Negative CO_2

Nordic Energy Research

Bio-CLC: Need for, 100-kW Operational results and Potential in the Nordic Region

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CHALMERS

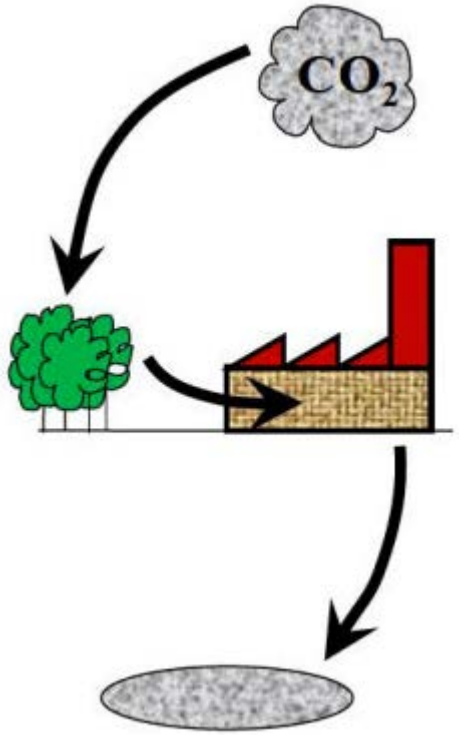
7th High Temperature Solids Looping Cycles Network Meeting

Luleå, September 4-5, 2017

So what are Negative CO_2 Emissions?

BIOMASS  **CCS**

= CO_2 Capture and Storage



Bio-CCS
or
BECCS
(Bio-Energy CCS)

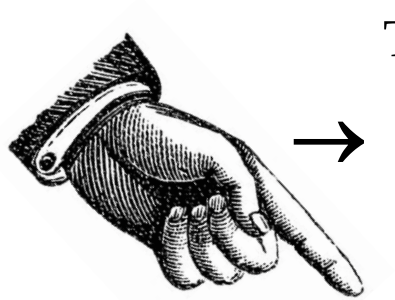
*The Paris agreement to stay **well below** 2ºC:*

How much additional carbon dioxide can be emitted ??

Carbon dioxide budget for max 1.5ºC and 2ºC :

200 and 800 Gton CO_2

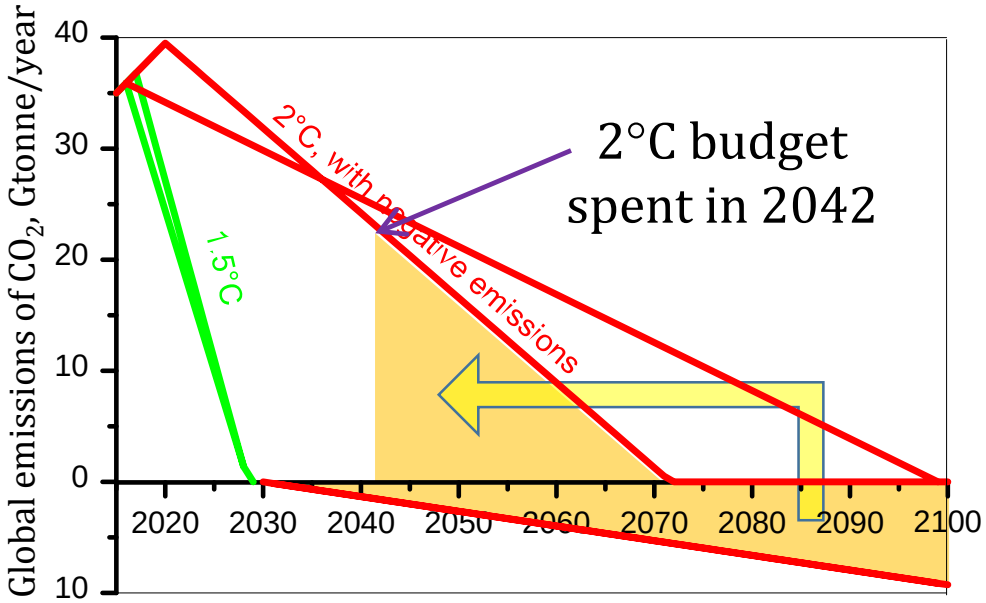
Today's emissions >35 Gton CO_2/year :

