Negative CO_2

Nordic Energy Research

The Necessity of Negative CO_2 Emissions
A Nordic Perspective

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CHALMERS

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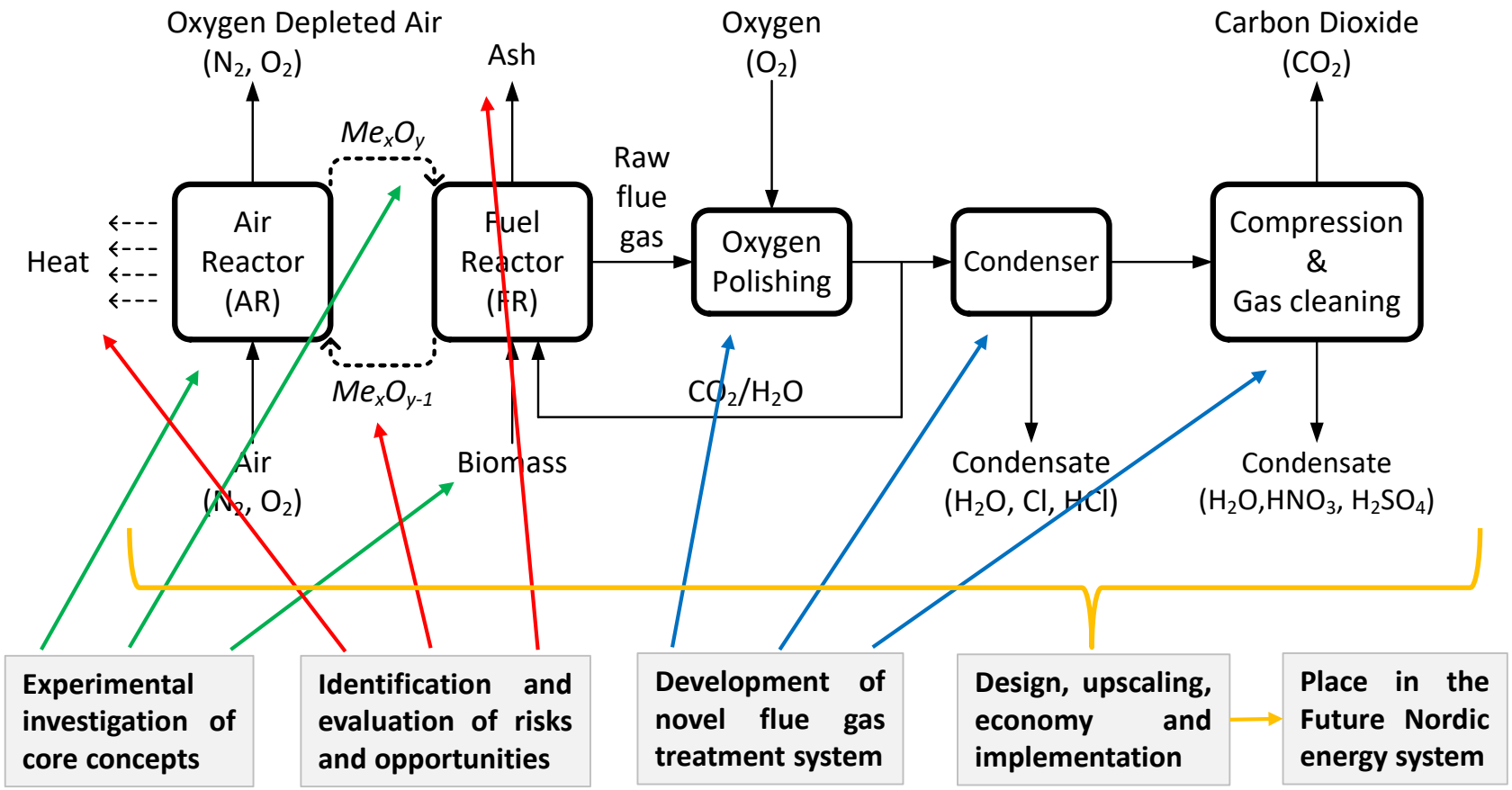
Negative CO_2 - Project Partners

Chalmers University of Technology	Sweden
The Bellona Foundation	Norway
Sibelco Nordic AB	Sweden
SINTEF Energy Research	Norway
SINTEF Materials and Chemistry	Norway
VTT Technical Research Centre of Finland Ltd	Finland
Åbo Akademi University	Norway

Research questions



Two main Principles of Negative Emissions

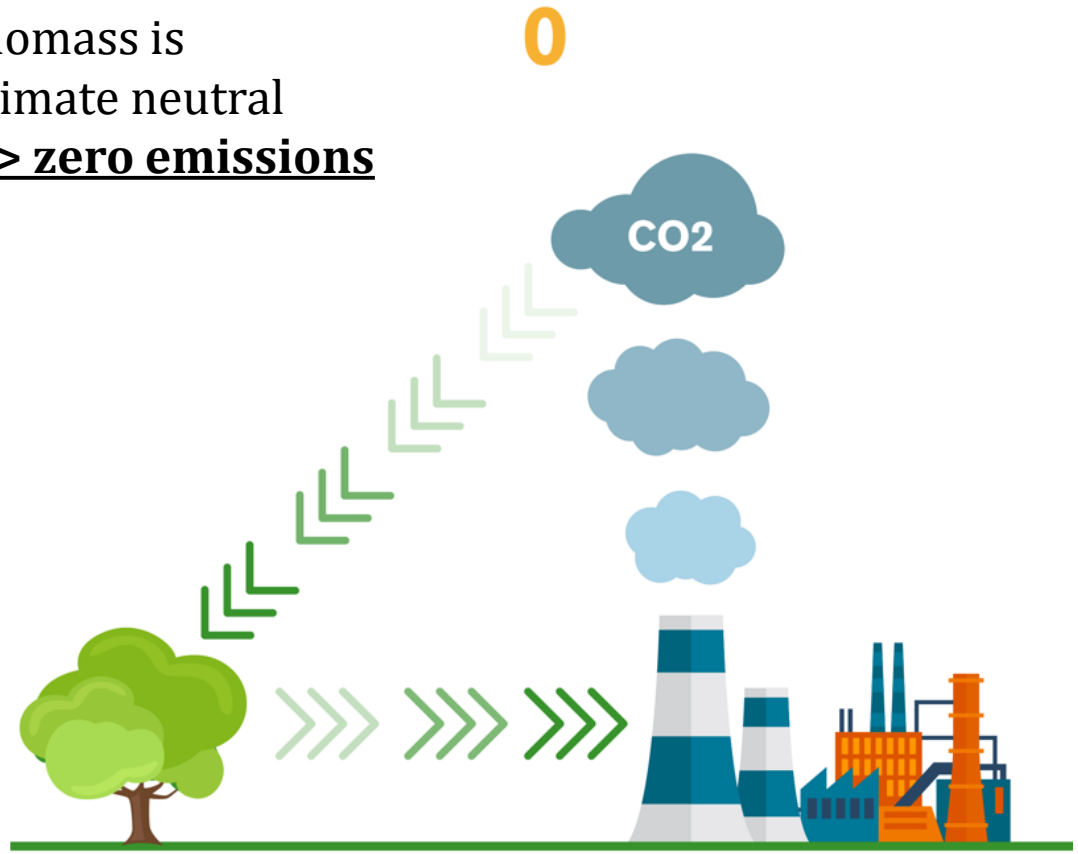
- **Capture and storage of CO_2 from combustion of biomass/biowaste**

