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Innovation in the energy sector:
Paradigm-busting or paradigm-reinforcing?

Edinburgh Centre for Carbon Innovation

25 November 2014

Jim Skea

Research Councils UK Energy Strategy Fellow

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Outline

- Introduction
- Context
- Research objectives
- Case studies
- Methods
- Theory
- Emerging issues

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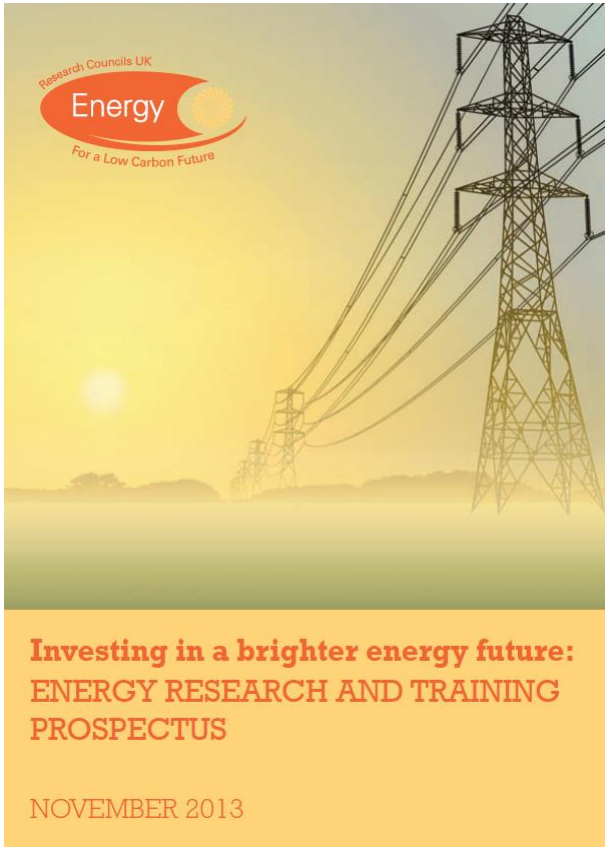
RCUK Energy Strategy Fellowship

Synthesis of a prospectus for research, skills and training needs across the UK energy landscape

The prospectus is informing the development of the Research Councils Energy Programme. It was published in November 2013 and will be maintained and updated until the end of the Fellowship in 2017.

The development of the prospectus responds to a recommendation from the International Review of Energy Research undertaken by the Research Councils in 2010.



+ Research programme: the effectiveness of systems of energy innovation

The research programme will compare the effectiveness of energy innovation systems in a number of leading countries

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The team

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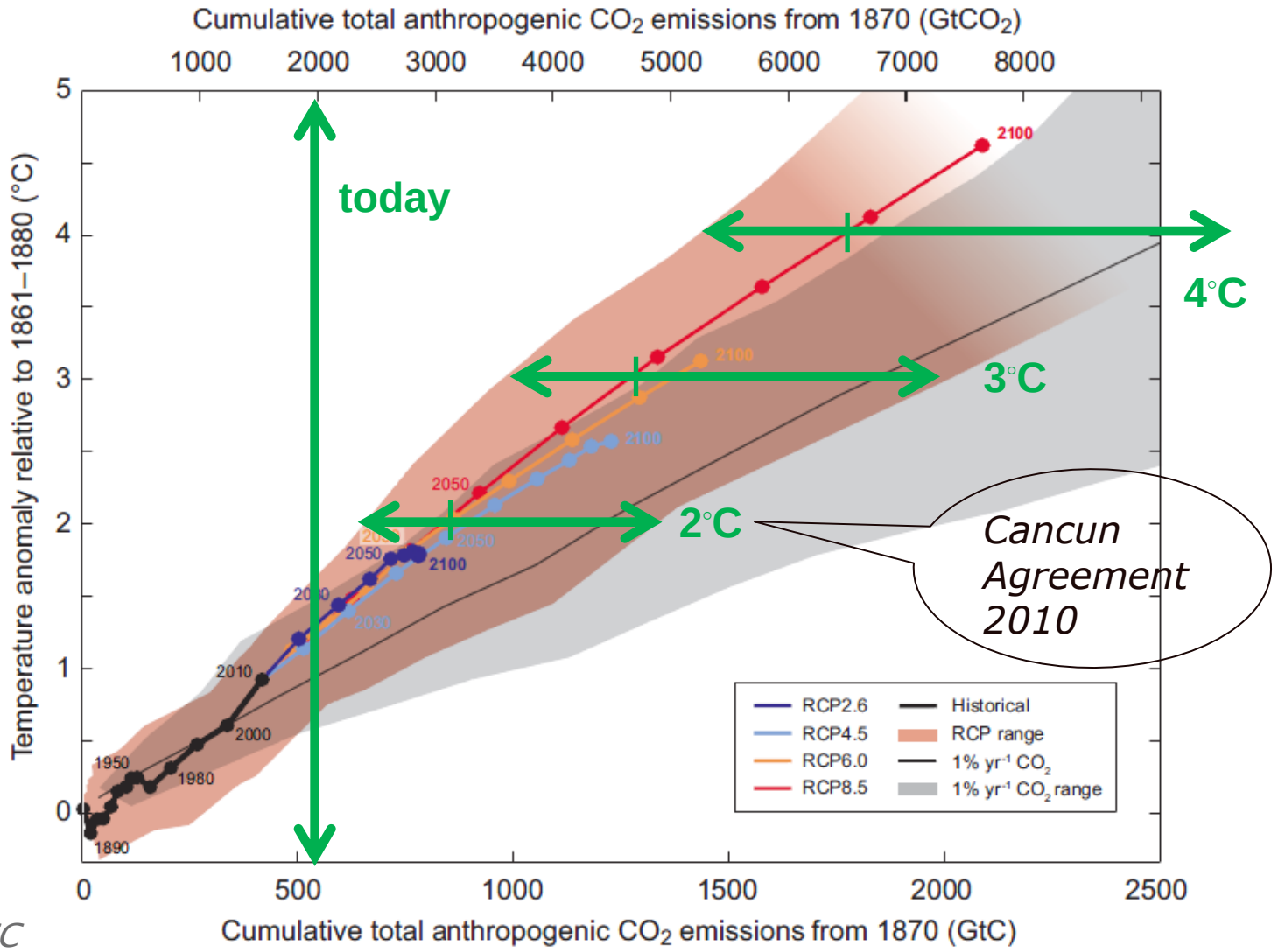
Cumulative CO_2 emissions are correlated with global temperatures



