Is there a Future for Coal

CO_2 Free Combustion-Technology and Economics

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Vattenfall Capital Markets Day, October 5th 2004

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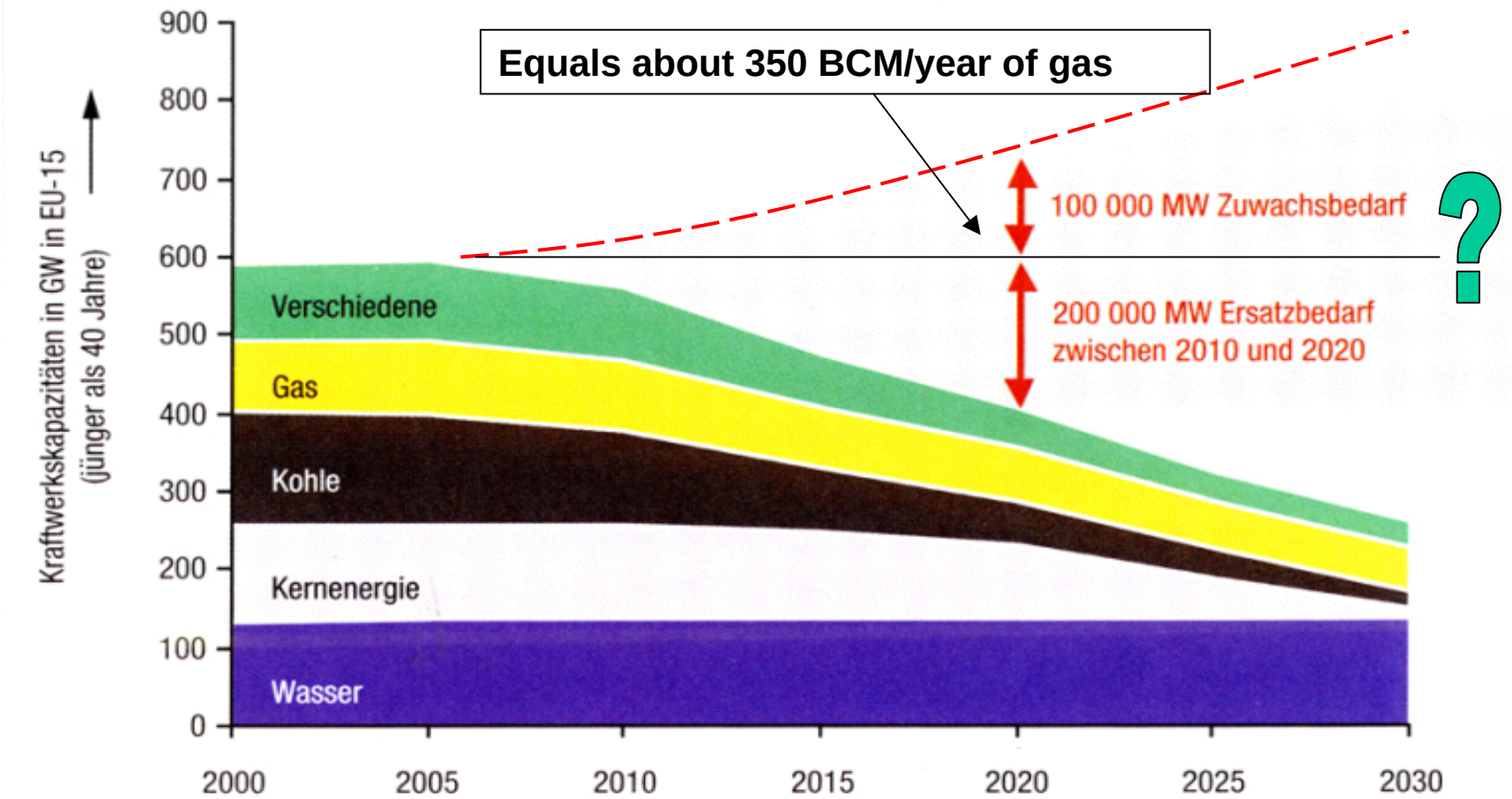
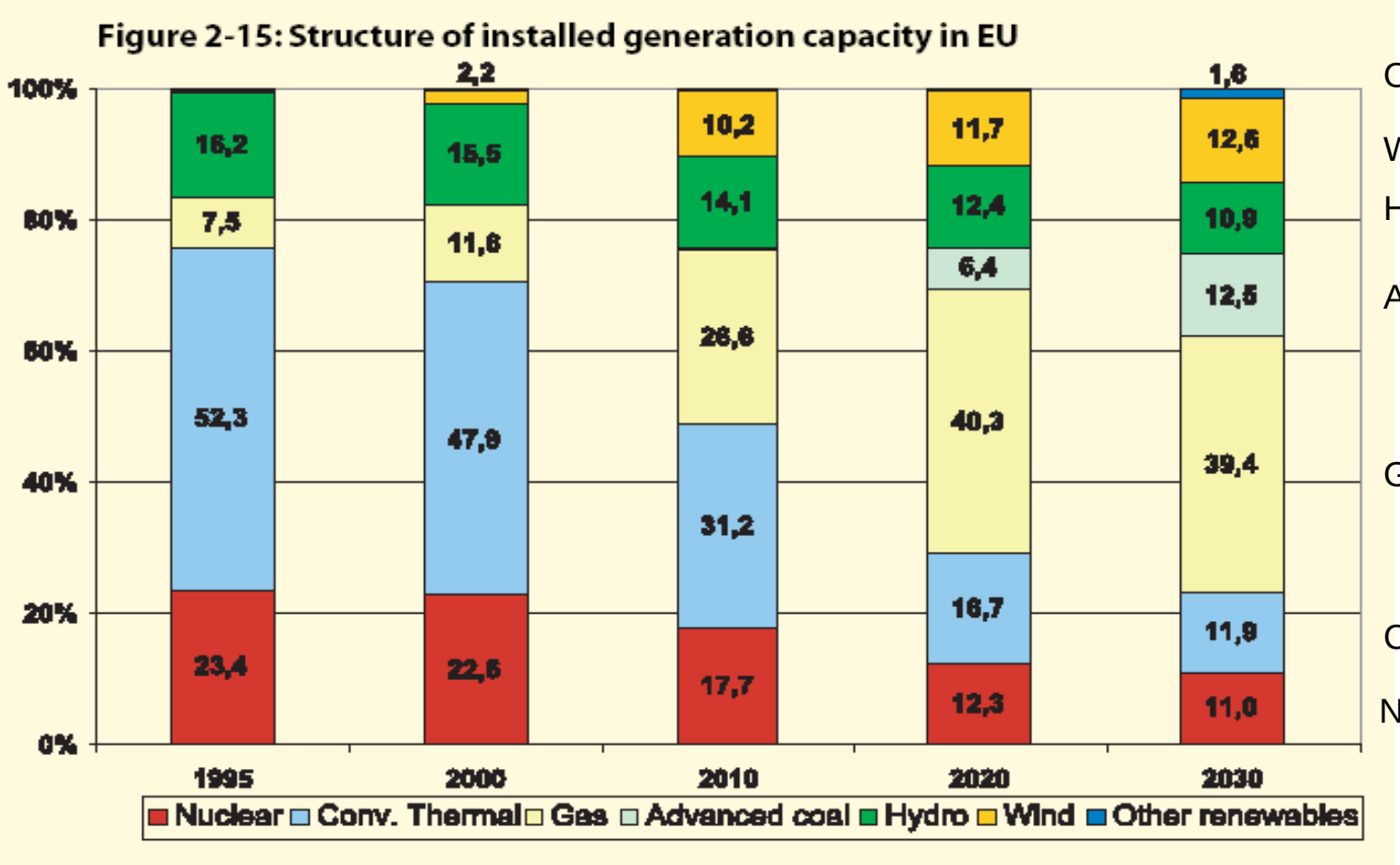
Need for New Capacity in Europe (EU 15)