- **Afforestation/Reforestation**

Negative emissions with Bio-CCS (CCS = Carbon Capture and Storage)

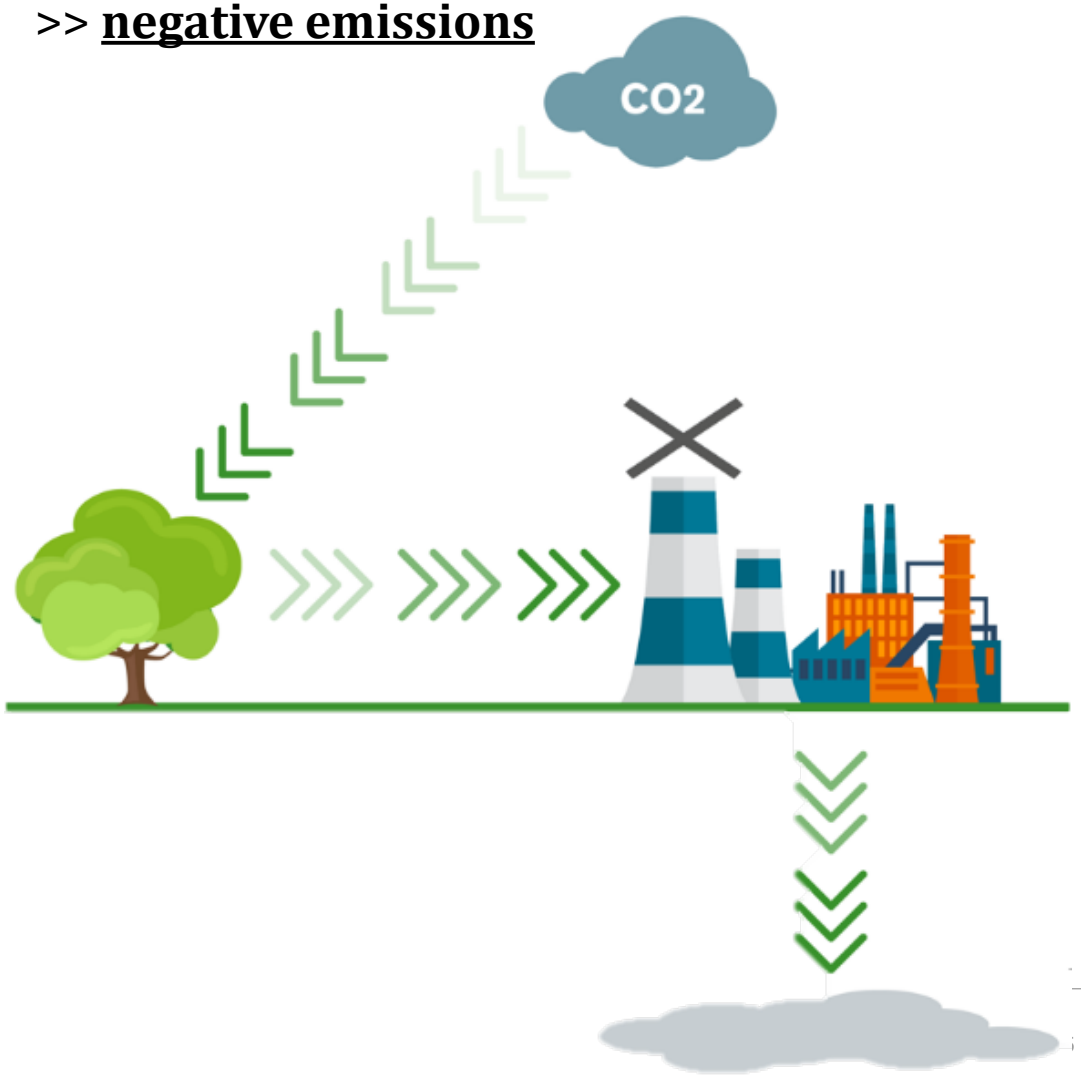
Combustion of biomass is climate neutral

