UNIVERSITY OF CAMBRIDGE | Energy Policy Research Group

UK CCS RESEARCH CENTRE

"I dare say you haven't had much practice," said the Queen. "When I was your age, I always did it for half an hour a day. Why, sometimes I've believed as many as six impossible things before breakfast." –Lewis Carroll

Six Impossible Things: Debating the Future of Negative Emissions Technologies

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EPSRC Pioneering research and skills

What are Negative Emissions Technologies (NETs)?

- Unlike conventional mitigation, negative emissions technologies (NETs) are defined by a net flux of carbon from atmosphere into long-term storage
- Potential to address emissions already in atmosphere
- Suite of 'geoengineering' options include:
  - bioenergy plus CCS (BECCS) (Kraxner, et al, 2003)
  - enhanced weathering (Kohler et al, 2010)
  - ocean liming (McLaren, 2012)
  - afforestation (Lenton, 2010)
  - biochar (Woolf et al., 2010)
  - direct air capture (Keith et al, 2005)

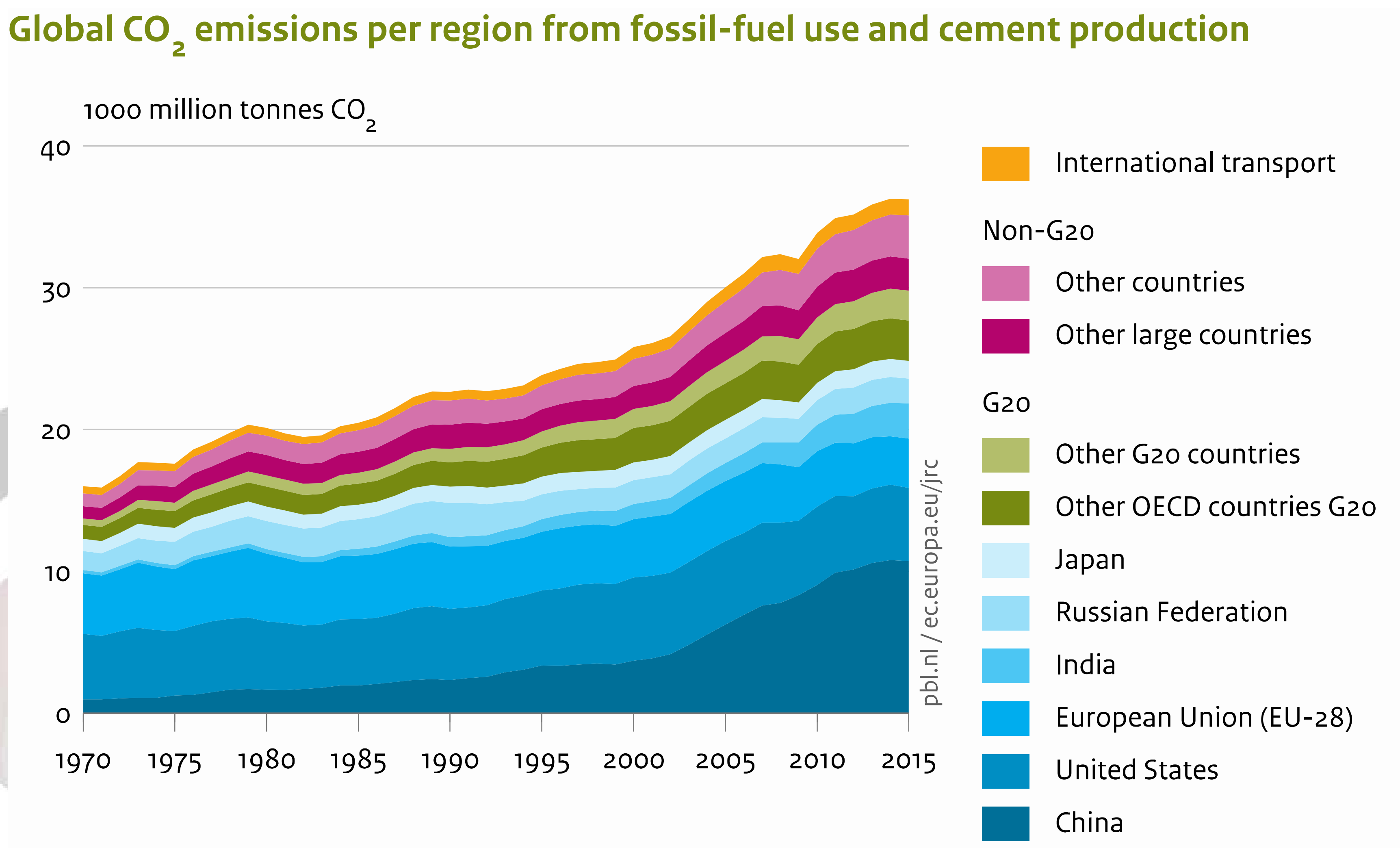
Q1. Impossible! NETs are not 'real' simply a figment of models that cannot solve otherwise

A1. It is true that most NETs are at a (very) early stage and much attention has been driven by Integrated Assessment Model (IAM) results, but they build on existing technologies and are analogous to other technologies such as CCS or biofuels

NETs emerged in IAMs because of a need to represent deferring a global peak and more rapid decline of GHG emissions compared to earlier scenarios and the corresponding need for an overshoot and decline of atmospheric GHG concentrations in scenarios but still limiting global temperature rise below 2 °C of warming

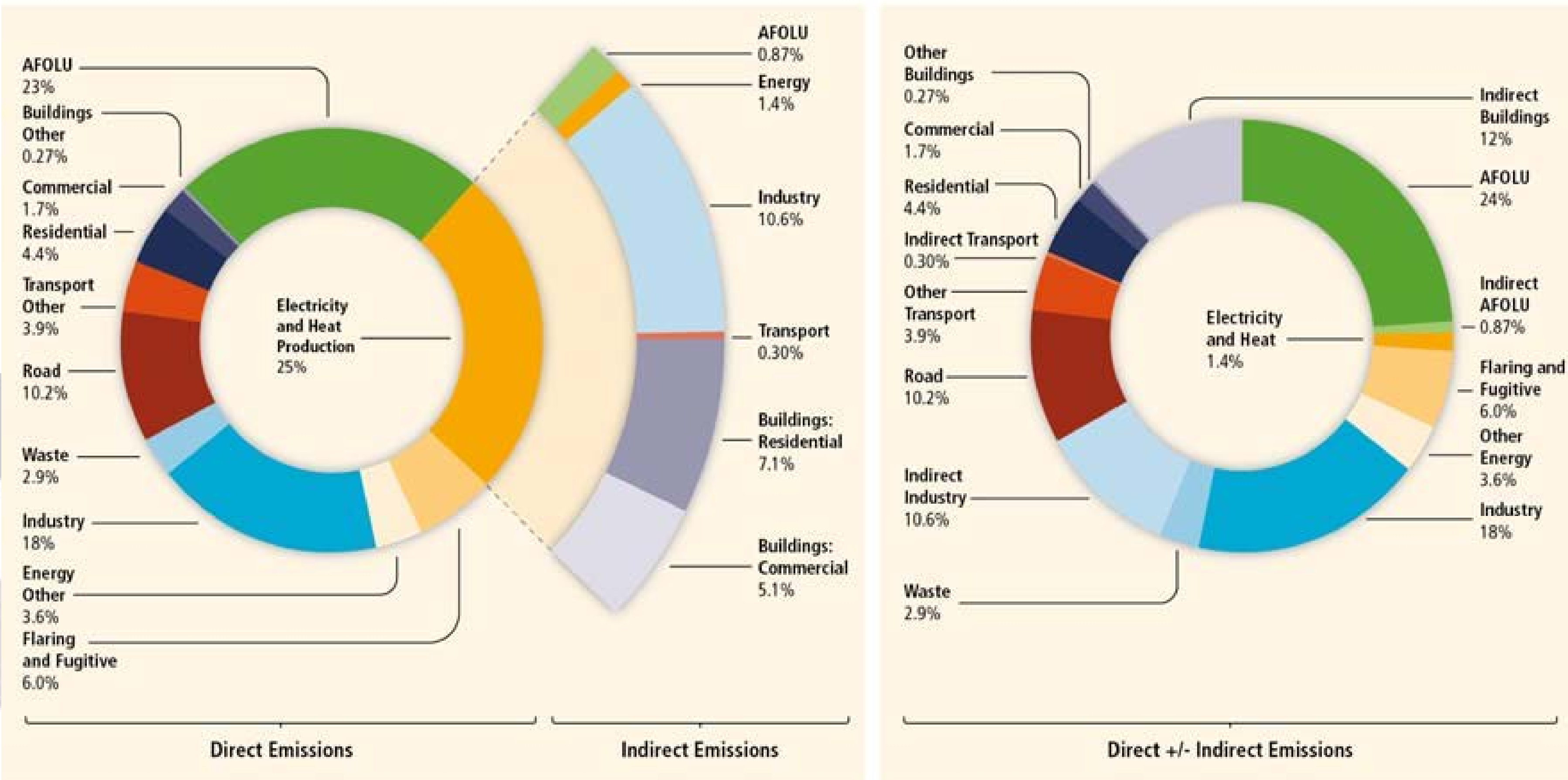
IAM studies do not address questions of feasibility of NETs, but indicate that there is a very real need for them if 1.5 °C or 2 °C are to be achieved.

