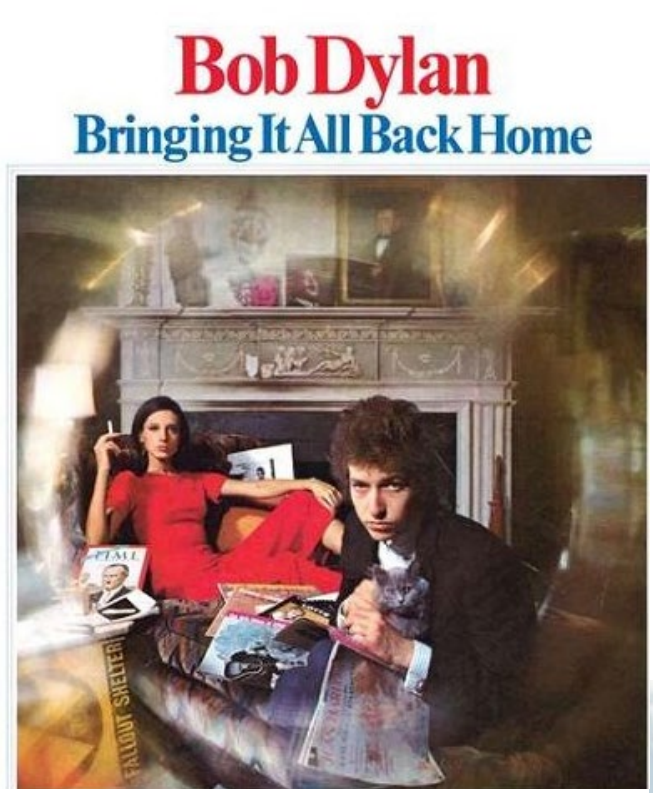
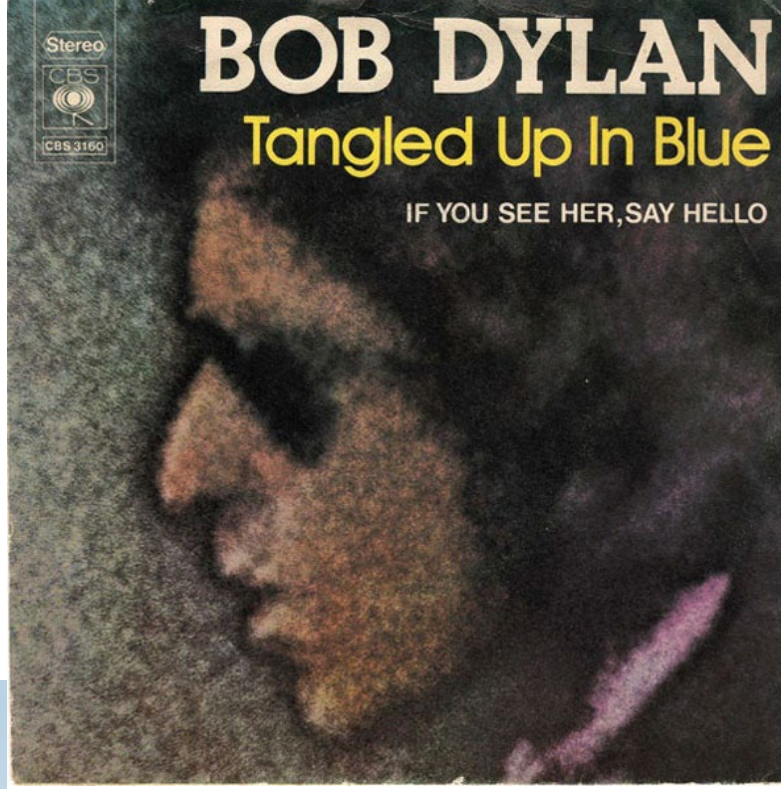


Negative CO_2 Emissions

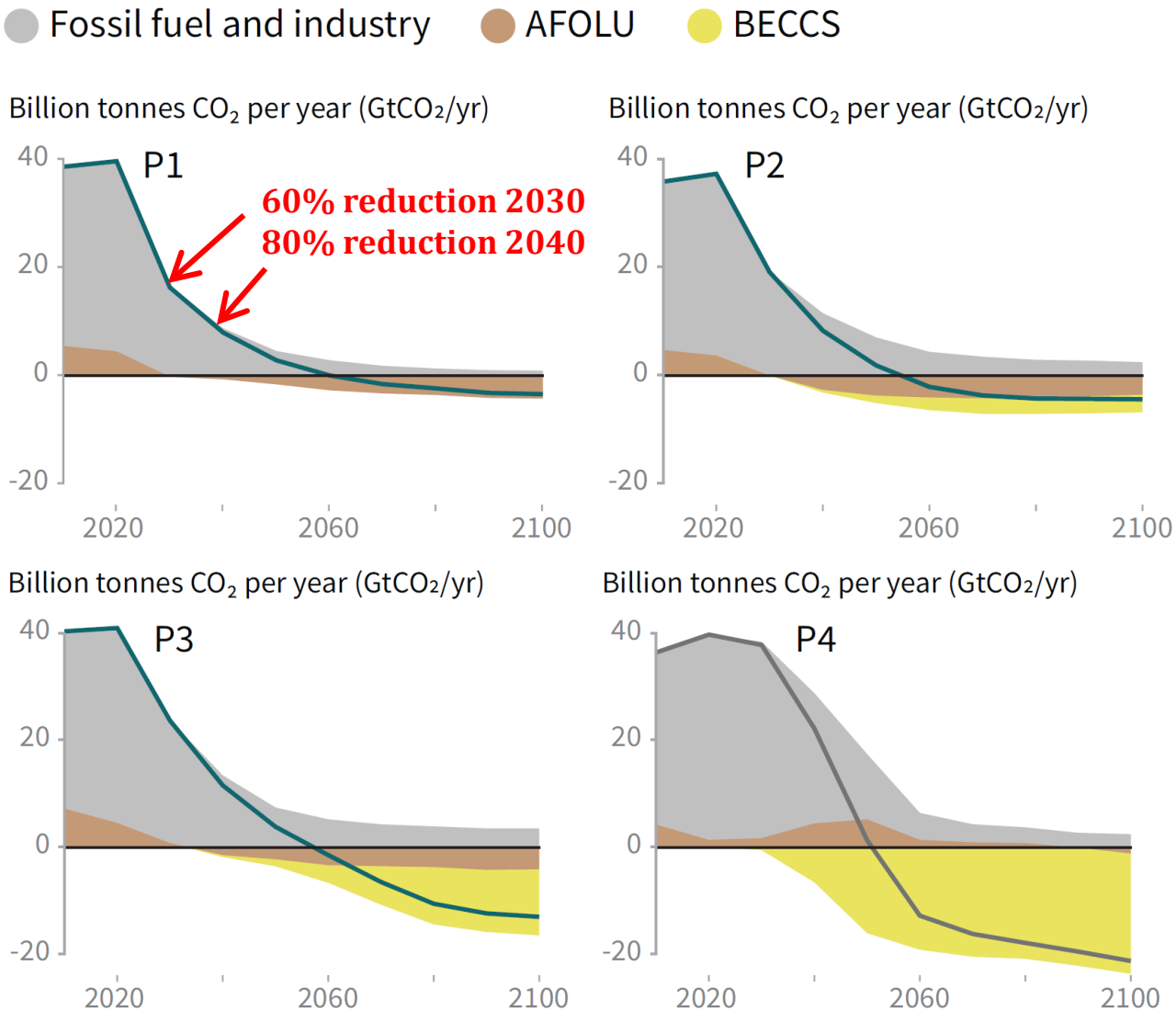
-

Bringing it all Back Home or Tangled up in Blue

Anders Lyngfelt



Biggest misconceptions of Bio-CCS: **1. Not needed**.



