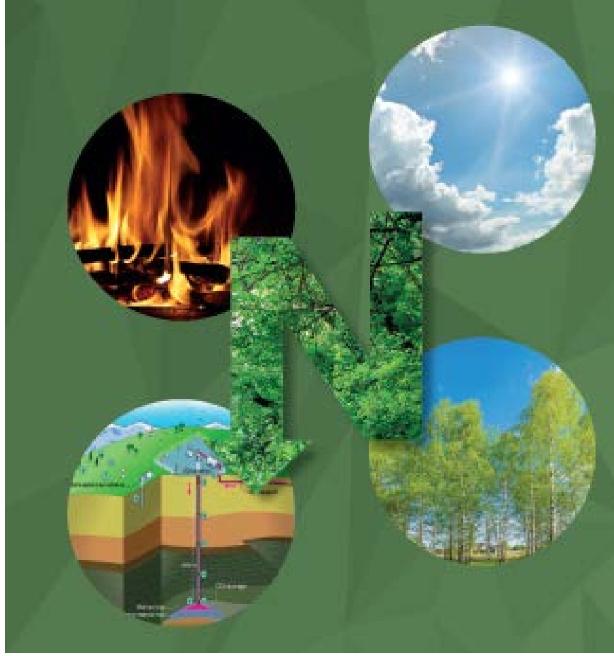
Negative CO_2 Emissions
-
An Analysis of the Retention Times Required with Respect to Possible Carbon Leakage



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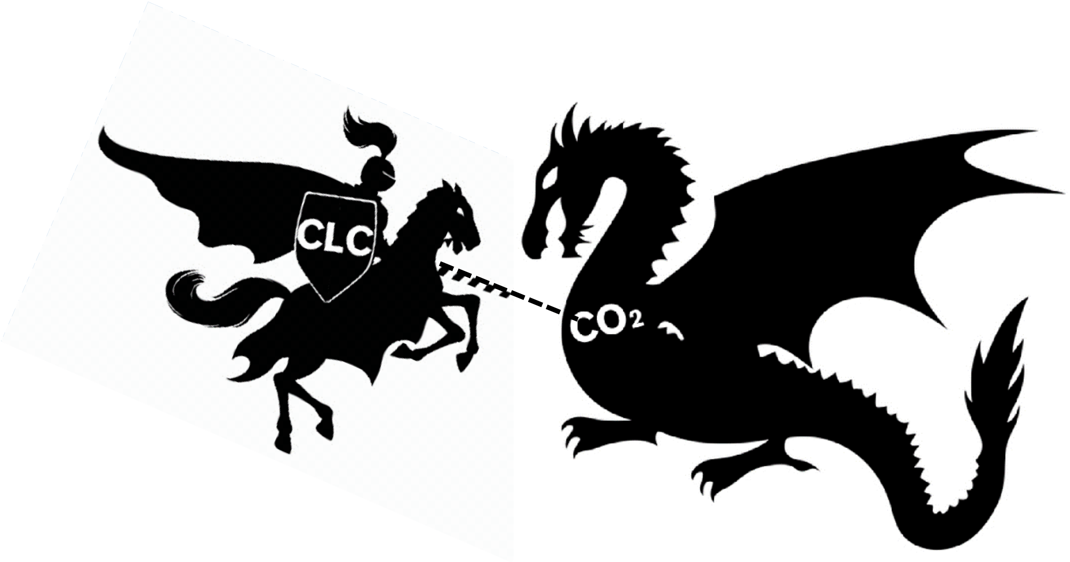
GHGT14
October 21-25, 2018
Melbourne



Negative CO2
Negative CO2 Emissions with Chemical-Looping Combustion of Biomass

Nordic Energy Research

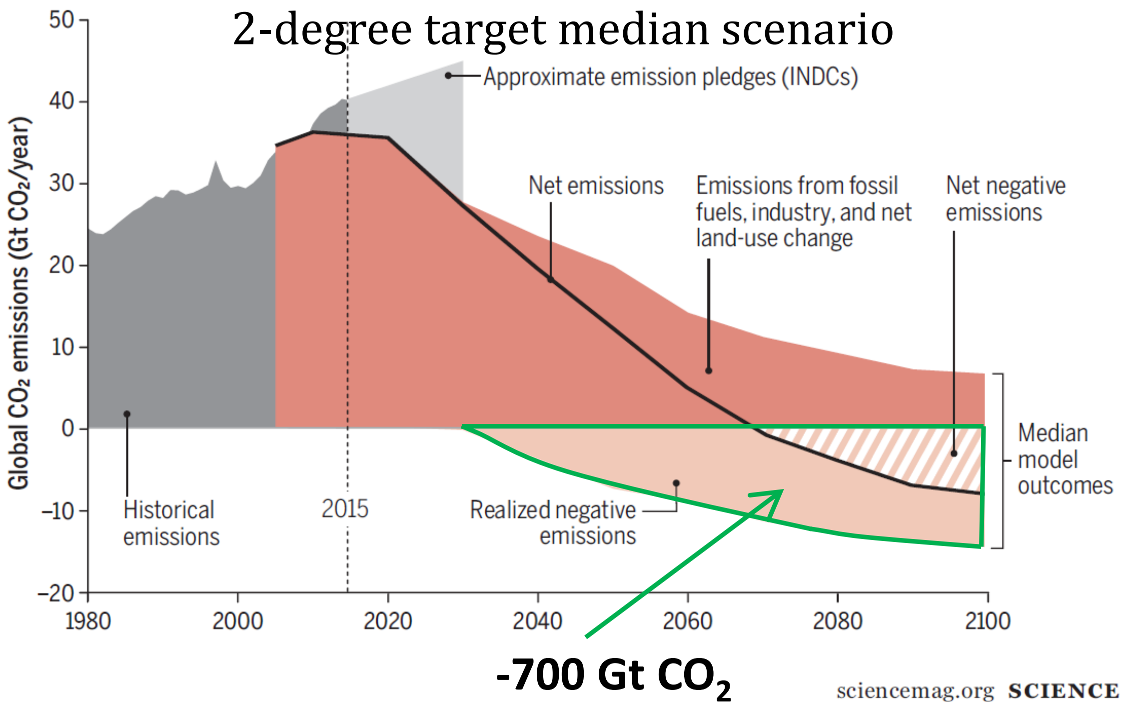
*The Paris agreement to stay **well below** 2ºC*

