THE NOVO NORDISK FOUNDATION CO2 RESEARCH CENTER

Circle U Staff Week 2022

Carbon Capture, Storage and Utilization

Background and Technical Challenges

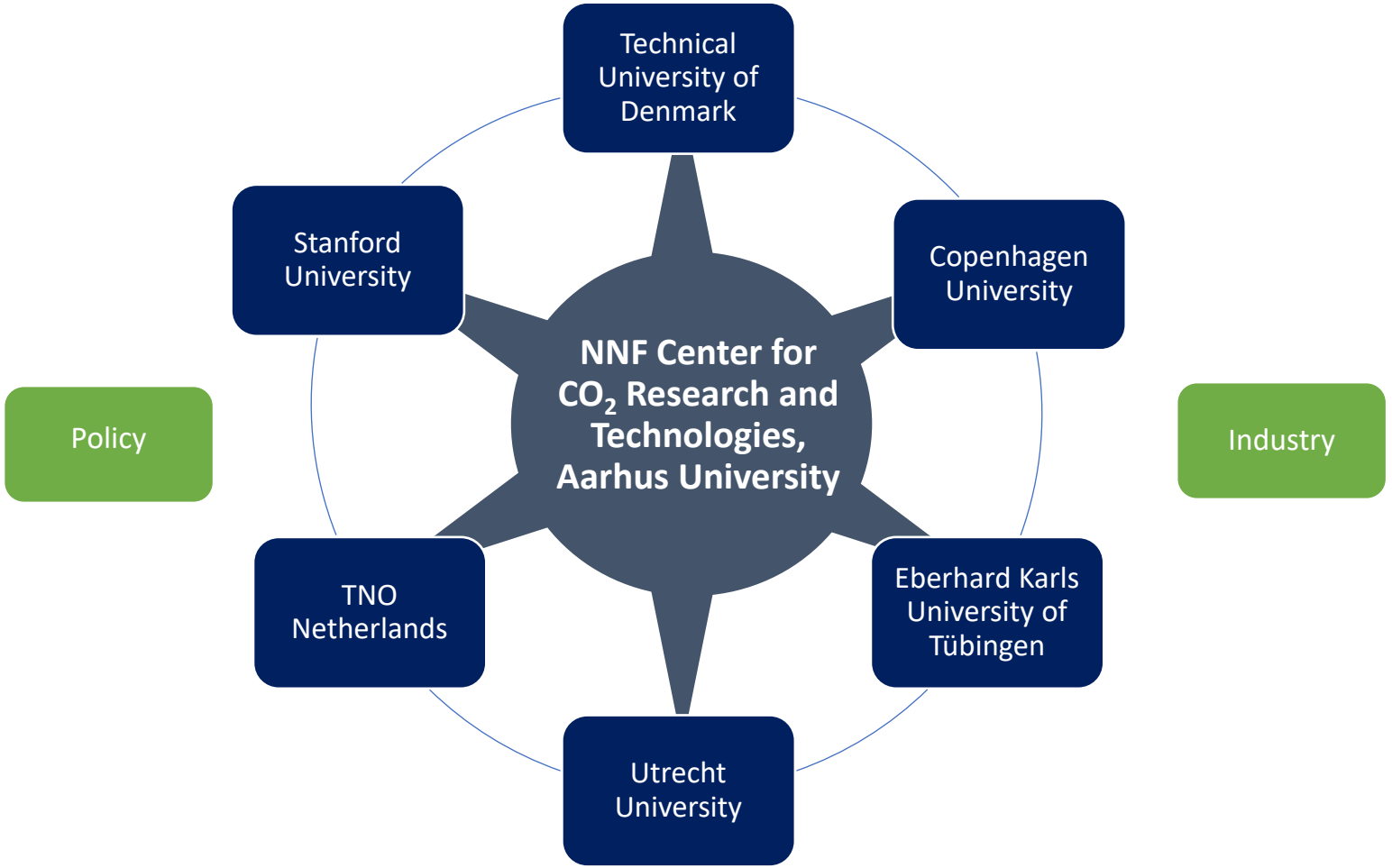
Mission-oriented, interdisciplinary research on CO_2 capture and conversion for storage and use at scale

Novo Nordisk Foundation
CO_2 Research Center

https://corc.au.dk

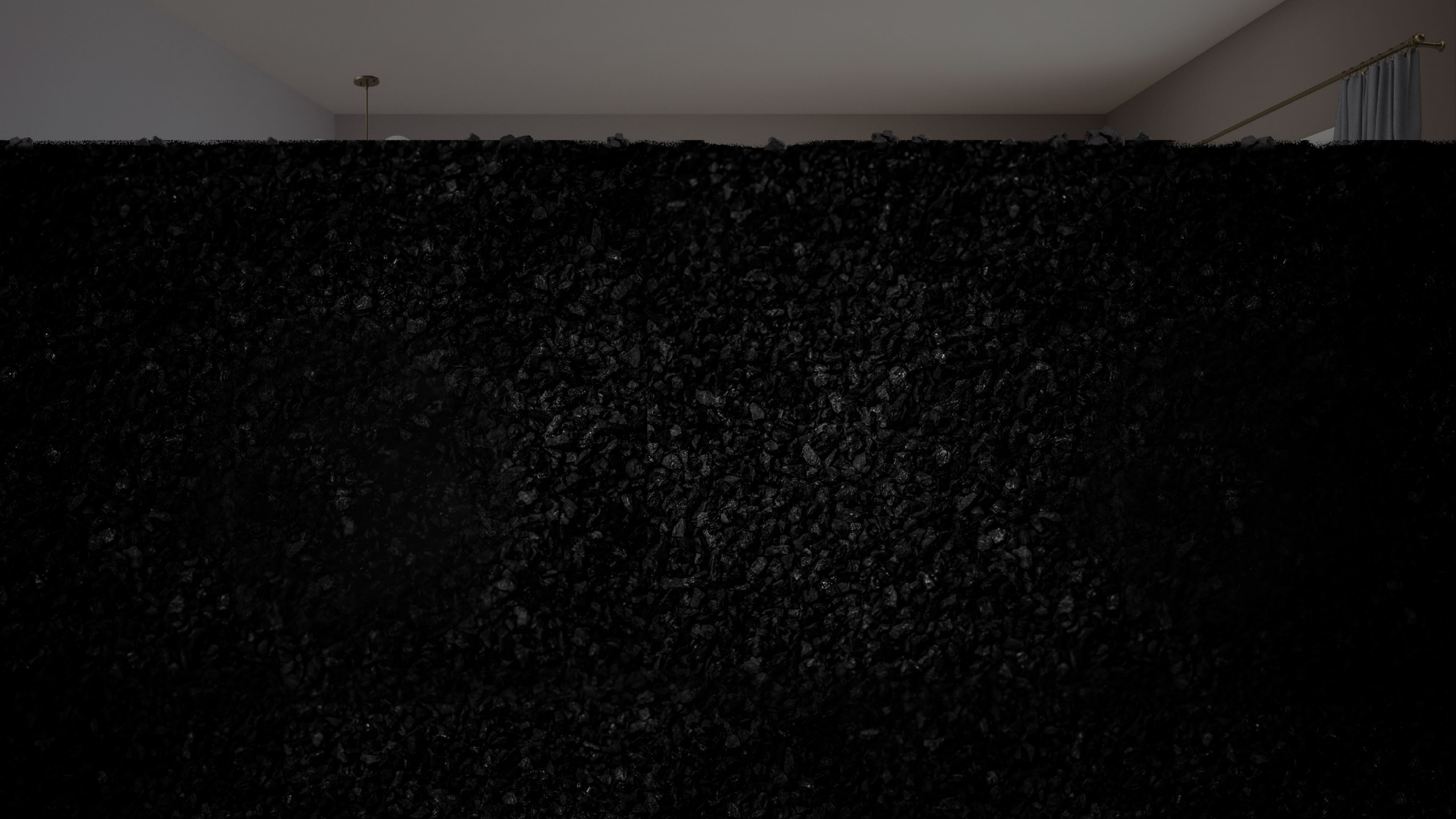
info@corc.au.dk

CORC Structure & Organization



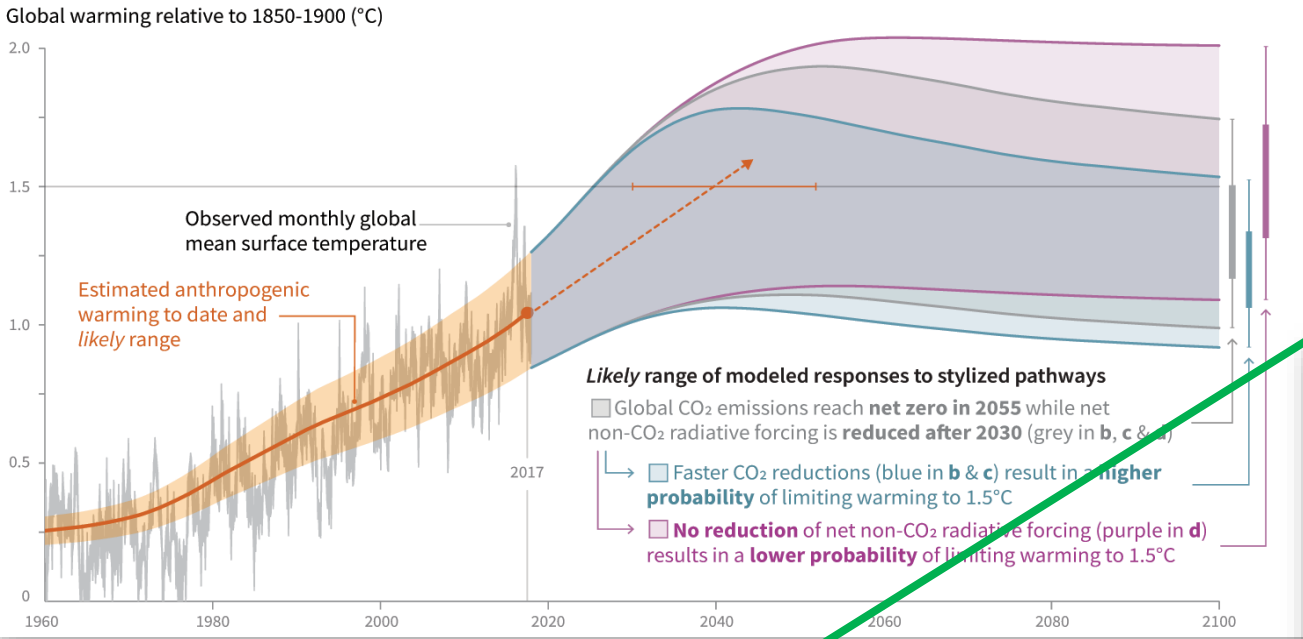
Novo Nordisk Foundation
CO_2 Research Center

