CCS developments in Norway

Workshop on Mapping of Potential Reservoir for CCS & Selection Criteria

Bali, Indonesia, Sept. 28, 2010

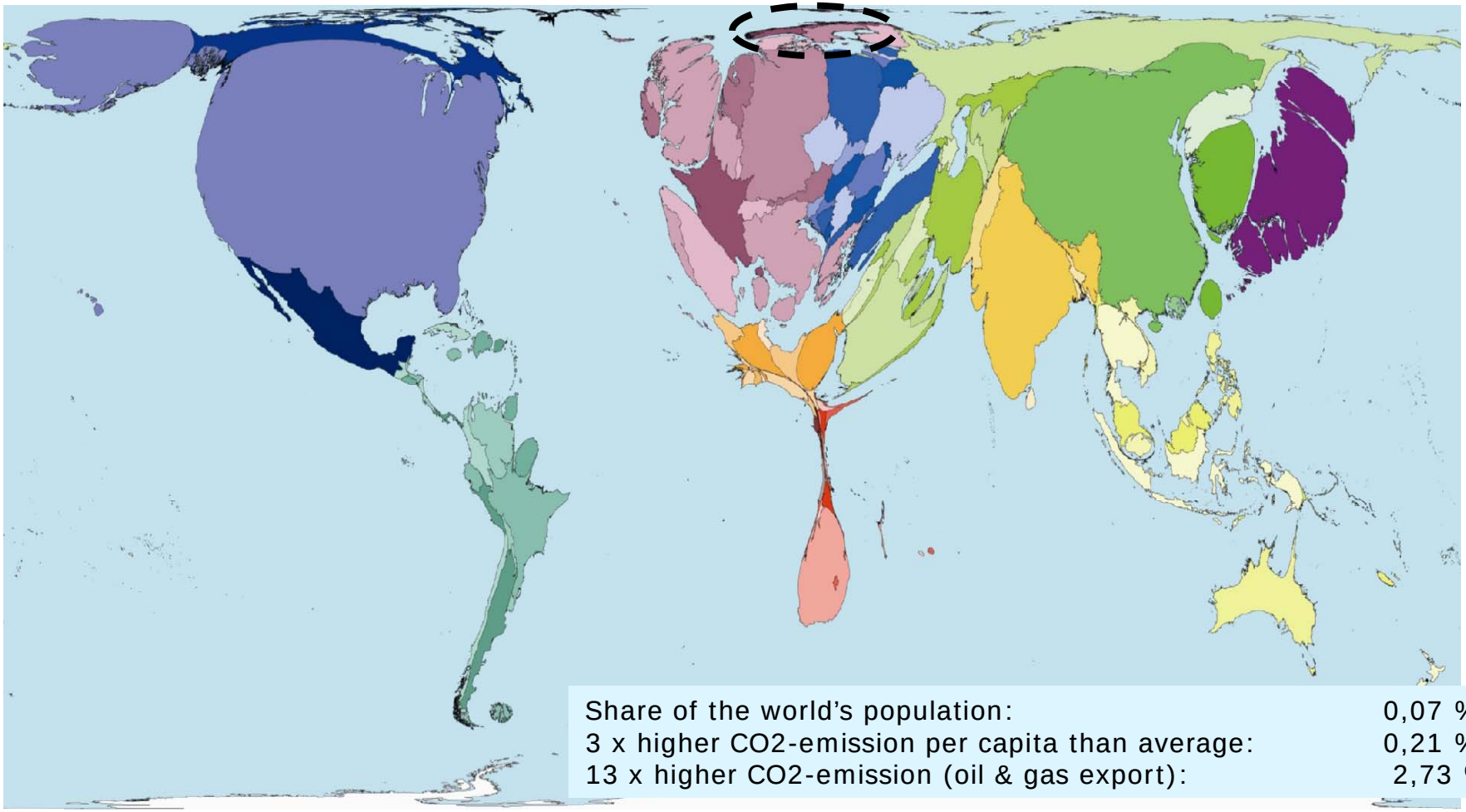
Dr. Per Christer Lund, Counsellor Science and Technology, Innovation Norway, Tokyo

We give local ideas global opportunities

Norway's CO2 footprint.

World's 2nd largest exporter of natural gas
World's 5th largest exporter of oil
The petroleum industry is important for Norway:
- **One half of total exports**
- **One fourth of GDP**
- **One third of total Government income**

World's 2nd largest Sovereign Wealth Fund USD 400 million



Share of the world's population:	0,07 %
3 x higher CO2-emission per capita than average:	0,21 %
13 x higher CO2-emission (oil & gas export):	2,73 %

