

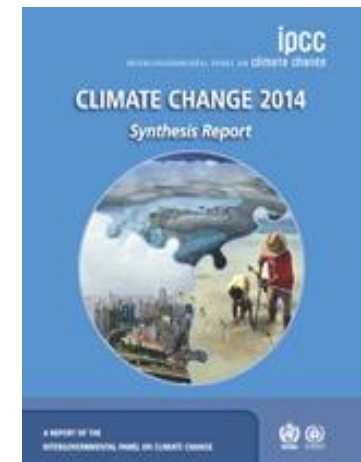
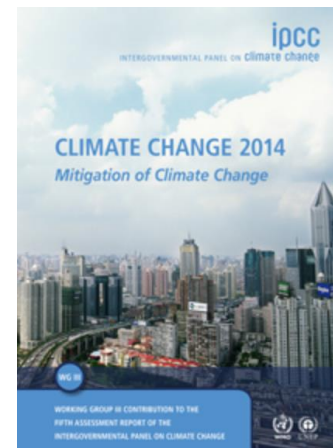
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CCS in a broader European context and the Norwegian experience

Dr. Aage Stangeland

The Research Council of Norway, email: ast@rcn.no

Global warming



IPCC conclusions

- It is beyond doubt that the global climate system is getting warmer
- Historic and future GHG emissions from human activities contributes to the heating

The world: 4°C warmer

No one knows exactly what this world will look like, but models provide insights into forced human migrations and our future power generation

Arctic passage

With no sea ice, this valuable shipping route is open all year, providing transportation links between habitable zones in Canada and Russia

Canada

Reliable precipitation and warmer temperatures provide ideal growing conditions for most of the world's subsistence crops

South-west US

Desertification led to the last inhabitants of this region migrating north. The Colorado river is a mere trickle. The land is used for solar farming and geothermal energy

Peru

Deglaciation means this area is dry and uninhabitable

Western Antarctica

Unrecognisable now. Densely populated with high-rise cities

Greenland

Greenland's ice sheet will be melting rapidly

Scandinavia/UK/Northern Russia/Greenland

Compact high-rise cities would provide shelter for much of the world's population

Siberia

Reliable precipitation and warmer temperatures provide ideal growing conditions for most of the world's subsistence crops

Southern Europe

Deserts have encroached on the continent, rivers have dried up and the Alps are snow-free. Goats and other hardy animals are kept at the fringes

North Africa/Middle East/Southern US

Solar Energy Belt stretches for thousands of kilometres, employing a mixture of photovoltaic and solar thermal energy. At frequent intervals a high voltage direct-current substation sends power north

Amazon Desert

Africa

Mostly desert, though some models show greening of the Sahel

Asia

Most of the Himalayan glaciers have melted, with repercussions for many of the major rivers in the region. Bangladesh is largely abandoned, as is south India, Pakistan and Afghanistan. Isolated communities remain in pockets

Southern China

Dried rivers and aquifers mean this region has been abandoned. Intense monsoons have helped erode the land, leaving a dustbowl

Polynesia

Vanished beneath the sea

Patagonia

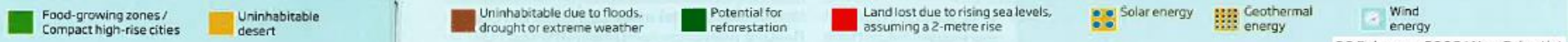
Melted glaciers revealed a new arable zone, although the poor soils needed preparation

