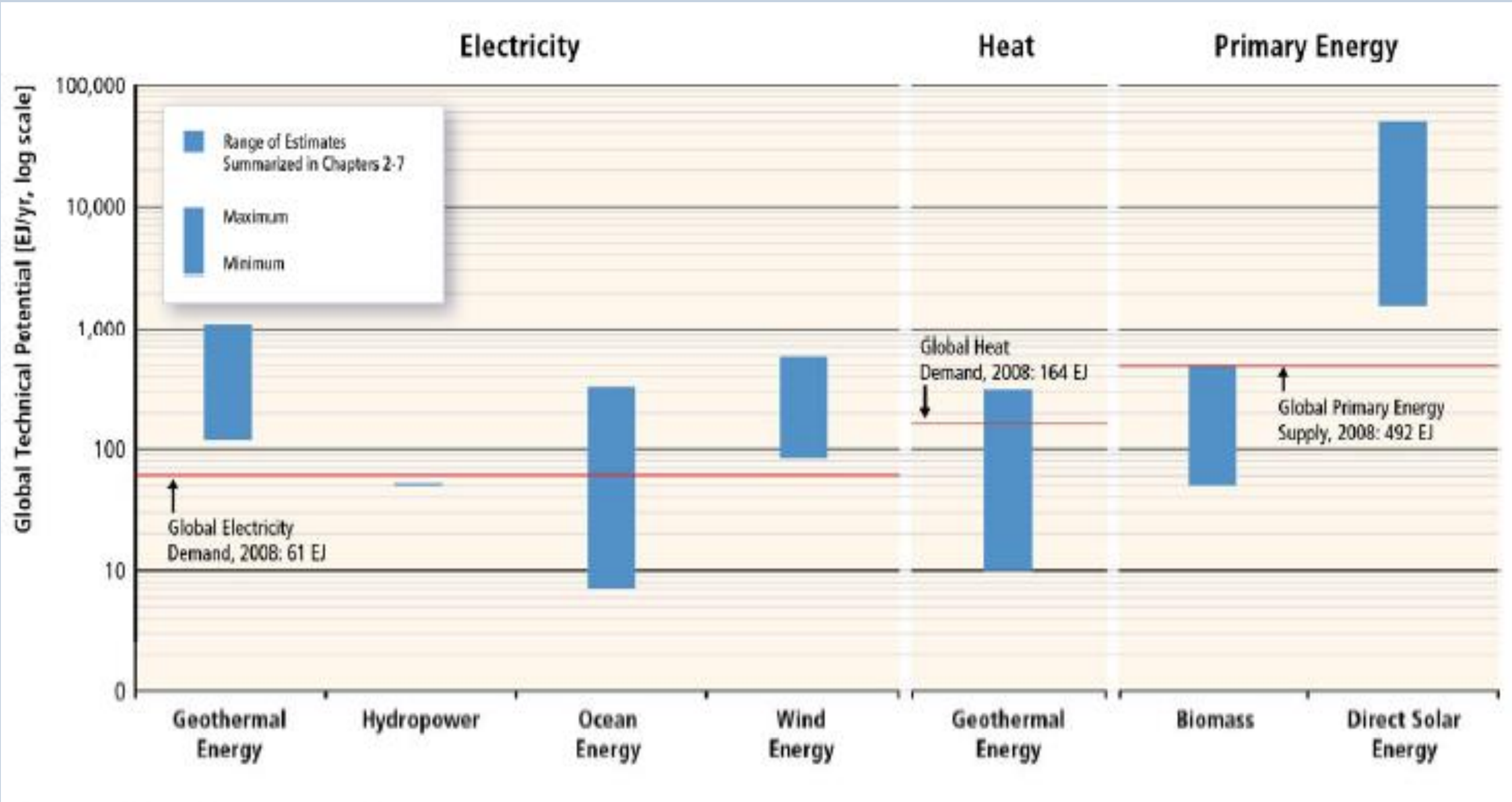


Source: IRENA Renewable Cost Database.