Carbon budget for 60% chance of max 1,5°C exceeded around 2029.

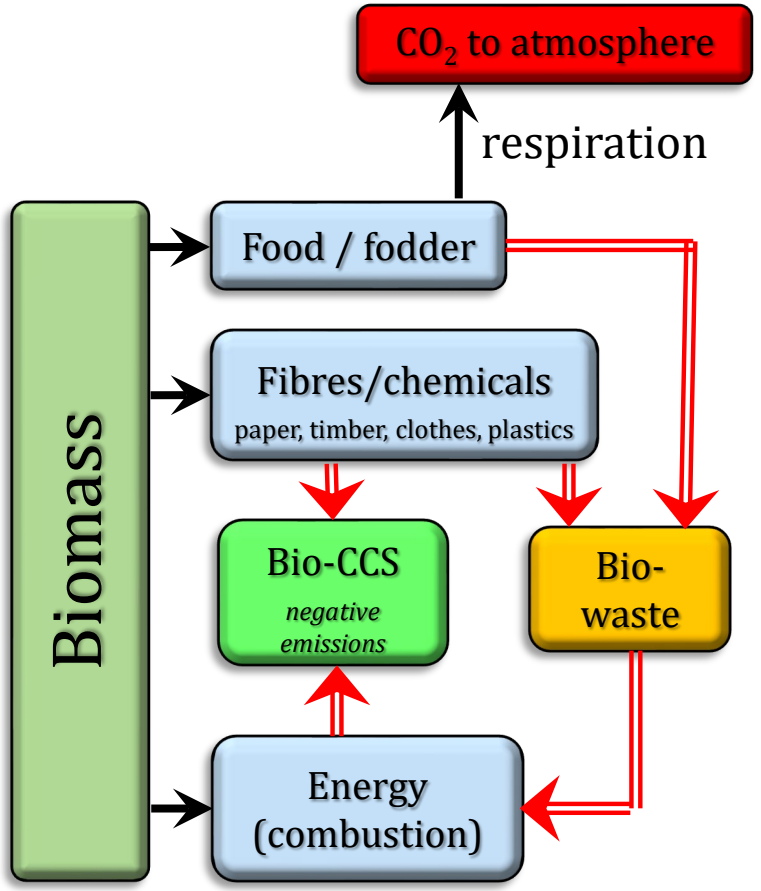
Biggest misconceptions of Bio-CCS: **2. Not enough ("Two more India needed …")**

Bio-CCS, can/should be combined with other uses of biomass

Total primary production:
220 Gton CO_2/year

Global extraction of biomass corresponds to 22 Gton CO_2/year (6 lost in respiration)

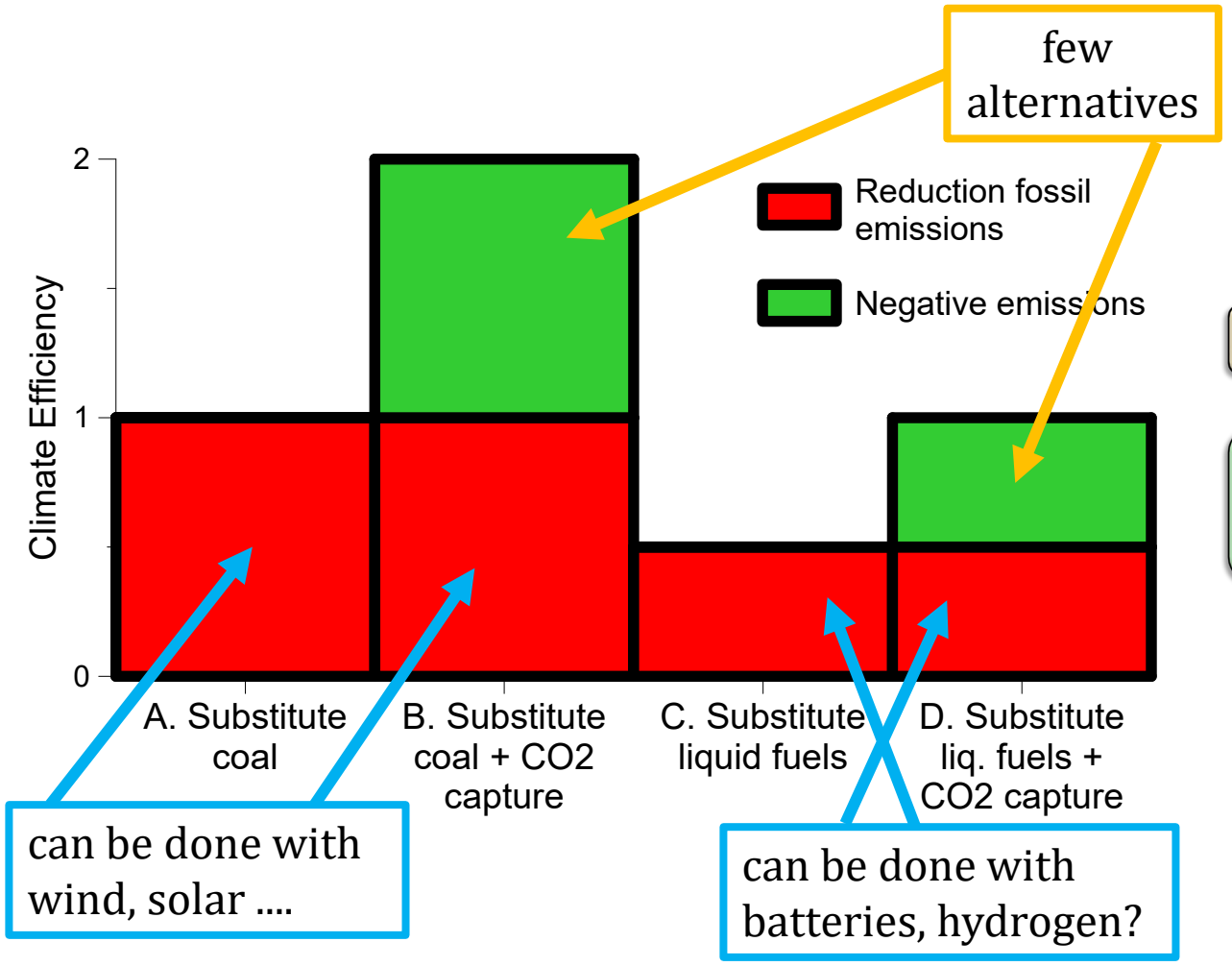
(fossil emissions are 37 Gton CO_2/year)