The CORC-family (or… workforce)



Cumulative emissions of CO_2 and future non-CO_2 radiative forcing determine the probability of limiting warming to 1.5°C

a) Observed global temperature change and modeled responses to stylized anthropogenic emission and forcing pathways



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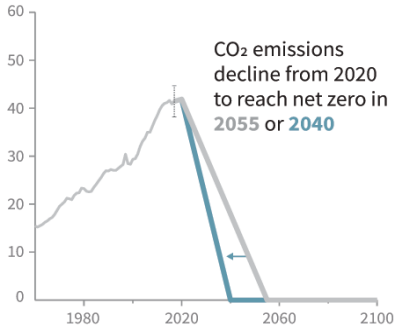

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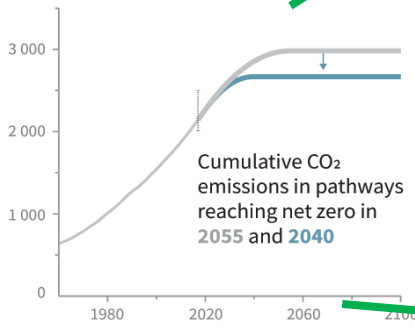

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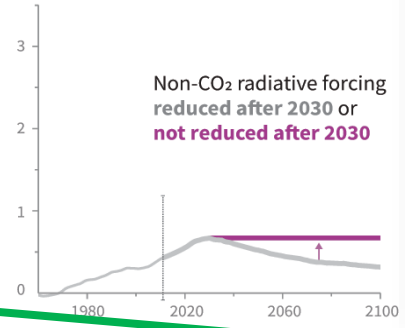


Faster immediate CO_2 emission reductions limit cumulative CO_2 emissions shown in panel **(c)**.

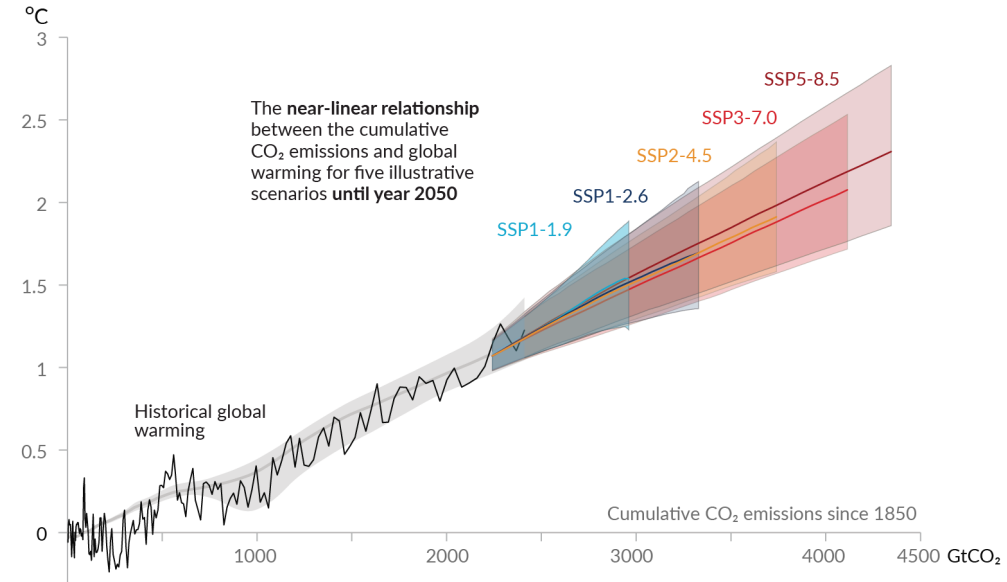
Maximum temperature rise is determined by cumulative net CO_2 emissions and net non-CO_2 radiative forcing due to methane, nitrous oxide, aerosols and other anthropogenic forcing agents.

IPCC Fig: SPM. 1: – modified (cropped)

Figure SPM.10 in IPCC, 2021: Summary for Policymakers. In: *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change* [Masson-Delmotte, V., P. Zhai, A. Pirani, S.L. Connors, C. Péan, S. Berger, N. Caud, Y. Chen, L. Goldfarb, M.I. Gomis, M. Huang, K. Leitzell, E. Lonnoy, J.B.R. Matthews, T.K. Maycock, T. Waterfield, O. Yelekçi, R. Yu, and B. Zhou (eds.)]. Cambridge University Press, Cambridge, UK and New York, NY, USA, pp. 3–32, doi:10.1017/9781009157896.001.

Every tonne of CO_2 emissions adds to global warming

Global surface temperature increase since 1850–1900 (°C) as a function of cumulative CO_2 emissions ($GtCO_2$)



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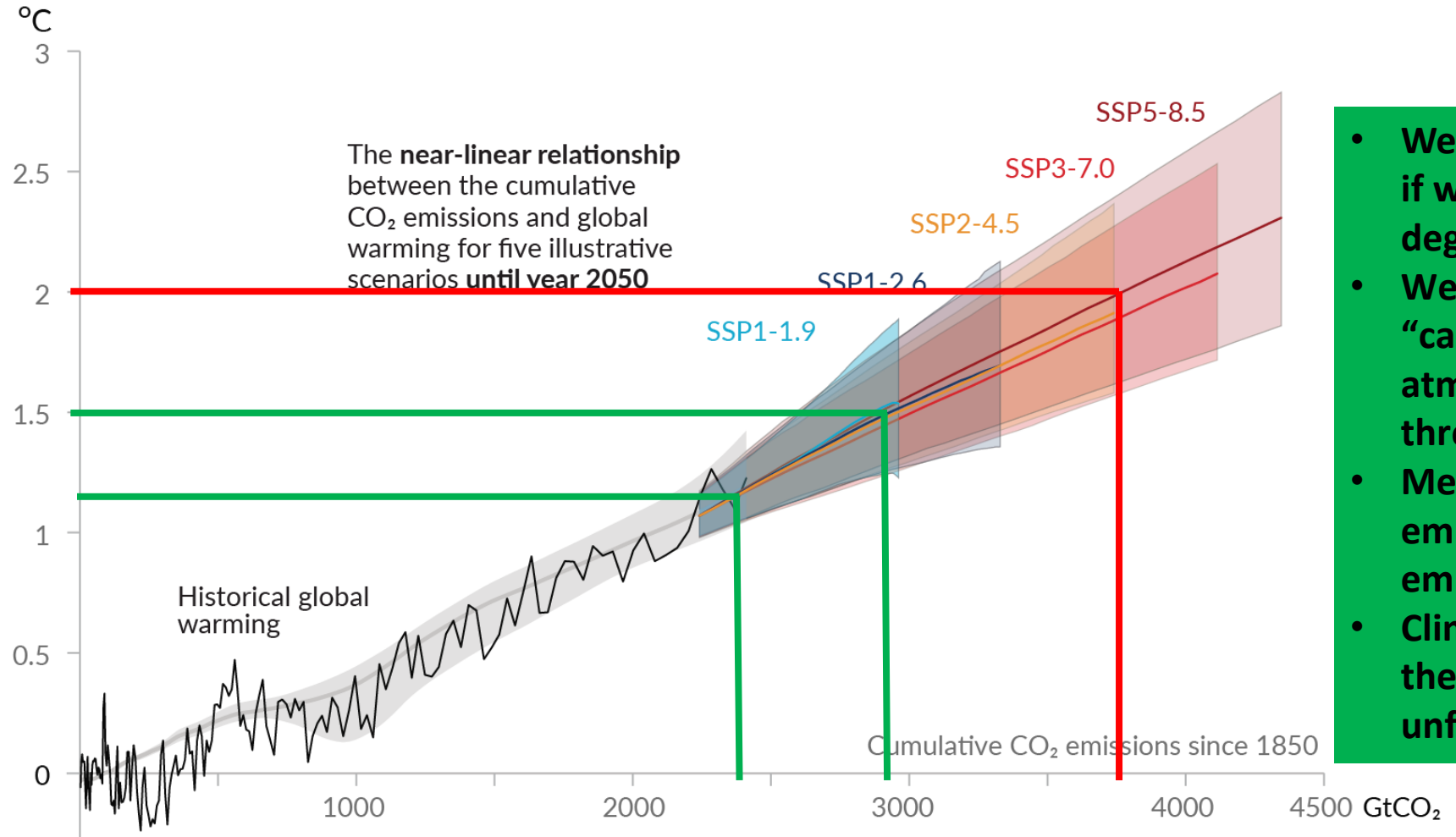

- **We have a global carbon budget if we want to stay below 2 degrees (1.5 best case scenario)**
- **We have around 800 Gt of "carbon space" left in the atmosphere before reaching that threshold**
- **Meaning ≈ 20 years, if current emissions don't increase (as we emit around 40Gt CO2e PA)**
- **Climate tipping points increase the probability of increasing unforeseen emissions**