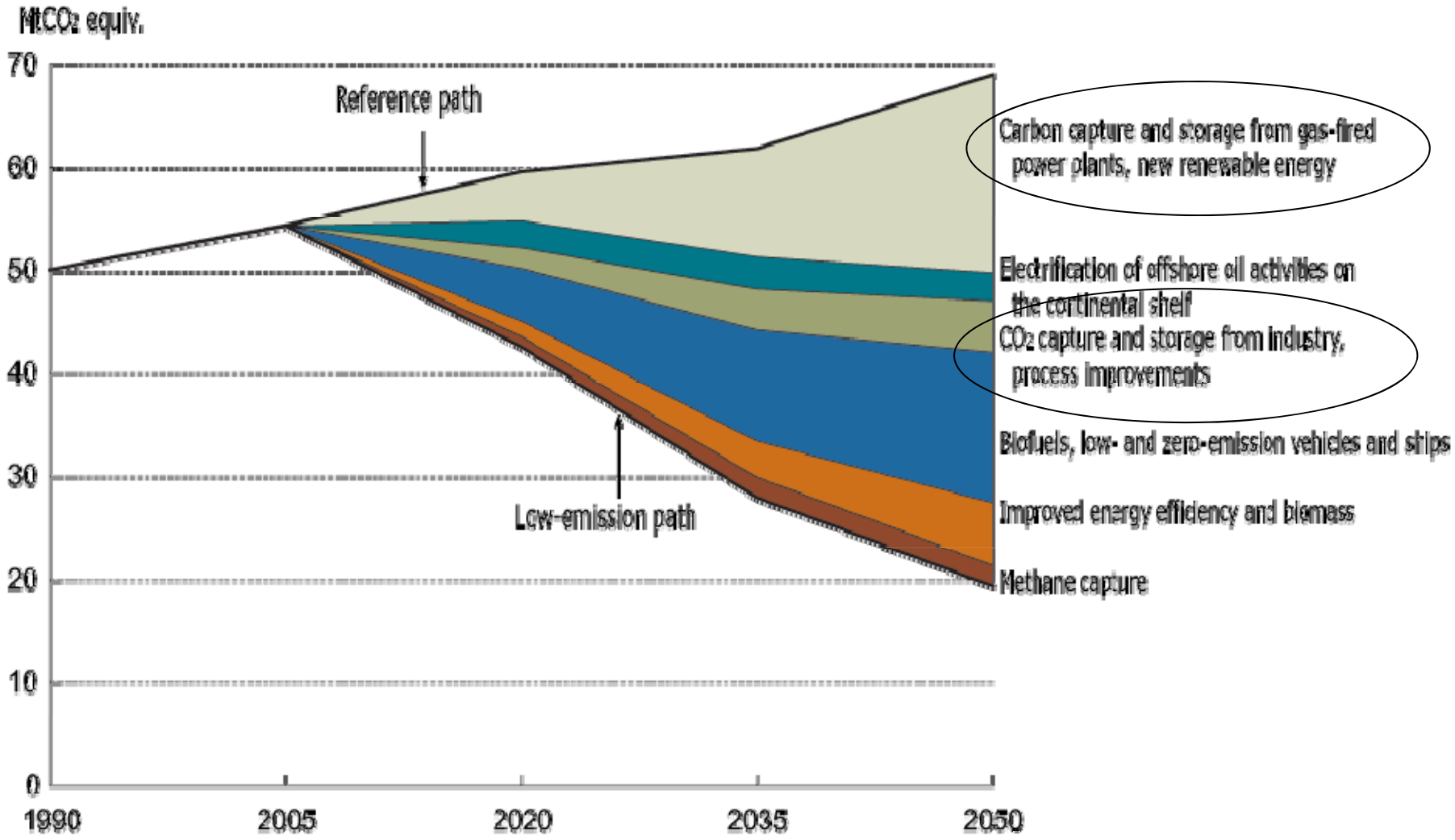
Courtesy: www.worldmapper.org

The Norwegian Climate Policy

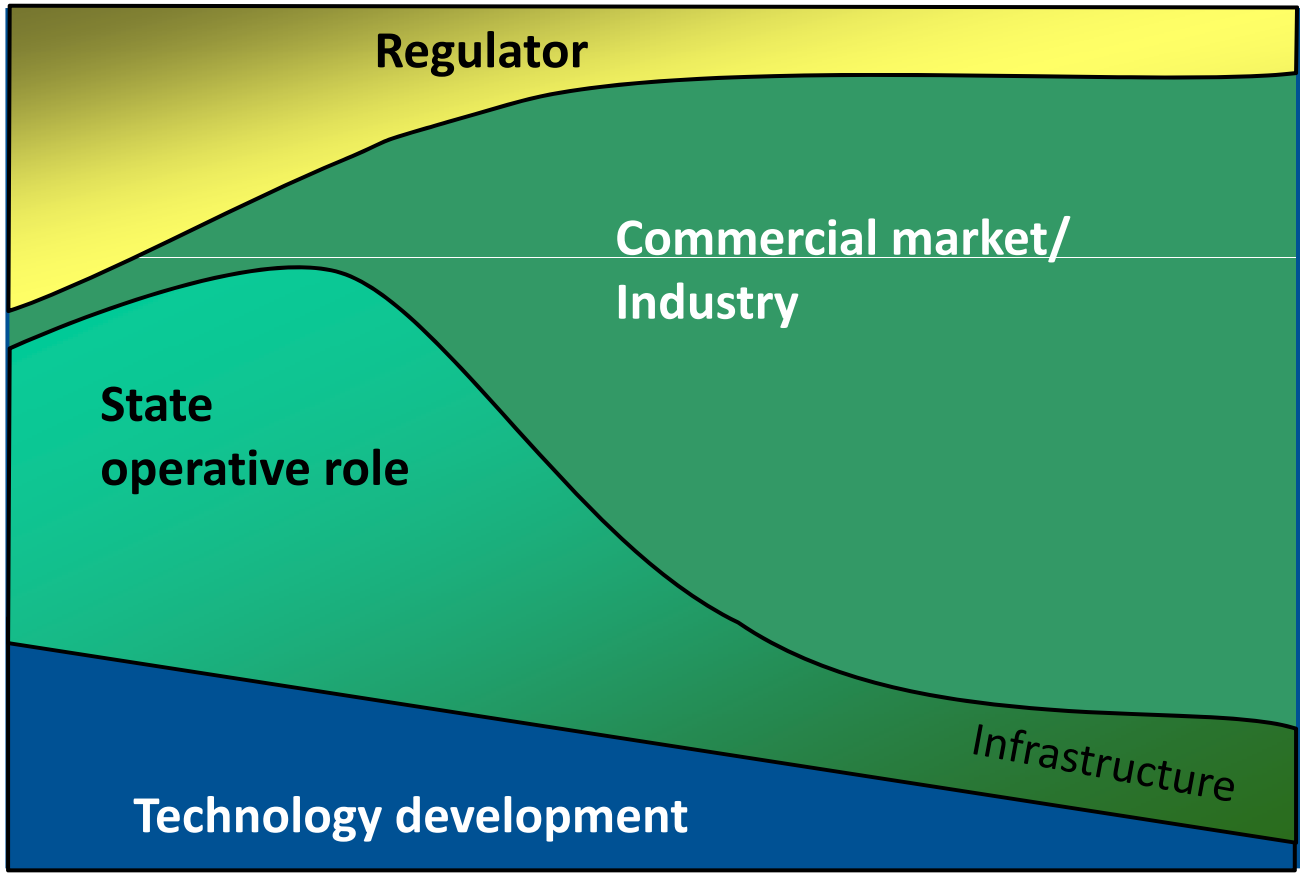
- **Agreement among ruling and opposition parties in the parliament Jan 2008 :**
  - **Global target: limit average temperature hike to 2° C above pre-industrial level**
  - **Strengthen Norway's "Kyoto commitment" from 1% above 1990-level to 9% below 1990 level**
  - **Reduce Norway's carbon emission footprint with 30% within 2020**
    - **Reduction of 15-17 MtonCO2 including forestation**
  - **Norway shall be "carbon neutral" within 2050**
    - **Carbon emission reductions may be domestic/offshore reductions or through purchase of international emission credits**
    - **However – the target is that 50%-65% of the reduction shall be domestically**

www.lavutslipp.no/english.shtml
www.aftenposten.no/english/local/article2201986.ece

How to get there?



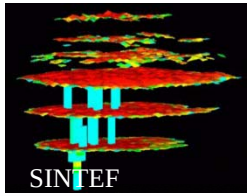
CCS – government vs industry roles



Source:
Gassnova

Challenges in the Carbon Value Chain

Complex value chain: Market design and regulations

Source	Capture	Transport	EOR	Storage	Control
	 Aker Kværner		 Statoil	 Statoil	 SINTEF

Cost

- ✓ Technology development
- ✓ Scale up & verify
- ✓ "First of its kind"

Confidence

- ✓ Methods
- ✓ Demonstration
- ✓ legislation

Source: Gassnova

CO_2 value chain with revenue streams → income is needed!

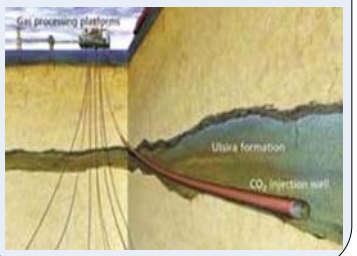
CO_2 sources

CO_2

Transport

CO_2

CO_2 sinks



Kyoto Mechanisms and emission trading schemes

Revenues

CO_2 permit market

Oil market

Revenues

Additional oil if CO_2-enhanced oil recovery feasible

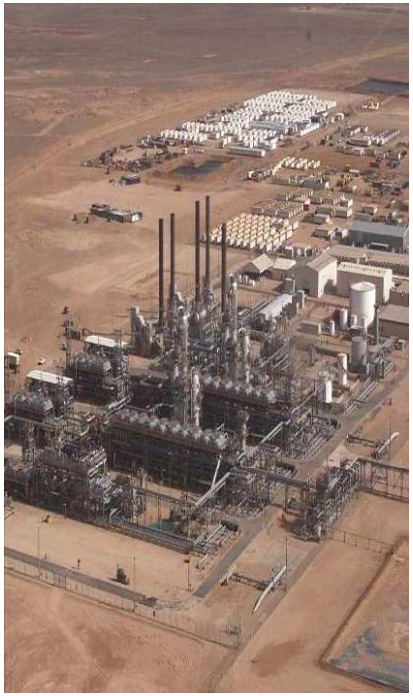
Four Large CO2 Commercial Projects in Operation