Source: VGB PowerTech Annual Report 2002 / 2003 + EU and Eurelectric

Electricity in EU 15 – EU Commission



Other renewables

Wind

Hydro

Advanced coal

Gas

Conv. thermal

Nuclear

Suurce: EU 15 Energy and Transport Outlook 2030

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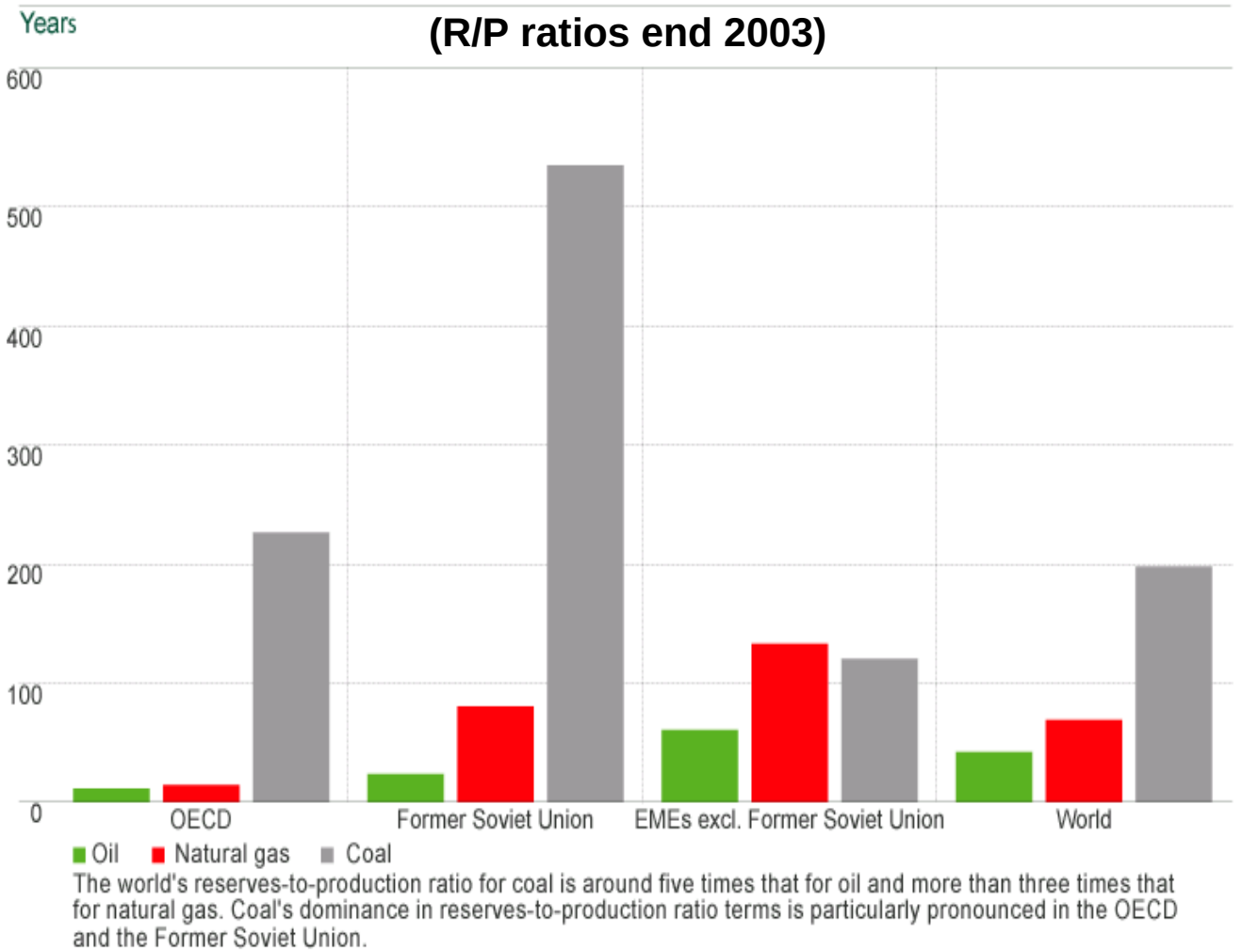
Fossil Fuel Reserves-to-production



Source:BP Statistical Review 2004

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The Challenges for Coal

Coal is a good fuel …..

- Very easy to burn and safe to store and transport
- The cost is low and “stable”.

Modern technology allow us to….

- Eliminate almost all emissions of “conventional” pollutants as sulfur and nitrogen oxides, hydrocarbons and particulates, it is only a matter of cost.
- Get a very high efficiency (over 45 %).