Source: IPCC

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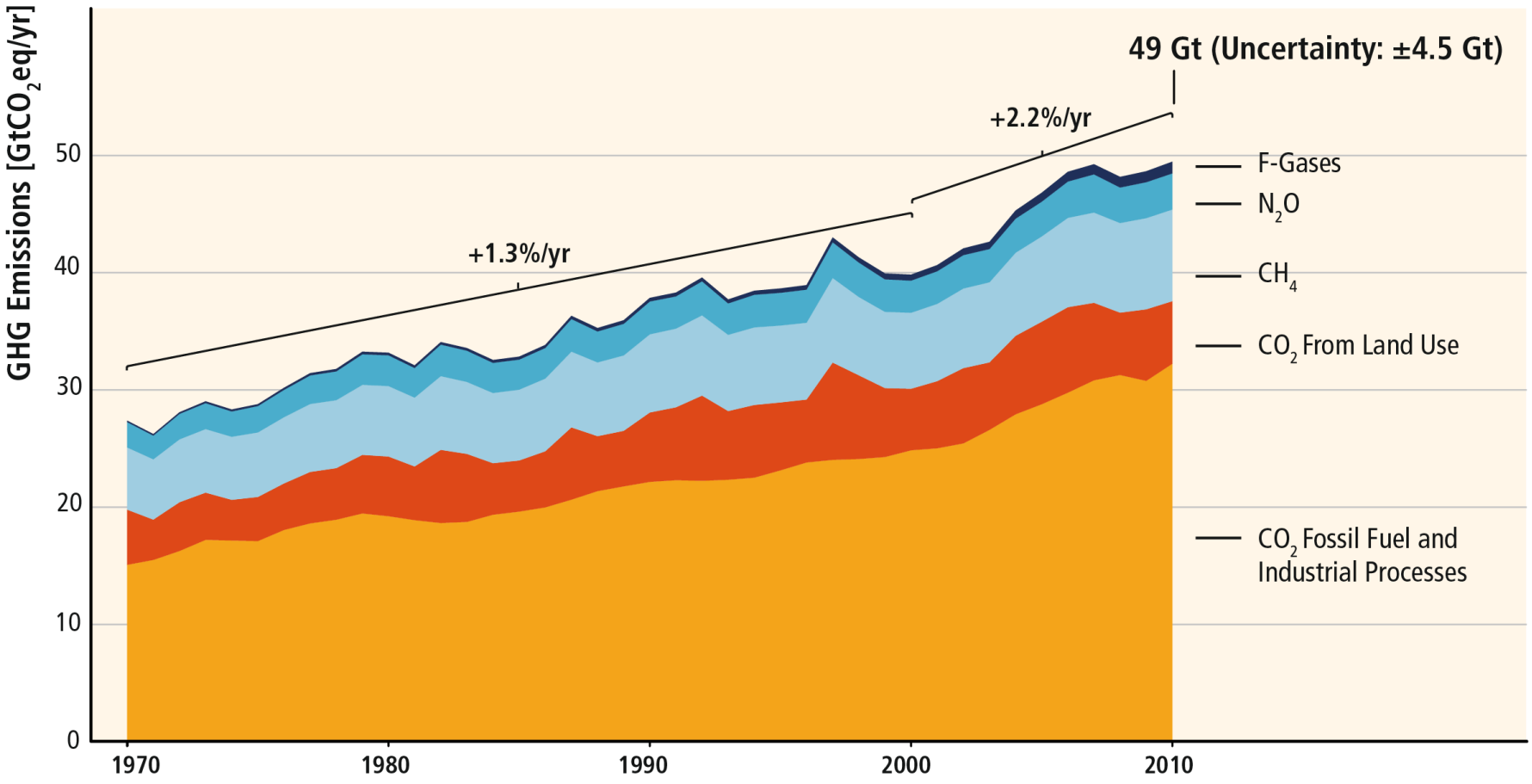
GHG emissions growth has accelerated in the last decade driven by CO_2 from fossil fuel combustion



Source: IPCC

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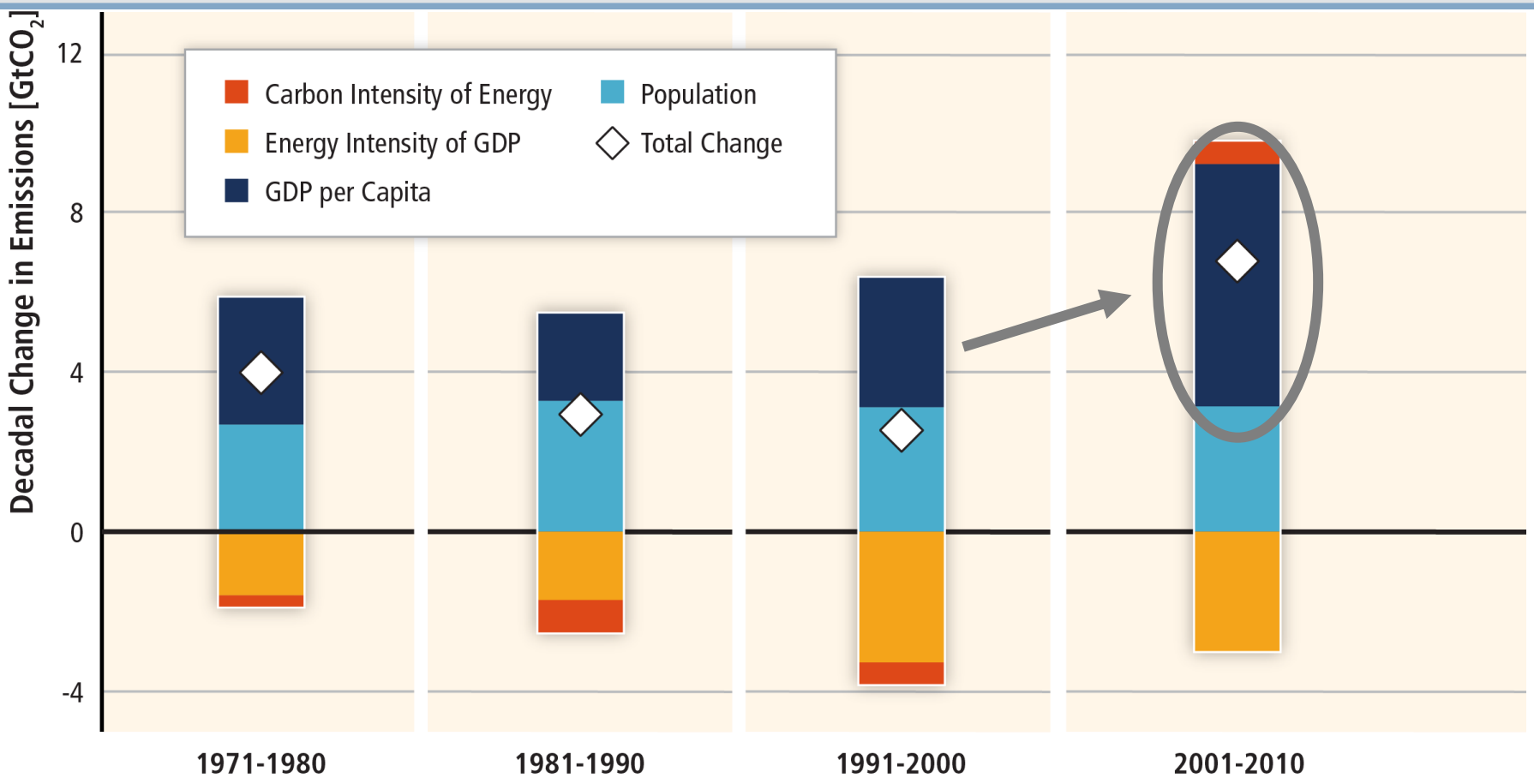
GHG emissions rise with income and population but are moderated by energy efficiency



