Cumulative carbon and its implications

What they could agree in Paris…

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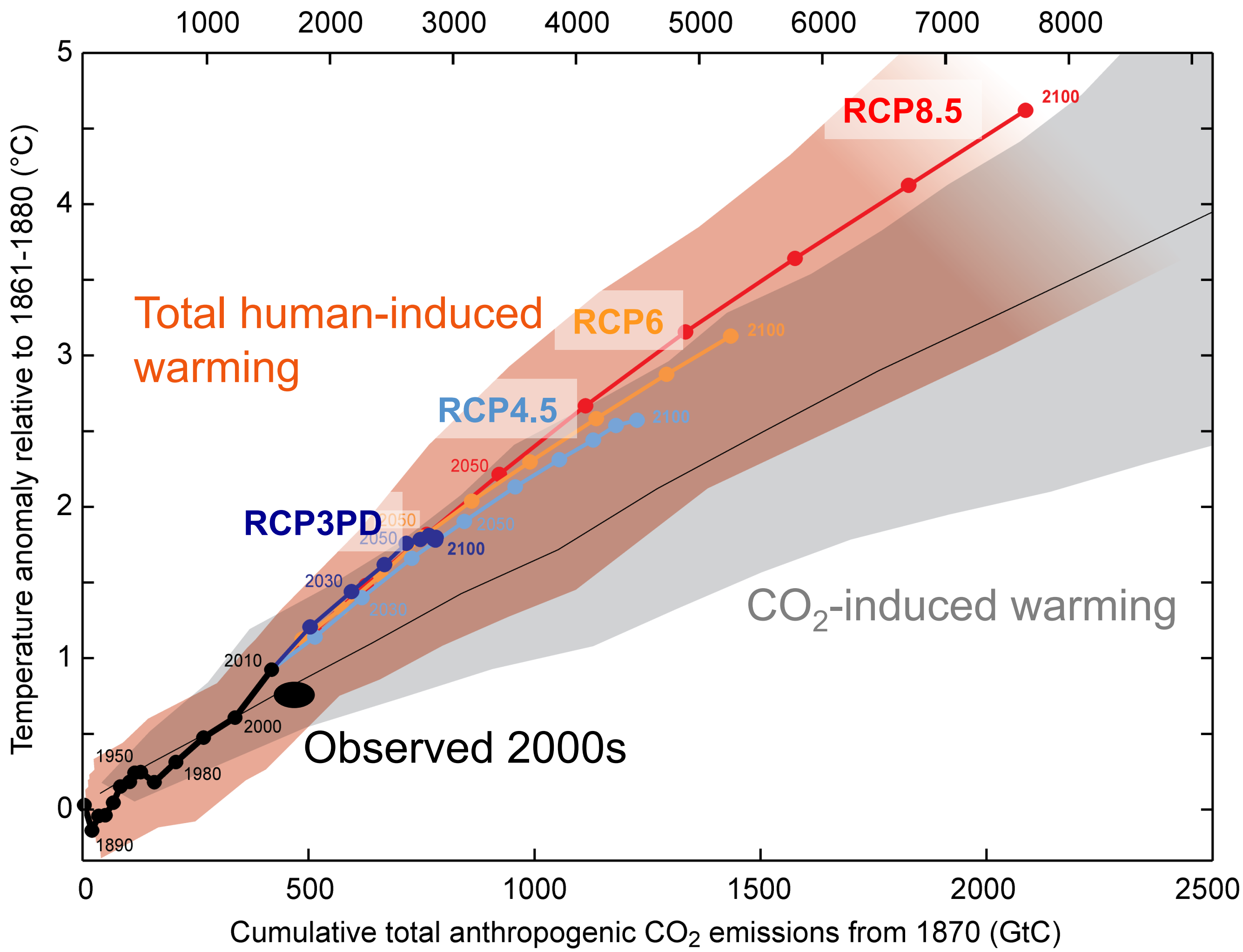
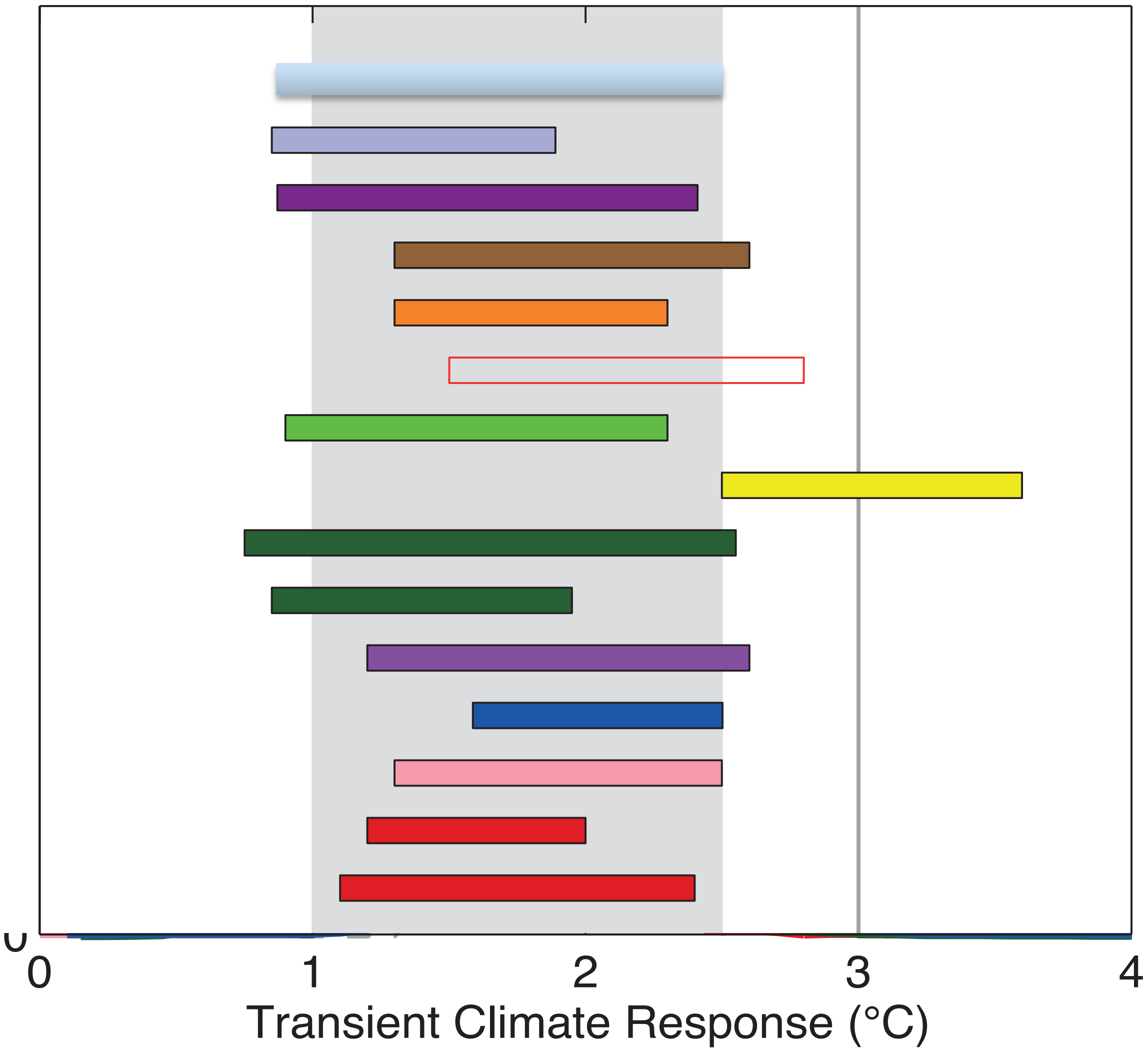
Cumulative emissions of CO_2 largely determine global mean surface warming by the late 21st century and beyond