Sleipner, Norway

Operator: Statoil

1 million tonnes of CO2/year

In Salah, Algeria



Operators: BP, Statoil and Sonatrach

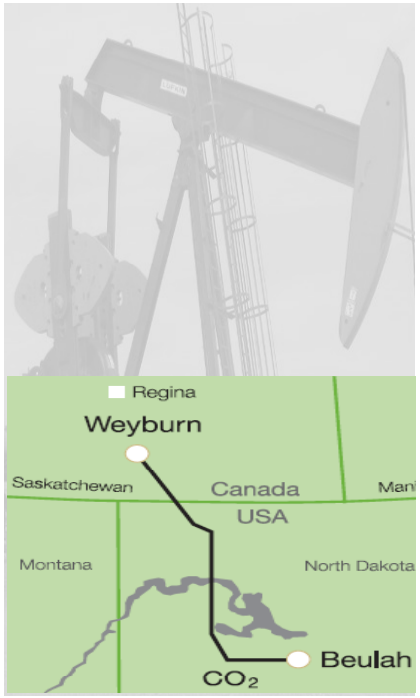
0.8-1.2 million tonnes of CO2/year

Snøhvit, Norway

Operator:Statoil

0.7 million tonnes of CO2/year

Weyburn, Canada



Operator: EnCana

1.8 million tonnes of CO2/year

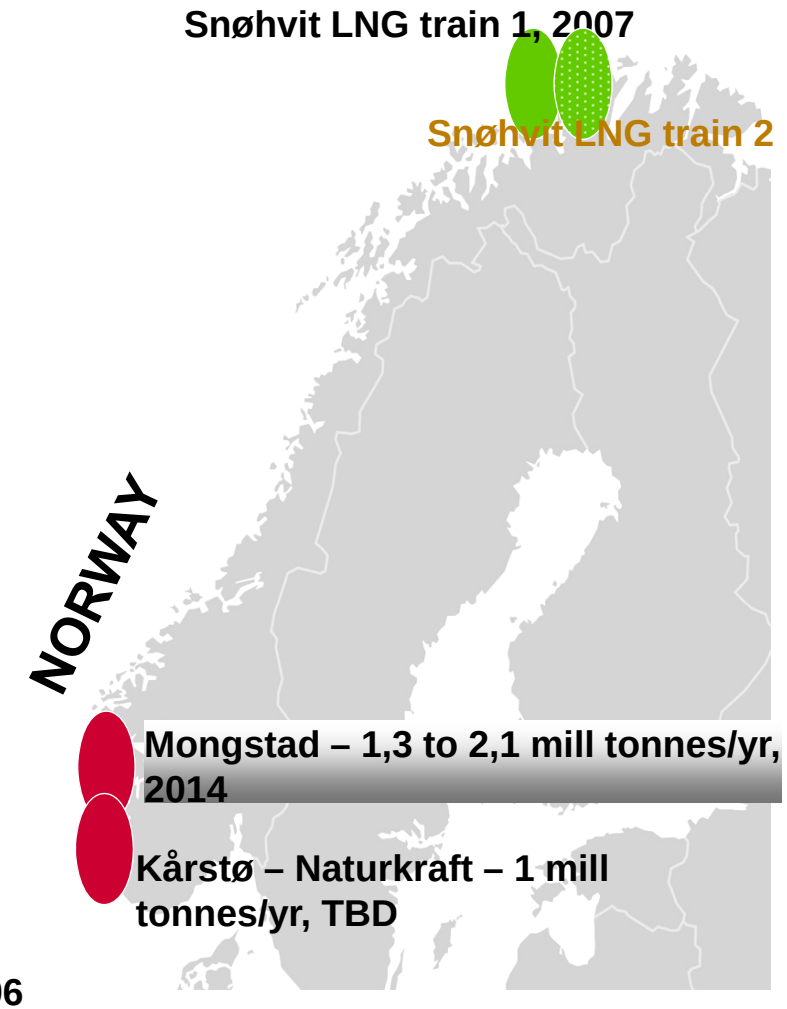
Norwegian CCS projects

Cleaning up our operations

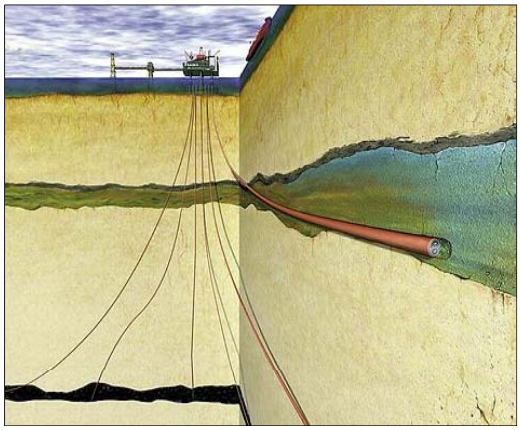
CO_2 from natural gas

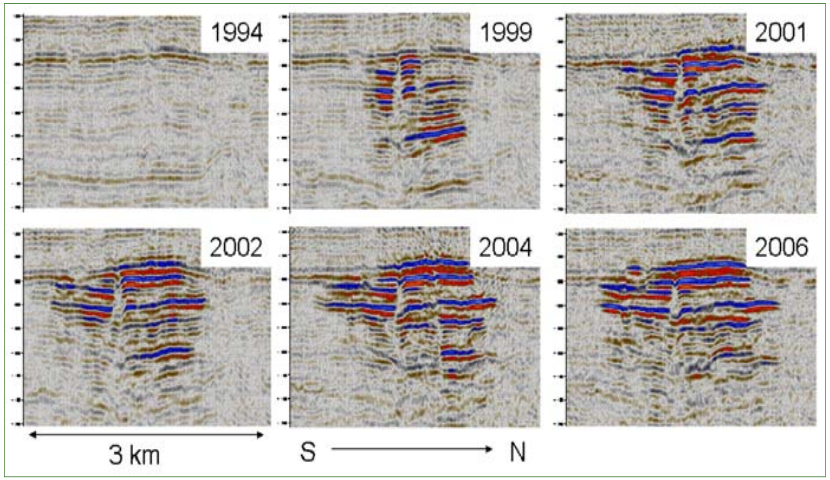
Cleaning up our products

CO_2 from electricity generation



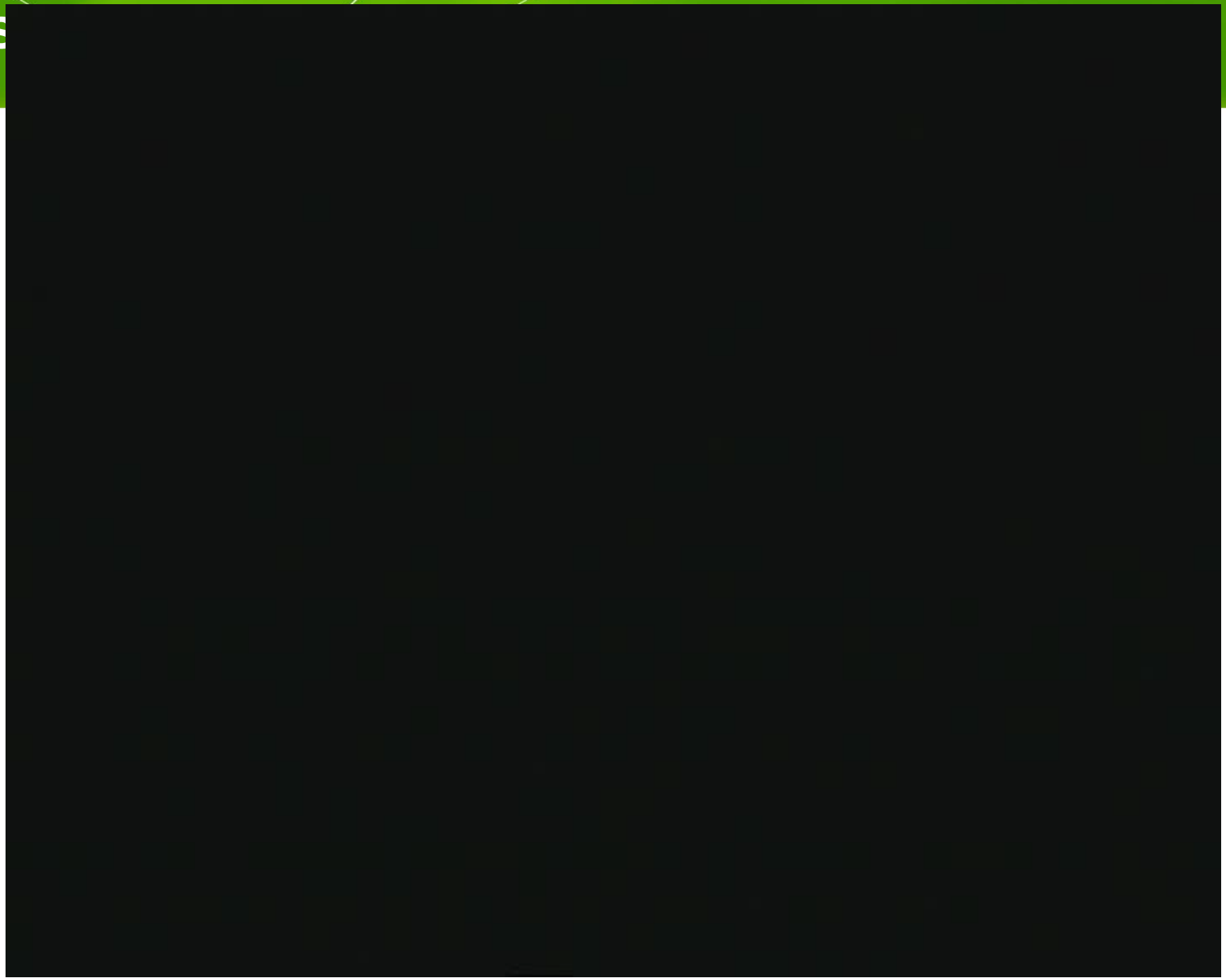
The Sleipner experience – the starting point





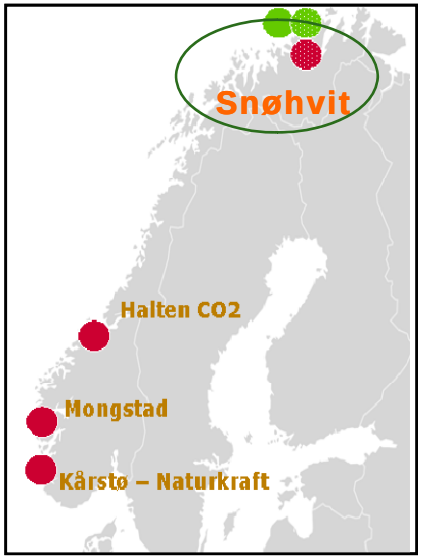
- **Started in 1996 – 10 year of CO2-injection in October 2006**
- **Separating and injecting nearly 1 mill. tons CO2 annually**
- **Storing in saline aquifer above natural gas reservoir**
- **Driver: the ~45US$/ton CO2-tax imposed in 1992**
- **Learning and confidence building through a series of large EU-wide R&D programs**

