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Environmental Change and Low Carbon Emissions, including Policies and Research

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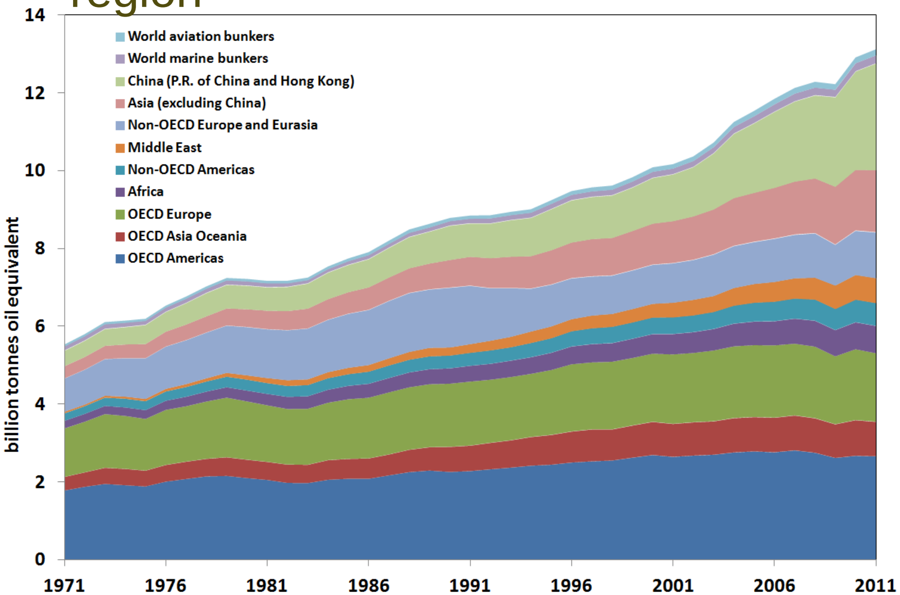
The Energy Trilemma

The objectives of energy policy for many countries are basically three:

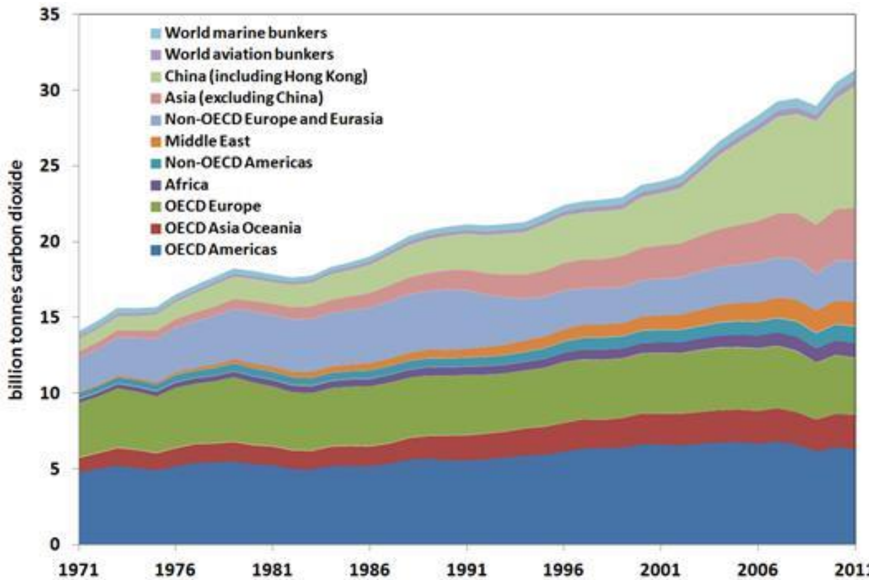
- Transition to a low-carbon energy system (involving cuts of at least 80% in greenhouse gas (GHG) emissions by 2050, which will require the almost complete decarbonisation of the electricity system), and a wider 'green economy'
- Increased security and resilience of the energy system (involving reduced dependence on imported fossil fuels and domestic system robustness against a environmental, economic, social and geo-political shocks)
- Affordability
  - For businesses: need for competitiveness (some sectors will decline as others grow – allow time for the transition) and cost efficiency (ensuring that investments, which will be large, are timely and appropriate and, above all, are not stranded by unforeseen developments)
  - For vulnerable households: need to be able to pay energy costs