>> zero emissions

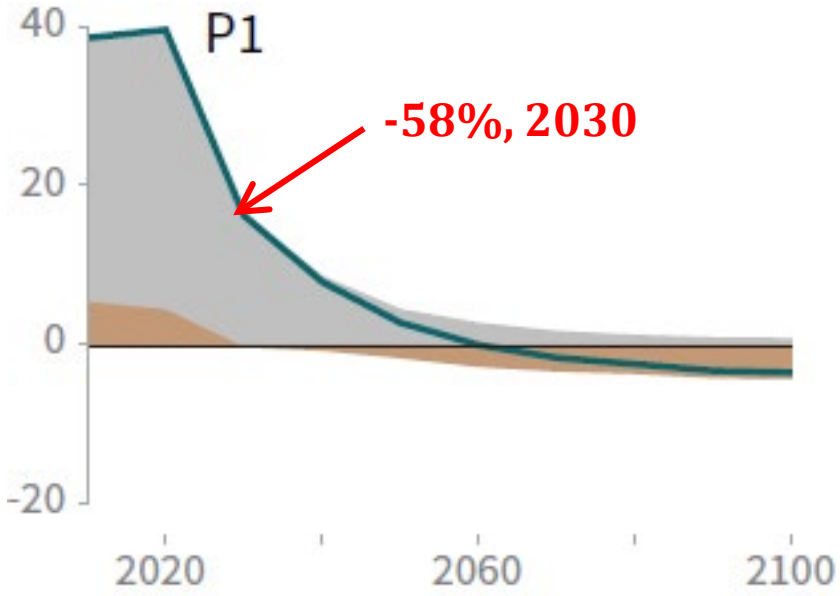


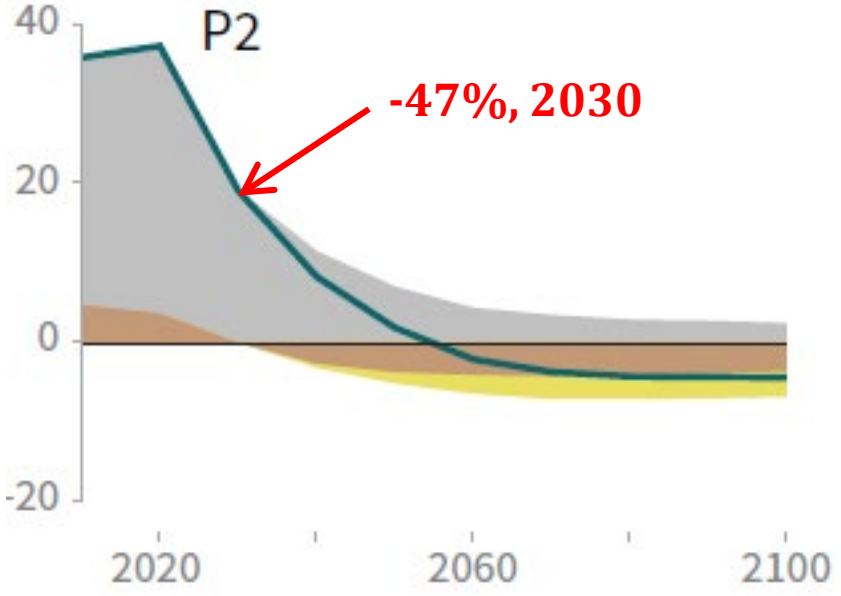
Combustion of biomass with CO2 capture

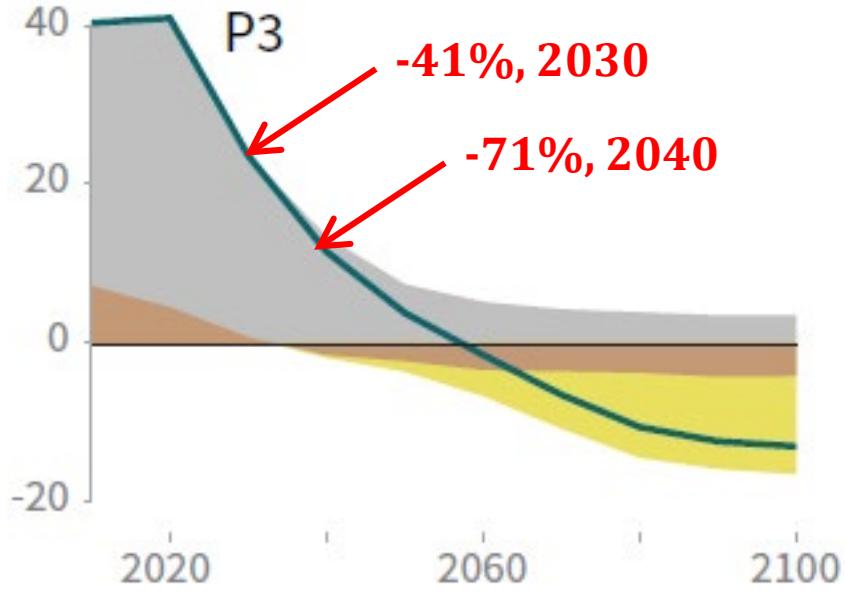
>> **negative emissions**

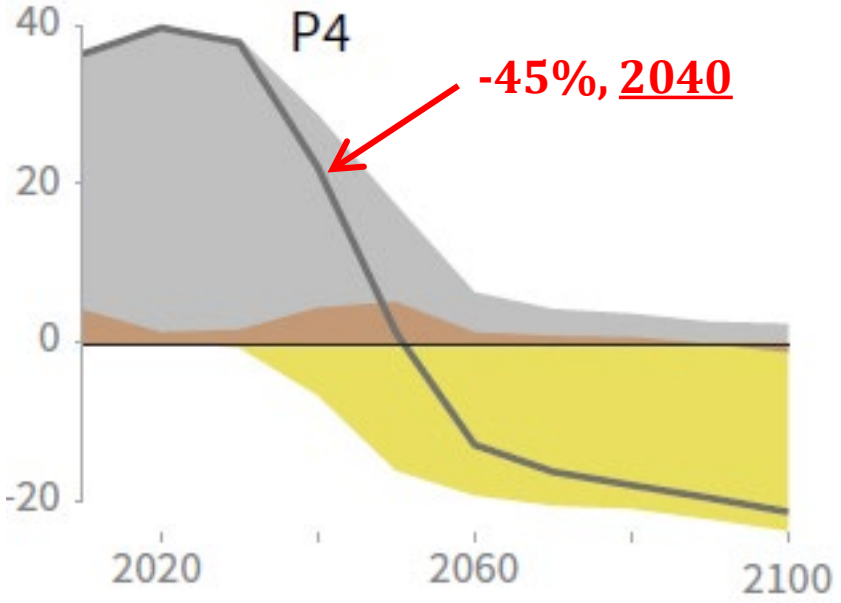


The four main scenarios for meeting 1.5 degree target (IPCC)