The big challenge is the carbon dioxide emission. If this can be eliminated we can utilize coal with confidence without endangering the climate

Options to Reduce CO_2

The options available to reduce the CO_2 emissions from fossil fuelled plants are:

- To increase efficiency. Example: Renewal of the power plants in the new countries in Germany reduced the CO_2 emissions by 40% adjusted for the same energy production.
- Change to another fuel with less carbon (gas), or to biofuels which is renewable.
- Capture and permanent storage of CO_2

Vattenfall works with all options

The EU Emission Trading System

- The long term price of the allowances will be set by reduction requirements and the costs of physical reduction
- As emission allowances become scarce they will have an increasing value
- The cost for allowances will be added as a direct marginal production cost and therefore increase the spot price of electricity

Analyses show that…

by 2010 …..

- Costs for emission allowances might be around 10 EUR/ton of CO2

but in 2015….

- If the trading system prevails
- When new technology for fossil fuels with near zero emissions, can play a significant role
- The cost for emission allowances will increase to 20 EUR/ton of CO_2 or higher depending on reduction demand.

This is the target to be met by new ”zero emission” technology

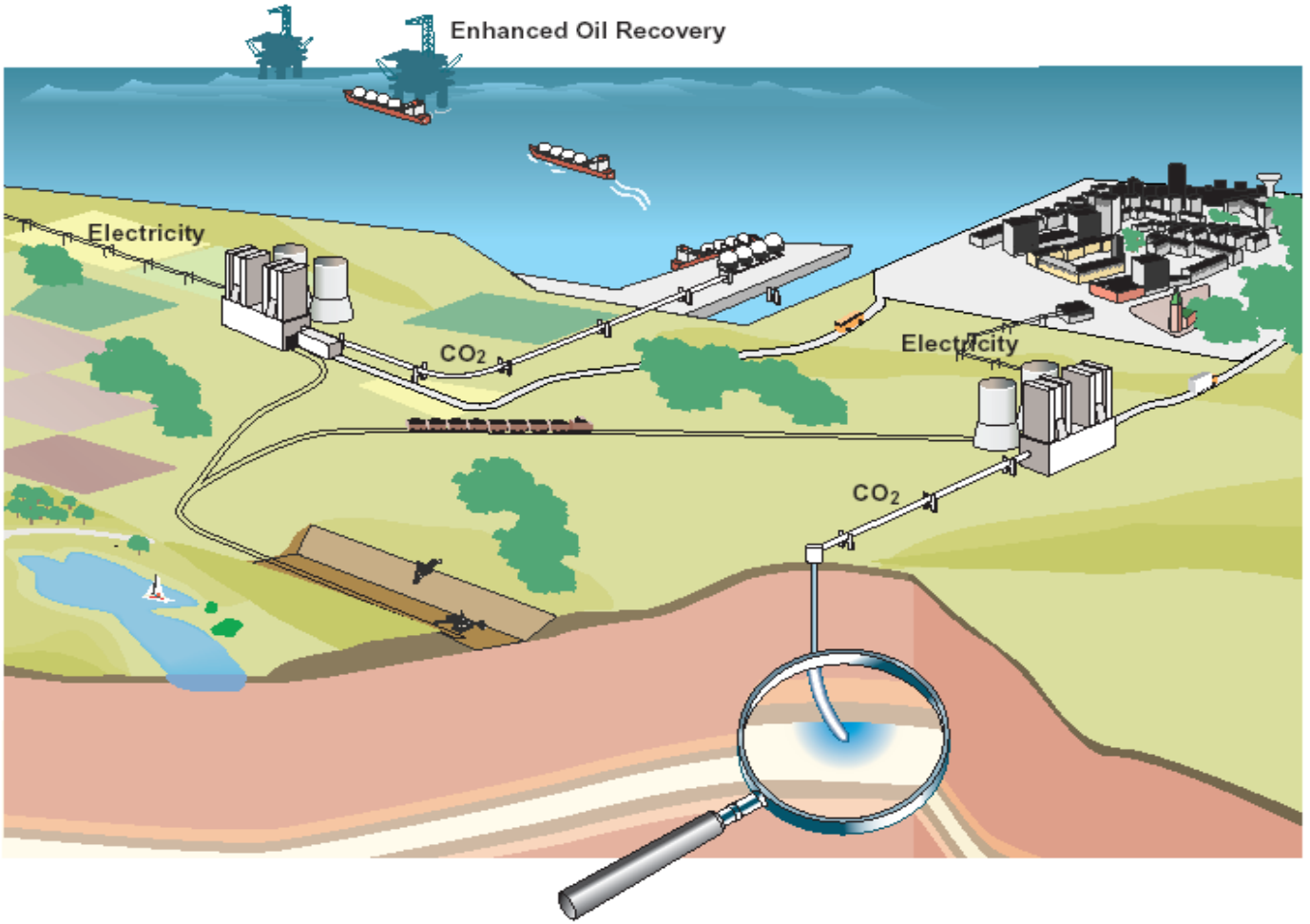
Focus for Work to Reduce CO_2

Focus for the work to reduce the CO_2 emissions from fossil fuelled plants for Vattenfall is based on:

- Our role as a leading power company in northern Europe
- Gas is always an option, but coal gives the largest potential and is the preferred energy source besides renewables
- Vattenfall would like to build on and utilize the successful development of the modern large scale lignite plants
- Capture and permanent storage of CO_2 is the main track.

  The technology choice for capture is still open
- Vattenfall is determined to have a commercial solution available in 2015.