Australia

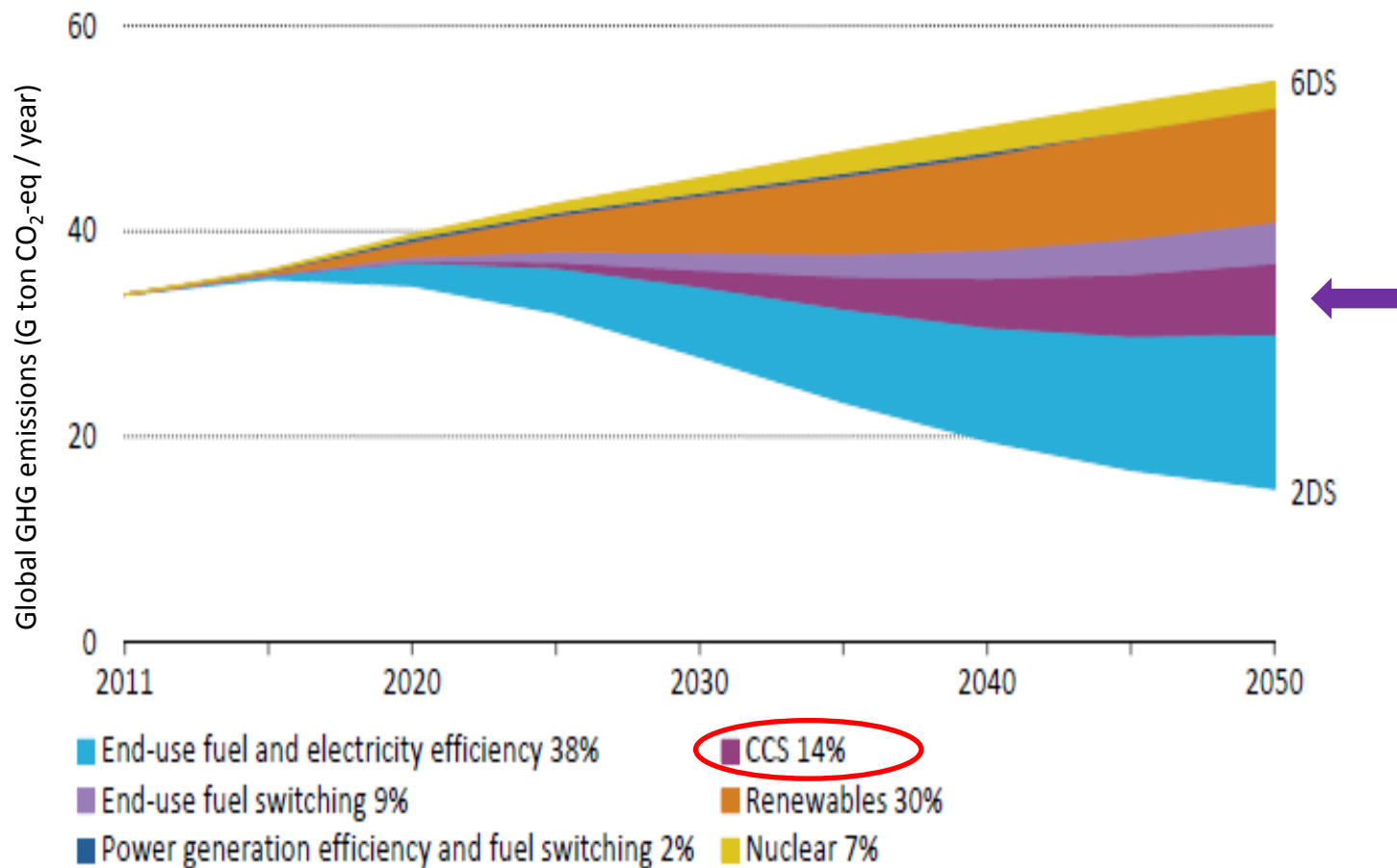
In the far north and Tasmania, compact cities house people and crops are grown. The rest of the continent is given to solar energy production and uranium mining for nuclear power

New Zealand

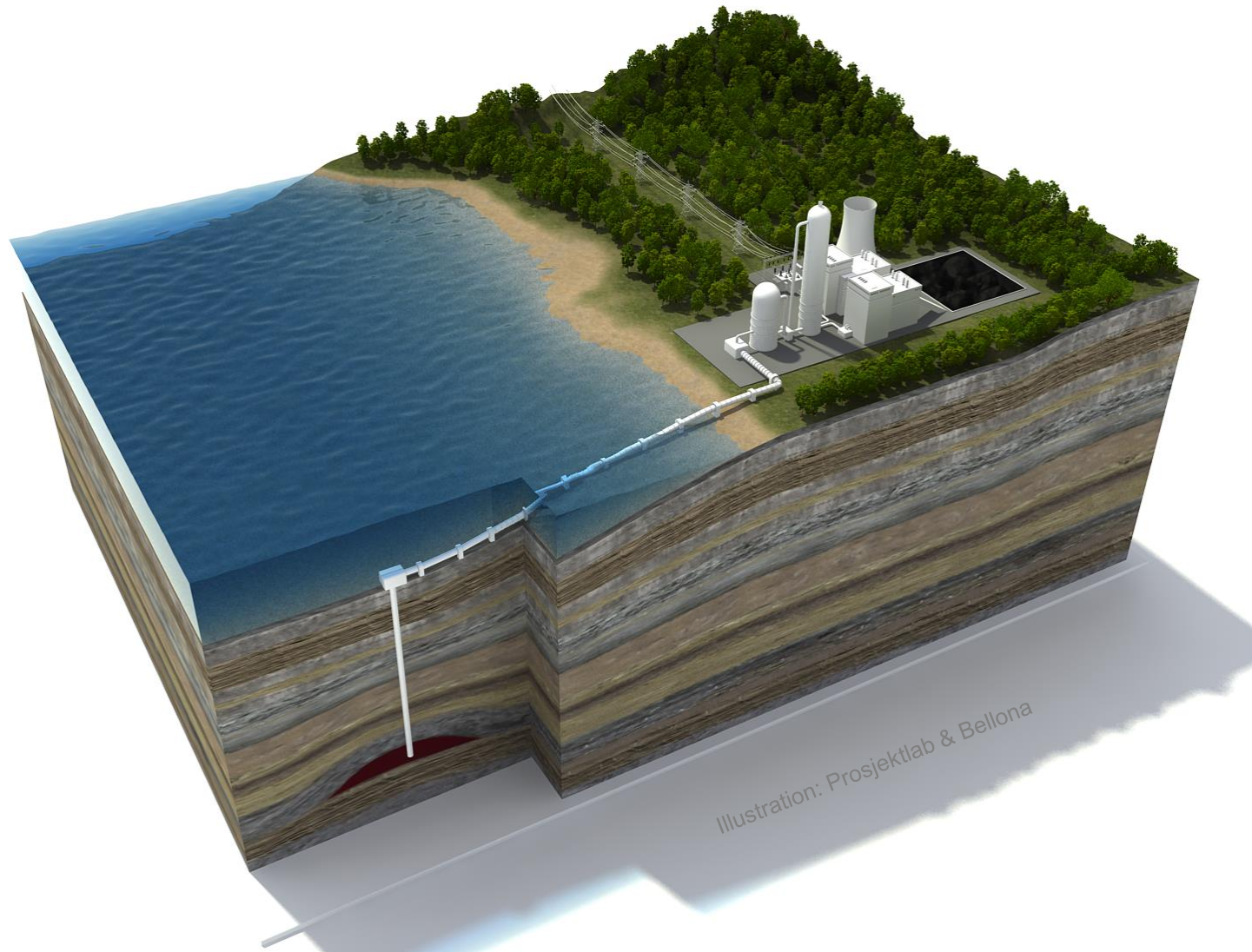
Unrecognisable. This densely populated island state has high-rise cities and intensive farming



