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Curbing of industrial CO_2 emissions for climate change mitigation

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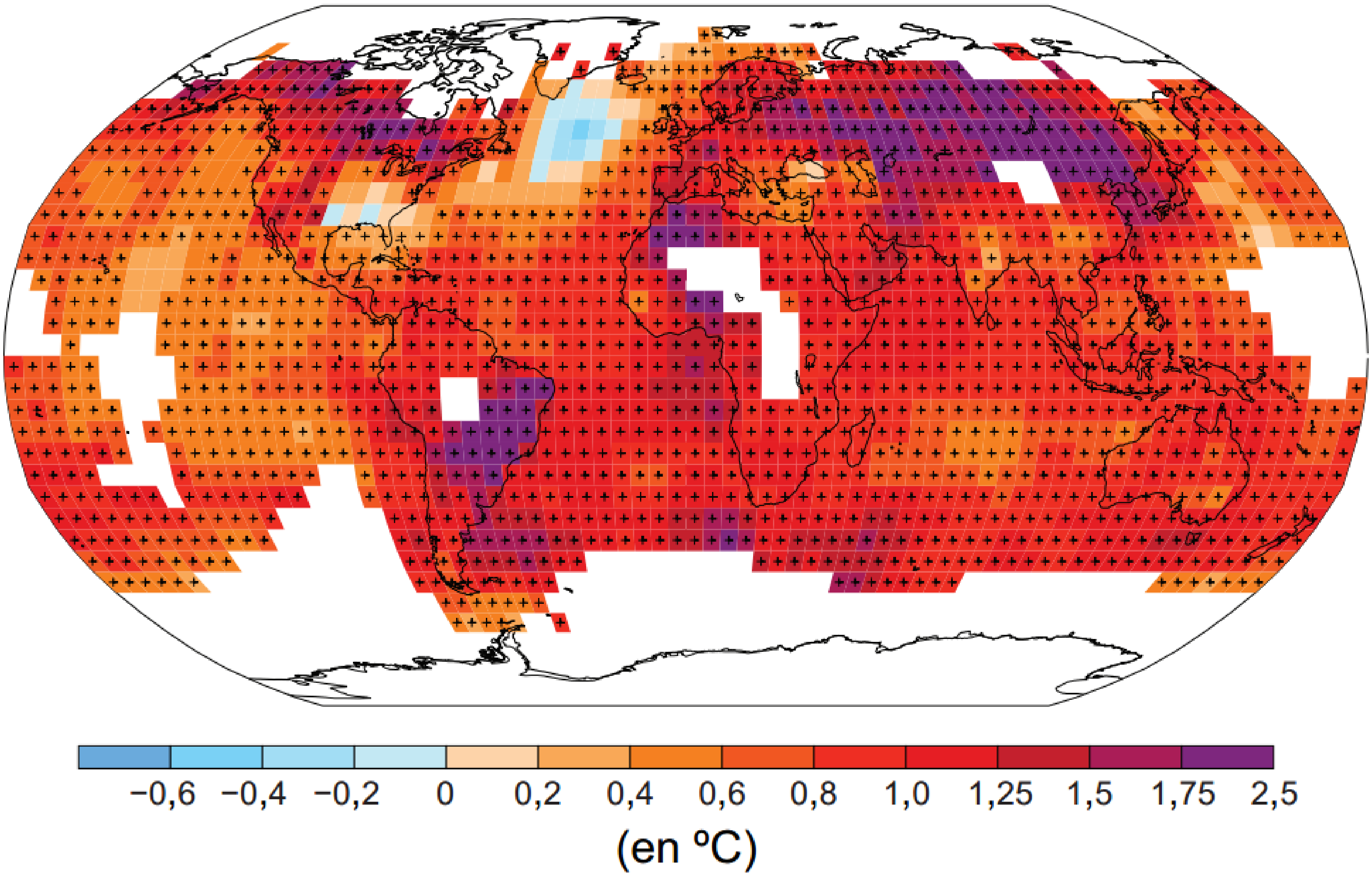
2nd ECRA/CEMCAP Workshop on CCS, Dusseldorf, 6-7 November 2017

Outline

- Climate change: the new context after COP21
- CCS and CCU? for climate change mitigation
- Conclusion

A warming planet



IPCC, V Assessment Report, Synthesis Report 2015   www.ipcc.ch

A warming planet

National Oceanic and Atmospheric Administration
U.S. Department of Commerce

Search NOAA sites

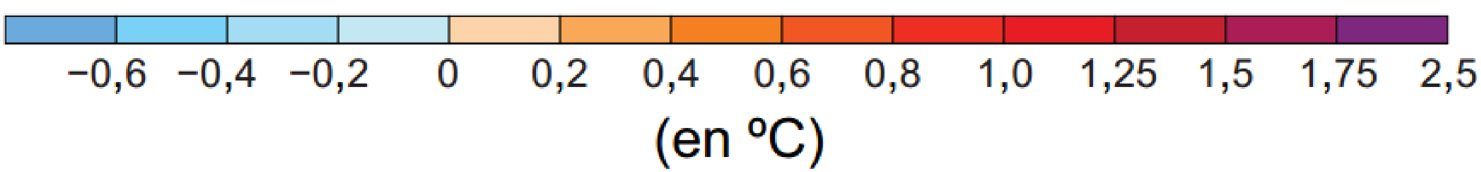
‹ NEWS & FEATURES

International report confirms 2016 was warmest year on record for the globe

Last year marked the 3rd consecutive year of record warmth

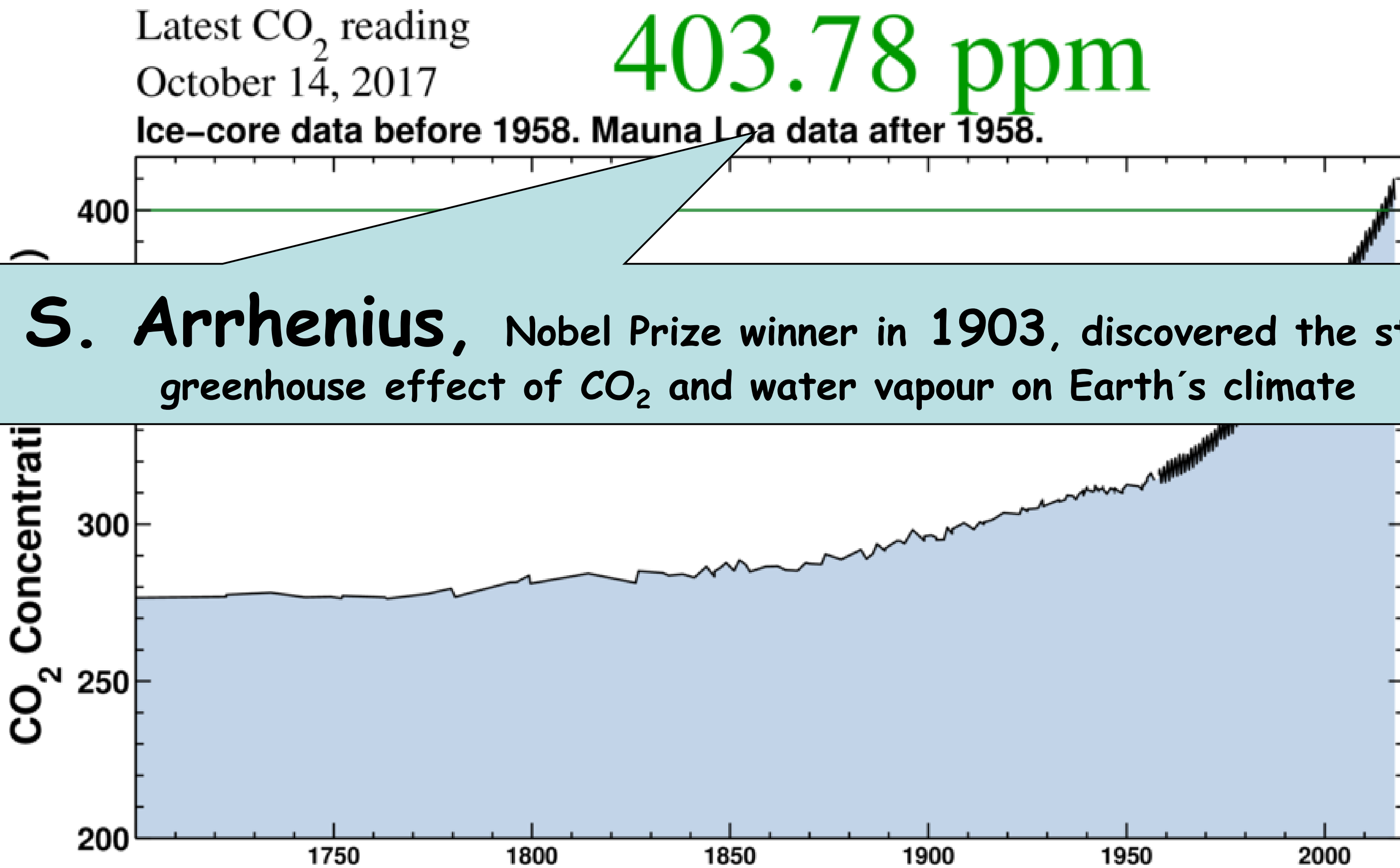
Climate | greenhouse gases sea level rise SHARE