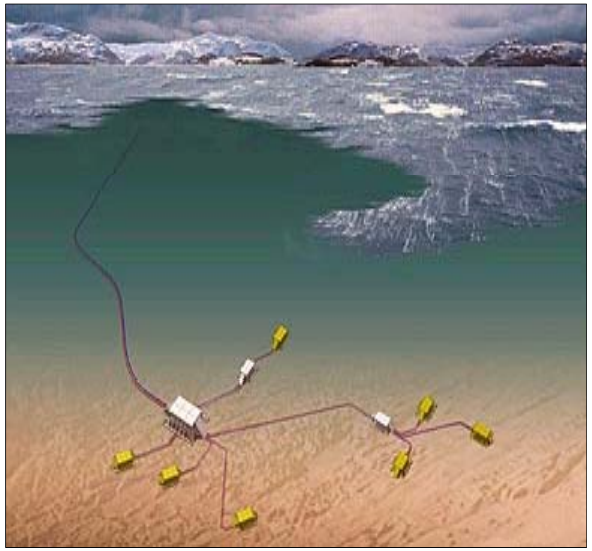
Source: Statoil



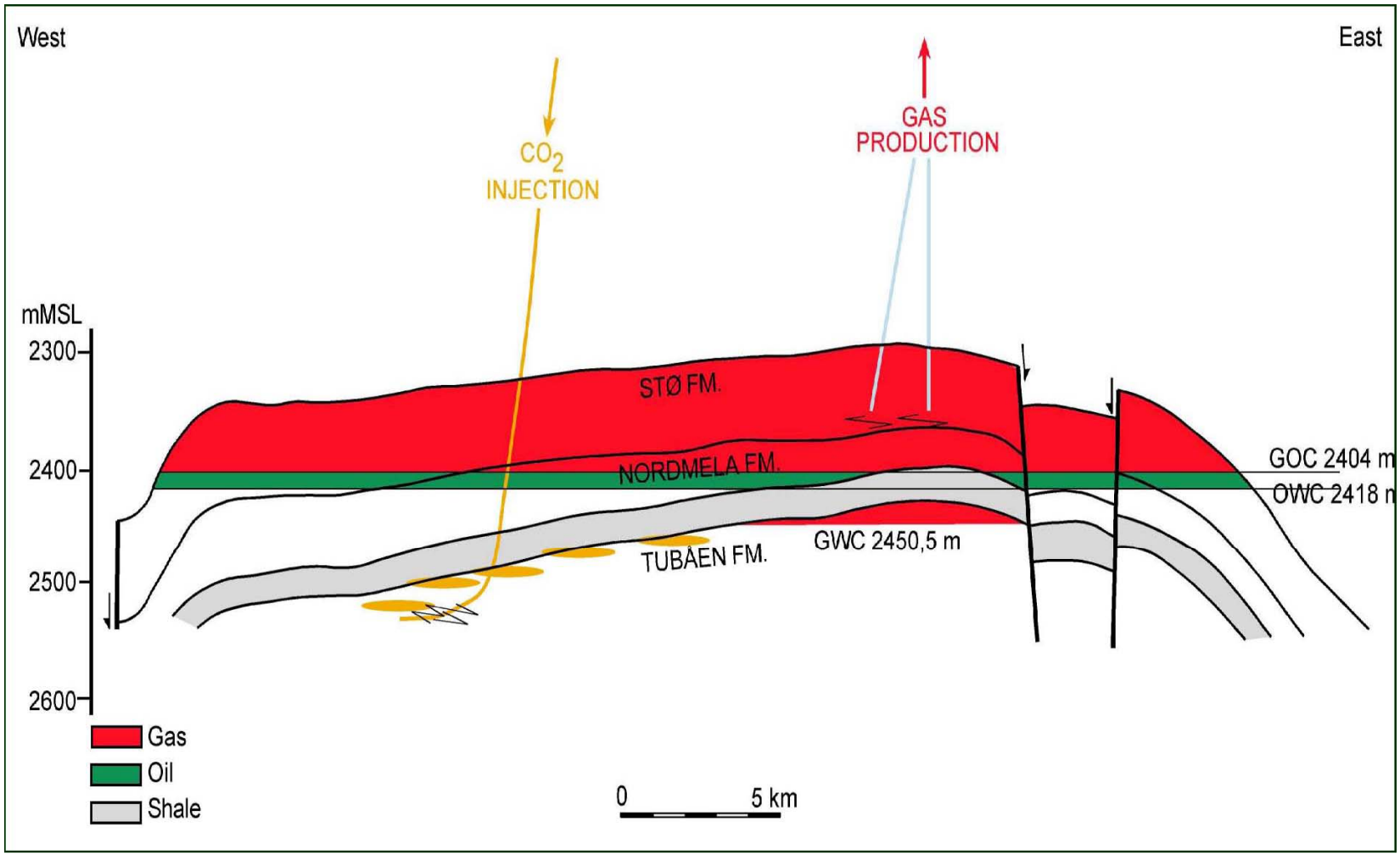
Snøhvit LNG with CCS

- Piped CO2 separated from natural gas (5-8% CO2) in onshore LNG plant, and re-injecting in sandstone below natural gas reservoir
- 145 km subsea pipeline transport.
- CCS started April 2008 – capacity 700,000 ton/yr

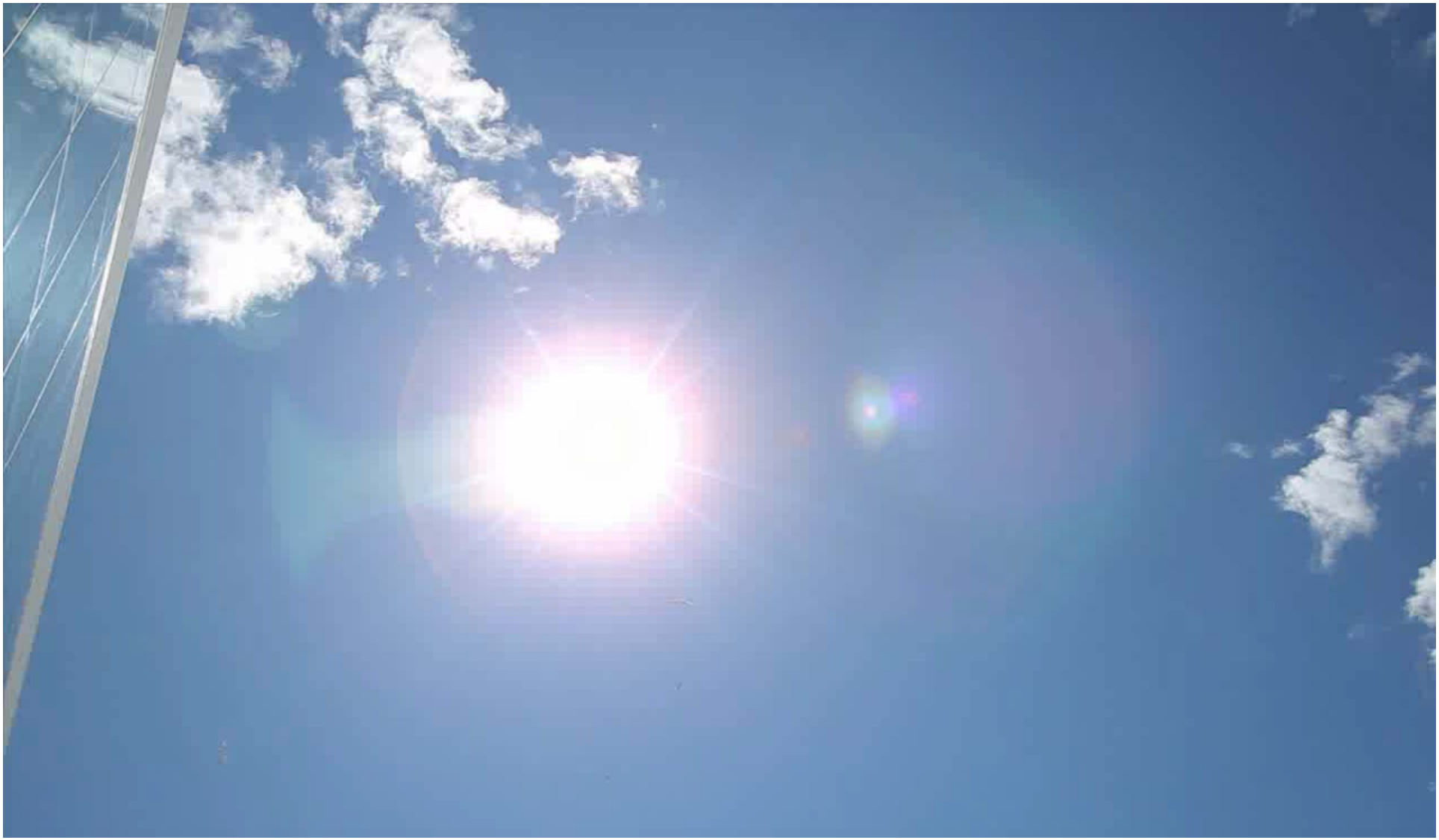




Snøvit injection site



TCM Film



TCM Test Objectives

- Determine emissions and discharges from the Test Facilities
- Verify safe and stable continuous operation
- Determine design limits
- Minimise energy demand
- Identify and assess critical equipment
- Develop control philosophy and train advanced control system
- Develop and validate modelling tools
- Measure and compare overall test results against reference cases
- Assess cost efficiencies
- Establish cost models.