Negative emissions are not an option

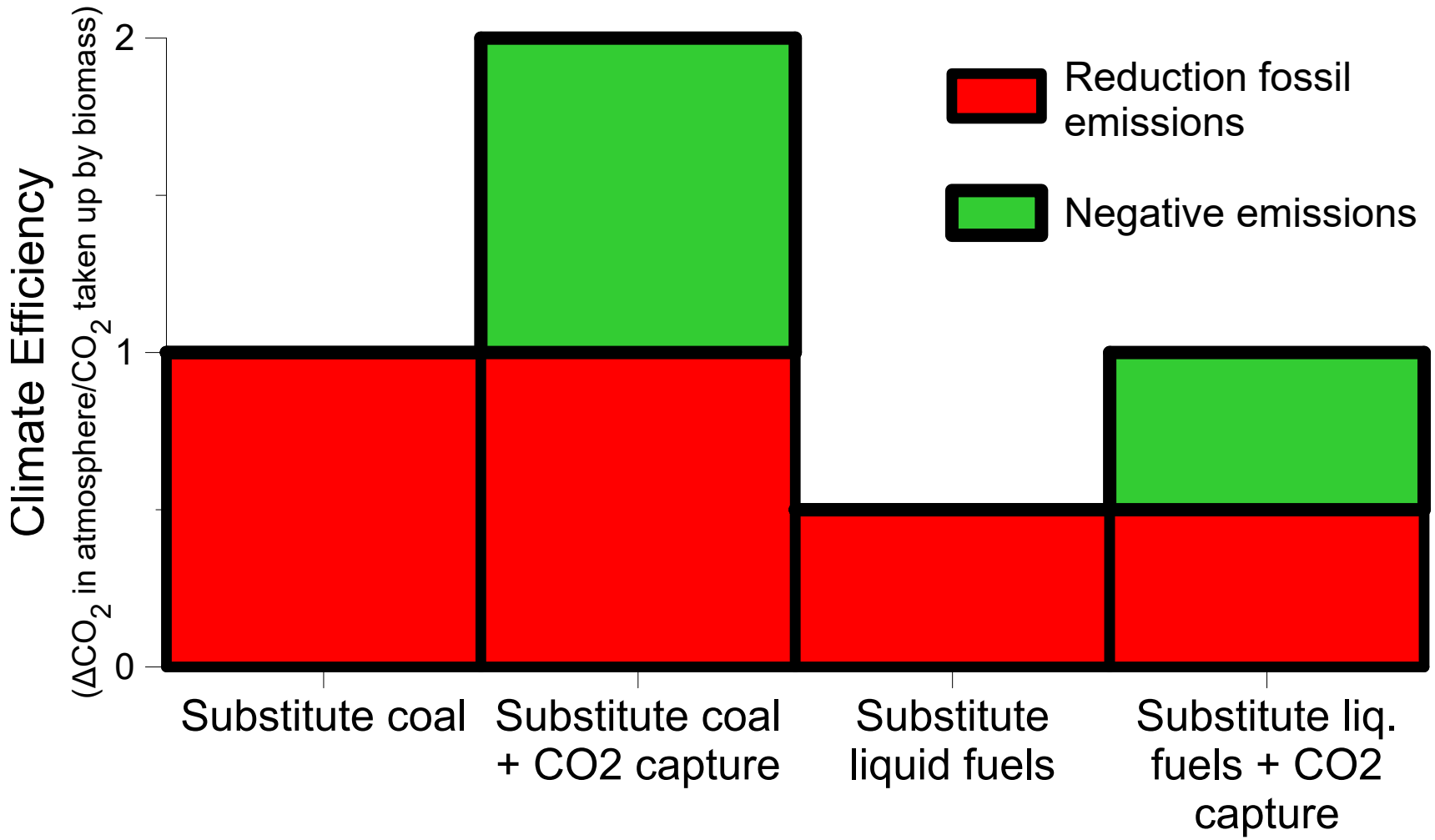
They are a necessity !

But we leave our grandchildren with a gigantic debt.

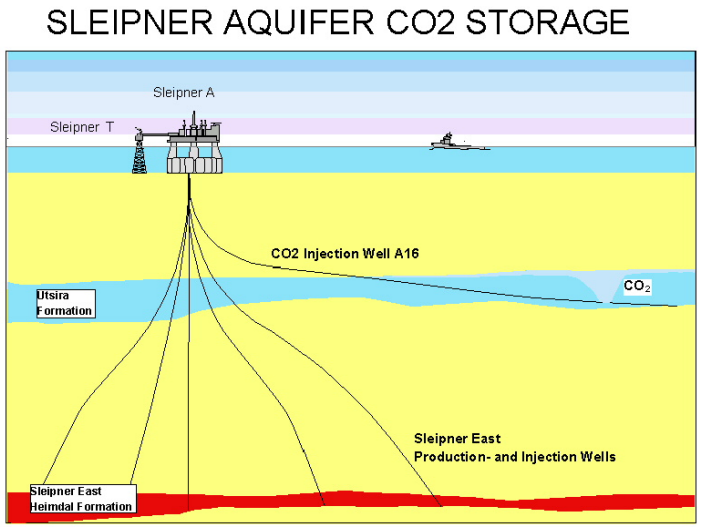
Perhaps :

100.000 €/capita

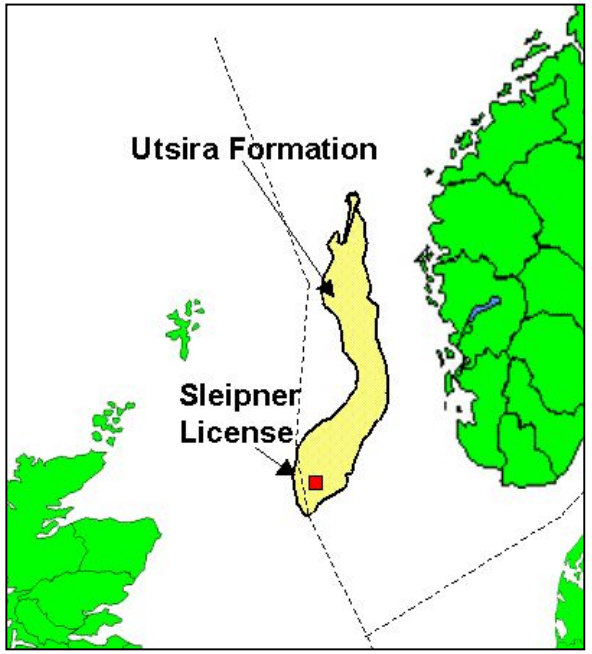
Biomass is a limited resource-
How is it used most efficiently for the climate ?



Large-scale storage today



Totally stored 30 Mton CO_2/year
Appr. 0.1% of global emissions



Storage started 1996
1 million ton CO_2/year
(3% Norway's total emission)