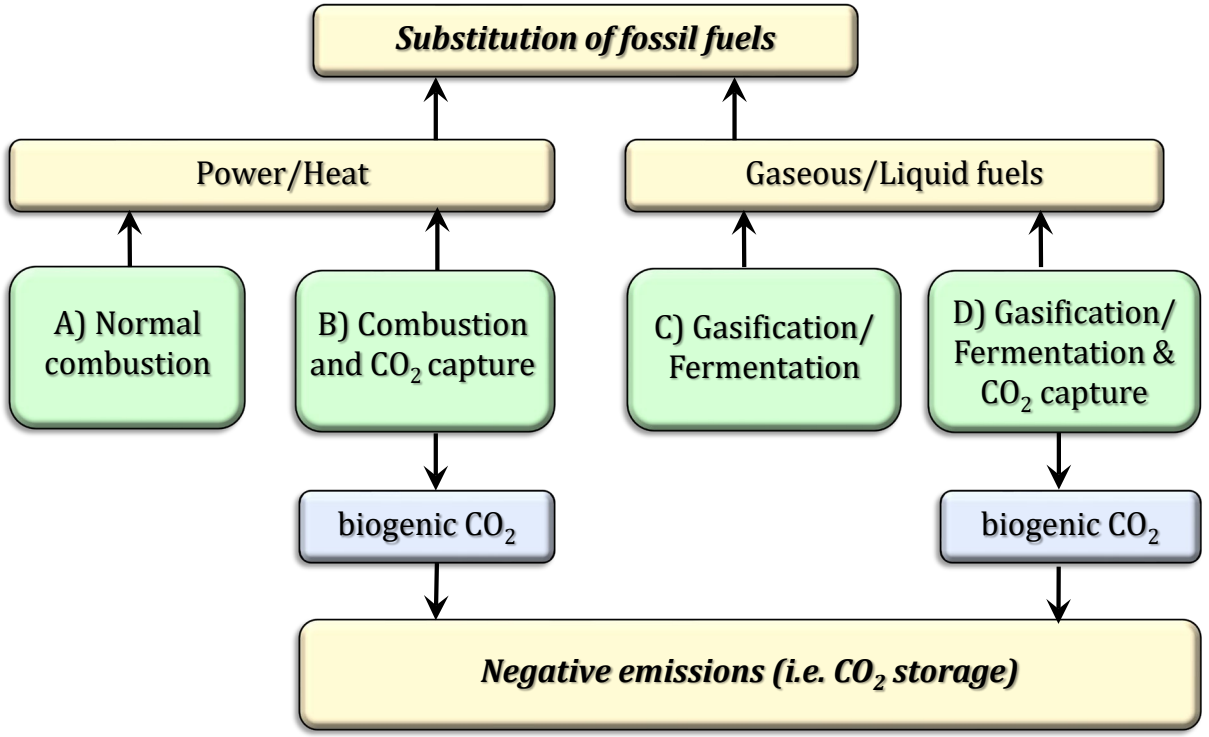


…. ***except*** when used as transportation fuel.

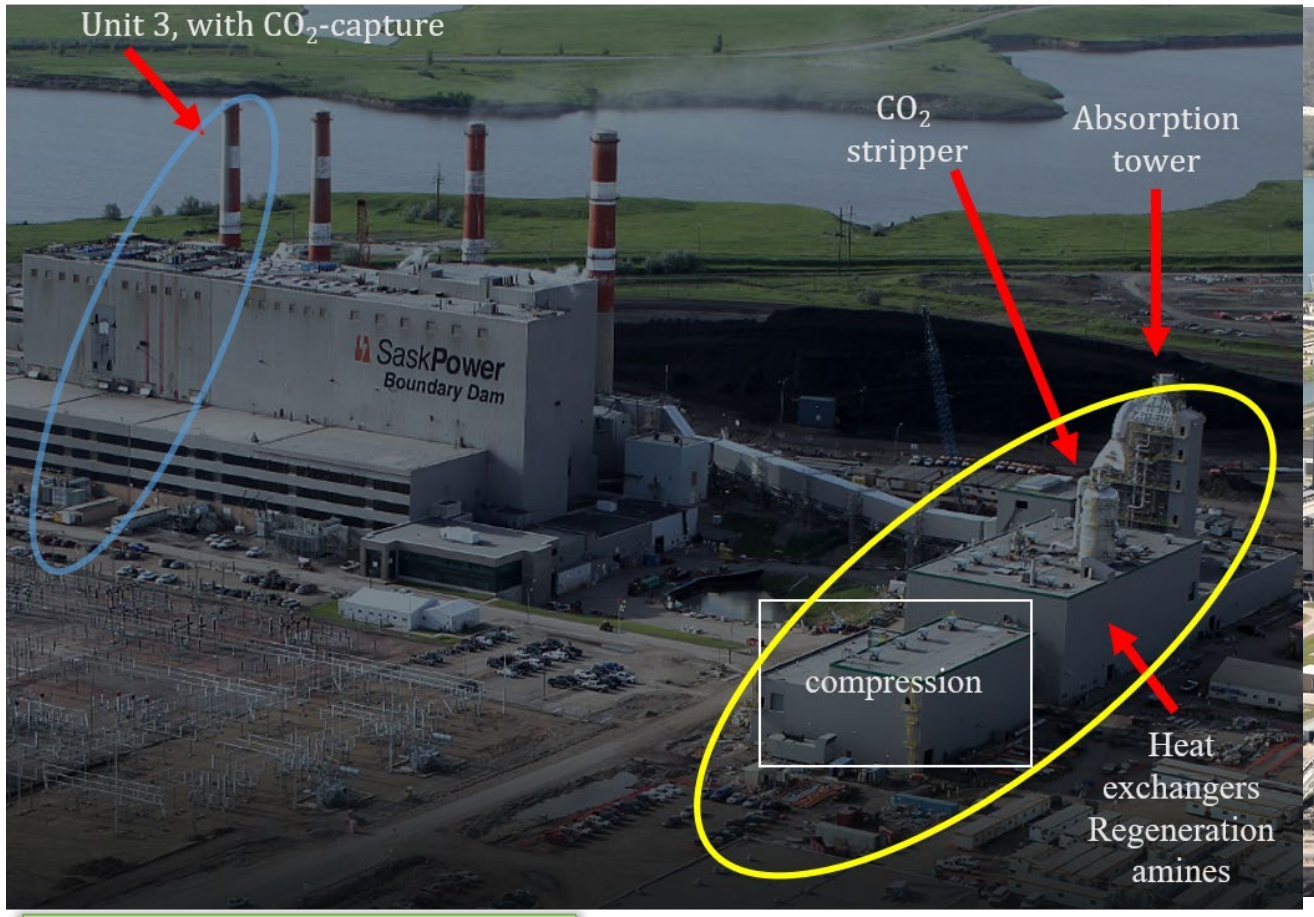
Biomass limited resource, should be used efficiently

$$\textbf{Climate Efficiency} = \frac{\textbf{reduction of } CO_2 \textbf{ in atmosphere}}{CO_2 \textbf{ captured by biomass harvested}}$$



