Status and Policy of CCUS in the European Union

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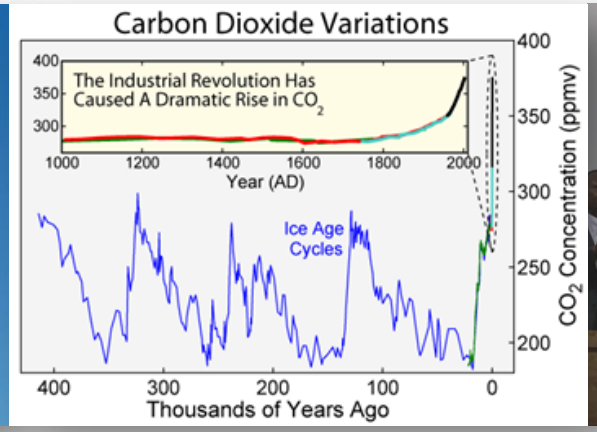
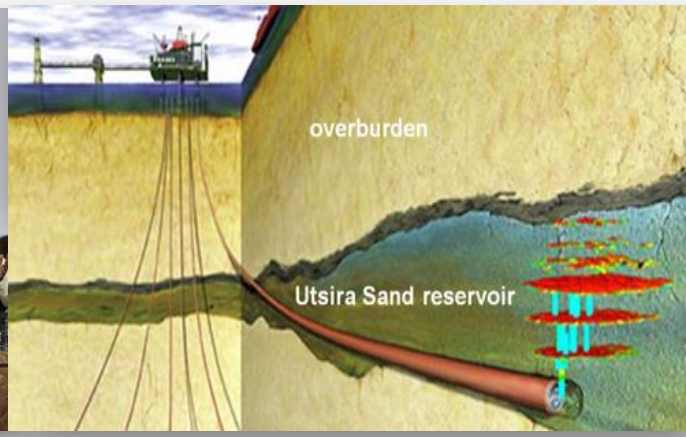
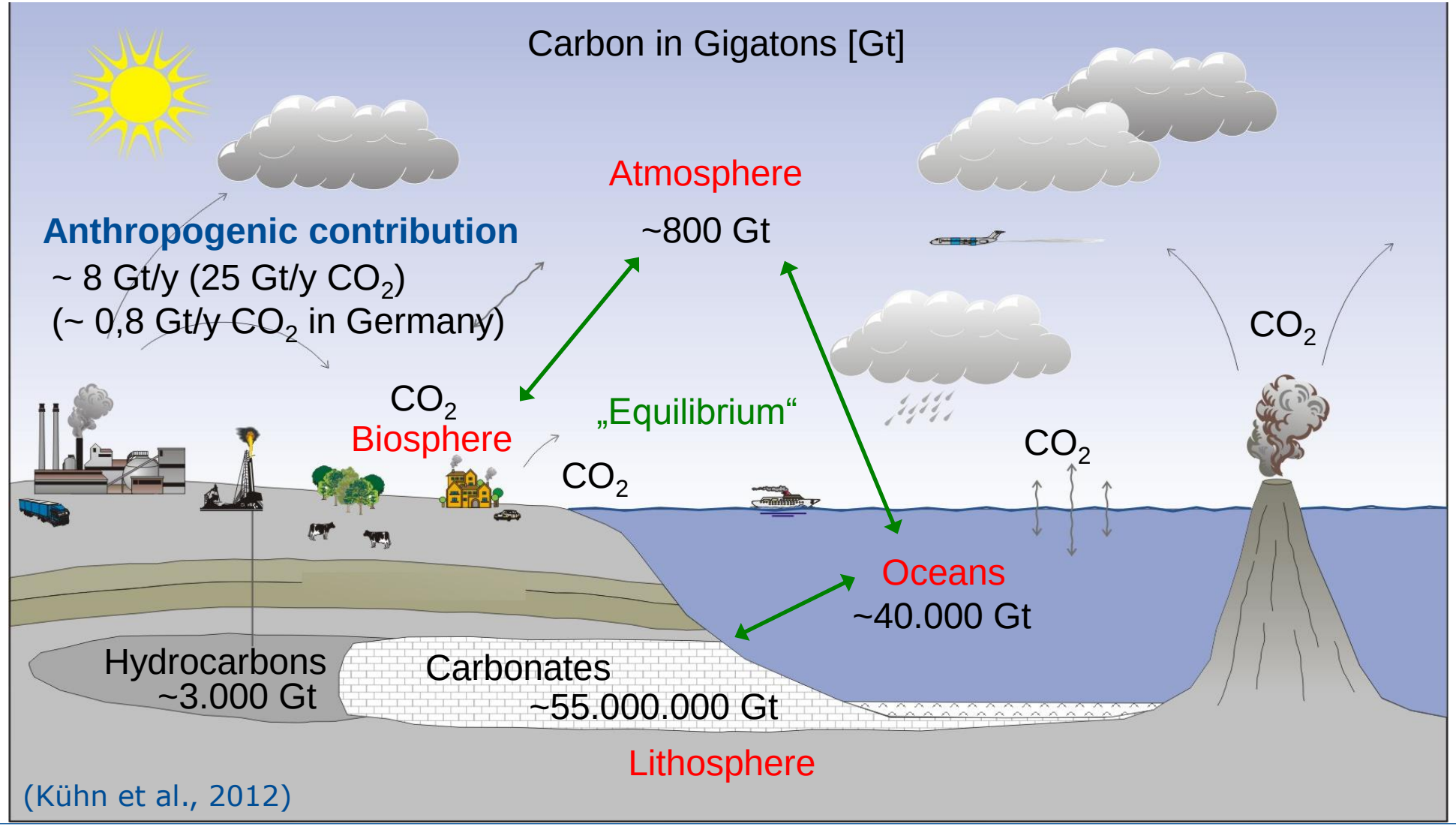
Section 6.3 Geological Storage