Cumulative emissions of CO_2 and future non-CO_2 radiative forcing determine the probability of limiting warming to 1.5°C

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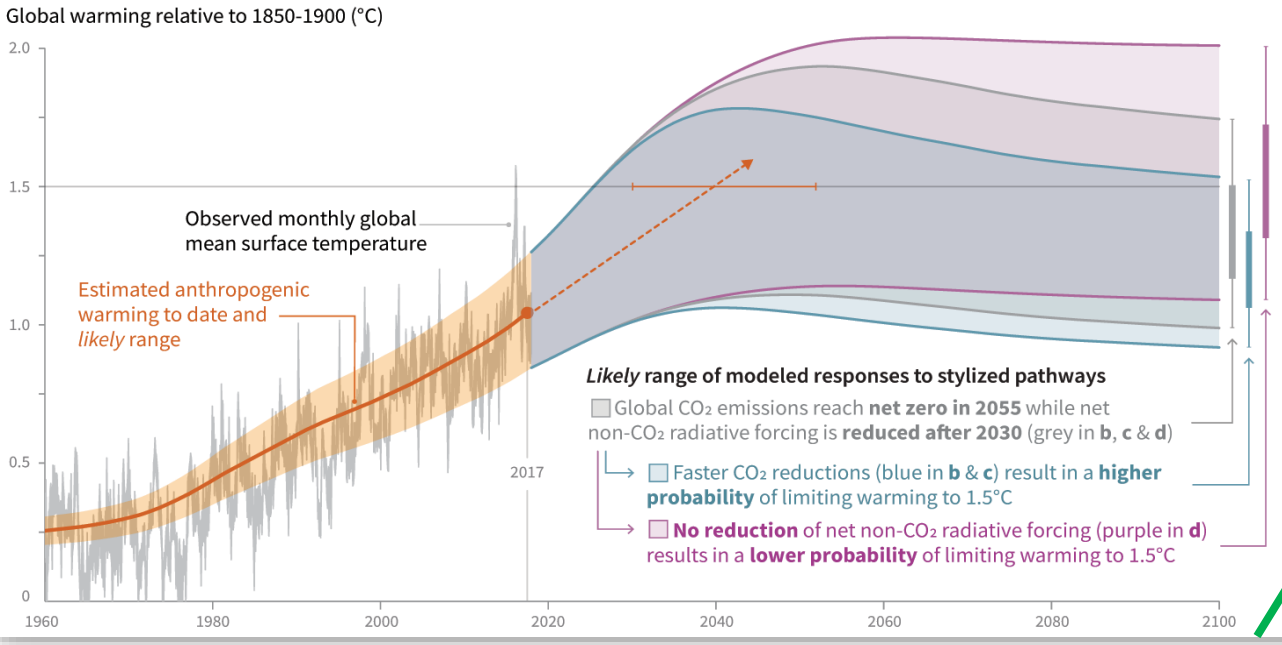

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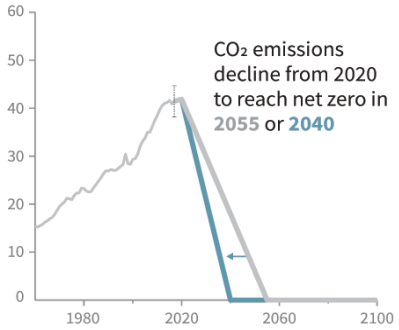

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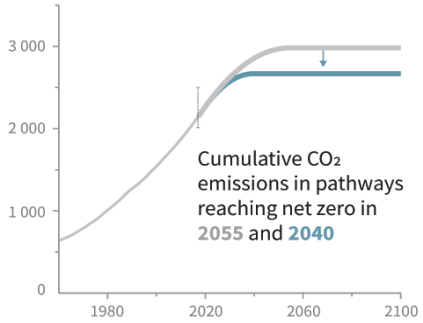

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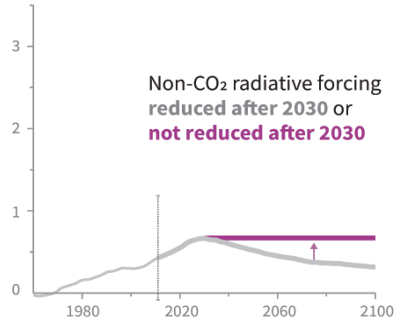

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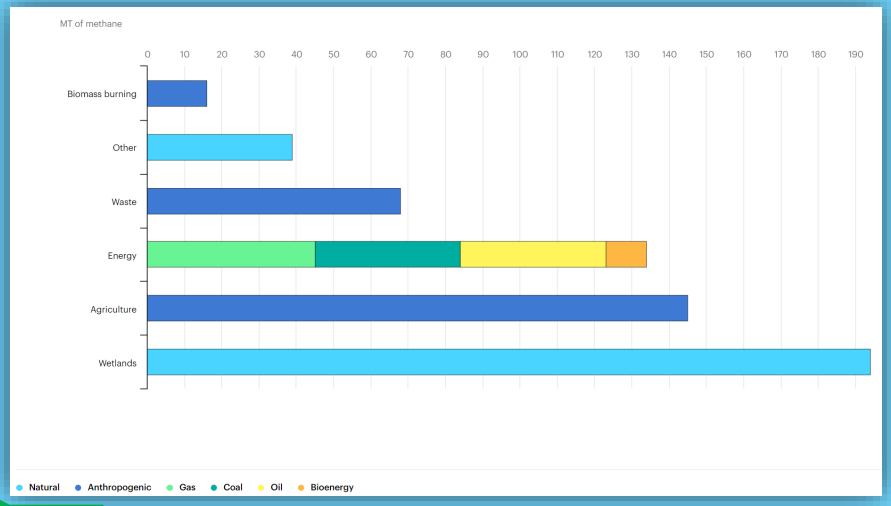
IPCC Fig: SPM. 1: – modified (cropped)

- Methane (CH_4) and Nitrous Oxide (N_2O)
- ≈ 30 and 270 times the GHG potential of carbon dioxide
- Only lasts around 10 and 100 years in the atmosphere



De nye respirationskamre ved AU Viborg - Forskningscenter Foulum er allerede taget i brug. Foto: Maria Eksildsen.

- **Denmark has the most extensive agriculture by percent area in the EU**
- **Aarhus is doing something about it!**

Arkivfoto:Bo Amstrup/Ritzau Scanpix

THE NEED FOR CDR!!

Carbon Dioxide Removal

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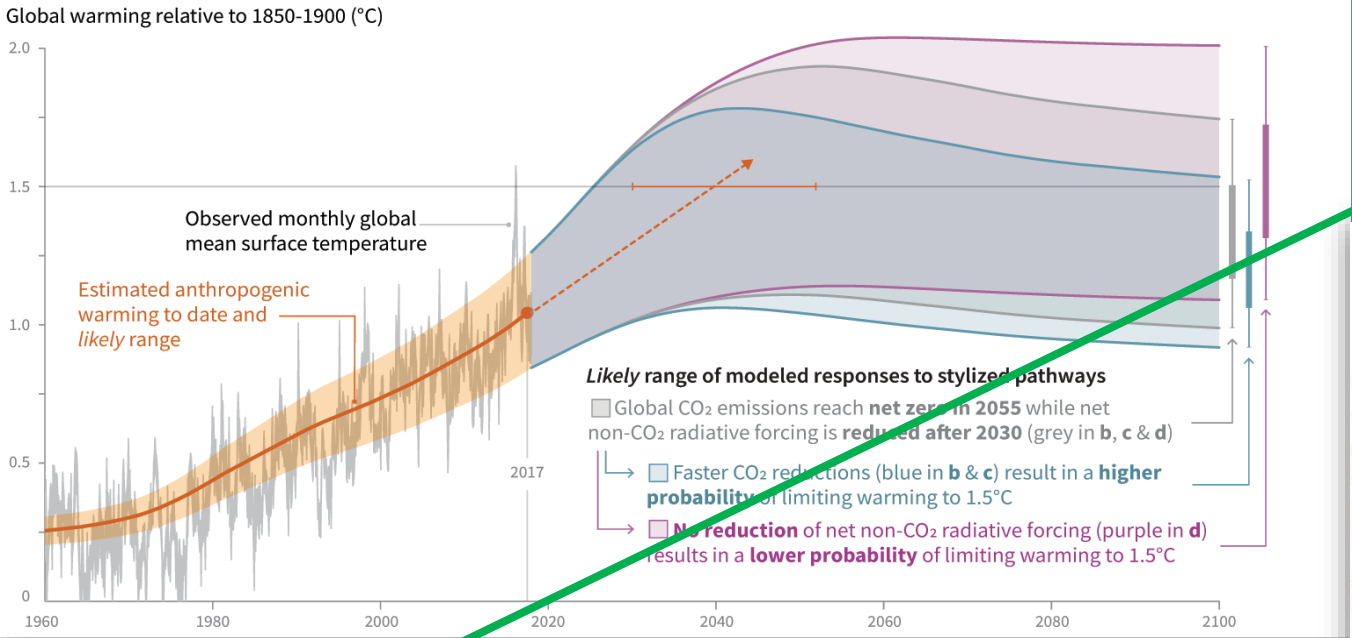

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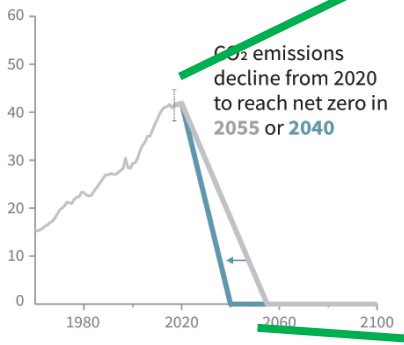