CO_2 Capture and Storage



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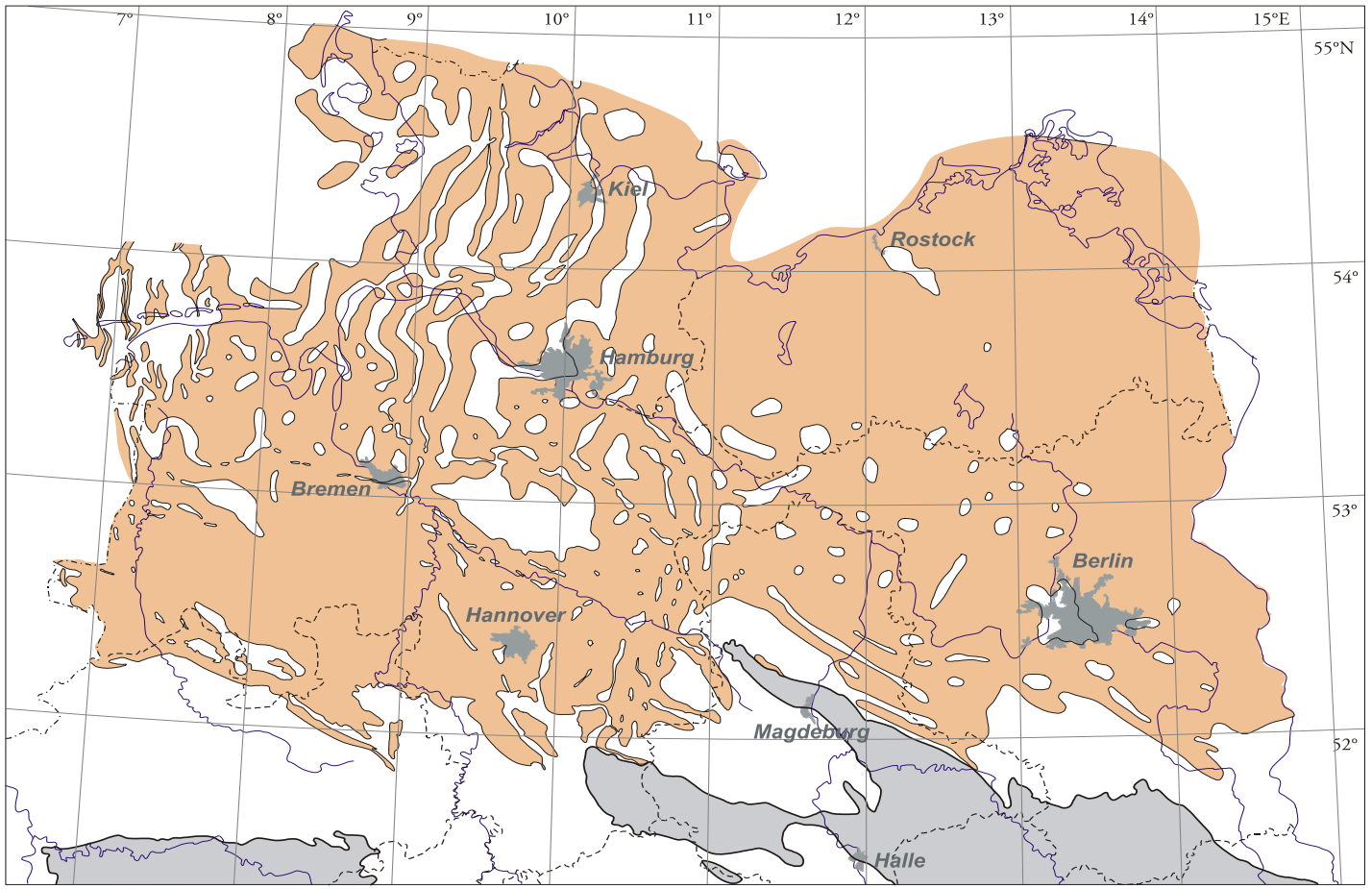
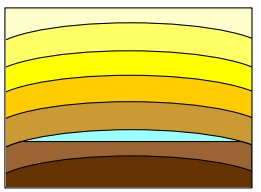
Storage Capacity, Saline Aquifers



Present day distribution of the Rhetian - aquifers (a. DIENER et al. 1984, FRISCH & KOCKEL 1998)

Specific problems:

- structurally complex
- thickness variation
- porosity variation
- residual saturation



Source: Franz May, Peter Gerling, Paul Krull, Bundesanstalt für Geowissenschaften und Rohstoffe, Hannover

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Storage of CO_2 in a Saline Aquifer under the North Sea

CO_2-injection into the saline aquifer Utsira. (Source:STATOIL)

The Sleipner field. Oil and gas production facilities. (Source: STATOIL)

CO_2 Pipelines in Operation in the USA

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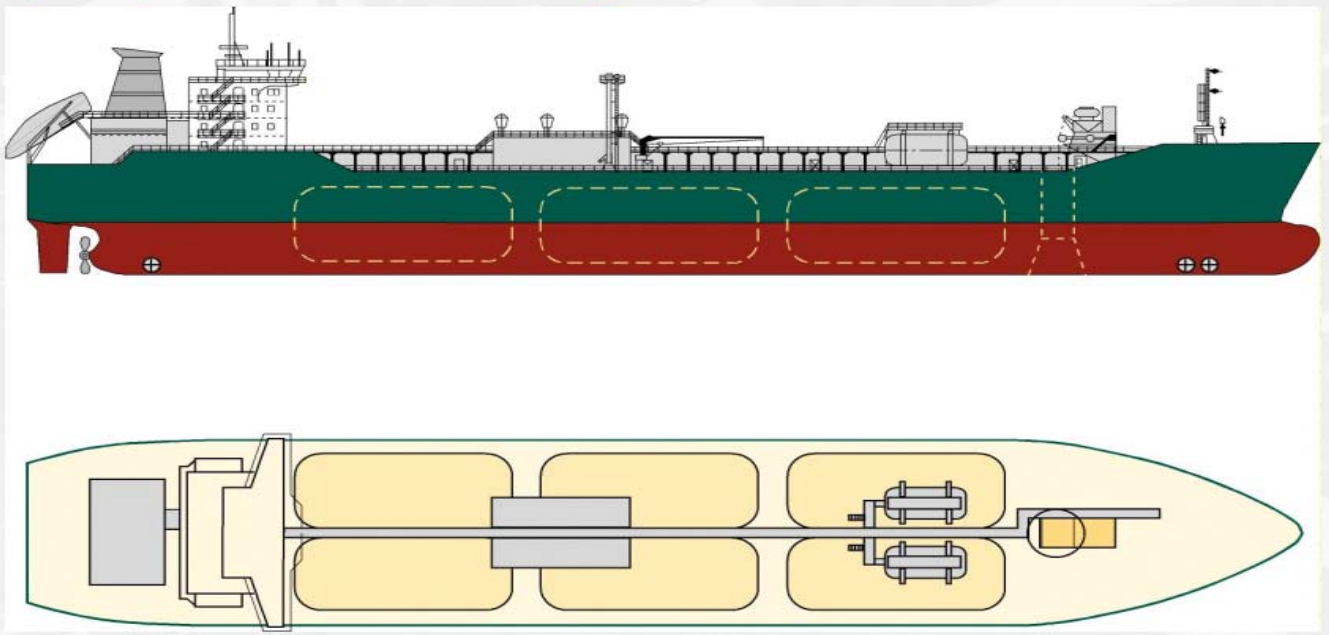
Transportation with Water Carriers

Transportation of CO_2 in Semi-Cooled Ships.