The inexorable increase in energy use and CO2 emissions

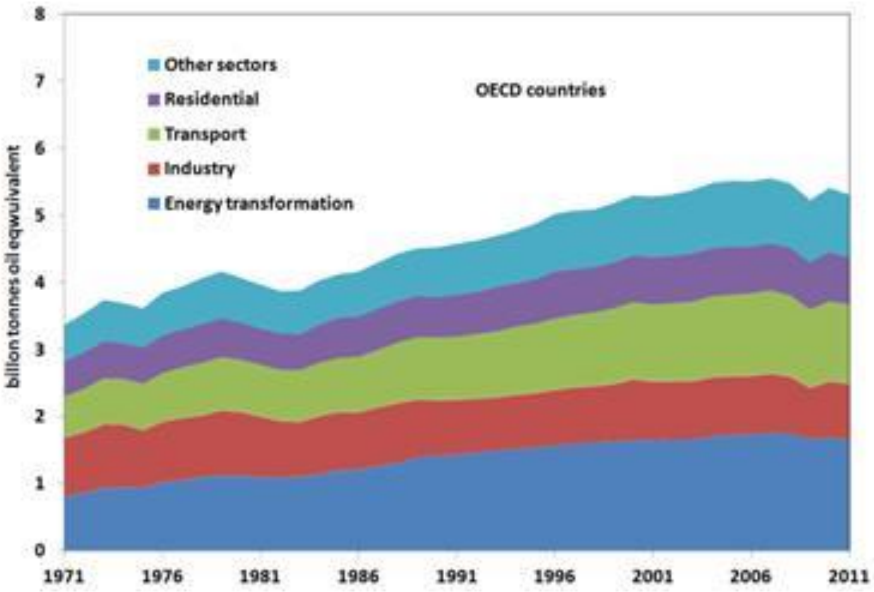
Global primary energy demand by region

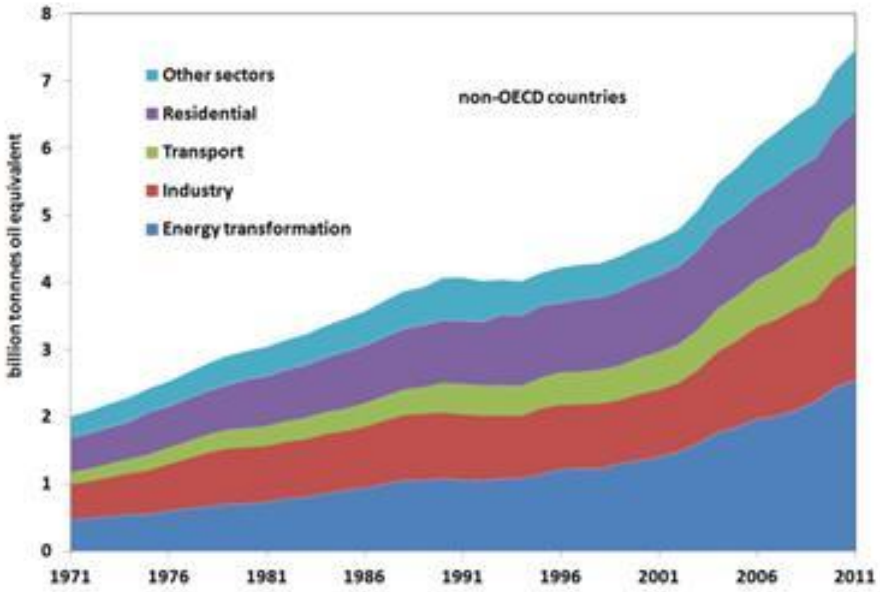


Global CO2 emissions by region



Energy use by sector
OECD and non-OECD countries





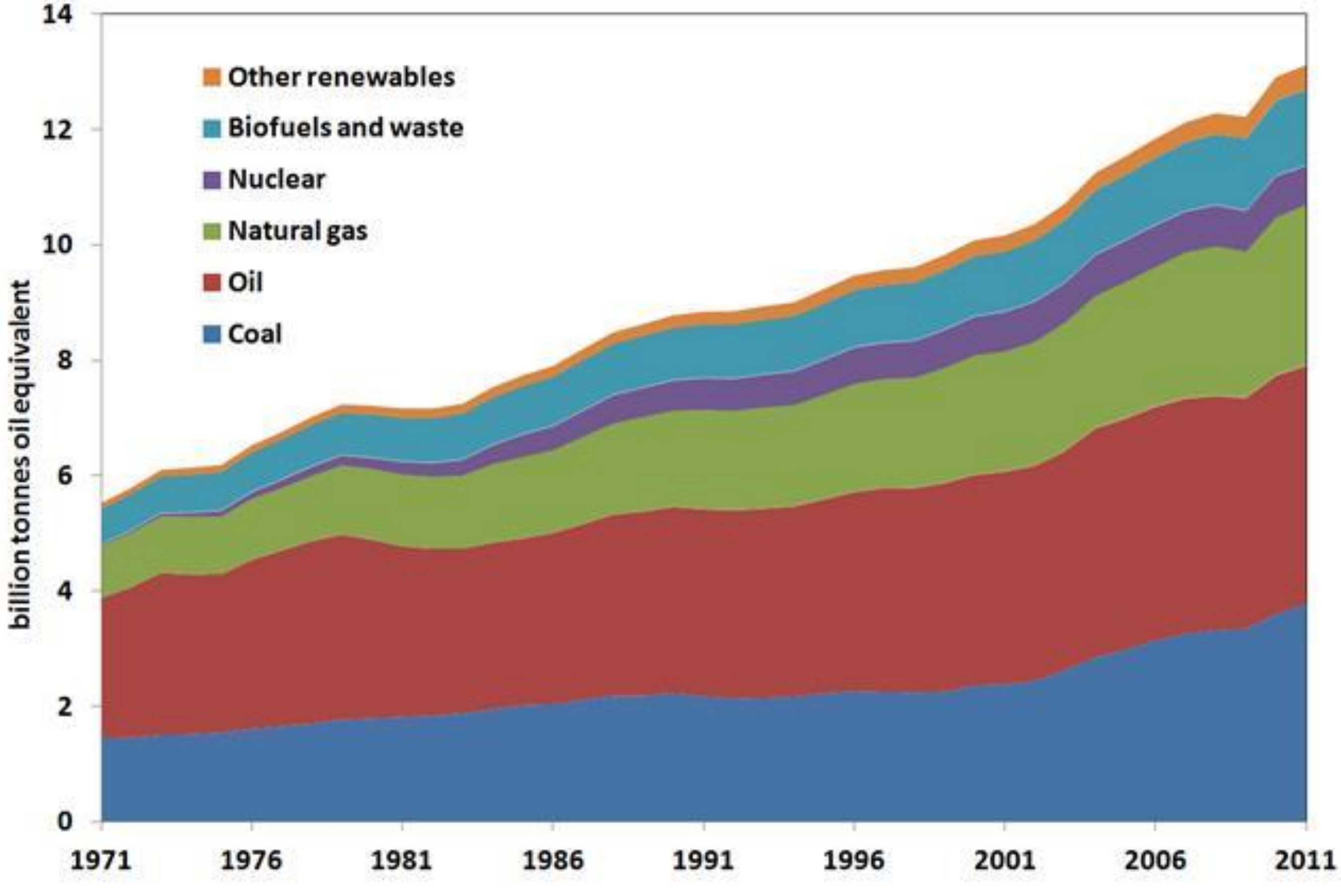
Energy unequally consumed

Primary energy consumption in selected countries in 2011 (tonnes of oil equivalent per capita)