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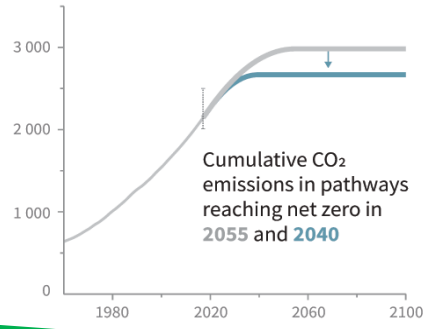

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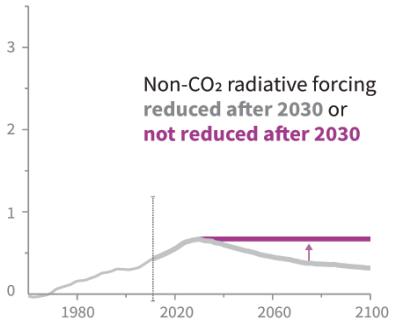

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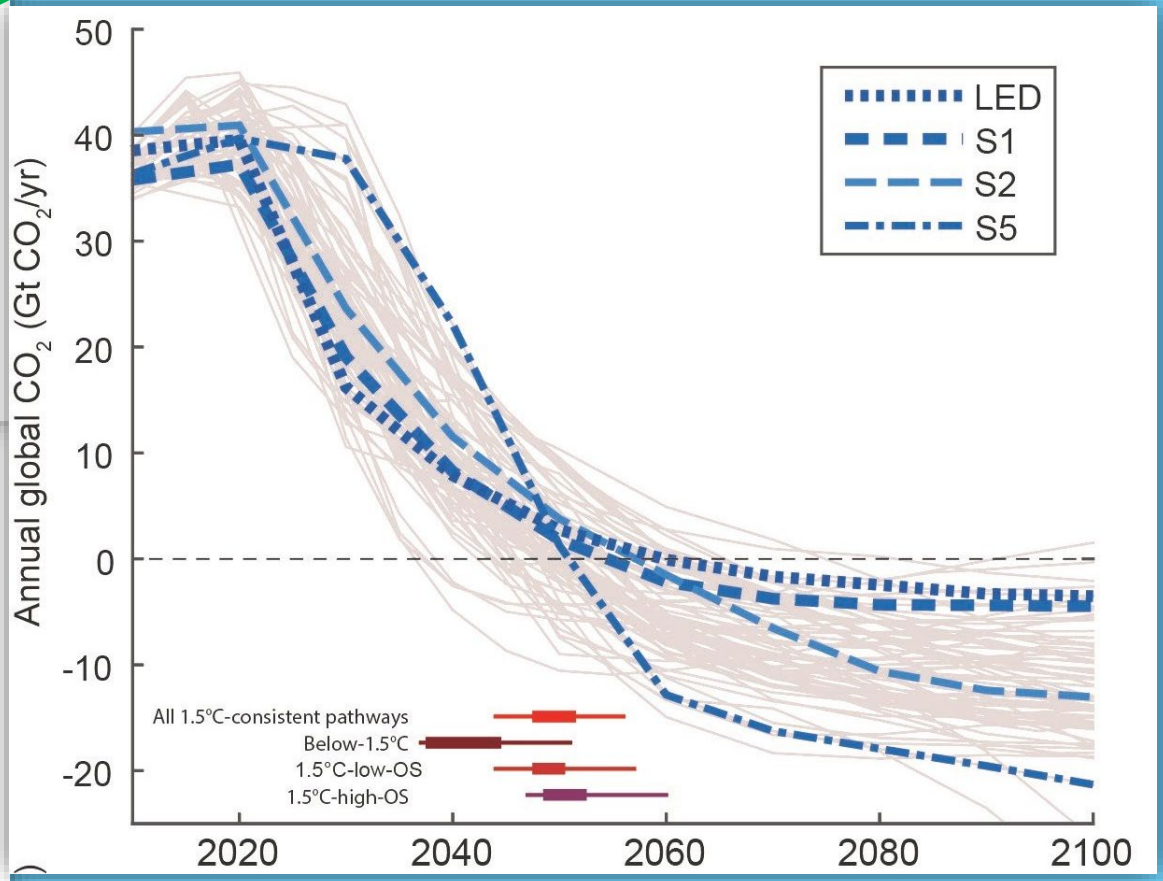
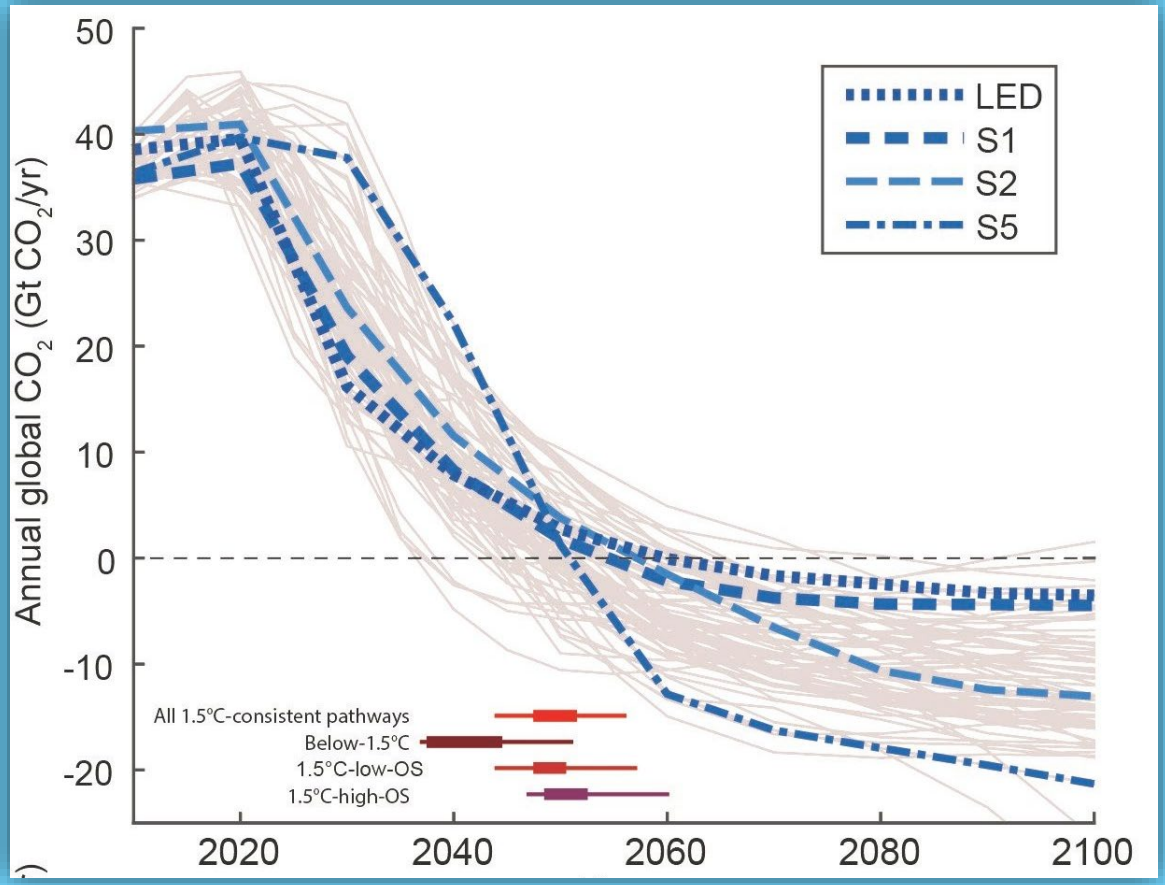


IPCC Fig: SPM. 1: – modified (cropped)

CDR “Carbon Dioxide Removal” Why is it needed?

- IPCC: more than half of below 2-degree models include carbon capture – among other CDR technologies
  - Without carbon capture emission reduction cost increases by 138%
  - *“The deployment of carbon dioxide removals to counterbalance hard-to-abate residual emissions is unavoidable if net-zero…emissions are to be achieved”*



IPCC Fig: 2.5: Evolution and break down of global anthropogenic CO2 emissions until 2100: Original Creation for this Report (IPCC 6) using IAMC 1.5°C Scenario Data hosted by IIASA – modified (cropped)