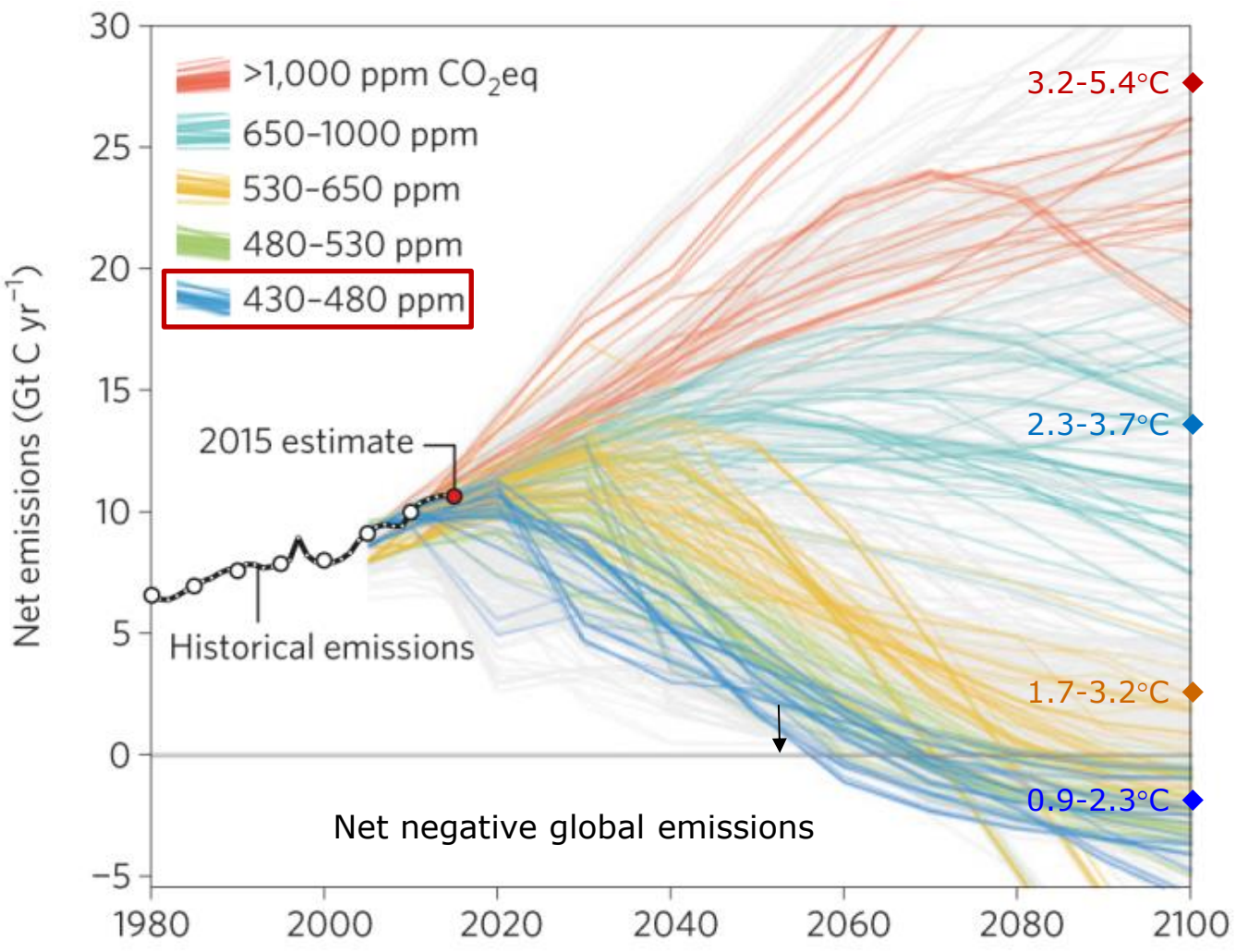




Humanity is a major factor in the global carbon cycle



Global emissions and 2°C goal – The role of COP21



World Climate Conference Paris, December 2015 (Paris Agreement/Conference of Parties COP21):

First climate agreement, which takes all countries into the duty to climate change mitigation actions

International and legally binding objective: limit the temperature increase < 2°C

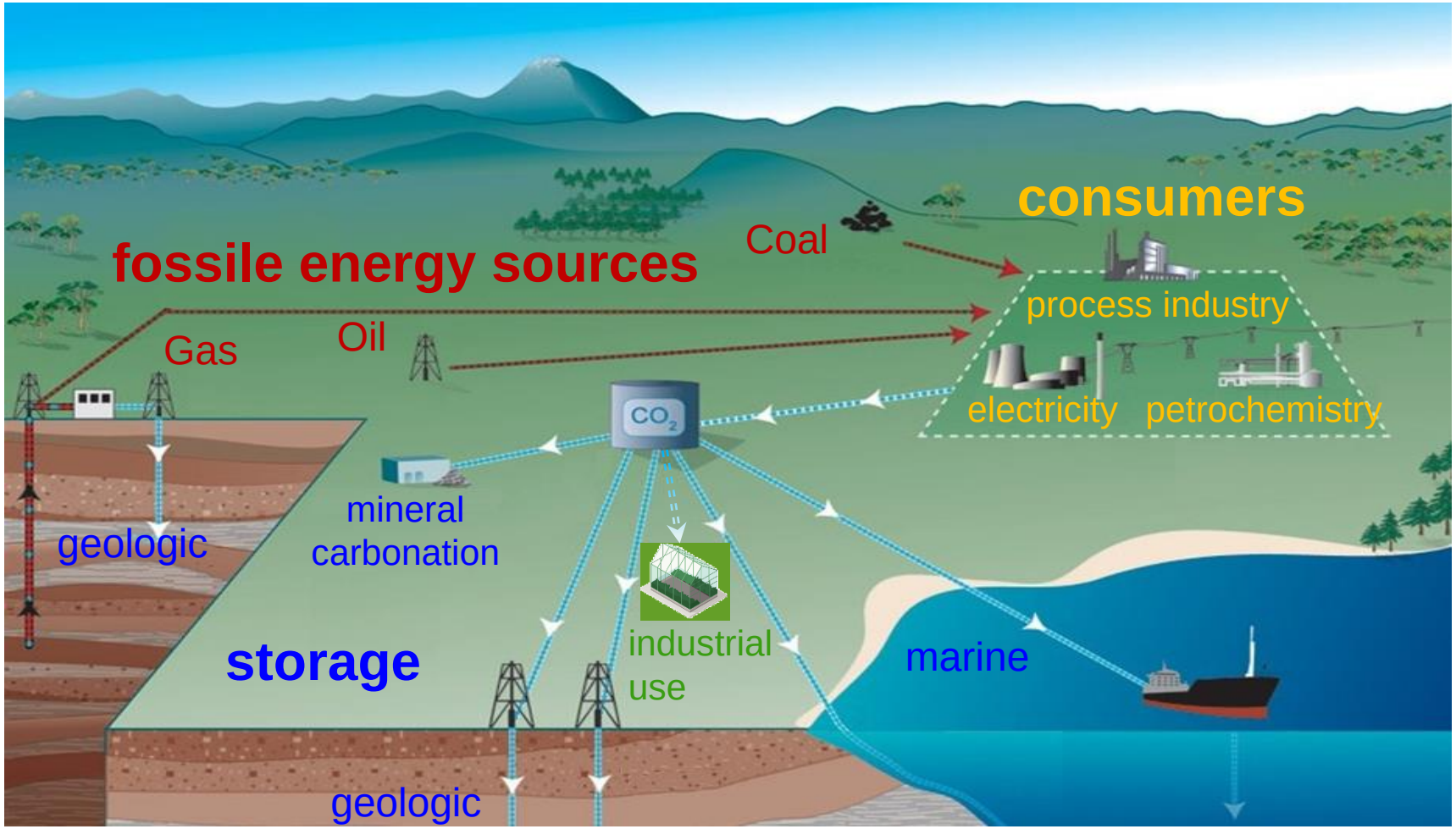
A below 2 °C goal requires atmospheric CO_2eq concentration of 430 – 480 ppm in 2100
for comparison: pre-industrial, historic (1850-1900) CO_2 concentration ~ 280 ppm *not shown here*

CCS should be part of the portfolio of GHG reduction

To achieve scenarios with 430 – 480 ppm CO_2eq in 2100, so-called „negative" CO_2 emissions in the 2nd half of the century are demanded, as e.g., by BioEnergy-CCS (BECCS)