Source: IPCC

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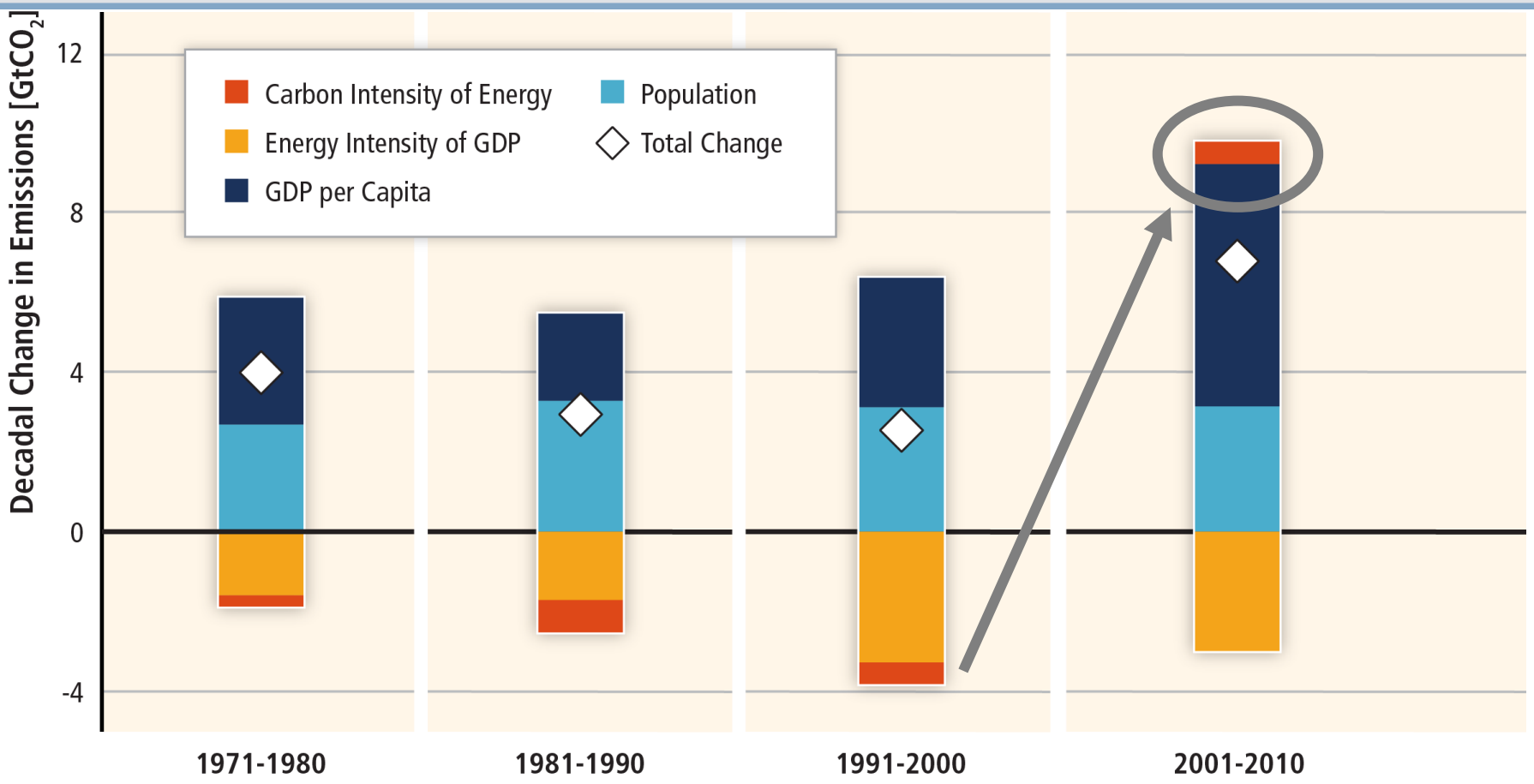
...but long-term energy decarbonisation has been reversed



Source: IPCC

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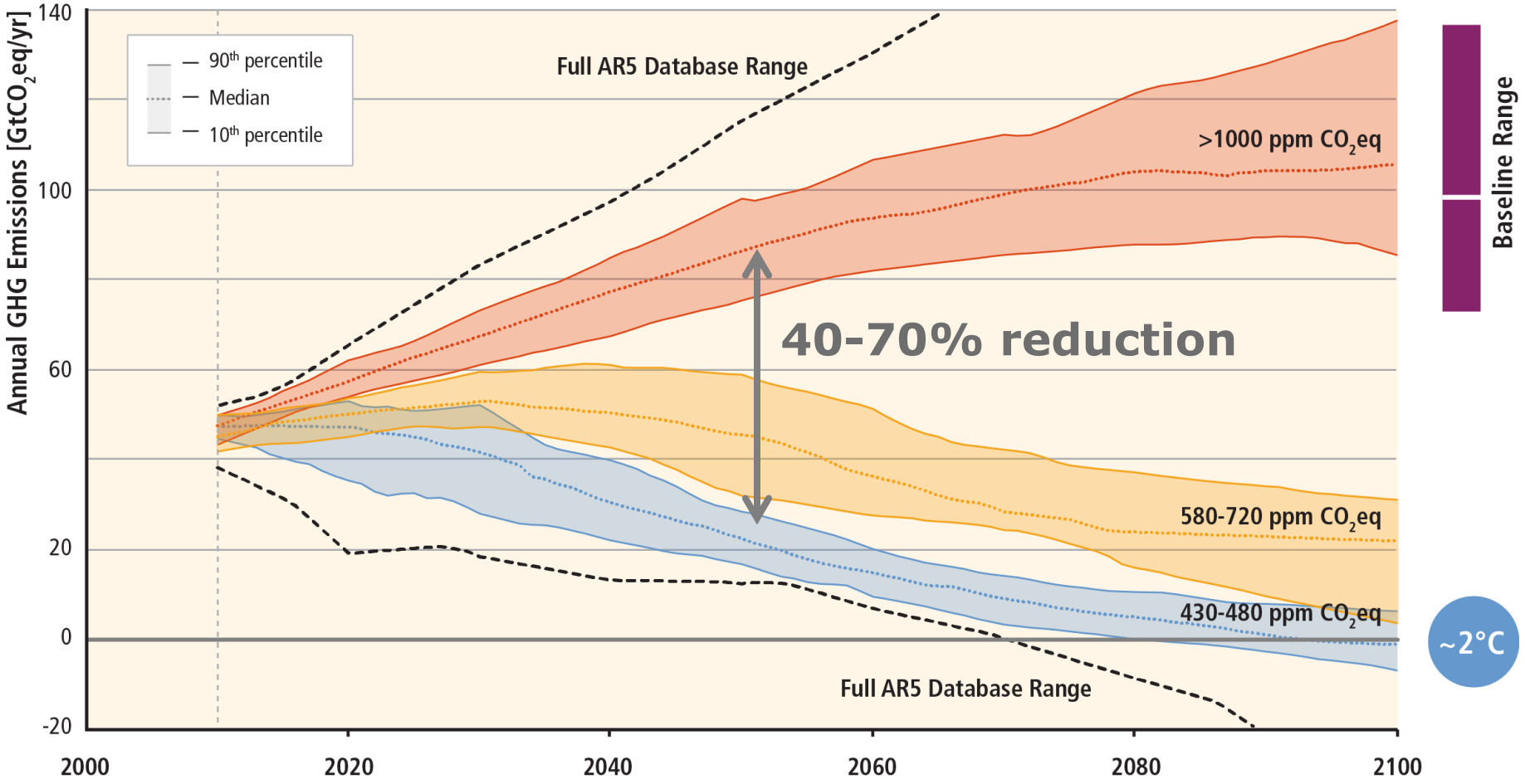
Stabilising the atmosphere means moving away from business-as-usual – regardless of how ambitious we are