TCM - Status Sept. 2010

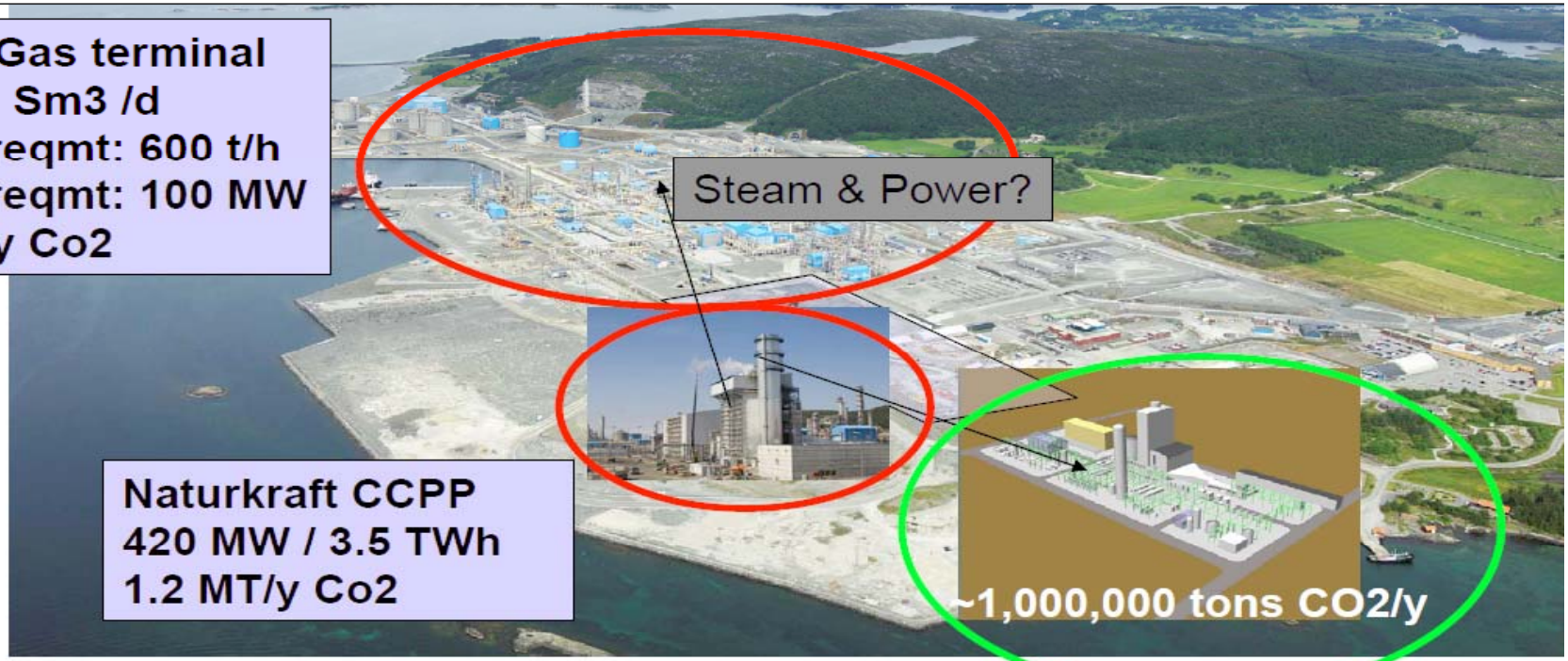
- Total CAPEX budget: 5.2 billion NOK
- Start-up early 2012
- Progress per July 2010
  - 50 % complete
  - 1 520 000 hours worked without absence
  - 2.2 billion NOK expensed
  - 1 100 people involved
  - 280 people at Mongstad
- Major installation work starts September 2010
  - Soon nearly 700 workers on site at Mongstad

Ownership structure

- The Norwegian State through Gassnova SF (75.12%)
- Statoil ASA (20%)
- A/S Norske Shell (2.44%)
- Sasol (2.44%)
- Other potential partners to be invited

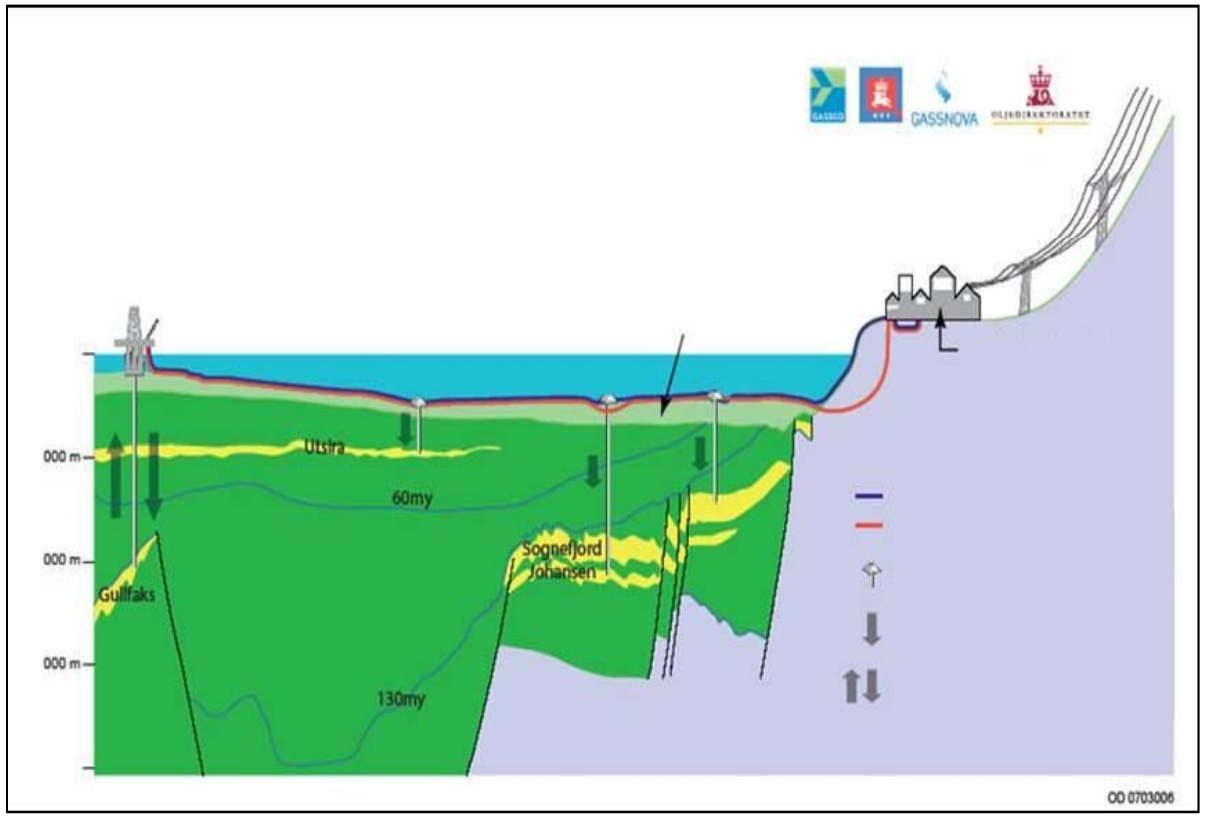
Kårstø: Full-scale carbon capture plant

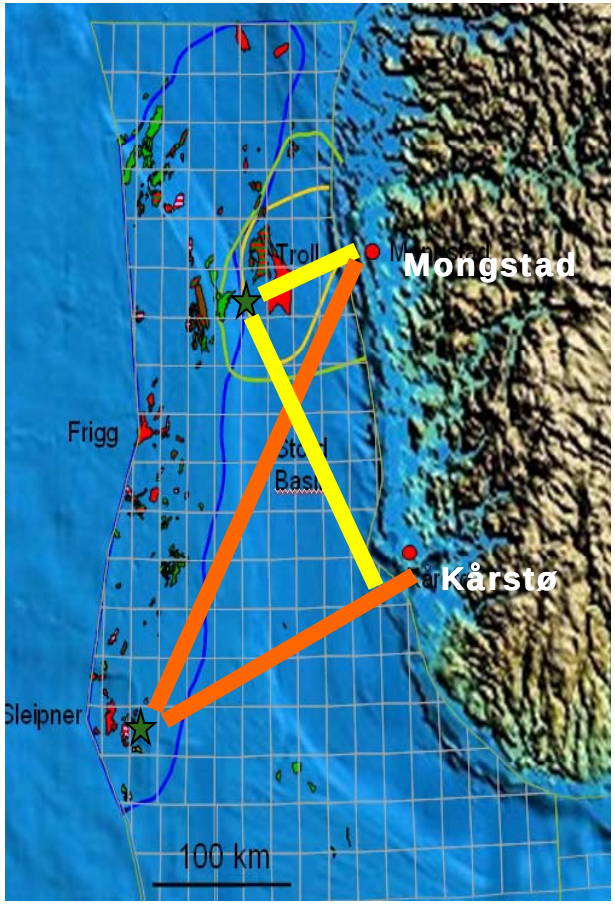
- Original project to capture from Power Plant (1.2 MT/yr) with State funding 100%
- Project scope changed; integration of gas terminal to be evaluated – power plant to be energy supplier (steam & el) to replace 5 current energy suppliers
- Total emission removal 2.4 MT/yr CO2 + significant NOX reductions
- Investment decision 2011/12?



