Cumulative carbon and its implications What they could agree in Paris...

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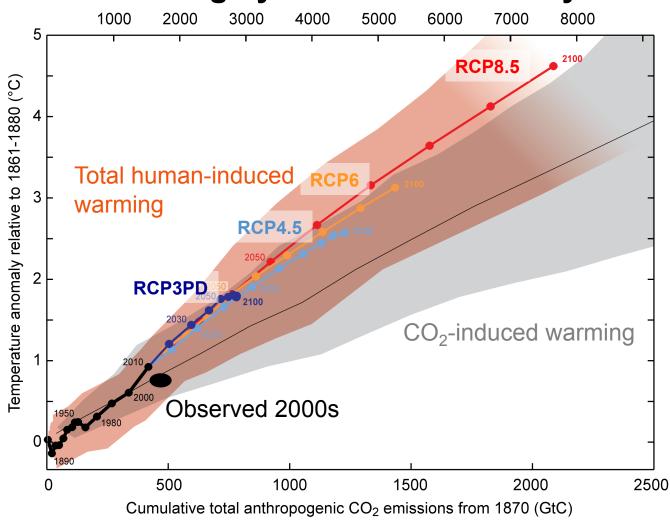
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Cumulative emissions of CO₂ largely determine global mean surface warming by the late 21st century and beyond