Source: IPCC

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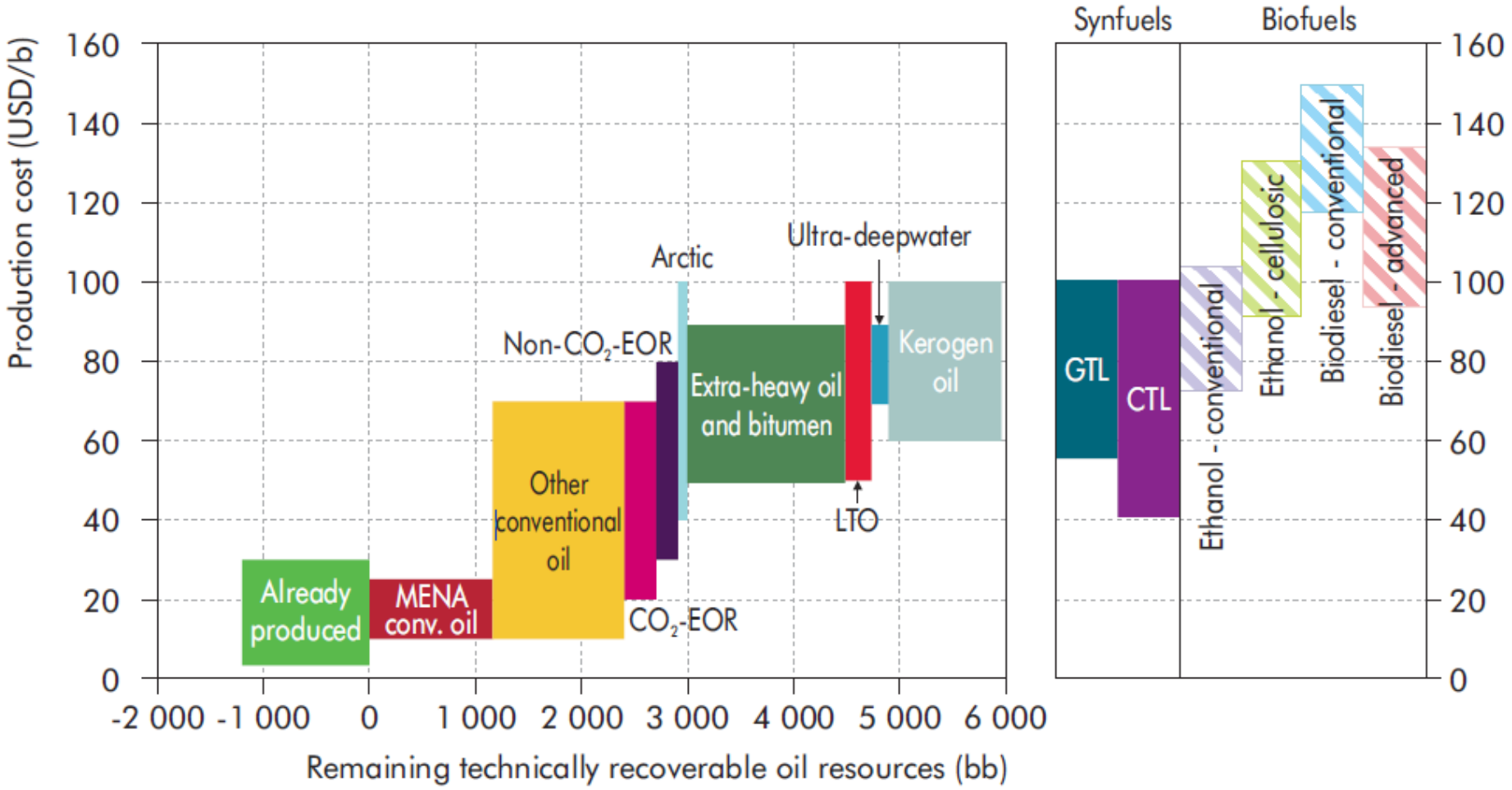
There is a lot of oil out there



Source: IEA

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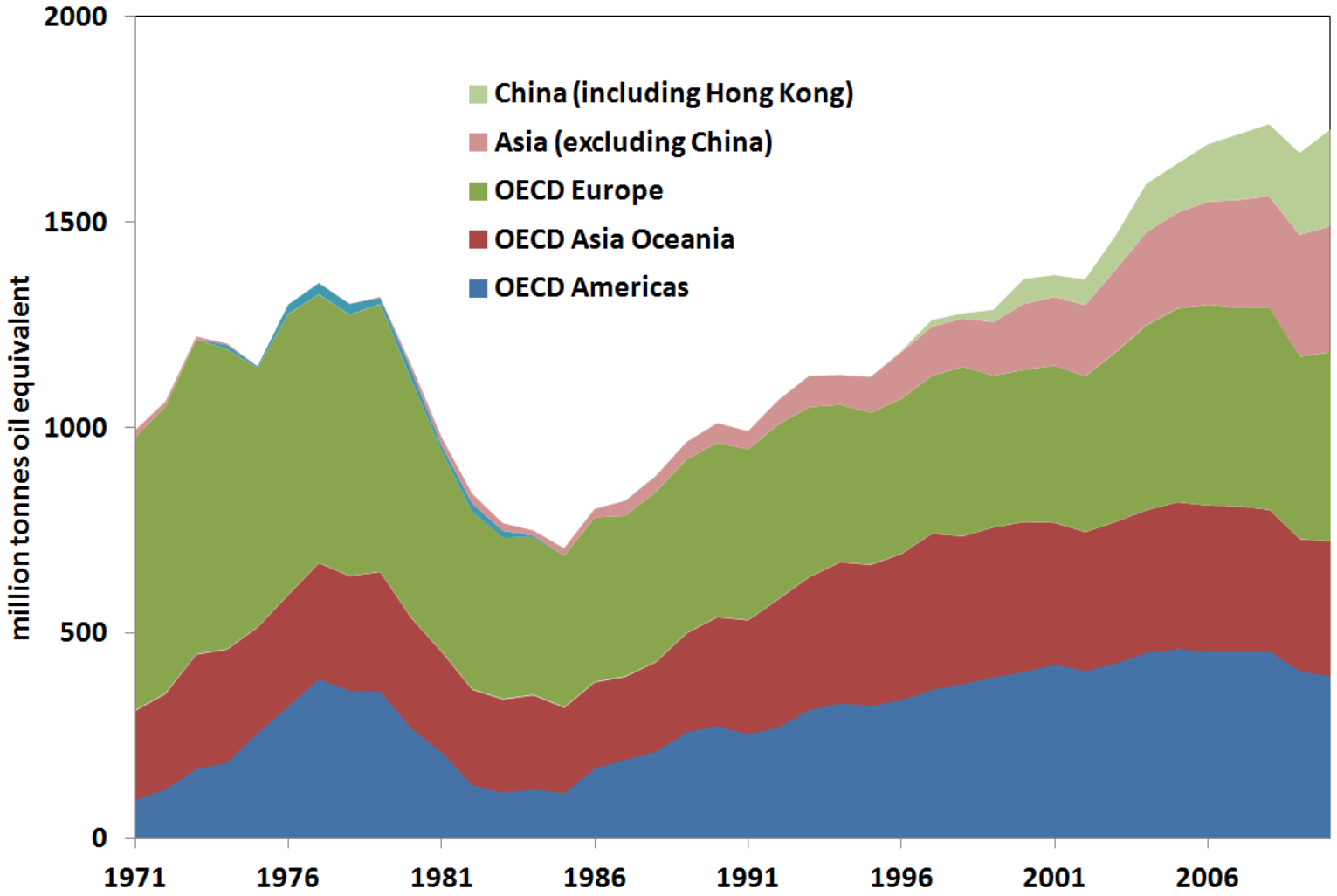
....and import dependence has been rising again