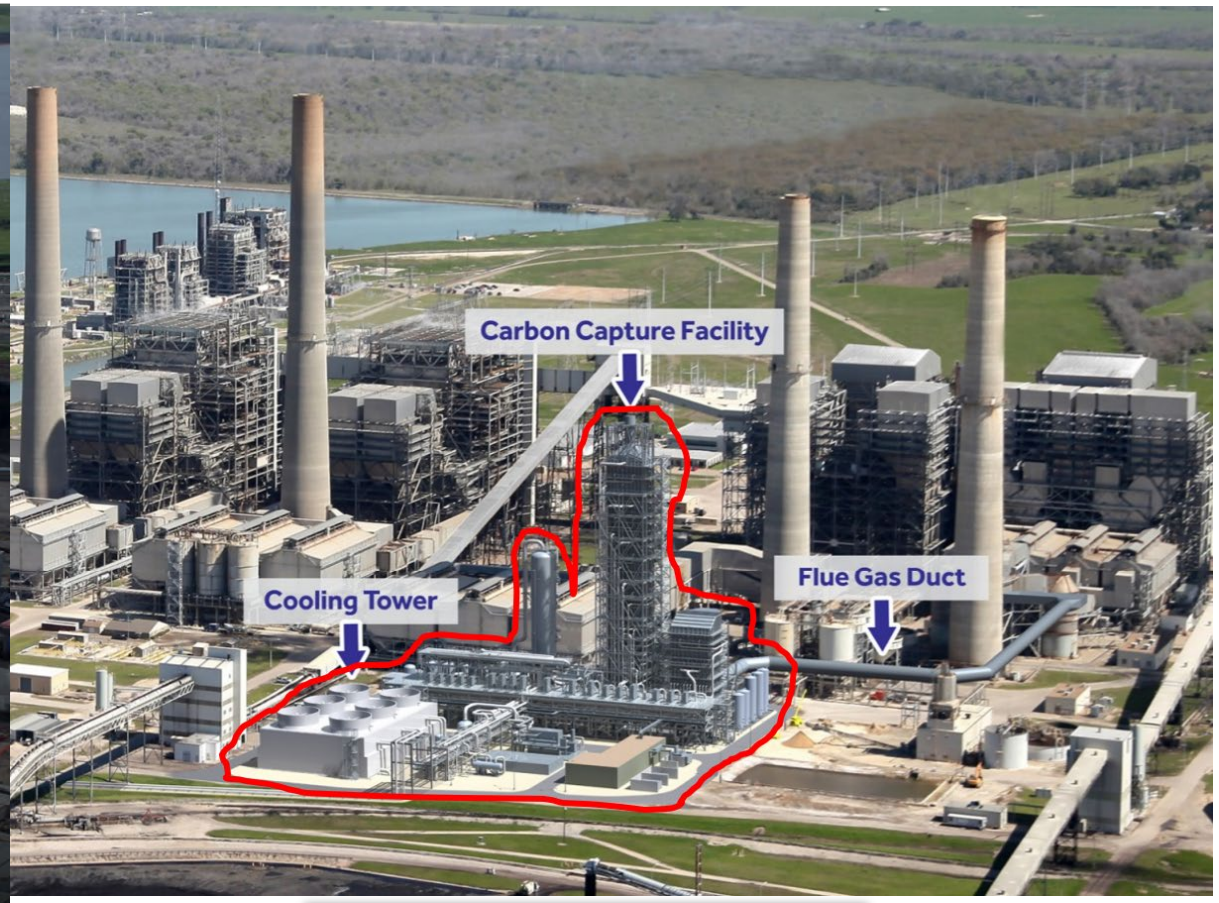


Biggest misconc. .... : 3. Not existing technology / not existing at scale



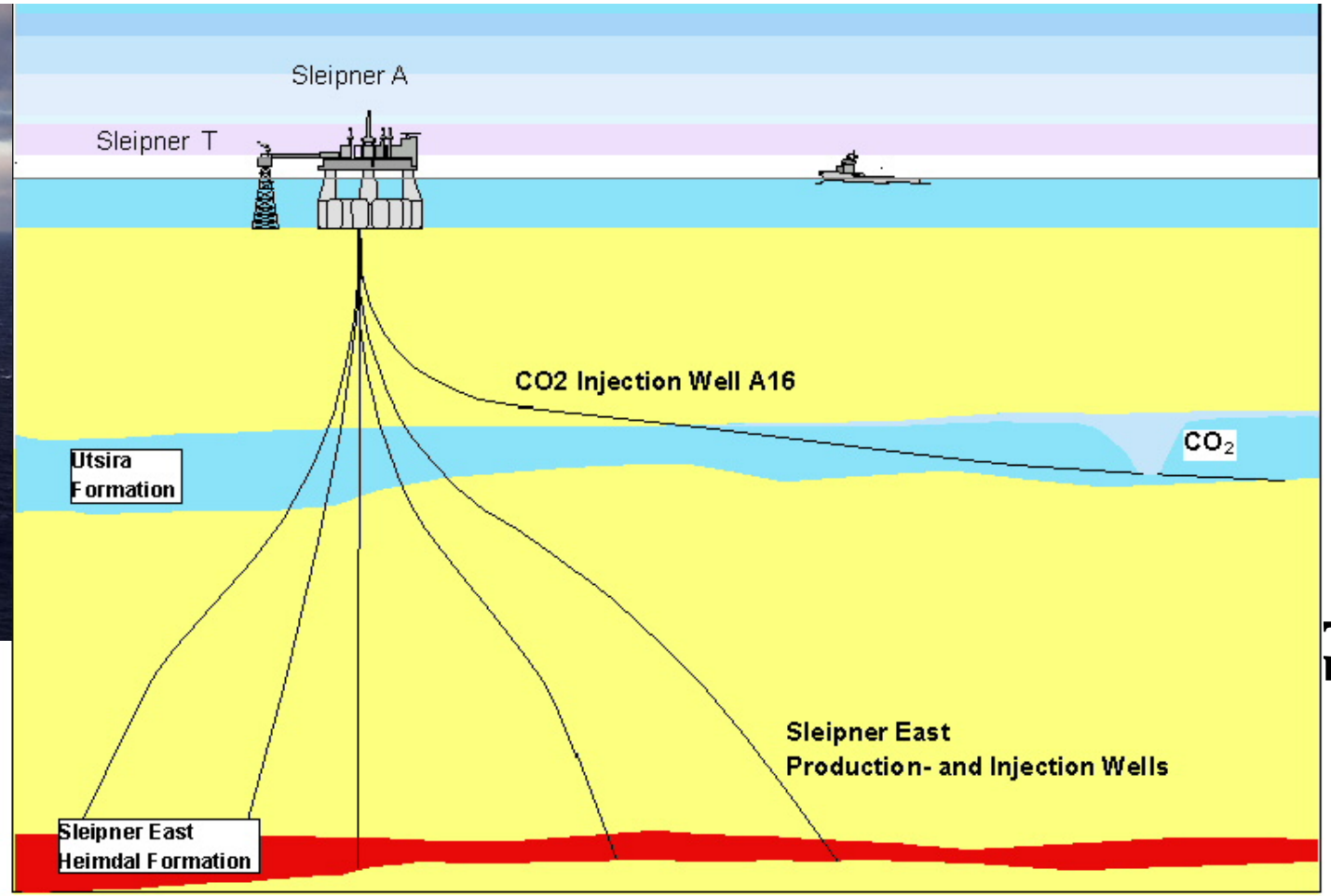
Boundary Dam, Canada.
1 Mton CO_2/year since 2014.