Technologies for the 2°C scenario



CCS - CO₂ Capture and Storage



Technologies for the 2°C scenario

Meeting the 2 °C target without CCS:

138 %

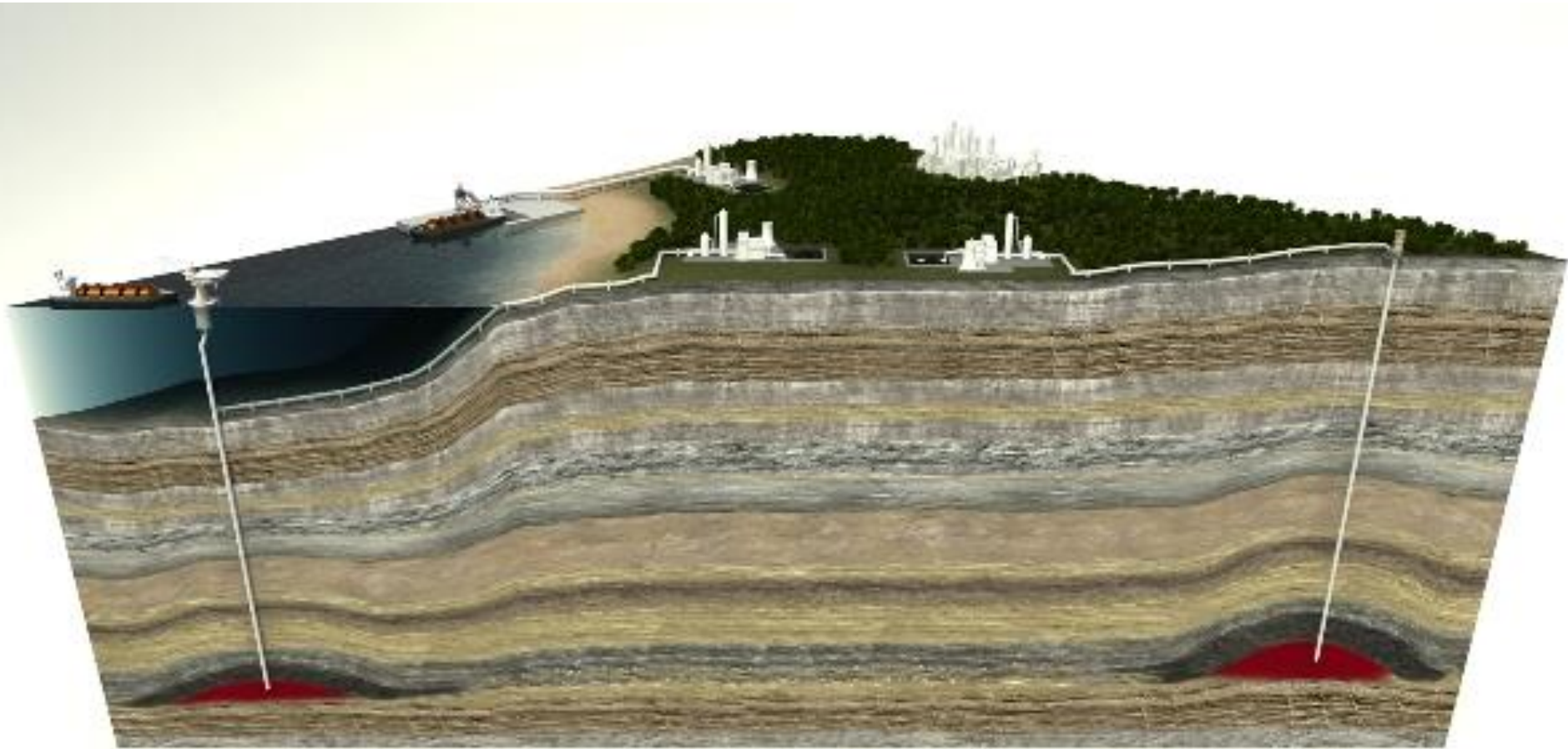
more expensive

Source: IPCC (2014)