Global Emissions have more than doubled since 1975



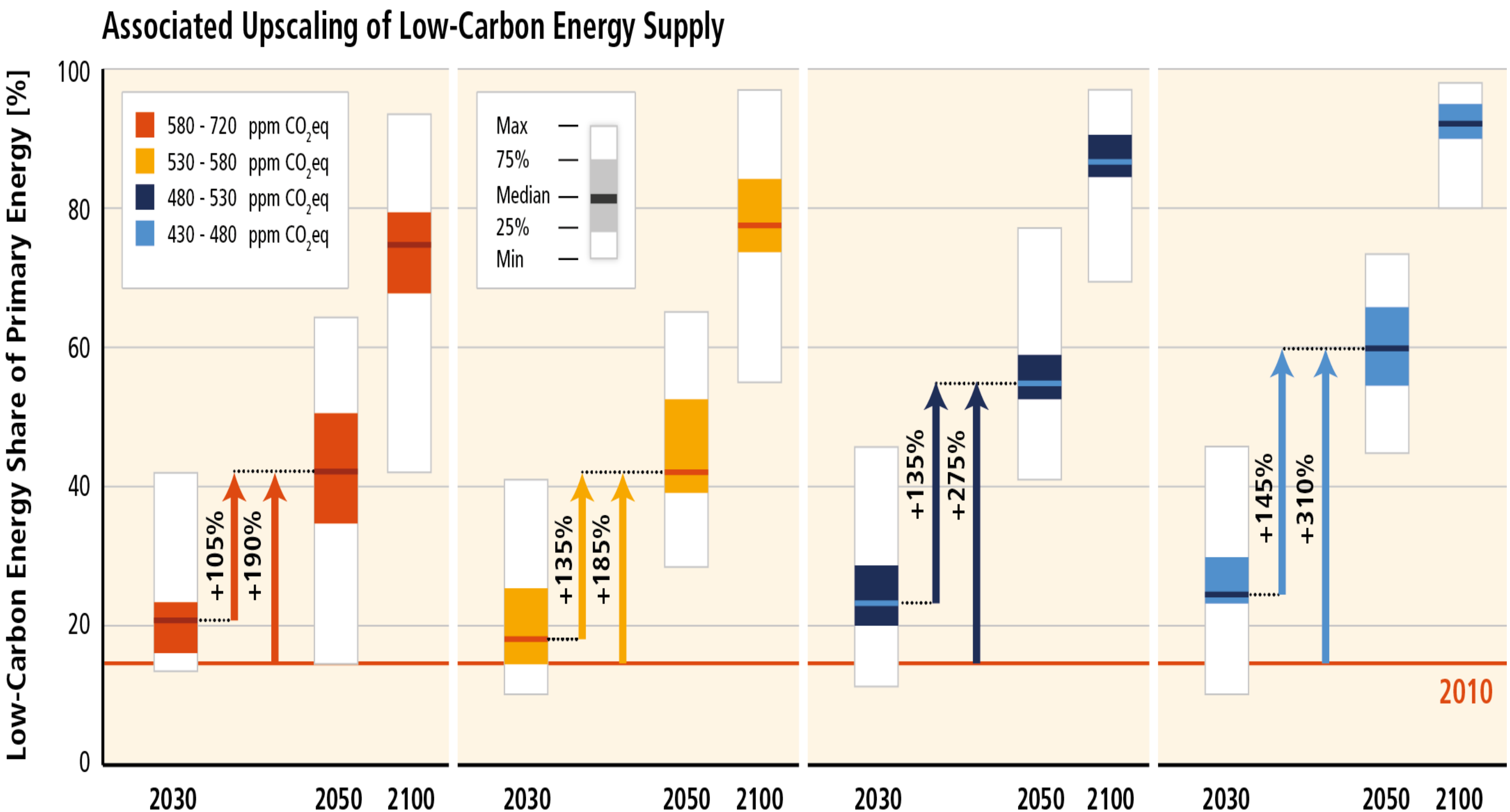
Joint Research Centre, Trends in global CO2-emissions. 2016 Report, European Commission

Emissions would need to be reduced across every sector of the economy



IPCC AR5

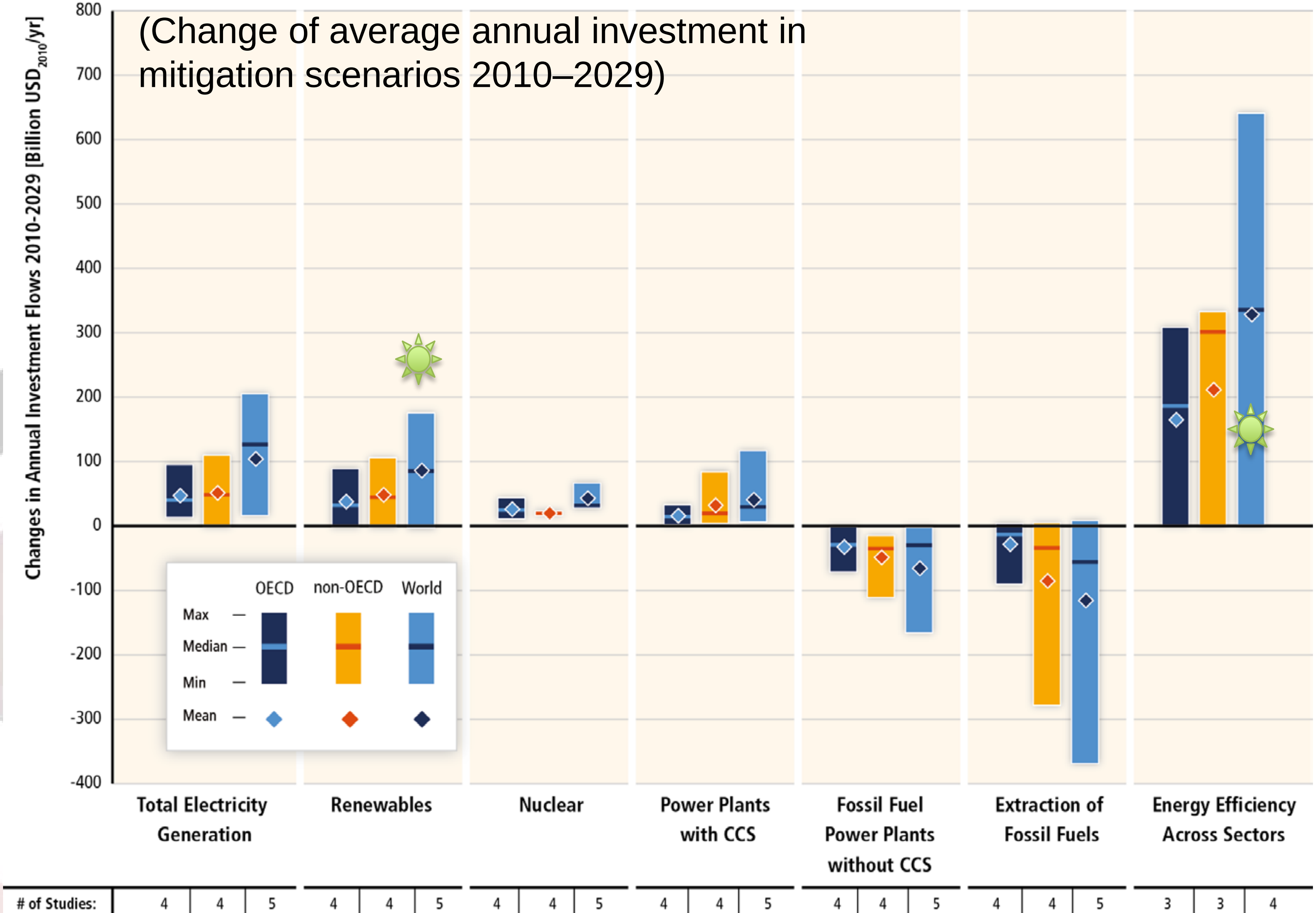
Mitigation requires major technological and institutional changes including the upscaling of low- and zero carbon energy