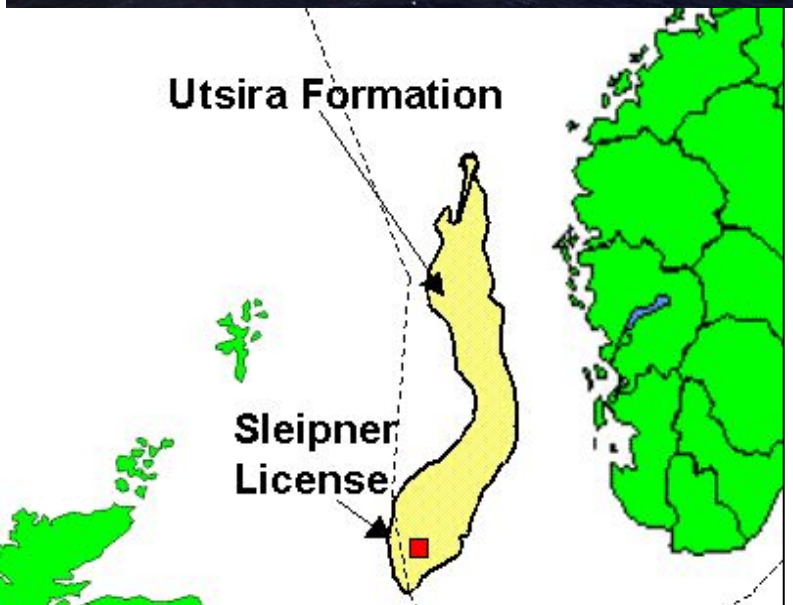
" Next time 1/3 of cost: 45 $/ton CO_2 "



Petra Nova, Texas,
1.4 Mton/year, started 2017

Biggest misconc. …. : 3. Not existing technology / not existing at scale



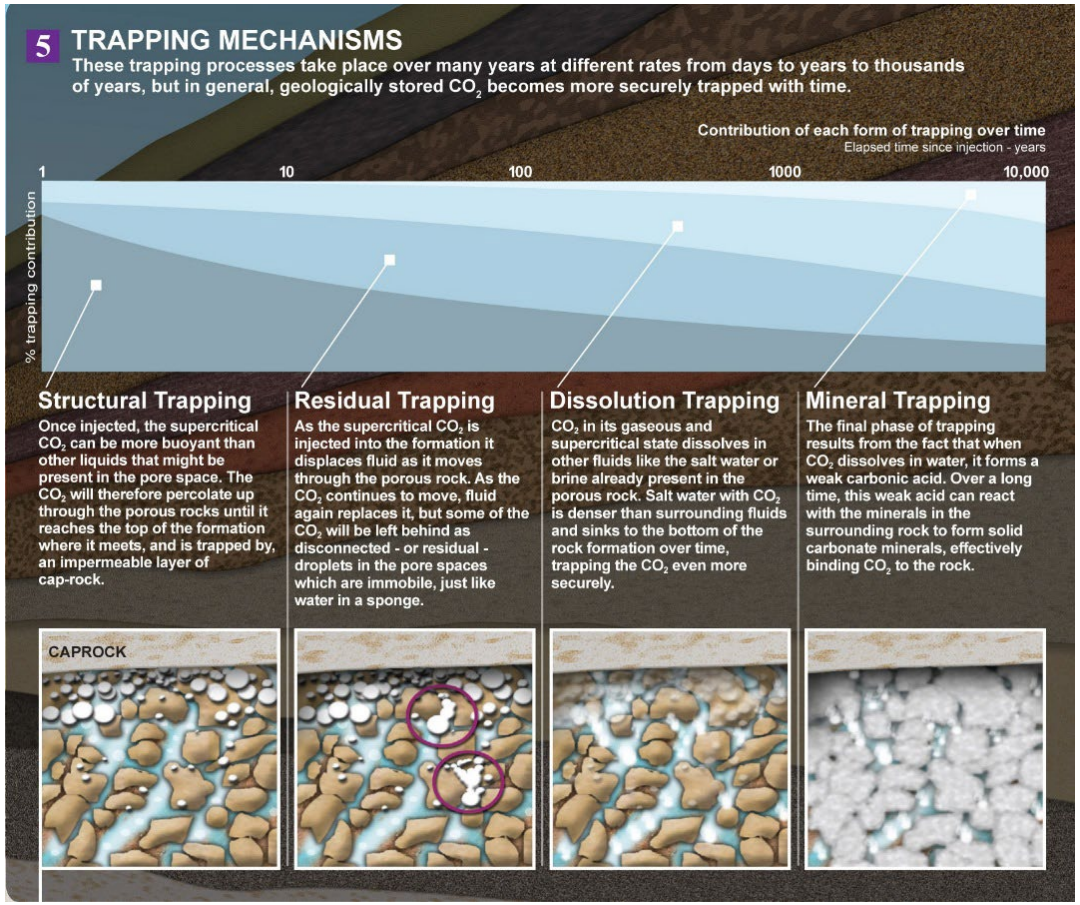


1 million ton CO_2/year, since 1996 Area: 26 000 km^2,
Depth: ~1000 m, Height: 200-300 m, Porosity: 30-40%

Worldwide: 40 Mton/year captured and stored (0.1% of global emissions)

Biggest misconceptions of bio-CCS: 4. It's not safe

True for nature-based NETs, but not for bio-CCS



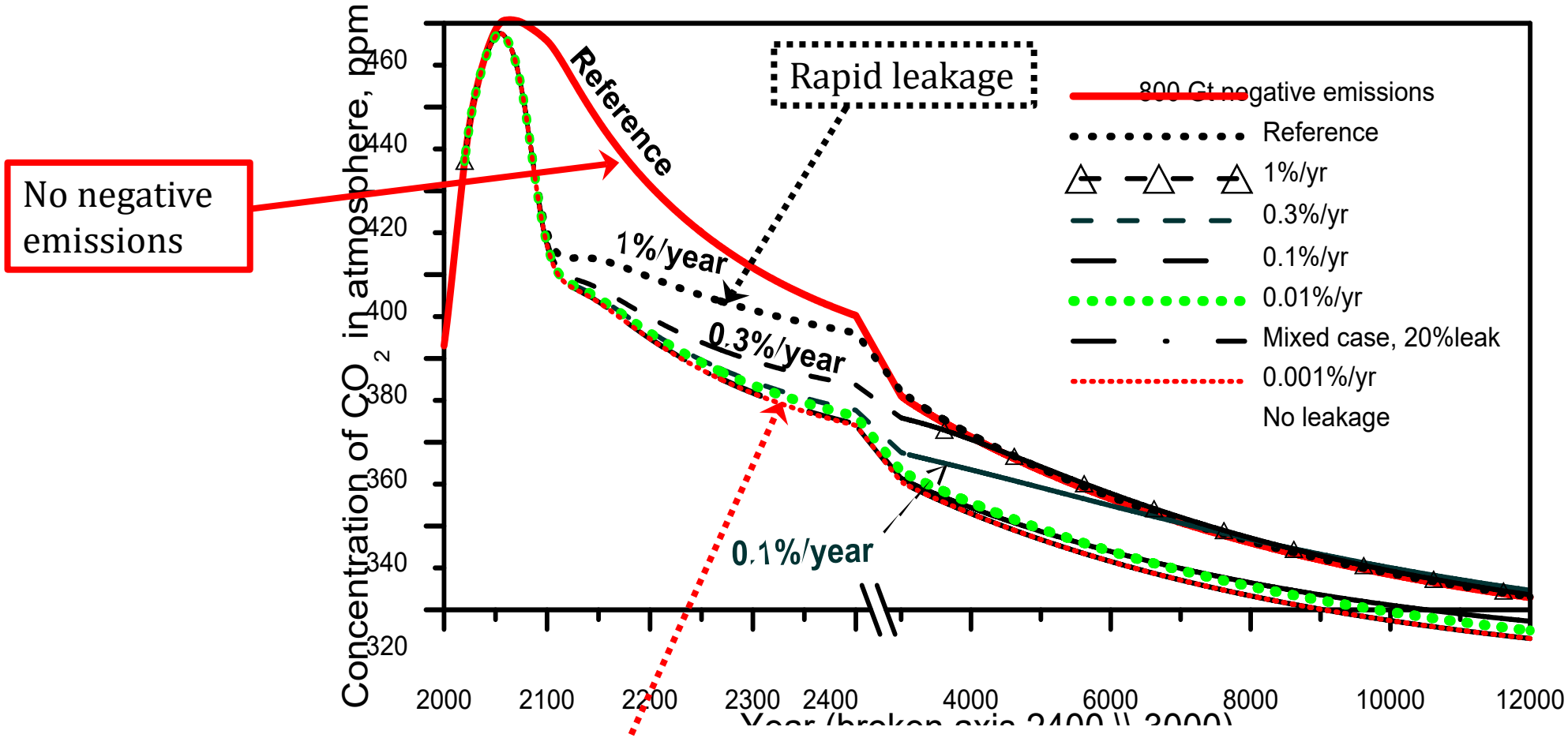
Uses similar geological formations that have stored oil and gas for 10-100 millions of years

Trapping mechanisms:

1) Structural: Tight roof / caprock
2) Residual: gets stuck in pores
3) Dissolution: dissolved in water
4) Mineral: reacts with minerals

Expected leakage:
<1% per thousand years
Greatest risk: other wells (gas, oil)

Recommended: Stuart Haszeldine's plenary on CO_2 storage on Friday



Atmospheric CO_2 for no negative emissions and negative emissions with and without leakage.