*and pursue .... to limit .... to **1.5 degrees**:*

Carbon dioxide budget for max 1.5ºC and 2ºC :

200 - 800 Gt

or 5 – 20 years with present 40 Gt/y



Negative emissions are needed

to reach climate targets

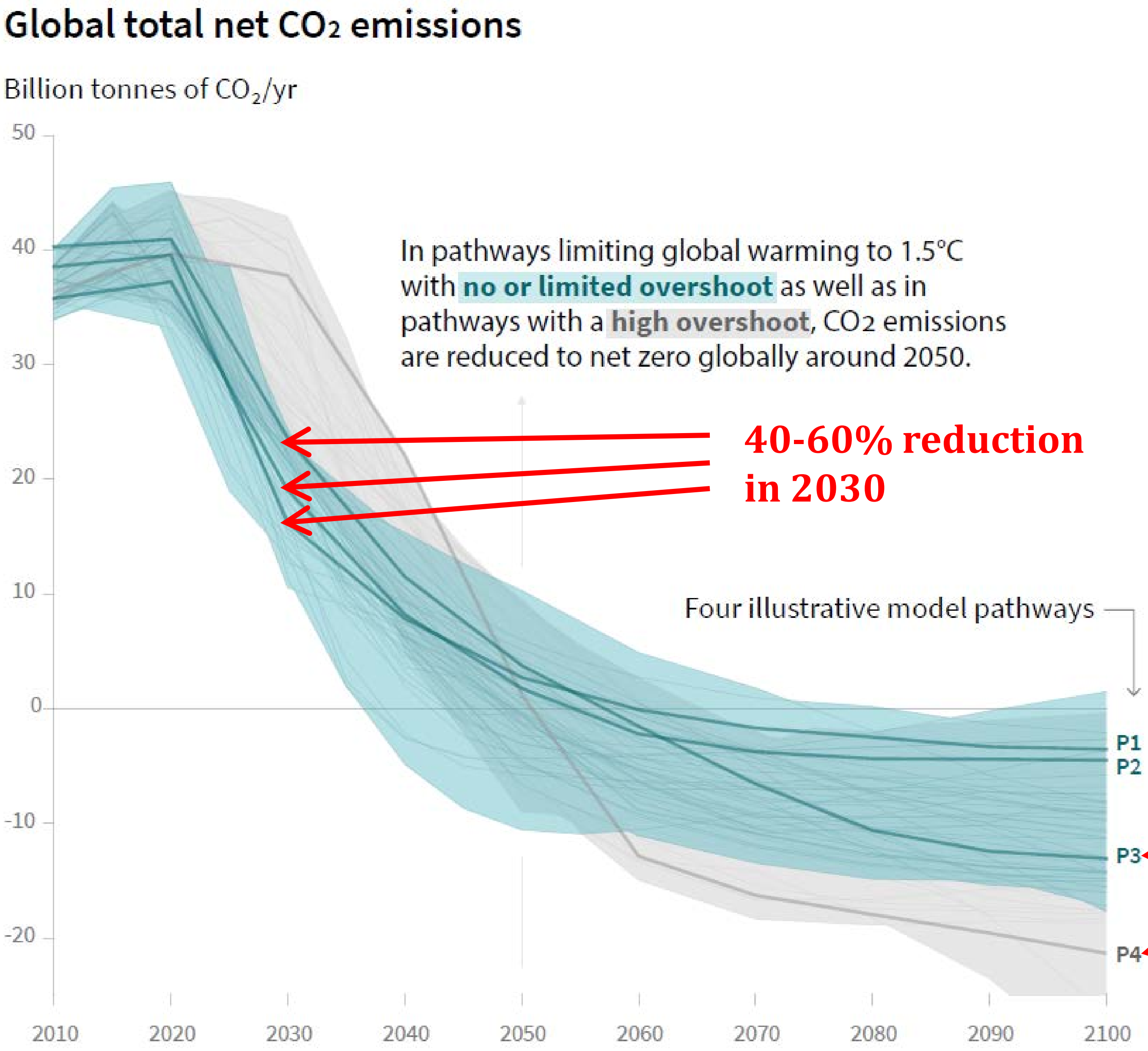
or

100 tonnes per now living human being

or

≈10.000 € per now living human being

1.5 degree target



Case	Reduction by 2030/2040, %	Negative emissions, Gt
P4	5 / 45	**-770**
P3	**41 / 71**	**-370**
P2	**53 / 69**	-160
P1	**60 / 80**	-90

very large negative emissions

Purpose of paper

WE NEED NEGATIVE EMISSIONS

DIFFERENT OPTIONS DISCUSSED

- Bio-CCS of BECCS
- Afforestation/reforestation
- Altered agricultural practices to increase carbon in soil
- Biochar
- Direct Air Capture (DAC)
- Enhanced Weathering