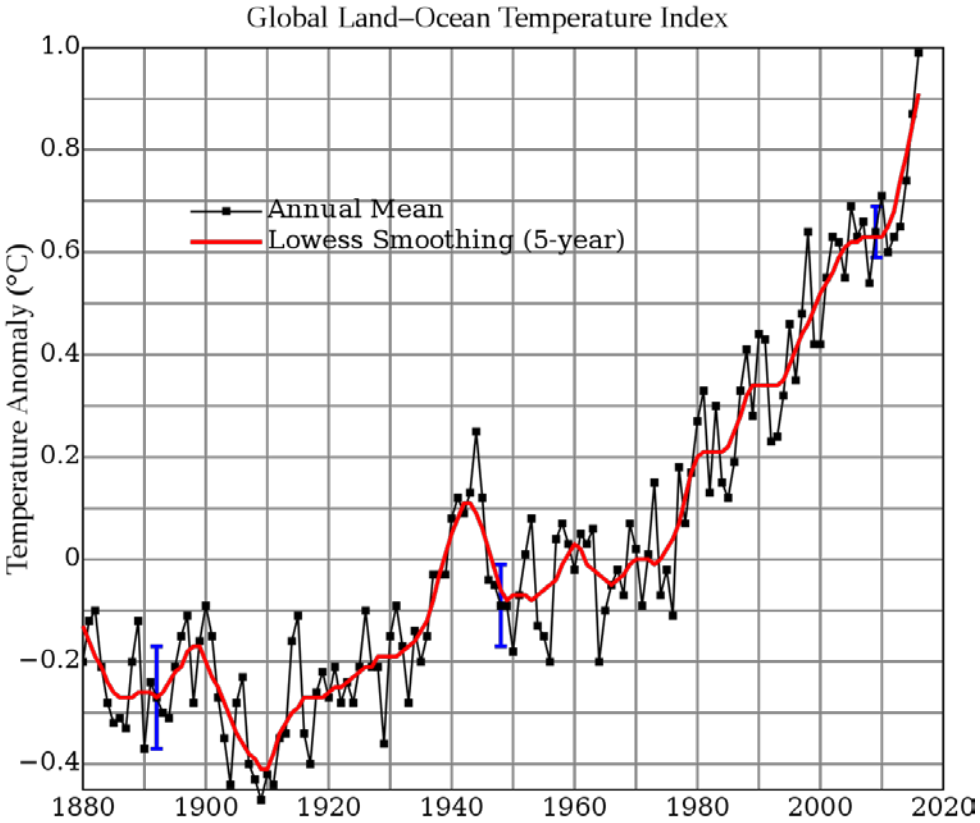


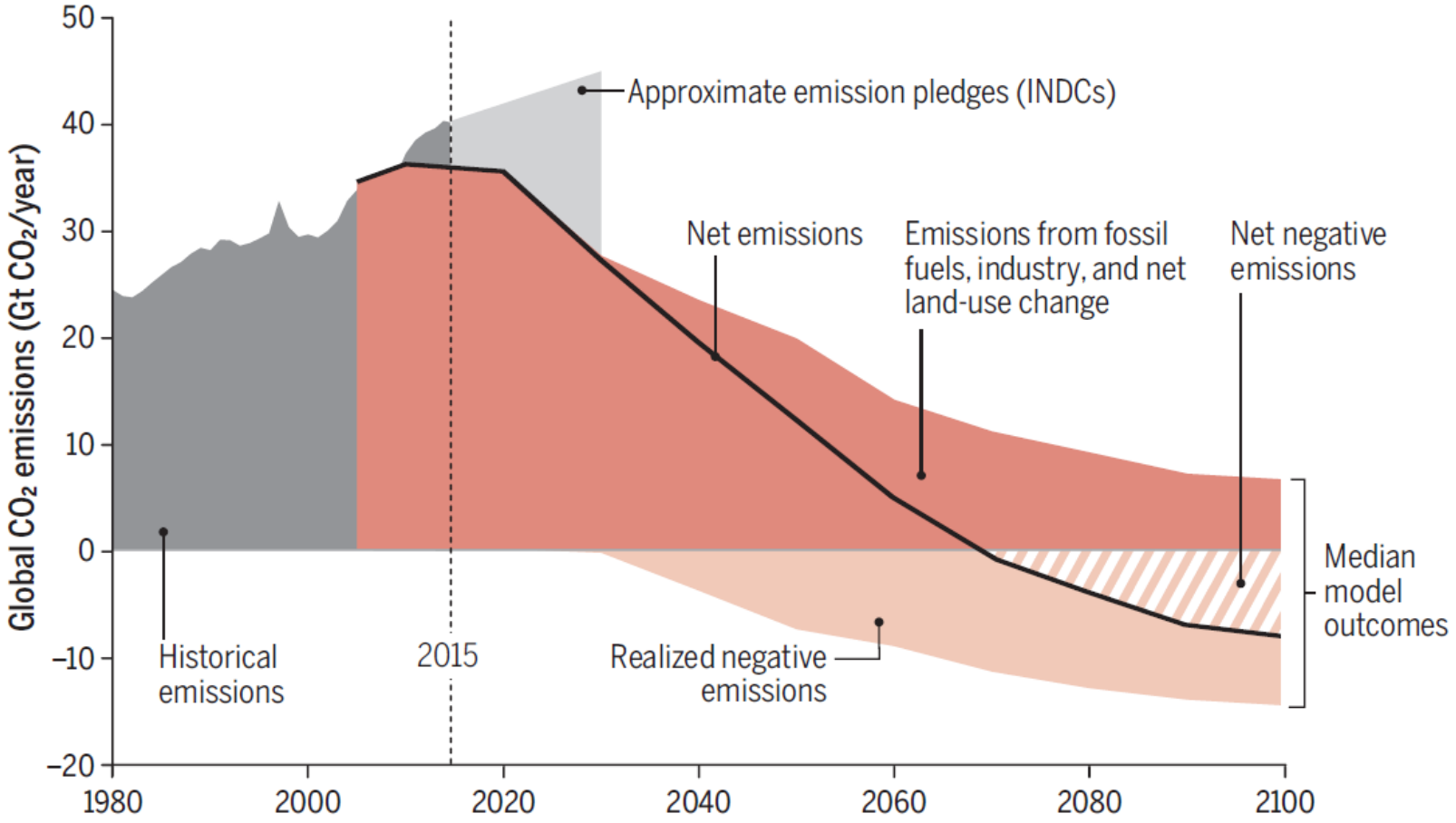
→ **6 - 25 years with today's emissions**

Negative emissions are needed

to reach climate targets



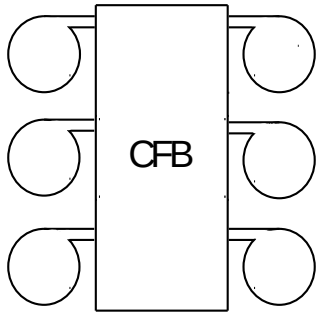


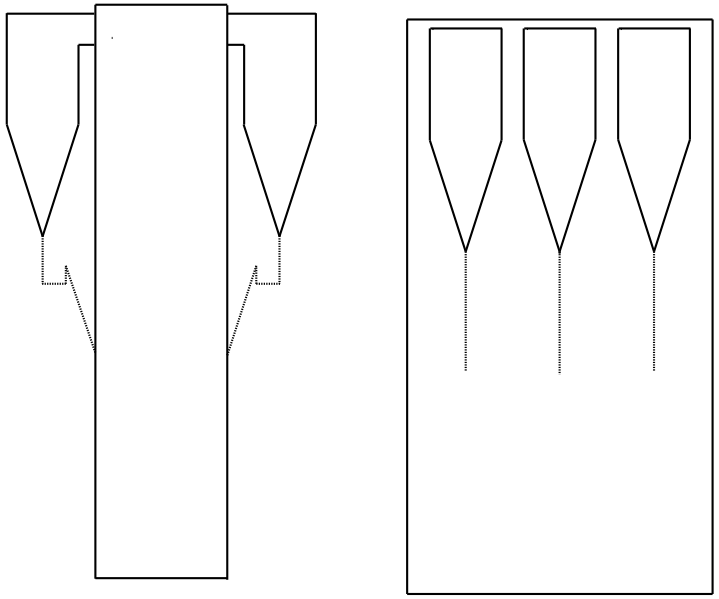


Median of IPCC scenarios to reach max 2C. Net emissions negative after 2070.
But negative emissions already from 2030. 15 Gton/year in 2100.
(Total bioenergy today about 5 Gton / year.)
Budget about 800 Gton.
Extended with 600 Gton through negative emissions !!!

Anderson, K.; Peters, G., The trouble with negative emissions. Reliance on negative-emission concepts locks in humankind's carbon addiction. *Science* **2016,** *354* (6309), 182-183.

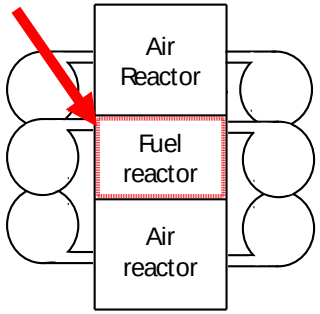
1000 MW_{th}
CFB boiler
dimensions
11x25.5x48

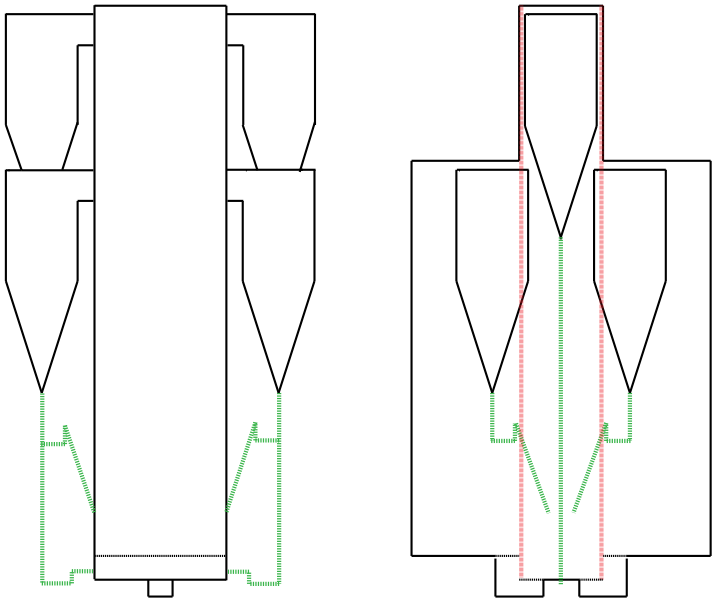




1000 MW_{th}
CLC boiler
dimensions
11x25x48

Added cost: insulation of fuel reactor





Walls of fuel reactor, cyclones, ducts and post-oxidation chamber:
→ 2500 m^2

Cost: 1500 €/m^2

<u>Thus, added cost of CLC fuel reactor:</u>

≈ 4 M€

⇒ 0.4 M€/year
÷
2 Mton CO_2/year

= 0.2 €/ton CO_2

From: Lyngfelt, A., and Leckner, B., A 1000 MWth Boiler for Chemical-Looping Combustion of Solid Fuels - Discussion of Design and Costs, *Applied Energy* 157 (2015) 475-487 *(Open Access)*

•Added cost relative to CFB[1]