REF: Lyngfelt A, Johansson D, and Lindeberg E. Negative CO2 Emissions - An Analysis of the Retention Times Required with Respect to Possible Carbon Leakage. *International Journal of Greenhouse Gas Control* **87** (2019) 27–33.

Biggest misconceptions of bio-CCS: **5. Not needed now / not priority...**

To reach the volumes needed, we need to start now!

The later we start, the greater the overshoot of the budget, resulting in much more damage and risks of feed-back loops and reaching tipping points.

Biggest misconceptions of bio-CCS: **6. It's expensive**

Cost of CCS/Bio-CCS ≈ 0.1 €/kg CO_2

Carbon dioxide intensity in global economy: 0.25 kg CO_2/€

Thus: a CO_2 fee/tax of 0.1 €/kg corresponds to ***2.5% of global economy***

The cost to avoid CO_2 emission is often lower than this.

Thus: The cost for the economy would be considerably less than 2.5%.

New technology may significantly reduce cost of Bio-CCS

Chemical-Looping Combustion (CLC)

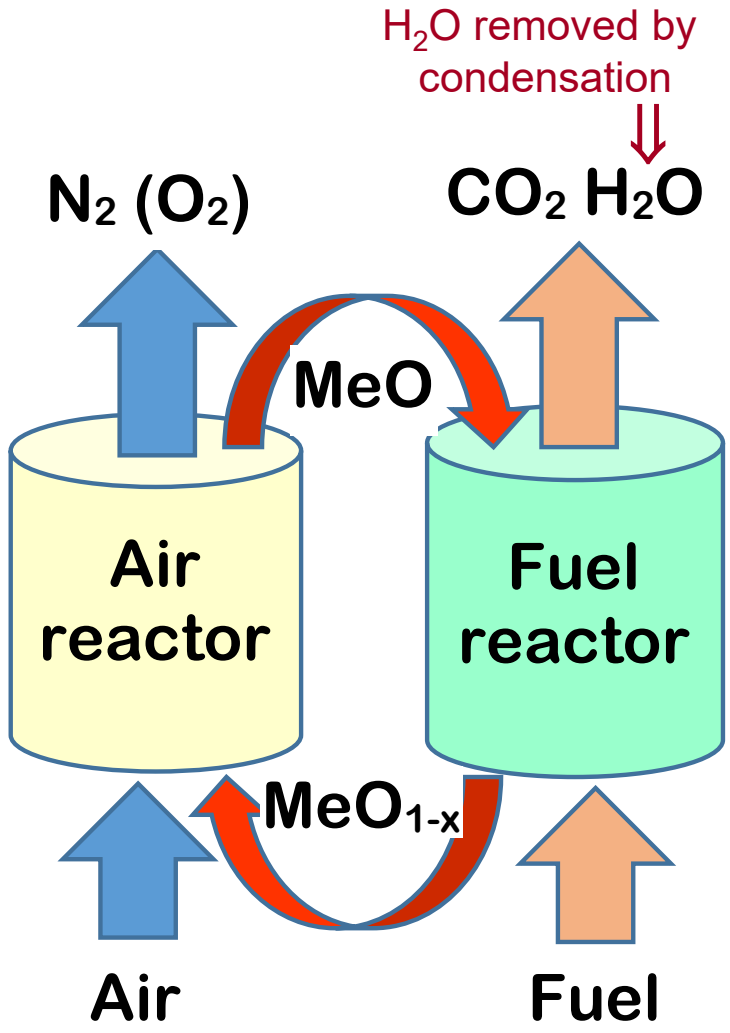
Oxygen is transferred from air to fuel by metal oxide particles

Inherent CO_2 capture:

- fuel and combustion air *never mixed*
- *no active gas separation needed*

Unique potential for reducing costs of CO_2 capture

But does it work ?



Yes, it works!!

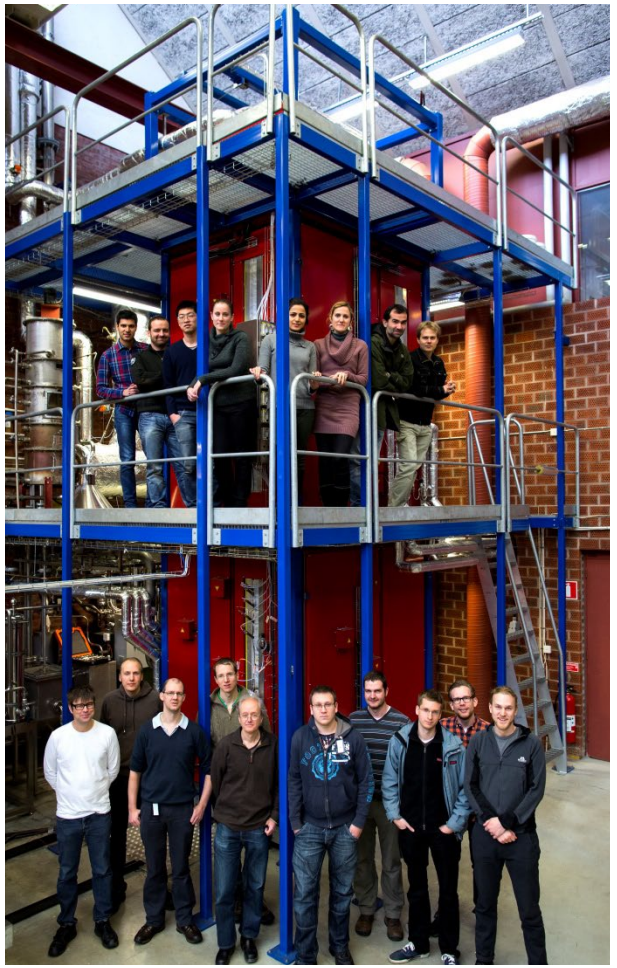
Total chemical-looping operation at Chalmers: 4 200 h in four pilots

Worldwide: 12 000 h in 49 pilots

10 kW gas, 2003

300 W gas, 2004

10 kW solid fuel, 2006



100 kW solid fuel, 2011

Estimated CO_2 capture cost for Chemical-Looping Combustion of solid fuels :

20-25 €/tonne CO_2

REF: Session 4D:
Chemical-Looping Combustion - Avoiding the Large Energy and Cost Penalty of BECCS
Anders Lyngfelt

Biggest misconceptions of bio-CCS:

7. Handing over a gigantic climate debt, the challenge to clean up the atmosphere, to our children and grandchildren is a moral hazard or moral collapse.