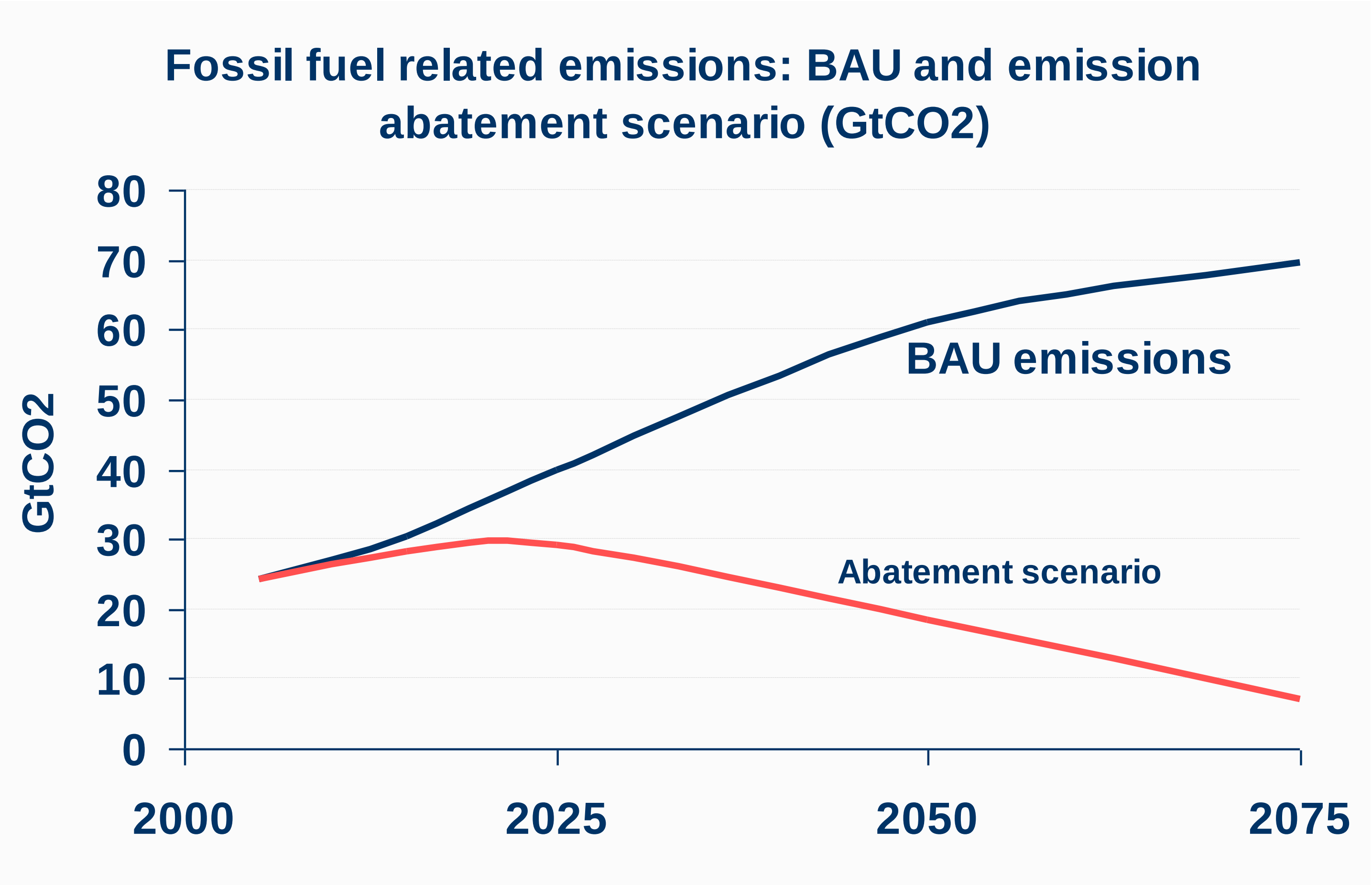
High consuming countries		Major developed economies		Emerging economies		Lower-income countries	
Iceland	17.9	United States	7.0	South Africa	2.8	DR Congo	0.4
Qatar	17.8	Australia	5.4	PR China	2.0	Tajikistan	0.3
Trinidad and Tobago	15.5	Korea	5.2	Argentina	2.0	Nepal	0.3
Kuwait	11.5	Russian Federation	5.2	Thailand	1.7	Cameroon	0.3
Netherlands Antilles	10.9	Netherlands	4.6	Mexico	1.7	Haiti	0.3
Brunei Darussalam	9.3	France	3.9	Turkey	1.5	Yemen	0.3
Oman	8.9	Germany	3.8	Brazil	1.4	Myanmar	0.3
United Arab Emirates	8.4	Japan	3.6	Indonesia	0.9	Senegal	0.3
Luxembourg	8.0	United Kingdom	3.0	Nigeria	0.7	Bangladesh	0.2
Canada	7.3	Italy	2.8	India	0.6	Eritrea	0.1

The dominance of fossil fuels

Global primary energy demand by fuel



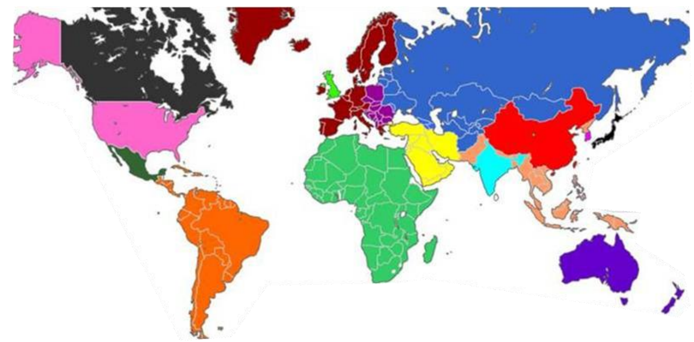
Emissions trajectory to limit temperature change

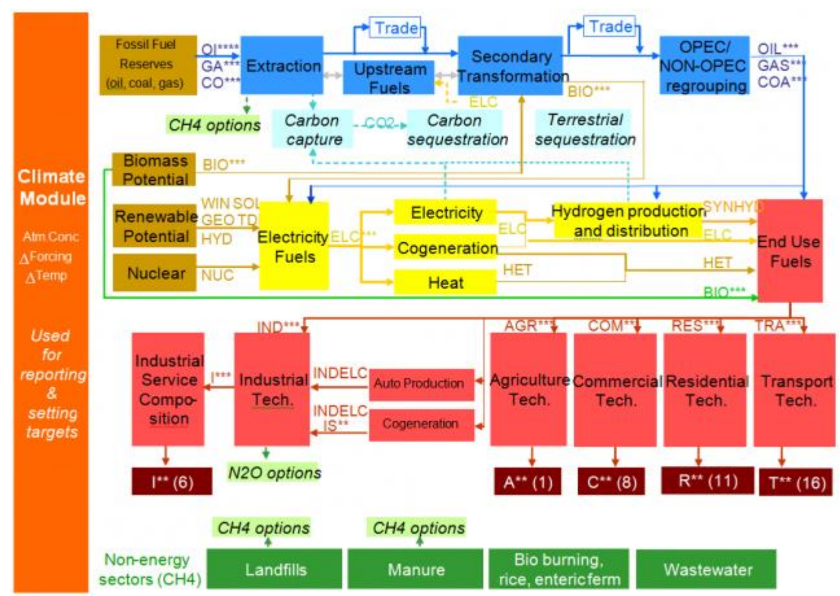


Source: Stern Review, Part III, Chapter 9

TIAM-UCL finds the cost-optimal global energy system that meets energy demands within 16 individual regions

- Technologically-detailed, bottom-up energy system model, developed through UK Energy Research Centre
- Models the energy system by maximising global welfare over the duration of scenario
- Optimises energy service demands for 16 regions given available primary energy sources and technologies
- Calculates impact of selected primary energy sources on emissions and temperature rise