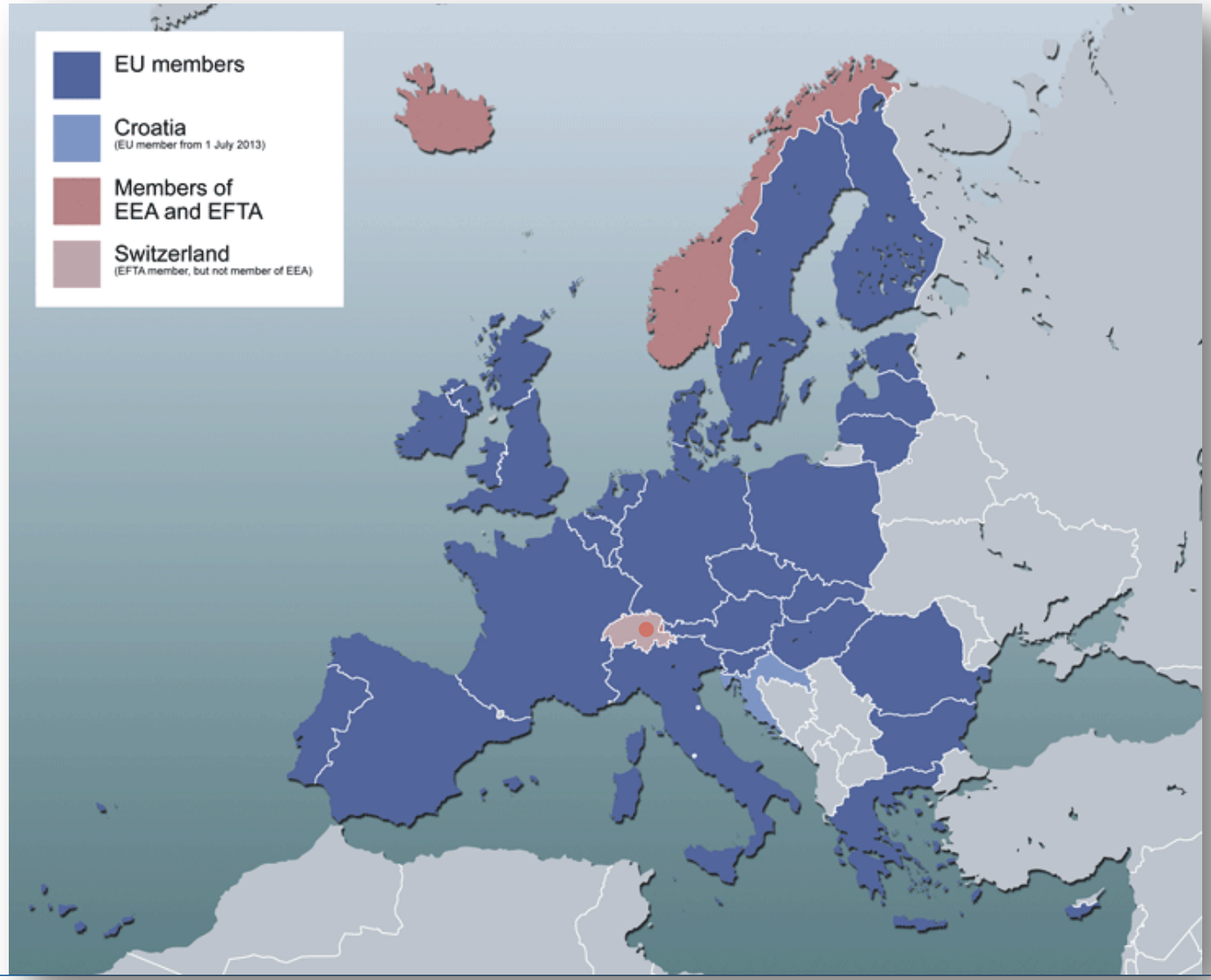
Nature Climate Change 6, pp.42–50 (2016), doi:10.1038/nclimate2870 / ◆ Representative Concentration Pathways (RCP)

Carbon dioxide capture – transport – storage - usage
Goal: Reduction of CO_2 emissions



Modified after: Special Report CCS, IPCC 2005

The European Economic Area (EEA)



- Agreement on the free movement of persons, goods, services and capital within the European Single Market is in place

28 EU member states

3 EFTA member states: Norway, Island, Liechtenstein
(European Free Trade Association)

Switzerland: bilateral treaties with EU

Source:
https://www.regjeringen.no/en/dokumenter/meld.-st.-5-2012-2013/id704518/sec1

European and national climate objectives

European Union (reference year 1990)

- Reduction of greenhouse gas emissions until 2030 by 40%

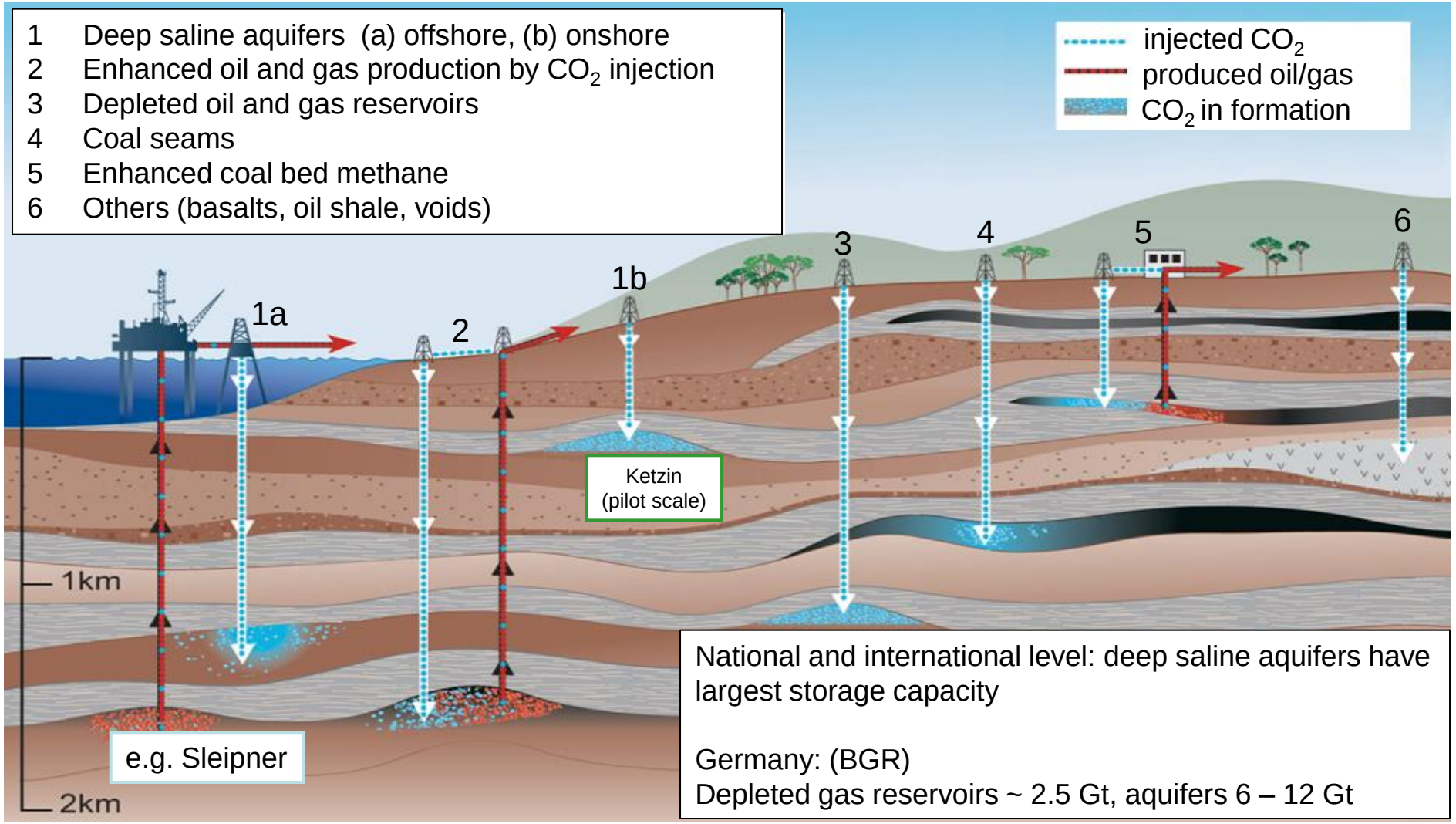
National (reference year 1990)