IPCC WGI SPM Fig. 10

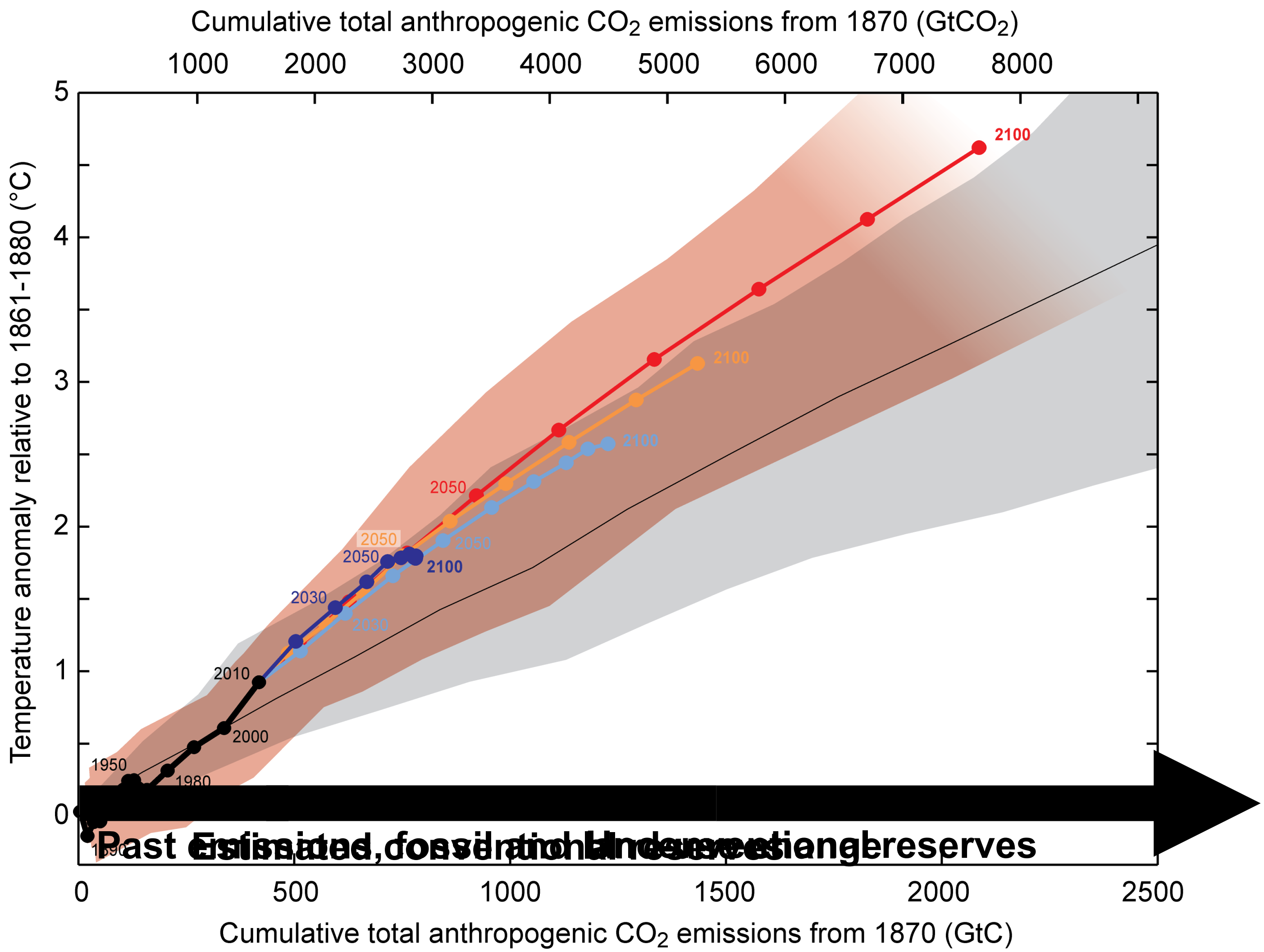
High level of agreement on the global-scale warming response to rising greenhouse gas levels