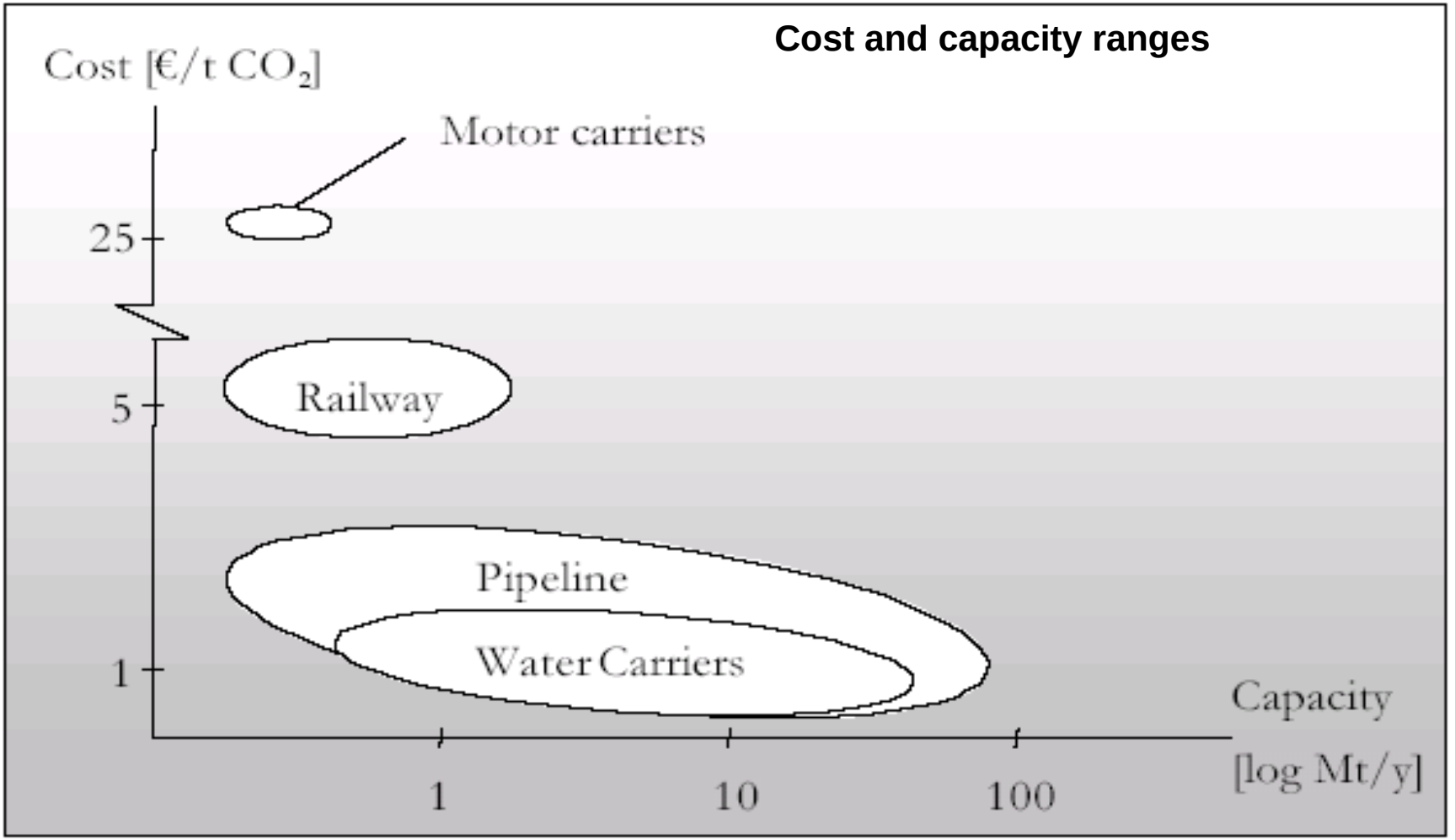
Illustrated ship has a carrying capacity of 20 000 m3

Project participants: Navion, SINTEF, Vigor and Statoil

STATOIL



Transport Costs for CO2



Source: Odenberger M, Svensson R, Analysis of Transportation Systems for CO2, Chalmers, 2003