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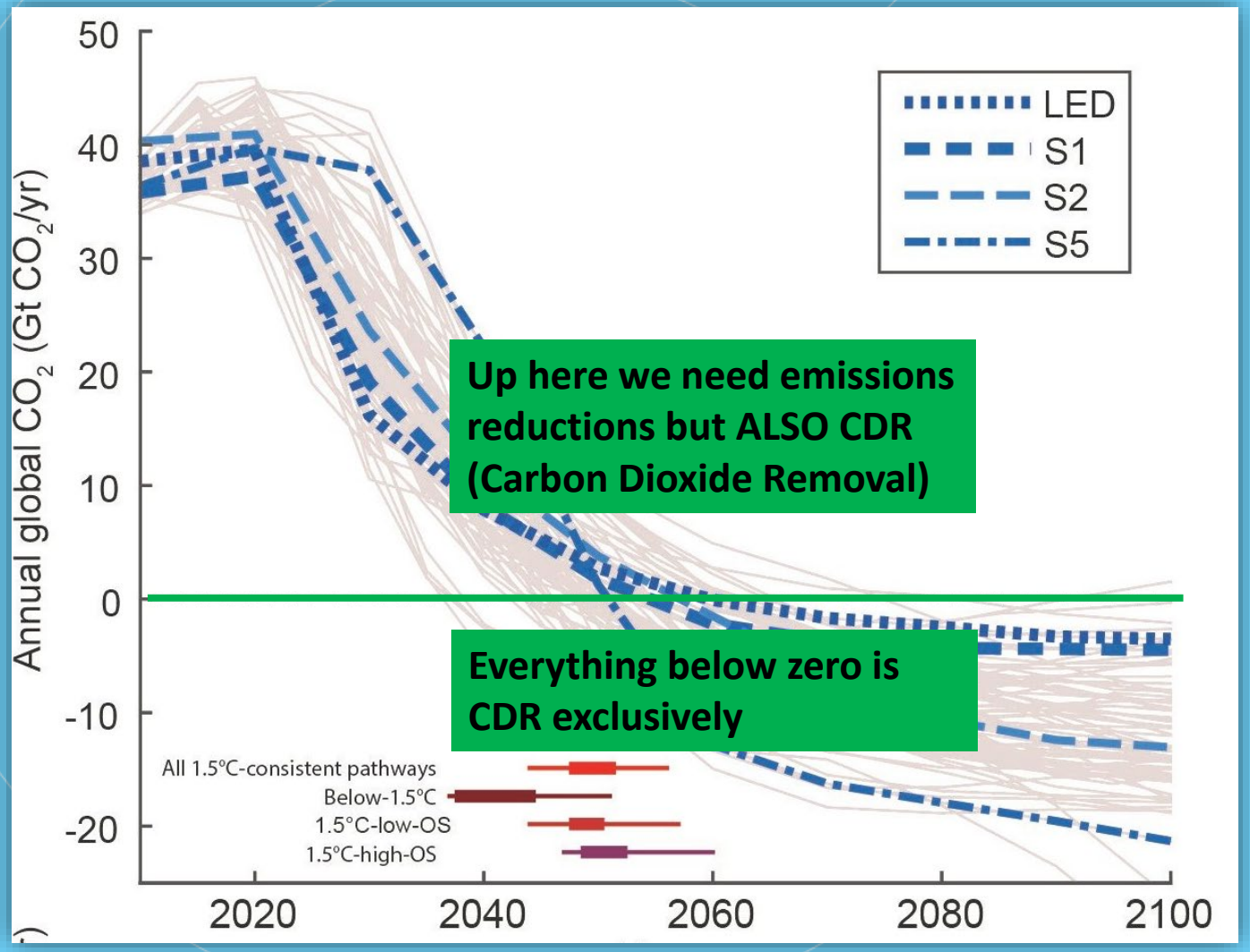

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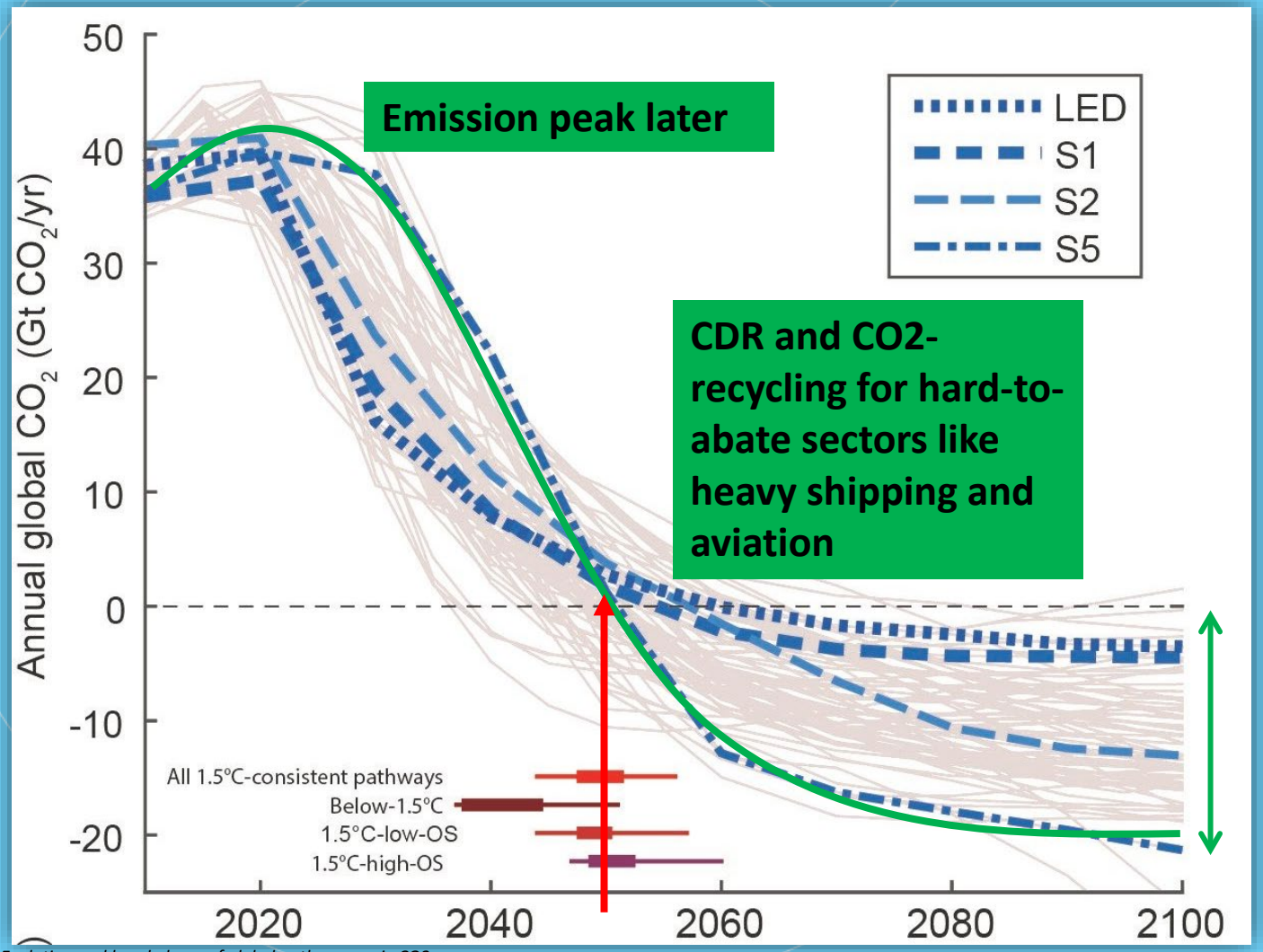

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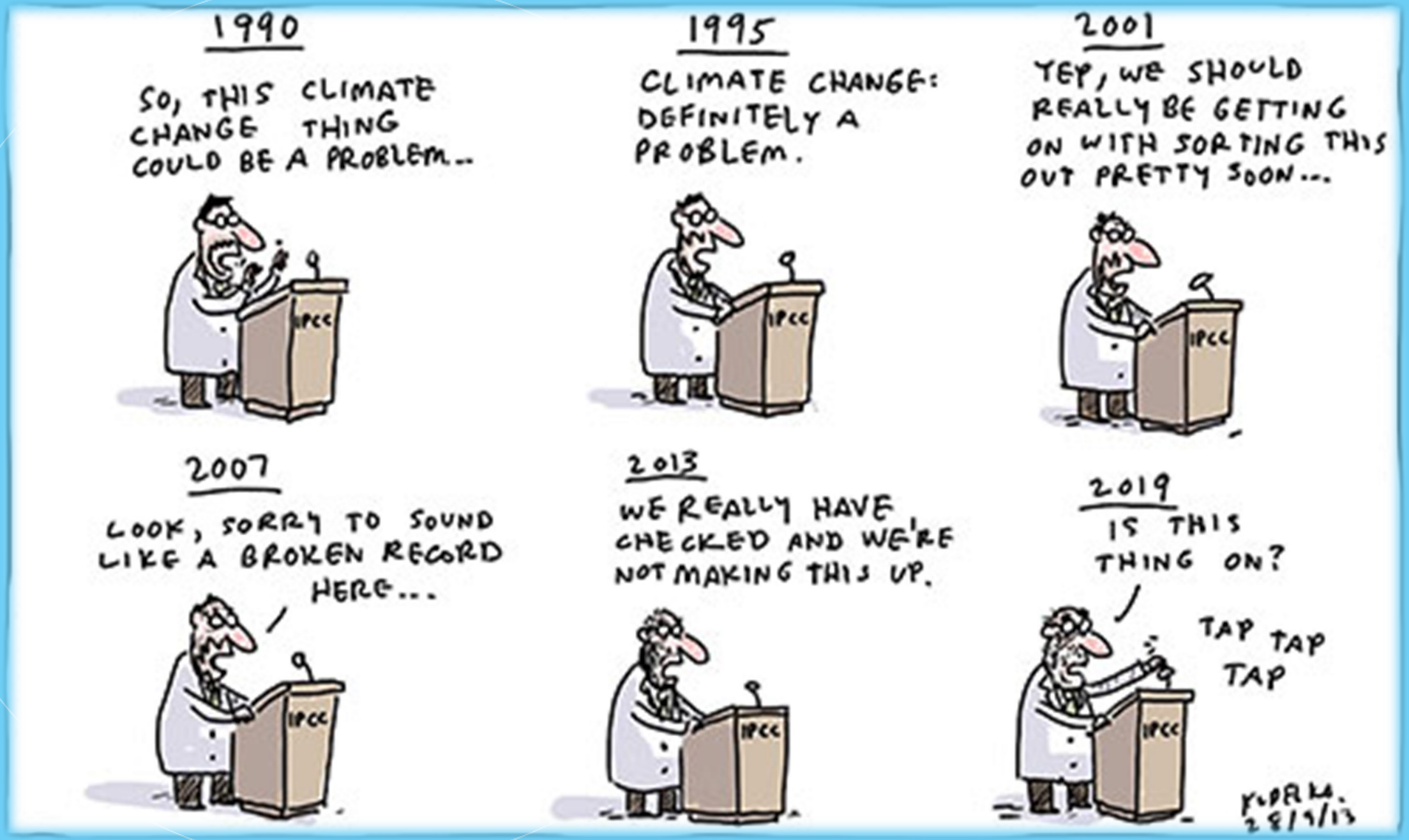
By 2050 we need to start going “negative” if we want to stay within the scope of the Paris agreement (up to 20Gt pr. year)