Type of cost	estimation, €/tonne CO_2	range, €/tonne CO_2	Efficiency penalty, %
CO_2 compression	10	10	3
Oxy-polishing	6.5	4-9	0.5
Boiler cost	1	0.1-2.3	-
Oxygen carrier	2	1.3-4	-
Steam and hot CO_2 fluidization	0.8	0.8	0.8
Fuel grinding	0.2	0.2	0.1
Lower air ratio	-0.5	-0.5	-0.5
Total	20	15.9-25.8	3.9

Type of cost	estimation, €/tonne CO_2	range, €/tonne CO_2	Efficiency penalty, %
~~CO_2 compression~~	~~10~~	~~10~~	~~3~~
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Fuel grinding	0.2	0.2	0.1
Lower air ratio	-0.5	-0.5	-0.5
Total	3.5	1.9-6.8	0.4

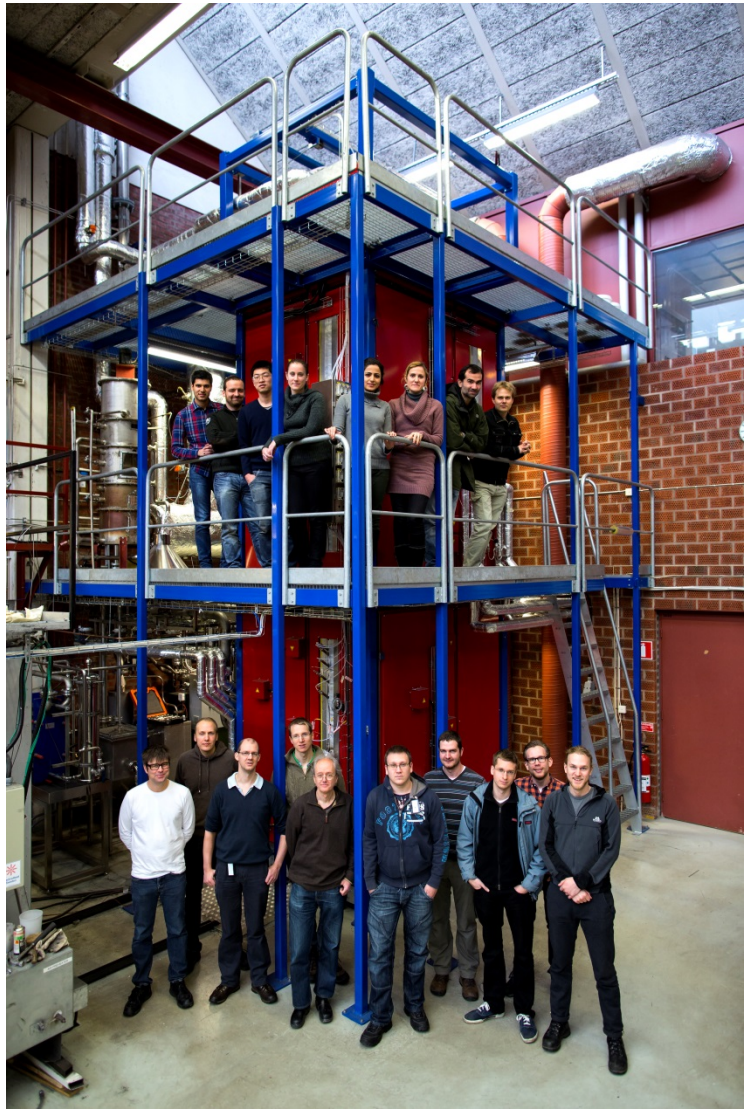
Demonstration without CO_2 capture can significantly reduce costs.

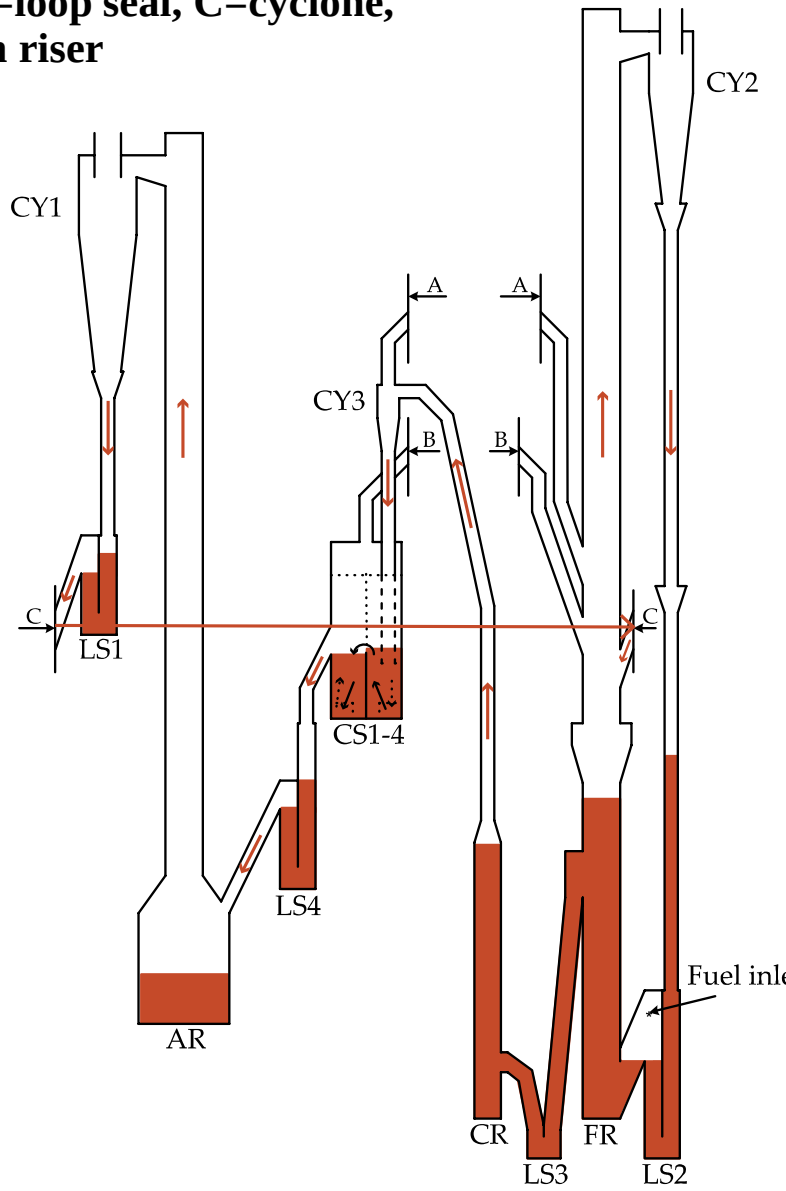
1) Verify concept
2) Add CO_2 capture

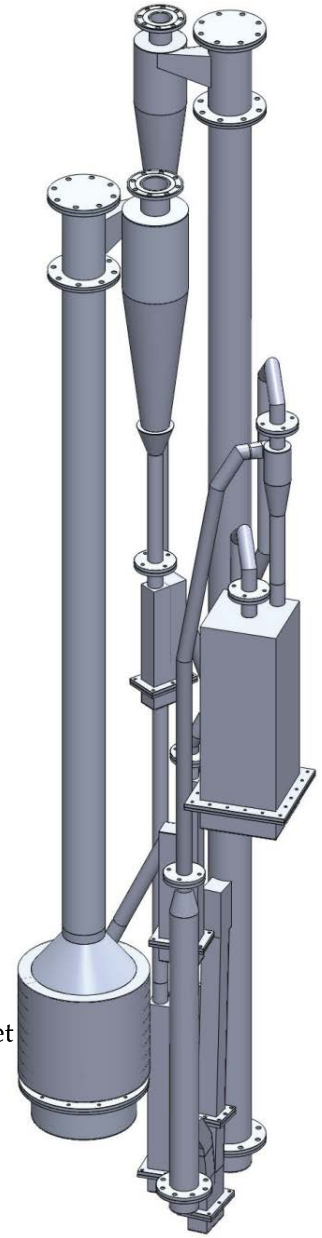
[1]Lyngfelt, A., and Leckner, B., A 1000 MW_{th} Boiler for Chemical-Looping Combustion of Solid Fuels - Discussion of Design and Costs, *Applied Energy* 157 (2015) 475-487