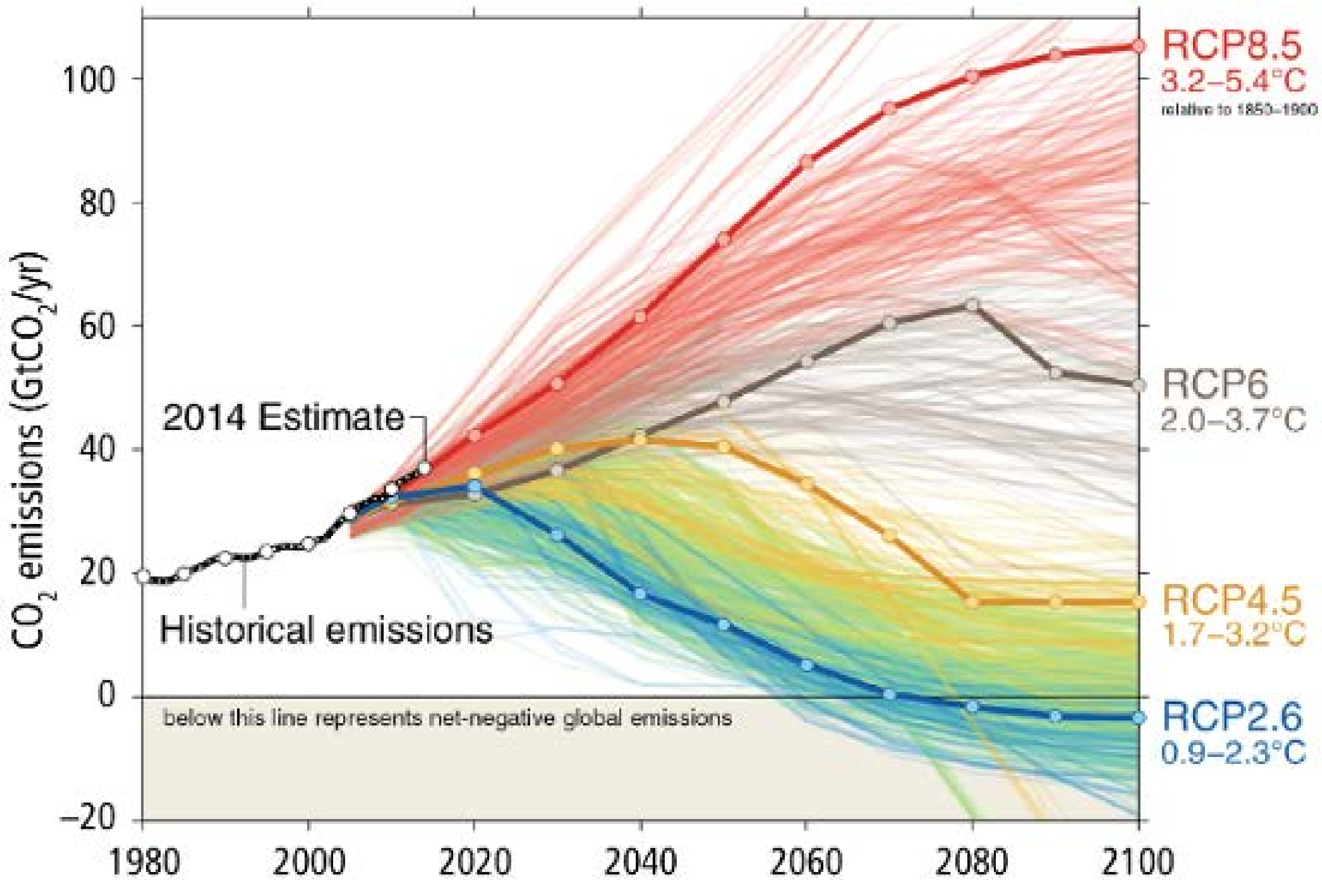
IPCC AR5

Substantial reductions in emissions would require large changes in investment patterns

(IEA global fossil fuel investment in 2013 = $1100 bn)



Paris Agreement has established the goal of 2°C with an aim towards 1.5°C, but virtually all of these scenarios require net-negative emissions



Fuss et al (2014) Betting on Negative Emissions, *Nature Climate Change*

Q2. Impossible, NETs build on CCS and CCS will never happen at scale

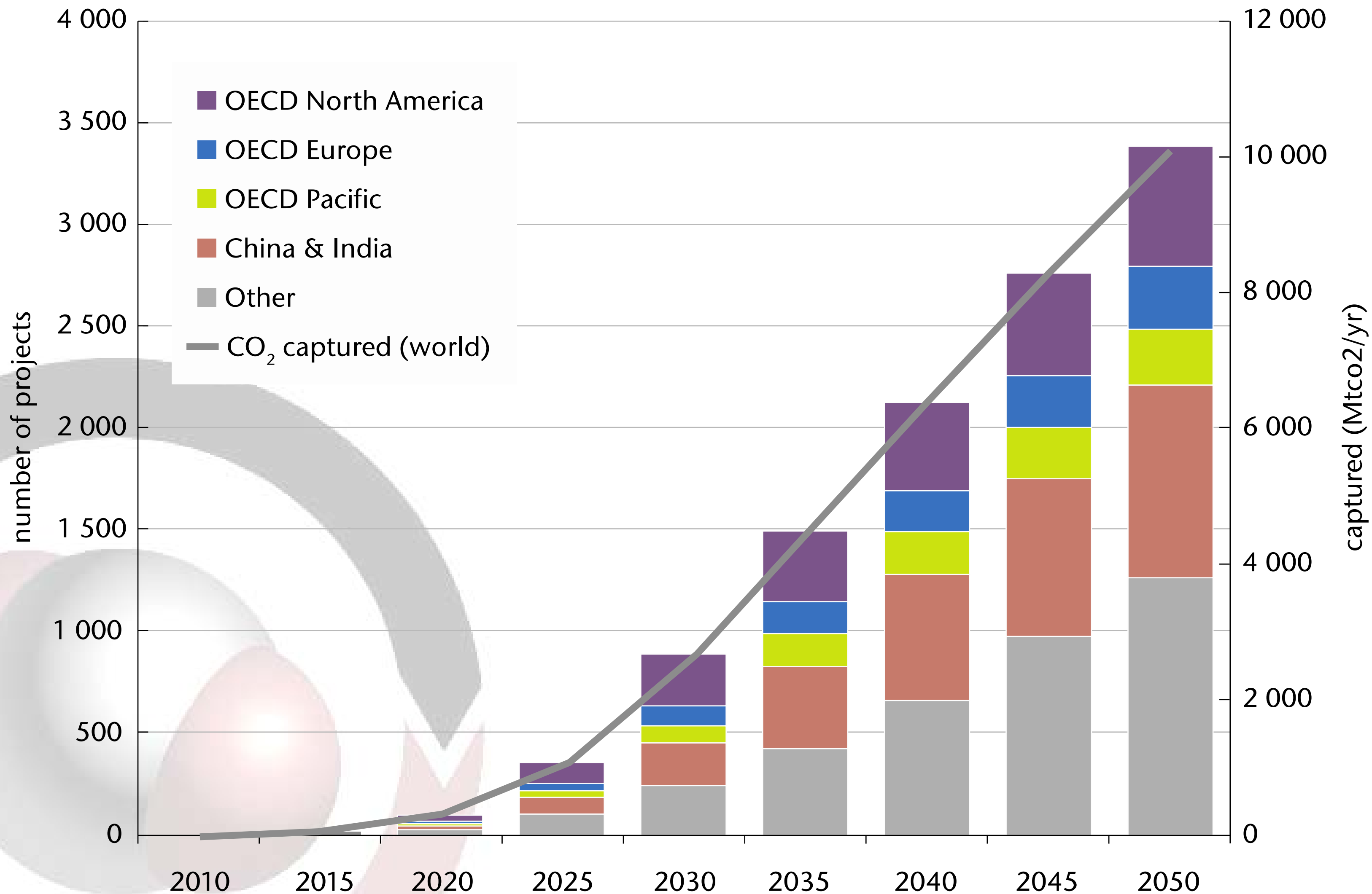
A2. Perhaps – the short history of CCS has been littered with failed efforts, but the fate of CCS is a measure of commitment to climate action and if CCS fails that indicates an inability/unwillingness of governments to take the necessary action. Major modeling studies continue to show CCS as, by far, the most important technology needed to keep costs of emissions reductions low.