CO₂ capture - How it works



CO₂ transport and injection - How it works



CO₂ storage - How it works



CCS – Embraced by the EU

- The 2020 targets
- The 2030 Framework
- The 2050 Roadmap
- The Energy Union



CCS is a key element to achieve 2030 and 2050 ambitions

CCS – Embraced by the EU

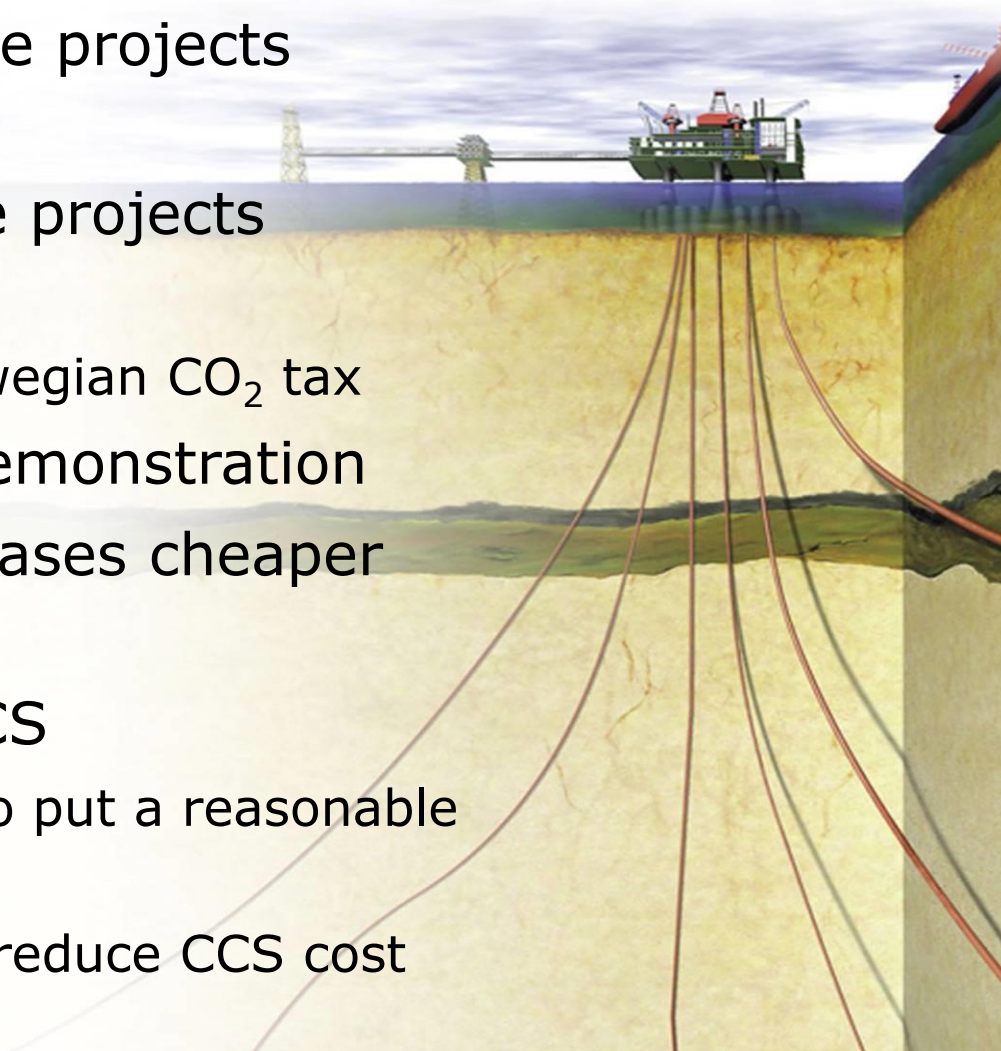


- The 2020 targets
 - 20 % reduction in GHG emissions
 - 20 % more renewable energy
 - 20 % more energy efficiency
- The 2030 Framework
 - 40 % reduction in GHG emissions
 - 20 % more renewable energy
- The 2050 Roadmap
 - 80 % reduction in GHG emissions
- The Energy Union

CCS is a key element to achieve 2030 and 2050 ambitions

Where do we stand today?