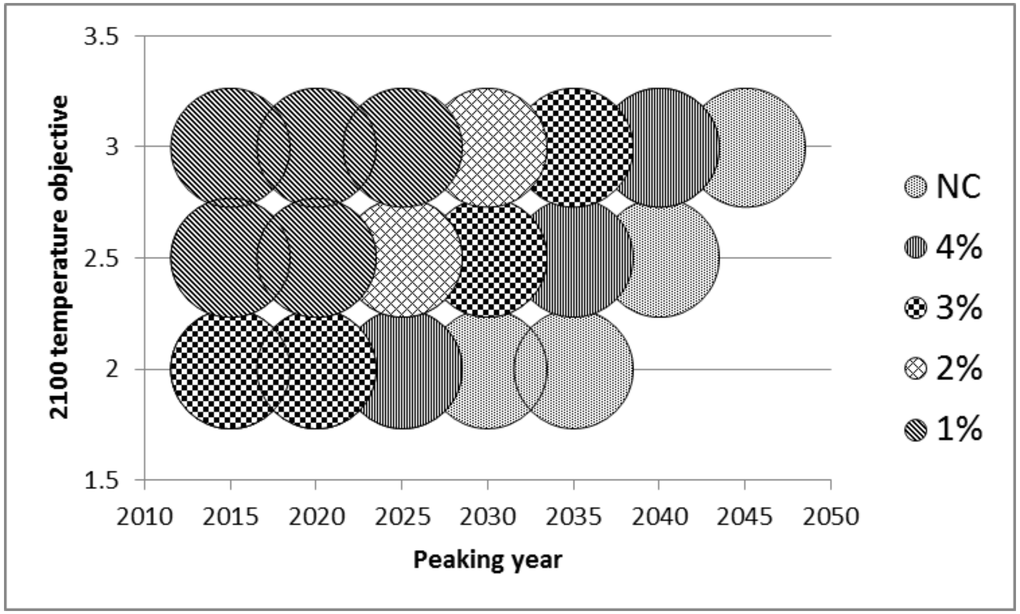




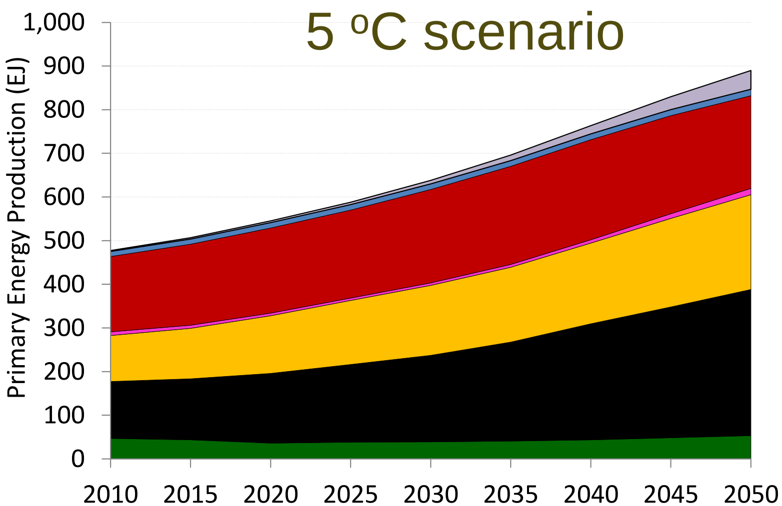
How long can we delay action while limiting climate change?

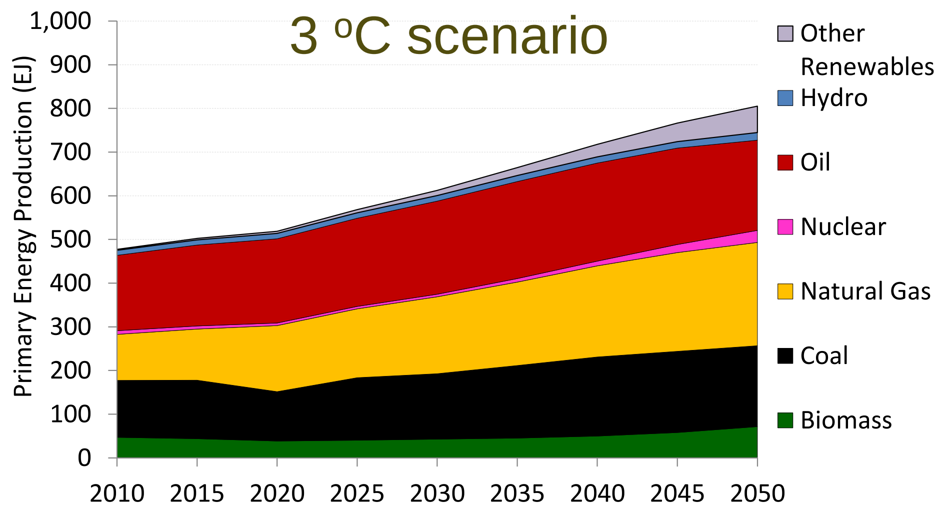
Ch.24 in Ekins, P., Bradshaw, M. and Watson, J. 2015 (forthcoming) *Global Energy: Issues, Potentials and Policy Implications*, Oxford University Press, OUP

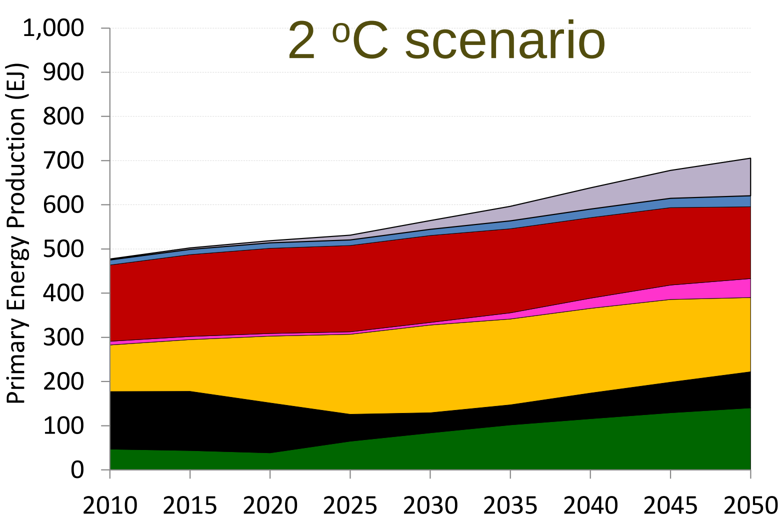
- Can use integrated assessment models to examine climate and energy system dynamics in conjunction
- When must global emissions peak and how quickly they must they decline to stay within temperature limits?
- The 2°C target is now only achievable if annual global CO_2 emissions can fall by at least 3% per year
- It is not possible for emissions to peak after 2035 and still restrict the temperature rise to 2°C.