The more aggressive we reduce now, the less is needed in the future.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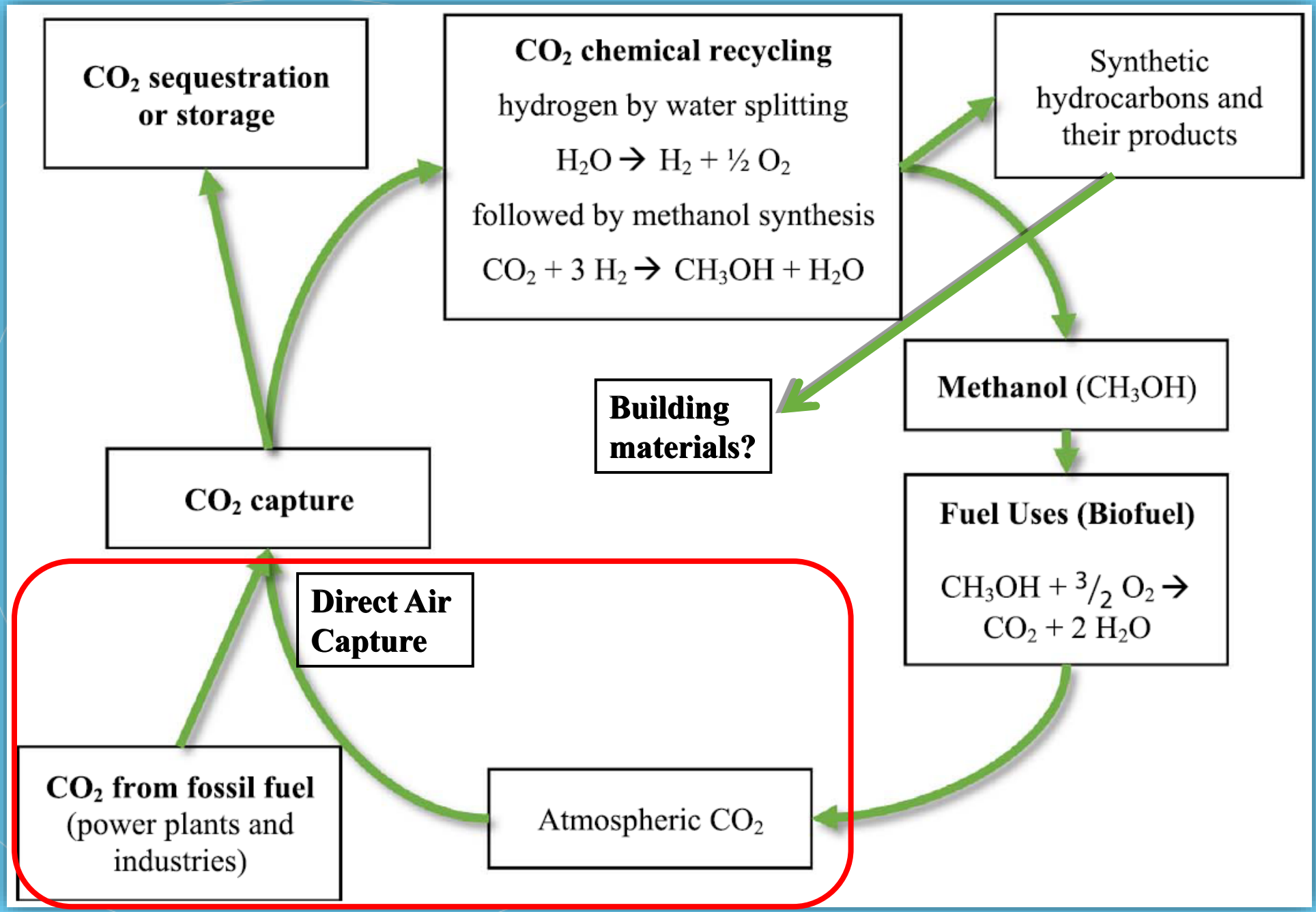
IS THIS THING ON?
TAP TAP TAP
IPCC
KUDELKA. 28/9/13

Jon Kudelka

EXAMPLE OF CARBON CAPTURE AND UTILIZATION

Not removal – rather an avoidance…

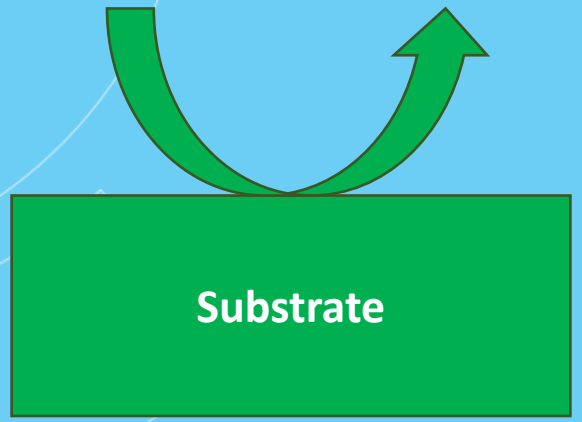


Norhidayah Abdul Hassan et al.: Pollution to solution: Capture and sequestration of carbon dioxide (CO2) and its utilization as a renewable energy source for a sustainable future, Renewable and Sustainable Energy Reviews, Volume 71, 2017.

CCUS – Carbon Capture Utilizations and Storage

Carbon dioxide in the atmosphere, flue gas or biogas (more or less concentrated sources).

CO_2 CO_2 CO_2 CO_2 CO_2 CO_2 CO_2



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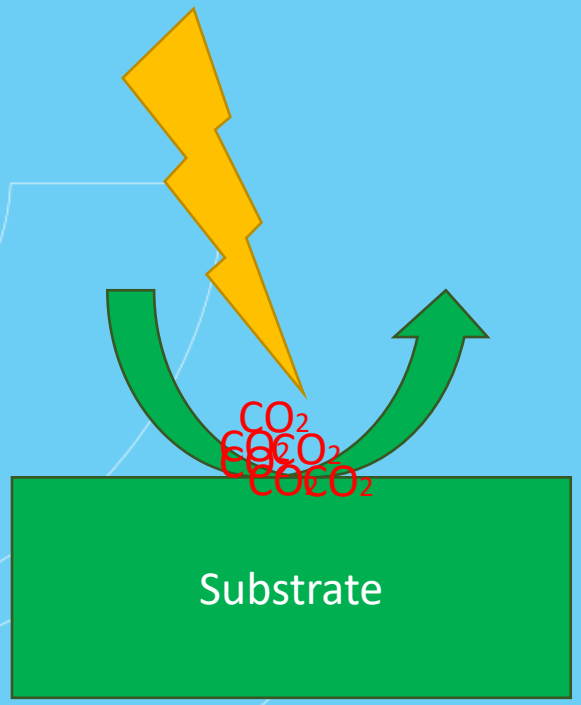
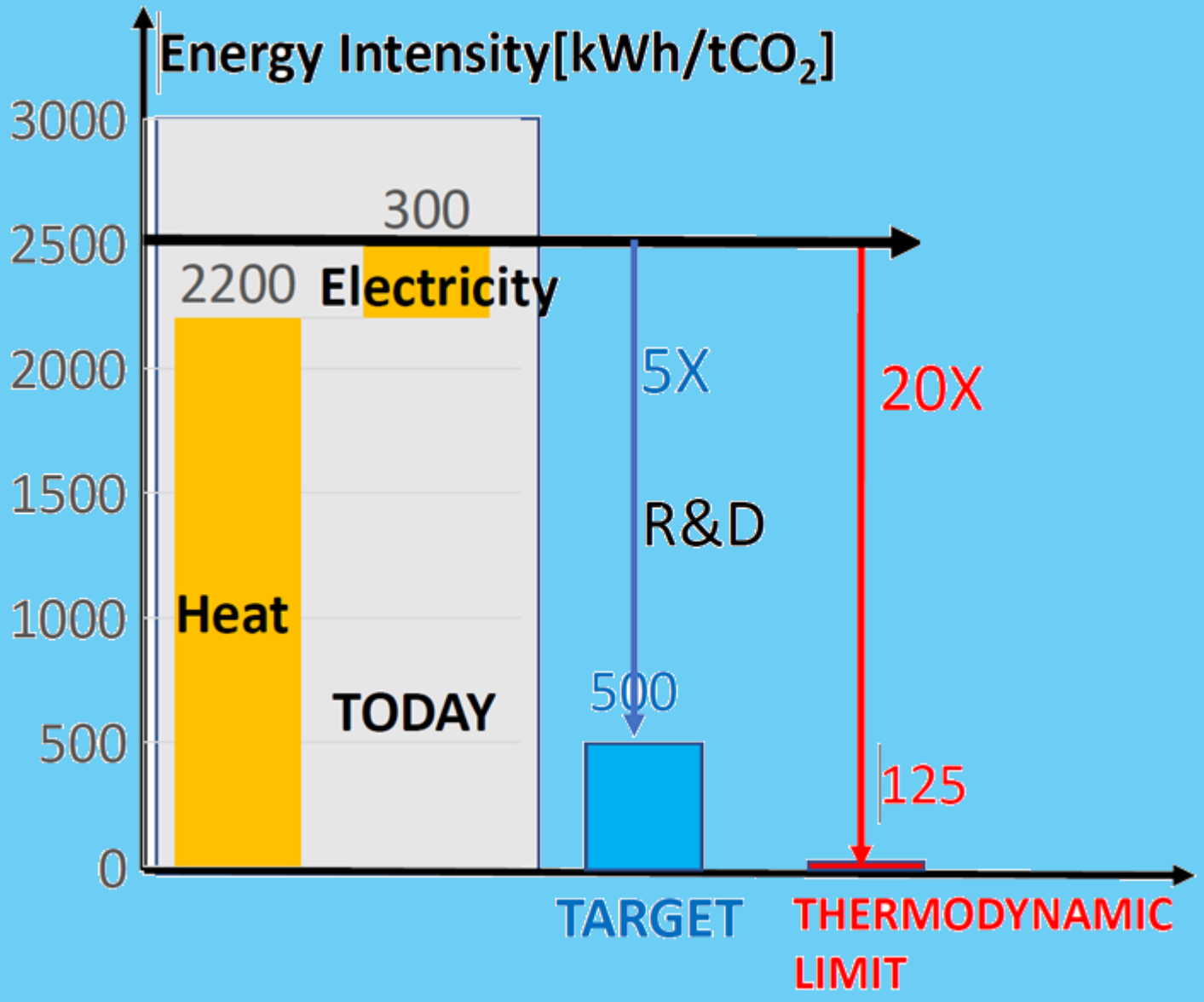
Carbon dioxide in the atmosphere, flue gas or biogas (more or less concentrated sources).