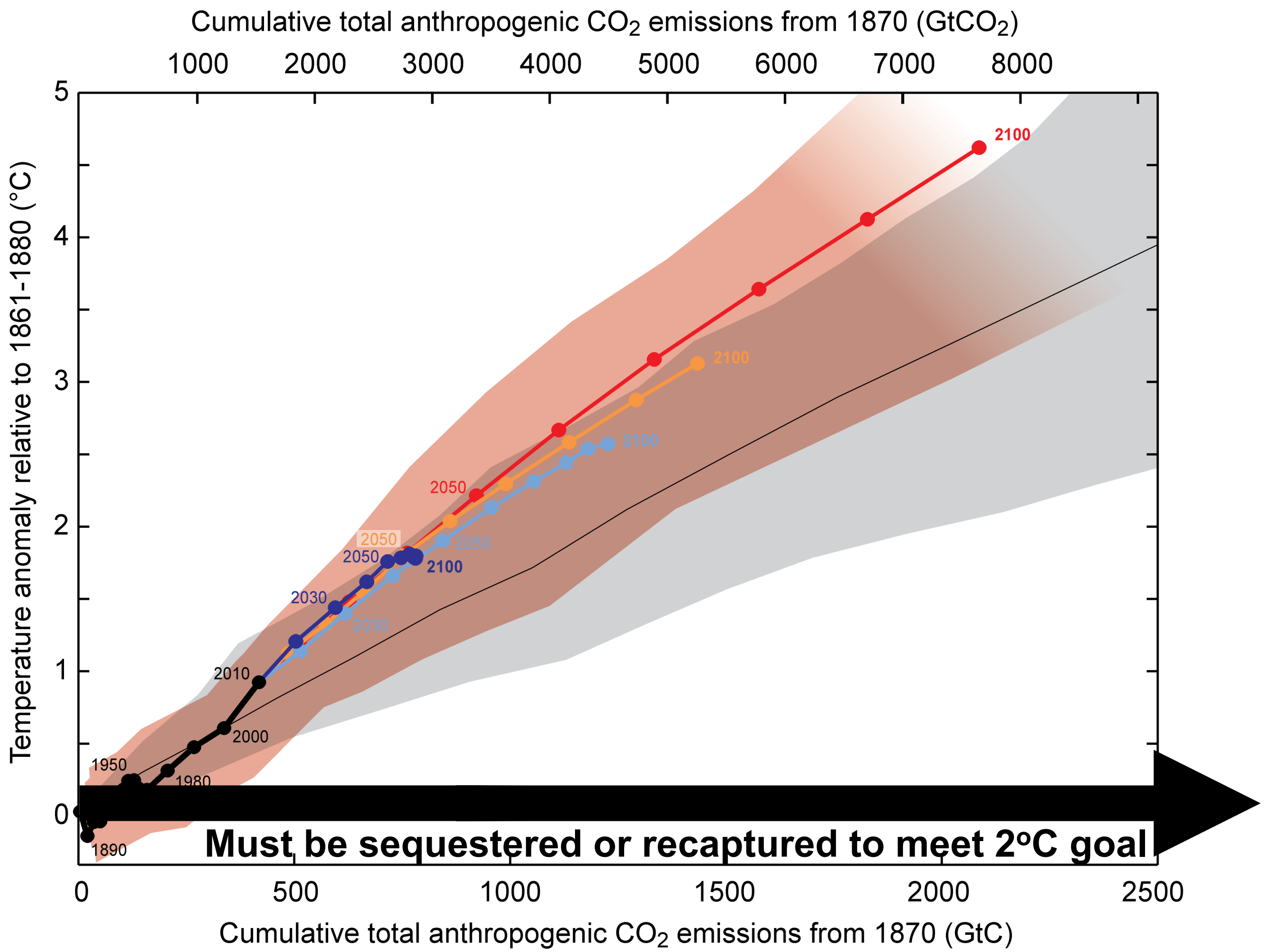
5-95% range from Lewis and Curry, 2014

5-95% ranges on Transient Climate Response from various studies Fig. TS.TFE6.2

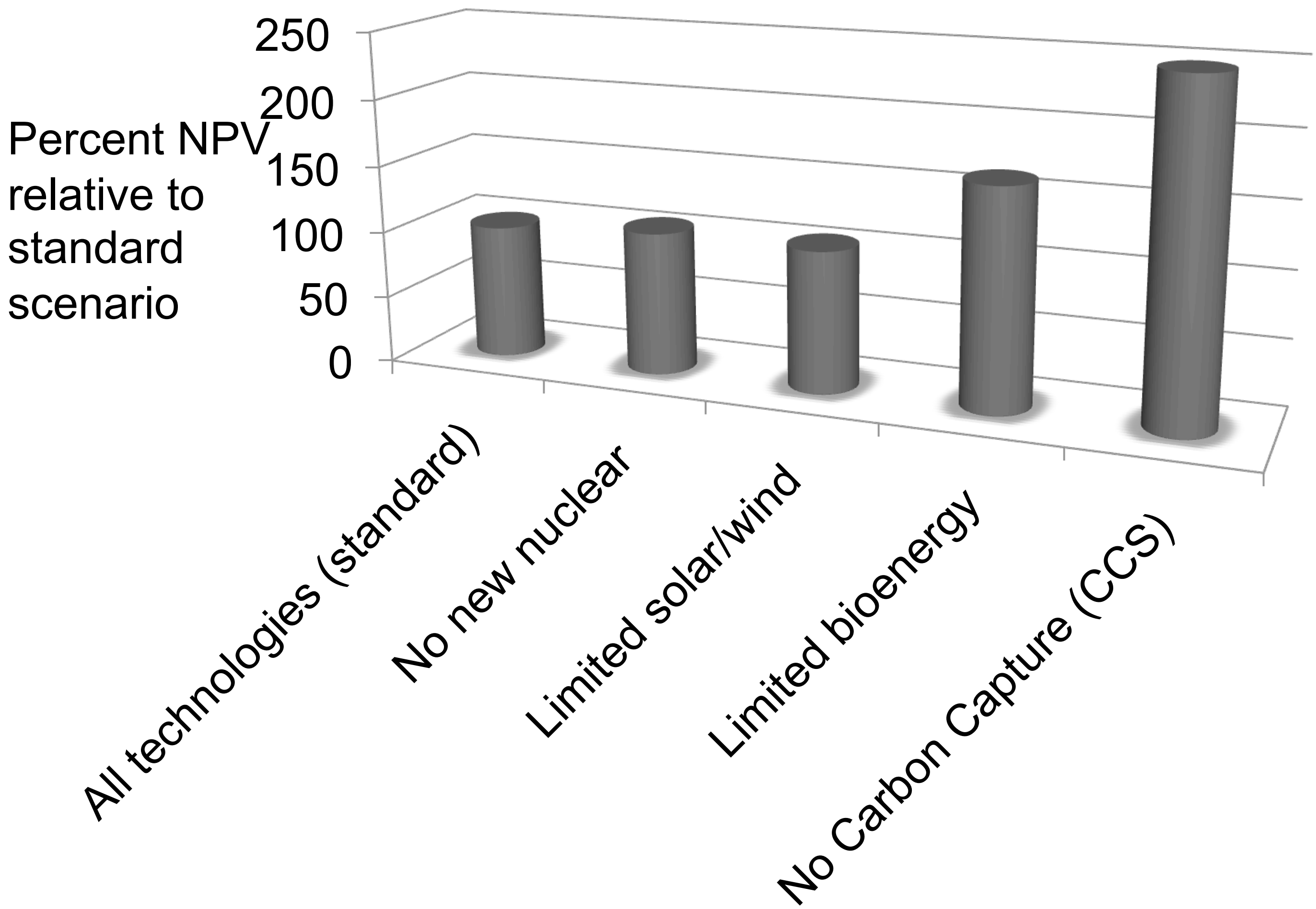
Cumulative emissions and fossil carbon reserves