August 10, 2017 —



IPCC, V Assessment Report, Synthesis Report 2015 www.ipcc.ch

CO_2 and global warming

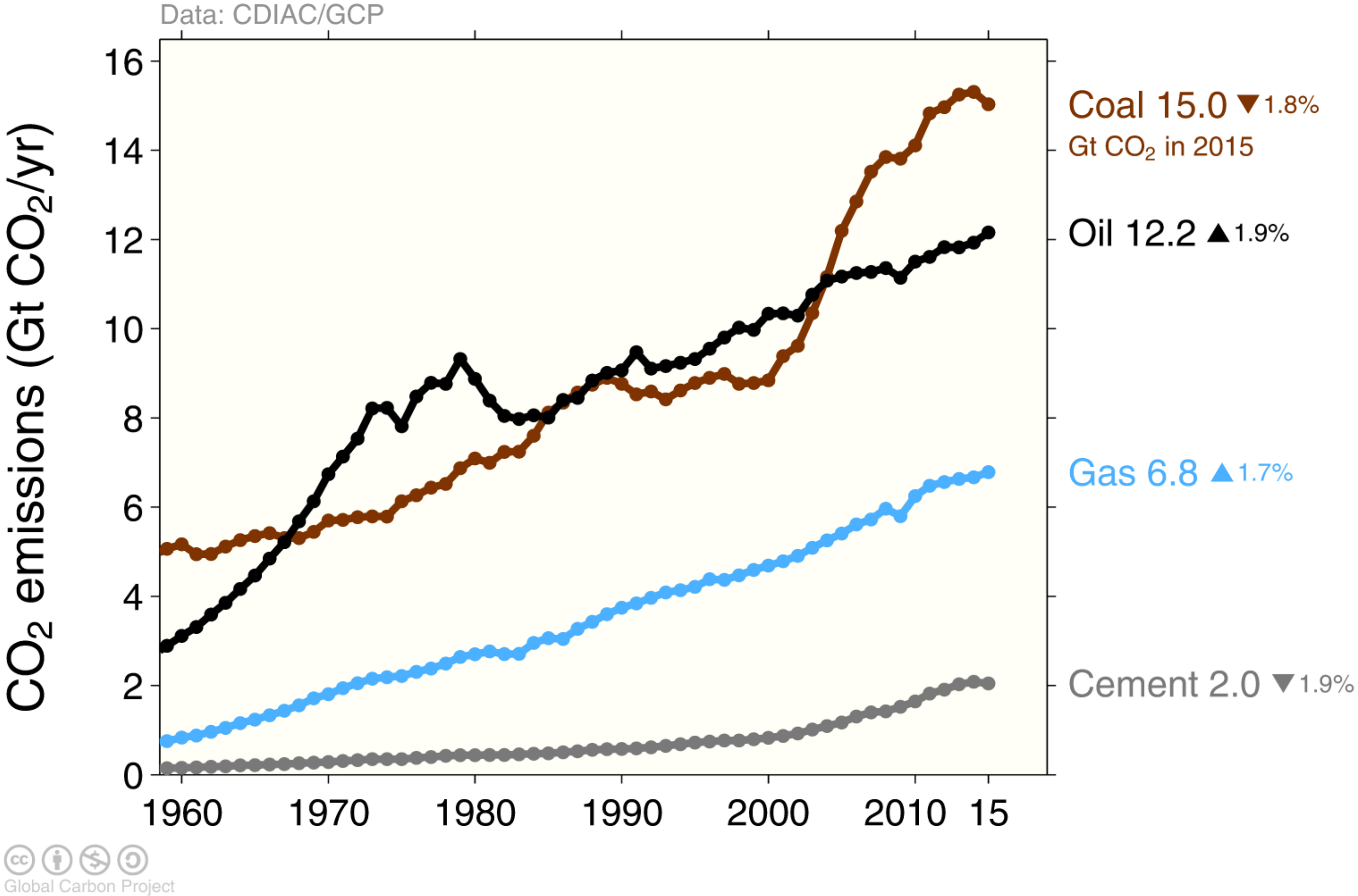


S. Arrhenius, Nobel Prize winner in 1903, discovered the strong greenhouse effect of CO_2 and water vapour on Earth´s climate