Increase in NPV mitigation costs under technology limitation scenarios (2015–2100, discounted at 5% per year)

Mitigation cost increases in scenarios with limited availability of technologies[4]

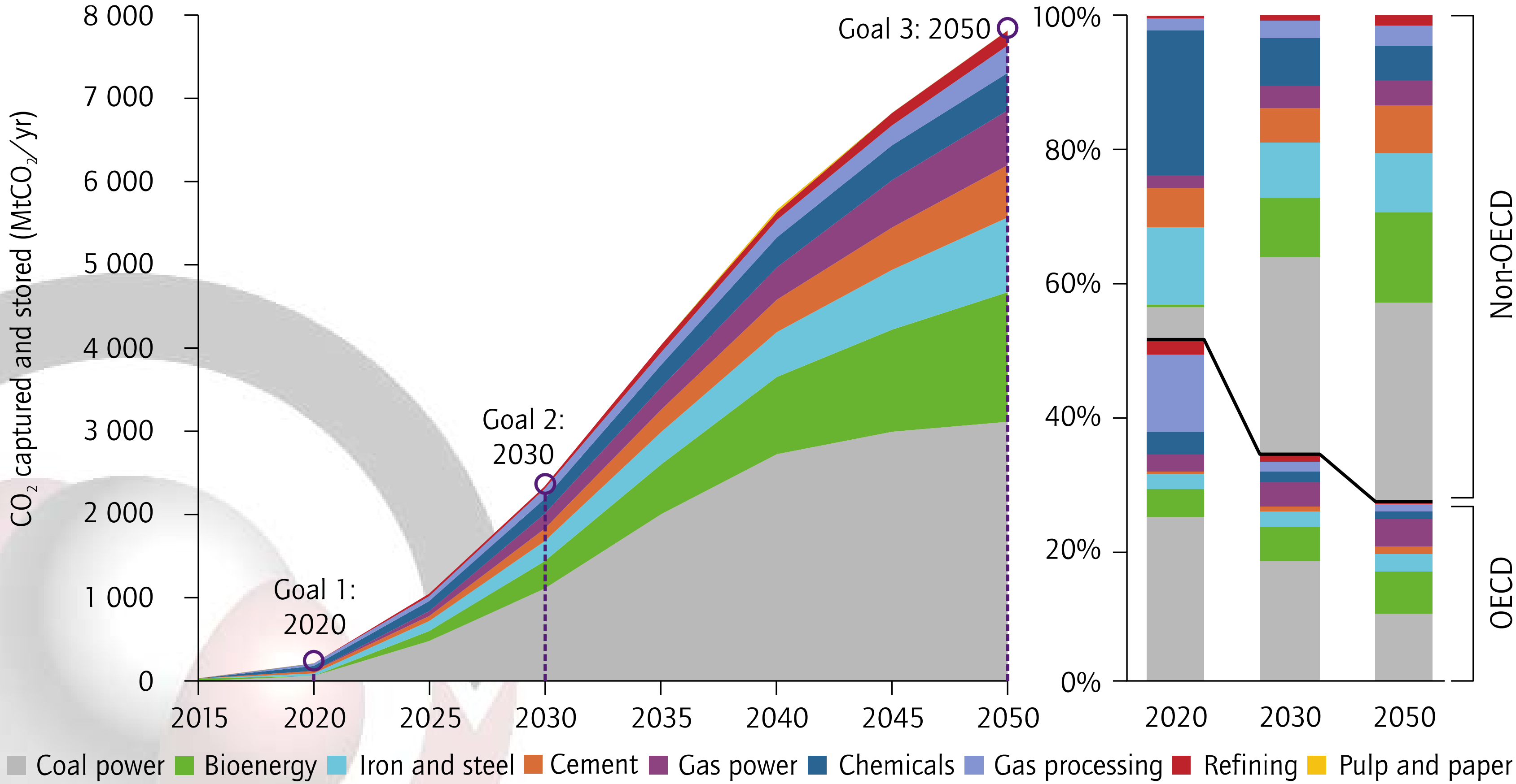
IPCC AR5 Synthesis Report

2009 IEA vision of CCS rollout



IEA Roadmap 2009

2013 Update to IEA Roadmap



Timeline in 1998

	1996	1998	2000	2002	2004	2006	2008	2010	2012	2014	2016
USA											
Canada											
Australia											
Norway		Sleipner 1 Mt CO_2/ yr									
UK											
Other											
Multinational Initiatives		1st full GHGT Conference (GHGT-4)									
Major Reports											

O Project Announced

Construction

X Cancelled

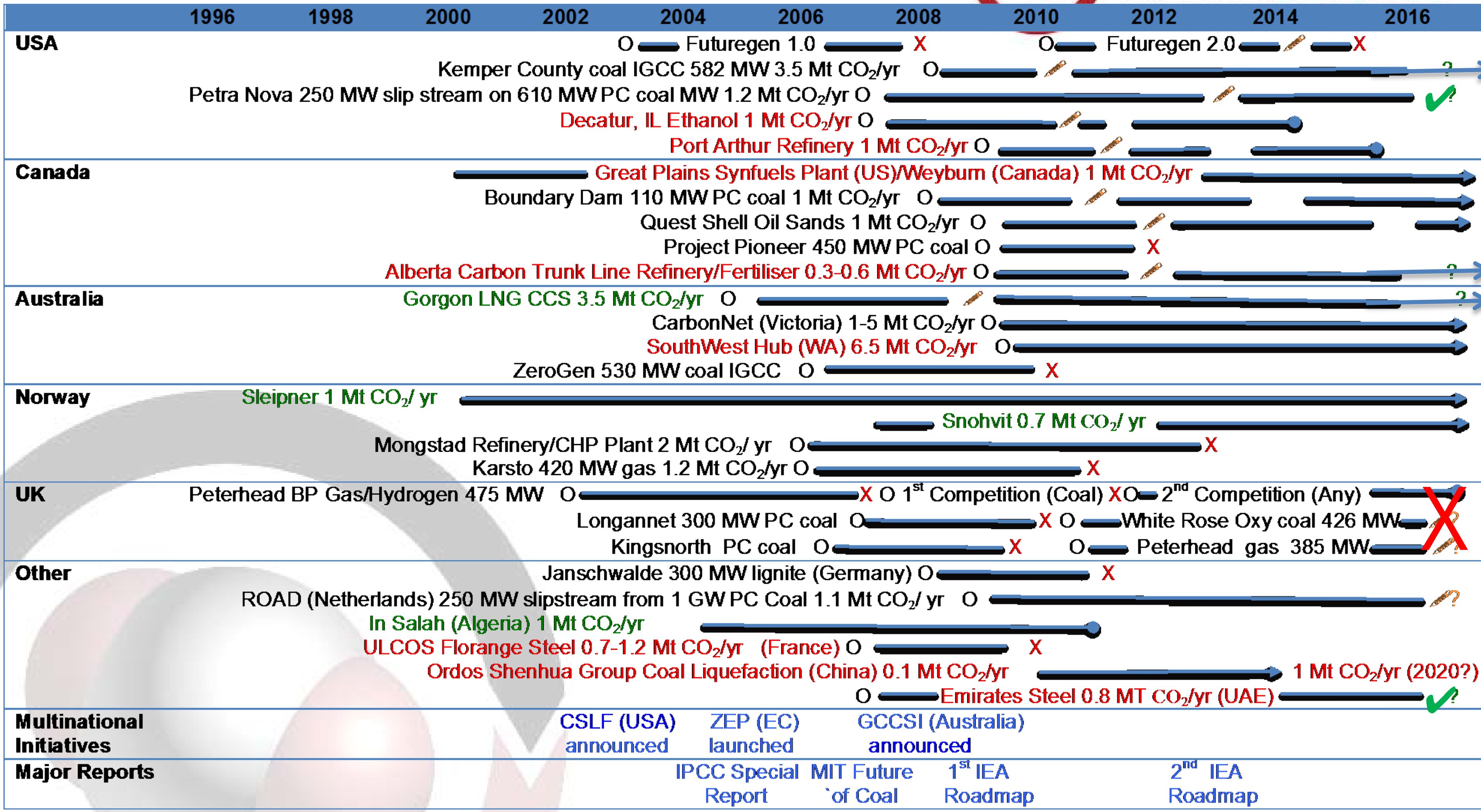
Project Operational

Gas processing projects

Power projects

Industrial projects

Timeline in late 2015 (+update)



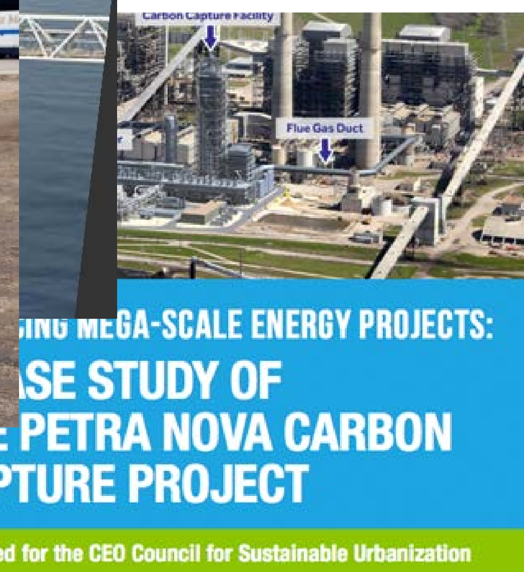
O Project Announced
Construction
X Cancelled
Project Operational

Gas processing projects
Power projects
Industrial projects

DM Reiner, Learning through a portfolio of carbon capture and storage demonstration projects, *Nature Energy* 1 (1) doi: 10.1038/nenergy.2015.11


Critics love to hate bold
projects. Like those who
The Agenda
FUTURE OF POWER
Billions over budget. FOUR years after deadline. What's gone wrong for the 'clean coal' project that's supposed to save an industry?
By DARREN SAMUELSOHN | 05/26/15 11:31 PM EDT
Learn more at:
kemperproject.org/apollo

With some notable exceptions



Committee on Climate Change

Report 'UK climate action following the Paris Agreement', October 2016.