- Reduction of greenhouse gas emissions until 2020 by 40%
  Reduction from ~ 1.250 $MtCO_2eq$ towards max. 750 $MtCO_2eq$
- Reduction of greenhouse gas emissions until 2050 by 80 - 95%
  but: in 2013 already a gap between the real trend and the envisaged goal of 85 $MtCO_2eq$

Global

The national climate protection plans submitted to Paris COP21 are insufficient to reach the 2 ° C target

Options for geological CO_2 storage



Modified after: Special Report CCS, IPCC 2005

The European legal framework – Directive 2009/31/EC

High level criteria of the so-called CCS Directive, which have to be fulfilled:

- Safe and reliable storage operation, no detectable leakage
- Monitoring of injected CO_2 conforms modelled behaviour
- The site is evolving towards long-term stability

General Progress in Transposition:

(Source: Report from the EC to the European Parliament and the Council, reporting period May 2013-April 2016, based on the individual reports of 26 member states)

- The legislation of 16 Member States is fully conforming to the Directive
- Exchanges are ongoing with remaining Member States to bring their legislation fully in line

Specific Implementation Issues:

- Member States have not determined any new areas for storage sites, only Poland determined one storage area
- New assessments of available storage sites ongoing or planned: Bulgaria, (Germany), Greece, Hungary, Italy, The Netherlands, Sweden and UK
- Five German federal states have passed laws limiting or banning undergound CO_2 storage

The European legal framework – Directive 2009/31/EC

Feasibility for CCS retrofitting for new large-scale combustions plants:

- Assessment of technical and economical feasibility were made in Belgium (1), Czech Republic (1), Germany (5), Romania (6), Poland (10), Slovenia (1), Spain (5) → problems: economically not feasible, no suitable storage sites, technical incompatibility with the plants in operation

Research projects with relevance to the CCS Directive:

- Inspite of stagnation, ongoing research activities on underground storage in B, CZ, GE, F, HU, Malta, Lithuania, NL, Slovakia, Spain and UK.
- Some countries explored alternatives to CO_2 storage through various CO_2 utilisation options (Estonia, NL, Slovakia, Poland).

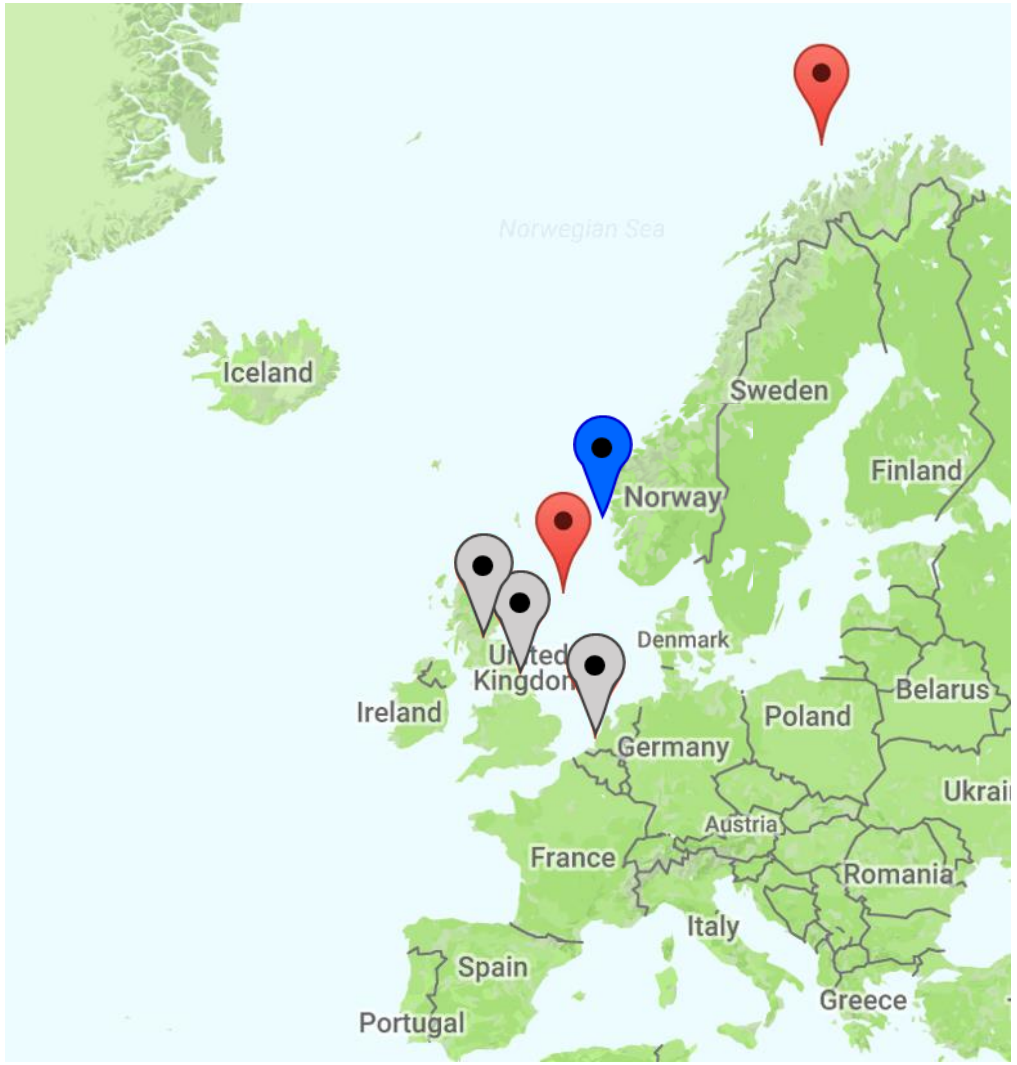
CO_2 transport and storage networks:

Two active CCS regional networks exist to develop transboundary solution for transport & storage:

- North Sea Basin Task Force (UK, NL, N, GE, B)
- Baltic Sea Region CCS Network (Estonia, GE, FIN, N, S)

In addition, B, NL, UK, F exploring possibilities for hubs for industrial & power CO_2 emissions in the areas of ports (Antwerpen, Rotterdam, Grangemouth, Tees Valley, Fos-sur-Mer) → offers alternatives for countries without possibilities of storage.