Source: IEA

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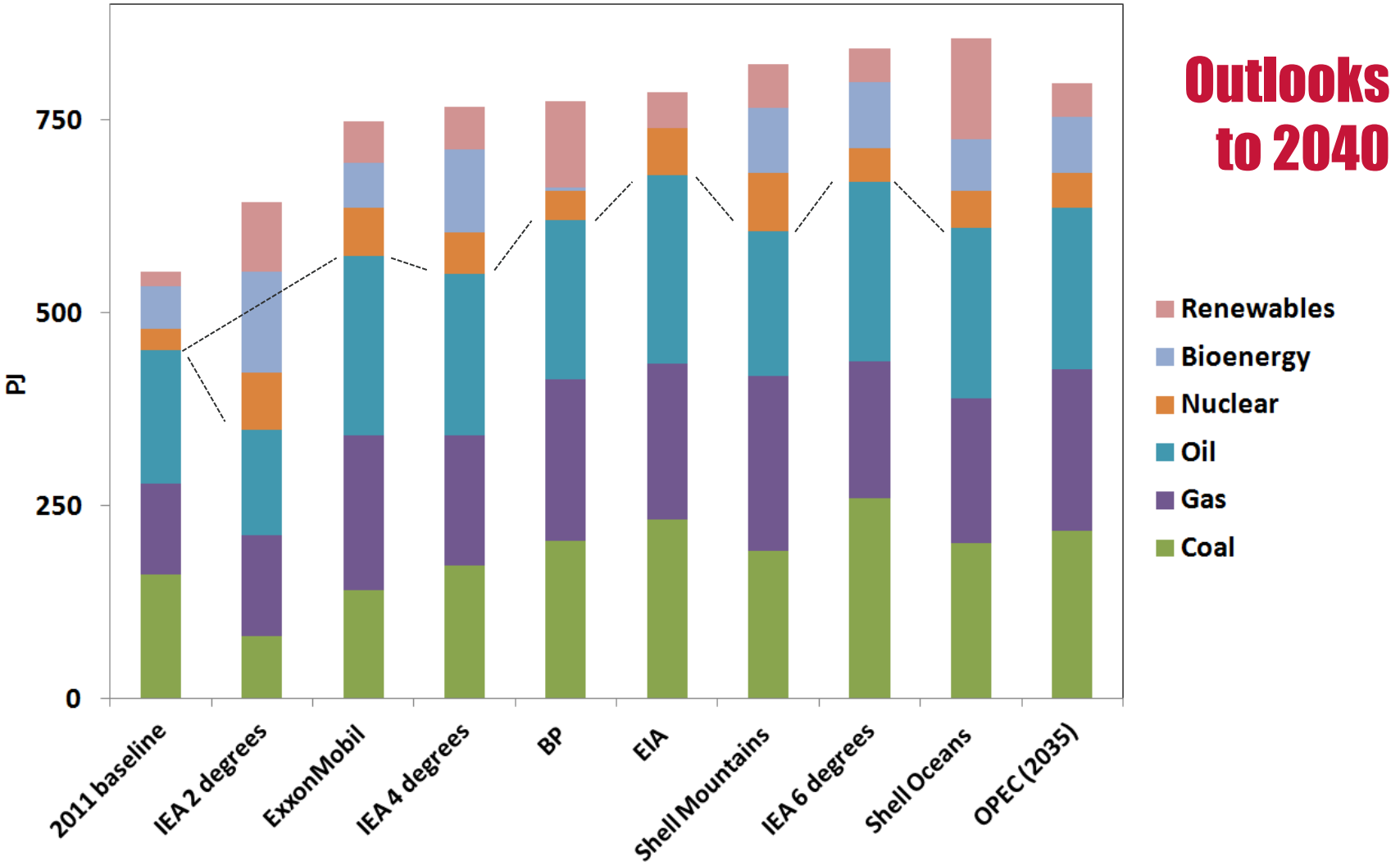
Energy scenarios and outlooks are diverging – and the response to climate change is the biggest differentiator



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Areas of agreement

Energy demand

- Will rise, but has saturated in developed countries
- *Could* start to saturate in *some* emerging economies (e.g. China) by the late 2020s…but other economies may "emerge" to take their place
- Electricity will take an increasing proportion of demand

Energy supply

- Fossil fuels will continue to dominate the world energy system…there is no physical constraint on their supply
- Natural gas will expand
- Renewable energy output (wind, solar) will expand, but will not dominate the energy system

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Areas of uncertainty

Energy supply

- Peaking (plateauing?) of oil
- Coal use – could go down
- The role of CCS
- The role (if any) for biofuels – declining role in successive outlook exercises

Energy demand

- The role of natural gas in transport
- Whether electric/H_2-fuel cell vehicles take any significant market share
- The impact of energy efficiency on demand

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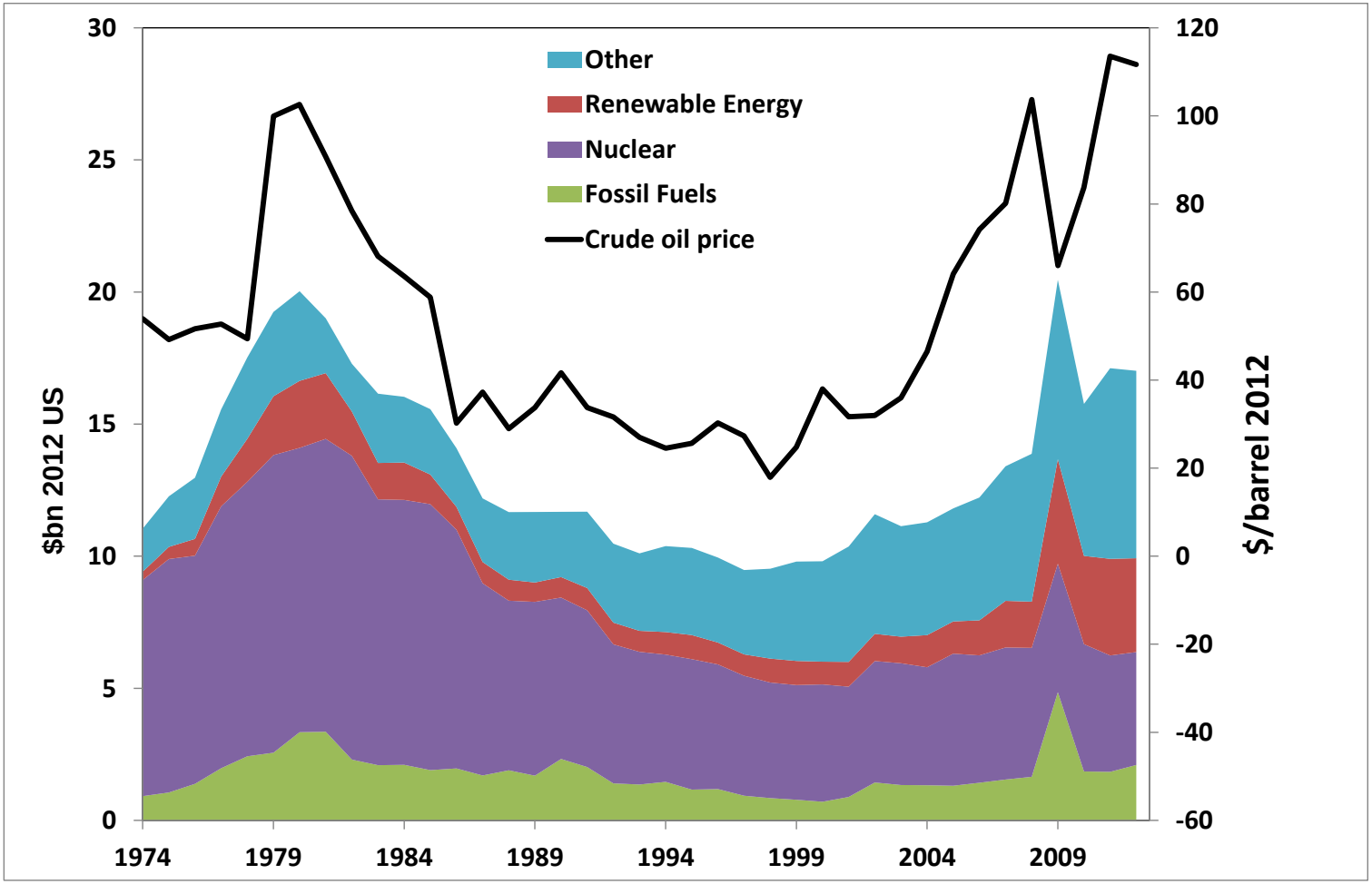
Public sector energy RD&D spend has recovered, and is focusing increasingly on renewables and efficiency