Carbon capture and storage is very important given its potential to reduce emissions across heavy industry and the power sector, open up new decarbonisation pathways (e.g. based on hydrogen) and remove CO_2 when coupled to bioenergy. **Estimates by the Committee and by the ETI indicate that the costs of meeting the UK's 2050 target could almost double without CCS.**

Energy Technology Institute

Report 'Carbon capture and storage: Building the UK carbon capture and storage sector by 2030', 2015

A complete failure to deploy CCS would imply close to a doubling of the annual cost of carbon abatement to the UK economy from circa 1% to 2% of GDP by 2050 (or roughly an extra £1000 on annual average household bills for energy and transport services).

Why have CCS politics been so difficult in many parts of the world?

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- *Orphan/Imaginary Technology/Lack of Champions:* Unlike nuclear (or onshore wind), there are no strong opponents, but equally there are few if any advocates willing to lobby strongly since their preferred alternative is unabated fossil gen
- *Lack of policy logic:* In UK, from Peterhead (DF-1) to Peterhead (2nd UK Competition) strong logic of using competition to drive down prices rather than industrial policy as motivation
- *Guilt by Association/End of Pipe:* Championed by Bush Administration, some viewed CCS as diversionary or a white elephant, others believe the approach harkens back to an earlier conceptions of pollution control and waste disposal
- *CCS as bellwether for climate policy:* Other technologies in the energy mix can be justified without climate change -- politically, economically and commercially viable path towards a 3-4°C world

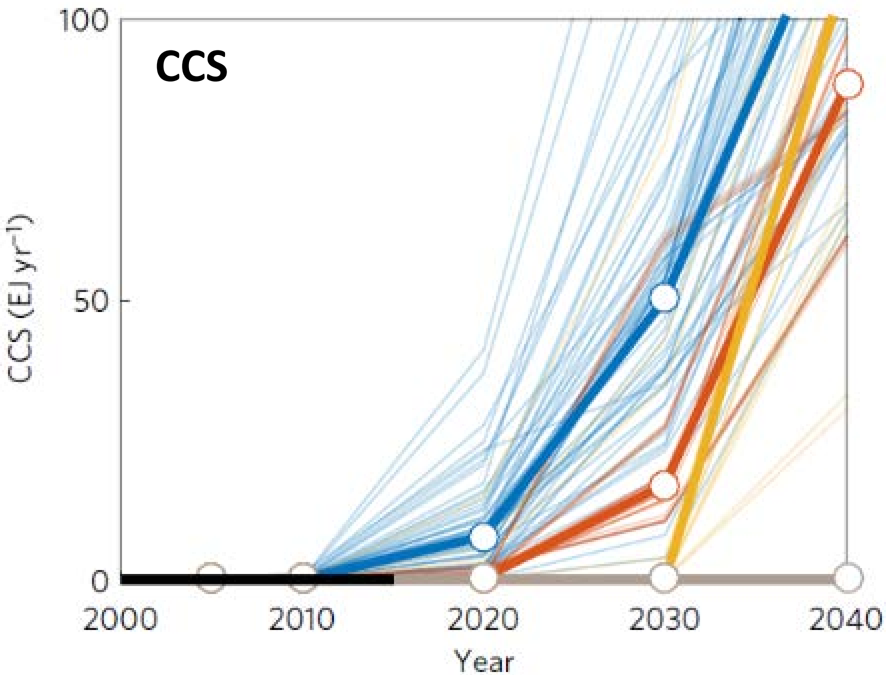
Why have CCS politics been so difficult? Part II

- *2009 Perfect Storm:* Combination of the failure of Copenhagen, fiscal blackholes, collapsing EUA price (linked to EU CCS), 'easier' Kyoto targets and no carbon price – leads to paradox of temporary upward blip in funding with no serious follow-up on horizon
- *R&D means Failure:* Demonstration means need for tolerating failures and lumpiness of full-scale CCS demos makes those failures very visible and 'expensive'
- *Need for more compelling narrative and stronger coalitions:* 'saving' coal, potential for decarbonising China, low-carbon dispatchable power, industrial CCS and net negative emissions have all been tried and either do not resonate or are insufficient in and of themselves to underpin support

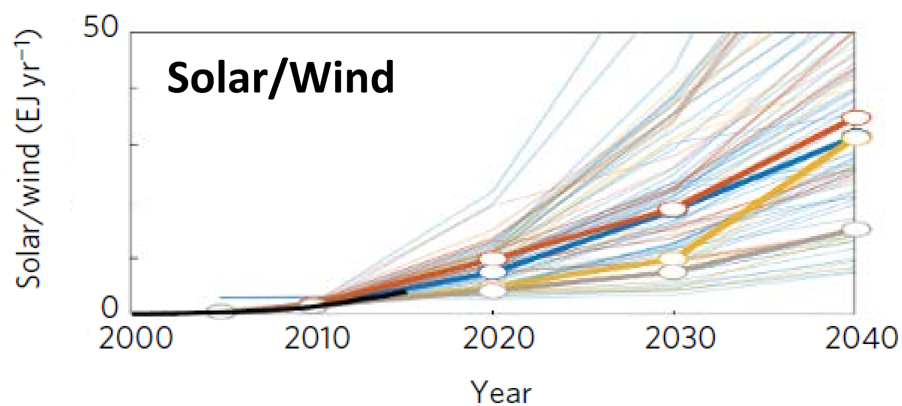
Key indicators to track current progress and future ambition of the Paris Agreement

Peters, G. P. et al. , Nature Climate Change, 2017.

… without large-scale CCS deployment, most models cannot produce emission pathways consistent with the 2^{o}C goal. ….. **a globally coordinated effort is needed to accelerate progress,** better understand the technological risks, and address social acceptability.



Historical trends and future pathways to 2040



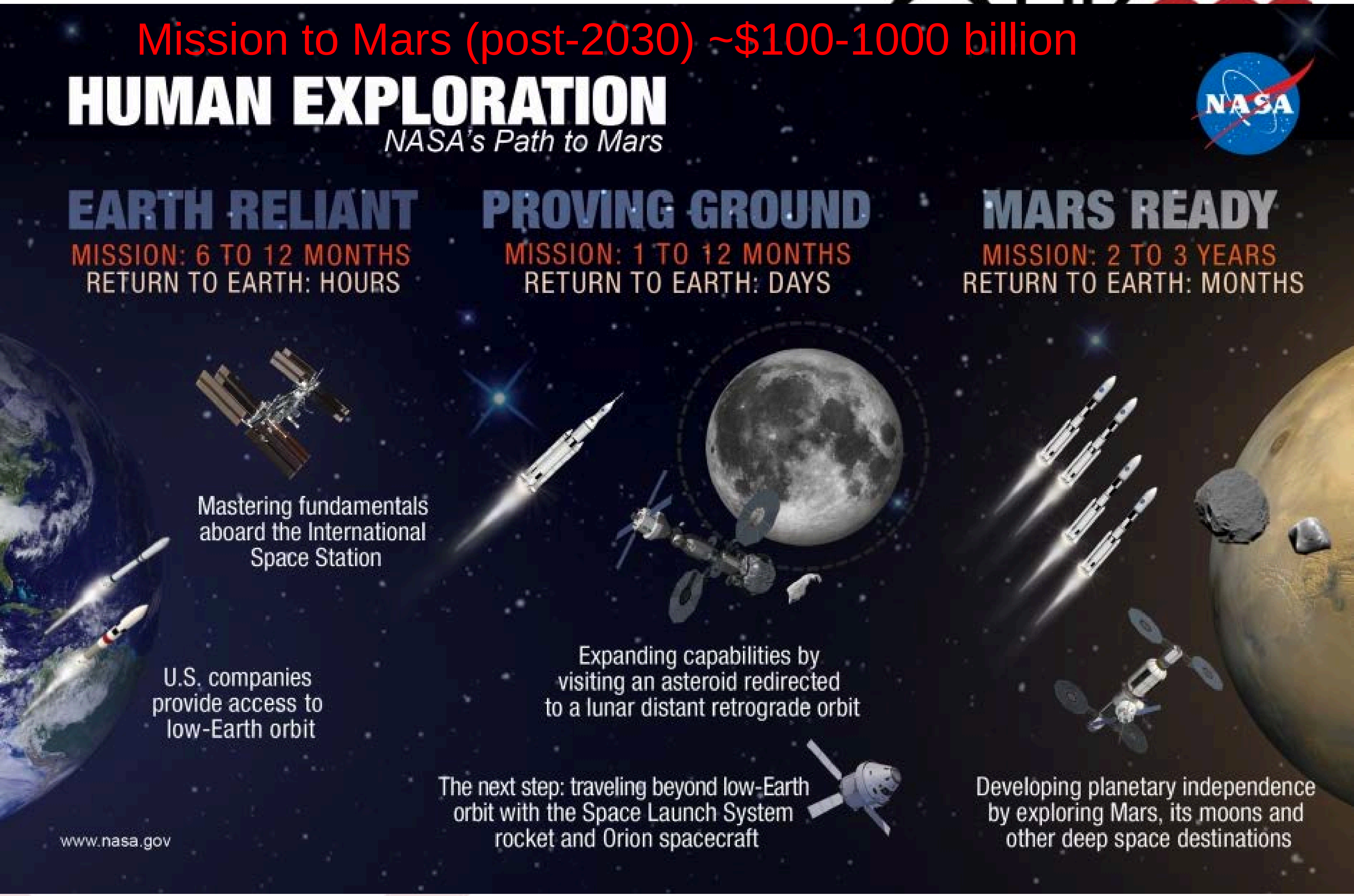
Q3. Impossible, NETs will be far too expensive