Implementation of CCS – status in the European Union



Large-scale CCS facilities:

Norway:

Sleipner CO2 Storage Project
in operation, ~1 Mt CO_2/year

Snøhvit CO2 Storage Project
in operation, ~0.7 Mt CO_2/year

Norway Full Chain CCS Project
FEED of demo, expected to finalize in 2022

The Nederlands:

Rotterdam Opslag en Afvang Demonstratieproject (ROAD), *stagnation/minor ongoing*

UK:

Teesside Collective, *emerging infrastructure of industrial hub, national strategic asset for UK*

Caledonia Clean Energy Project, *interim feasibility findings ongoing*

(Modified after:http://www.globalccsinstitute.com/projects/large-scale-ccs-projects)

Implementation of CCS – status in the European Union

(Source:http://www.globalccsinstitute.com/projects/ → modified)

Pilot and demonstration projects:

Norway:
Svelvik Field Lab (Test bed, especially CO2 leakage testing)

(Photo: SINTEF)

Island
CarbFix Project (Full chain)

(Photo: ResearchGate)

France:
Lacq/Rousse (Storage)

(Photo: TOTAL)

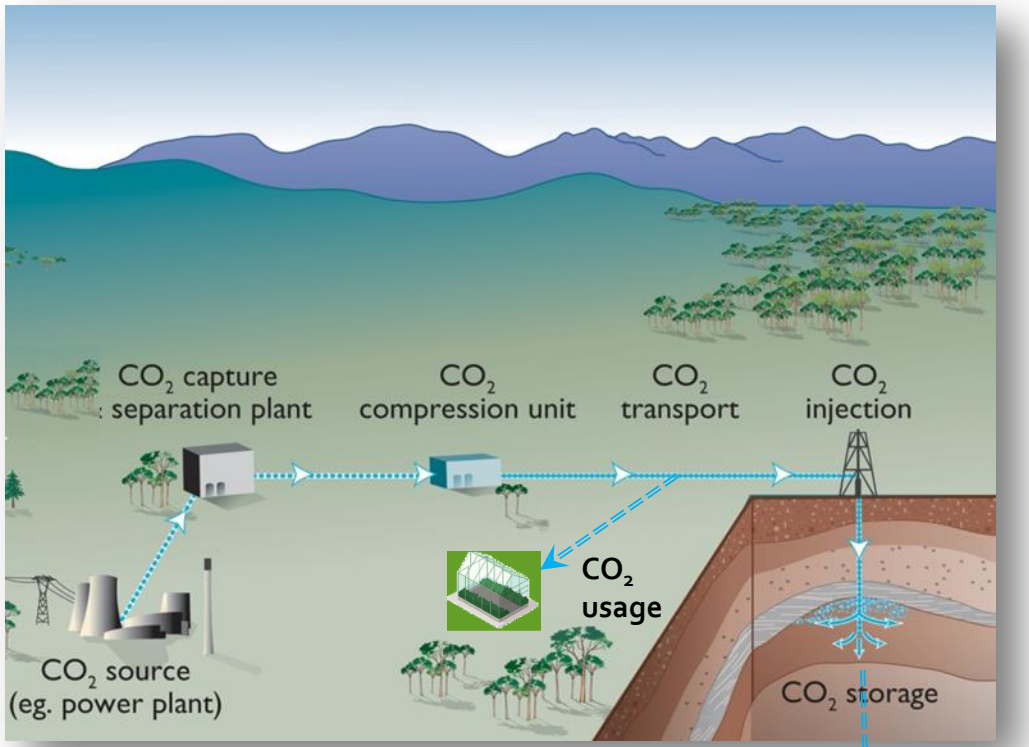
Germany:
Ketzin pilot project (Storage)

(Photo: GFZ)

Spain:
Hontomín (Storage)

(Photo: CIUDEN)

European and national funding for all parts of the value chain

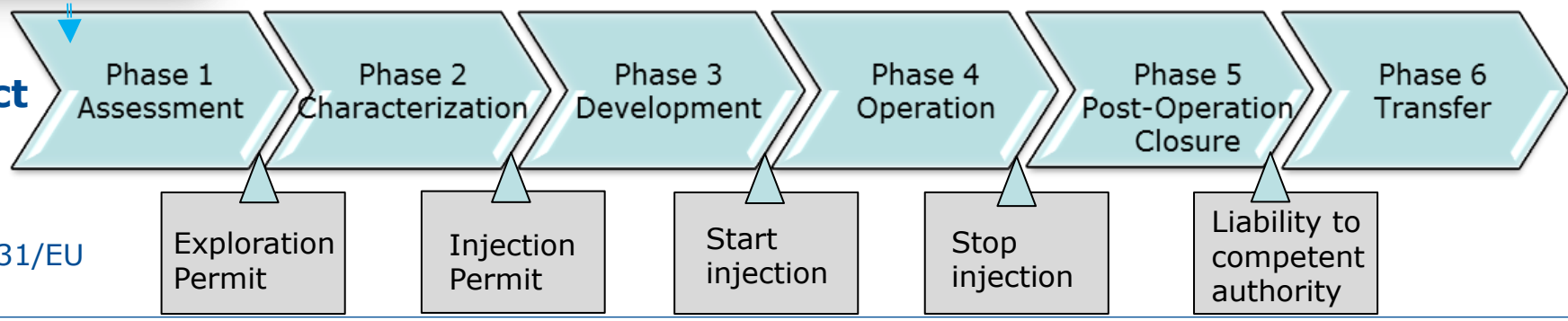


First EU funding from 2004 until today via **FP6, FP7, H2020**, and special programs as **NER300, ERA-ACT**

Selected research examples:

- Assessing the CO_2 storage potential in Europe **CO_2StoP**
- Vattenfall capture pilot plant **Schwarze Pumpe**
- Transport infrastructure for large-scale CCS in Europe **CO_2Europipe**
- First on-Shore CO_2 pilot storage in Europe **CO_2SINK**
- CO_2 capture from cement production **CEMCAP**