THEY COME WITH DIFFERENT STORAGE SAFETY AND EXPECTED LEAKAGE RATES

WHAT LEAKAGE RATES ARE ACCEPTABLE ?

Model

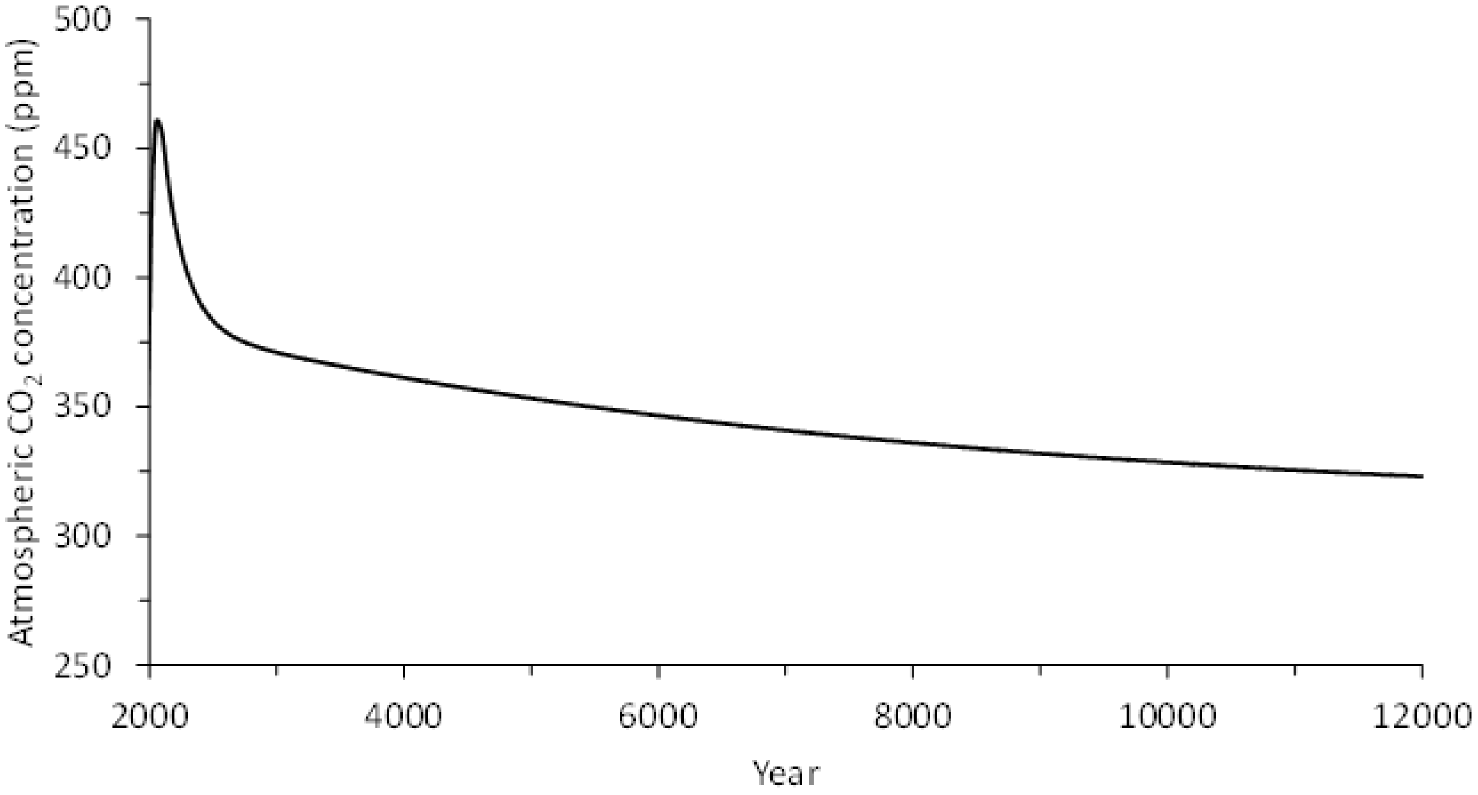
Response to emission

$$f(t) = A_0 \cdot \left(\sum_j B_j \cdot e^{-t/\tilde{\tau}_j} \right) + \sum_i A_i \cdot e^{-t/\tau_i}$$

where Aj represent fast response, and Bj represents slower response
(i.e. dissolution of seafloor carbonates, weathering of terrestrial carbonate rocks and silicate weathering)