This is NOT a misconception!

It is unfortunately TRUE!

7. Handing over a gigantic climate debt, the challenge to clean up the atmosphere, to our children and grandchildren is a moral hazard or moral collapse.

I think it's true, not because of

lack of potential for negative emissions

or lack of money

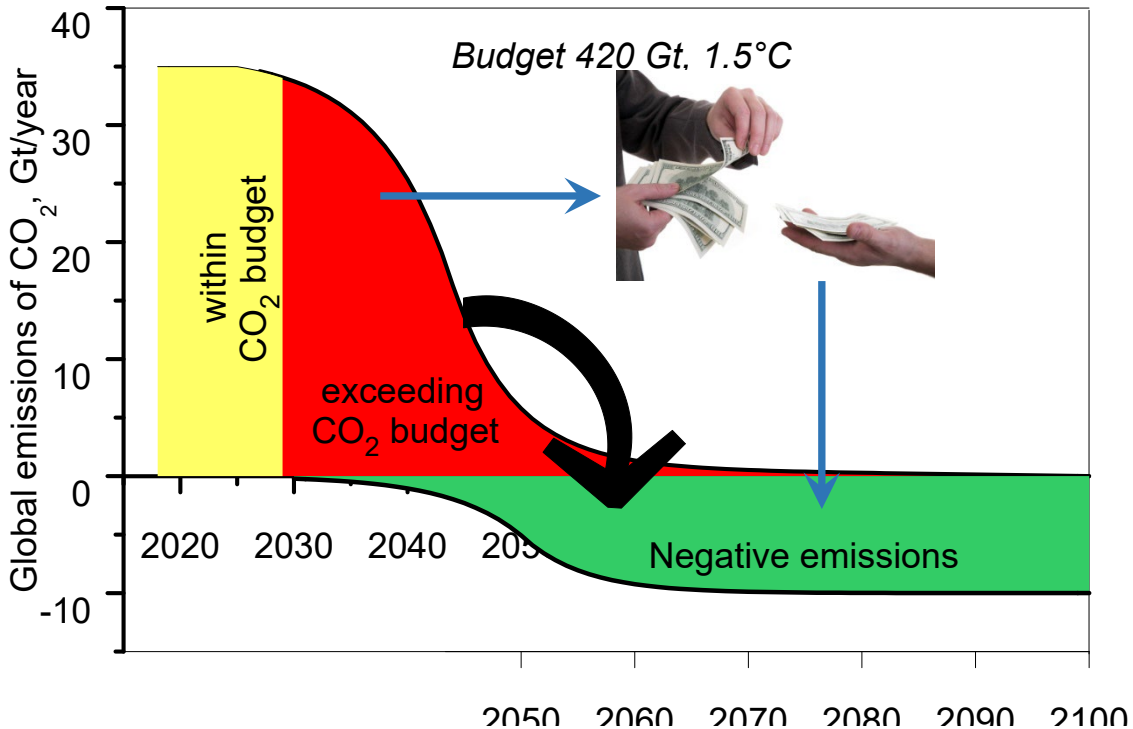
but because of the insoluble challenge in sharing the gigantic climate debt, perhaps 100.000 €/capita

Major problem with negative emissions:
Who will pay?

"CO_2 Emitter Liability"

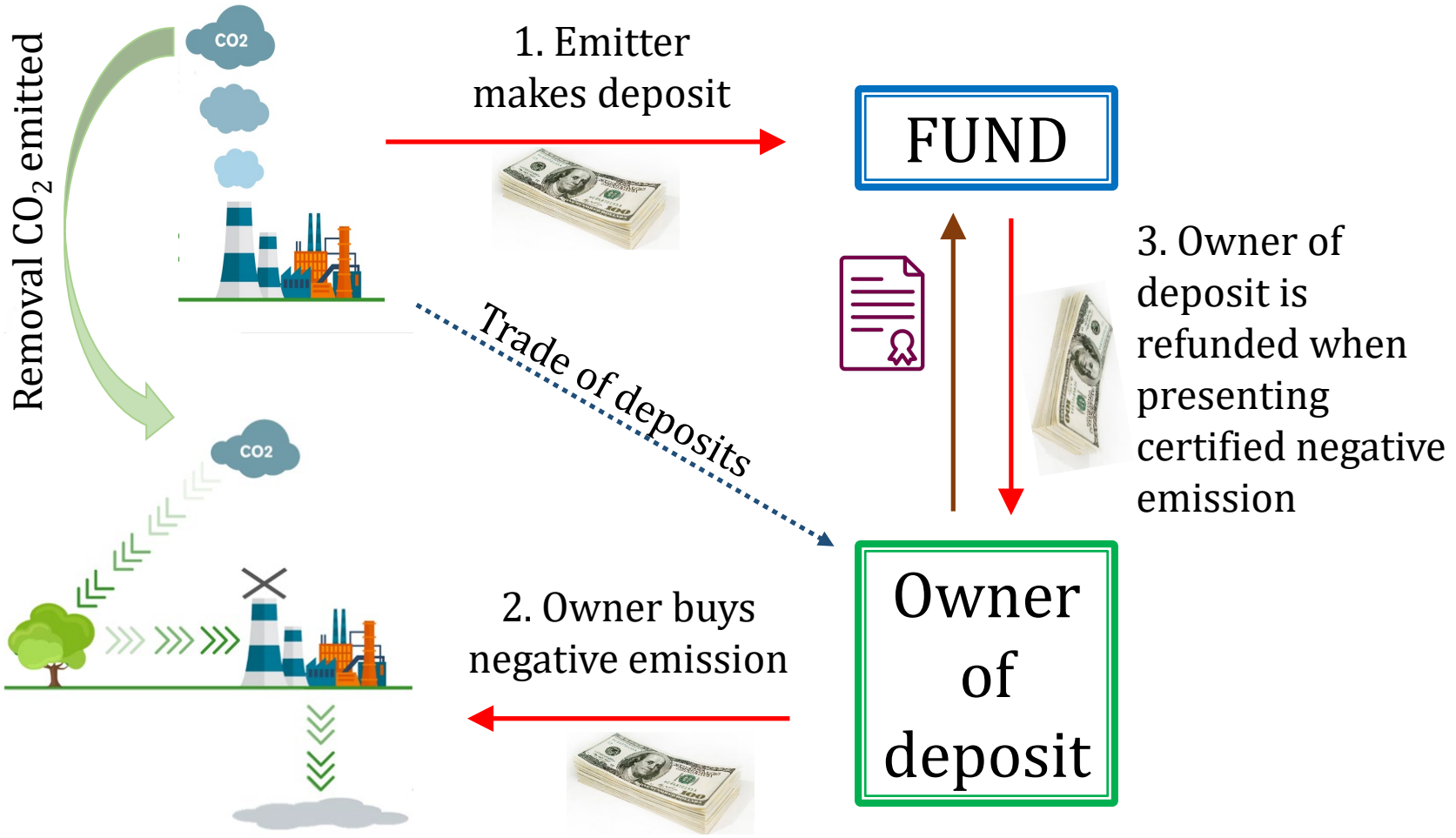
Emitters are responsible for, and need to pay for, removing any emitted CO_2 from atmosphere.

Note the need to pay for future negative emissions



REF: Session 9A. *CO_2 Emitter Liability using Atmospheric CO_2 Removal Deposits (ACORDs) for Financing of Future Negative Emissions*, Lyngfelt & Fridahl

Atmospheric CO_2 Removal Deposits (ACORDs)



Session 9A. *CO_2 Emitter Liability using Atmospheric CO_2 Removal Deposits (ACORDs) for Financing of Future Negative Emissions*, Lyngfelt & Fridahl

Famous Swedes

”You grown-ups don’t give a shit about my future.”