- The technology works
- Only a few industrial scale projects worldwide in operation
- Two European large scale projects
 - Sleipner and Snøhvit
 - Project enabler: The Norwegian CO₂ tax
- Next step: Large scale demonstration
- Emitting CO₂ is in most cases cheaper than implementing CCS
- How to commercialize CCS
 - Bold political leadership to put a reasonable cost on CO₂ emissions
 - Comprehensive RD&D to reduce CCS cost



54 large scale CCS projects worldwide

Reference: Global CCS Institute



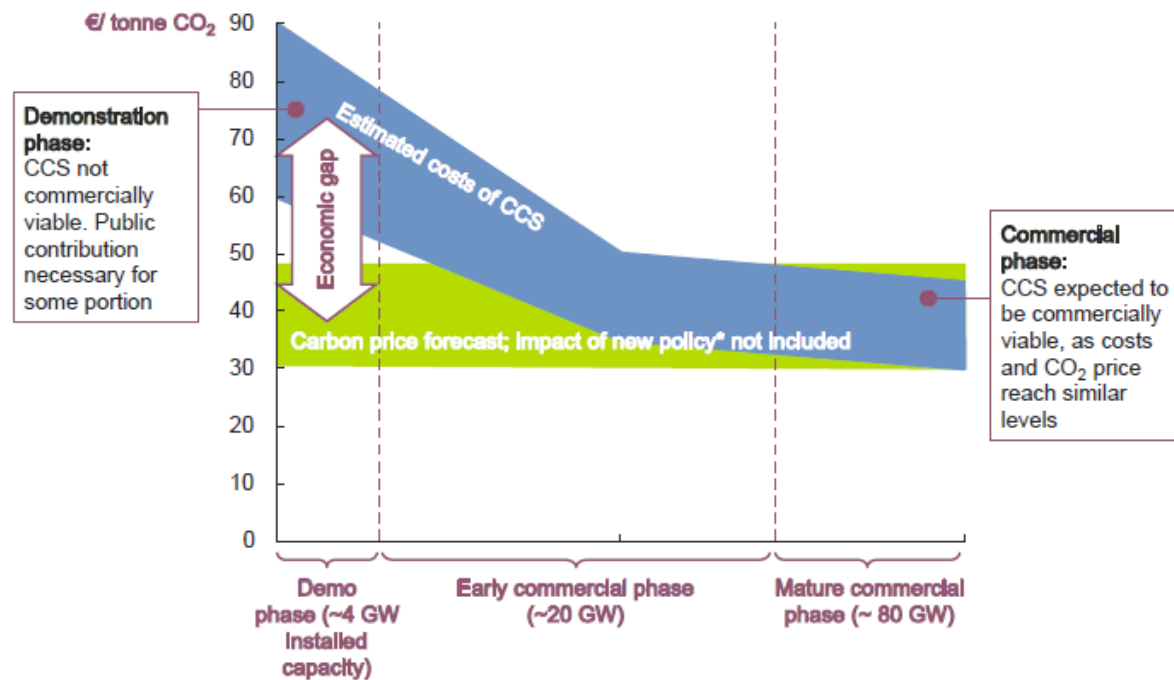
Boundary Dam

- Boundary Dam is the first coal power plant with CCS.
- CCS in operation October 2014
- 1 M ton captured and stored annually



Brief History of CCS in Europe - 2008

- Ambition of up to 12 CCS demonstration plants by 2015
- The ETS CO₂ quota price supposed to be the enabler for CCS deployment