Cumulative emissions and fossil carbon reserves

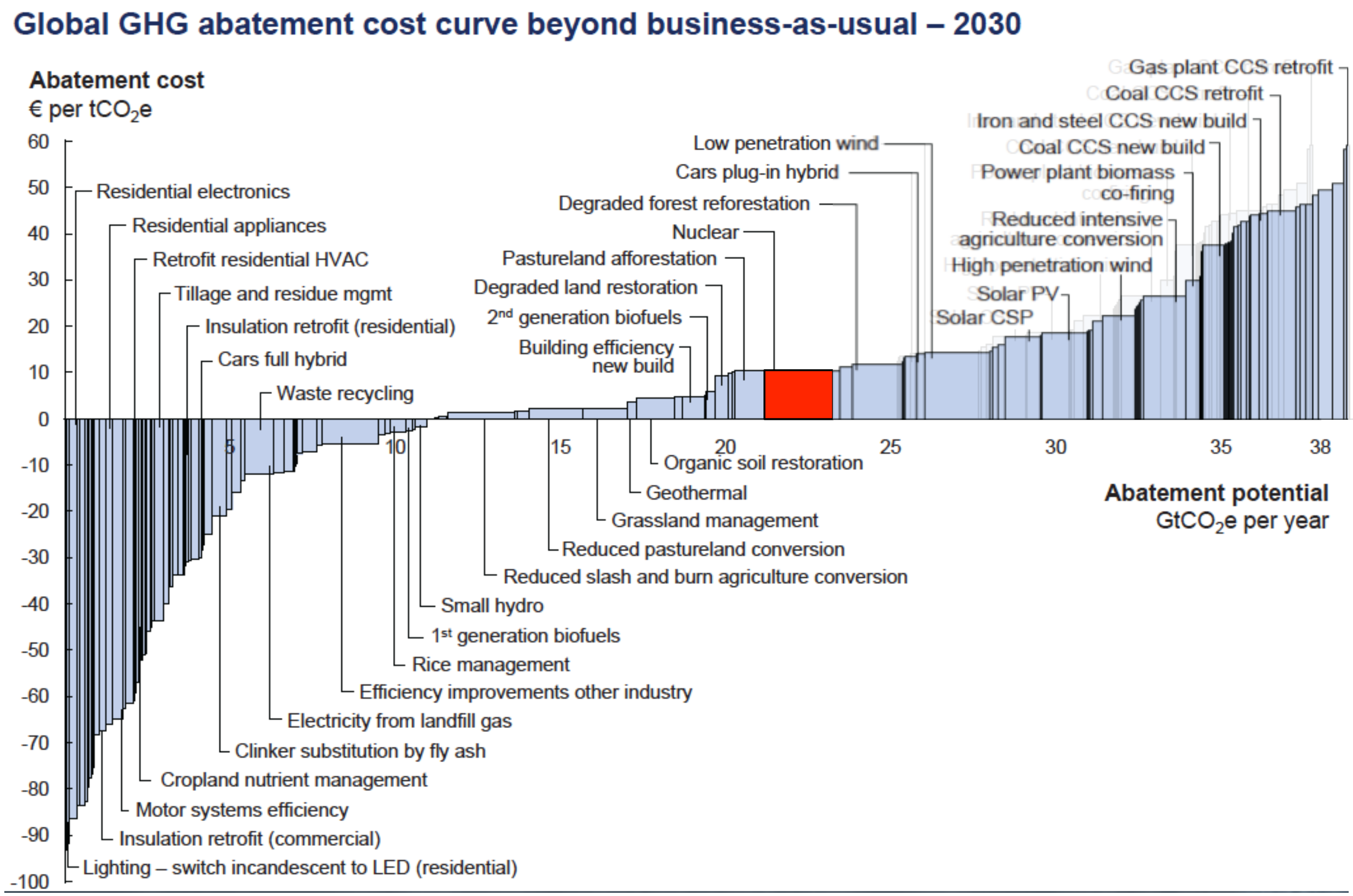


Cost of mitigation scenarios likely to meet the 2°C goal



Adapted from IPCC WGIII Fig. 6.24

Why is CCS so important?