i	A_i	τ_i [yr]
0	0.217	-
1	0.186	1.186
2	0.338	18.51
3	0.259	172.9

j	B_j	$\tilde{\tau}_j$ [yr]
1	0.54	5.5 k
2	0.14	8.2 k
3	0.32	200 k



Effect of ***leakage time scale****

Assumption: all leaks, but with different leakage time scales

**1%/year is a leakage time scale of 100 years*

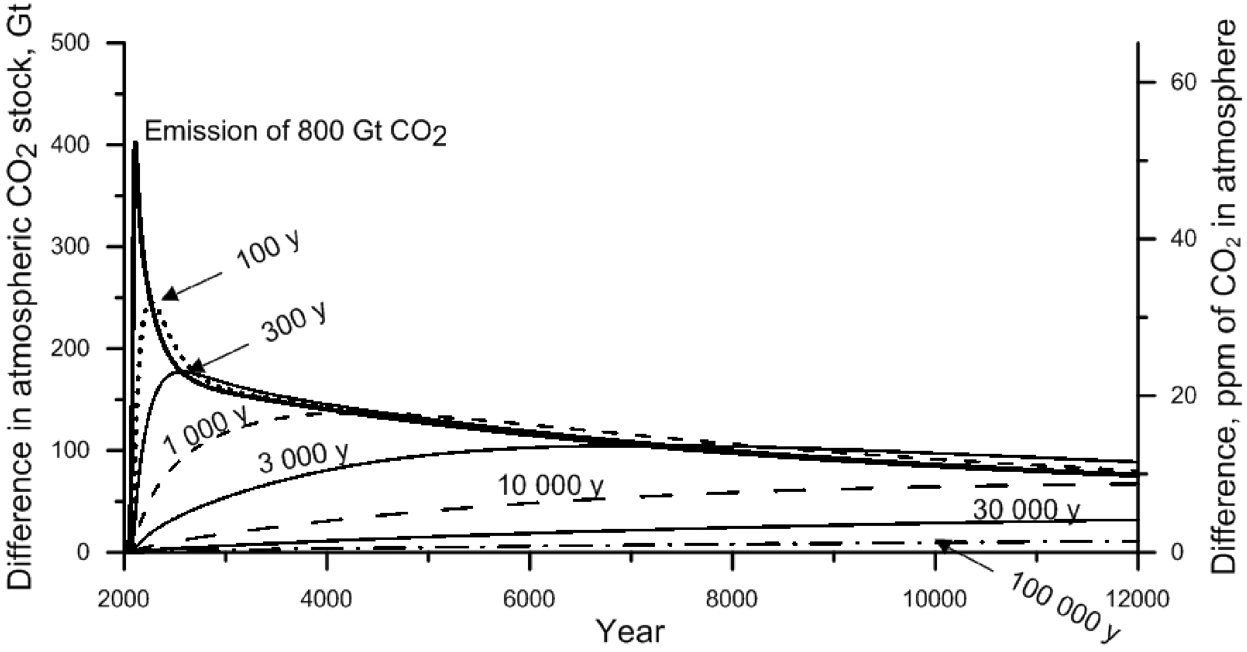


Figure 2. Increased stock of atmospheric CO_2 from 800 Gt of CO_2 for different leakage rates. For comparison emission of 800 Gt is also shown.

Table 3. Peaks reached for the different leakage time scales shown in Fig. 2.

Leakage case	CO_2 peak Gt	ppm	Peak year	Fraction at peak year
No capture	402	52	2111	100%
Leakage time scale, years				
100	246	32	2263	61%
300	177	23	2568	44%
1000	137	18	4265	34%
3000	105	14	7125	26%
10000	67	9	14262	17%
30000	32	4	46588	8%
100000	11*	1*	100000*	3%*

* at 100 000 years peak not reached

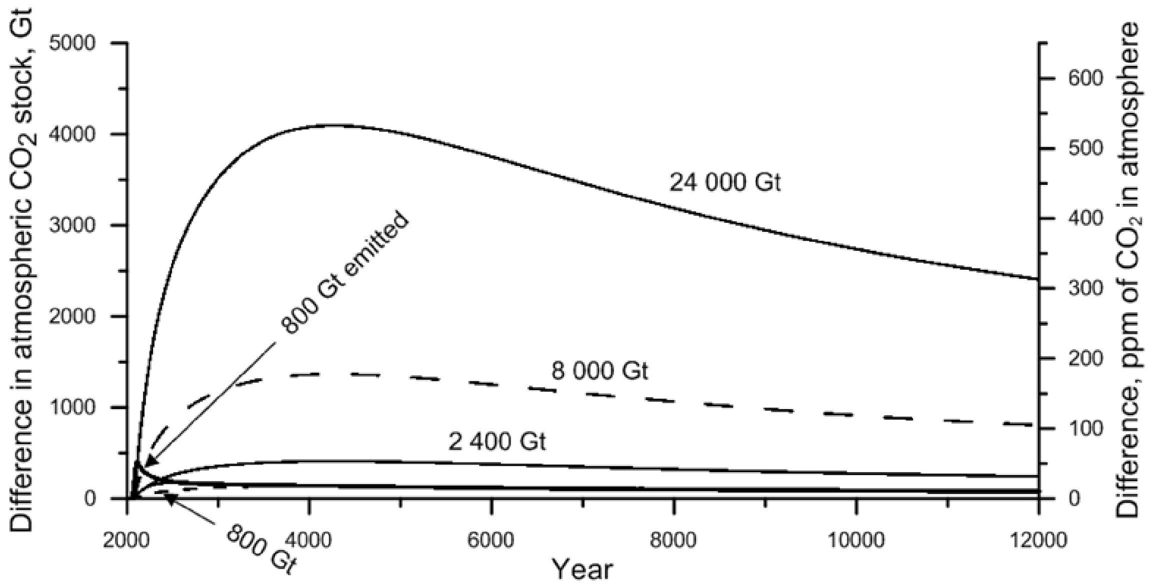
Even if all leaks, the delay of the emissions gives (as compared to emitting the same amount)