CO_2 Free Power Plant - Capture

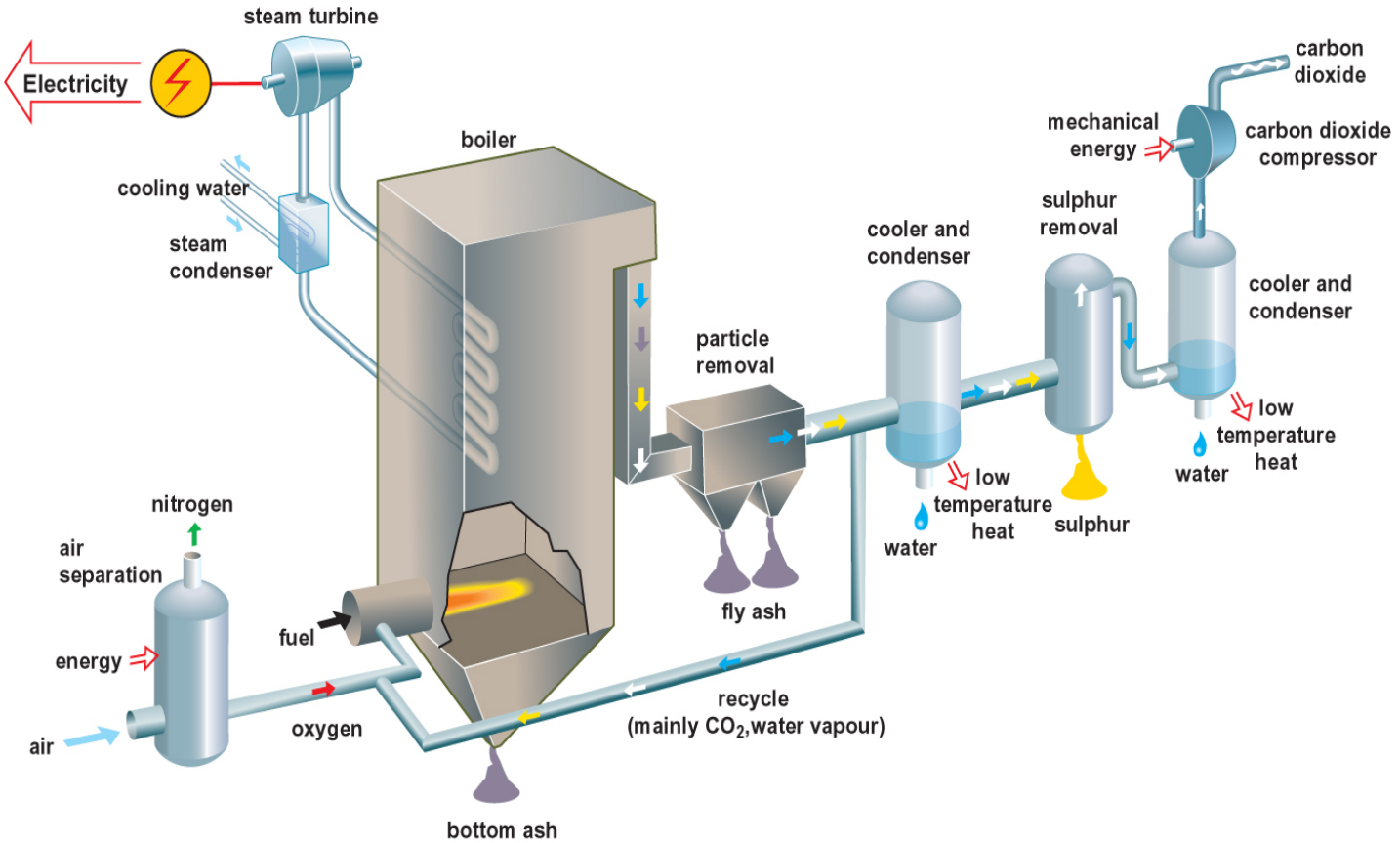
Reasonably matured technologies for capture of CO_2 are usually divided in three categories:

- Post-combustion capture, where the flue gas from the combustion is cleaned from CO_2.
- Pre combustion capture, where the carbon is removed from the fuel before the combustion.
- Utilization of oxygen for the combustion, but without the nitrogen in air, in form of either air separation or a solid oxygen carrier

Vattenfall works with all three options, but we have made an agreement with our collegues to share the workload and share results

O_2/CO_2 Combustion

-The preffered option at the moment



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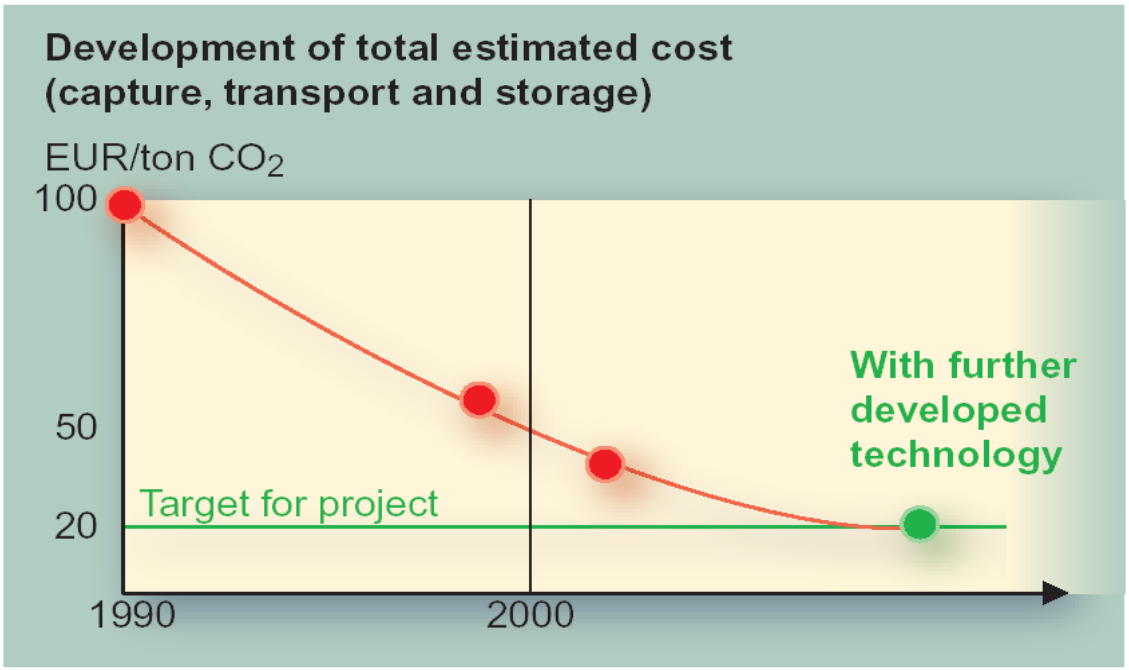
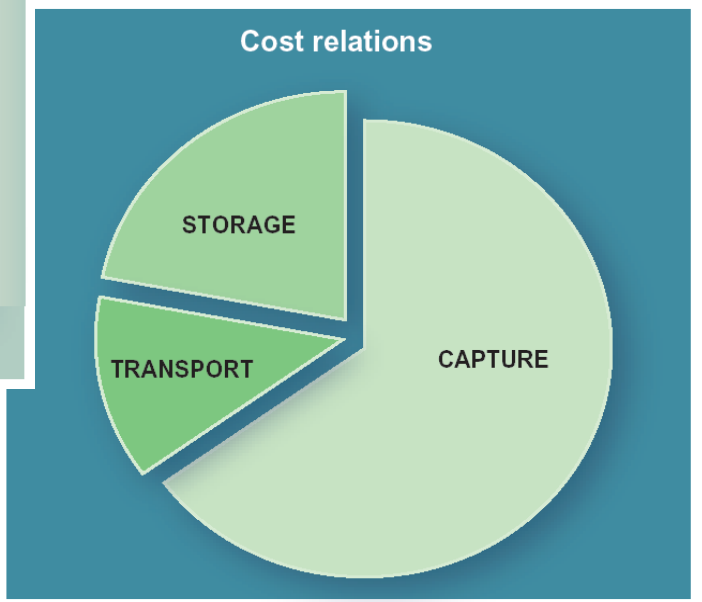
CO_2 Capture and Storage – Cost Estimates