https://scripps.ucsd.edu/programs/keelingcurve/

Emissions from coal, oil, gas, cement

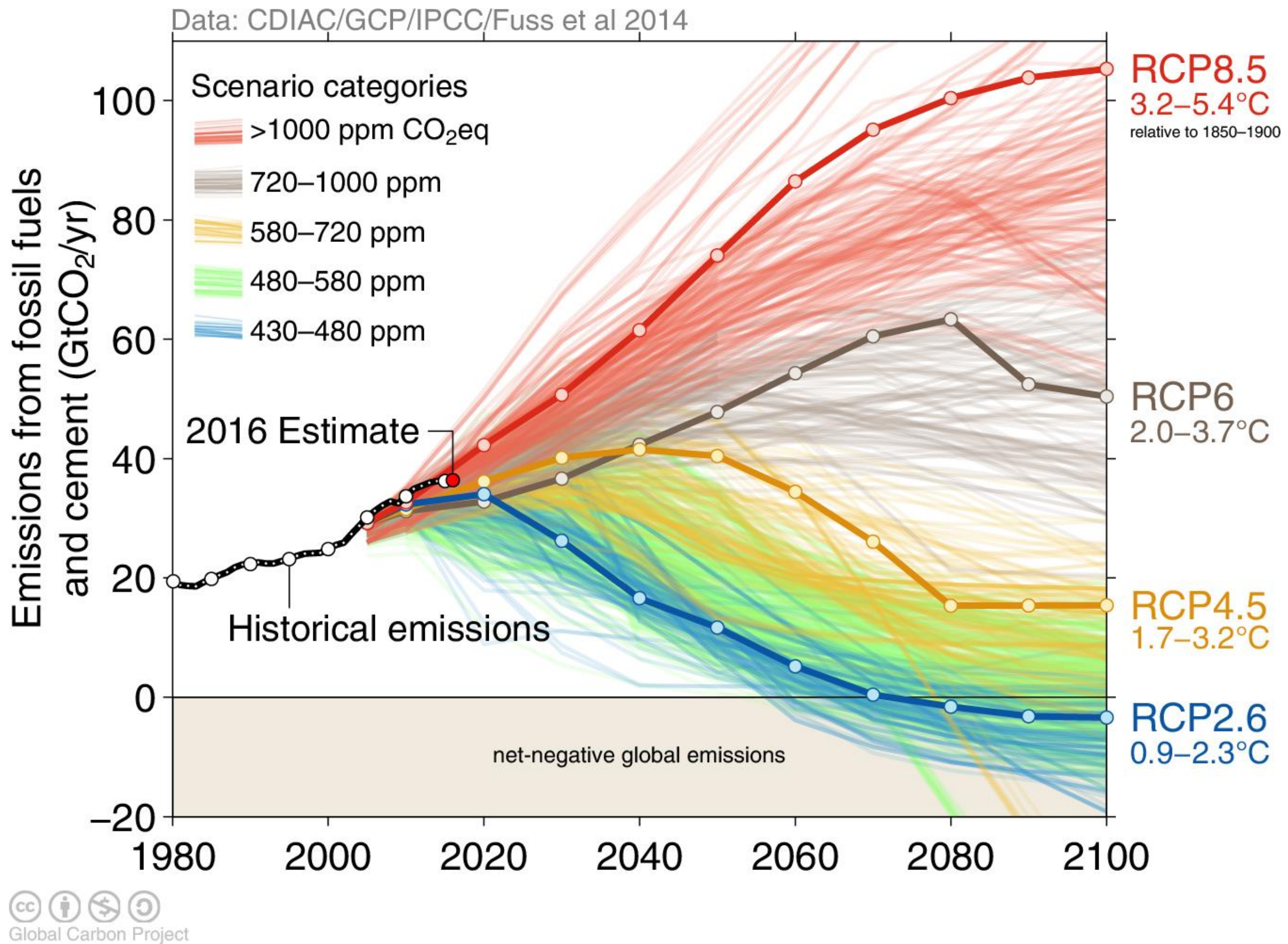
Share of global emissions in 2015:
coal (41%), oil (34%), gas (19%), cement (6%), flaring (1%, not shown)



Source: CDIAC; Le Quéré et al 2016; Global Carbon Budget 2016

Observed emissions and emissions scenarios

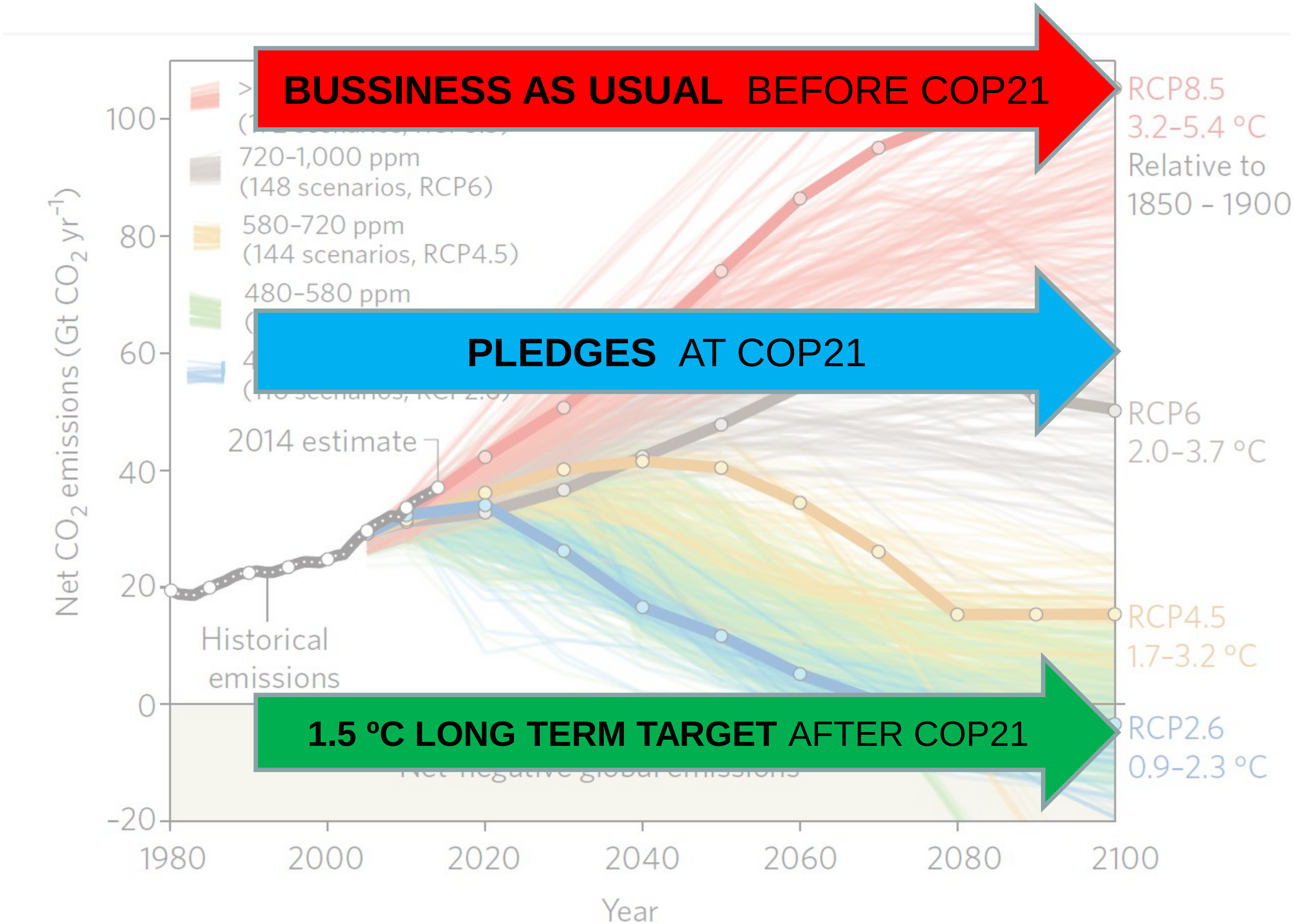
The emission pledges to the Paris Agreement avoid the worst effects of climate change (4-5°C) Most studies suggest the pledges give a likely temperature increase of about 3°C in 2100



The IPCC Fifth Assessment Report assessed about 1200 scenarios with detailed climate modelling on four Representative Concentration Pathways (RCPs)

Source: Fuss et al 2014; CDIAC; IIASA AR5 Scenario Database; Global Carbon Budget 2016