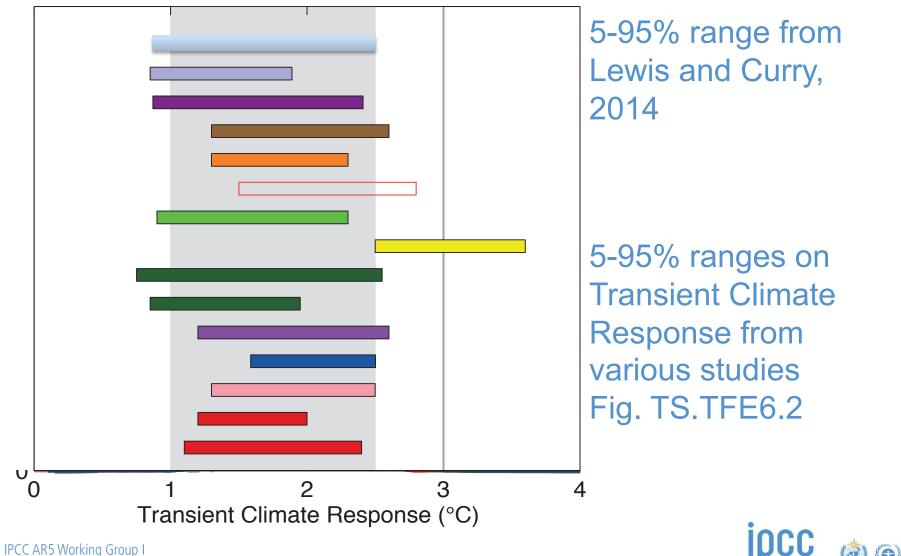


UNEF

IPCC AR5 Working Group I Climate Change 2013: The Physical Science Basis

INTERGOVERNMENTAL PANEL ON Climate change

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

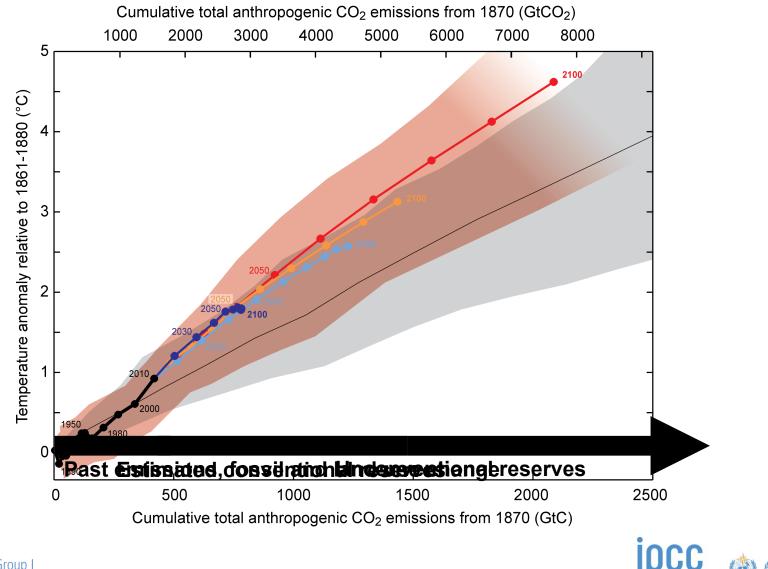


Climate Change 2013: The Physical Science Basis

INTERGOVERNMENTAL PANEL ON CLIMATE CHANES

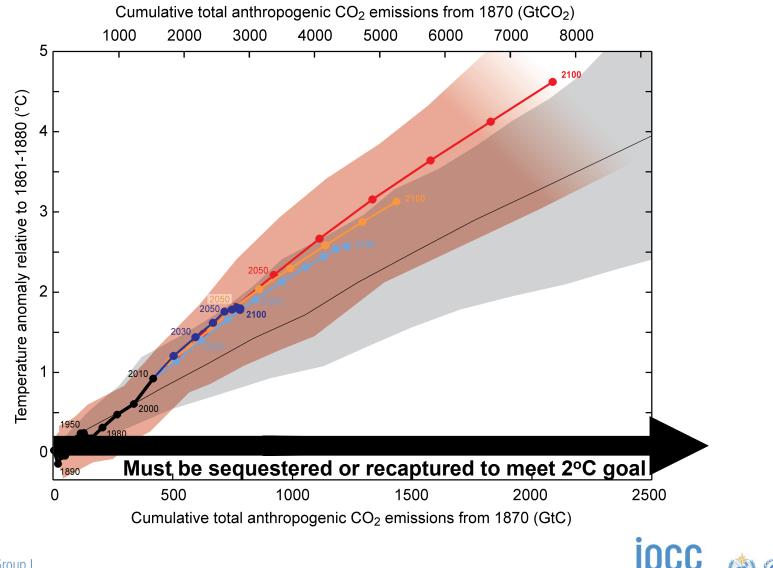


Cumulative emissions and fossil carbon reserves





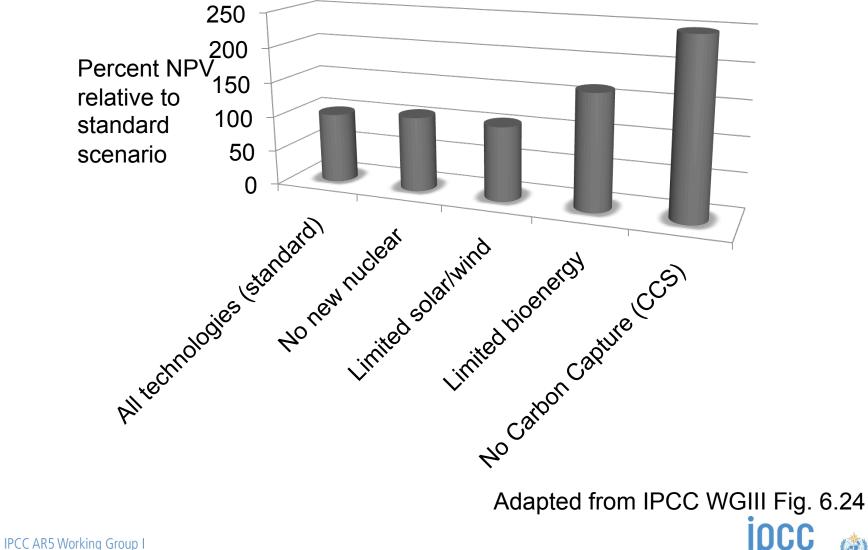
Cumulative emissions and fossil carbon reserves