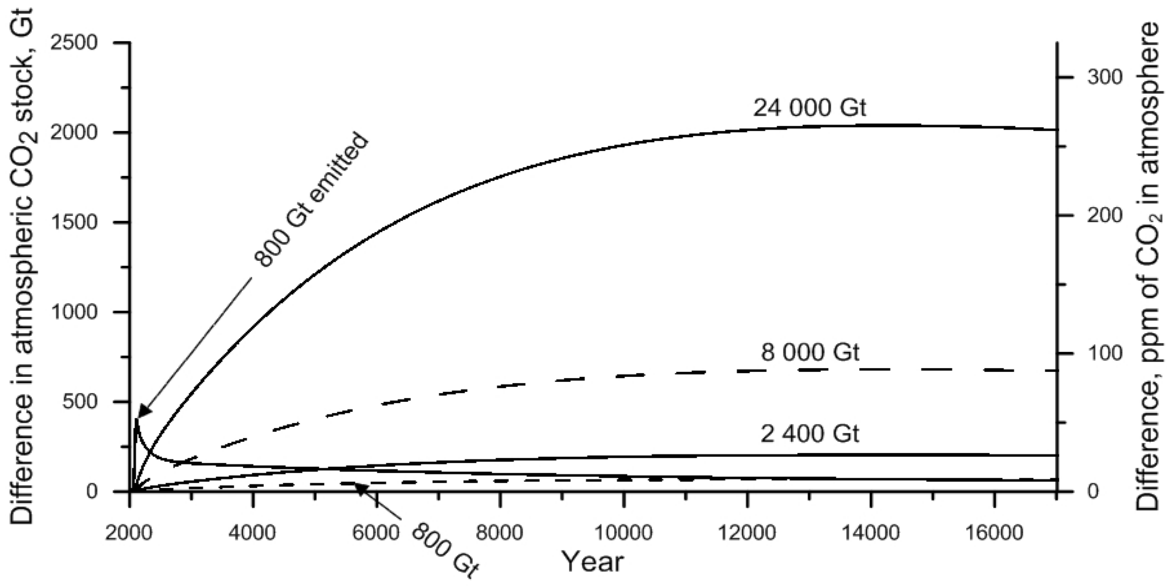
- a significantly delayed peak
- a significantly lower peak
- only a few ppms for longer leakage time scales

Effect of total amount leaked

Assumption: all leaks, but with different total amounts

leakage time scale is 1000 years (left) and 10 000 years (right)





If a very large amount is stored and leaks

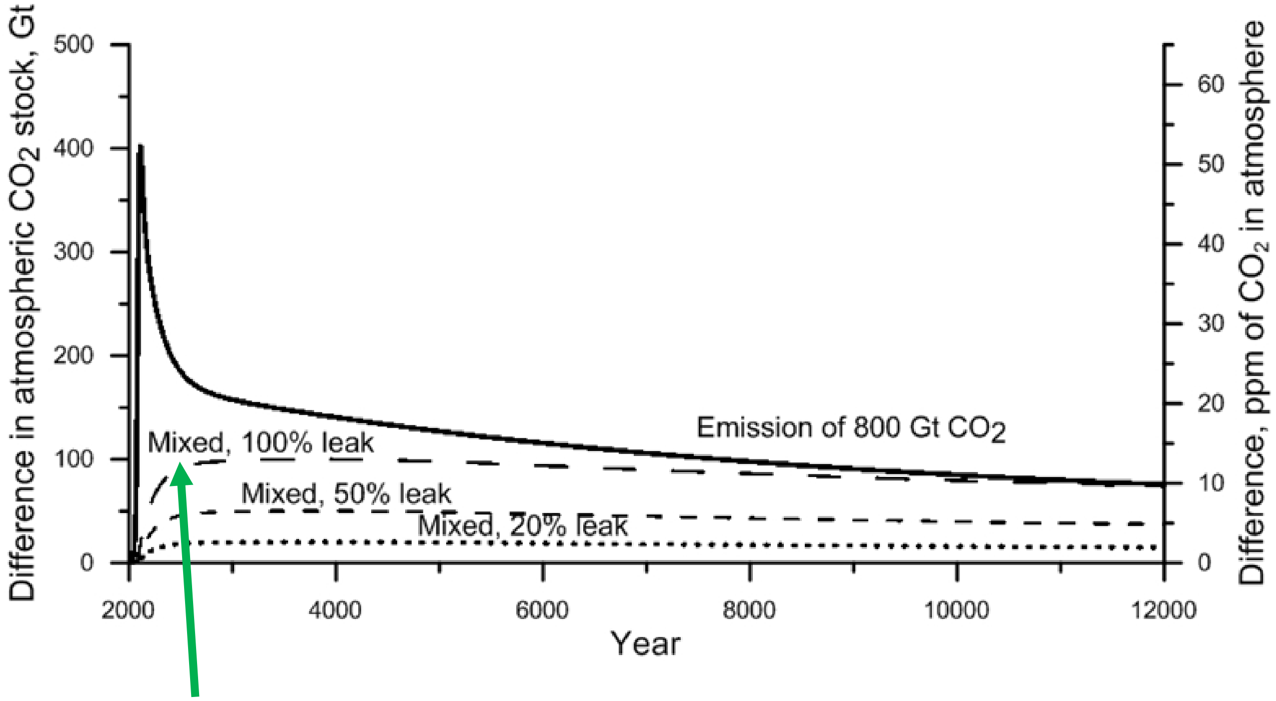
- very high increases in CO_2 are seen
- it doesn't help even with a long leakage time scale