Storage alternatives for the Norwegian North Sea

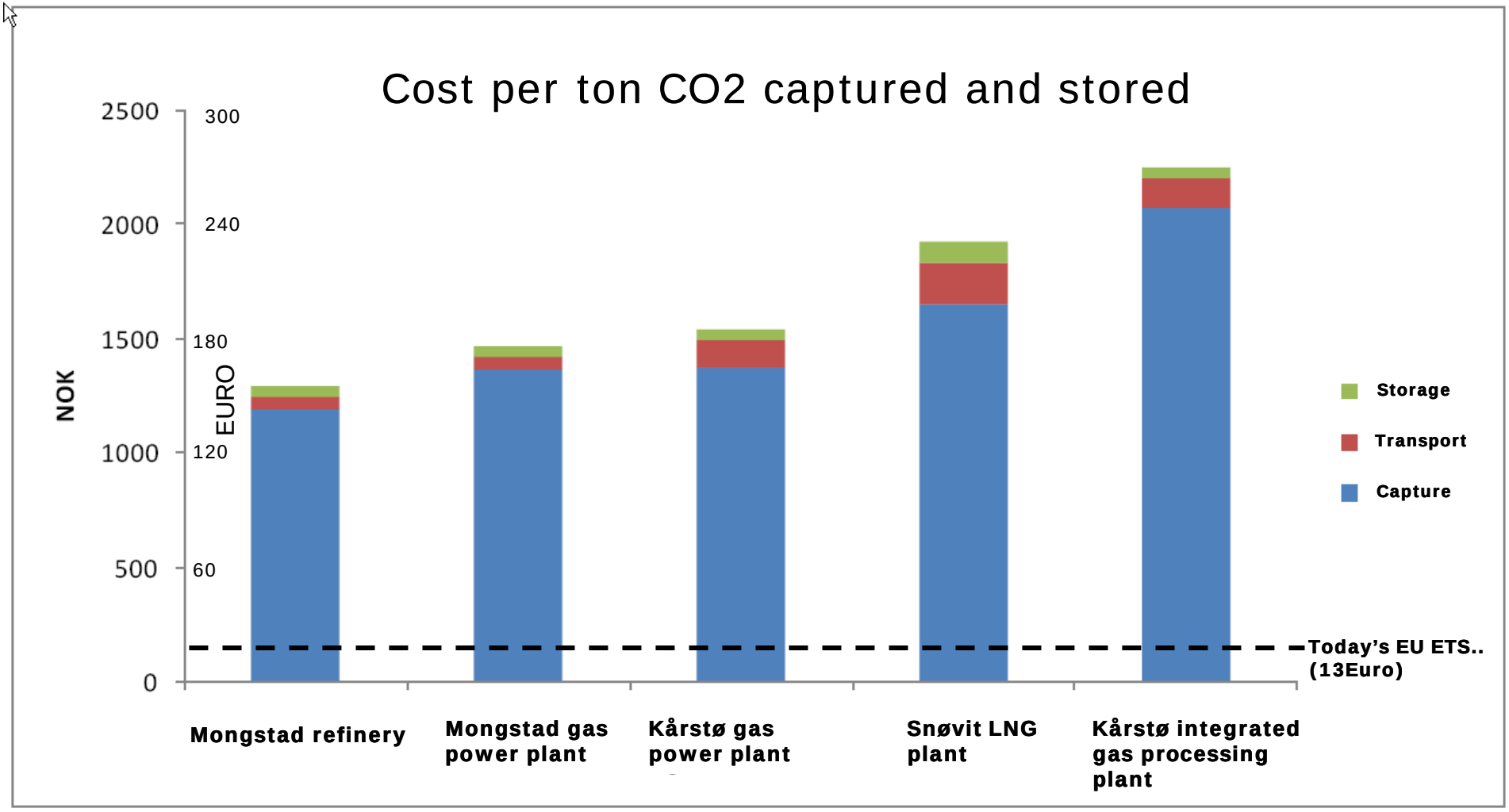
- **Pipelines from Mongstad and Kårstø**
- **Deposition sites:**
  - **Utsira (Sleipner)**
  - **Johansen formation (south of Troll)**





Source: Gassnova

Costs: Norwegian projects



Source: Govt. report: "Klimakur 2020", Feb. 2010

The Norwegian CO2 Capture Research Structure

The Gas Technology Fund
2 billion NOK (350 mill. $)

NORWEGIAN MINISTRY OF PETROLEUM AND ENERGY

The Research Council of Norway

GASSNOVA

The Technology Research Programme CLIMIT

Industry

Project Support

Research **Innovation** **Demonstration** **Commercialization**

Gassnova SF
The Norwegian state enterprise for carbon capture

- Established 2005 as part of Ministry of Petroleum and Energy
- Transformed Jan-08 to state enterprise (SF)
- Managing the Norwegian state's interests in CCS
  - Support to technology development
  - Project development and execution
  - Acting as an advisor for the authorities

Project portfolio:

- Technology Centre Mongstad
- Full-scale CO2 capture facility at Kårstø
- Transport & storage of CO2 from Kårstø & Mongstad
- Statoil/GASSNOVA full-scale CO2 capture from the combined heat and power plant at Mongstad
- SOLVit project: Solvent development and validation