UNEP

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



Climate Change 2013: The Physical Science Basis

INTERGOVERNMENTAL PANEL ON Climate change



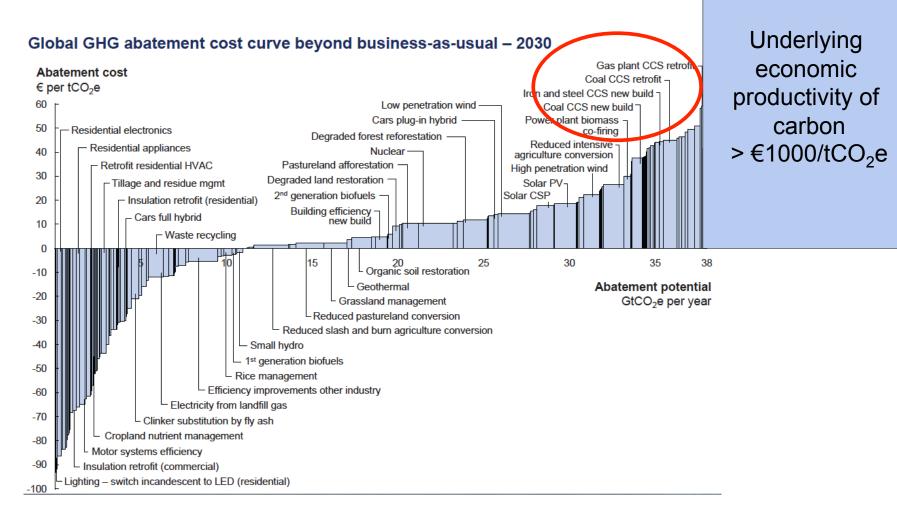
Why is CCS so important?

Gas plant CCS retrofit Abatement cost Coal CCS retrofit € per tCO₂e Iron and steel CCS new build -60 Low penetration wind -Coal CCS new build Cars plug-in hybrid Power plant biomass 50 -Residential electronics co-firing Degraded forest reforestation Reduced intensive Residential appliances 40 Nuclear agriculture conversion Retrofit residential HVAC Pastureland afforestation High penetration wind 30 Degraded land restoration Tillage and residue mgmt Solar PV Solar CSP 2nd generation biofuels 20 Insulation retrofit (residential) Building efficiency Cars full hybrid new build 10 Waste recycling 0 15 25 30 35 38 20 Organic soil restoration -10 Geothermal Abatement potential -20 Grassland management GtCO₂e per year Reduced pastureland conversion -30 Reduced slash and burn agriculture conversion -40 Small hydro 1st generation biofuels -50 Rice management -60 Efficiency improvements other industry Electricity from landfill gas -70 Clinker substitution by fly ash Cropland nutrient management -80 Motor systems efficiency -90 Insulation retrofit (commercial) Lighting - switch incandescent to LED (residential) -100

Global GHG abatement cost curve beyond business-as-usual - 2030



Why is CCS so important?





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



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 CO₂ disposal, for the foreseeable future (well into the 22nd century).
 - David Hone on the Kaya Identify: http://blogs.shell.com/ climatechange/2014/04/revisiting-kaya/



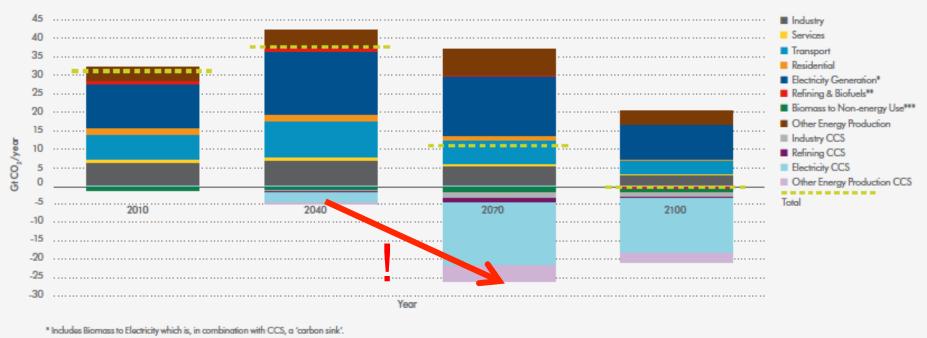
The dangers of relying on a carbon price or emission trading system

- 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-andtrade, 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

CO, BY POINT OF EMISSION



Includes Biofreds, treated as 'carbon credit'. Emissions from liquids counted in Transport.

** Includes Biorulais, fredred as carbon creatric critissions from liquids counted III Communicative and an and counted in with the final data.