Chalmers' 100 kW CLC for solid fuel, 2011

AR=Air reactor, FR=fuel reactor, LS=loop seal, C=cyclone, CS=Carbon stripper, CR=Circulation riser





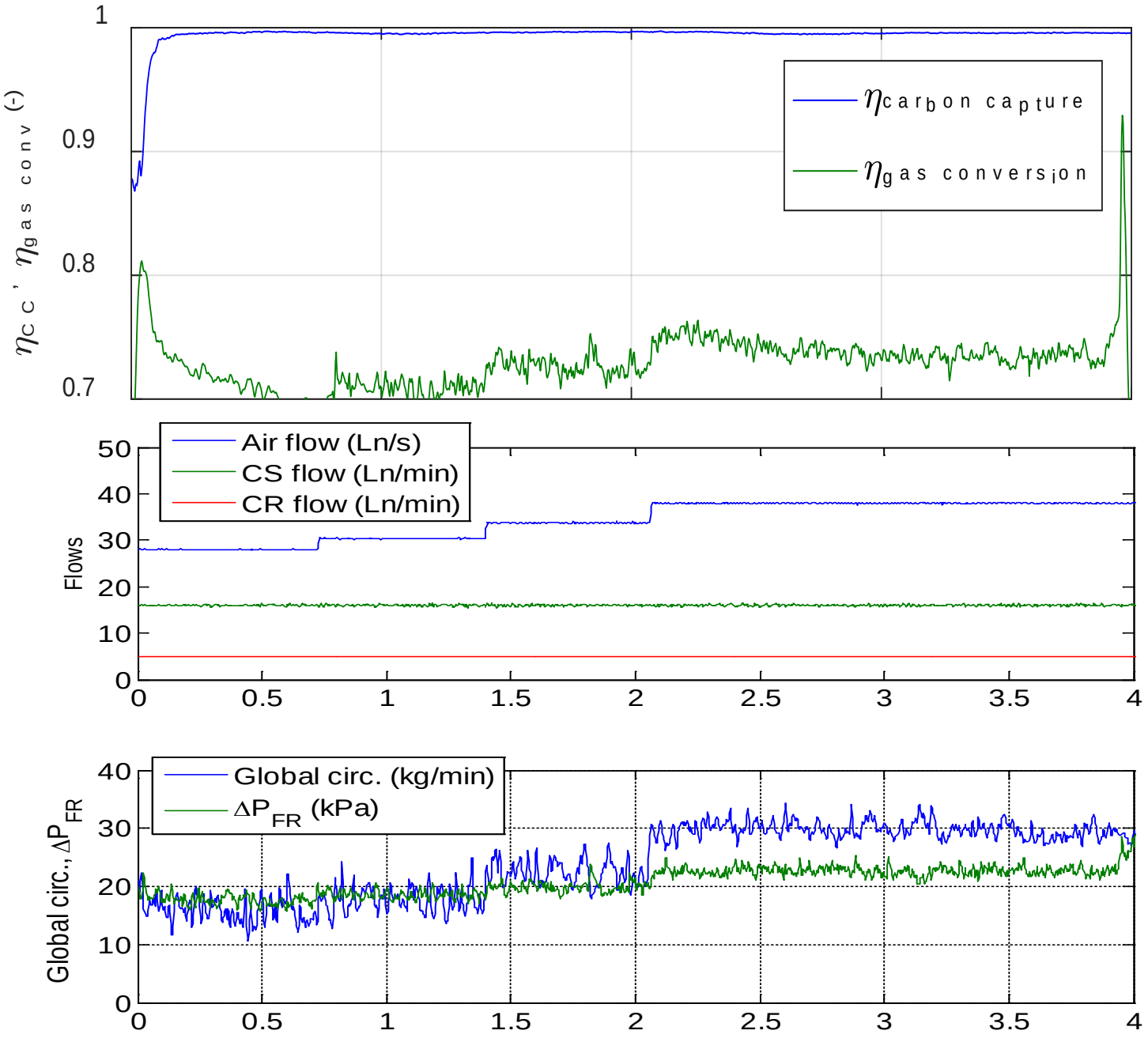


FUEL, ground wood pellets (Black are steam-exploded)

Table I: Fuel analyses.

		White pellets	Black pellets
Moisture	m-% a.r.	6.9	4.9
Ash	m-% a.r.	0.6	0.5
Volatiles	m-% a.r.	77.1	75.0
Fixed carbon	m-% a.r.	15.5	19.6
C	m-% a.r.	47.6	51.4
H	m-% a.r.	5.7	5.8
N	m-% a.r.	<0.1	<0.1
S	m-% a.r.	<0.01	<0.01
O (as diff.)	m-% a.r.	39.3	37.5
LHV	MJ/kg a.r.	17.5	19.2

a.r. = as received

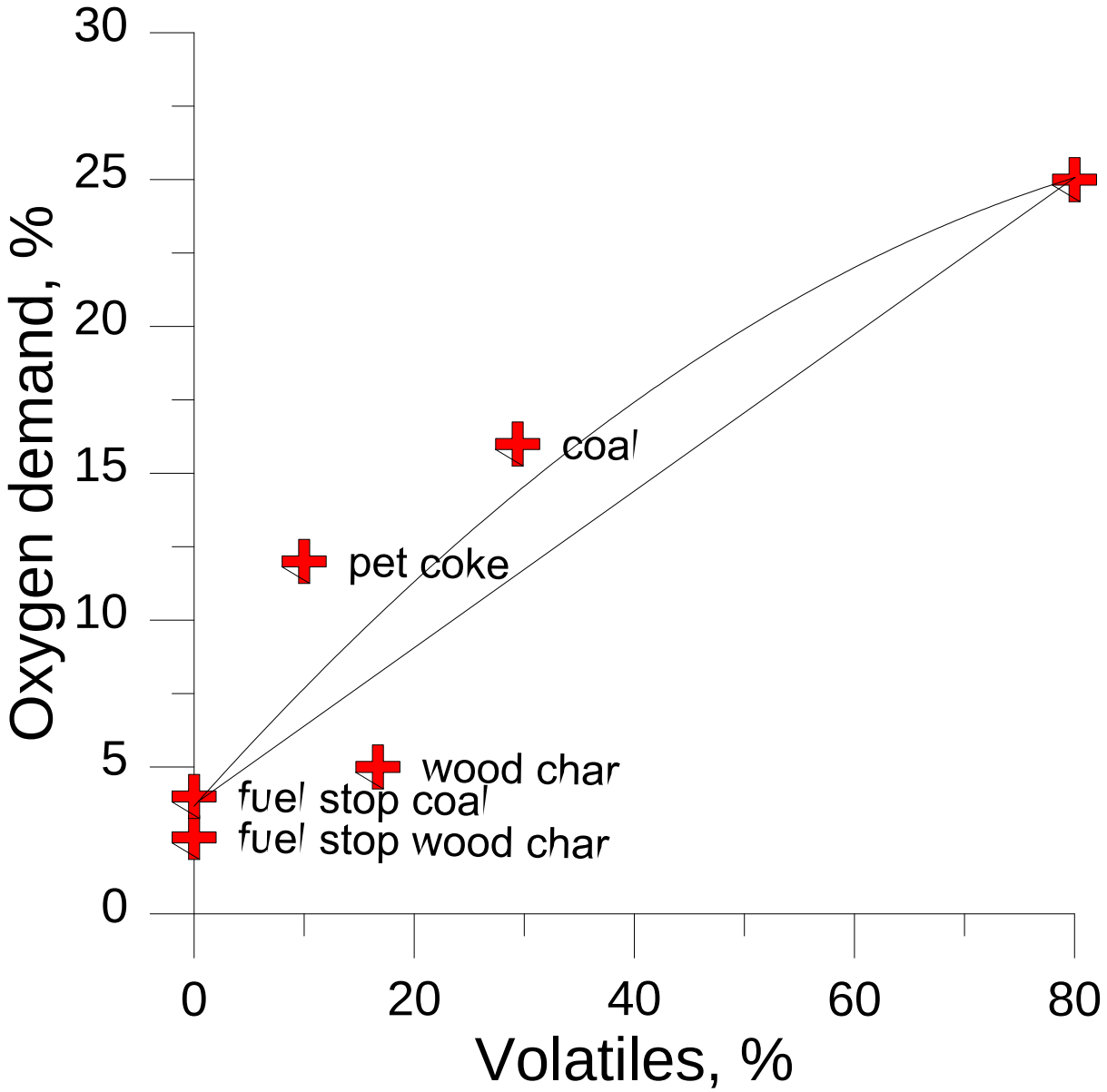


4 h of operation with black pellets.