A GRAFIC SUMMARY OF COP 21



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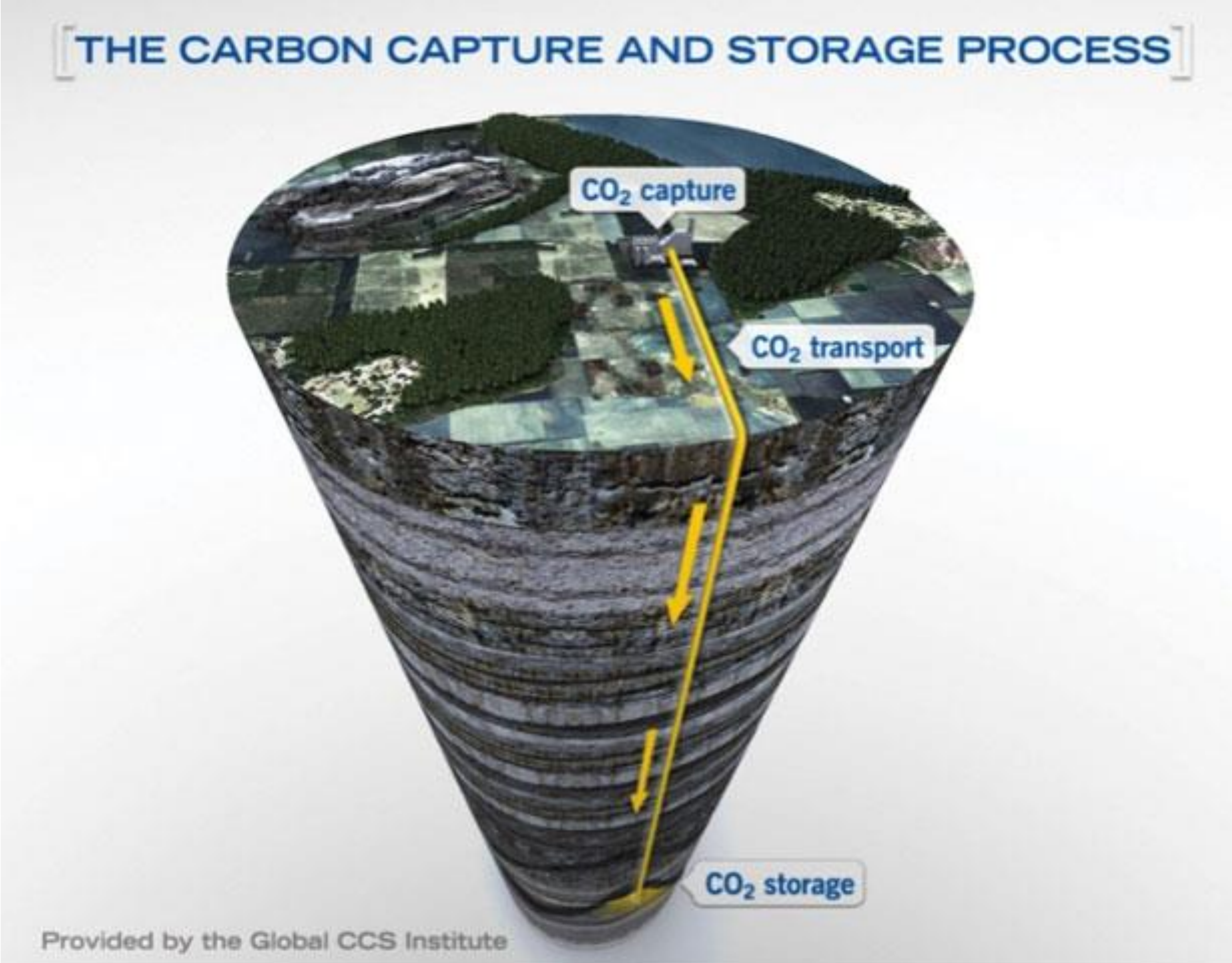
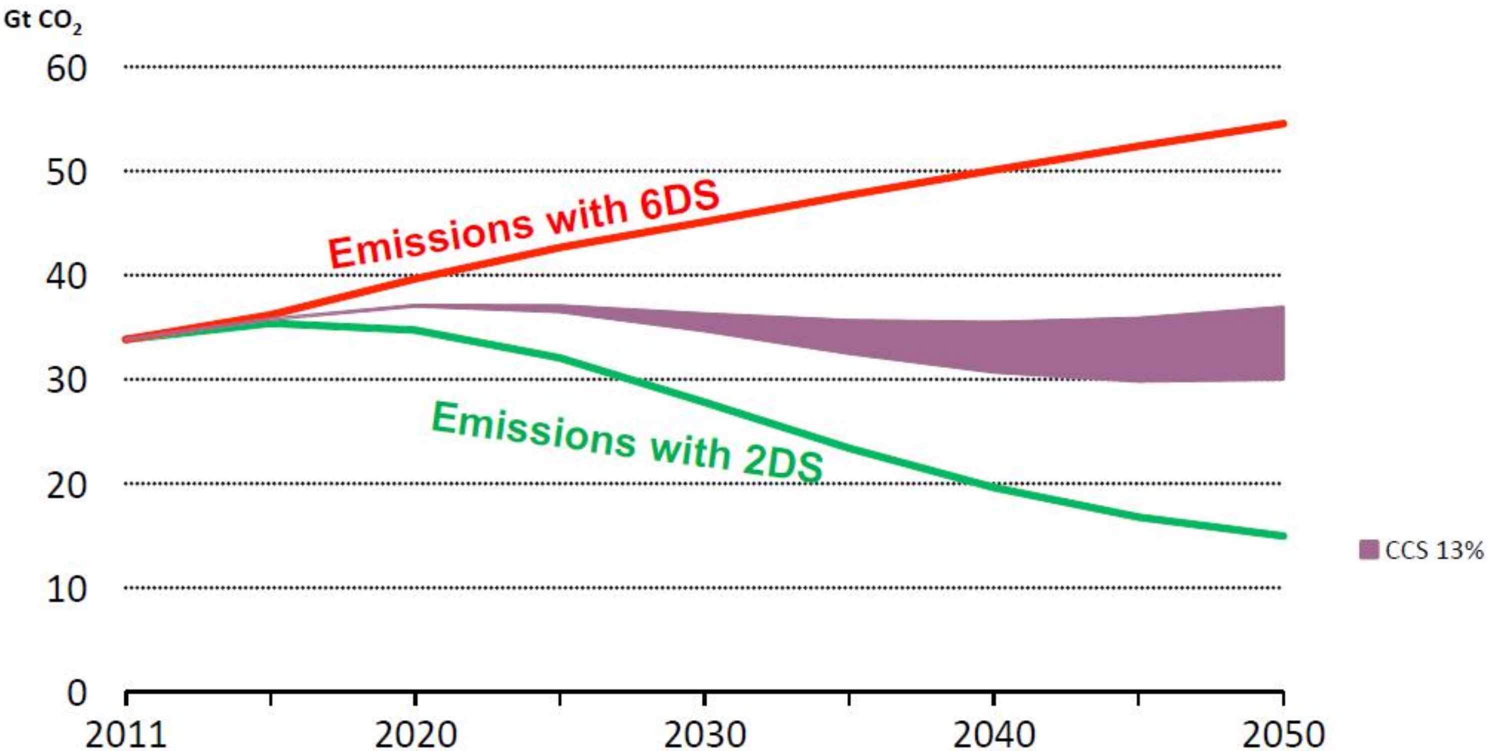

THE CARBON CAPTURE AND STORAGE PROCESS
CO2 capture
CO2 transport
CO2 storage
Provided by the Global CCS Institute