Global primary energy production varies according to temperature thresholds

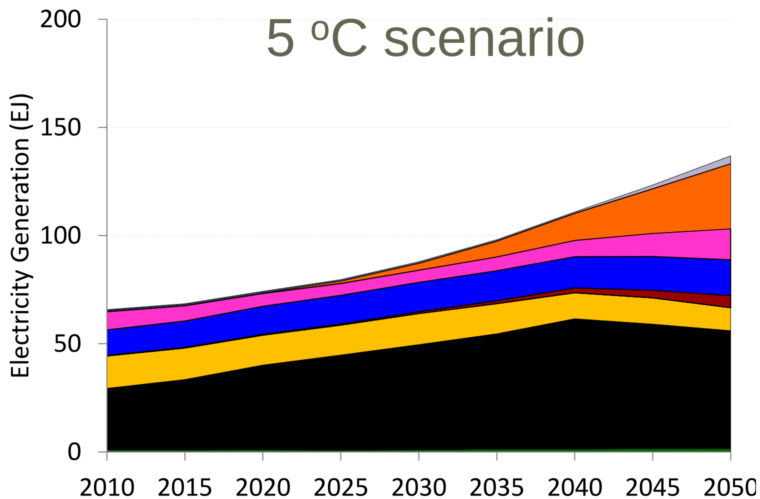


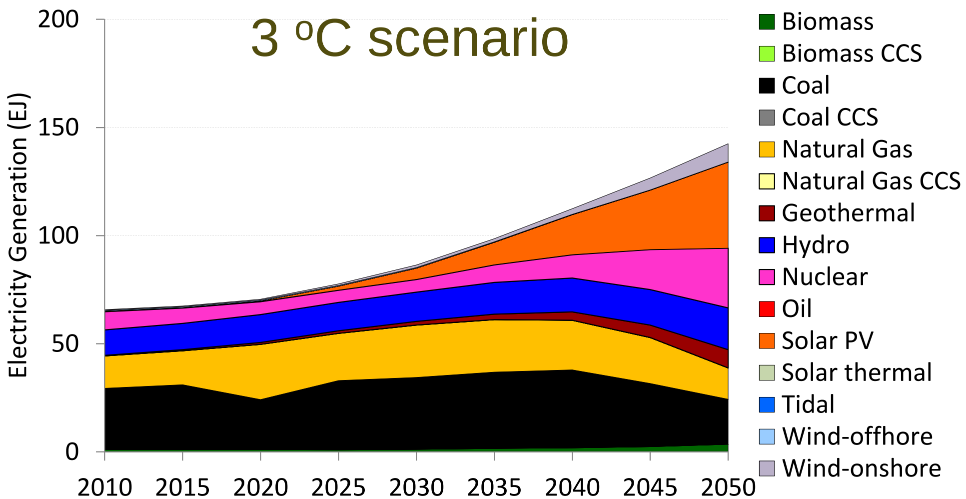


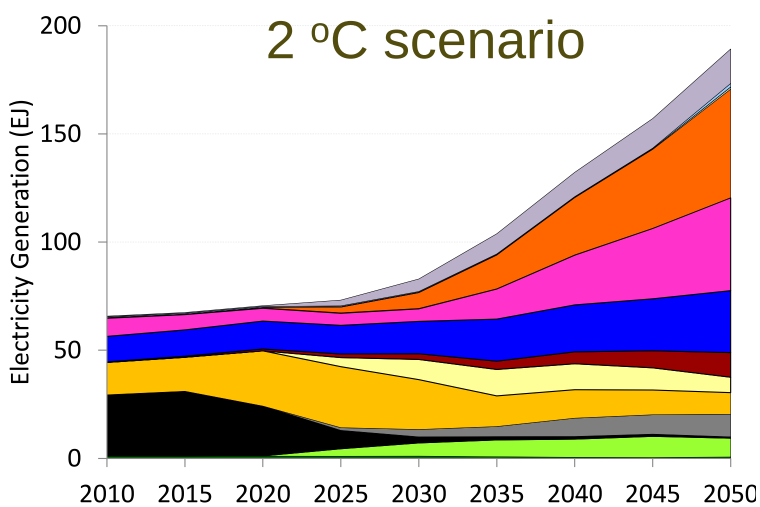


- Fossil fuels' share of primary energy in 2°C scenario drops from 85% to less than 60% by 2050
- Gas consumption is greater in the 2°C scenario over medium timescale (2010 – 2035) than in 5 °C scenario
- Gas can play an important role as a 'bridging fuel' but dependent on rapid reduction in coal consumption and availability of carbon capture and storage

Electricity generation is much higher when mitigating emissions and rapidly shifts to low-carbon technologies

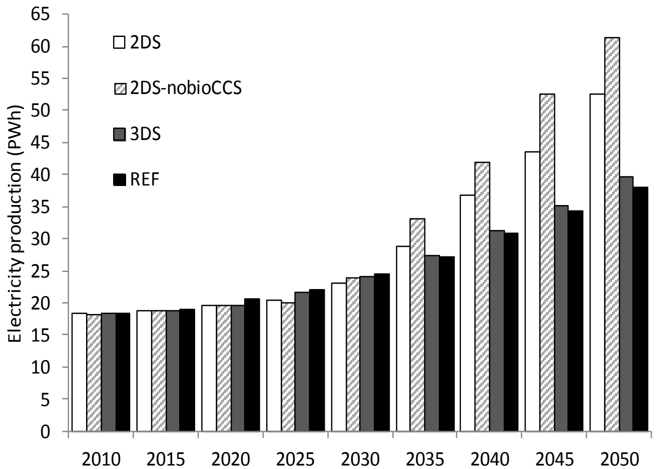


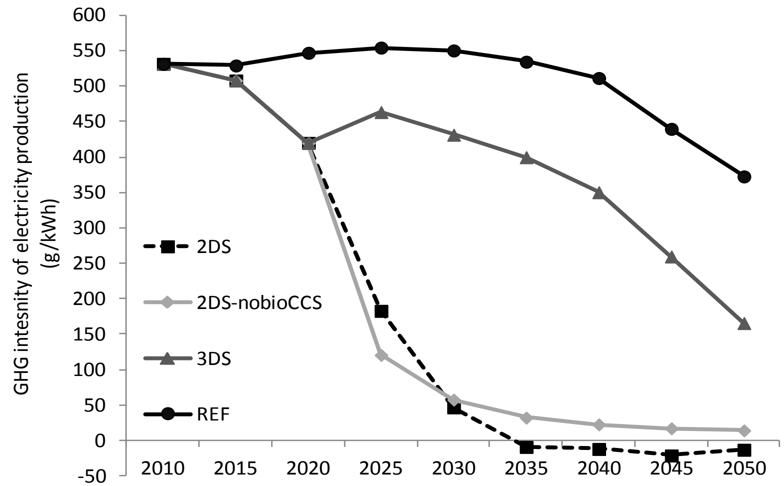


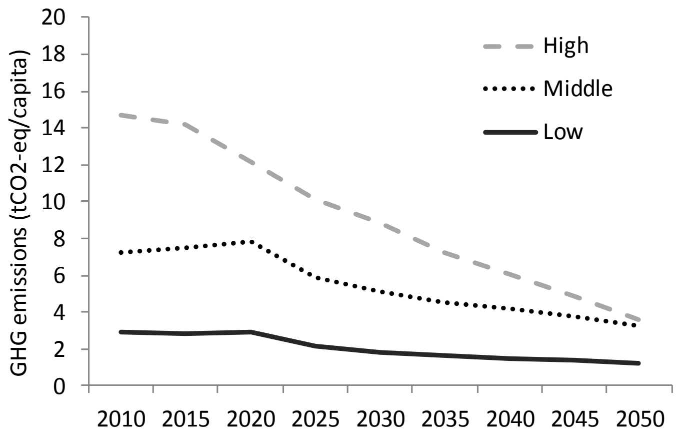


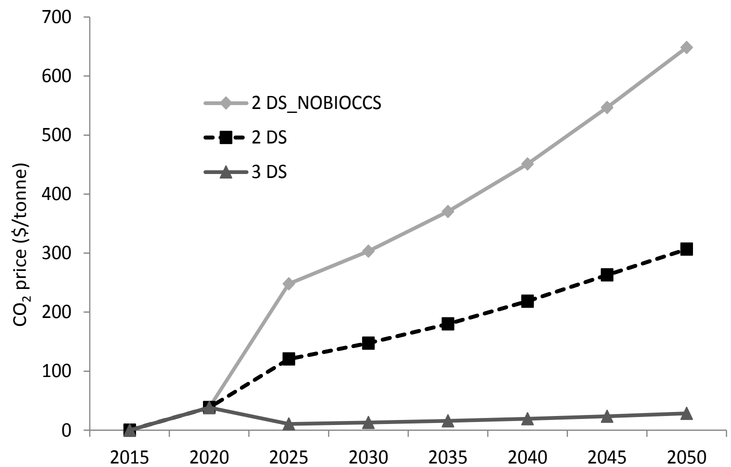
- Under 2 °C scenario emissions from the electricity sector drop over the 2020s, so that they are almost zero by 2030
- GHG-negative electricity is the most cost-effective manner to decarbonise many end-use sectors so overall production is much higher
- Electricity-sector emissions also fall significantly in 3 °C scenario