Very high CO_2 capture, ≈100%.

Gas conversion 70-75%
= Oxygen demand, 25-30%

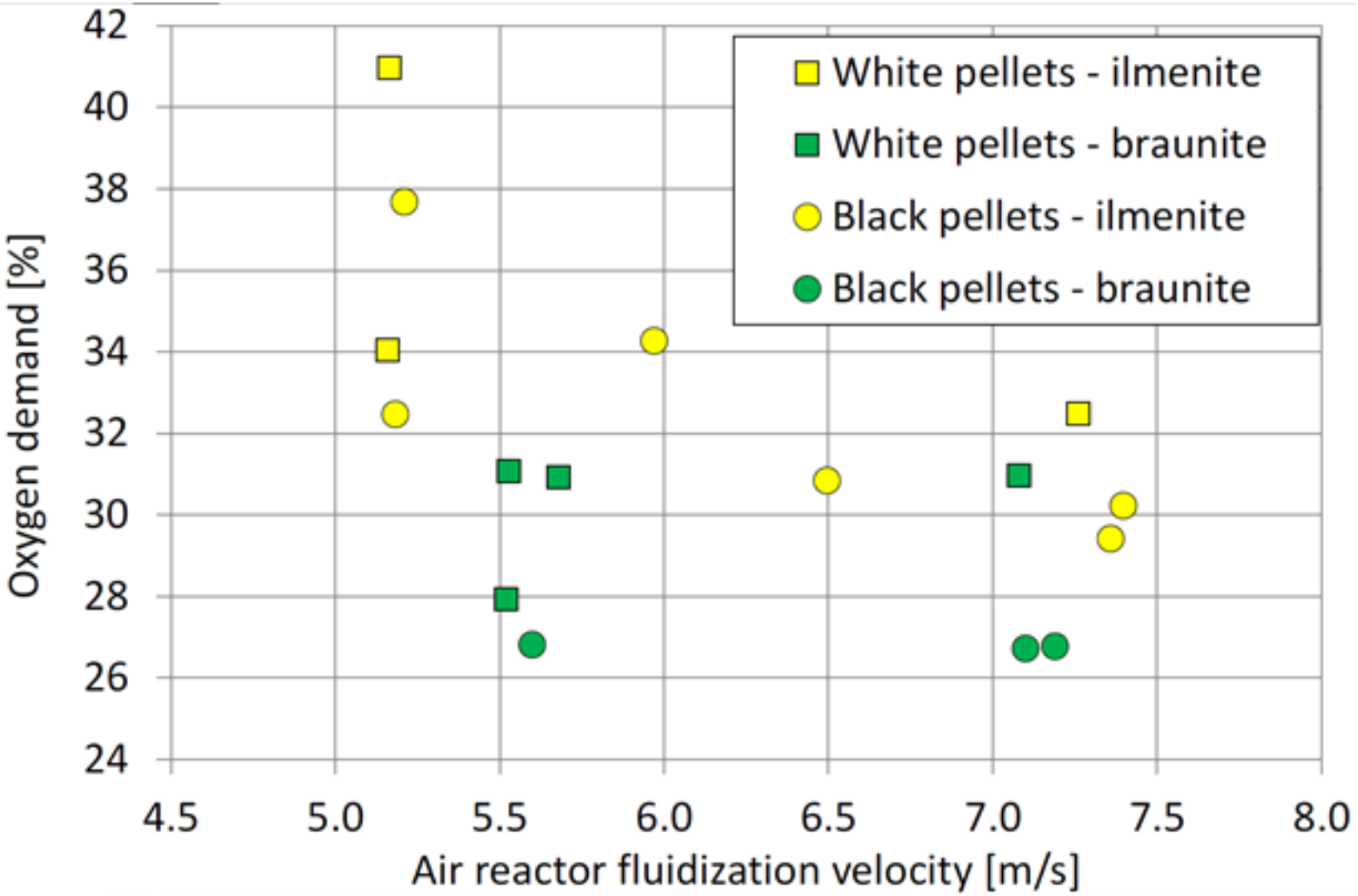
Oxygen demand decreases with increased air flow, i.e. increased circulation and increased pressure drop (solids inventory in fuel reactor).



Oxygen demand rises with volatiles' content.

Slugging conditions in 100 kW CLC reactor.

Significant "by-pass" of volatiles, in spite of addition in the bottom of the bed.



Similar results in dual fluidized bed gasifier at VTT:

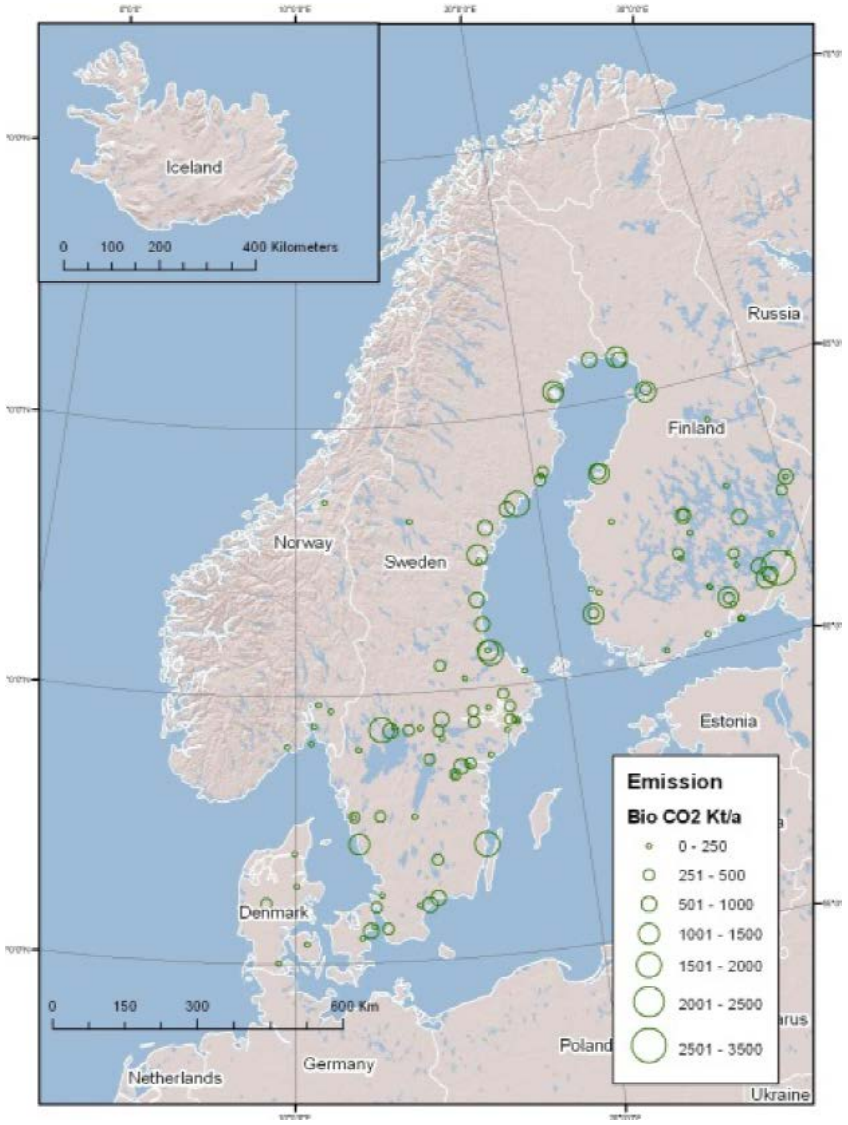
Oxygen demand for manganese ore and black pellets:

27%

Wood char (not shown):

11-13%

Swedish CO_2 emissions from biomass, (larger point sources): *31 Mtonnes/år*



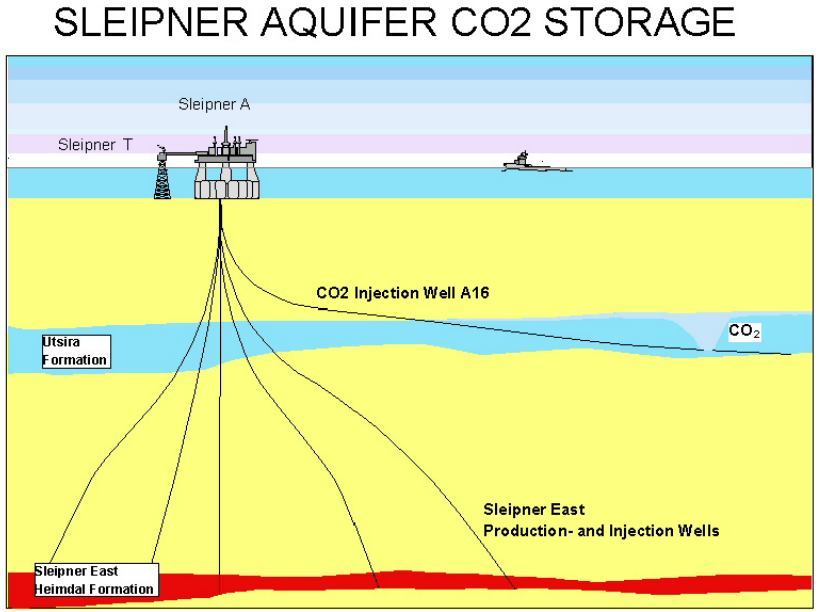
Sweden's total fossil CO_2 emissions are:

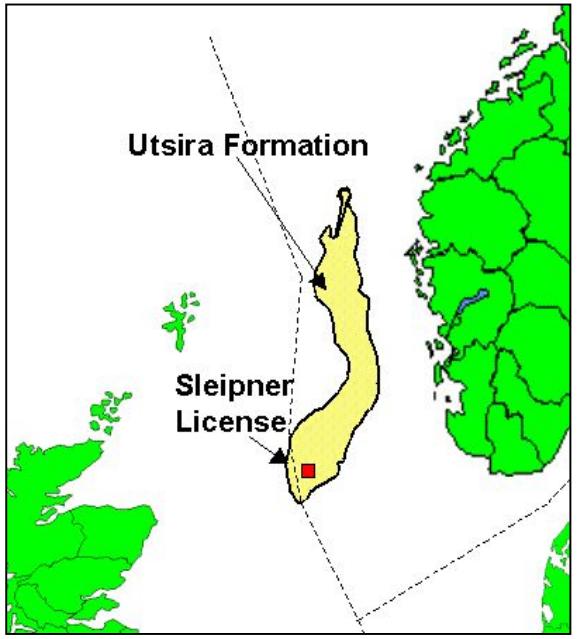
43 Mtonnes/year

If fossil CO_2 emissions are stopped and CO_2 emissions from biomass are captured, we can reduce emissions by

more than 150% !!!

It is time to start the clean-up of the atmosphere !