Approx. 2500 kWh pr. ton CO_2



The carbon dioxide is bound tightly – an enormous energy input is needed to release the carbon again.



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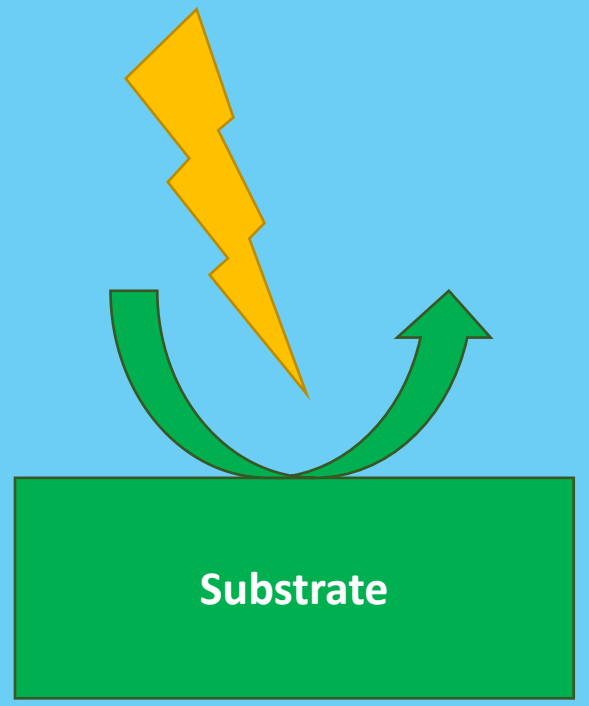
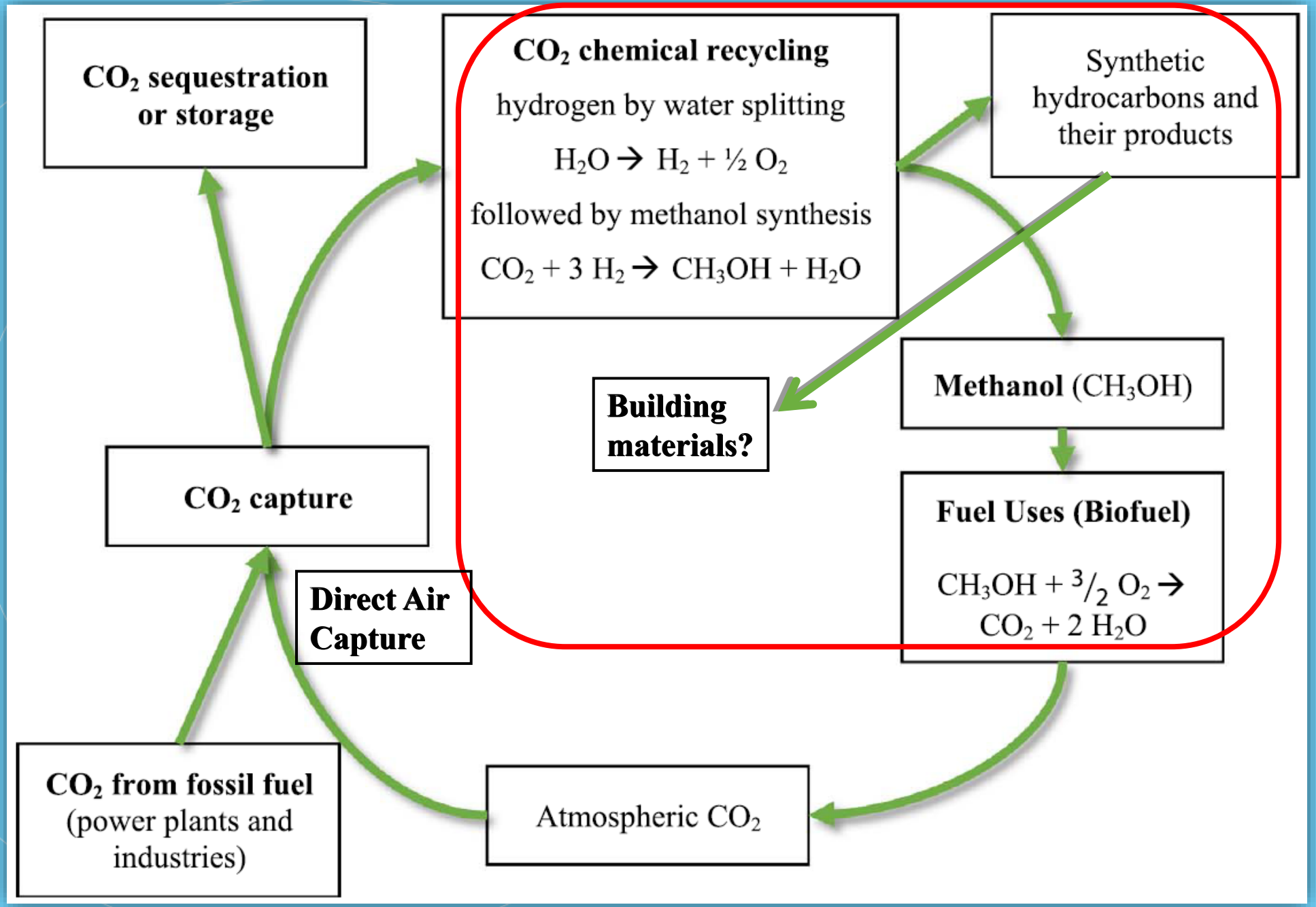


1 KWh is around 3 DKK (spring 2021)

≈ around 7500 DKK pr. ton

≈ 7.5*10^12 DKK pr. GT or roughly 3.1 times more than Denmark's BNP



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Hydrogen and energy boundaries…