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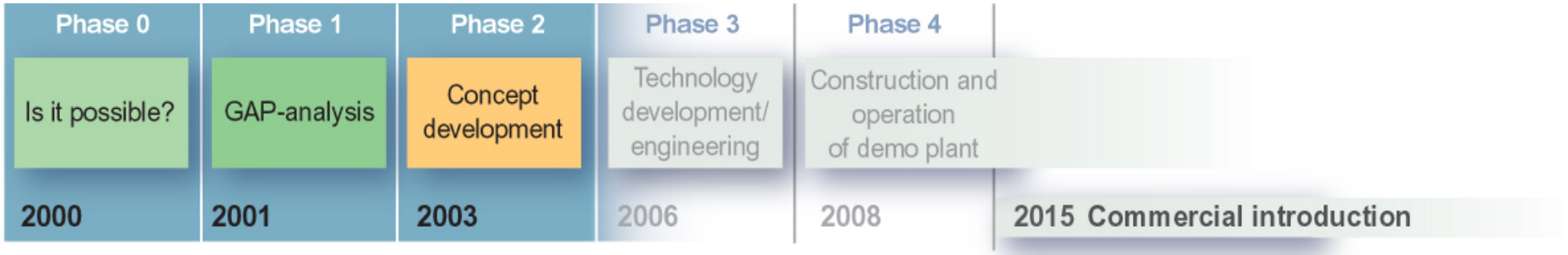
15 Years of Research and Development



- Development target 20 €/ton stored CO_2
- Initial feasibility studies in 2001
- GAP analyses in 2002
- Concept development in 2003-2006
- A 250 MW electric demo-plant by latest 2010
- Commercial concept by 2015

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Conclusions

- Fossil fuels are needed many decades yet. There is no other option available large enough
- CO_2 capture and storage can enable energy generation at a lower cost than most renewable alternatives.
- The CO2 emission trading scheme sets the commercial framework for new technology
- If CO_2 capture and storage is developed to a viable option with avoidance costs down to 20 €/ton of CO_2, the technology can be commercially introduced.
- ”Carbon dioxide free” energy production from fossil fuels can not be introduced at a larger scale before 2015.

Coal is competitive with gas. The commercial alternatives will be coal with CO2 capture and storage and gas without capture, taking the punishment from the trading system.

Back-up slides

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ENCAP Project Partners

Power companies

- Energi E2, Public Power Corporation, RWE Rheinbraun, RWE Power, Vattenfall (project leader)