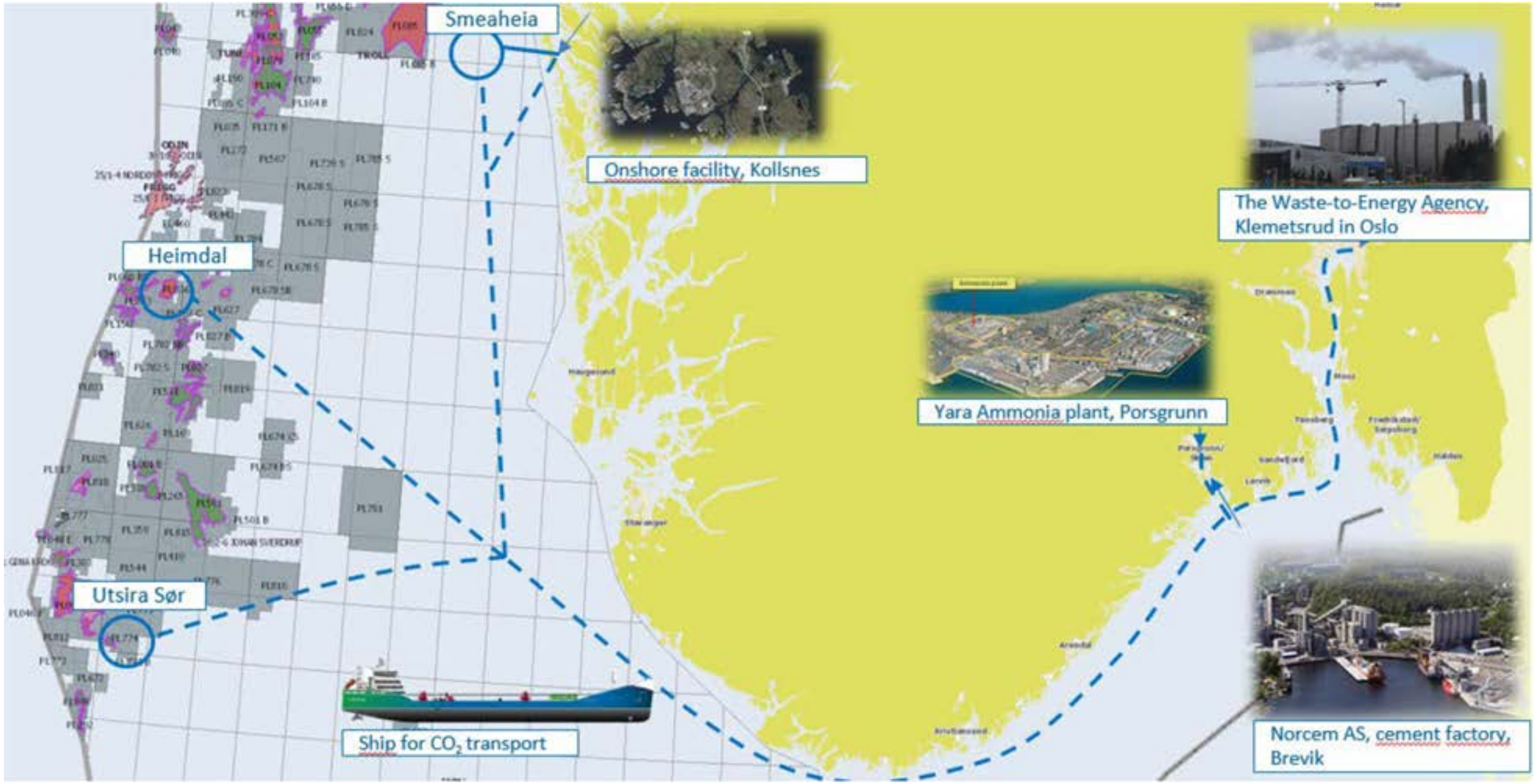


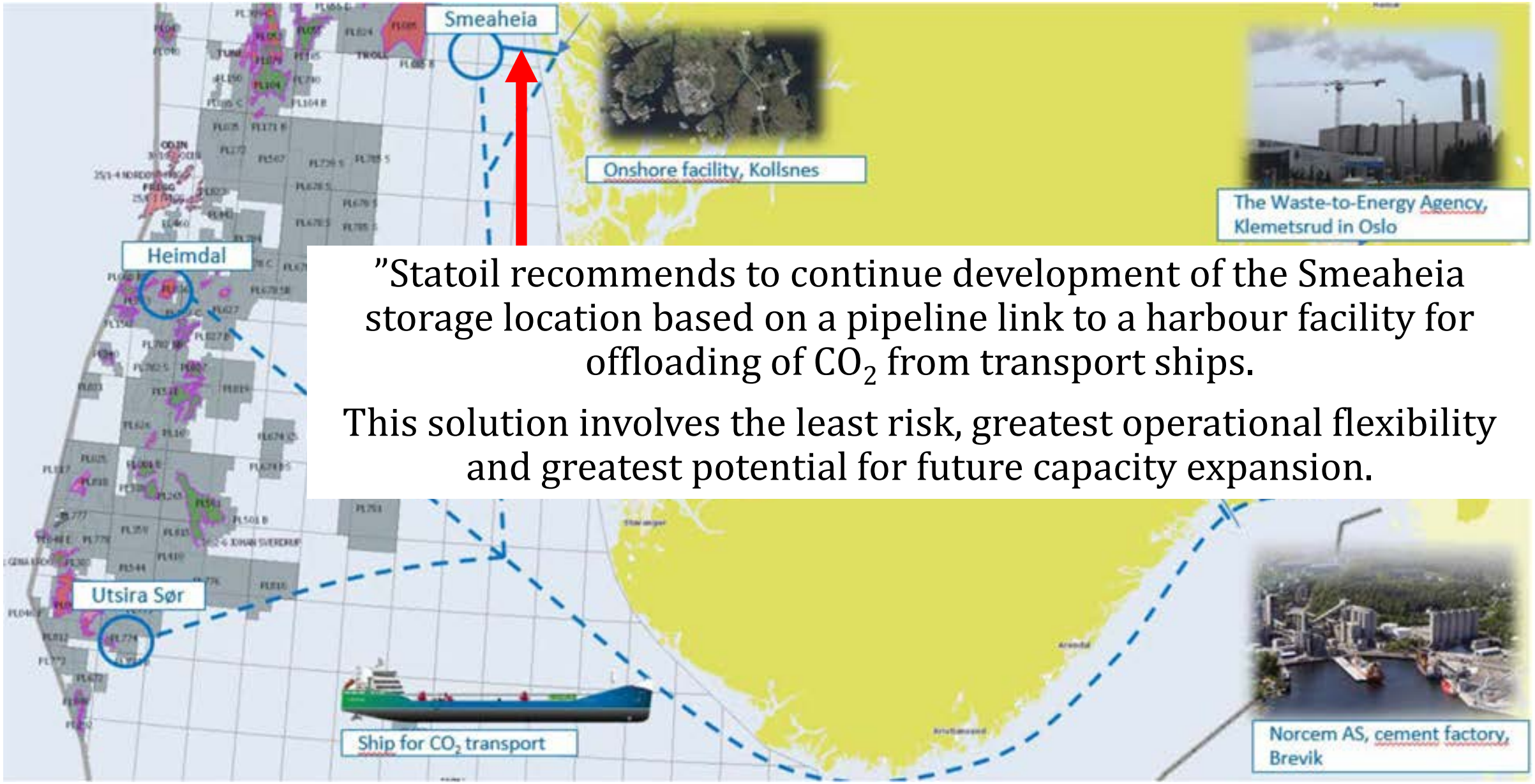


Storage since 1996
1 Mton CO_2/year
(3% Norway's emissions)

Area: 26 000 km^2
Depth: 550 to 1500 m
Height: 200-300 m
Porosity: 30-40%

Options for storing CO_2 from three facilities in Norway





”Statoil recommends to continue development of the Smeaheia storage location based on a pipeline link to a harbour facility for offloading of CO_2 from transport ships.

This solution involves the least risk, greatest operational flexibility and greatest potential for future capacity expansion.

STATUS OF CLC

>9000 h of operation in 34 pilots with 70 different oxygen carrier materials, of which >3000 h with low-cost materials (e.g. ores of ilmenite, iron and manganese)

SOLID FUELS:

- >3000 h of operation in 17 pilots
- major cost of CO_2 capture, i.e. gas separation, is uniquely avoided (depending on gas conversion)
- unique potential for low energy penalty
- transparent cost evaluation based on difference compared to circulating fluidized bed available, 16-26 €/ton
- cost expected less than half of competing technologies
- could likely be demonstrated at low cost (e.g. 1 M€) using existing biomass gasifier (e.g. GobiGas, 120 M€ investment)
- no interest from coal industry
- no incentives for negative emissions

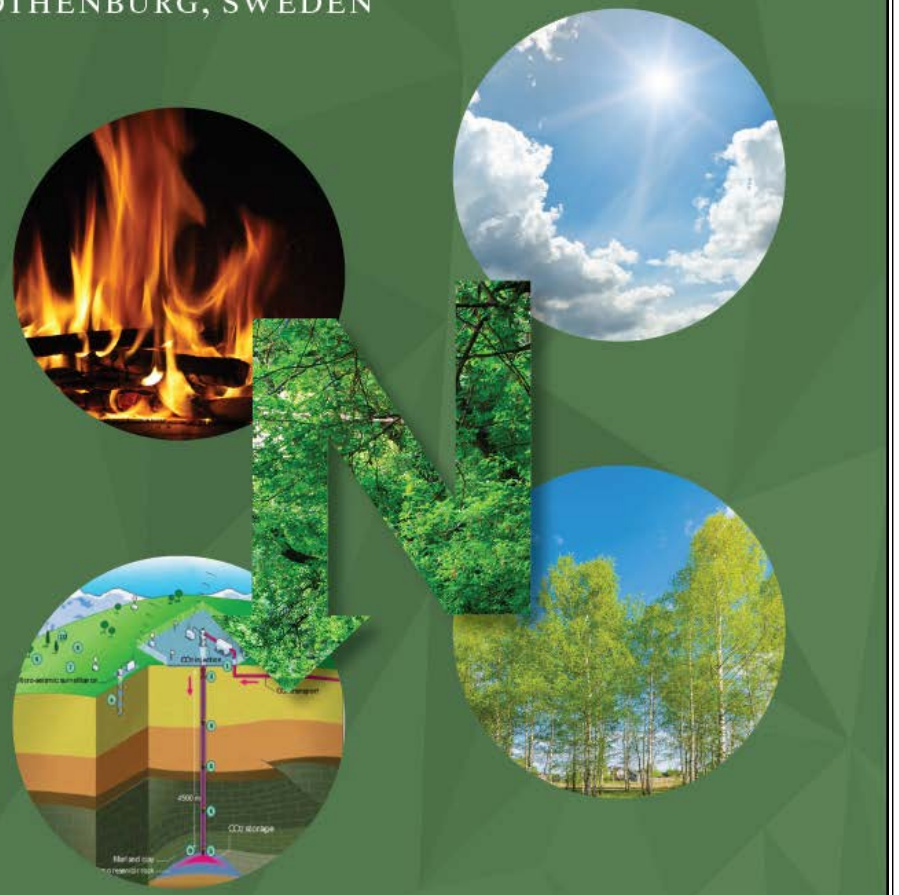
http://negativeco2emissions2018.com/

INTERNATIONAL CONFERENCE ON

NEGATIVE CO_2 EMISSIONS

MAY 22-24, 2018

CHALMERS UNIVERSITY OF TECHNOLOGY
GOTHENBURG, SWEDEN



GENERAL INFORMATION

The objective of the Paris Agreement is to limit warming to well below 2ºC, and to pursue efforts to limit the temperature increase to 1.5ºC. The IPCC Fifth Assessment Report quantified the global "carbon budget", that is the amount of carbon dioxide that we can emit while still having a likely chance of limiting global temperature rise to 2 degrees Celsius above pre-industrial levels.