Note: 24 000 Gt is of the order of the total reserves of fossil fuels, or 600 years of todays emissions.

A mix of different leakage time scales

Assumption: 20 – 100% leaks

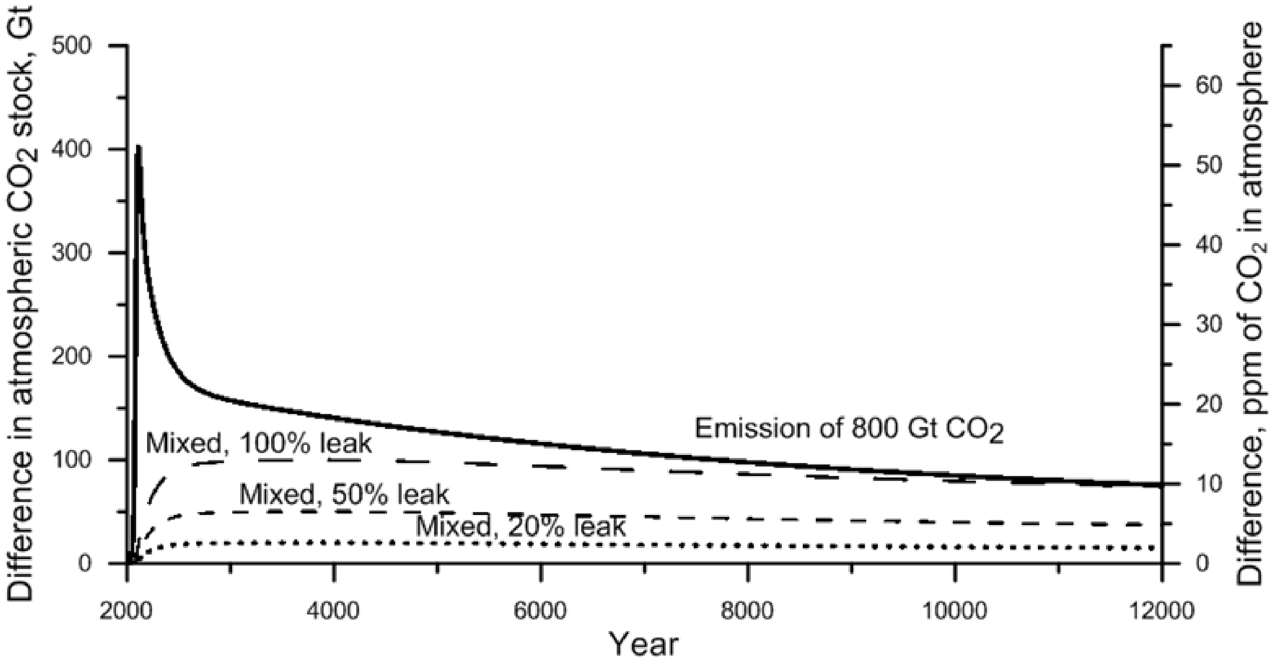
Leakage case (type)	CO_2 stored, Gt (fraction)	Fraction leaked	Leakage time scale, years
Rapid (“afforestation/reforestation”)	300 (37.5%)	20, 50 and 100%	300
Median (“biochar”)	200 (25%)	20, 50 and 100%	1000
Slow (“geological storage”)	300 (37.5%)	20, 50 and 100%	10000



Leakage case	CO_2 peak Gt	CO_2 peak ppm	Peak year	Fraction at peak year
No capture	402	52	2111	100%
100% leakage	100	13	3802	25%
50% leakage	50	7	3802	12%
20% leakage	20	3	3802	5%

delay of a few hundred years

A mix of different leakage time scales (cont'd)



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CO_2 reaching atmosphere is delayed considerably

Even with 100% leakage, the peak is reduced by 75%

Small effect on atmospheric stock with 20-50% leakage

Costs and financing

CO_2 BUDGET SOON EXHAUSTED!
WHO SHOULD PAY FOR FUTURE NEGATIVE EMISSIONS?

THE EMITTERS !