Famous Swedes: C

Anders Celsius, 1701- 1744

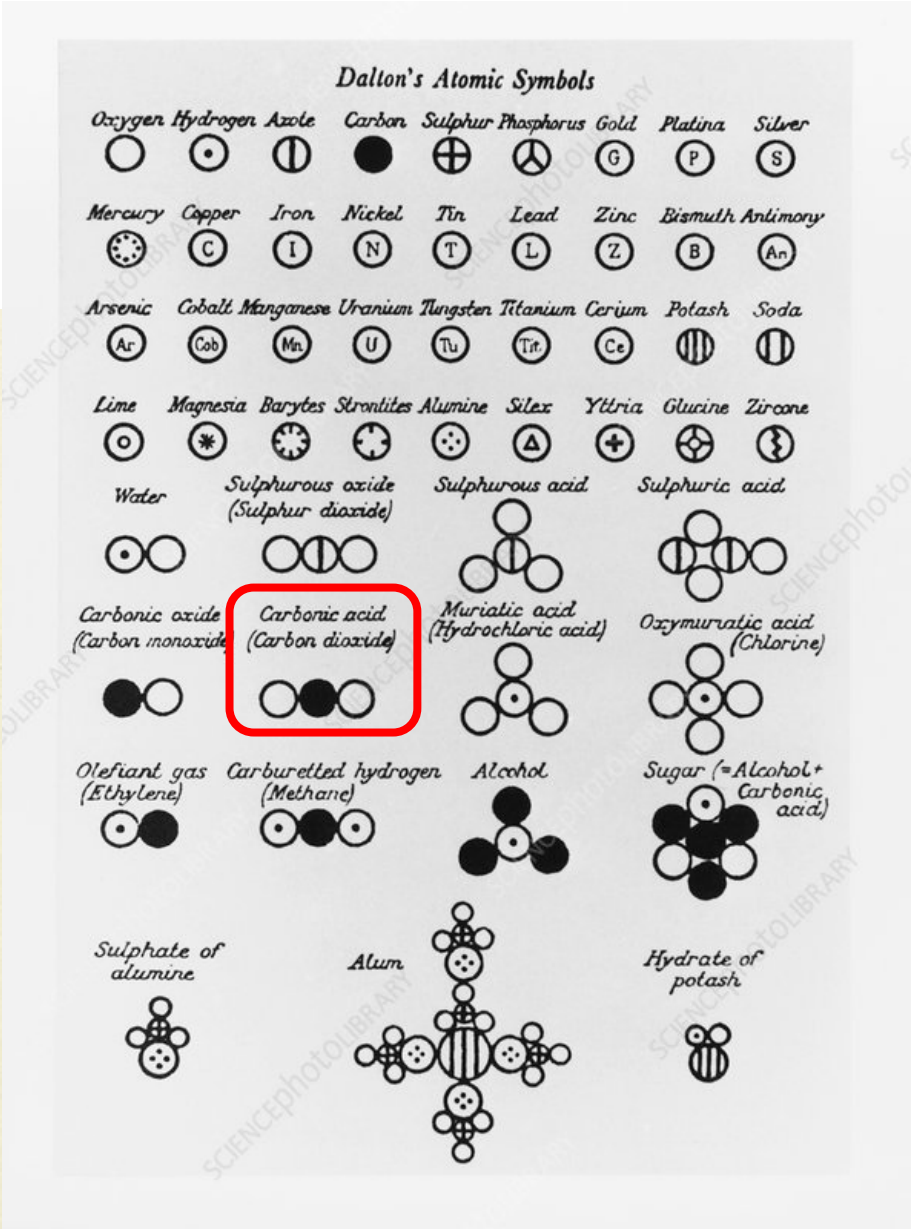
Proposed the Celcius temperature scale:

Boiling point of water: **0°C**
Freezing point of water: **100°C**

$\Rightarrow CO_2$

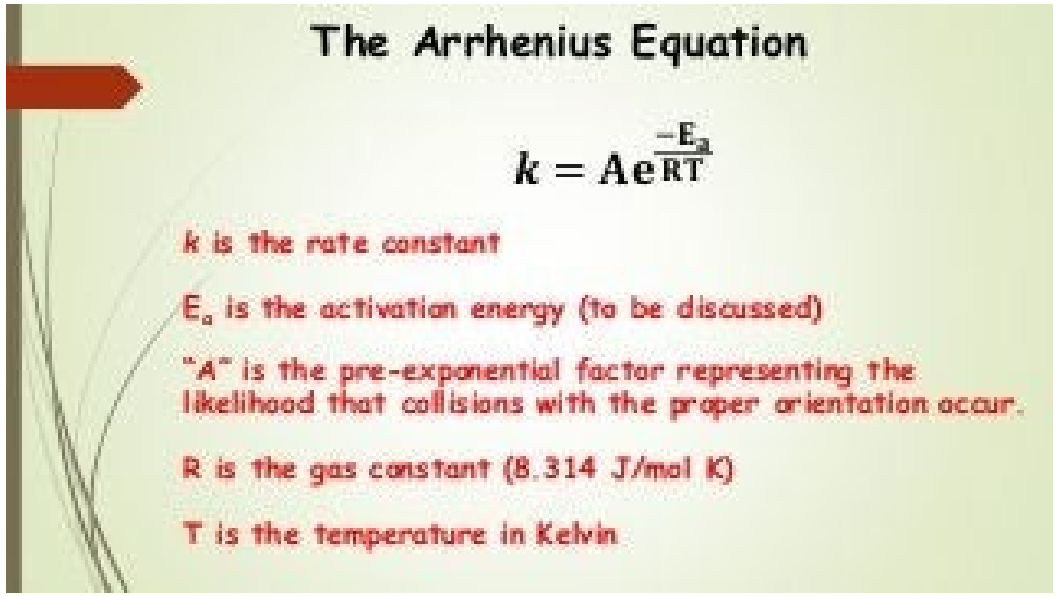
Famous Swedes: B

Jöns Jacob Berzelius, 1779- 1848



Famous Swedes: A

Svante Arrhenius, 1859-1927



PHILOSOPHICAL MAGAZINE
AND
JOURNAL OF SCIENCE.

[FIFTH SERIES.]

APRIL 1896.

XXXI. *On the Influence of Carbonic Acid in the Air upon the Temperature of the Ground.* By Prof. SVANTE ARRHENIUS *.

Negative emissions and Bio-CCS

- It's needed.
- Biomass: It could be enough, if we can prevent the harvested carbon from returning to the atmosphere. (Subject to rapid reduction of fossil fuel emissions. Also, we have to be careful with use of biogenic transportation fuels.)
- Technology is known, and used in large scale. (*i.e.* CCS)
- Storage is safe. (Bio-CCS) Later leakage not necessarily a problem (Nature-based)
- Not needed now / Not priority. – Stupid!
- Bio-CCS is not cheap, but the cost is reasonable. Novel technology (chemical-looping) has potential for significant cost reduction.
- It is a moral collapse to hand over the insoluble question of how to share responsibility for, and costs of, gigantic negative emissions between nations
- Financing of negative emissions could be solved by introducing a CO_2 emitter liability, making the emittors pay for future negative CO_2 emission.
- This can be accomplished using Atmospheric CO_2 Removal Deposits (ACORDS)