Global electricity generation in the four scenarios and its GHG intensity (top left, right), per capita emissions 2DS, CO2 prices (bottom left, right)





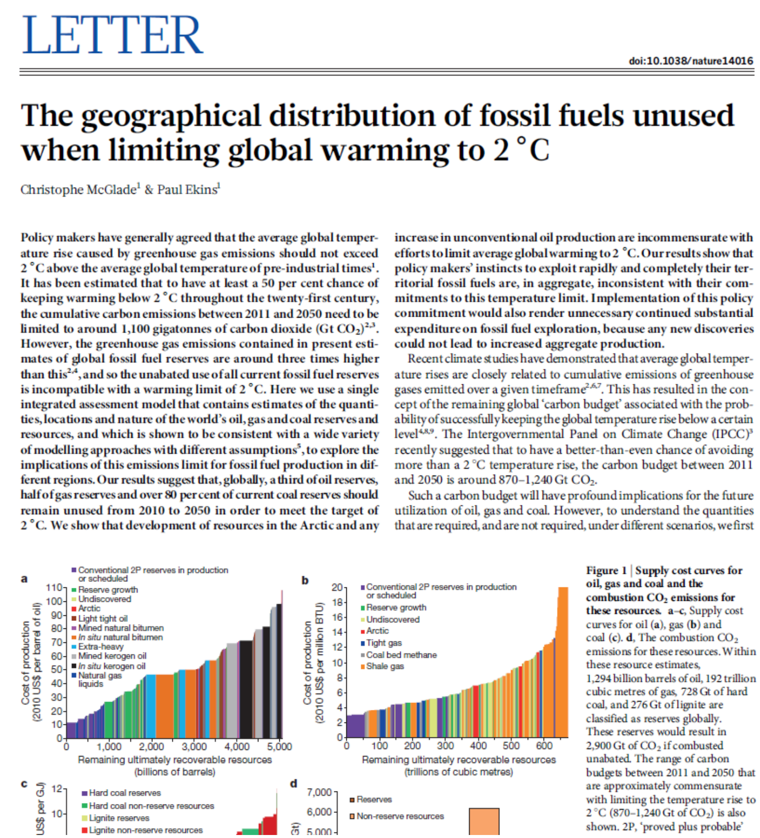




Which regions contain fossil fuels that should stay in the ground to stay within the 2ºC carbon budgets?

McGlade, C. and Ekins, P. 2015 ‘The geographical distribution of fossil fuels unused when limiting global warming to 2ºC’ *Nature*, pp.187-190

- Burning all current fossil fuel reserves exceed the 2 ºC ‘carbon budget’ by around three times
- But to date unknown which of oil, gas and coal are and aren’t developed and who owns these
- Used TIAM-UCL to investigate this and examine who owns the fossil fuel reserves and resources that are ‘unburnable’



LETTER

doi:10.1038/nature14016

The geographical distribution of fossil fuels unused when limiting global warming to 2 °C

Christophe McGlade[1] & Paul Ekins[1]

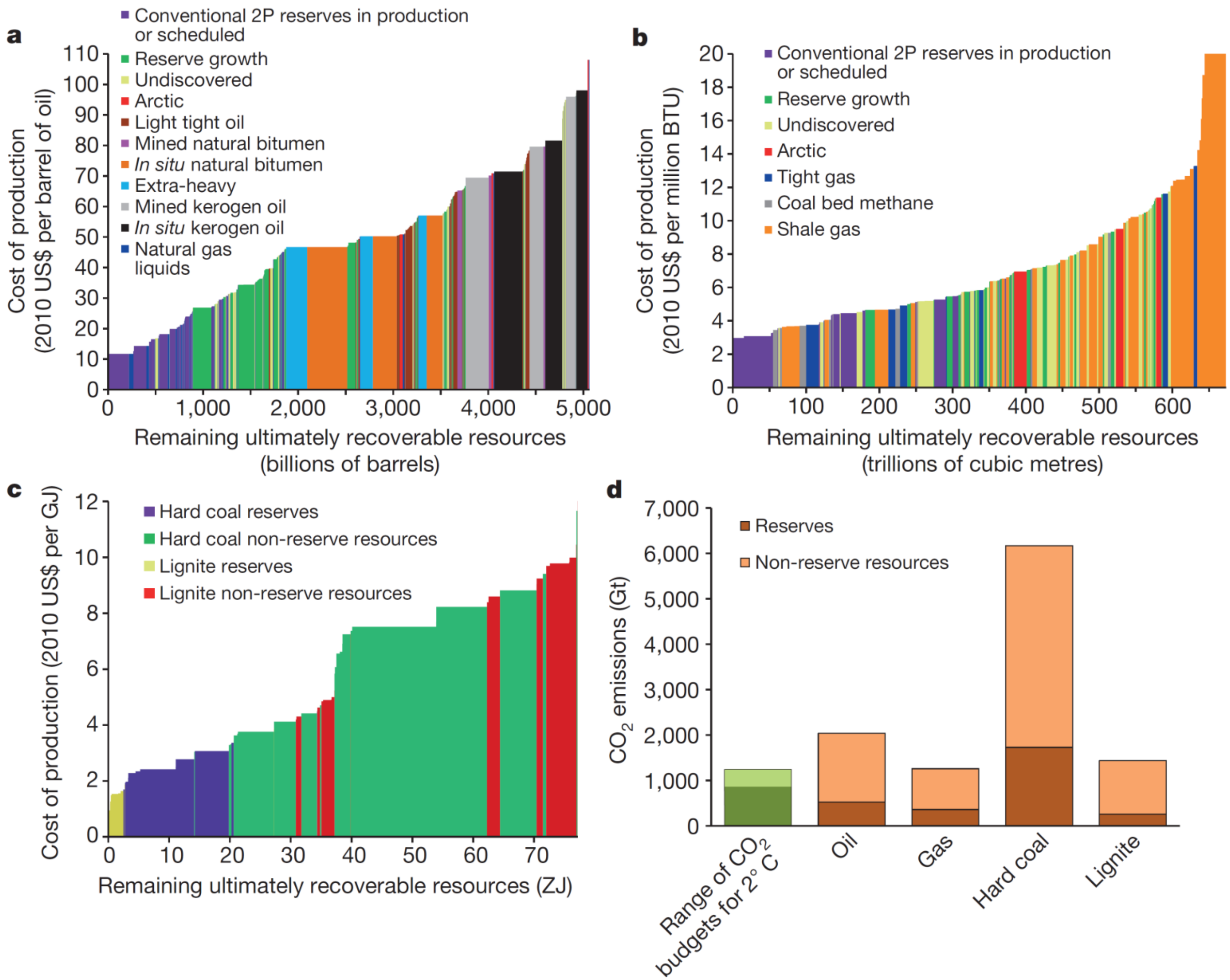
Policy makers have generally agreed that the average global temperature rise caused by greenhouse gas emissions should not exceed 2 °C above the average global temperature of pre-industrial times[1]. It has been estimated that to have at least a 50 per cent chance of keeping warming below 2 °C throughout the twenty-first century, the cumulative carbon emissions between 2011 and 2050 need to be limited to around 1,100 gigatonnes of carbon dioxide (Gt CO_2)[2,3]. However, the greenhouse gas emissions contained in present estimates of global fossil fuel reserves are around three times higher than this[2,4], and so the unabated use of all current fossil fuel reserves is incompatible with a warming limit of 2 °C. Here we use a single integrated assessment model that contains estimates of the quantities, locations and nature of the world’s oil, gas and coal reserves and resources, and which is shown to be consistent with a wide variety of modelling approaches with different assumptions[5], to explore the implications of this emissions limit for fossil fuel production in different regions. Our results suggest that, globally, a third of oil reserves, half of gas reserves and over 80 per cent of current coal reserves should remain unused from 2010 to 2050 in order to meet the target of 2 °C. We show that development of resources in the Arctic and any increase in unconventional oil production are incommensurate with efforts to limit average global warming to 2 °C. Our results show that policy makers’ instincts to exploit rapidly and completely their territorial fossil fuels are, in aggregate, inconsistent with their commitments to this temperature limit. Implementation of this policy commitment would also render unnecessary continued substantial expenditure on fossil fuel exploration, because any new discoveries could not lead to increased aggregate production.