Source: Gassnova

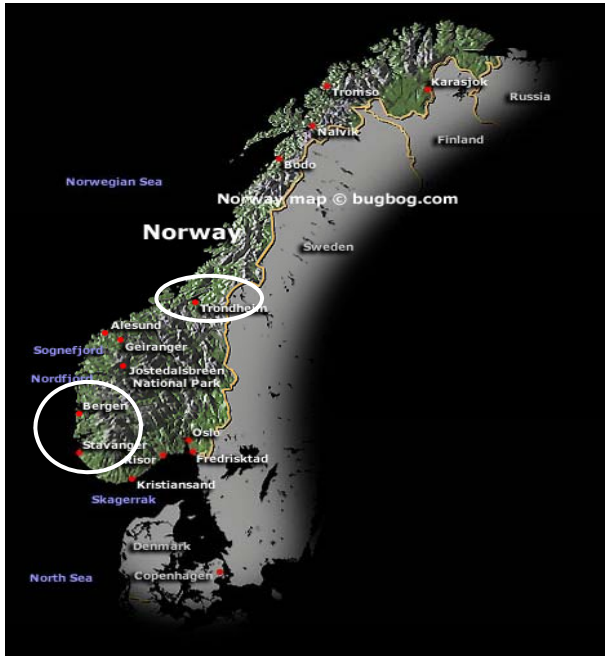
Norwegian CCS R&D clusters

INNOVATION NORWAY

BIGCCS
International CCS Research Centre

CENTRE FOR ENVIRONMENT-FRIENDLY ENERGY RESEARCH

success
SUbsurface CO2 storage- Critical Elements and Superior Strategy

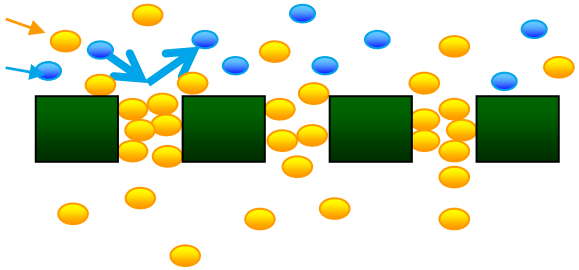


BIGCO2 National CCS R&D Platform

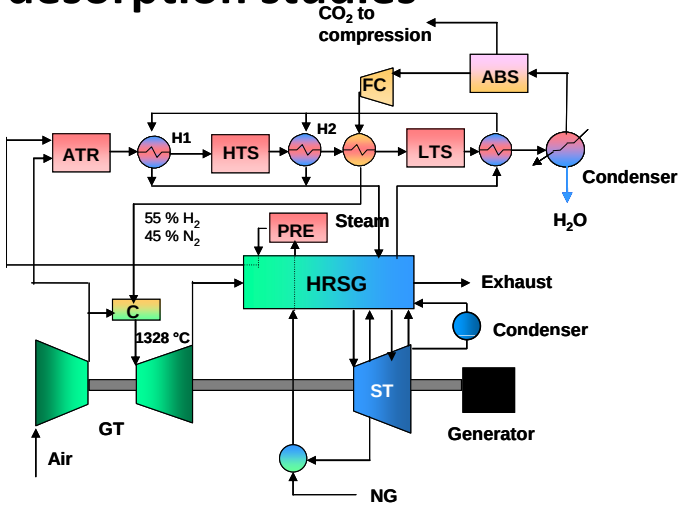
INNOVATION NORWAY

Membrane development

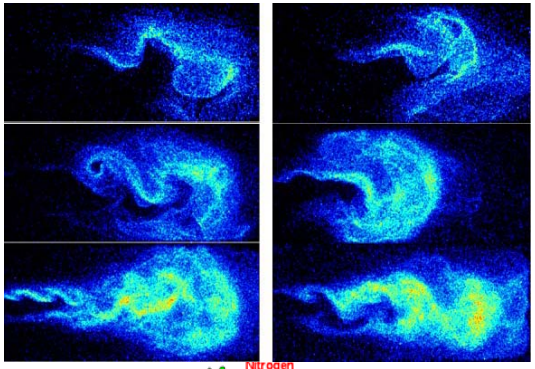
Membranes



Absorption and desorption studies

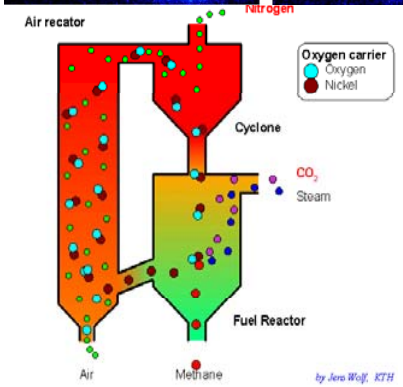


H_2 and De-N_2 combustion

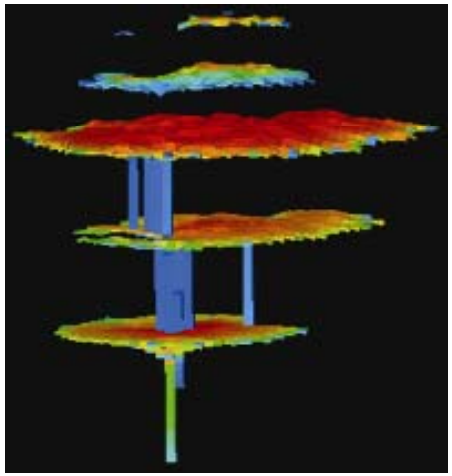


Power cycle analysis

Chemical Looping Combustion



Geological storage



BIGCO2, BIGCLC and BIGH2 – In short

Co-ordinator SINTEF Energy Research

R&D providers

- SINTEF, NTNU
- CICERO
- University of Oslo
- Deutsche Luft und Raumfahrt – DLR
- Technische Universität Munchen-TUM
- Co-operation with Sandia Nat. Labs Livermore

Funding (includes storage and EOR):

- Approx 65/35 % funded by Research Council of Norway/Industry
- 2001- 2006: Total of approx. 13 M€
- 2007 – 2011: 98 MNOK-12M€ (BIGCO2)
- 2007 – 2011: 107 MNOK- 13M€ (BIGH2)
- 2006 – 2012: 50 MNOK- 6M€ (BIGCLC)

Industrial consortium

- Aker Clean Carbon
- GE Global Research (Münich-DE)
- Statkraft
- StatoilHydro
- ALSTOM (Zürich-CH)
- SHELL
- ConocoPhillips
- TOTAL

success
SUbsurface CO2 storage- Critical Elements and Superior Strategy

INNOVATION NORWAY

Vision

- To provide a sound scientific base for CO2 injection, storage and monitoring, to fill gaps in strategic knowledge, and provide a system for learning and development of new competency
- Budget 160 MNOK over 8 yrs

Partners:

- Christian Michelsen Research (CMR)
- Institute for Energy Technology (IFE)
- Norwegian Institute for Water Research (NIVA)
- Norwegian Geotechnical Institute (NGI)
- Unifob (CIPR)
- University of Bergen (UiB)
- University of Oslo (UiO)
- University Centre in Svalbard (UNIS) - UNIS CO2 LAB

Research topics:

- Quantification and modelling of reactions and flow in storages
- Integrity and retention capacity of sealing materials
- Relation between flow, reactions and geomechanical response
- Flow and reaction in faults and fractures
- Test, calibrate and develop new monitoring techniques
- Ecological impact of CO2 exposure - marine monitoring methods
- Extensive high quality education for CO2 storage

cmr

IFE Institutt for energiteknikk

NIVA Norsk institutt for vannforskning

NGI

UNIFOB UNIVERSITETSFORSKNING BERGEN

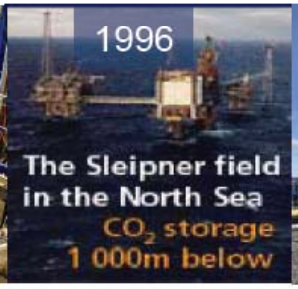
UNIS

Aker Clean Carbon

- More than 18 years experience and competence within CCS in Aker

- A focused technology company
  - Core competence within flue gas treatment and CO_2 capture
  - Invested 40M$ in technology
  - Leading one of the largest R&D programmes in Europe (SOLVit)
  - Operating an advanced mobile test plant
  - Engaged in several CCS projects
  - About 200 engineers in Aker have been engaged in CCS
  - Turn-key supplier of capture plants

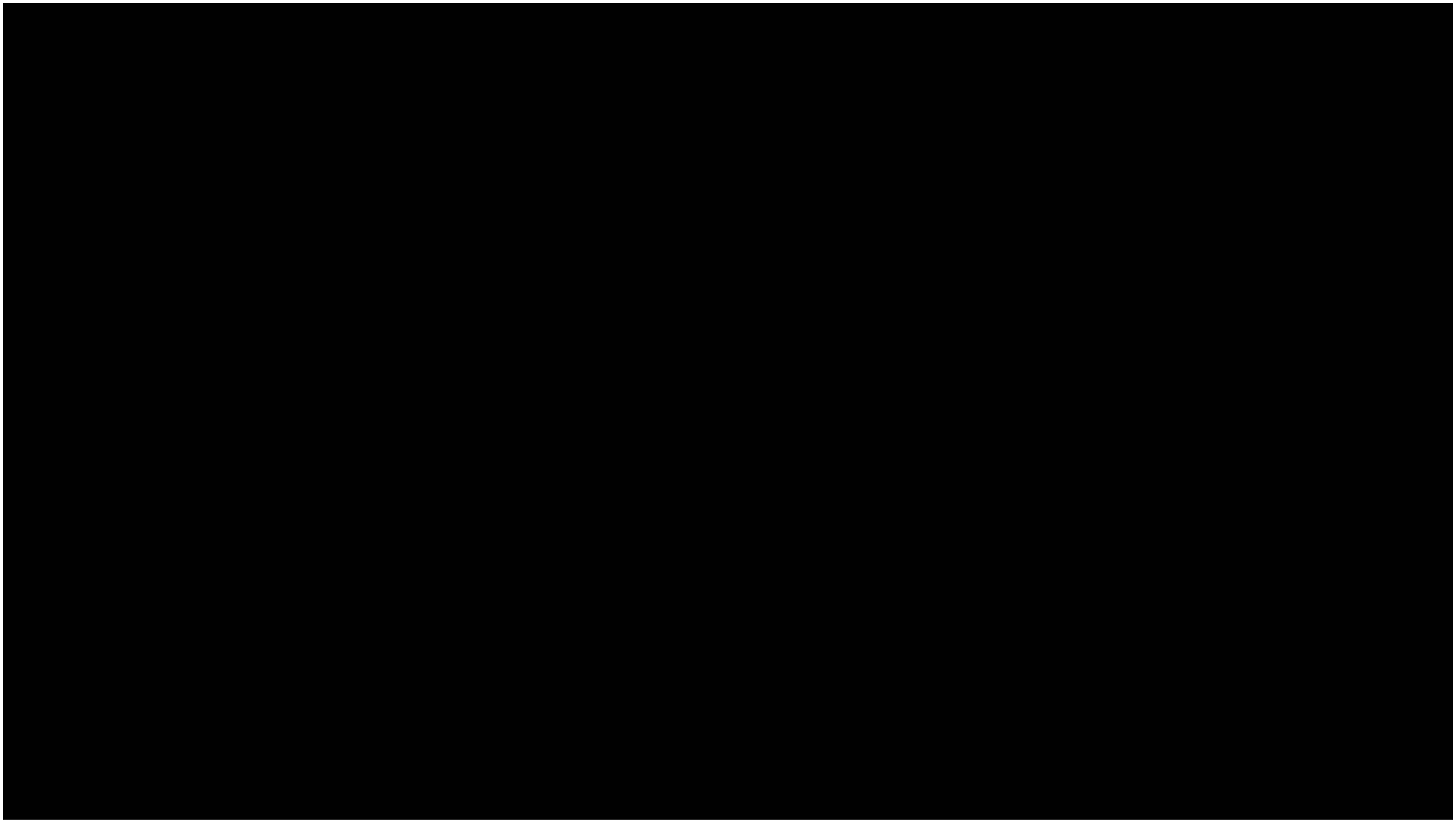
- Aker Solutions is our international partner for EPC projects
  - 25 000 employees in 35 countries (USA/Canada, Europe, Asia, Australia)