*** Commercial biomass, not competing with the food chain.

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

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

If $S = 0$ and $C_0 = C_{\text{max}} - C =$ "atmospheric space"
then $\frac{dS}{dC} = \frac{100}{C_0}$

Implications

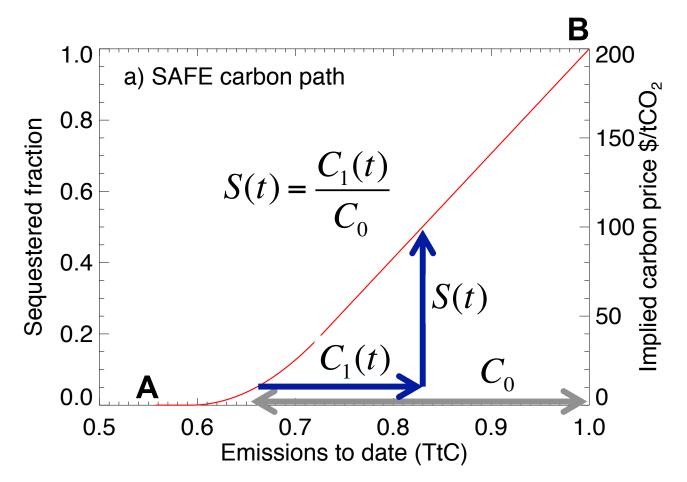
- Cumulative emissions to date are about 0.5TtC
- To limit cumulative emissions to 1 TtC, the sequestered fraction must increase in future, on average, by 2% for every 10GtC of carbon released into the atmosphere.

• 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

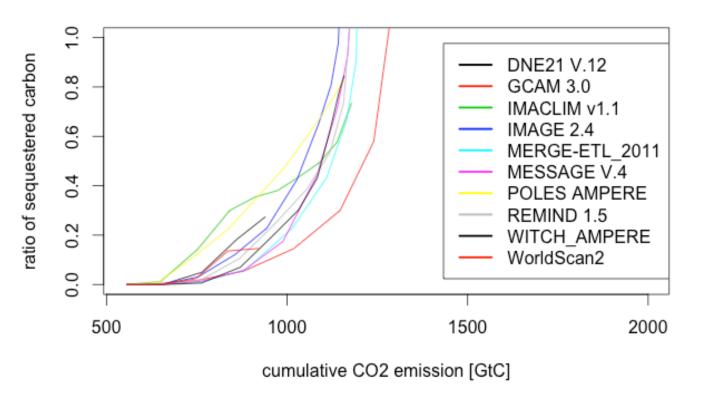


S = tonnes of carbon sequestered / (tonnes carbon extracted + leakage) C_1 = cumulative emissions from the time the policy is adopted



The evolution of sequestered fraction in typical 2°C scenarios

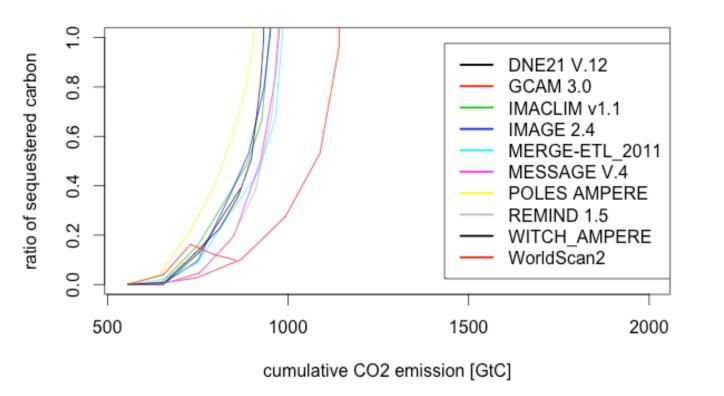
ratio of extracted carbon sequestered from AMPERE-550ppm





The evolution of sequestered fraction in typical 2°C scenarios

ratio of extracted carbon sequestered from AMPERE-450ppm





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 CO₂ 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 CO₂ 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 N₂O emissions)
- But these are things we need to do anyway: they are not "complementary" to solving the CO₂ problem.



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/tCO₂, this would appear to the consumer as a carbon price of \$2/tCO₂ in 2020 & \$20/tCO₂ in 2030.
- How else could you credibly solve the climate problem for a near-term carbon price of \$2/tCO₂?