- Future emissions need to be removed from the atmosphere
- Reasonable that the emitters pays
- Cost of 0.100 €/kg (100 €/tonne) is reasonable
- Global carbon intensity is 0.5 €/kg, so ”cost” is 5% of global economy
- But, most emitters would find ways to reduce/avoid emissions much cheaper than 0.1 €/kg
- Thus, the actual cost for global economy of staying within the budget is only a few %
- It could be less than one year of growth in economy
- But it would likely not affect the GDP, just a change of how we are using or money.

Conclusions

DELAYING RELEASE IS AN EFFICIENT WAY REDUCE CLIMATE IMPACT

- Even if **<u>all</u>** of the stored carbon would leak, storage would give a very significant reduction of the atmospheric CO_2 stock.
- A leakage time scale of a few hundred years is sufficient to give a significant reduction
- . . . and it significantly delays the peak.
- With increasing leakage time scale, the reduction becomes more and more significant.

- Conclusion above is valid for storing ***very large*** amounts,
  - e.g. 800 Gt, or 20 years of todays emissions
- It is not valid for storing ***extreme amounts***, not even assuming very long leakage time scales
  - e.g 24 000 Gt, or 600 years of todays emissions

Conclusions 2

A MIX OF DIFFERENT LEAKAGE TIME SCALES, IN COMBINATION WITH A SIGNIFICANT SHARE OF PERMANENT STORAGE, WILL ONLY GIVE A SMALL IMPACT ON ATMOSPHERIC CO_2 STOCK

Thus, the mixed case with leakage time scales 300, 1000 and 10 000 years gives

- 88% reduction with 50% leakage, or 7 ppm
- 95% reduction with 20% leakage, or 3 ppm
- in addition the contribution to the stock is delayed a few hundred years
- the contribution to the stock will be much smaller than the natural fall in stock, assuming no net future emissions