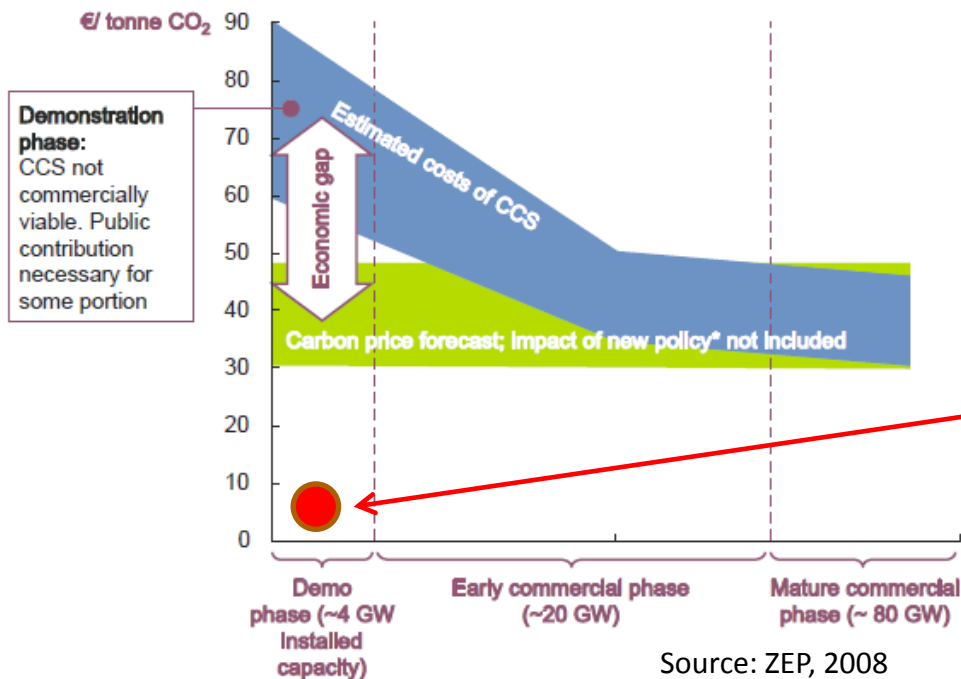


* Carbon price band for 2015 from 2008-15 estimates from Deutsche Bank, New Carbon Finance, Soc Gen, UBS, Point Carbo. Impact of the (possible) new ETS directive and the Copenhagen conference are not included in the analysis
Source: McKinsey & Company "CCS – Assessing the Economics" for the cost numbers; policy implications drawn by ZEP

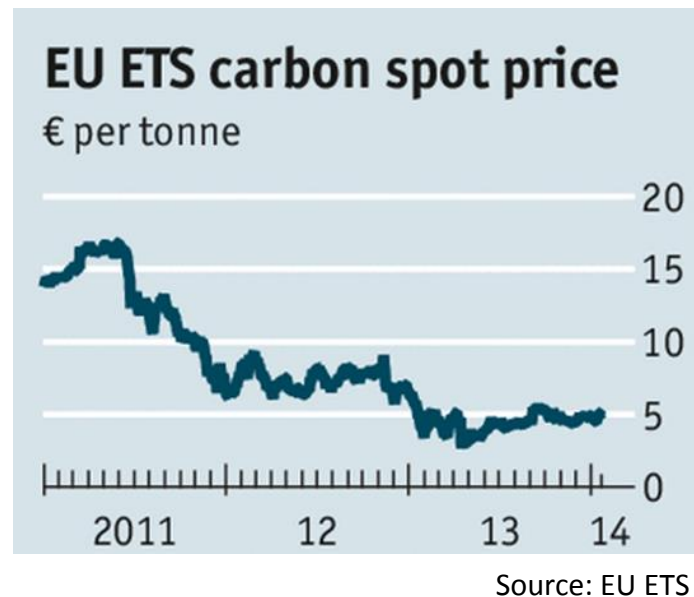
Lack of business case for CCS in Europe

- There is no business case in Europe because it is cheaper to emit CO₂ than to invest in CCS

Expectations 2008



Reality 2015



Brief history of CCS in Europe 2009-2014

- Demonstration programmes
 - EPR: 6 projects awarded € 1 bn in 2009. None realised
 - NER300: White Rose (UK) awarded € 300 M in 2014. Looks promising!
- CO₂ storage directive (2009)
 - A legal framework for the safe geological storage of CO₂
- FP7 & Horizon 2020
 - Comprehensive R&D