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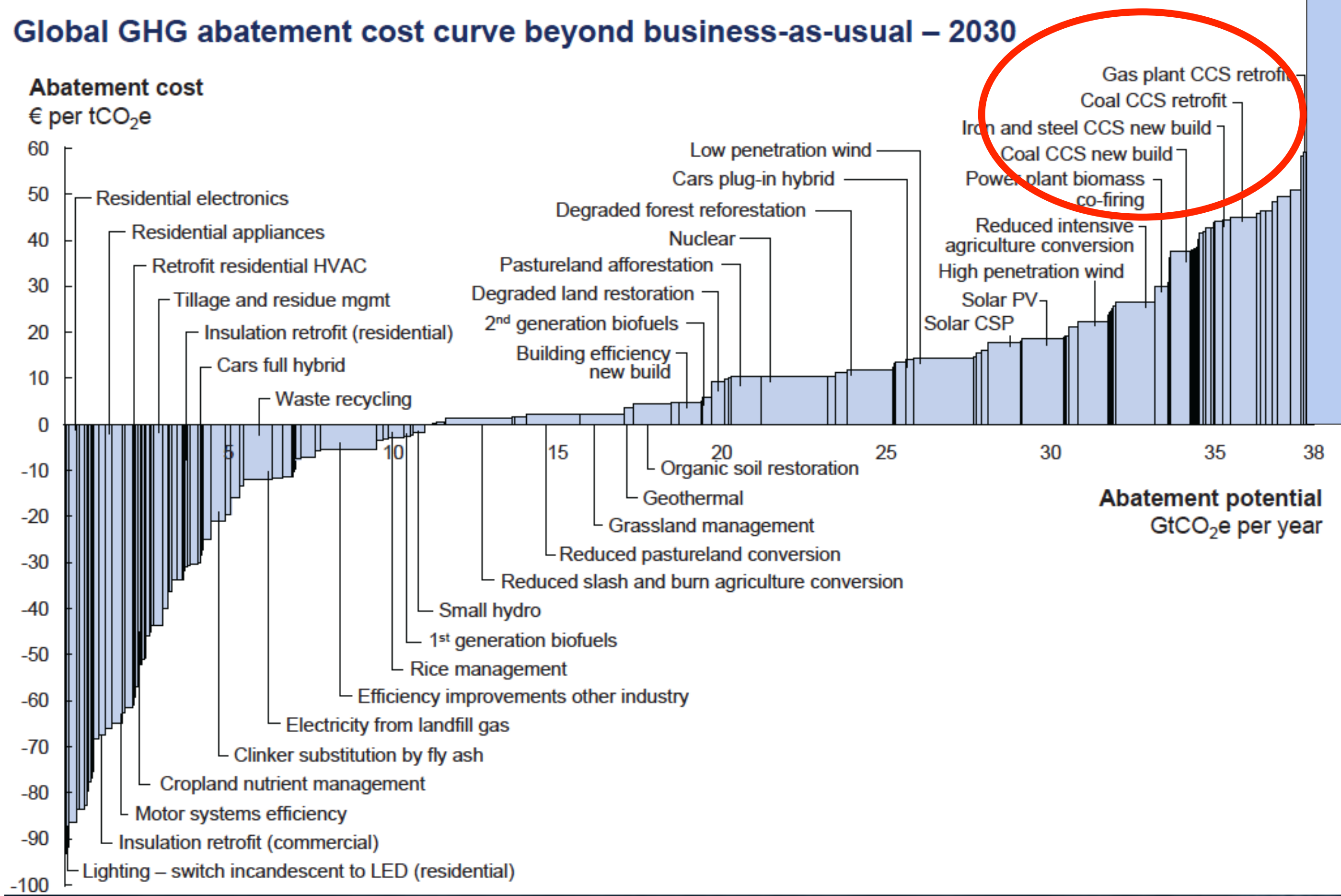

Underlying economic productivity of carbon > €1000/tCO_2e

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Why is CCS so important?

- **The Kaya Identity:**

  Carbon emissions = Population x consumption per capita x energy intensity of consumption x carbon intensity of energy