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

Source IRENA, 2017

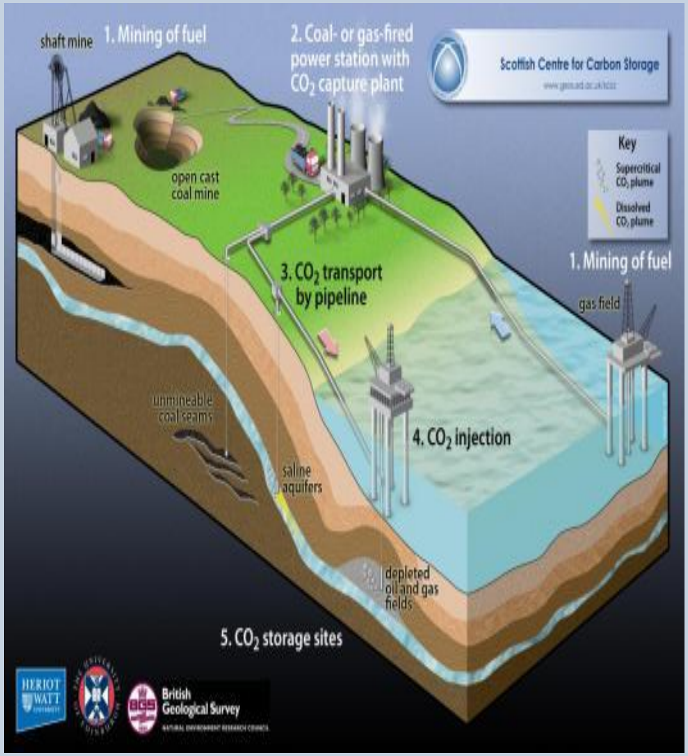
Renewable energy: estimated global technical potential



Source: IPCC, 2011

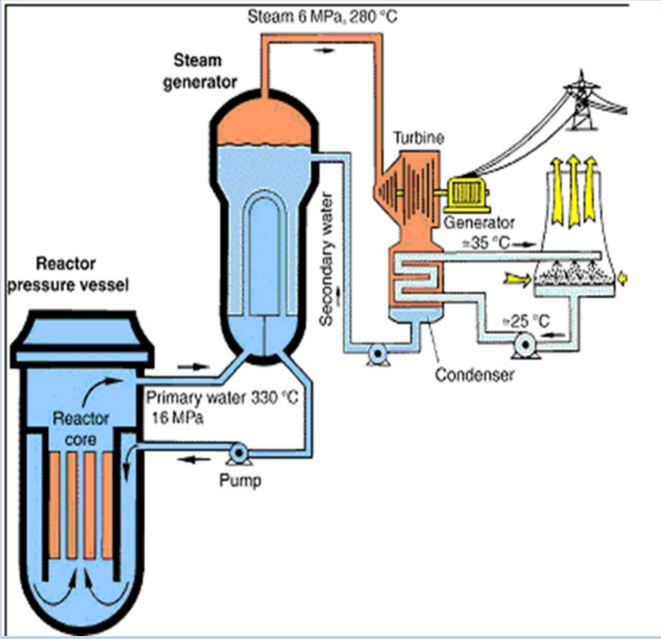
Carbon Capture and Storage (CCS)

- Despite research since 1990, significant deployment is unlikely before 2030.
- As an electricity generation option, as it cannot compete with renewables
- May be useful for decarbonising industrial processes, e.g. cement.
- Potential negative emissions via biomass with CCS (BECCS), but large scale feasibility unlikely.



Nuclear

- Longstanding concerns about waste disposal and nuclear proliferation
- The Fukushima disaster (2011) revived concerns about large accidents
- Costs are rising, due to increased safety precautions
- Costs and risks are too high for unsubsidised private investment
- No longer credible that nuclear will ever compete economically with renewables.
- Interest now largely in countries with nuclear weapons and submarine programmes or aspirations (Stirling and Johnstone, 2017)



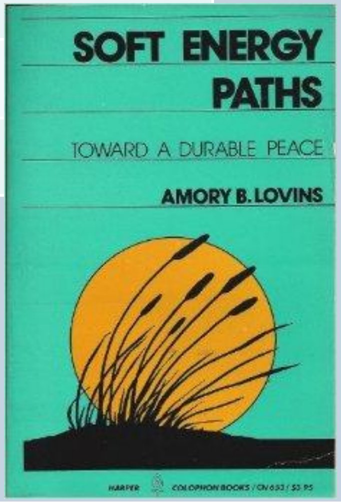
Summary of conclusions for low carbon energy

- The current contribution of renewables is small, but growing rapidly
- Solar and wind, now compete with conventional sources in electricity generation.
- CCS and nuclear are unlikely to be important, at least in electricity generation, largely for economic reasons.
- The low carbon economy will be fuelled by very largely by flows of energy from the natural environment.