A3. We can do lots of things, so that in itself is not a show stopper

- Many are very, very expensive (incl. some white elephants)
- Some are desirable (but perhaps inefficient)
- Others just plain stupid but politically appealing
- Tend to see a greater willingness for very expensive investments when it is viewed as essential (for national defense, stability of financial system) or of fundamental or deep-seated discovery (space travel)
- For energy, the hope/expectation is that initial high costs will decline over time with learning or build on an expectation of a certain energy economy (e.g., high oil prices)


International Space Station (1998) ~$150 billion

Mission to Mars (post-2030) ~$100-1000 billion



F-35 Joint Strike Fighter ~2500 to be produced at overall cost of $1.3 trillion

London Array (2014) 175 turbine 630 MW offshore wind farm construction cost $1.8 bn

Great Plains Synfuels Plant (2.1bn in 1984$ or $4.9bn today)

Kashagan:

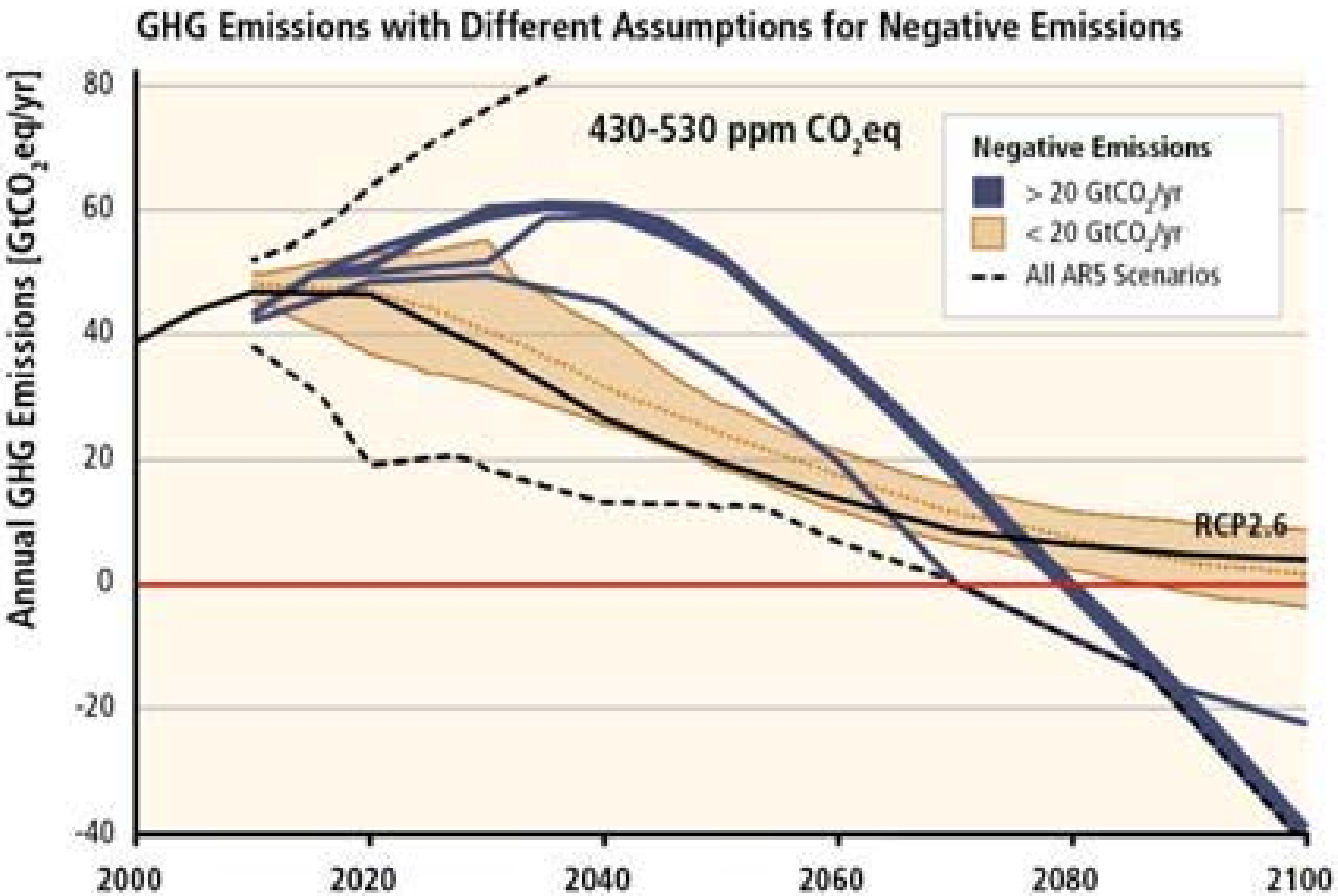
Costs rise from $10bn to >50bn start date from 2005 to 2016 (forced to shut twice in 2013 after brief operation due to pipeline leaks)

Q4. Impossible, or even worse, undesirable, NETs pose a moral hazard

A4. Perhaps, but the real question is whether NETs are a Plan Z (try everything else first) or a Plan B or C that should stand at the ready (break glass in case of emergency)