- **Population and consumption are usually taken as given. But are they?**

Where the Kaya Identity goes wrong

Low-energy light-bulbs in Doha

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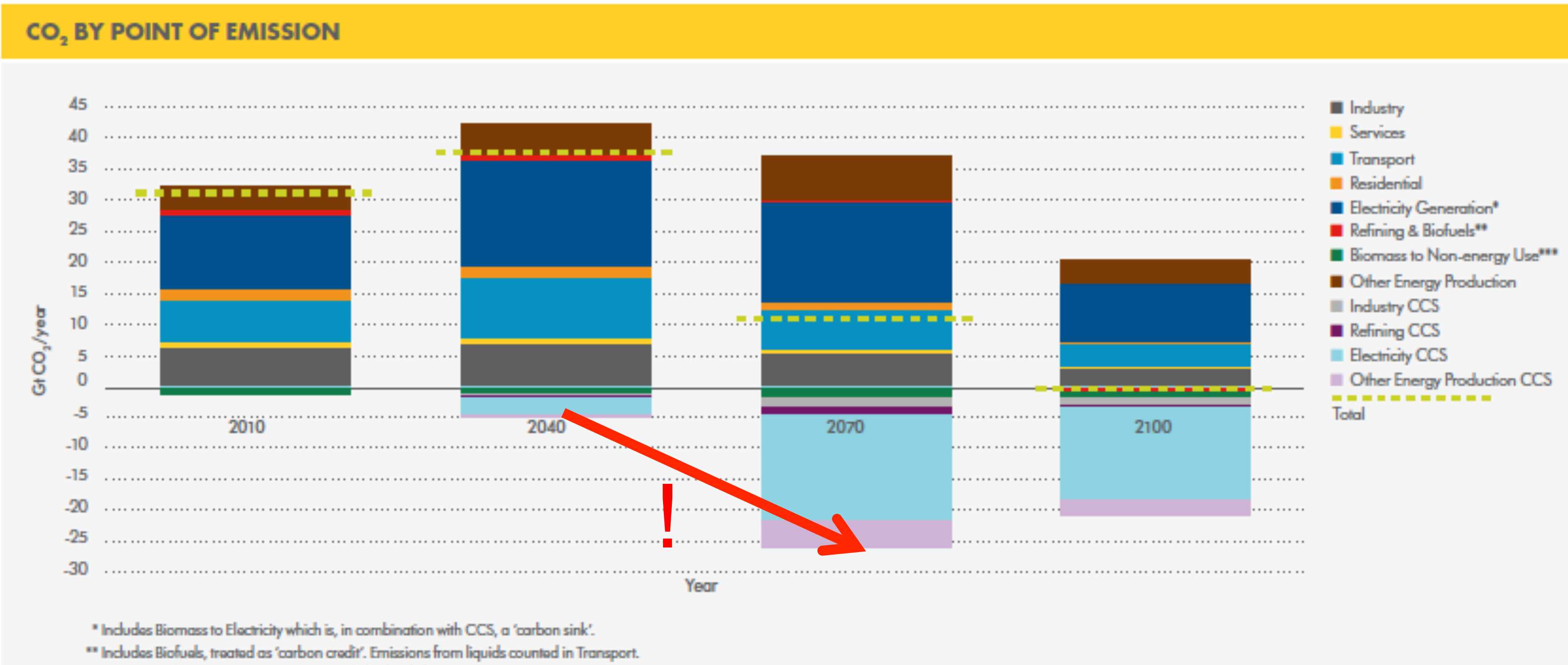
Where the Kaya Identity goes wrong

- **Consumption is not given: increased efficiency and lower carbon intensity mean more consumption per tonne of carbon, not (necessarily) lower emissions.**
- **Meeting any climate target without CCS must ultimately involve forgoing consumption, not just delaying consumption.**
  - **Assumption: fossil fuels will remain profitable for some applications, even with the added cost of CO_2 disposal, for the foreseeable future (well into the 22^{nd} century).**
  - **David Hone on the Kaya Identify: http://blogs.shell.com/climatechange/2014/04/revisiting-kaya/**

The dangers of relying on a carbon price or emission trading system

- Short-term impact: Some substitution, proceeds are recycled, minimal net impact on welfare.
- Long-term impact: investment in expensive mitigation options is postponed as late as possible, and then undertaken in a rush.
  - Particularly problematic for options with inelastic costs and long testing/deployment times – nuclear and esp. CCS.
- If you choose to rely on a carbon price or cap-and-trade, you are choosing to impose most of the burden of mitigation on a future generation.

The evolution of CCS in a relatively optimistic carbon-price-based scenario



Shell "Mountains" scenario

Another identity

- S = % net sequestered fraction = % tonnes carbon sequestered per year / (tonnes extracted + leakage)
- C_{max} = cumulative emissions over all time, proportional to total climate change commitment
- C = cumulative emissions to date
- To limit cumulative emissions to C_{max} GtC, S must increase, from now on, at an average rate of

$$\frac{dS}{dC} = \frac{100 - S}{C_{\max} - C} \ \text{\% per GtC emitted}$$

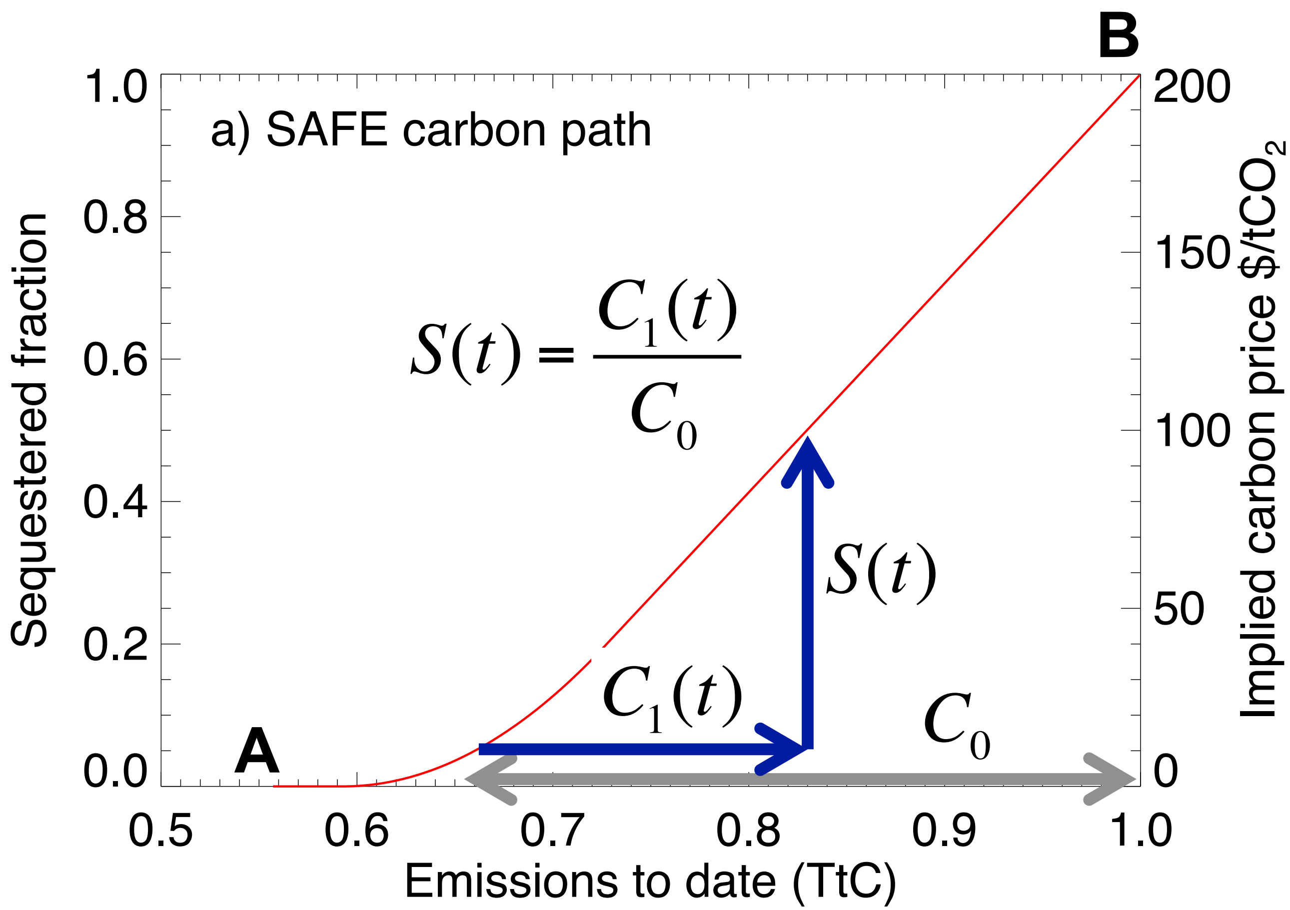
$$\text{If } S = 0 \text{ and } C_0 = C_{\max} - C = \text{"atmospheric space"}$$