Manufacturers

- ALSTOM Boilers, Power and Turbines, Mitsui Babcock, Siemens

Technical gas companies

- Air Liquide, BOC, Linde

Gas and oil companies

- Statoil, Norsk Hydro

Engineering companies

- Lurgi, Uhde

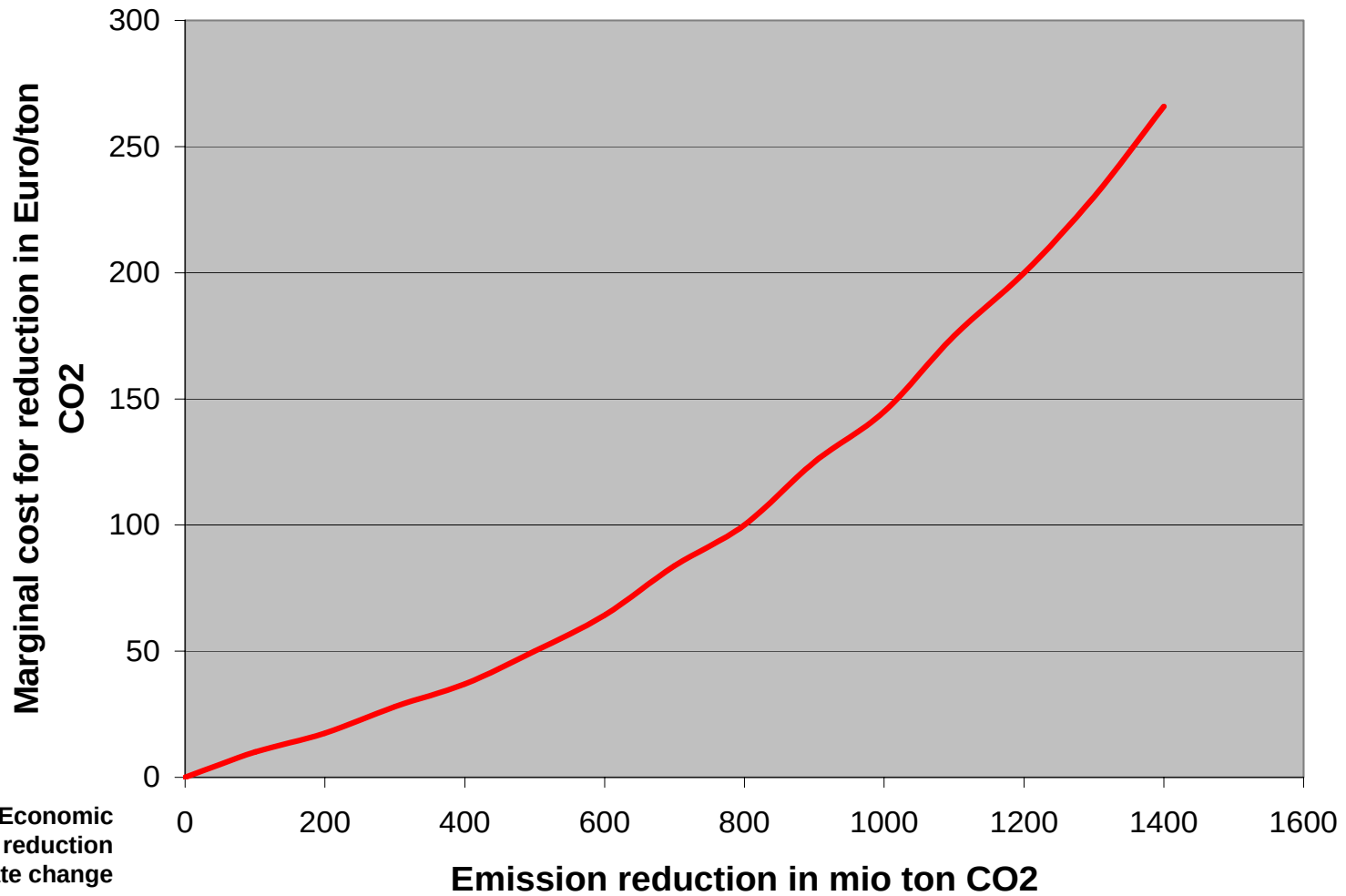
Research institutes

- IFP, Sintef, DLR, ISFTA, TNO

Universities

- Chalmers UT, Imperial College, IST, NTNU, U Lund, U Ulster, U Paderton, U Stuttgart, U Twente

Marginal Cost vs. Reduction of CO2 Emissions (EUR/ton CO2)



Source: ECOFYS Economic evaluation of sectorial reduction objectives for climate change

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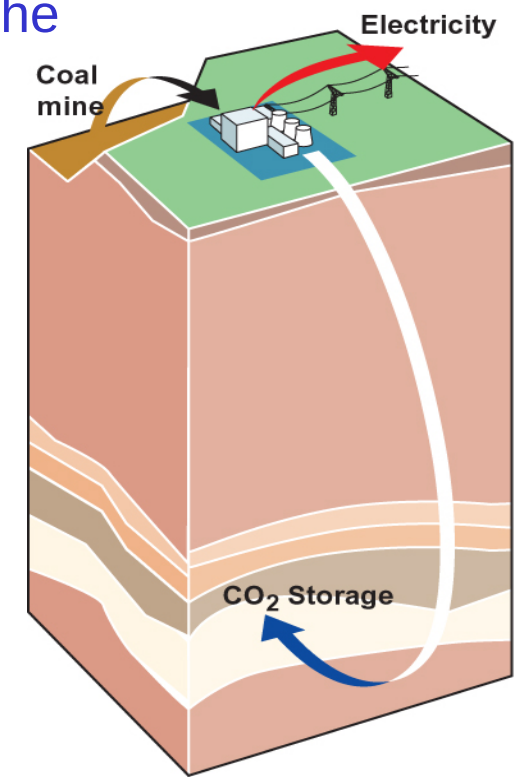
The CO_2-free Power Plant Principle

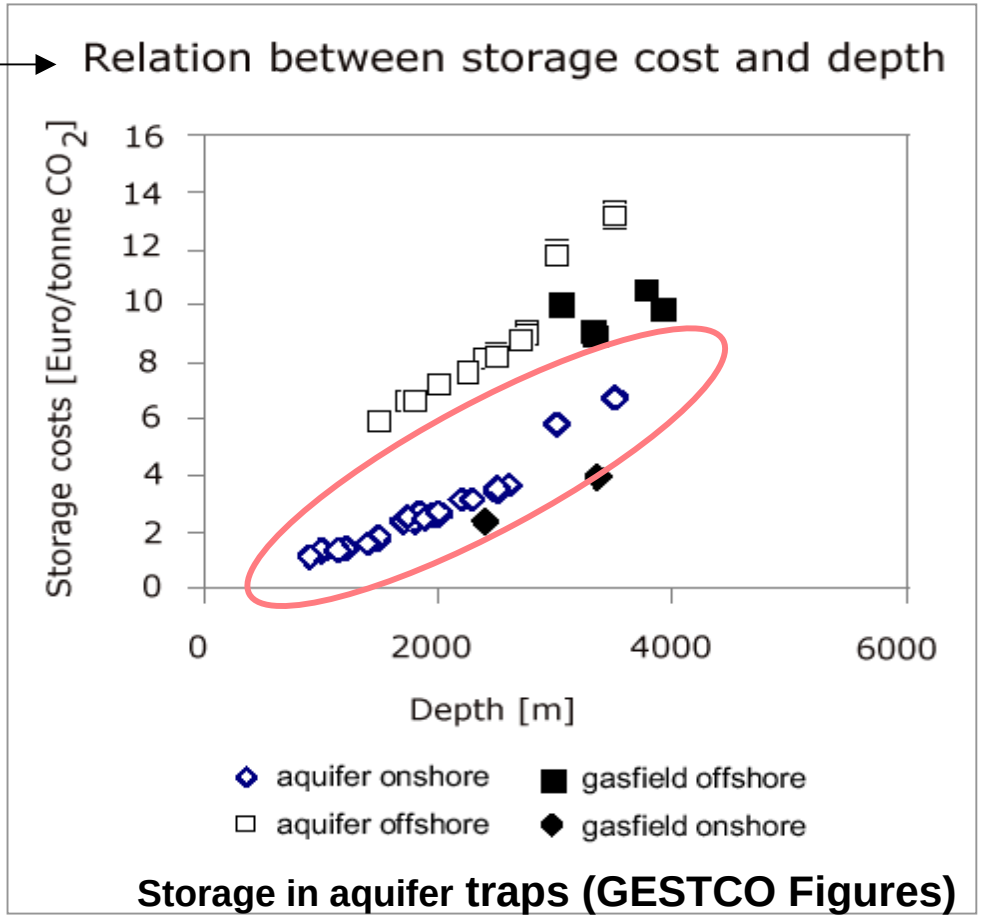
The principle of capture and storage of the CO_2 under ground



- The CO_2 can be captured either from the flue gases, or is the carbon captured from the fuel before the combustion process.
- The CO2 is cleaned and compressed. Then it is pumped as a liquid down into a porous rock formation for permanent storage.

Storage Cost Estimates

- **Costs depend strongly on the depth of subsurface layers used for storage**
- **The strongest subsurface uncertainty in storage costs lies in the time it takes to fill the trap**
- **The second important uncertainty parameter is the exploration success ratio of finding a suitable trap**
- **Dutch case: CO2 source of 5.7 Mton/year stored in one megatrap or a conglomerate of traps. Total sequestration cost: 17-20 Euro/ton CO2 .**



Storage in aquifer traps (GESTCO Figures)

Source: Christian Bernestone Vattenfall Utveckling

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