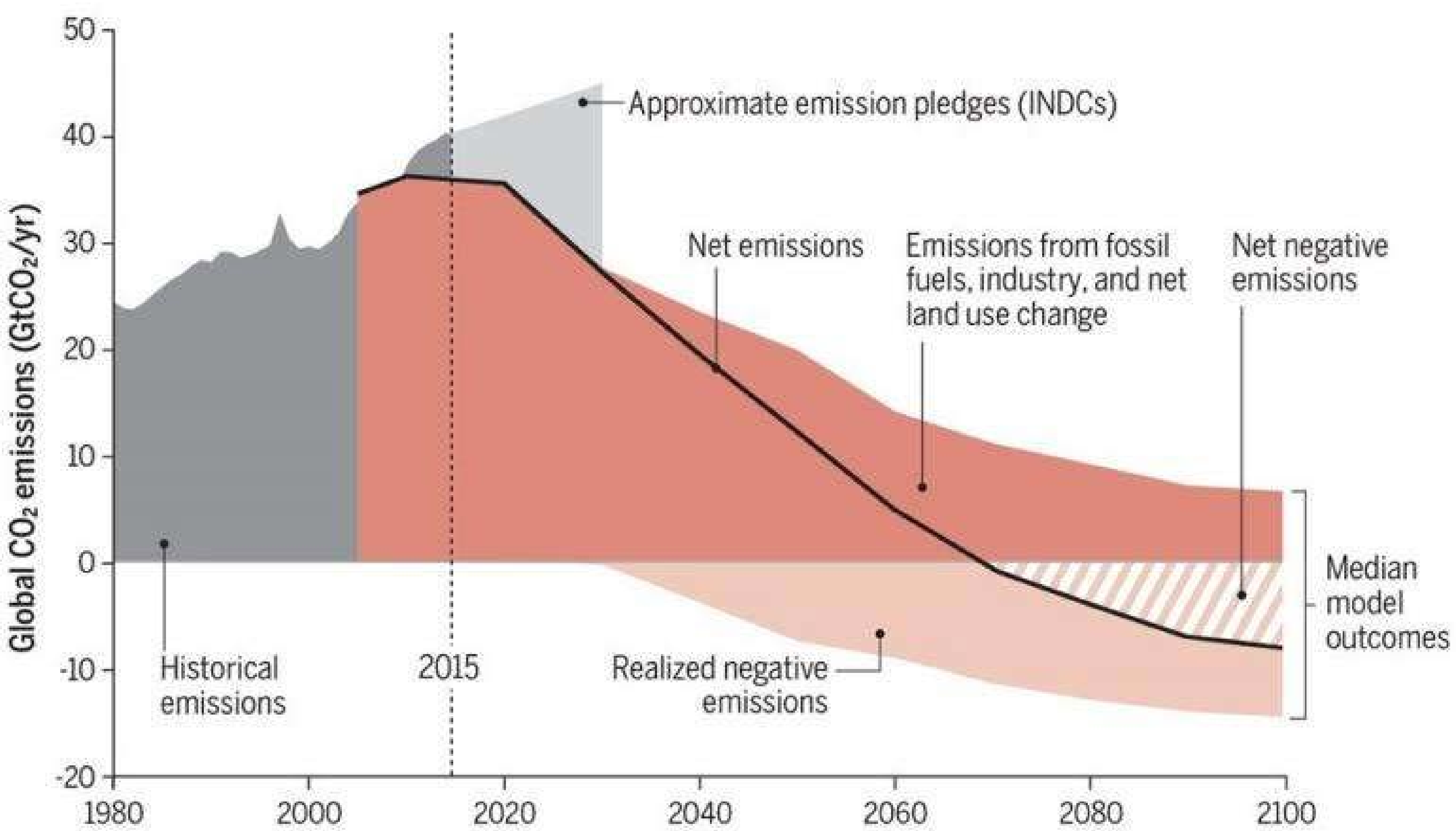
- There are many Plan Z options, notably some of the geoengineering options including Solar Radiation Management (SRM) (e.g., firing aerosols into the lower atmosphere) or NETs such as large-scale ocean liming.
- Arguably, these options simply replace one massive global planetary experiment (pouring 10s of gigatons of GHGs into the atmosphere) with others, whose implications are even less well understood

Implications of Incorporating Significant ($>20GtCO_2$) Negative Emissions



IPCC AR5

An updated view on NETs



Anderson & Peters (2016)

Plan Z:
NETs produce Moral Hazard

"The beguiling appeal of relying on future negative emission technologies (NETs) is that they delay the need for stringent and politically challenging polices today – they pass the buck for reducing carbon on to future generations… But if these Dr. Strangelove technologies fail to deliver at the planetary scale envisaged, our own children will be forced to endure the consequences of rapidly rising temperatures and a highly unstable climate."
Kevin Anderson & Glen Peters, The trouble with negative emissions, *Science* 14 Oct 2016: 354(6309): 182-183.

To believe there is a genuine moral hazard from NETs would require a belief that we would have carried out a massive and more costly decarbonisation programme were it not for the allure of NETs but now will not.

or Plan B: A realistic path to avoiding Overshoot and Collapse

- Realistically, given political and social inertia and the inevitable slow rollout of new technologies, it is difficult to see how we can avoid an overshoot if we wanted to meet a 2C target

- Even on the off chance we decide we did want to deploy these geoengineering technologies, we are in no position to know how they would operate in practice. There is a strong argument favouring an extensive programme of research to find out if these are even viable options as a Plan B/Z

- The key question then is whether we want to prioritise the targets above all else and single-mindedly seek to meet a 2 (or 1.5) C target or whether to focus on reducing emissions as quickly as possible using more 'acceptable' technologies

The Economist

Global warming

Another week, another report

The IPCC still thinks it might be possible to hit the emissions target by tripling, to 80%, the share of low-carbon energy sources, such as solar, wind and nuclear power, used in electricity generation. It reckons this would require investment in such energy to go up by $147 billion a year until 2030 (and for investment in conventional carbon-producing power generation to be cut by $30 billion a year). In total, the panel says, the world could keep carbon concentrations to the requisite level by actions that would reduce annual economic growth by a mere 0.06 percentage points in 2100.

These numbers look preposterous. Germany and Spain have gone further than most in using public subsidies to boost the share of renewable energy (though to nothing like 80%) and their bills have been enormous: 0.6% of GDP a year in Germany and 0.8% in Spain. The costs of emission-reduction measures have routinely proved much higher than expected.

Moreover, the assumptions used to calculate long-term costs in the models are, as Robert Pindyck of the National Bureau of Economic Research, in Cambridge, Massachusetts, put it, “completely made up”. In such circumstances, estimates of the costs and benefits of climate change in 2100 are next to useless. Of the IPCC’s three recent reports, the first two (on the natural science and on adapting to global warming) were valuable. This one isn’t.

COMMENT

Bold simplicity must now face reality. Politically and scientifically, the 2 °C goal is wrong-headed. Politically, it has allowed some governments to pretend that they are taking serious action to mitigate global warming, when in reality they have achieved almost nothing. Scientifically, there are better ways to measure the stress that humans are placing on the climate system than the growth of average global surface temperature — which has stalled since 1998 and is poorly coupled to entities that governments and companies can control directly1.

Failure to set scientifically meaningful goals makes it hard for scientists and politicians to explain how big investments in climate protection will deliver tangible results. Some of the backlash from 'denialists' is partly rooted in policy-makers' obsession with global temperatures that do not actually move in lockstep with the real dangers of climate change.

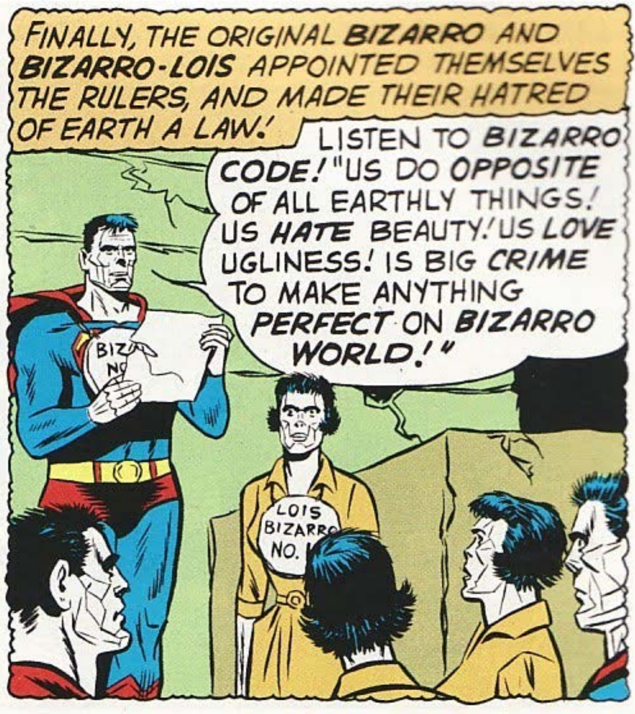
Q5. Impossible, or even worse, undesirable, NETs will result in a Bizarro World that will undermine efforts at energy savings

A5. Perhaps here more than elsewhere, we are in uncharted waters and much more work needs to be done to understand the change (in sign, not just in magnitude) that will be produced by wide-scale deployment of NETs.

A full-scale NET world could turn the logic of energy savings on its head, but for NETs to be rolled out, decisions still need to made at the margin in a world of PETs (positive emissions technologies)!

NET World = Bizarro World?