Competing paradigms for energy futures

	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 recent years, the soft pathway has become the more economic. Despite lobbying by vested interests, it is now the dominant narrative of the transition.

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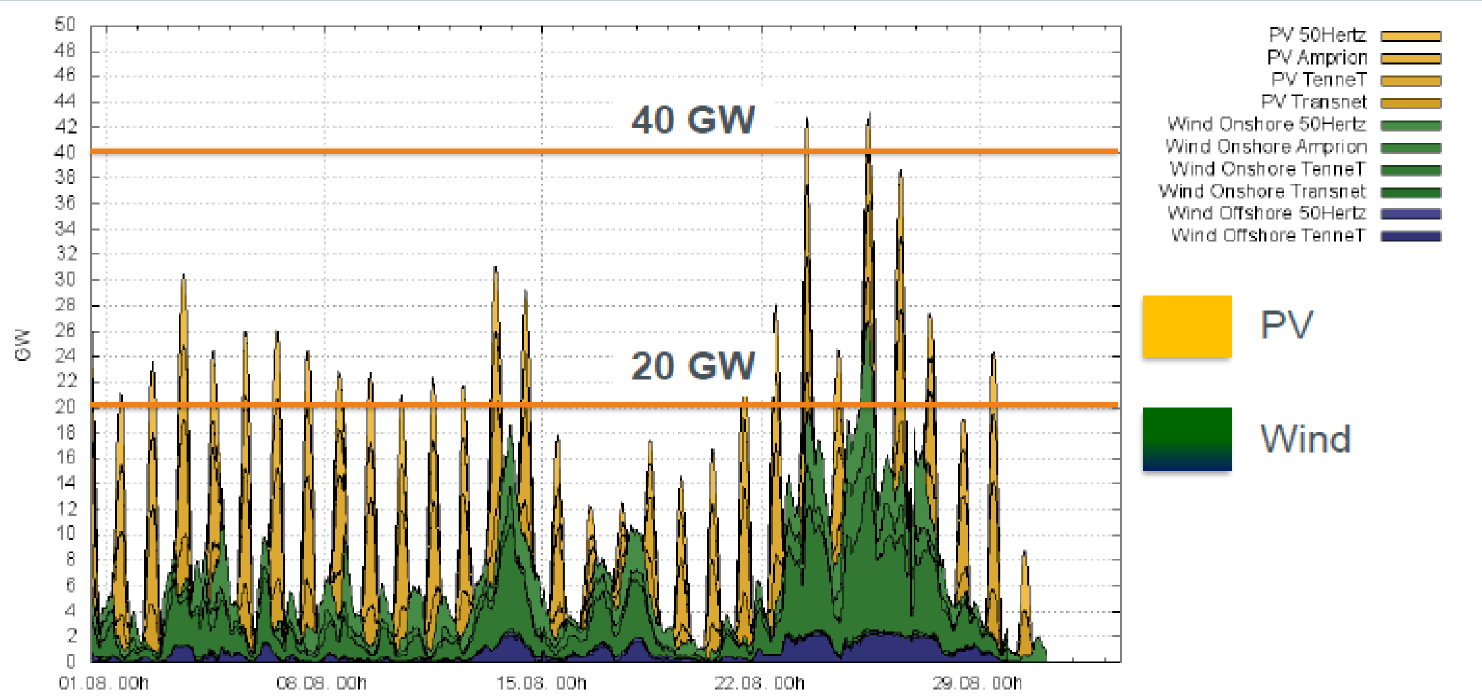
1. The challenge of variability