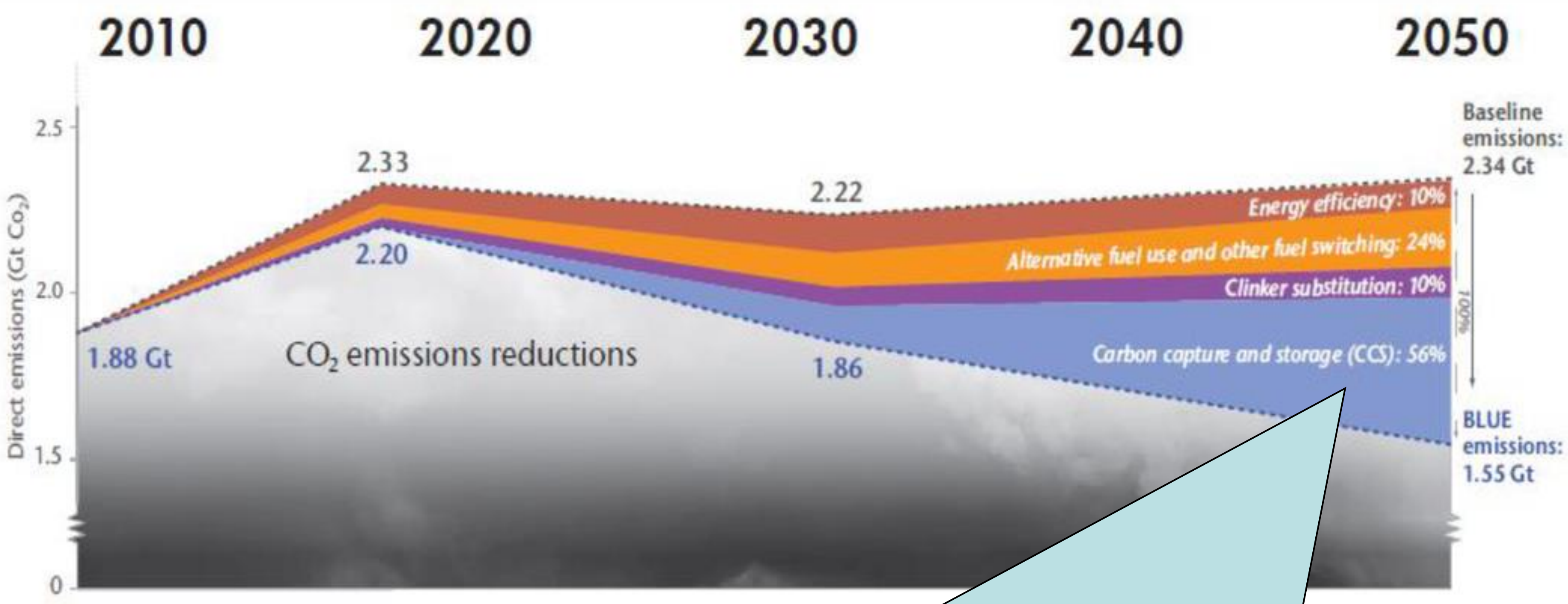
Portfolio of actions to reduce energy sector emissions

International Energy Agency
Secure
Sustainable
Together



Source: ETP 2014

IEA Cement Technology Roadmap for CO_2 reduction



CCS is most prominent in sectorial scenarios to decarbonise the cement industry

Outline

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ABSTRA... cently, a
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HOW TO MAKE THE MOST OF CARBON DIOXIDE

Researchers hope to show that using the gas as a raw material could make an impact on climate change.

BY XIAOZHI LIM

On 29 September, the XPRIZE Foundation based in Culver City, California, announced a 4½-year competition that will award US$20 million to the research team that can come up with the best way to turn carbon dioxide from a liability into an asset.

With gigatonnes of the gas pouring into the atmosphere each year, and with the consequences for global climate becoming increasingly obvious, the Carbon XPRIZE would reward technologies that can convert CO_2 emissions from coal and natural-gas power plants into useful products such as alternative building materials, fuels and raw material for the manufacture of plastics and other chemicals.

The invitation should have plenty of takers: ...

... plant is turning CO_2 into materials that go on to become coatings and adhesives. And in Tokyo, Japan, Asahi Kasei Chemicals is widely licensing its technique for turning CO_2 into the polycarbonate plastics used in bulletproof glass, spectacle lenses and electronic parts.

Using this greenhouse gas as a raw material is an idea that many scientists once dismissed as hopeless, says Chunshan Song, a chemical engineer at Pennsylvania State University, University Park. As a practical matter, he says, "lots of people believed that nothing could be done with CO_2 utilization" after the stuff went up the smokestack.

As a source of carbon, sceptics argued, the gas was far more difficult and expensive to obtain than the petroleum, coal and natural gas that now provide the raw material for most ... even if CO_2 ...h, converting ...-useful chem... ...ots of energy, ...sil-fuel plants. ...ine and make ...

But the balance is starting to shift. New conversion technologies are allowing

ASIM HAFEEZ/BLOOMBERG/GETTY

Nature, 29 October 2015

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Cite this: *Energy Environ. Sci.*, 2012, **5**, 7833

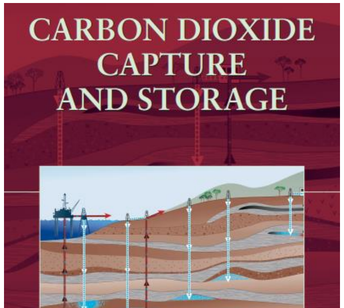
www.rsc.org/ees

REVIEW

Air as the renewable carbon source of the future: an overview of CO_2 capture from the atmosphere†

Alain Goeppert,* Miklos Czaun,* G. K. Surya Prakash* and George A. Olah*

Avoided emissions of future CCU processes



"This can be evaluated correctly only by considering proper system boundaries for the energy and material balances of the CO_2 utilization processes, and by carrying out a detailed life-cycle analysis of the proposed use of CO_2."

Fundamental questions regarding Carbon accounting in CCU still persist in 2017

nature climate change

Energy & Environmental Science

PAPER

Cite this: *Energy Environ. Sci.*, 2013, **6**, 2721

Life-cycle assessment ... utilization: avoiding t...

Niklas von der Assen, Johannes J...

important economic incentive for some early ... from the real task of mitigation.

Environmental Science & Technology

Article

pubs.acs.org/est

Energy and Climate Impacts of Producing Synthetic Hydrocarbon Fuels from CO_2

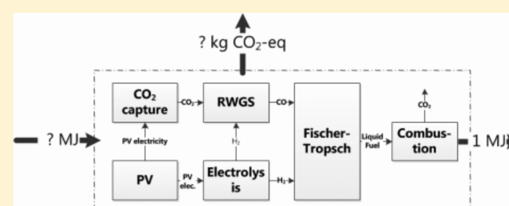
Coen van der Giesen,*,† René Kleijn,† and Gert Jan Kramer†,‡

†Institute of Environmental Sciences, P.O. Box 9518, 2300 RA Leiden, The Netherlands

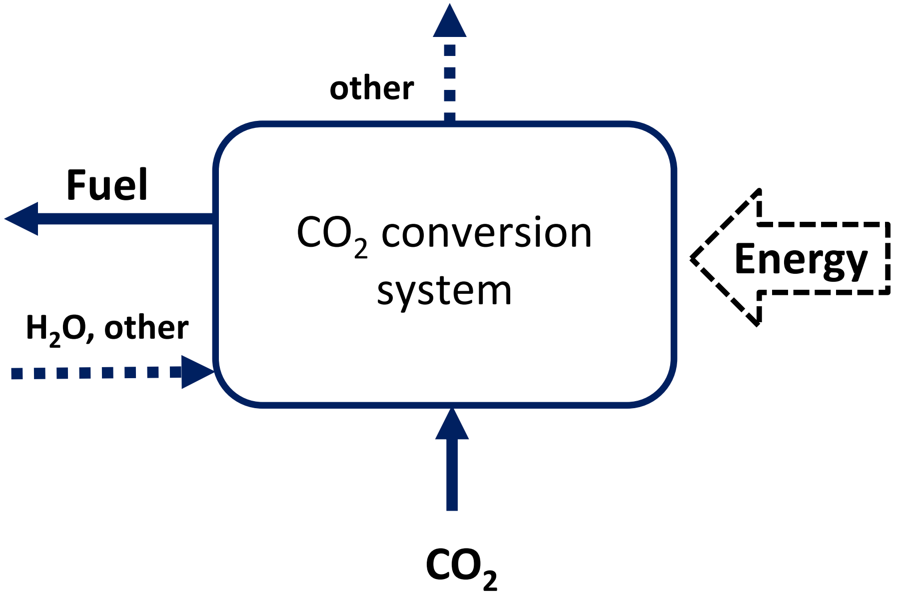
‡Shell Global Solutions, P.O. Box 38000, 1030 BN Amsterdam, The Netherlands

Supporting Information

ABSTRACT: Within the context of carbon dioxide (CO_2) utilization there is an increasing interest in using CO_2 as a resource to produce sustainable liquid hydrocarbon fuels. When these fuels are produced by solely using solar energy they are labeled as solar fuels. In the recent discourse on solar fuels intuitive arguments are used to support the prospects of these fuels. This paper takes a quantitative approach to investigate some of the claims made in this discussion. We analyze the life cycle performance of various classes of solar fuel processes using different primary energy and CO_2 sources. We compare their efficacy with respect to carbon mitigation with ubiquitous fossil-based fuels and conclude that producing liquid



System boundaries for CCU ?