Recent climate studies have demonstrated that average global temperature rises are closely related to cumulative emissions of greenhouse gases emitted over a given timeframe[2,6,7]. This has resulted in the concept of the remaining global ‘carbon budget’ associated with the probability of successfully keeping the global temperature rise below a certain level[4,8,9]. The Intergovernmental Panel on Climate Change (IPCC)[3] recently suggested that to have a better-than-even chance of avoiding more than a 2 °C temperature rise, the carbon budget between 2011 and 2050 is around 870–1,240 Gt CO_2.

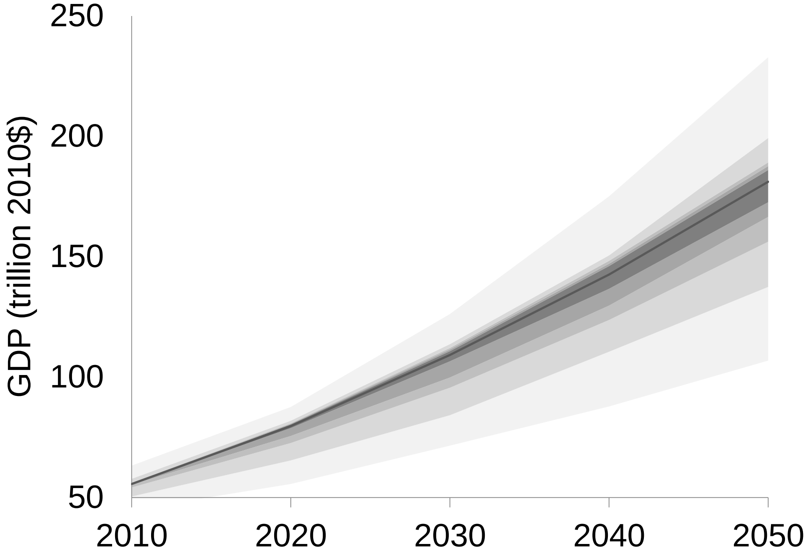
Such a carbon budget will have profound implications for the future utilization of oil, gas and coal. However, to understand the quantities that are required, and are not required, under different scenarios, we first

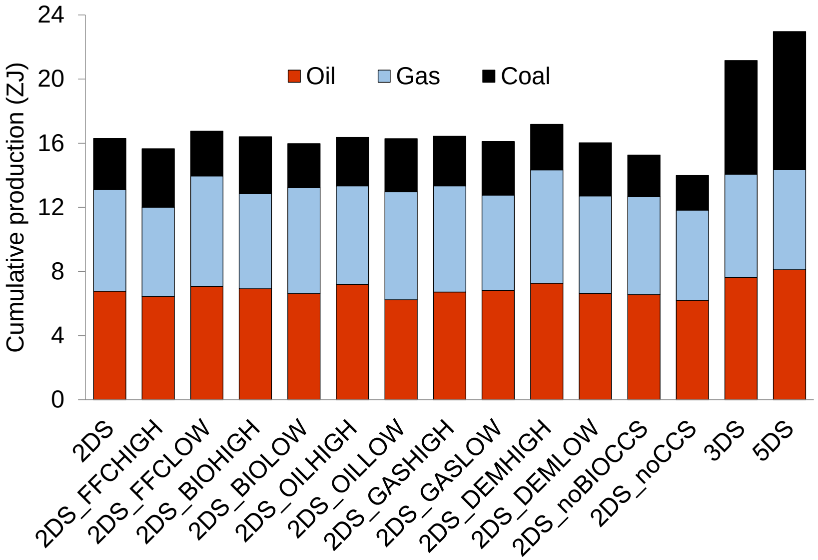
Figure 1 | Supply cost curves for oil, gas and coal and the combustion CO_2 emissions for these resources. **a–c**, Supply cost curves for oil (**a**), gas (**b**) and coal (**c**). **d**, The combustion CO_2 emissions for these resources. Within these resource estimates, 1,294 billion barrels of oil, 192 trillion cubic metres of gas, 728 Gt of hard coal, and 276 Gt of lignite are classified as reserves globally. These reserves would result in 2,900 Gt of CO_2 if combusted unabated. The range of carbon budgets between 2011 and 2050 that are approximately commensurate with limiting the temperature rise to 2 °C (870–1,240 Gt of CO_2) is also shown. 2P, ‘proved plus probable’

Reserves, resources and carbon budgets



Scenarios were run under a wide range of assumptions on both supply and demand sides and climate change





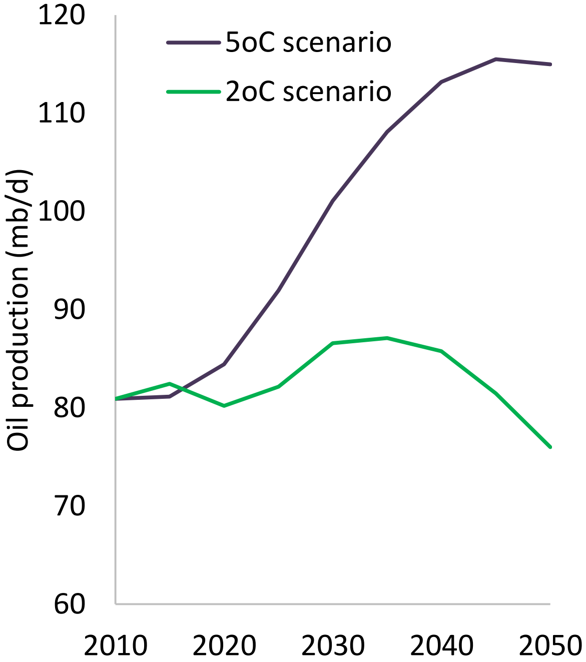
- Left panel shows range in projected global GDP from all scenarios used in the IPCC 5th Assessment Report
- Right panel shows cumulative fossil fuel production for different temperature scenarios (2 ºC, 3 ºC, 5 ºC) and sensitivity of 2 ºC scenario to assumptions on fossil fuel costs, bioenergy, oil and gas availability, demand (GDP) and carbon capture and storage (CCS)