The exact size of the carbon budget cannot be specified with high confidence since it depends on many uncertain factors, including emission pathways for non-CO_2 climate forcers. This said, the remaining budgets for the 1.5ºC and 2ºC targets have been estimated at about 200 and 800 Gt of CO_2. With unchanged present emissions at about 40 Gt CO_2/year these budgets would be exhausted in as few as 5 and 20 years, respectively. Consequently, most of the IPCC emission scenarios able to meet the global two-degree target require overshooting the carbon budget at first and then remove the excess carbon with large negative emissions, typically on the order of 400-800 Gt CO_2 up to 2100.

At the same time as negative emissions appear to be indispensable to meet climate targets decided, the large future negative emissions assumed in climate models have been questioned and warnings have been raised about relying on very large and uncertain negative emissions in the future. With the future climate at stake, a deeper and fuller understanding of the various aspects of negative emissions is needed.

The purpose of the conference is to bring together a wide range of scientists, experts and stakeholders, in order to engage in various aspects of research relating to negative CO_2 emissions. This will include various negative emission technologies, climate modelling, climate policies and incentives.

ANNOUNCEMENT

The International Conference on Negative CO_2 Emissions will be held May 22-24, 2018, at Chalmers University of Technology, Gothenburg, Sweden. The conference is organized by Chalmers with support from Global Carbon Project and International Energy Agency, i.e. IEAGHG, IEA-IETS and IEA Bioenergy.

Will negative CO_2 emissions be able to meet expectations when confronting the climate threat?

The front page representation illustrates BECCS, one example of negative CO_2 emissions. The geological storage picture is by courtesy of Total.

CONFERENCE PROGRAM

Main sessions:

- Negative CO_2 in climate modelling
- Negative CO_2 policy
- Negative CO_2 incentives
- BECCS technologies
- Enhanced weathering
- Afforestation and reforestation
- Altered agricultural practices
- Soil management/biochar
- Direct air capture

A poster session

WEBSITE

www.negativeCO2emissions2018.com

DEADLINES

Submission of documents via email to:
NegativeCO2@chalmers.se

ABSTRACT (ONE PAGE)
December 1, 2017
Please use the template provided on our website.

NOTIFICATION OF ACCEPTANCE
January 15, 2018

FULL PAPER
April 1, 2018
Selected papers will be published in Special Editions of scientific journals.

Early bird registration is recommended as limited places are available.

Traditional agricultural and forestry practices captured by Swedish painter Carl Larsson.




SCIENTIFIC COMMITTEE

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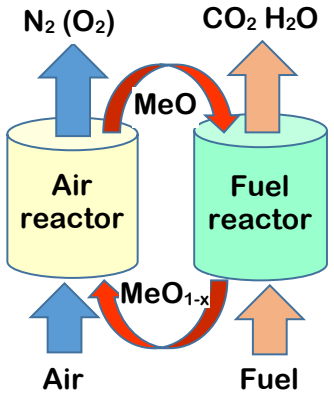
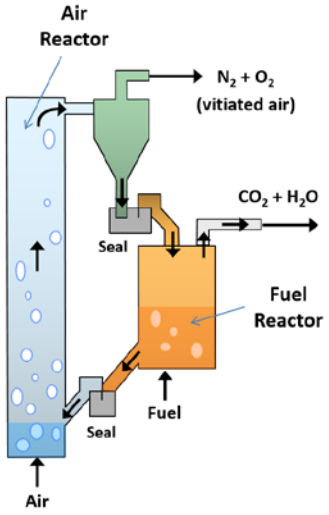


PRINCIPLE

metal oxide (MeO) transfers oxygen from air to fuel

⇒

no separation needed

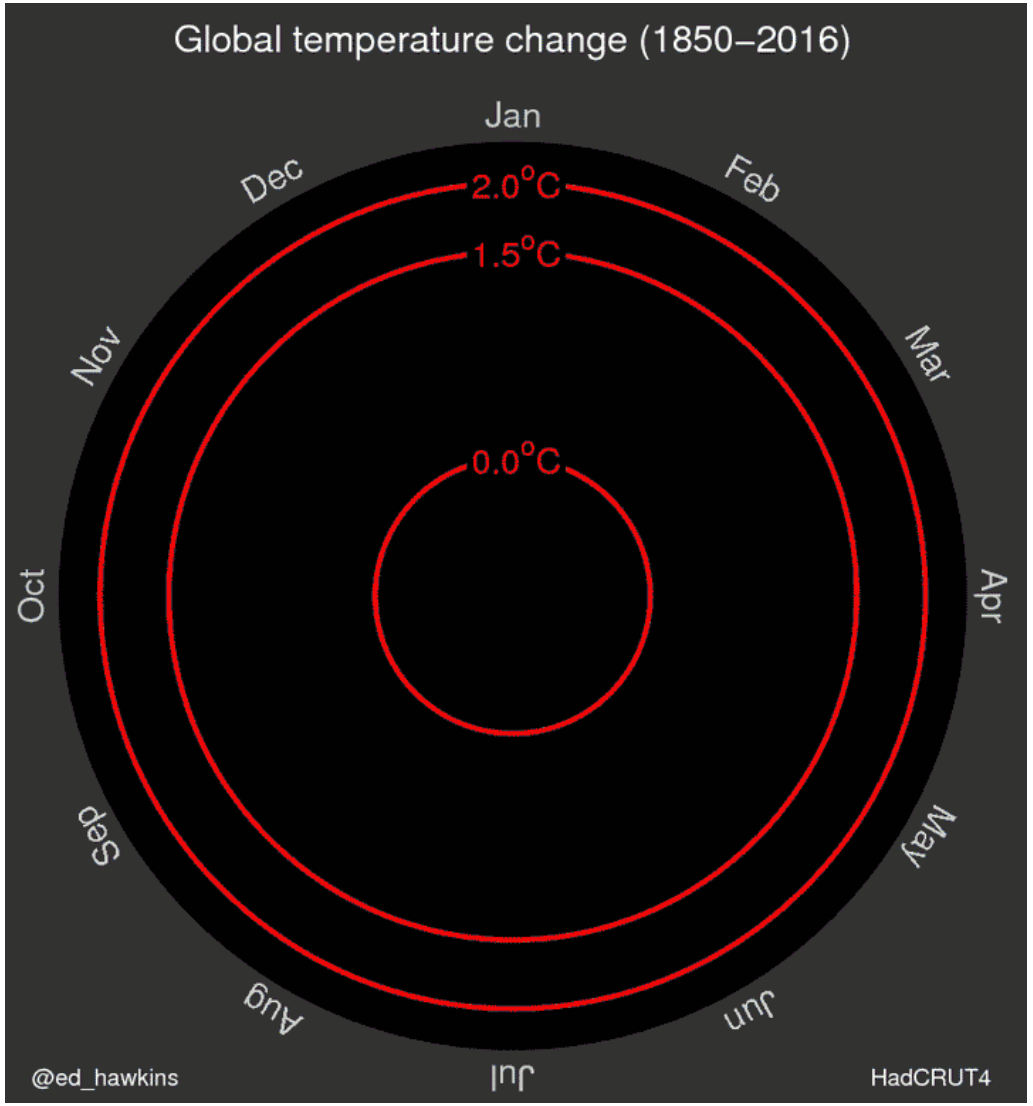


PRACTICE

well established circulating fluidized-bed technology

PURPOSE

Thank you!!! Questions



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