- NET World Policy-maker: Encourage greater energy use since that reduces emissions faster
- NET World Engineer: Build less efficient plants since that yields higher net negative production
- NET World Green Architect: Build bigger houses since more green cement sucks up more CO2
- NET World Environmentalist:
  - Consume, consume, consume…



Q6. Impossible, NETs are a political dead end that will compete with food crops

A6. NETs do pose an enormous challenge in terms of imagining how there would be sufficient land to accommodate the fuels/afforestation needed for NETs and feed a wealthier global population of 10bn in 2050, but we do have a strong track record in terms of agricultural producitivity

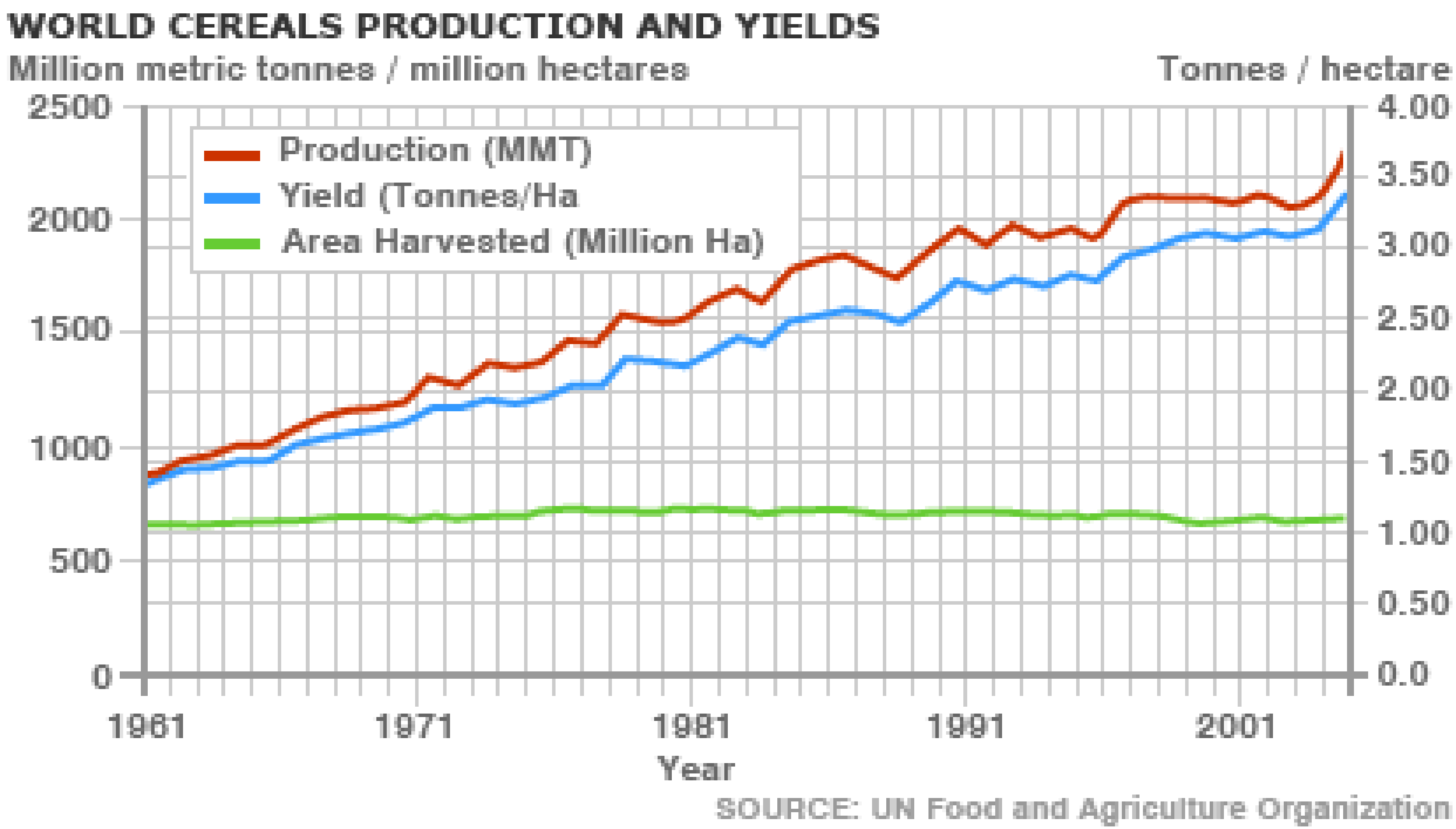
- The Green Revolution allowed cereals crop yields to double between 1965 and 2000
- There are major efforts underway to produce fuel crops on marginal lands and second generation crops for both food and fuel using biotechnology

Fuel


OH, NO! YOU CAN'T EAT THIS! THIS IS TO MAKE ETHANOL SO I CAN POWER MY SUV!
CORN
BIOFUELS
THE WEST


NO, BUT I CAN OFFER YOU A GALLON OF ETHANOL!

Impact of the Green Revolution



Many Next Steps:
Our small part in the puzzle

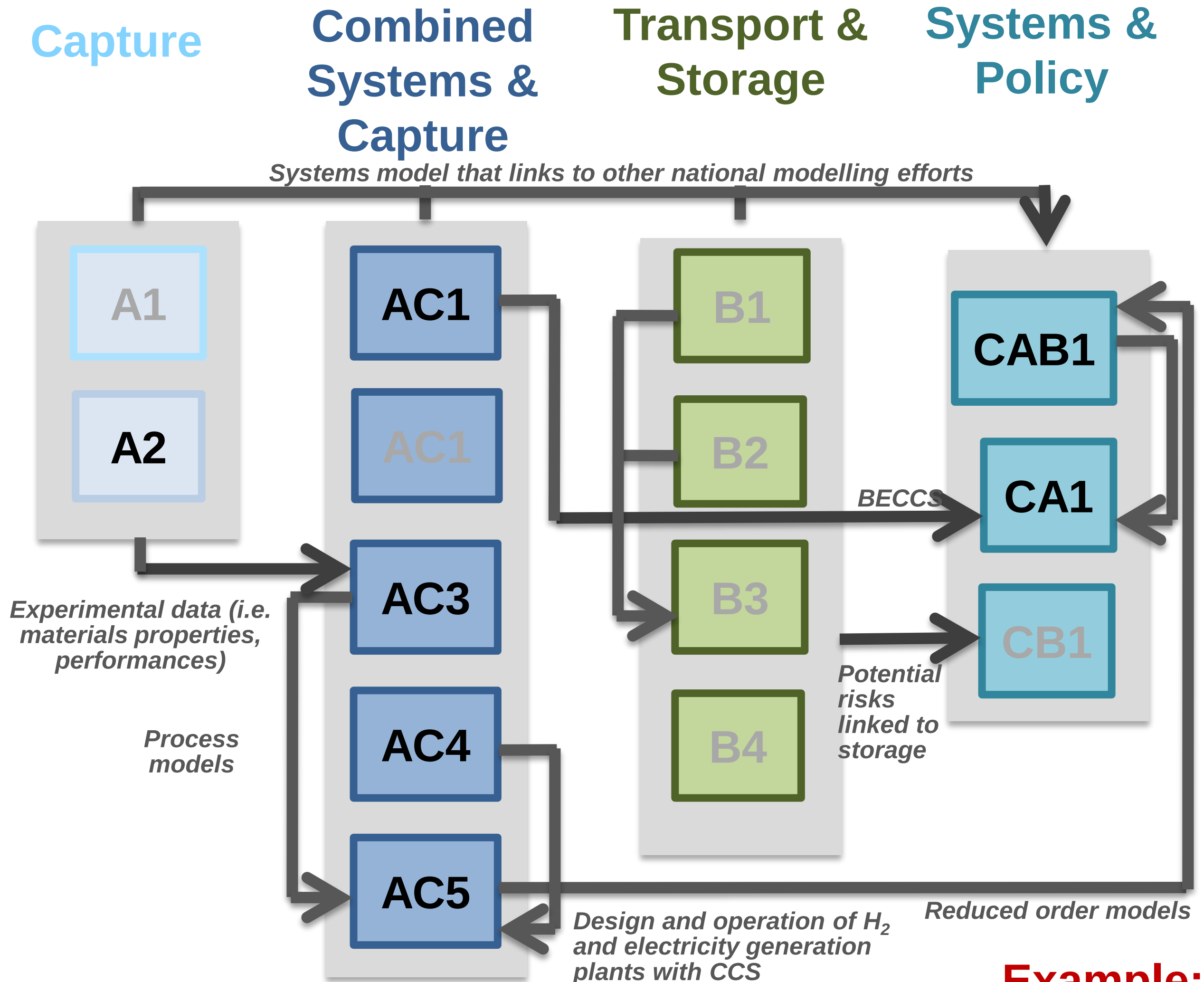
- 12 April -- UK Research Councils announces £6.1m for renewal of UK CCS Research Centre for 2017-22

https://ukccsrc.ac.uk/ukccsrc-announces-funding-next-five-years

- 20 April -- UK Research Councils announces £8.6m UK research programme on greenhouse gas removal

http://www.nerc.ac.uk/press/releases/2017/09-greenhousegas/

UKCCSRC 2017 Integrated Research



Example: BECCS

NERC-funded GGR projects

- Four multi-institute consortium projects:
  - Soils research to deliver greenhouse gas removals and abatement technologies
  - Feasibility of afforestation and biomass energy with carbon capture storage for greenhouse gas removal.
  - Releasing divalent cations to sequester carbon on land and sea.
  - Comparative assessment and region-specific optimisation of greenhouse gas removal
- Seven specific projects on GGR & (i) land sector; (ii) iron and steel industry; (iii) mitigation deterrence; (iv) consequential LCA; (v) metrics for nature; (vi) methane removal; (vii) Co-delivery of food and climate regulation

Comments? Thoughts? Additional Impossibilities? Undesirables? Solutions?

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