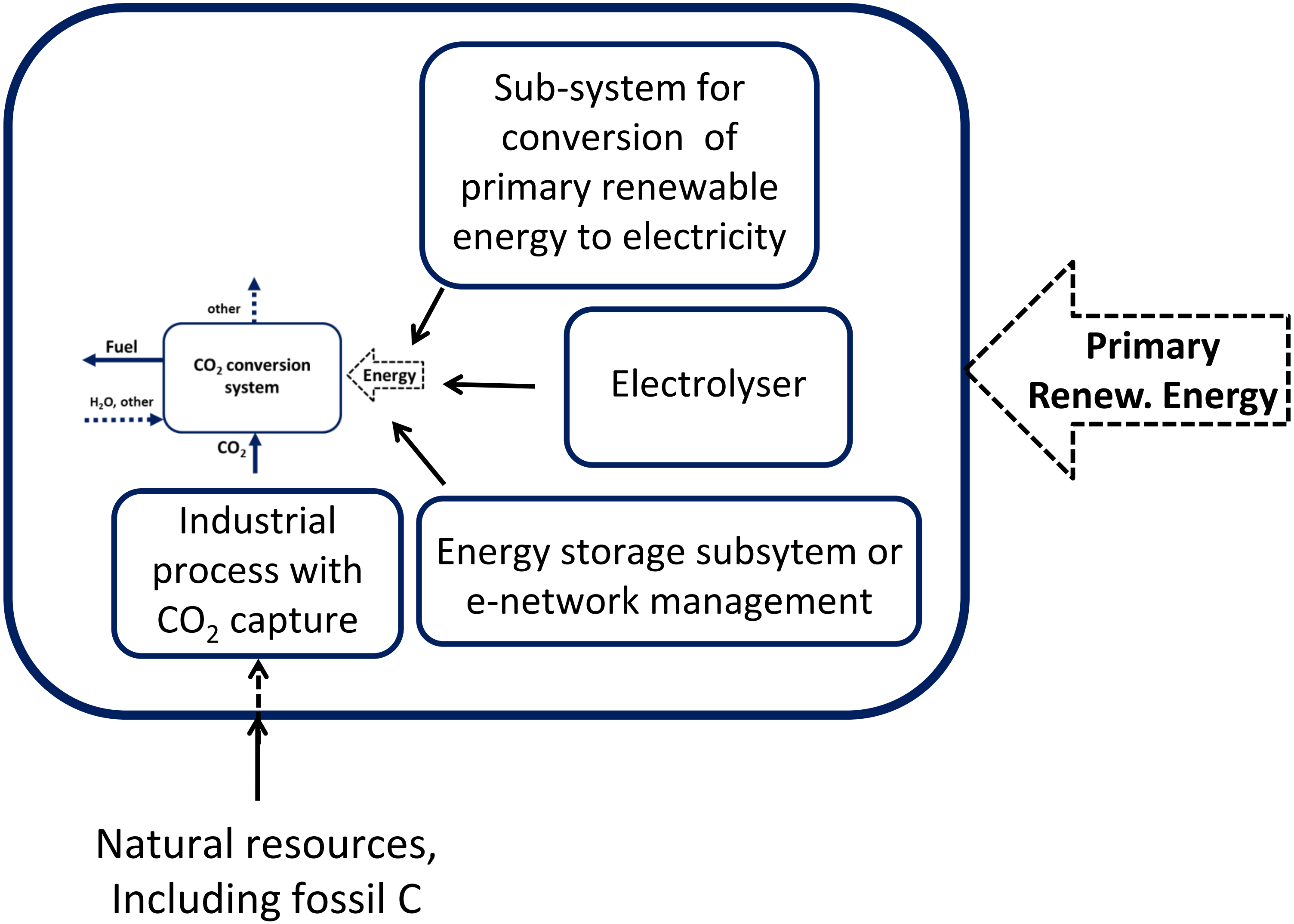


"Each atom of C we can recycle is an atom of fossil carbon left in the underground for next generations that will not reach the atmosphere today."

Aresta, M., et al. **(2016)** *Journal of Catalysis* 343, 2-45, doi:10.1016/j.jcat.2016.04.003