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

Conventional CO_2 capture,
Significant costs for equipment and operation

Boundary Dam, Canada. 115 MW_e

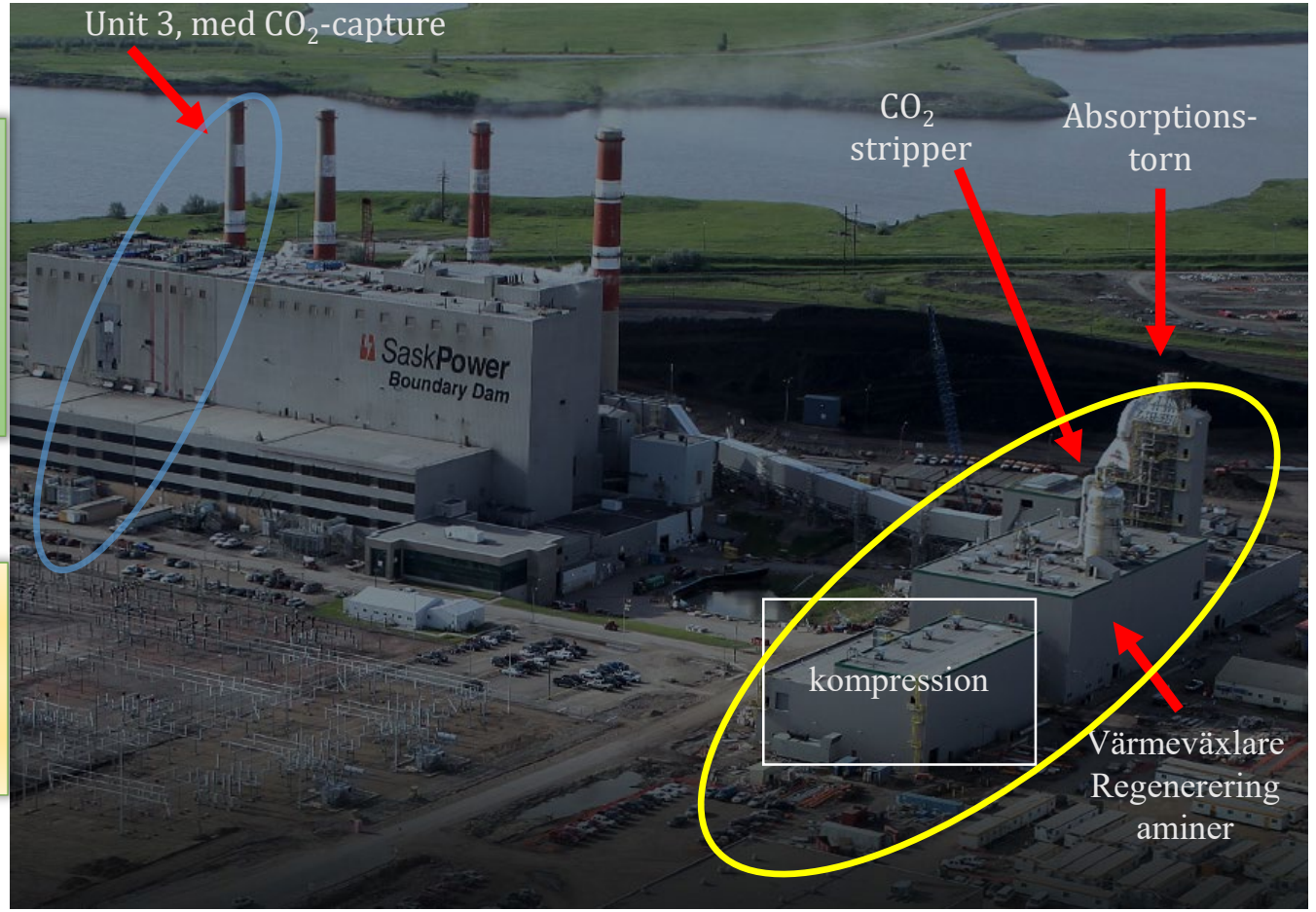
Coal power plant with CO_2-capture:
1 Mton CO_2/year

In operation since october 2014.

Owner (Sask Power) says:

Next time 1/3 of cost:

45 \$/ton CO_2

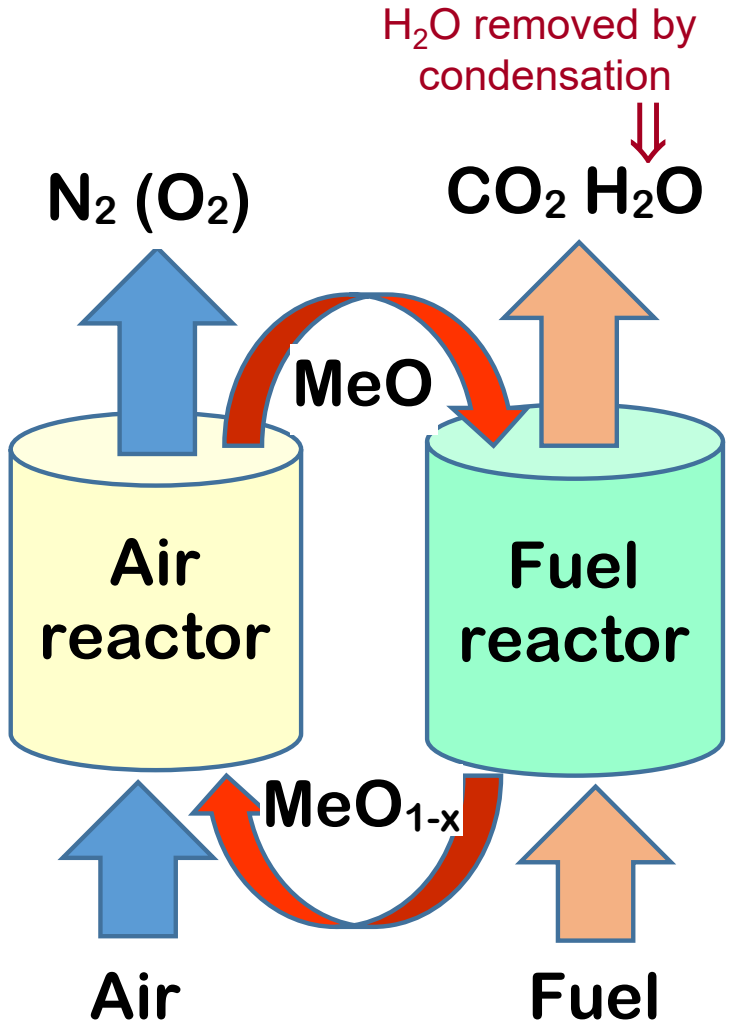


Chemical-Looping Combustion (CLC)

Oxygen is transferred from air to fuel by metal oxide particles

Inherent CO_2 capture:

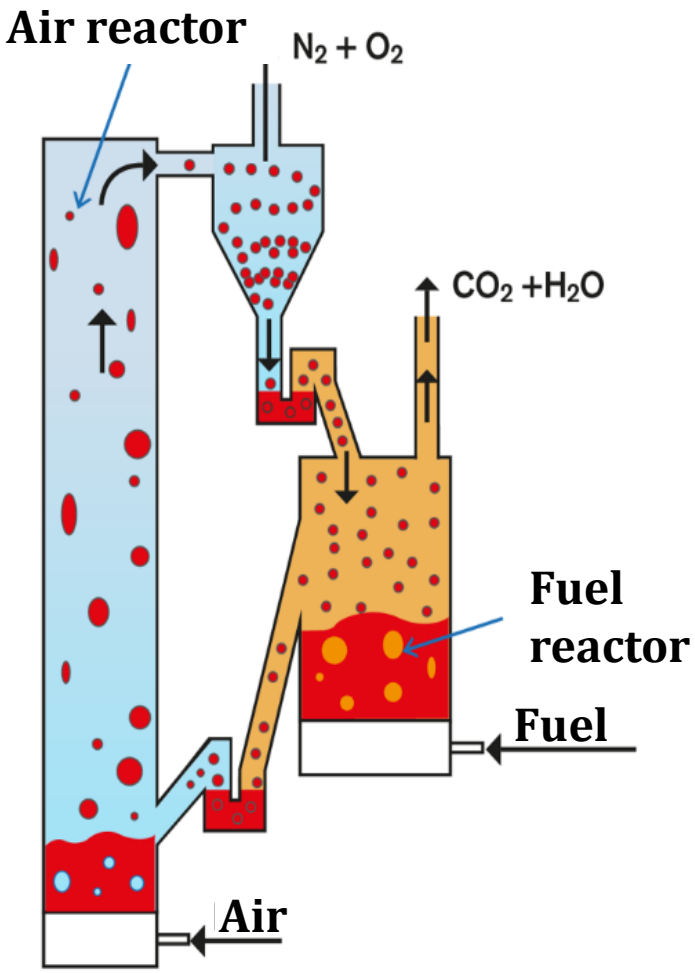
- fuel and combustion air *never mixed*
- *no active gas separation needed*



Unique potential for reducing costs of CO_2 capture

Circulating fluidized-bed boiler

Chemical Looping Combustion



But, does it work in practice ?

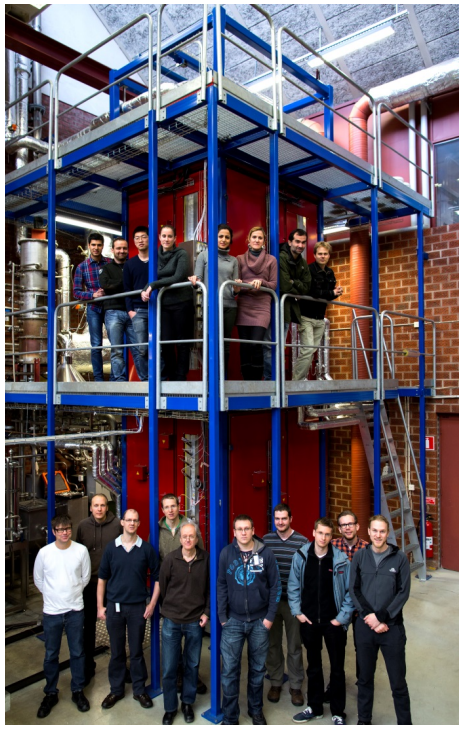
Yes, it works!!

Total chemical-looping operation
at Chalmers:
4 000 h in four pilots

10 kW gas, 2003

300 W gas, 2004

10 kW solid fuel, 2006



100 kW solid fuel, 2011

Worldwide: 11 000 h in 46 pilots

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

Negative CO_2 project has shown *Chemical-Looping Combustion works with biomass*

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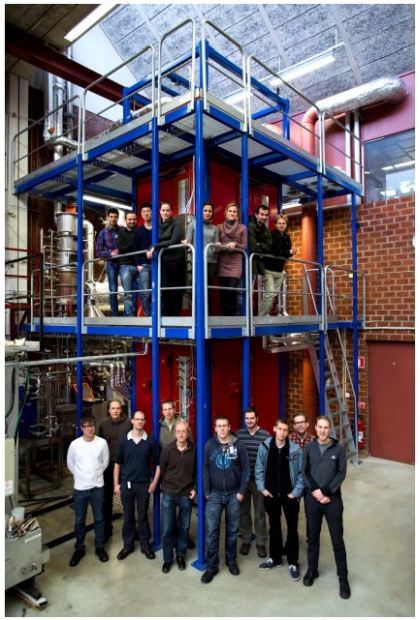
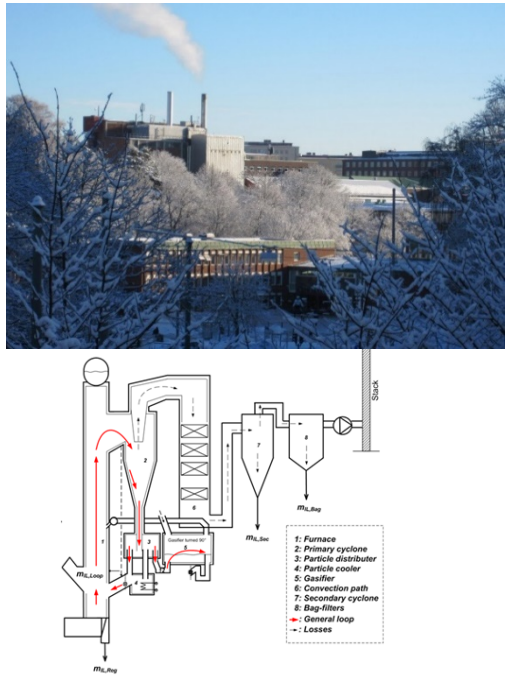
This has been shown in three chemical-looping pilots + small commercial boiler

20-100 kW_{th} unit at VTT Finland



100 kW_{th} unit at Chalmers Sweden

150 kW_{th} unit at SINTEF Norway



10 MW circulating fluidized-bed boiler with gasifier, Chalmers Sweden

Chemical Looping combustion (CLC)

CLC boiler very similar to CFB boiler (=circulating fludized-bed boiler)