$$\text{then } \frac{dS}{dC} = \frac{100}{C_0}$$

Implications

- **Cumulative emissions to date are about 0.5TtC**
- **To limit cumulative emissions to 1 TtC, the sequestered fraction must increase in future, on average, by 2% for every 10GtC of carbon released into the atmosphere.**
- **Note:** $\frac{dS}{dC} = \frac{S'}{C'} = \frac{S'}{E}$
- **So we can meet a cumulative target either by increasing the rate of increase in sequestered fraction per year, or by reducing emissions, but only if *S'* > 0. Right now, *S* = 0.1% and *S'* ≈ 0**

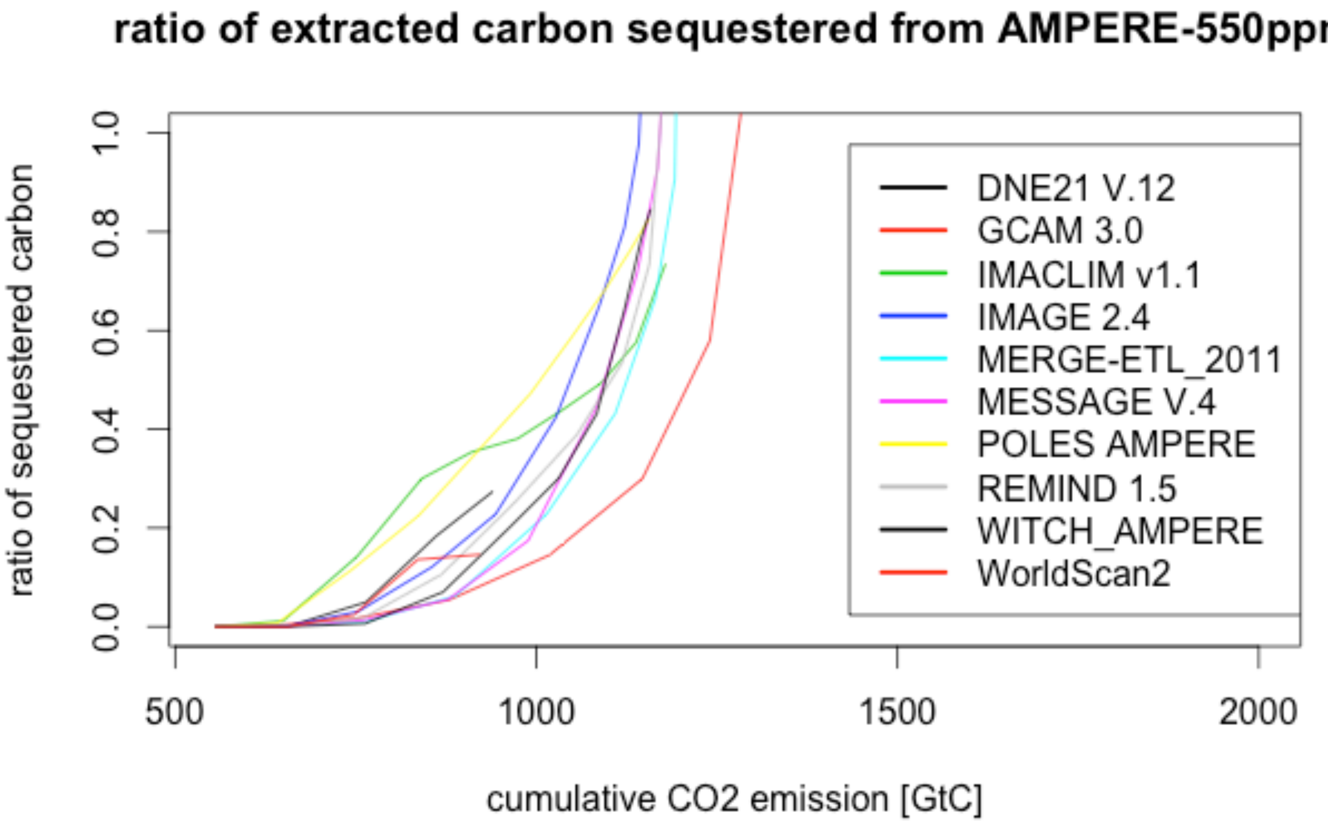
An alternative way of framing climate policy