- 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

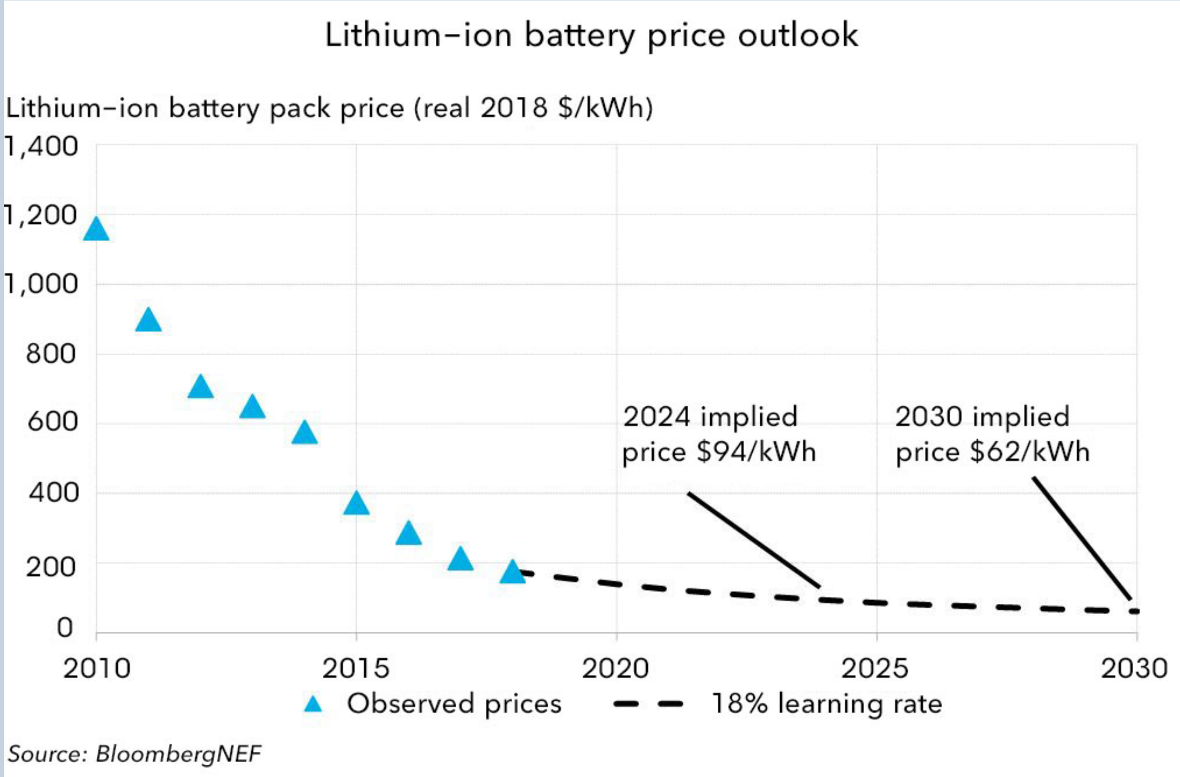
The share of wind & solar varies from 2% to 70% of 60 GW demand. This requires other generation to be flexible

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



But longer term storage (e.g. inter-seasonal) remains a technical challenge

2. The challenge of non-electric demand

- 80% of final energy demand is for transport and heating, and not typically supplied by electricity.
- They need supply by electricity 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.

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Options for low carbon heating

Options are:

- Reduced demand through radically improved efficiency.
- Biomass options, but limited by land use trade-offs in many places.
- Massive increases in electricity use, through heat pumps.
- Other zero carbon vectors, e.g. hydrogen and ammonia.

The balance between different approaches is an unresolved problem

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Rapid transition will require multiple policy instruments

Barrier / 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 distributed technologies	Regulation, incentives and social engagement

Based on Stern, 2006; Grubb, 2014

…and at multiple scales

- International climate agreements provide a context for change, but are only a part of effective 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.

Final Conclusions

- We need a zero carbon energy system
- Energy efficiency (EE) and renewable energy sources (RES) will be the major solutions.
- 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 RES and EE constitute a paradigm shift in energy markets and policy.
- Active public policy at multiple scales is needed to support investment, innovation and engagement.

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Energy systems – as a narrative of human history

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Modern	Consumer goods Mobility	Oil Gas	Engines Electric turbine Electric motor
Future	Information Services	Efficiency Renewables	Electrical heat and transportation Hydrogen