NEGATIVE EMISSIONS IS A VERY EFFICIENT WAY TO REDUCE CLIMATE IMPACT

THE SMALL CONTRIBUTION COULD BE NEUTRALIZED BY INCREASING THE AMOUNT CAPTURED BY E.G. 5-10%

Nordic Energy Research

CHALMERS

next conference
May 2020

INTERNATIONAL CONFERENCE ON

NEGATIVE CO_2 EMISSIONS

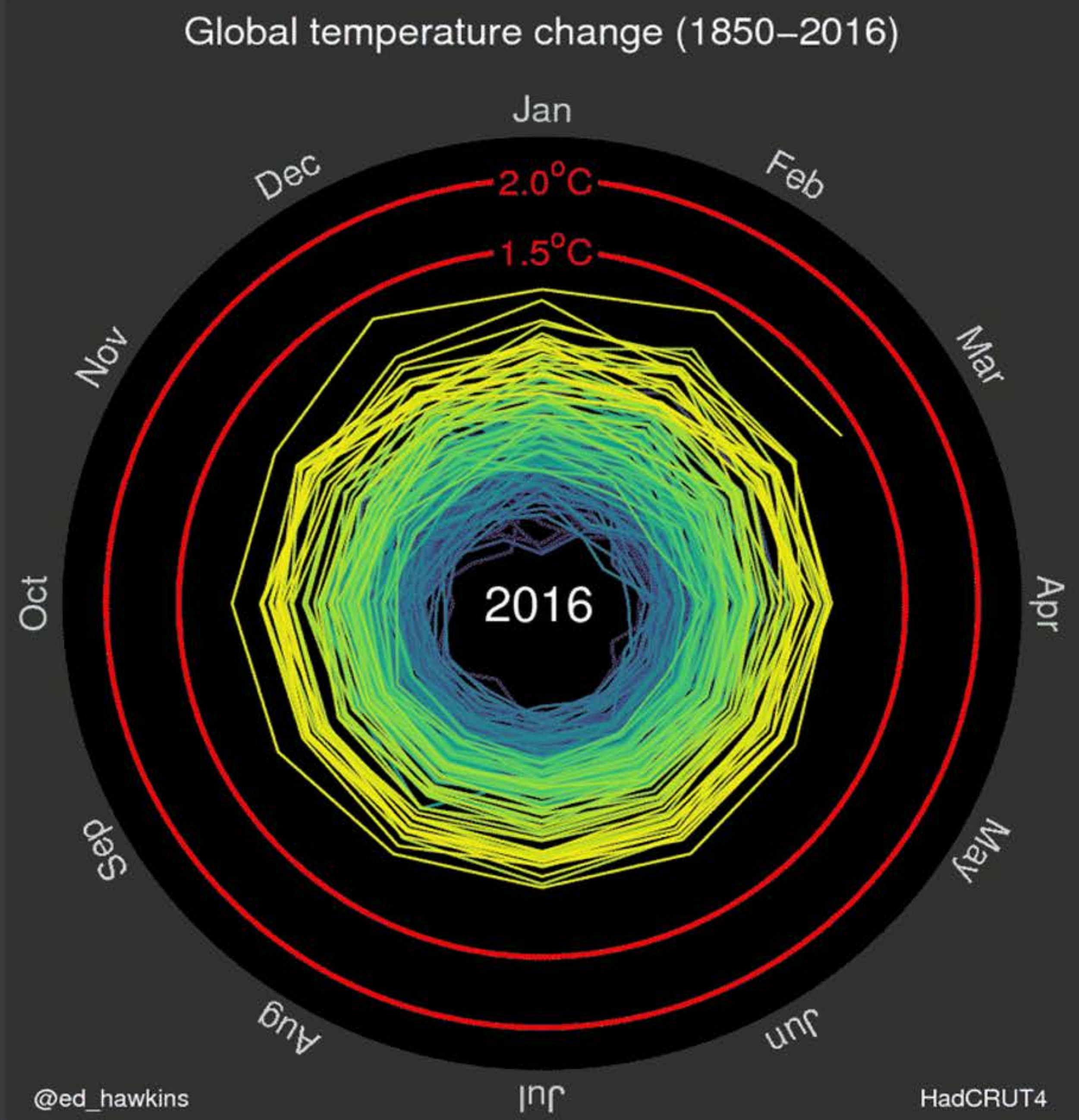
MAY 22-24, 2018

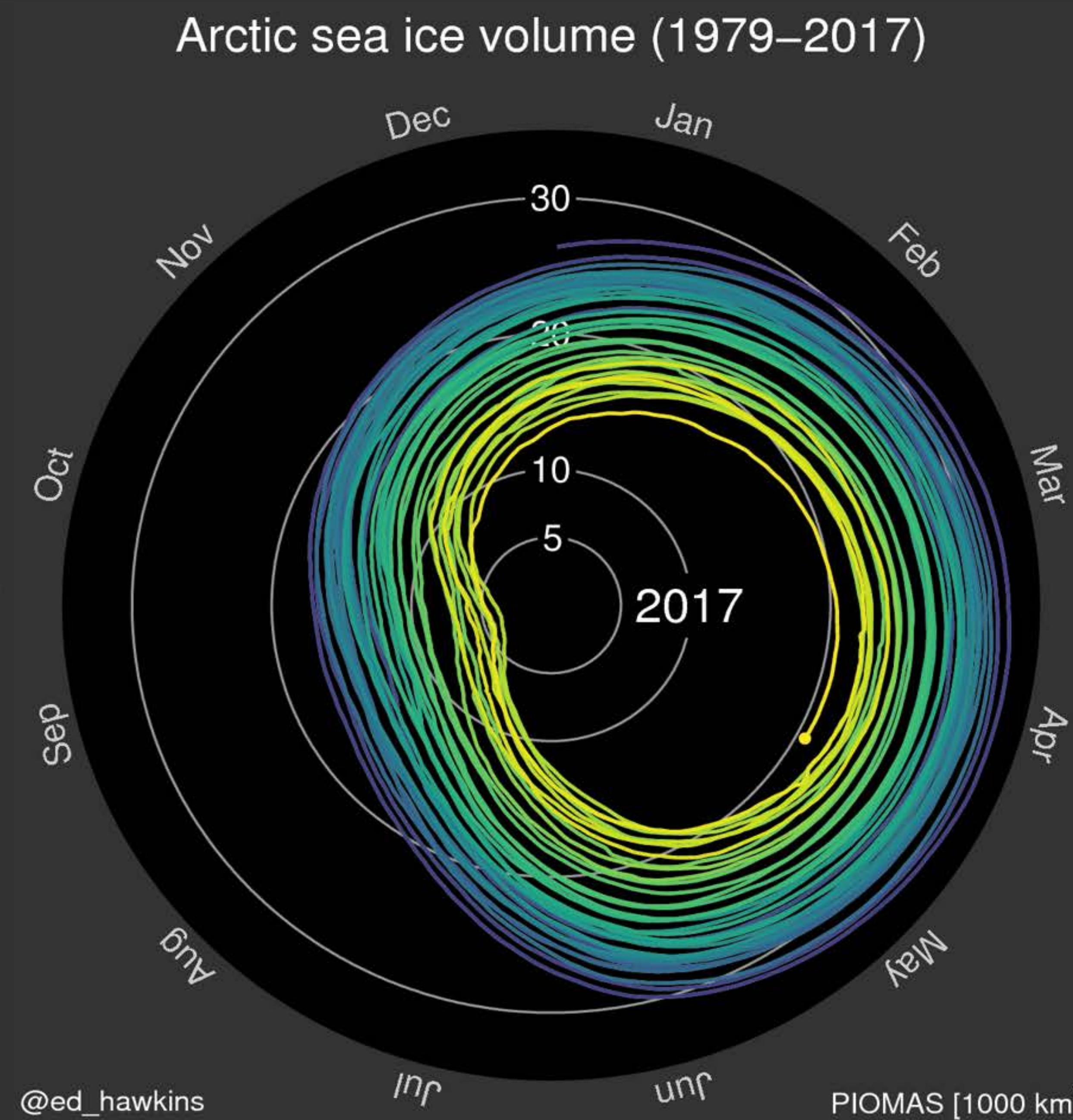
275 participants
11 keynotes
145 orals/papers
30 posters

Negative CO_2
Negative CO_2 Emissions with Chemical-Looping Combustion of Biomass

www.negativeCO2emissions2018.com

Thank you!


Global temperature change (1850–2016)
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
2.0°C
1.5°C
2016
@ed_hawkins
HadCRUT4


Arctic sea ice volume (1979–2017)
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
30
10
5
2017
@ed_hawkins
PIOMAS [1000 km