Source: IEA

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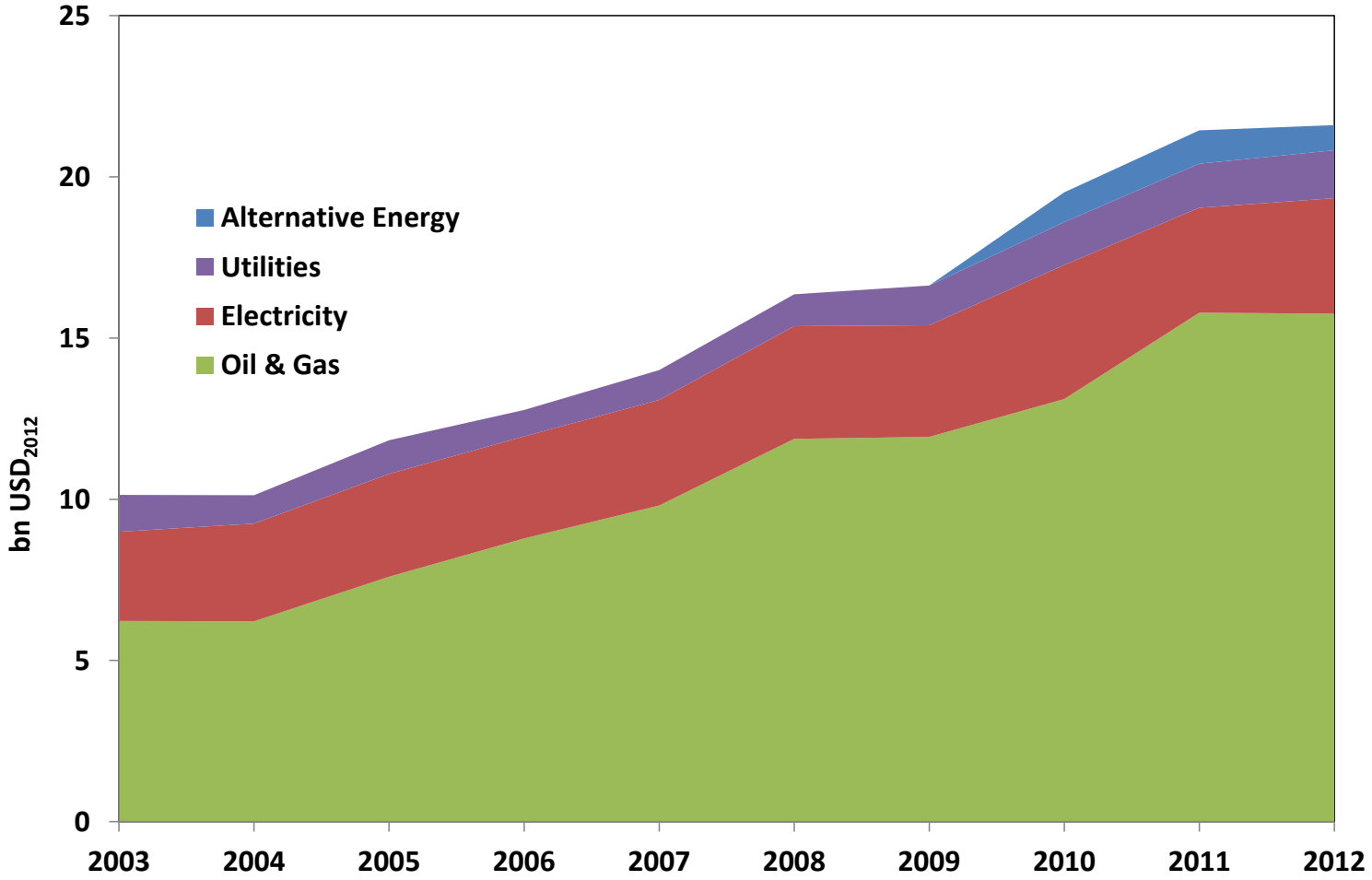
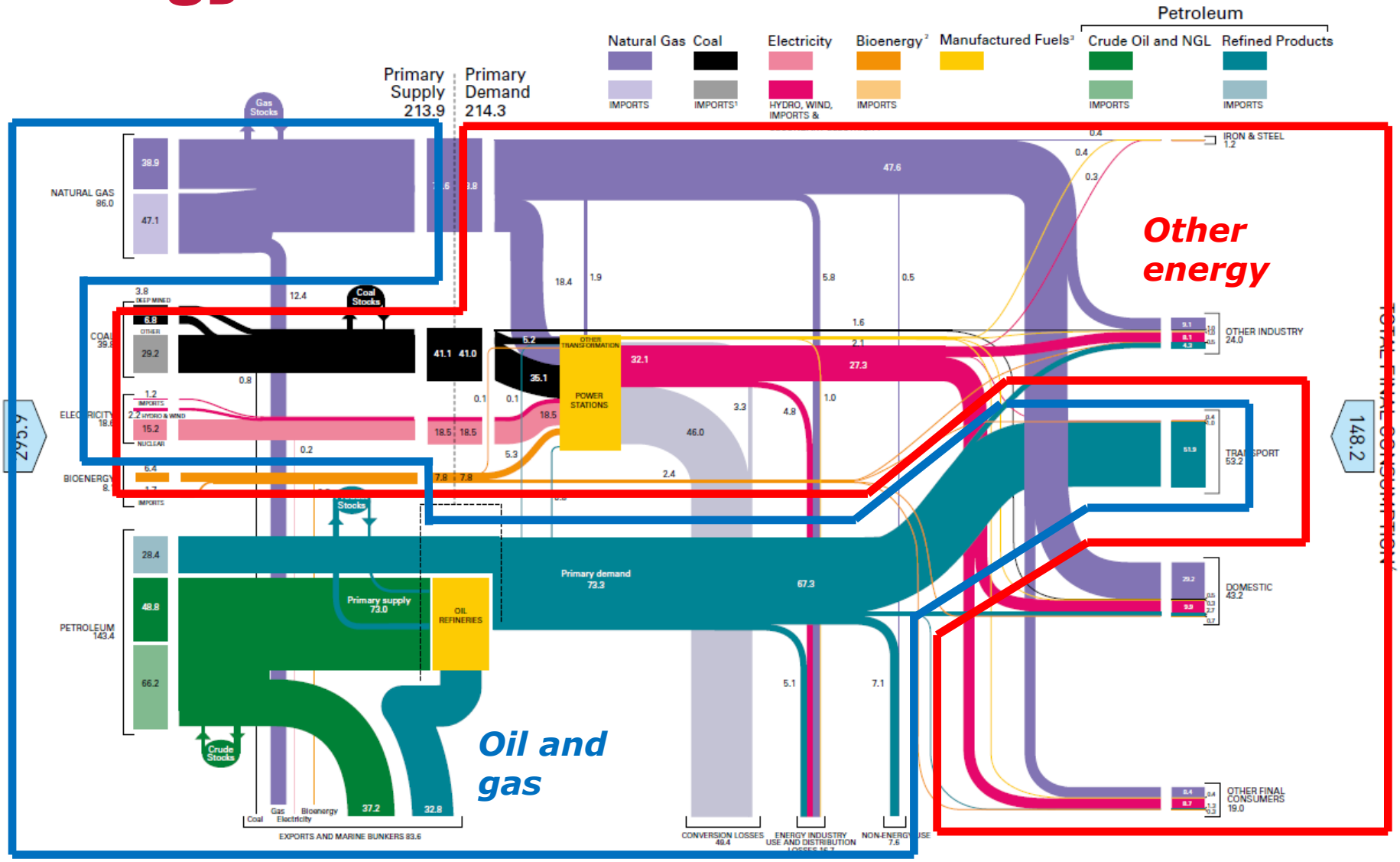
Private sector energy R&D has also recovered - but much of it is spent on oil and gas



Source: derived from EU R&D Scoreboard

Energy worlds.....