Highly concentrated CO_2 stream can be obtained at small added cost

Cost: less than half of competing technologies

Works with biomass

Eliminate/reduce emissions of NOx

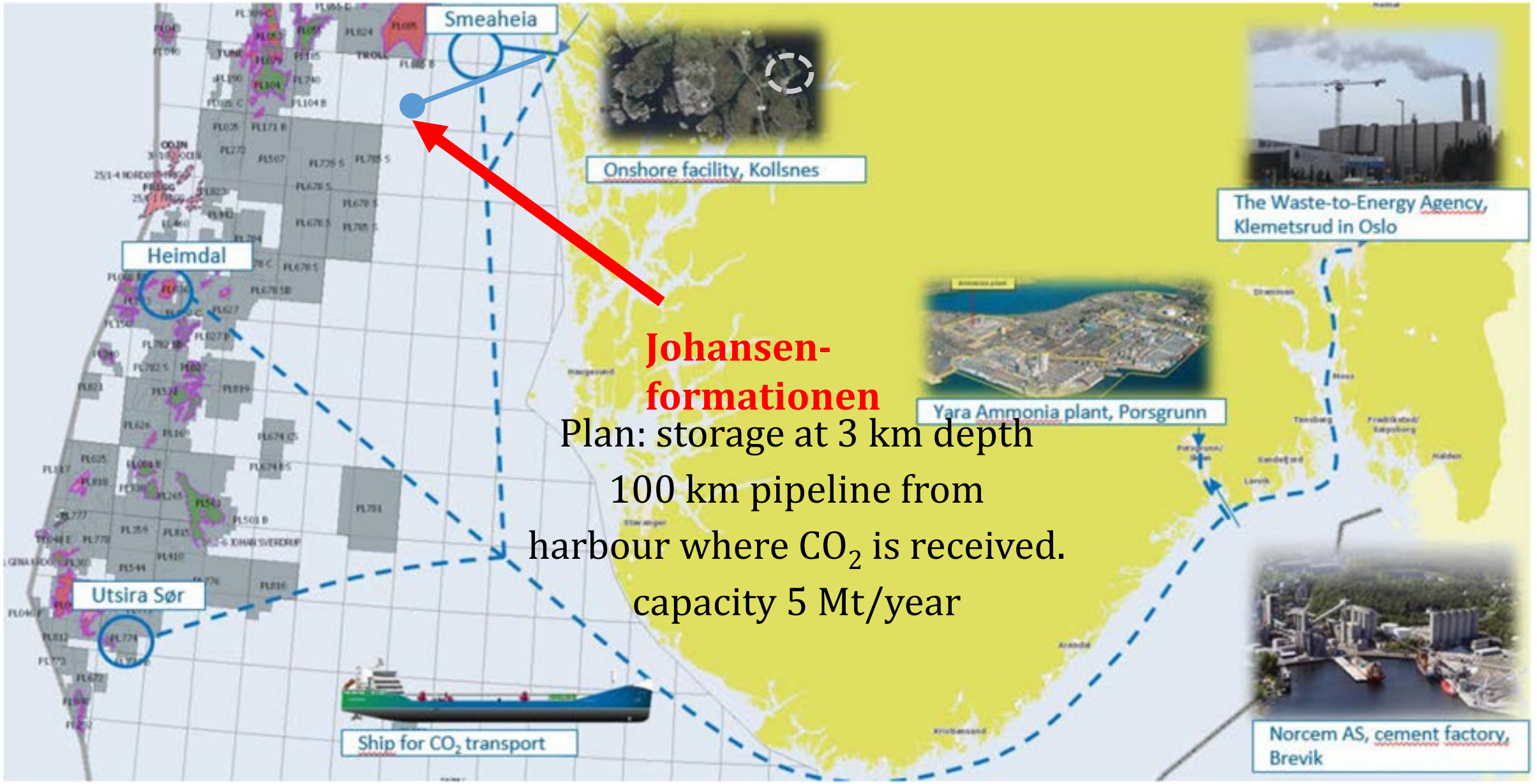
Eliminate/reduce problems with alkali ash components

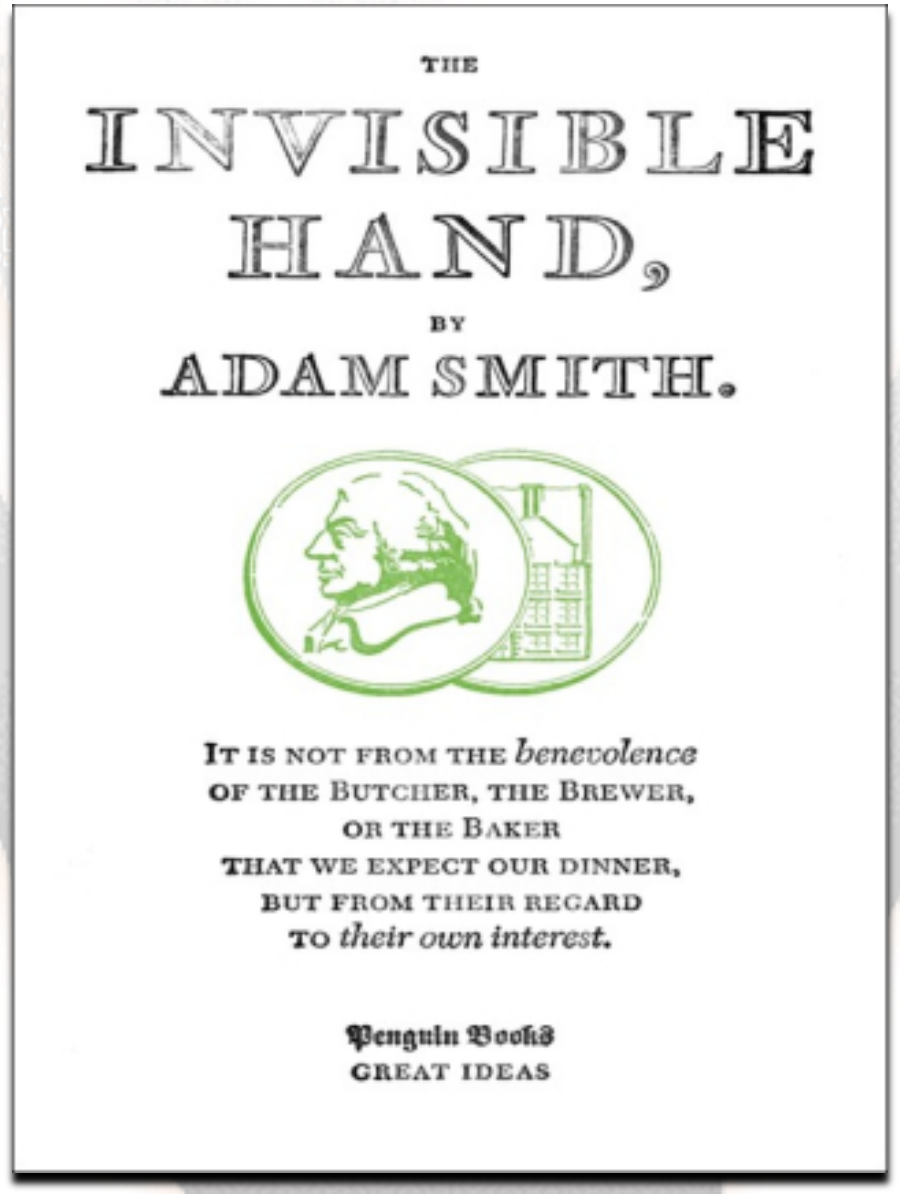
No market – meagre interest from industry to engage in development

Potential negative CO_2 emissions in Nordic countries

>50 Mt/year biogenic CO_2 emissions from point sources >100.000 ton/year

Total Nordic fossil CO_2 emissions 200 Mt/year


Smeaheia
Onshore facility, Kollsnes
The Waste-to-Energy Agency, Klemetsrud in Oslo
Heimdal
Johansen-formationen
Yara Ammonia plant, Porsgrunn
Plan: storage at 3 km depth
100 km pipeline from
harbour where CO_2 is received.
capacity 5 Mt/year
Utsira Sør
Ship for CO_2 transport
Norcem AS, cement factory, Brevik



Fossil fuels are too cheap.