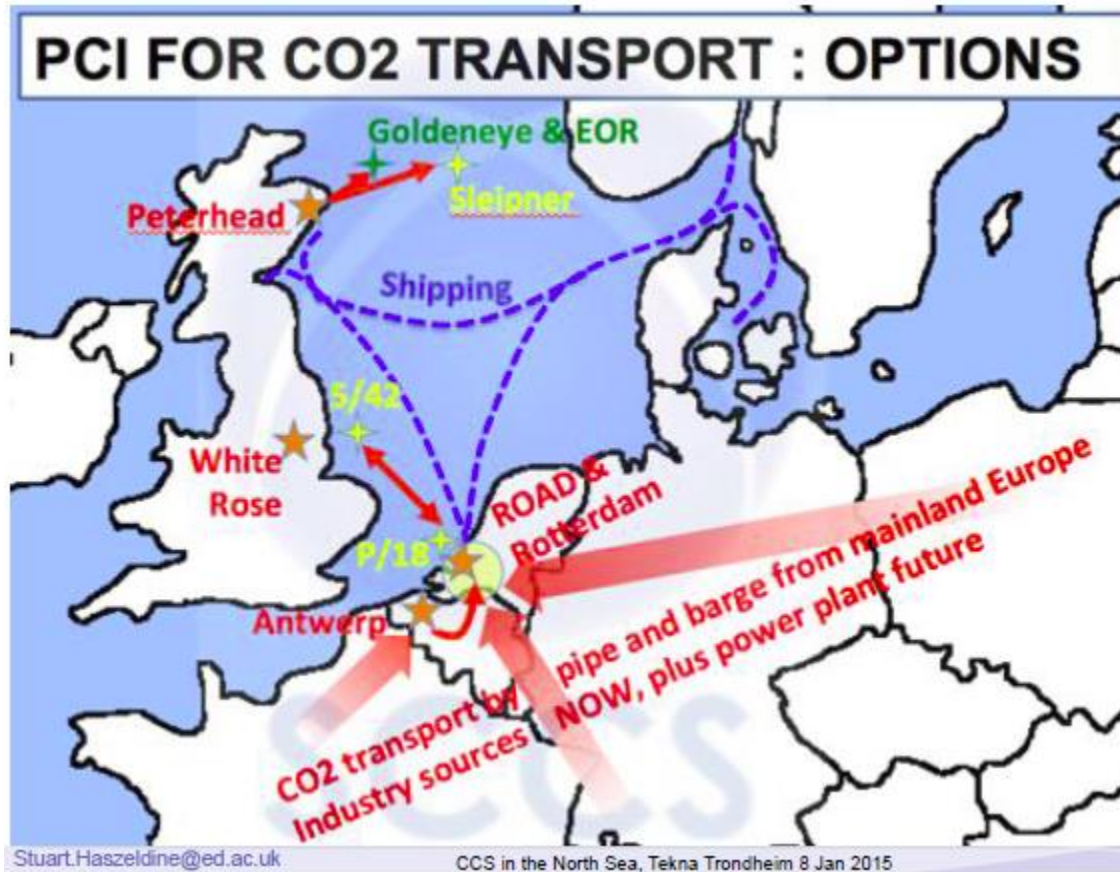
Public awareness of CCS is low



- The Barendrecht CCS project were stopped in 2010 because of public opposition
- Were the public well informed?



CO₂ transport network is needed



- Project of Common Interest (PCI) to build flexible shipping and barges to deepwater ports
- Linking CO₂ point sources and storage sites

CCS in Europe today

- Demonstration projects
 - UK competition: FEED ongoing for Peterhead and White Rose
 - ROAD: waiting for investment decision
- Regulations
 - UK: Electricity Market Reform & Contracts for Difference
- R&D
 - Horizon 2020 & National programmes
- Policy
 - Energy Union
 - 2030 Framework
 - ETS Market stability reserve