FOOTNOTES:
1. Coal imports include imports of manufactured fuels, which accounted for 0.1 million tonnes of oil equivalent in 2012.
2. Bioenergy is renewable energy made from material of recent biological origin derived from plant or animal matter, known as biomass.
3. Includes heat sold.
4. Includes non-energy use.

This flowchart has been produced using the style of balance and figures in the 2013 Digest of UK Energy Statistics, Table 1.1.

Department of Energy & Climate Change

NATIONAL STATISTICS

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Research objectives

Systems of innovation:

"networks of institutions in the public and private sectors whose activities and interactions initiate, import, modify and diffuse new technologies"

Seeking to better understand recent developments in energy research and assess the effectiveness of evolving arrangements in different countries and contexts

Objectives

- To map out systems of energy innovation for a range of countries and technologies
- To attempt to measure the effectiveness of these different arrangements
- To compare different approaches with a view to learning lessons for successful energy research and innovation policy.

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Technology case studies

The case studies cover a range of contrasting technologies and national circumstances. The chosen technologies are at different levels of maturity, ranging from modular products through to site-assembled installations and even entire energy systems. The country case studies cover three continents and include the world's largest investors in energy R&D. They also include smaller countries that have become global leaders in specific technologies.

Heat pumps

Smart grid

Shale gas

Wind energy

Wave energy

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Technology case studies (continued)

Heat Pumps – Heat pump technology is more than a century old. Heat pumps can contribute to energy sector decarbonisation by allowing low-carbon electricity to be used for heat. Heat pumps have rapidly gained market share in countries from the Mediterranean to Scandinavia, but have had limited take-up in the UK.

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Technology case studies (continued)

Smart Grids – The convergence of information/communication and energy technologies could transform electricity distribution as well as relationships between suppliers and consumers. Innovation is occurring not just in technology, but also in business models and consumer engagement.

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Technology case studies (continued)

Unconventional Gas – Shale gas production has expanded rapidly in the United States, enabled by a cluster of innovations. The pace has largely been set by the private sector and, unlike the other case studies, has not been driven by the low-carbon agenda.

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Technology case studies (continued)

Wind energy – Wind energy contributes more to electricity production than any renewable technology other than hydro. Output has been growing at more than 25% annually. Falling costs have been associated with economies of scale and market entry by diversified engineering majors.

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Technology case studies (continued)

Wave Energy – Wave energy has a huge resource potential but a dominant design has yet to emerge and there has been limited progress towards commercialisation. This case study helps us understand better the barriers to innovation.

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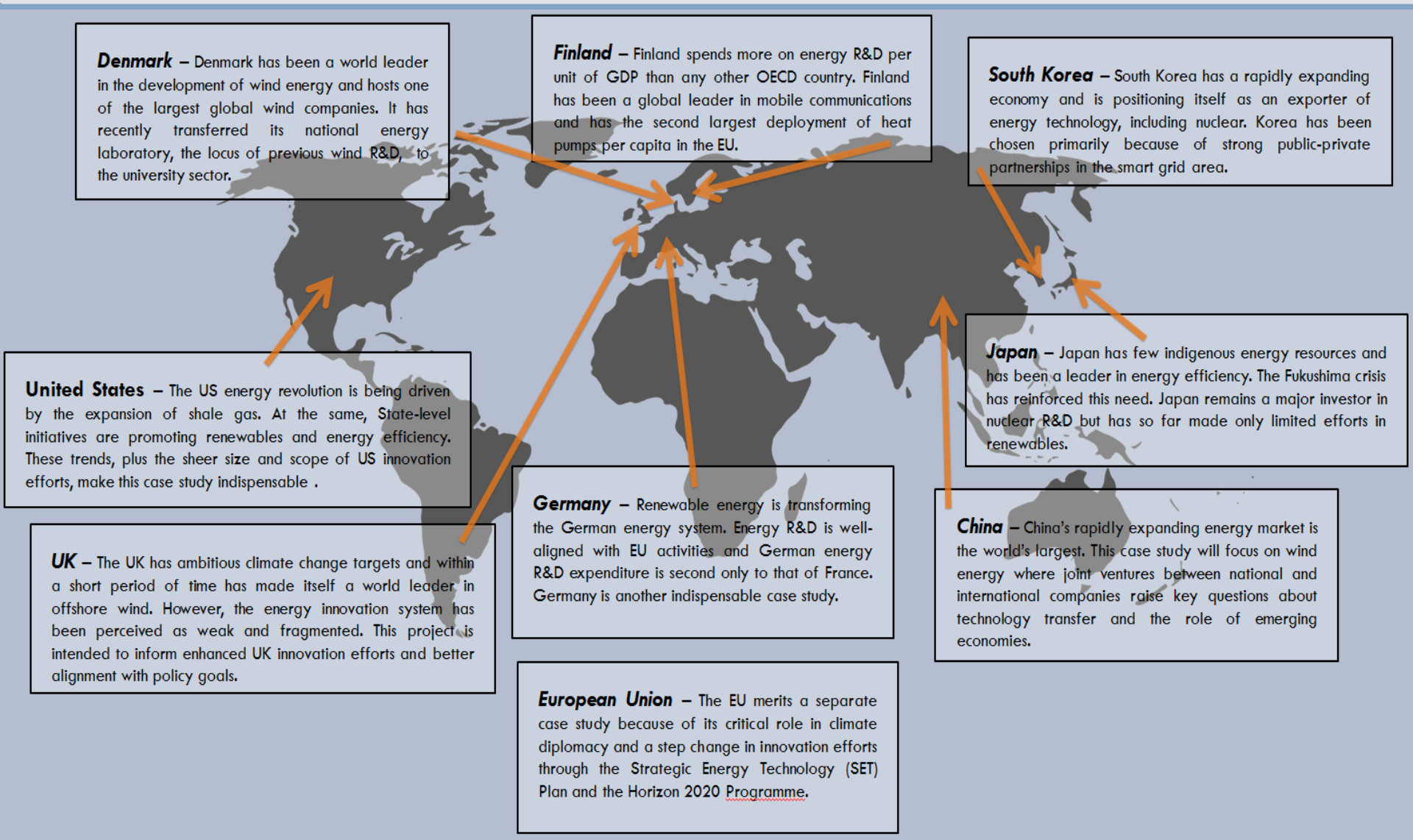
Country case studies



Denmark – Denmark has been a world leader in the development of wind energy and hosts one of the largest global wind companies. It has recently transferred its national energy laboratory, the locus of previous wind R&D, to the university sector.

Finland – Finland spends more on energy R&D per unit of GDP than any other OECD country. Finland has been a global leader in mobile communications and has the second largest deployment of heat pumps per capita in the EU.

South Korea – South Korea has a rapidly expanding economy and is positioning itself as an exporter of energy technology, including nuclear. Korea has been chosen primarily because of strong public-private partnerships in the smart grid area.

United States – The US energy revolution is being driven by the expansion of shale gas. At the same, State-level initiatives are promoting renewables and energy efficiency. These trends, plus the sheer size and scope of US innovation efforts, make this case study indispensable .

Japan – Japan has few indigenous energy resources and has been a leader in energy efficiency. The Fukushima crisis has reinforced this need. Japan remains a major investor in nuclear R&D but has so far made only limited efforts in renewables.

UK – The UK has ambitious climate change targets and within a short period of time has made itself a world leader in offshore wind. However, the energy innovation system has been perceived as weak and fragmented. This project is intended to inform enhanced UK innovation efforts and better alignment with policy goals.

Germany – Renewable energy is transforming the German energy system. Energy R&D is well-aligned with EU activities and German energy R&D expenditure is second only to that of France. Germany is another indispensable case study.

China – China's rapidly expanding energy market is the world's largest. This case study will focus on wind energy where joint ventures between national and international companies raise key questions about technology transfer and the role of emerging economies.