S = tonnes of carbon sequestered / (tonnes carbon extracted + leakage)

C_1 = cumulative emissions from the time the policy is adopted

The evolution of sequestered fraction in typical 2°C scenarios



Otto, Hepburn & Allen, 2014

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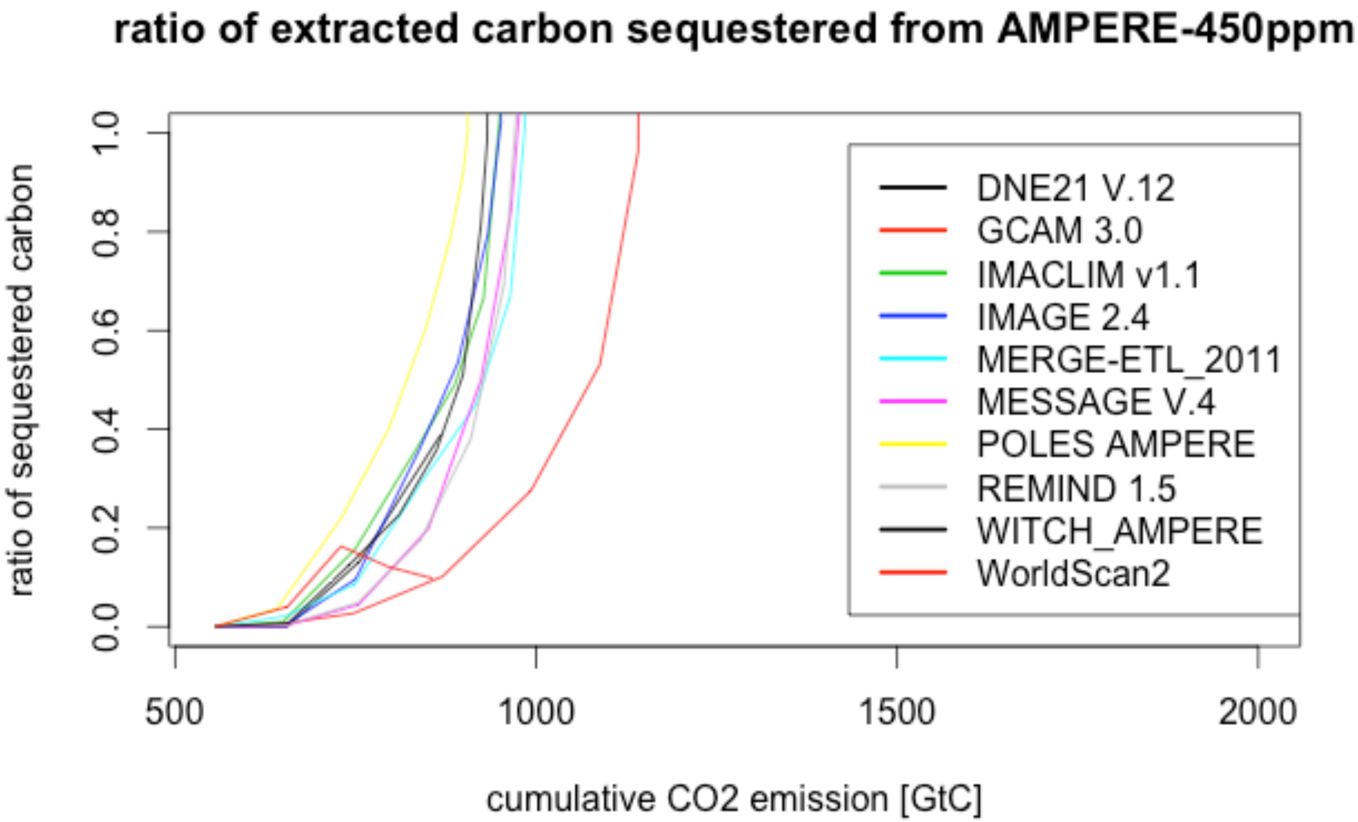

Otto, Hepburn & Allen, 2014

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Climate mitigation with no new taxes

- **Upstream mandatory sequestration: impose a licensing condition on any company wishing to extract or import fossil fuels to demonstrate that a set percentage *S%* of their carbon content has been verifiably sequestered.**
  - **Use a certificate system to allow cheapest CO_2 sources to be identified first.**
  - **Storage sites also have to buy certificates (at market value) to compensate for leakage.**
  - ***S* can be explicitly linked to climate response: "anti-fragile" policy.**
  - Allen, Frame & Mason, *Nature Geoscience*, **2**:813-814, 2009 & Otto et al, 2014

Climate mitigation with no new taxes

Upstream mandatory sequestration at work:
Gorgon gas project, Western Australia

Climate mitigation with no new taxes

- Upstream mandatory sequestration would solve the fossil CO_2 climate problem:
  - If CCS is expensive, by imposing a relatively predictable and apolitical implicit carbon price.
  - If CCS is cheap, by mandating large-scale deployment with minimal collateral economic damage.
- We would still need to
  - Stop net deforestation
  - Stabilize methane emissions
  - Stabilize the global nitrogen cycle (stop net N_2O emissions)
- But these are things we need to do anyway: they are not “complementary” to solving the CO_2 problem.

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So what they could agree in Paris (but won't)

- All parties impose a licensing condition on extraction or import of fossil fuels that *S*% of their carbon content has been verifiably sequestered.
- *S*=1% by 2020, *S*=10% and increasing at 2%/year by 2030, *S*=100% by the time anthropogenic warming reaches 2°C.
- If the cost of sequestration is \$200/tCO_2, this would appear to the consumer as a carbon price of \$2/tCO_2 in 2020 & \$20/tCO_2 in 2030.
- How else could you *credibly* solve the climate problem for a near-term carbon price of \$2/tCO_2?

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