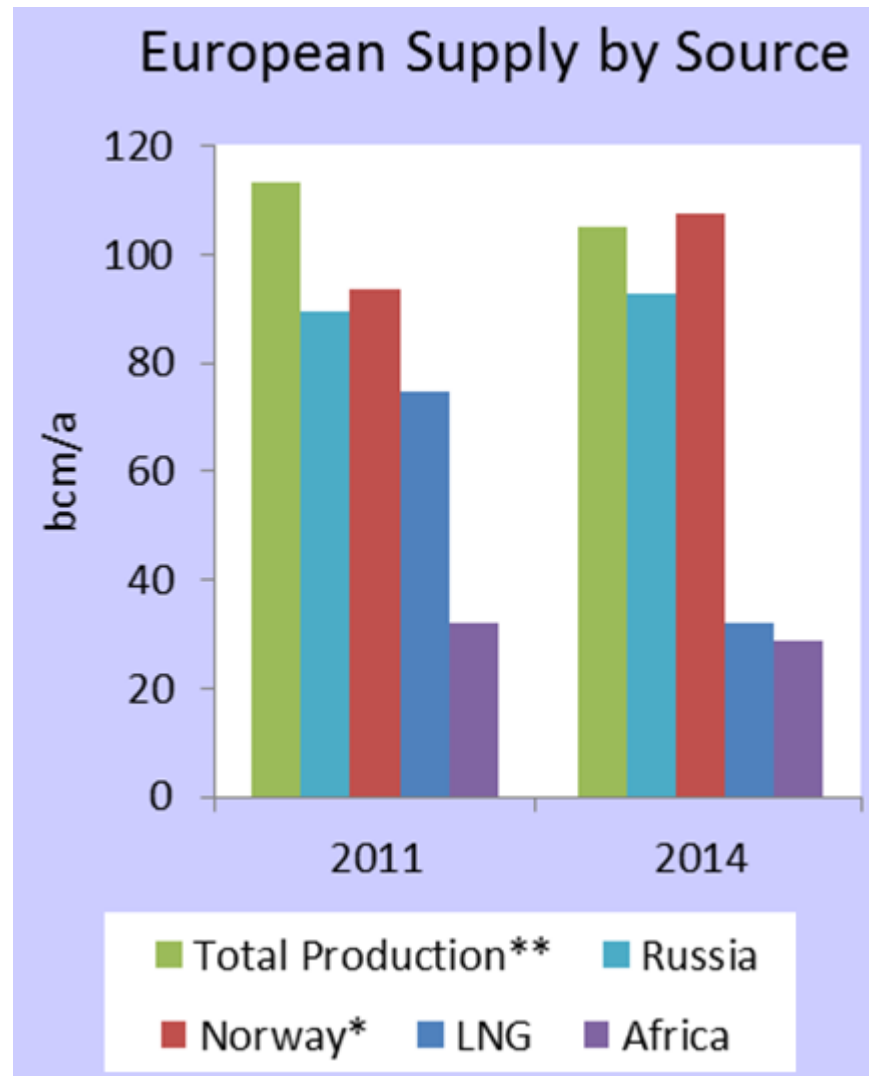
Norwegian CCS experiences

17/3 -2000

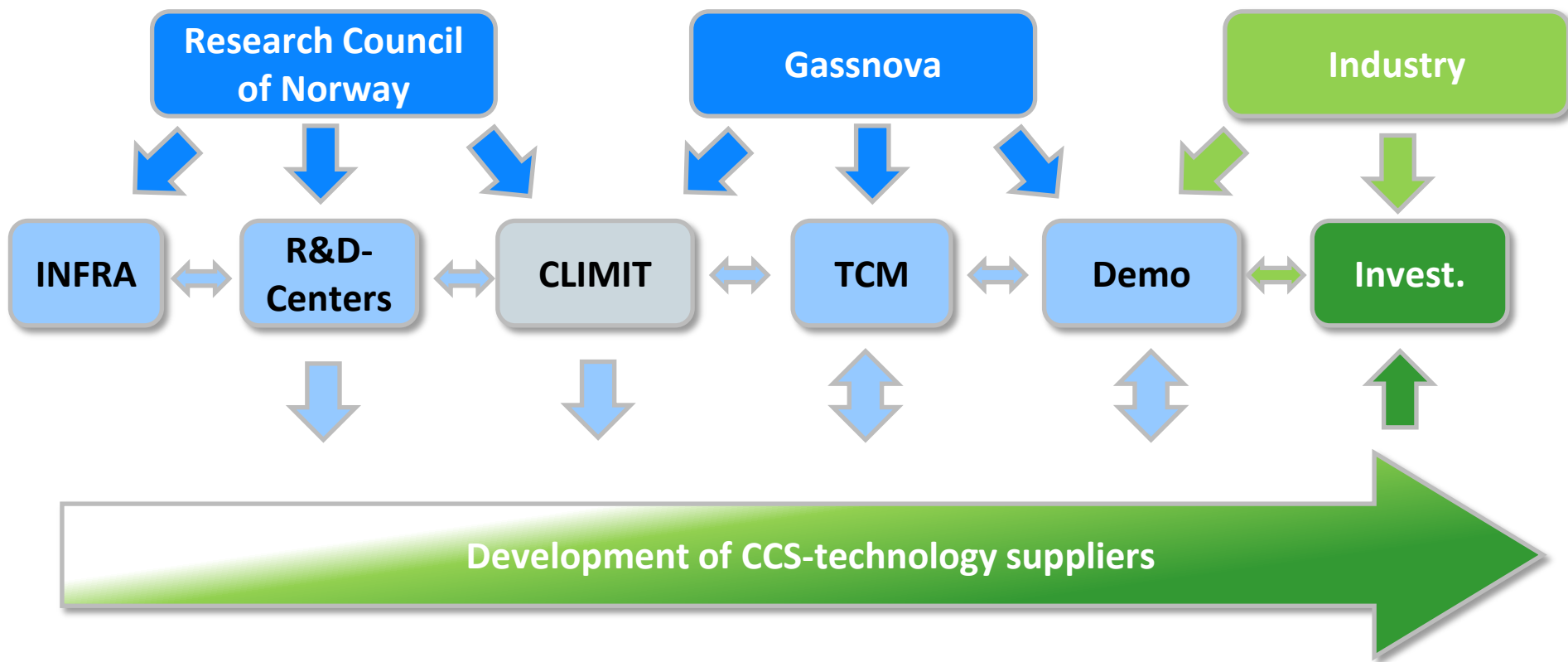


Prime minister Bondevik resigns after losing support in the Parliament for his policy of not allowing gas power plant without CCS

Natural gas supply in Europe



Policy Instruments for CCS in Norway



Public funding for CCS in Norway

INFRA

- ECCSEL
 - ESFRI project. R&D infrastructure
- **€ 6 M** from RCN 2013

R&D Centres

- BIGCCS and SUCCESS
 - CCS R&D centres
- **€ 3.5 M/yr** for 8 years

CLIMIT

- National program for CCS RD&D
- 2015: **€ 23 M**

TCM

- Technology Centre Mongstad
 - Large scale CO₂ capture pilot
- **€ 800 M** invested

Demo

- New government has promised full scale demonstration by 2020

TCM - Technology Centre Mongstad

- In operation since May 2012
- Capacity ~ 100 k ton CO₂/yr
- Post combustion CO₂ capture
- Two technologies: Amine and Chilled ammonia
- Flue gas from gas CHP and cracker (4-9 % CO₂)



Europe's first CO₂ capture test facility in cement industry, Norcem Brevik, Norway

- Small Scale Test Centre
- Basis for qualification of CO₂ capture technologies
- Project on behalf of the European Cement Industry
- Evaluation of full scale capture
- Partners: Norcem, HeidelbergCement and ECRA)
- Total budget: € 11 M

Concluding remarks

- CCS is needed to meet climate targets in a sustainable and cost effective way
- We need
 - Comprehensive R&D in parallel with demonstration projects to reduce CCS cost
 - Bold political decisions to put necessary incentives in place
 - International cooperation