Regional distribution of reserves unburnable before 2050 to stay below 2°C

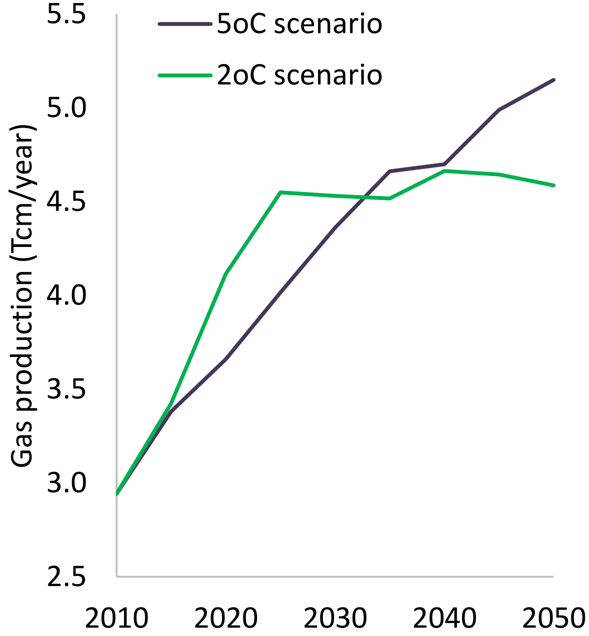
Region	Oil		Gas		Coal	
	Gb	%	Tcm	%	Gt	%
Africa	23	21%	4.4	33%	28	85%
Canada	39	74%	0.3	24%	5.0	75%
China	9	28%	2.6	75%	116	61%
C & S America	58	39%	4.8	53%	8	51%
Europe	5.0	20%	0.6	11%	65	78%
FSU	27	18%	31	50%	203	94%
India	0.4	7%	0.3	27%	64	80%
Middle East	263	38%	46	61%	3.4	99%
OECD Pacific	2.1	37%	2.2	56%	83	93%
ODA	2.0	9%	2.2	24%	10	34%
United States	2.8	6%	0.3	4%	235	92%
Global	431	33%	95	49%	819	82%

Oil and coal consumption significantly different between 2ºC and 5ºC scenarios but gas acts as a 'transition' fuel

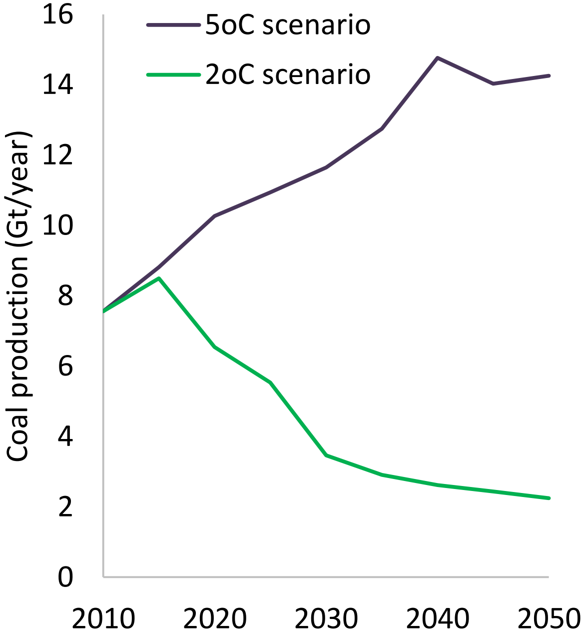
Oil



Gas



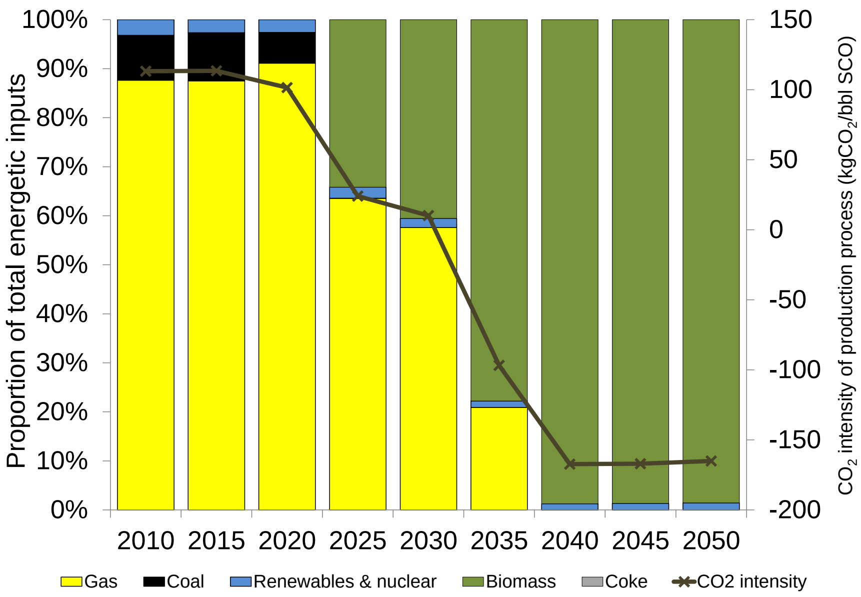
Coal



Limited effect of CCS on unburnable reserves, energy inputs for oil sands must be decarbonised, and all Arctic resources are unburnable

Unburnable reserves with and without CCS

	Oil		Gas		Coal	
	Gb	%	Tcm	%	Gt	%
With CCS	431	33%	95	49%	819	82%
No CCS	449	35%	100	52%	887	88%



- CCS has only a modest effect on the production of reserves
- Production of oil sands in Canada continues but this is accompanied by a rapid and total de-carbonization of the auxiliary energy inputs required
- No development of oil or gas resources in the Arctic

Factors for consideration

- Politics: inconsistency of stated commitments to 2 ^{o}C
  - Climate change as well as economic and (geo-) political implications
  - Licensing constraints for fossil fuel exploration?
- Corporates: justification for E&P financing
  - New discoveries cannot lead to increased aggregate production (e.g. European shale gas)
  - At the limit may be too risky for delivery of long-term returns

Conclusions

- Modelling tools can provide a holistic analysis of system-wide implications of a wide range of energy futures
- Addressing uncertainty: wide range of possible outcomes and developments can often be better assessed through scenarios than short-term deterministic ‘forecasts’
- Such uncertainties are exacerbated by the uncertainty surrounding the severity of future efforts to address climate change
- There is a huge amount at stake: economically, socially, politically and environmentally
- We will be developing and extending these tools in order to contribute further insights to the future possibilities for and implications of global, regional and national energy systems