Life-cycle of a CO_2 storage project



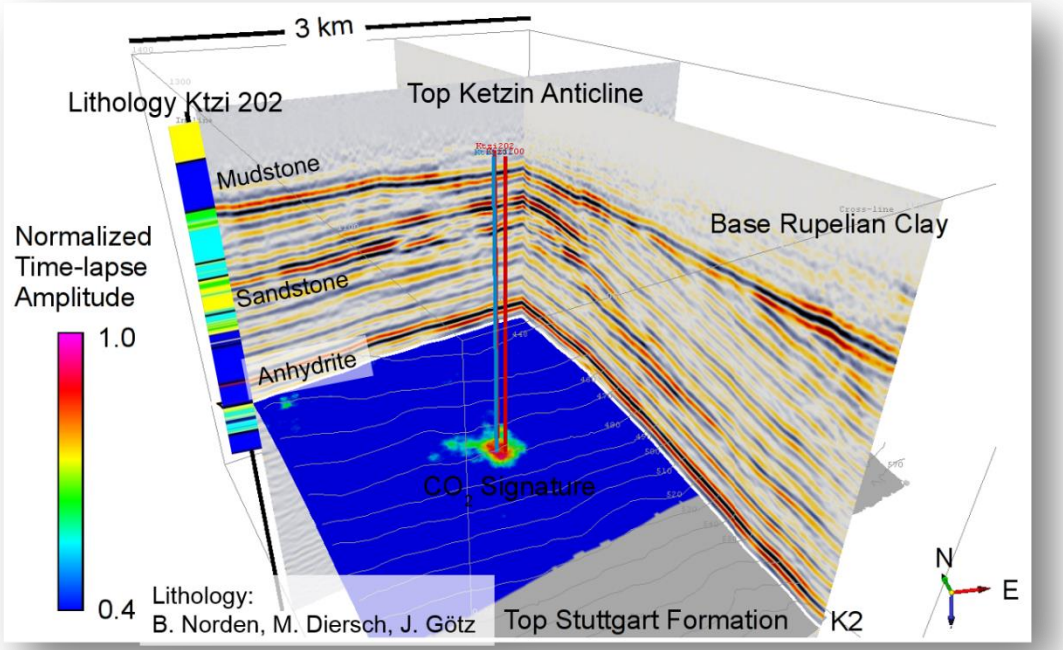
Source : Guidance Document GD3 to the 2009/31/EU CCS Directive

Current CCUS status in Germany

STORAGE

Ketzin – the first onshore European CO_2 pilot site
reservoir: saline aquifer, sandstones of Upper Triassic Stuttgart Formation
620 – 650 m depth
P/T_{ini} ~ 62 bar/33°C

- From 2008-2013 about 67.000 t CO_2 injected



USAGE

Based on a research project (academia/ industry consortium) the company **Covestro** starts sustainable plastics production.

cardyon® → CO_2-based polyurethane components, used as raw material for manufacturing premium foams.

- Polyurethane industry can reduce their dependence on oil and thus the size of their carbon footprint.

Current CCUS status in Germany

(Photo: Courtesy of DPA)

CAPTURE

CCS Demo-power plant Jänschwalde, developed by Vattenfall since 2008, (1.5 billion € cost, 300 MW, 1.7 Mt CO2/year)

Cancellation in Dec. 2011, also stop of further storage exploration in Brandenburg

Reason: unclear situation with the German CO_2 storage law (KSpG), temporal constraints of EU funding

Capture pilot plant in Schwarze Pumpe
(70 Mio. € cost, 30 MW-facility, production of 10.650 t CO_2, 99.7%)

Oxyfuel combustion technique safe and reliable, but termination in July 2014

Cooperation with SaskPower, SK, Canada

1.510 t liquid CO_2 to the Ketzin storage site / 10 t to algae production, rest to vent

Photo: Stefan Schroeter, Energy journalist)

Current CCUS status in UK

Leading role in Europe's CCS research by strong organisations:

- British Gelogical Survey (BGS) → recognised as a European centre of excellence for the study of CCS, and contributing to the Intergovernmental Panel on Climate Change (IPCC) special report.
- UKCCS Research Centre → leads and coordinates a programme of supporting research on all aspects of CCS
- GeoEnergy Research Centre (GERC) → acts as an independent, collaborative institution co-founded by BGS and the University of Nottingham.
- Scottish Carbon Capture & Storage (SCCS) → UK's largest CCS research group, partnership between the British Geological Survey, Heriot-Watt University, the University of Edinburgh and the University of Aberdeen, with researchers engaged in projects and joint industry projects across the full CCS chain

Break in progress: in November 2015, the UK government announced the cancellation of the **UK £1bn CCS Competition programme** → Two commercial scale projects are strongly affected:

White Rose consortium
(North Yorkshire)
new coal plant with CCS technology
(Photo: dailymail UK/Alamy)

Peterhead (Aberdeenshire)
Shell's scheme to fit CCS to an existing gas plant
(Photo: Shell)

Current progress:
Teesside Collective → cluster of leading industries with the shared vision to establish Tees Valley as the go-to location for future clean industrial development by **creating the UK's first Carbon Capture and Storage (CCS) equipped industrial zone** (http://www.teessidecollective.co.uk/)

Current CCUS status in the Netherlands

ROAD (Rotterdam Opslag en Afvang Demonstratieproject) 2009 - today

- Longstanding project for demonstrating the technical and economic feasibility of a large-scale, integrated CCS chain deployed on power generation
- Post-combustion capture of ~1.1 million tonnes of CO_2 per year from the flue gases of Maasvlakte Power Plant 3 (MPP3)
- Pipelining and off-shore storage in a depleted gas field in the North Sea

(Photo: E.ON)

Significantly delayed by several reasons:

- Challenging funding gaps
- storage permit delay by implementation of CCS Directive
- dominating political problems (Dutch Parliament votes for a phase-out of coal plants)

Yet, the project undergoes a remobilization and its operation is expected by the beginning of 2020.

Related Greenhouse applications

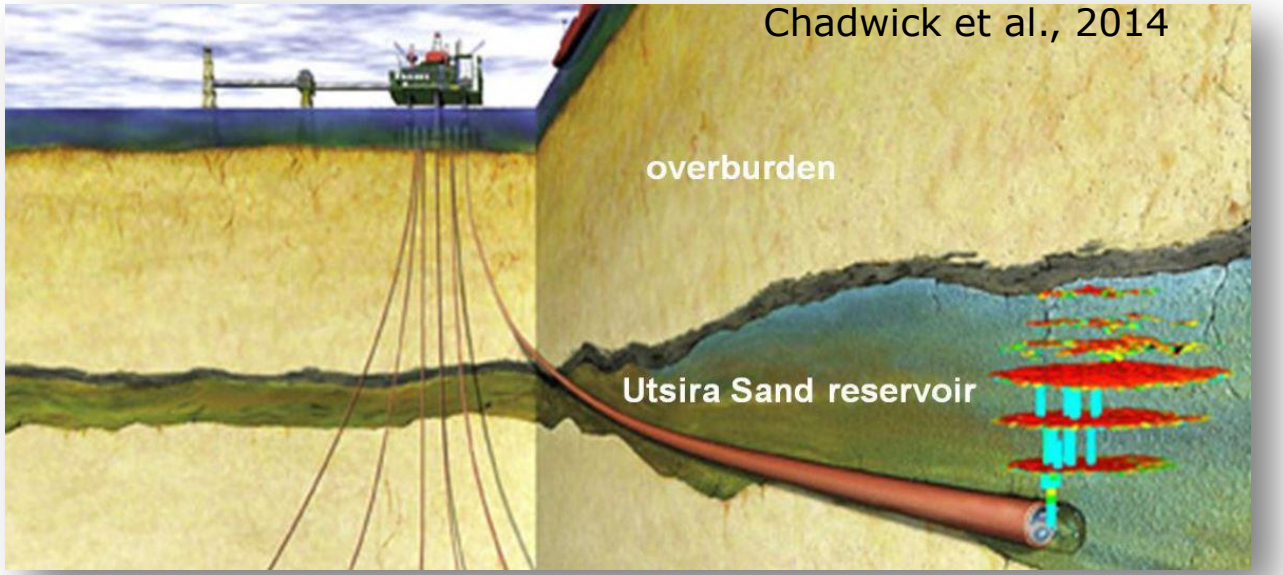
OCAP – Netherlands (owned by Linde Benelux since 2013) supplies pure CO_2 to greenhouse businesses in the Netherlands. CO_2 from two sources (a) by-product of the hydrogen production process at the Shell Pernis oil refinery, and (b) by-product from bio-ethanol production facility in Rotterdam