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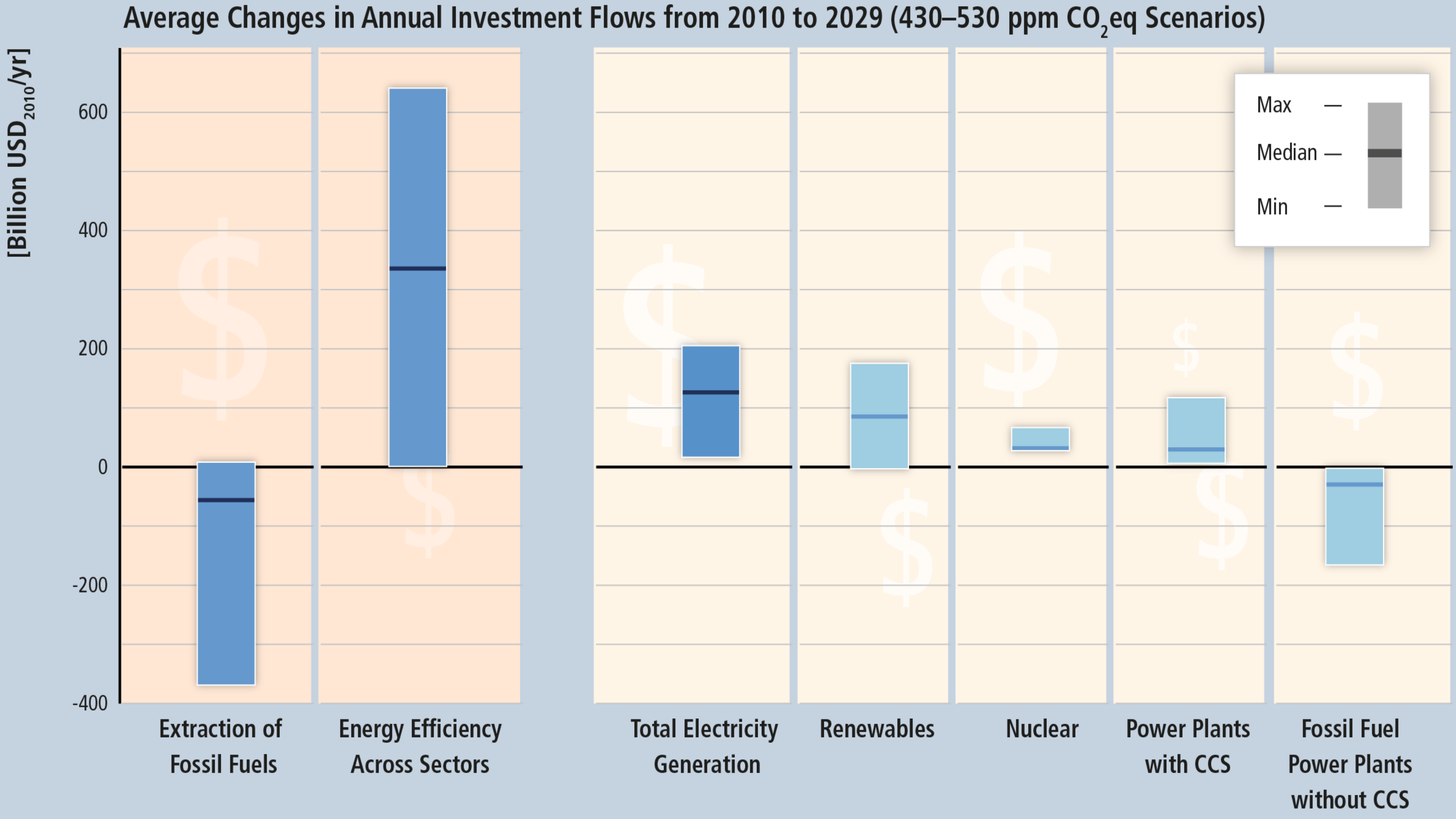
Questions and comments?