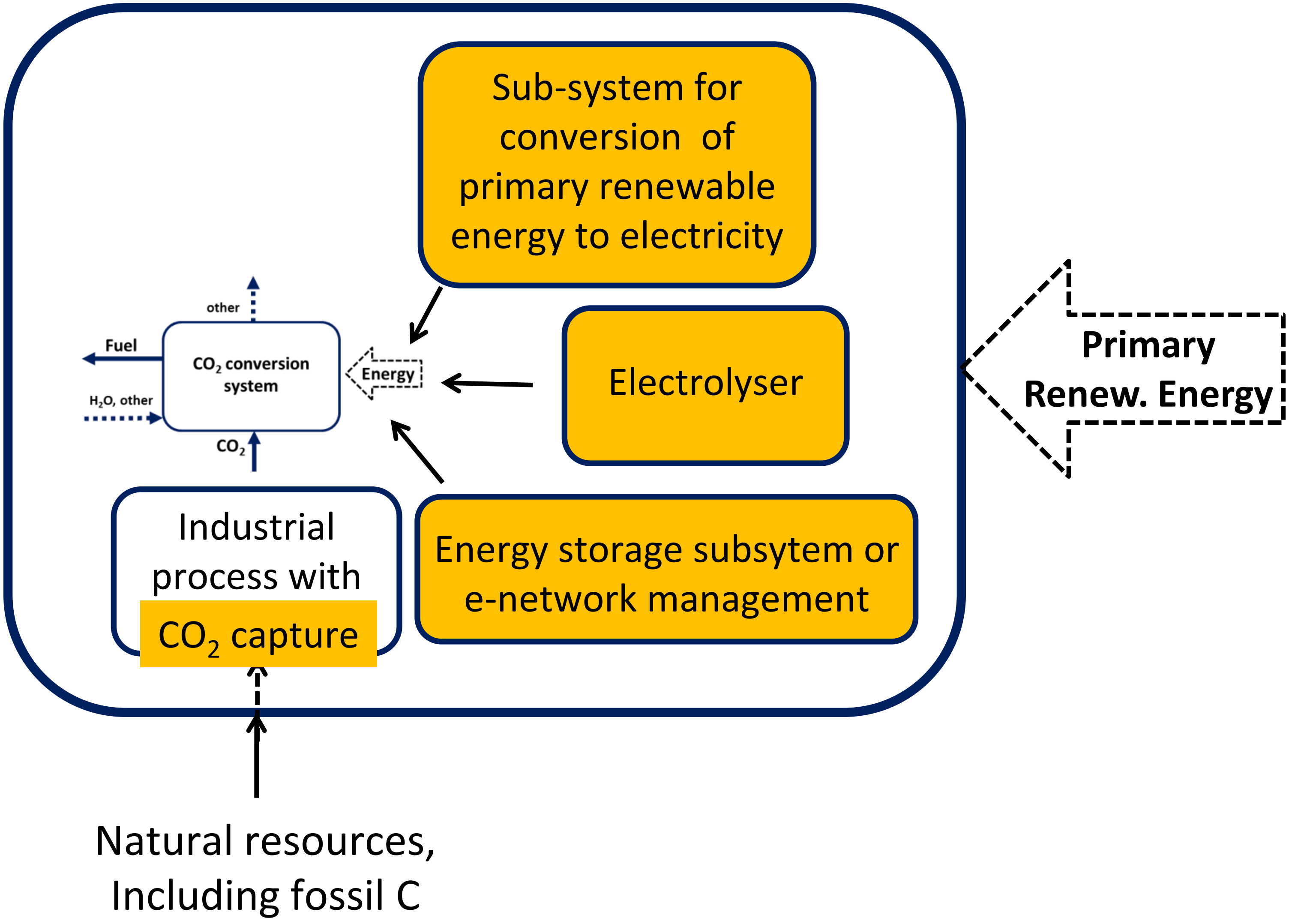
System boundaries for CCU

It is compulsary to account for the FULL value chain



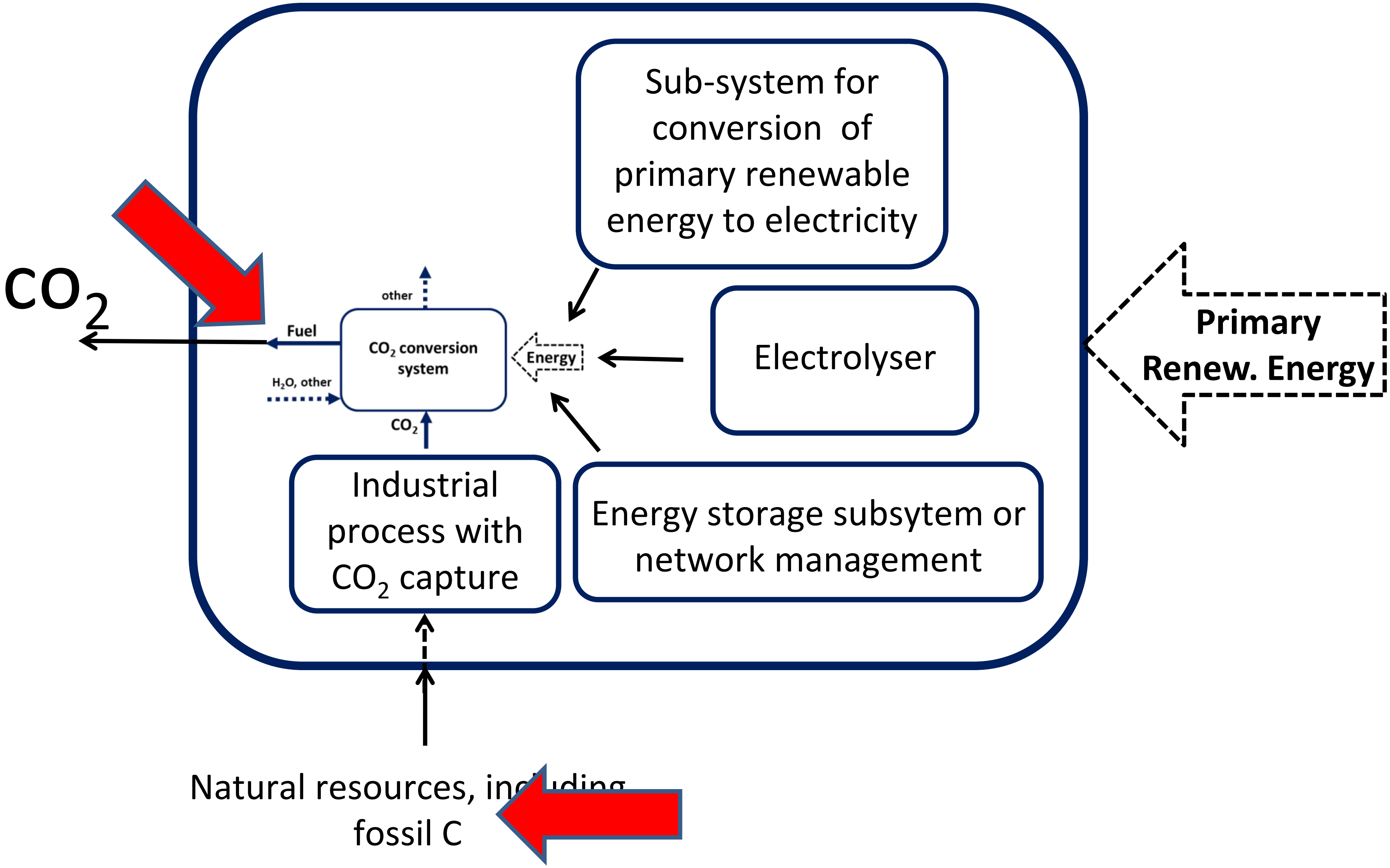
System boundaries for CCU

Who is allowed to claim for a CO_2 reduction credit?

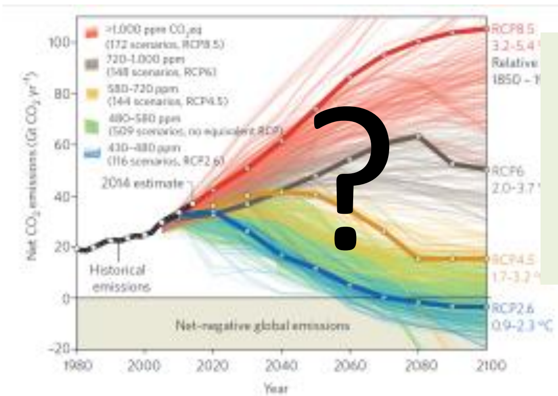


Carbon accounting for CCU

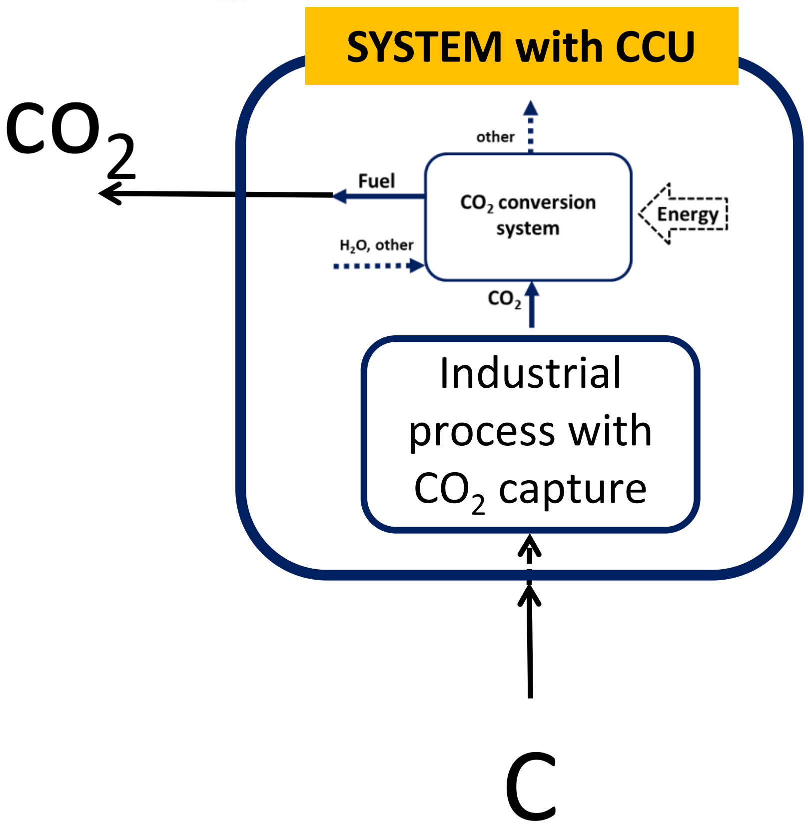
CARBON LEAKAGE unless CO_2 comes from Air Capture