CO_2 demand for greenhouse use is seasonal: highest demand in summer (April – September) and lowest during winter, when most of the CO_2 from the source facilities is emitted → need for buffer storage! (Source: www.ocap.nl)

Current CCUS status in Norway

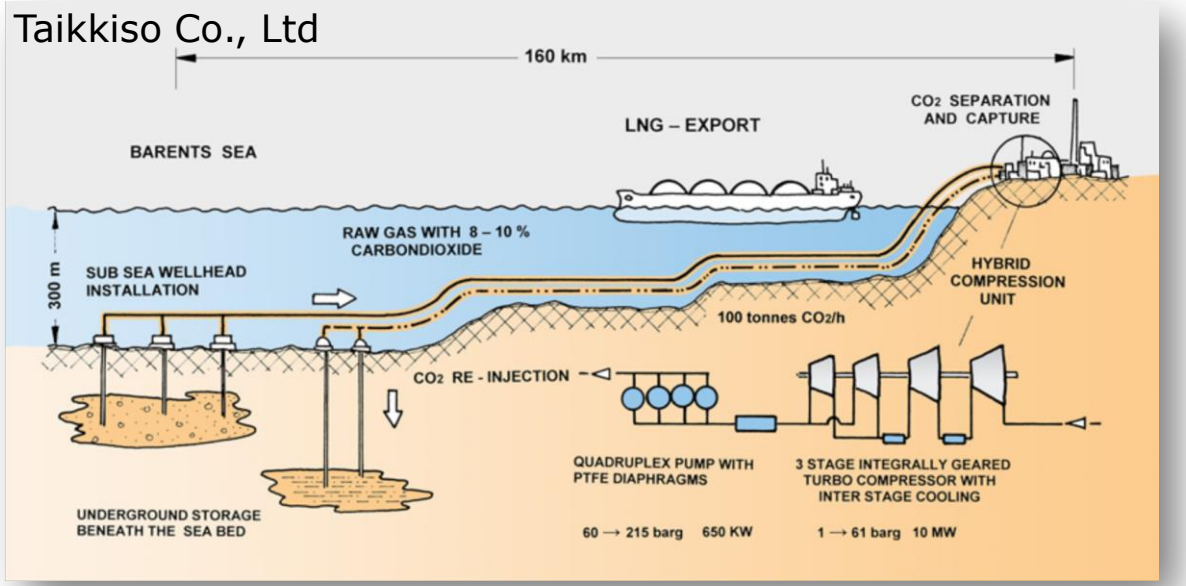
Sleipner

- Operator: Statoil, since Sep 1996
- About 0.8-1.0 million tonnes CO_2 per year stored in the Utsira sandstone
- Reservoir 1,000 m below the seafloor
- Gas produced from Sleipner West field: 15 % CO_2
- The introduction of CO_2 taxation on the offshore petroleum sector has triggered this project



Snøhvit

- Operator: Statoil, since April 2008
- About 0.7 million tonnes CO_2 per year have been safely injected and stored in the Tubåen sandstone
- Reservoir 2,600 m below the seafloor, about 45-75 m thick
- Maximum injection is planned for ~ 31-40 Mt



Current CCUS status in Norway

Norway is pioneering in the implementation of „full value chain" projects.

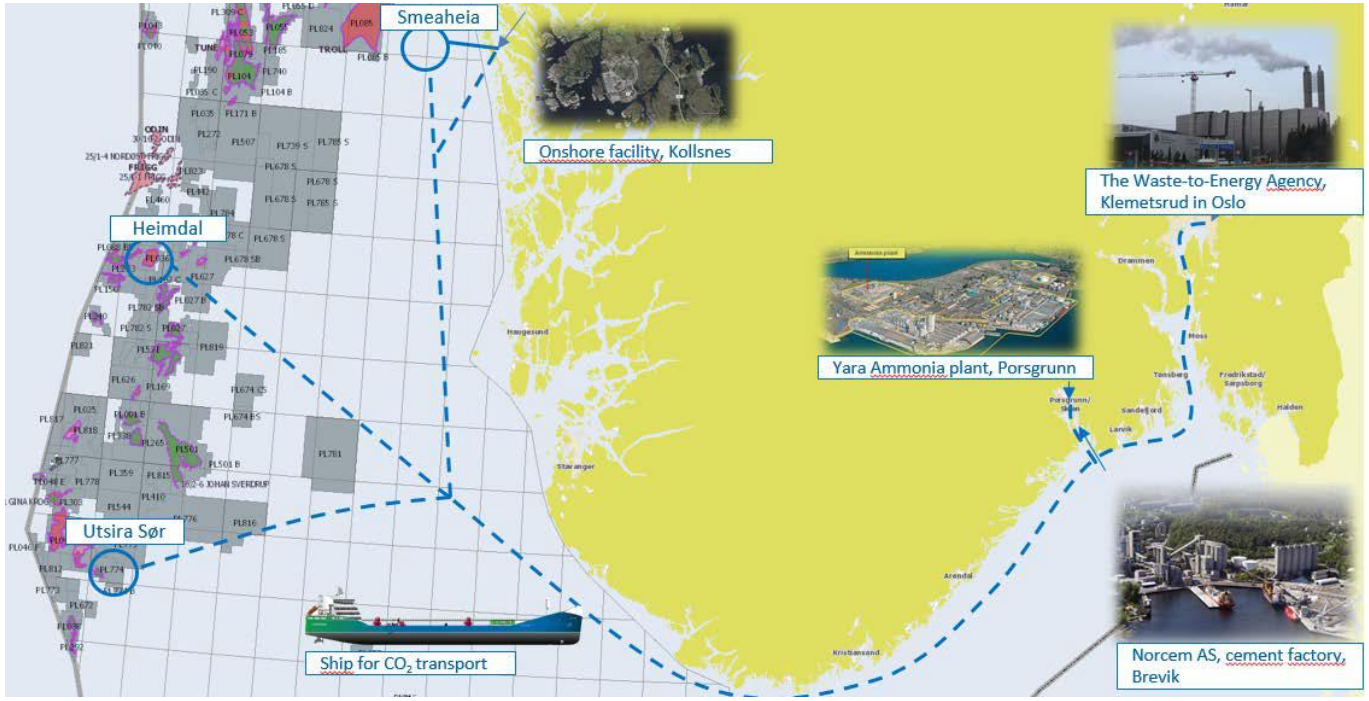
Capture: **Gassnova** has awarded contracts to Norcem AS (cement plant), Yara Norge AS (ammonia plant) and Klemetsrudanlegget AS (waste-to-energy-recovery plant) for further studies of full-scale carbon capture at their respective plants.

Transport: Gassco AS

Storage: In preparation; off-shore North Sea field Smeaheia under evaluation.

CLIMIT supports the CCS technologies of the future

CLIMIT is a programme for research, development and demonstration of CCS technologies. The programme is carried out in cooperation between the **Research Council of Norway** and **Gassnova**.