Some other useful information

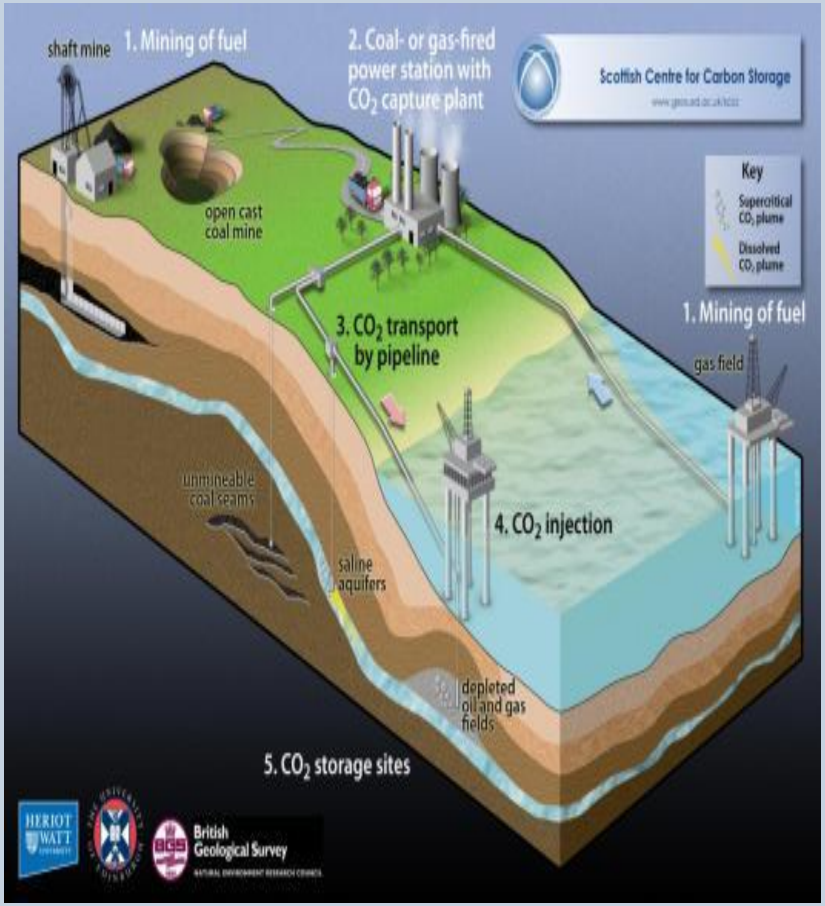
Energy efficiency requires most mitigation investment



IPCC WGIII, 2014

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 uncertain, but currently high
- 100% CO_2 capture is difficult
- There are risks associated with CO_2 transport and disposal in large volumes
- Social acceptability is already a problem in some places

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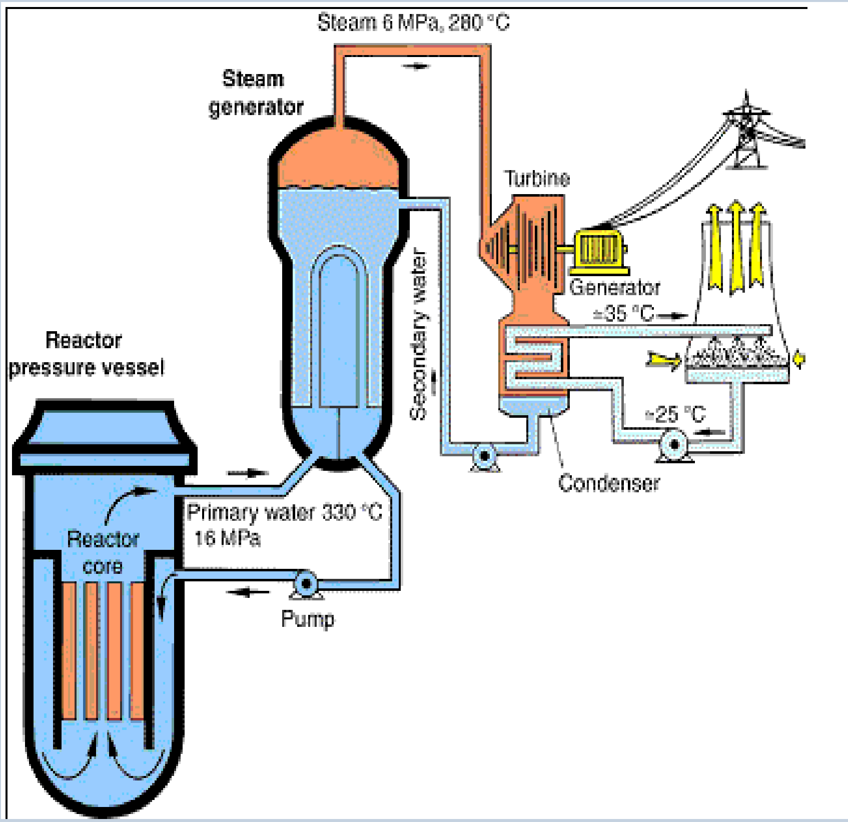
Nuclear – the technology

- Large resource base of uranium and thorium
- Proven technology – 50 years operational experience
- Large and replicable – ~1000 MW typical scale
- Smaller modular technologies require R&D



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