$CO_2 + 3H_2 \rightarrow [\text{-}CH_2\text{-}]_n + 2H_2O$

$CO_2 + 3H_2 \rightarrow CH_3OH + H_2O$

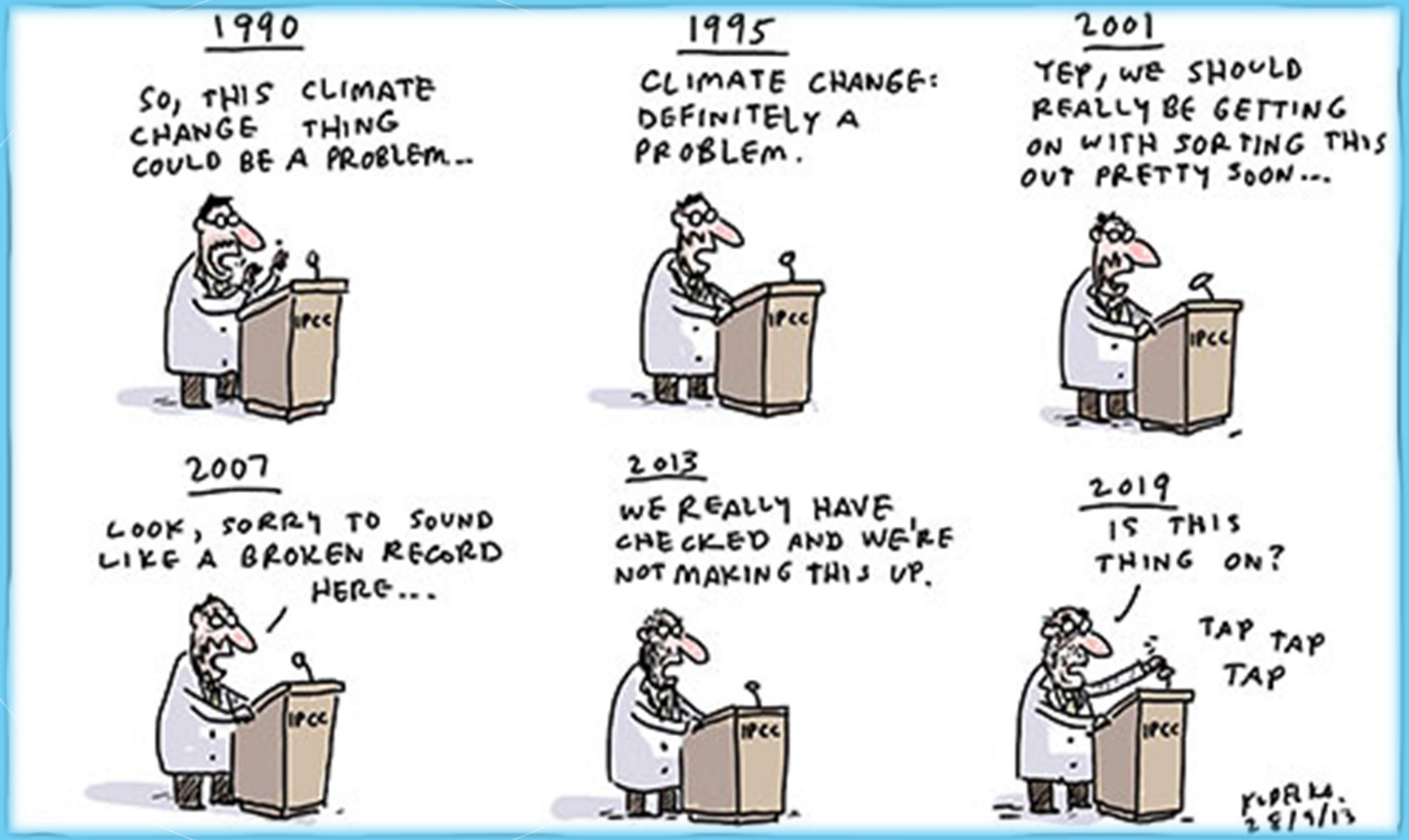
$CO_2 + 4H_2 \rightarrow CH_4 + 2H_2O$

This means that one mole of CO_2 reduced needs approx. 3 moles of H_2

So… 1 Gt of CO_2 needs 150 Mt of H_2

Consider producing 150 Mton-H_2 by electrolysis

- $H_2O \rightarrow H_2 + ½O_2$ ΔH = 286 kJ/mol ~ 40 kWh/kg-H_2
- Best catalysts today have overpotential ~ 50 kWh/kg-H_2
- 150 Mton-H_2 will need 7500 TWh of electricity
- ALL electricity production in 2020 in US was 4000 TWh; Carbon-free electricity (nuclear, hydro, solar, wind, geothermal, biomass) ~ 1500 TWh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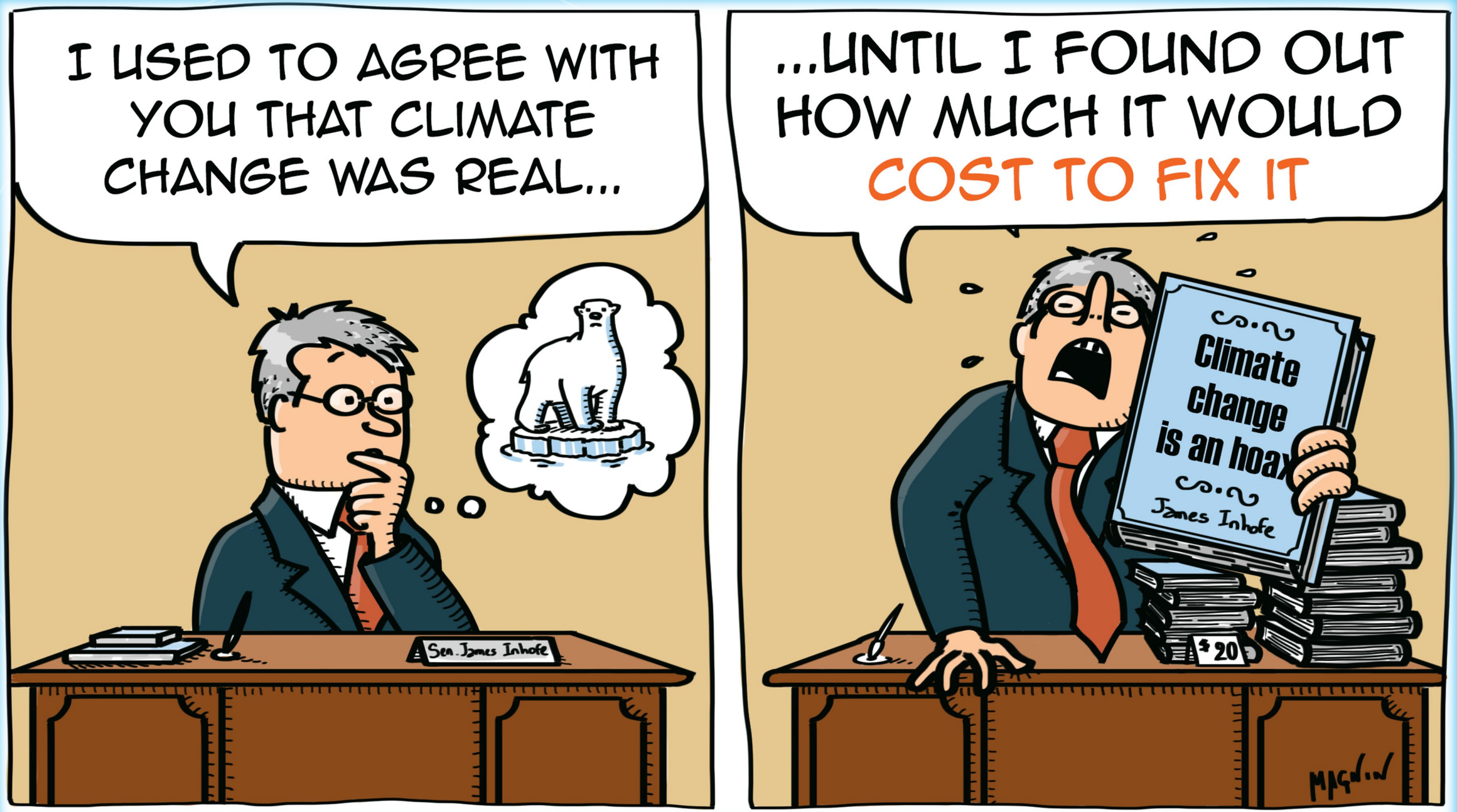
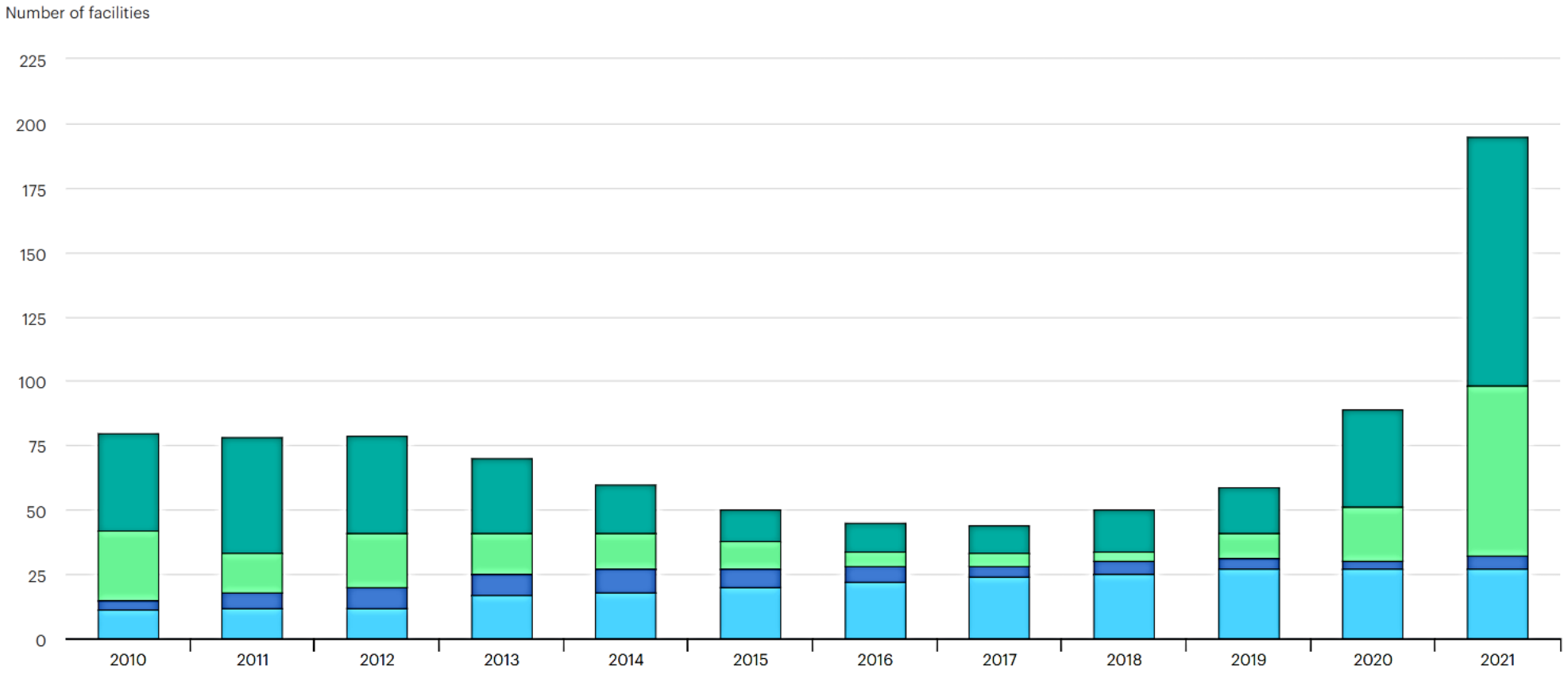


Global pipeline of commercial CCUS facilities operating and in development, 2010-2021



Take home messages:

- Now, to combat global warming, we need rigorous reductions in emissions **and** CDR (Carbon Dioxide Removal)
  - Hard-to-abate sectors (heavy transport, aviation, etc.) can become net-zero carbon emitters through **CCU, Carbon Capture, and Utilization**
  - Some emissions need to be offset/avoided by **CCS, Carbon Capture, and Storage**
- Negative emissions are needed by 2050 to stay below 1,5 degrees (on top of emission reduction)
  - We can use **CCS, carbon capture, and storage** for this purpose
  - It's very expensive and huge investments in R&D and education is needed
  - If we reduce more now, less **CCS** is needed later

Thank you for your attention

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