A price on CO_2 emissions is needed.

The ”invisible hand” must work FOR the climate.

Now it works against the climate.

A more difficult challenge is to find someone to pay for negative emissions.

Who will be willing … ?

Cost CCS/BECCS: ≈0.1 €/kg CO_2

Reasonable ?

Carbon dioxide intensity in global economy: 0.5 kg CO_2/€

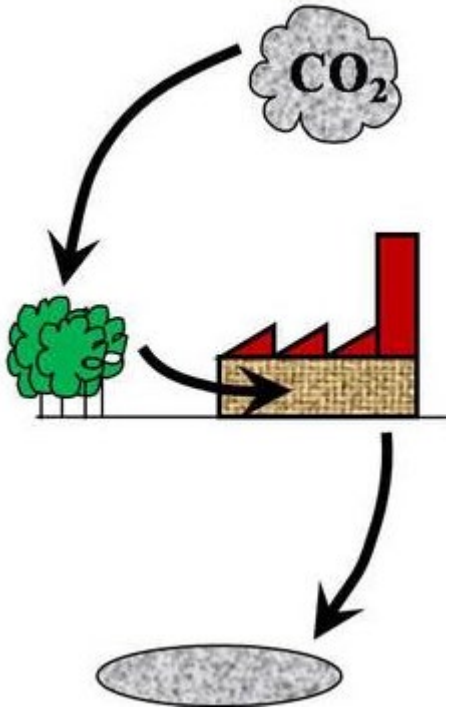
Thus: 0.1 €/kg CO_2 corresponds to 5% of global economy

Normally, the cost to avoid CO_2 emission is lower than atmospheric CO_2 capture.

Thus:

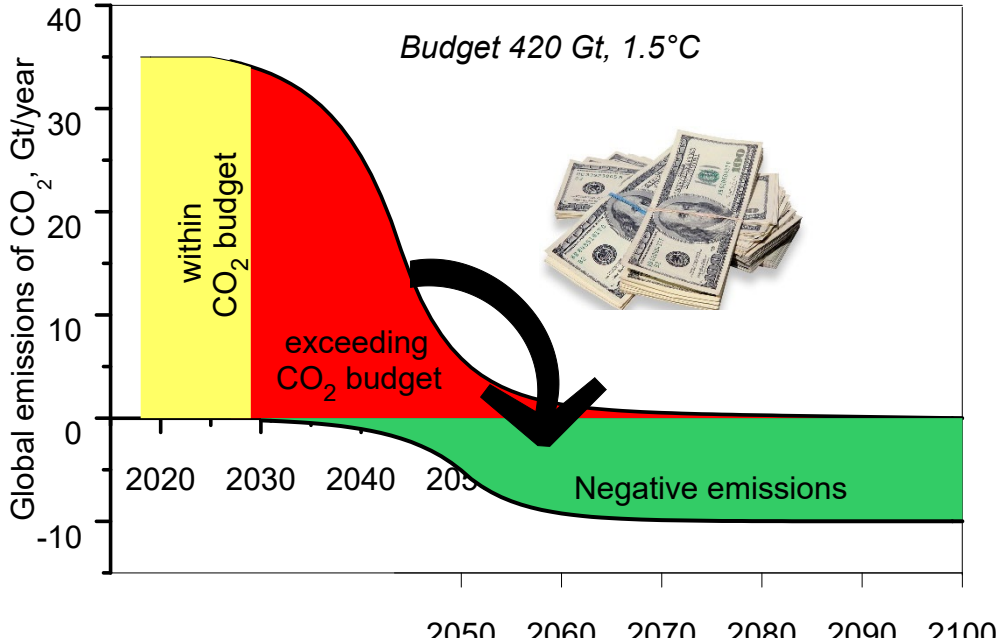
The cost for the economy would be considerably less than 5%.

But, how can we finance negative emissions?



"Emitter CO_2 Recovery Liability"

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



Example: Proposal for Sweden

Emitter Recovery Liability for non ETS-emissions.

- 23 Mt/year, >half Swedish domestic CO_2 emissions
- mainly transportation fuels

Cost: 23 billion kr/year
0.5% of GDP
2300 kr/Swede,year
2.3 kr/L petrol

In practice, a halving of Swedish emissions.

Key Messages

Carbon dioxide budget soon exhausted - large negative emissions are needed

Bio-CCS

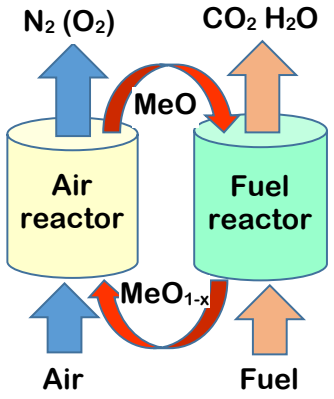
- climate-efficient use of limited resource
- technology well known (simple), but few large-scale plants
- cost is reasonable
- Chemical-Looping Combustion has potential for dramatic reduction of cost

Negative emissions must be financed

-Rational solution, "producer liability “, emitters pay for removing the CO_2 from the atmosphere

The Nordic region - great potential for bio-CCS, plus very good storage facilities.

http://negativeco2emissions2020.com/

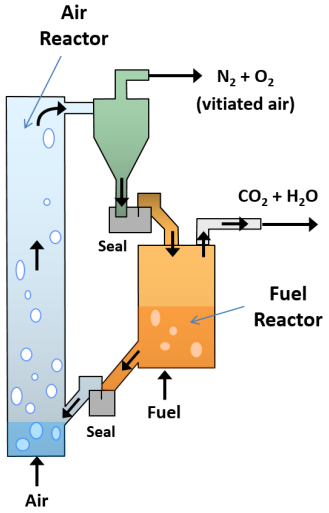


PRINCIPLE

metal oxide (MeO) transfers oxygen from air to fuel

⇒

no separation needed



PRACTICE

well established circulating fluidized-bed technology

PURPOSE