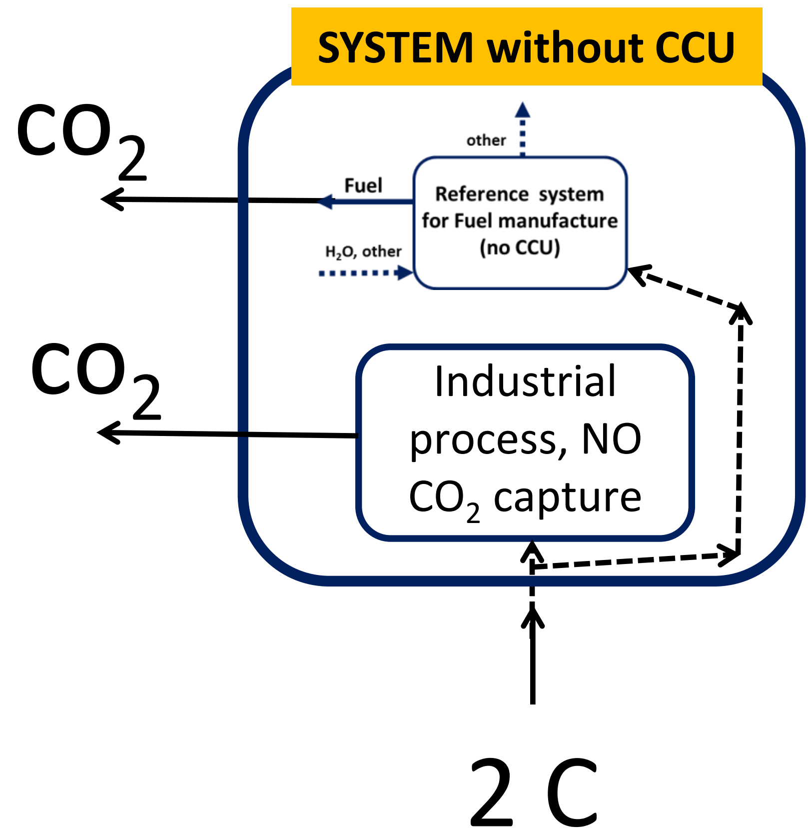


The avoided CO_2 by Substitution



- **Every atom of fossil Carbon used, is no longer stored away from the atmosphere**
- **Substitution can only avoid 50% of emissions**





Concluding remarks

- Climate change policies will eventually force a high cost per tonne of CO_2 emissions.
- CCS can be deployed today at competitive cost respect to other low C technologies (at 50-100 €/tonne). Great prospects for cost reductions by "learning by doing" and/or by new technologies. 2/3 of the total CCS cost comes from CO_2 capture.
- There is no economic incentive to deploy CCS at large scale in Europe at present. Time to bet on R&D on emerging technologies ? .

- The impact of CCUs other than "CO_2 to fuels" can only be very small.
- Betting on CO_2 Utilisation for climate change mitigation may be risky: no transparent method for carbon accounting is yet avaialble (source of carbon?, life time of product ?, carbon footrpint of all inputs of energy and materials ?)
- Estimation of CO_2 avoided cost by CCU is uncertain and highly sensitive to "attribution issues" regarding the low carbon energy needed for CCU.

Thank you for your attention!

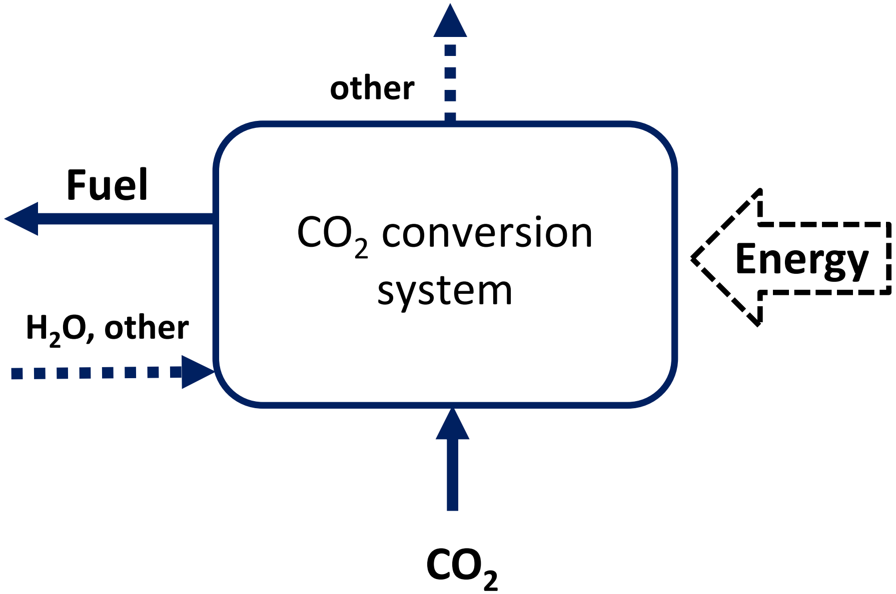
Acknowledgement

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement no 641185

www.sintef.no/cemcap

Twitter: @CEMCAP_CO2

System boundaries for LCA of CCU ?



“Each atom of C we can recycle is an atom of fossil carbon left in the underground for next generations that will not reach the atmosphere today.”

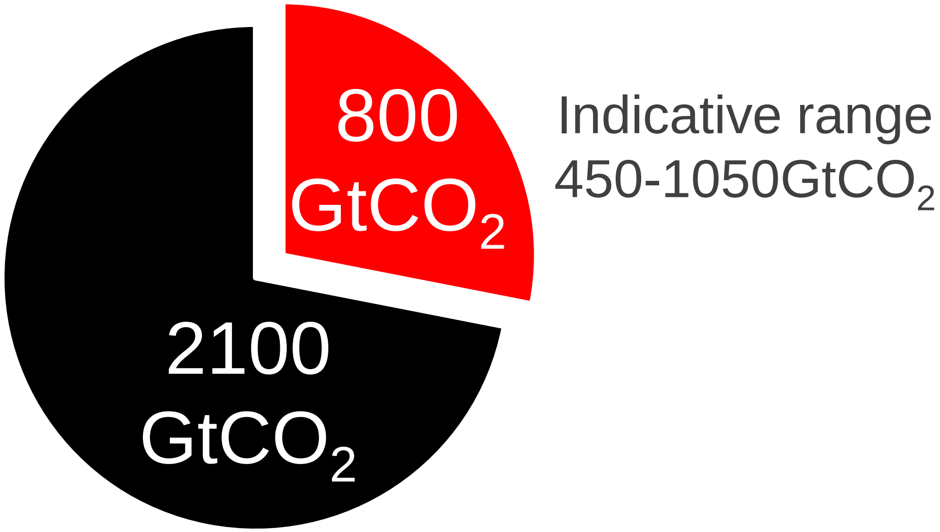
IF

The source of CO_2 is the atmosphere, AND
There are no penalties in energy conversion processes, AND
Air Capture+Renewables have a zero carbon footprint

Carbon quota for a >66% chance to keep below 2°C

For a >66% chance to keep global average temperature below 2°C above pre-industrial levels, society can emit 2900 billion tonnes CO_2 from 1870 or about 800 billion tonnes CO_2 from 2017

<2.0°C, >66%



Historical emissions 1870-2016: 2100GtCO_2. All values rounded to the nearest 50 GtCO_2

The remaining quotas are indicative and vary depending on definition and methodology (Rogelj et al 2016).

Source: IPCC AR5 SYR (Table 2.2); Le Quéré et al 2016; Global Carbon Budget 2016