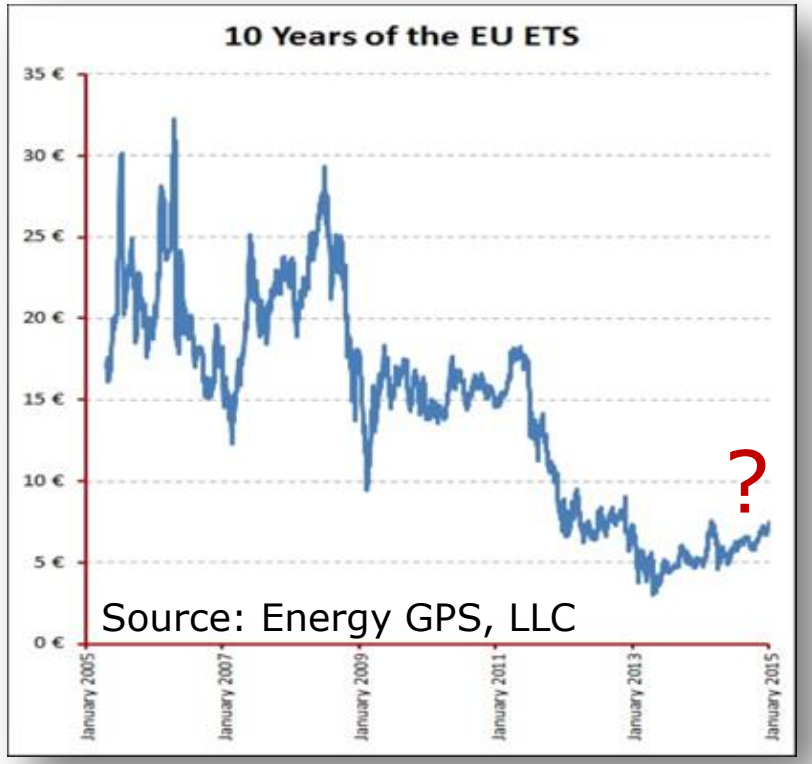


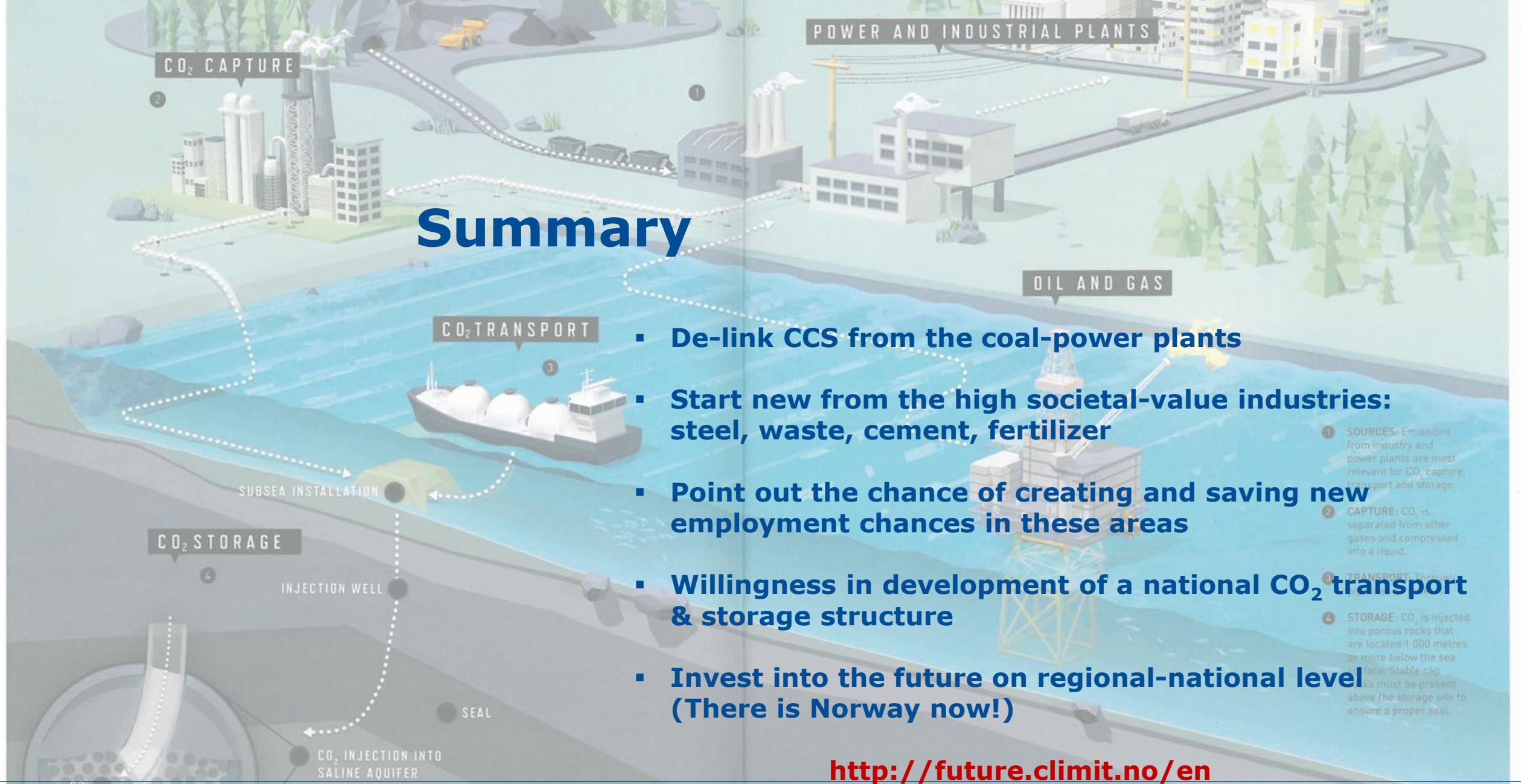
(Source: Ministry of Petroleum and Energy: Feasibility study for full-scale CCS in Norway)

Implementation of CCUS –Items of an European „To Do“ list after more than 10 years working on pilots

- Implementation of CCS projects on **commercial scale**
  - *first-of-a-kind* projects with public co-funding
  - „learning by doing“
- Establishment of a **mature legal framework**, which supports CO_2 storage
  - adaptation/change of the German KSpG, EU Directive
  - transnational CO_2 transport, regional infrastructure
- Establishment of **market mechanisms**, which create an realistic CO_2 price (Emission Trade System – ETS), and make the system functioning
- Detailed assessment of **reliable storage capacities** (location/volume)
  - minimizing of exploration risk
  - estimation of potential for CCS-Cluster/-Hub solutions
- Additional pilot- und demonstration sites
  - **public acceptance**
  - conducting focused research projects

  (ideally with potential for upscaling towards commercial size)
- Instead of simple “source - sink” systems, R&D investment into **cluster solutions**, integration into future energy systems, “subsurface spatial planning”





Summary

- De-link CCS from the coal-power plants
- Start new from the high societal-value industries: steel, waste, cement, fertilizer
- Point out the chance of creating and saving new employment chances in these areas
- Willingness in development of a national CO_2 transport & storage structure
- Invest into the future on regional-national level (There is Norway now!)

http://future.climit.no/en