European Union – The EU merits a separate case study because of its critical role in climate diplomacy and a step change in innovation efforts through the Strategic Energy Technology (SET) Plan and the Horizon 2020 Programme.

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The research plan

1. Mapping systems of energy innovation through documentary analysis and field trips….
   ……"system boundaries" will emerge from the mapping exercise; different systems of innovation are associated with different technologies. These might have sub-national and international dimensions.
2. Development and analysis of innovation indicators covering all parts of the energy innovation chain

3. Phases 1 and 3 will give rise to a set of hypotheses and findings, which will be tested through structured interviews and re-interviews with experts inside and outside the case study countries.

4. A desk-based comparison of different approaches to energy innovation to tie together the findings.

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Case study templates

Technologies

1. Technology description
2. History of the technology – narrative
3. Deployment and resources
4. Commercial players
5. Environmental impacts and management
6. Social acceptability and community impacts
7. Innovation activity
8. Roadmaps and scenarios

Countries

1. Population and economy
2. Geography and climate
3. Governance
4. Education
5. Environment and climate change
6. Science and technology
7. The energy sector
8. The energy innovation system

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Field trips: first wave early 2015

Generic aspects (all countries):

- Science and innovation system
- Energy policy and technology
- Energy innovation system

Technology specific aspects (selected countries):

- Narrative for technology development and deployment
- Mapping of technology innovation system
- Role of technology of innovation system actors

Contacts through:

- FCO/BIS Science and Innovation Network;
- other international contacts (e.g. IPCC)

Outcomes:

- Refinement of country and technology case studies
- Pointers to the collection and analysis of innovation indicators

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Innovation metrics

Input indicators	Throughput indicators	Output indicators	Outcome indicators
Research and development expenditure Human resources in science and technology Science and research hubs, e.g. top universities, top think tanks and top corporate R&D investors	Publications Patents Trademarks and designs International flows of researchers Government budgets for demonstration, deployment and public procurement of new products or services	% of innovative firms with significantly improved or new products/services % of innovative firms with significantly improved or new processes % of innovative firms with new organisational practices % of innovative firms with new marketing practices	Export and market shares of commodities and services Revenues of international technology transfers Labour and energy productivity Energy mix and self-sufficiency CO_2, SO_X and NO_X emissions
Contextual indicators: Macroeconomic situation, international linkages, business climate,			

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Methodological challenges

- Comparability of data between countries: are we comparing like with like?
- Data availability, e.g. private sector, variability across countries
- Over-emphasis of metrics on particular elements of the energy innovation system
- Identifying causality in a ‘noisy’ policy/economic context…….how do we know the success of technology X was predominantly due to factors Y & Z?

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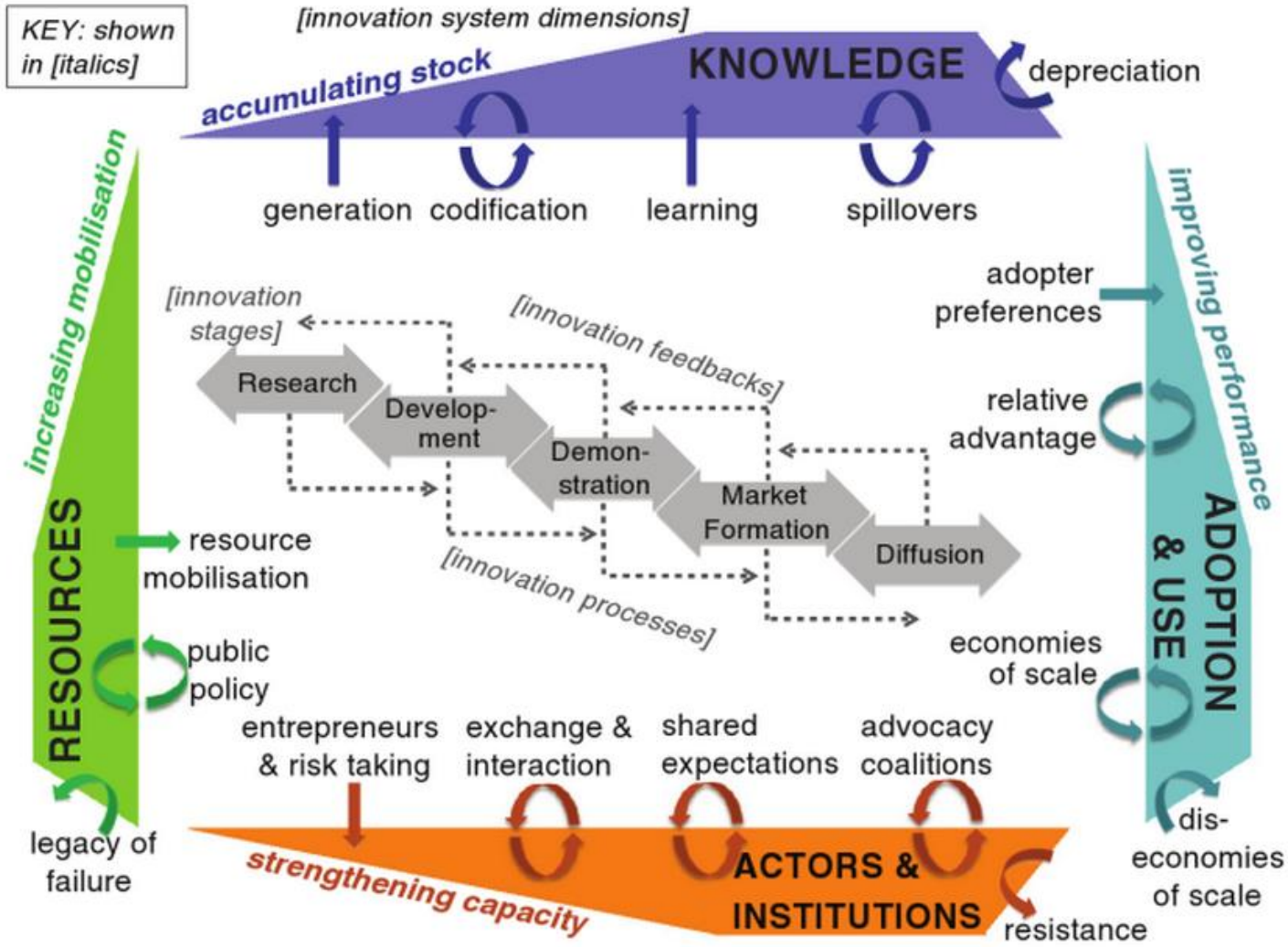
The energy innovation system



Grubler & Wilson (2014)

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Theoretical underpinnings

Innovation systems

- Innovation as a complex evolutionary process shaped by a wide variety of system components (e.g. actors, institutions, resources etc.) and dynamics (e.g. positive feedbacks, accumulation/depreciation of stocks etc.)
- Scale of analysis split between national, regional, sectoral and technology innovation systems

Energy innovation

- Focus on distinctive aspects of energy innovation systems, e.g. capital intensity, longevity of capital stock, politicisation of energy etc.

Socio-technical transitions

- Concerned with the conditions that result in a shift from socio-technical system state to another

Wider innovation theory

- Business and management literature e.g. Porter, disruptive innovation, open innovation etc.

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Emerging issues

- The globalised nature of energy innovation systems,
- Energy innovation systems outside Europe/North America/Anglophone countries
- The role of private sector activity and public-private engagement in shaping the development and performance of innovation systems
- The influence of the physical/engineering aspects of energy technologies: e.g. system v. component; commodity v. site-assembled
- The roles of: learning by doing; transfer of non-codified knowledge (e.g. training and human mobility); “secondary” research (learning by osmosis)
- Measuring innovation system performance to inform innovation policy and institutional design

Thank you!

http://www3.imperial.ac.uk/rcukenergystrategy