CCS = Carbon Capture & Storage

part of Aker
Aker CleanCarbon

Aker Clean Carbon



We have extensive CO_2 capture experience and competence

Projects: CO_2 capture from HC gas

- 16 CO_2 amine based removal plants delivered since 1980

R&D: CO_2 capture from flue gas

- Test rig at SINTEF (Trondheim,1996)
- Pilot plant at K-lab (Kårstø,1998)
- Castor EU Pilot (2006)
- Developing Improved Technology (2004) & Capture w/ Bio Energy (2007)
- Mobile Test Facility (2008)
- SOLVit (Sintef & NTNU, 2008)
- Test Pilot Rig, Tiller, Norway(2009)
- European Technology Centre Mongstad (2011)

Norway keen to exploit its carbon capture lead

Clean energy

Oslo wants to turn an environmental imperative into a commercial opportunity, writes **Joshua Chaffin**

One hour by helicopter from the Norwegian coast, the mammoth Sleipner platform rises more than 200 metres above the grey water of the North Sea. Named after a mythical eight-legged horse, it sucks natural gas from dozens of underwater wells and then sends it through a tangle of pipelines to destinations across Europe.

But a lone pipe, painted green, never reaches the mainland's kitchen stoves or furnaces. Inside is a stream of carbon dioxide, a natural gas byproduct that is one of the main causes of global warming. The green pipe carries the CO_2 from Sleipner back underwater and deposits it into a reservoir more than one kilometre beneath the ocean floor.

There, at least in theory, it will rest for thousands of years. Since 1996, Statoil, the Norwegian state-owned energy company that operates Sleipner, has disposed of almost 13m tonnes of CO_2 in this way.

Statoil has taken repeated images of the undersea reservoir since it began injecting CO_2. Thus far, it has shown no signs of leakage.

That has made Sleipner something of a holy site for believers in carbon capture and storage (CCS), a promising but controversial technology in the fight against climate change.

Now Statoil is trying to turn an environmental imperative into a lucrative commercial opportunity: it has dedicated a group of geologists to mapping the undersea region with the aim of one day providing carbon storage for power plants and manufacturers across Europe.

"We want to build a business at Statoil as a carbon dioxide storage provider," says Kristofer Hetland, a Statoil executive.

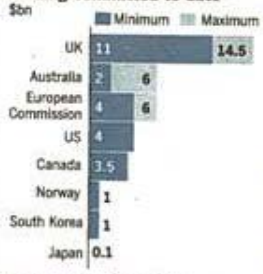
The fate of Norway's carbon capture plans will have ramifications well beyond the North Sea. The International Energy Agency has identified CCS as a cornerstone in the fight against climate change. It is calling for 3,400 projects worldwide by 2050 – along with investments in renewable energy, energy efficiency and nuclear energy – to keep global warming within reasonable bounds.

The European Union, the US and China are all investing billions of dollars in the technology in an effort to bring down its costs and make it widely available over the next decade. They are also hoping that their energy and infrastructure companies will gain a commercial advantage.

But thanks to Sleipner, Statoil remains the leader in the field. The company began to bury the field's CO_2 after the government imposed a tax on carbon in the early 1990s. The technology to do so was

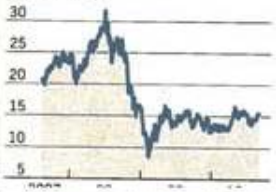
Sleipner: keeping CO_2 out of the atmosphere

Carbon capture and storage funding committed to date*



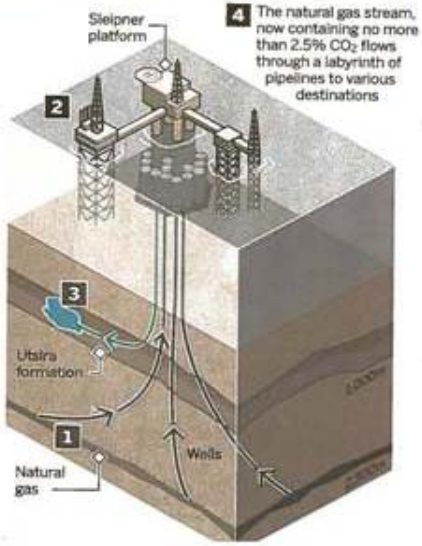
European carbon price

December 2010 contract (€ per tonne)



How it works

1. Natural gas (containing 9% carbon dioxide) is siphoned to the Sleipner platform from wells that extend about 2,500m below the surface
2. CO_2 is extracted from the gas via absorption towers on the platform
3. It is injected into the Utsira sandstone formation about 1km below the seabed – also known as a saline aquifier – where it is stored
4. The natural gas stream, now containing no more than 2.5% CO_2 flows through a labyrinth of pipelines to various destinations



where oil companies began injecting CO_2 into depleted wells in the 1970s to enhance production.

"What is so important about Sleipner is the track record," says Chris Davies, a member of the European Parliament and a staunch advocate of carbon capture. "CO_2 has been injected into the rocks below the North Sea there for more than a decade, and there appears to be have been no leakage whatsoever."

The venture's success, said Mr Davies, provided confidence that it could be replicated again and again.

But expanding CCS beyond Sleipner will not be easy. One problem is that it remains far more difficult and expensive to capture CO_2 from a power plant or factory than from a natural gas well.

That has become evident at the Norwegian coastal city of Mongstad, where the government had planned to build a power plant and oil refinery equipped with CCS technology. The idea was to provide an example of how CO_2 could be captured at onshore industrial facilities and then piped offshore for storage. But in May Oslo was forced to shelve those plans amid rising costs and questions about the technology.

CCS sceptics claim the technology will never be economically viable and that government funds should instead be directed at wind, solar and other forms of renewable energy. While supporters dispute this, they acknowledge that the depressed price of carbon on Europe's emissions trading system is providing little incentive for companies to make the necessary investments.

Another challenge is public acceptance. Like nuclear before it, CCS is fast becoming a bogeyman in communities across Europe, where residents

lead to the release of toxic gas. Those concerns have already halted a project in the Netherlands, where Shell was planning to inject CO_2 into a depleted gas well just down the street from an Ikea store. They are also slowing efforts in Germany to pass legislation that would govern carbon transport and storage.

The disastrous BP oil spill in the Gulf of Mexico has cast a new shadow of risk over the practice of boring holes beneath the ocean floor. It is also leading some MEPs to call for a review of CCS policy.

"Just like oil drilling, you have the same potential danger with carbon capture and storage," says Bas Eickhout, a Green MEP from the Netherlands.

> 'We want to build a business at Statoil as a carbon dioxide storage provider'

Statoil executives and their allies insist their work should not be compared with the BP spill because Statoil is operating at a depth of just 80m in the North Sea, compared with several thousand in the Gulf of Mexico.

Mike Stephenson, head of the British Geological Survey's energy division, sympathises with the public's concerns but says that CO_2 could be safely stored for thousands – if not millions – of years in saline aquifers, where it solidifies after binding with the surrounding brine and minerals.

"The public are right to worry because you are putting CO_2 into the ground and hoping it will stay there for a very long time," he says. "But the

Conclusions

- **Norway is a promoter for technologies to combat global warming, with focus on CCS, new/renewable energy, energy efficiency and global carbon markets.**
- **Gassnova SF established to run projects, support RD&D and advise the government**
- **Frontrunner on CCS projects and demonstrations:**
  - **The Sleipner CO2 storage project since 1996**
  - **The Snøvit CO2 storage project since 2008**
  - **The European CO2 Technology Centre Mongstad**
- **The largest R&C cluster on CCS in the world.**
- **Aker Clean Carbon among world leading CCS technology companies**
- **Norway is actively seeking international collaboration on research and demonstration projects and technology transfer on CCS.**