Office of Technology Assessment at the German Parliament

Climate Protection via CO_2-Capture and -Storage

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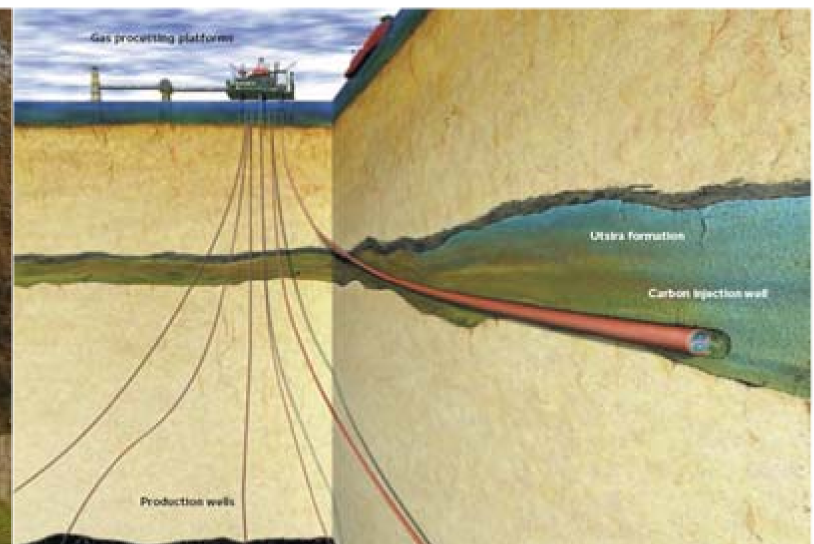


Université de Genève Seminar 5. March 2009

What is TAB?

- Independent scientific institution, operated by Research Centre Karlsruhe
- Work exclusively for Parliament and its Committees
- Main Objective:

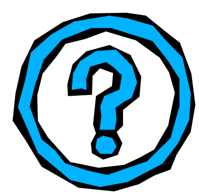
  Enhancing the information/knowledge basis of parliamentary deliberations and decision making on scientific and technological topics

Starting Point

- Energy supply in Germany (and other countries) is not sustainable
- Fossil energy sources (Oil, Gas, Coal) contribute > 80 %
  - Fossil resources are limited
  - Greenhouse gas CO_2 is produced
- 2°C - goal requires that greenhouse gas emissions are brought down by ~80% till the middle of this century

➔ **Key Question:**

Can Carbon Capture and Storage contribute to a more sustainable energy supply?



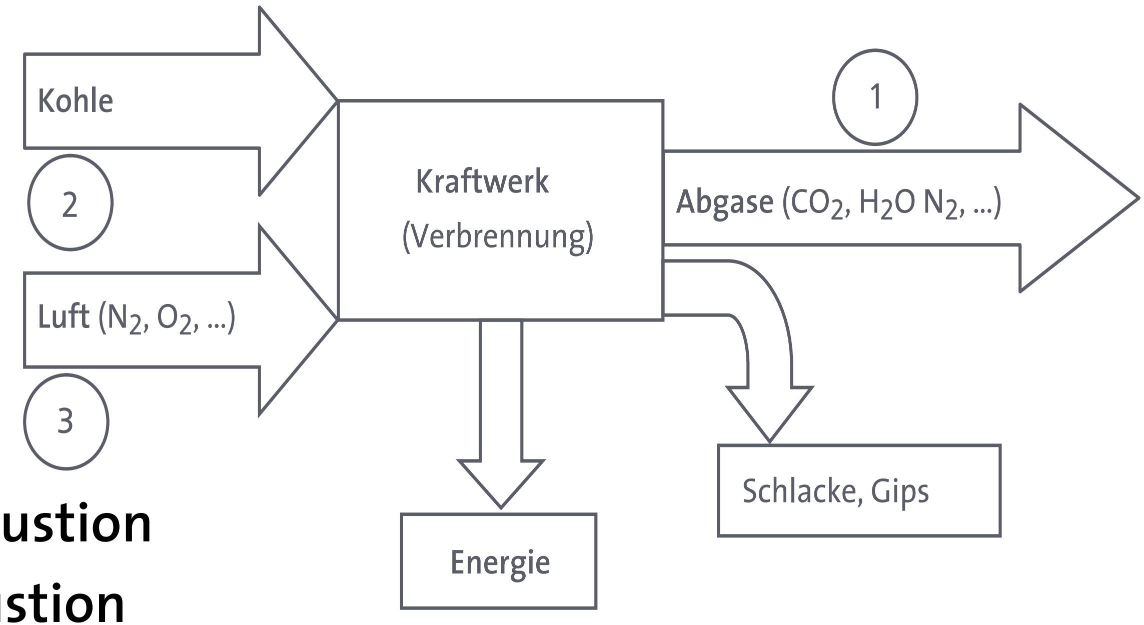
Overview

- State of Development
  - CO_2-Capture
  - Conditioning and Transport
  - CO_2-Storage
- Storage Potential
- Safety, Risks, Environmental Impacts
- Costs
- Integration into the Energy System
- International Perspective
- Public Opinion and Acceptance

State of Development

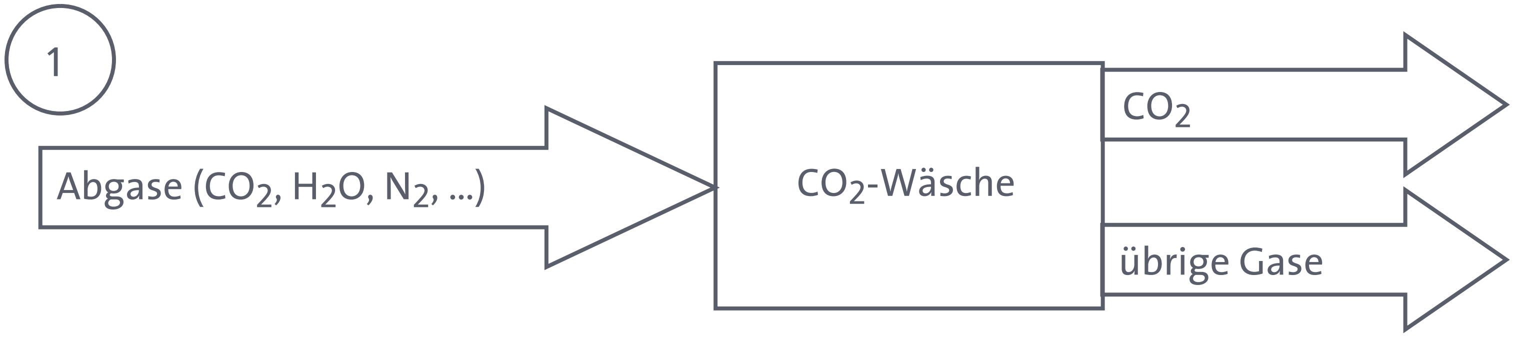
- CCS is suitable for big stationary CO_2-Sources
- It is being particularly discussed for coal power stations „Clean Coal“
- Technology Chain
  - CO_2-Capture
  - Conditioning and Transport
  - Storage (deposition)
- for operational availability the year 2020 is often quoted

Processes for CO_2-Capture



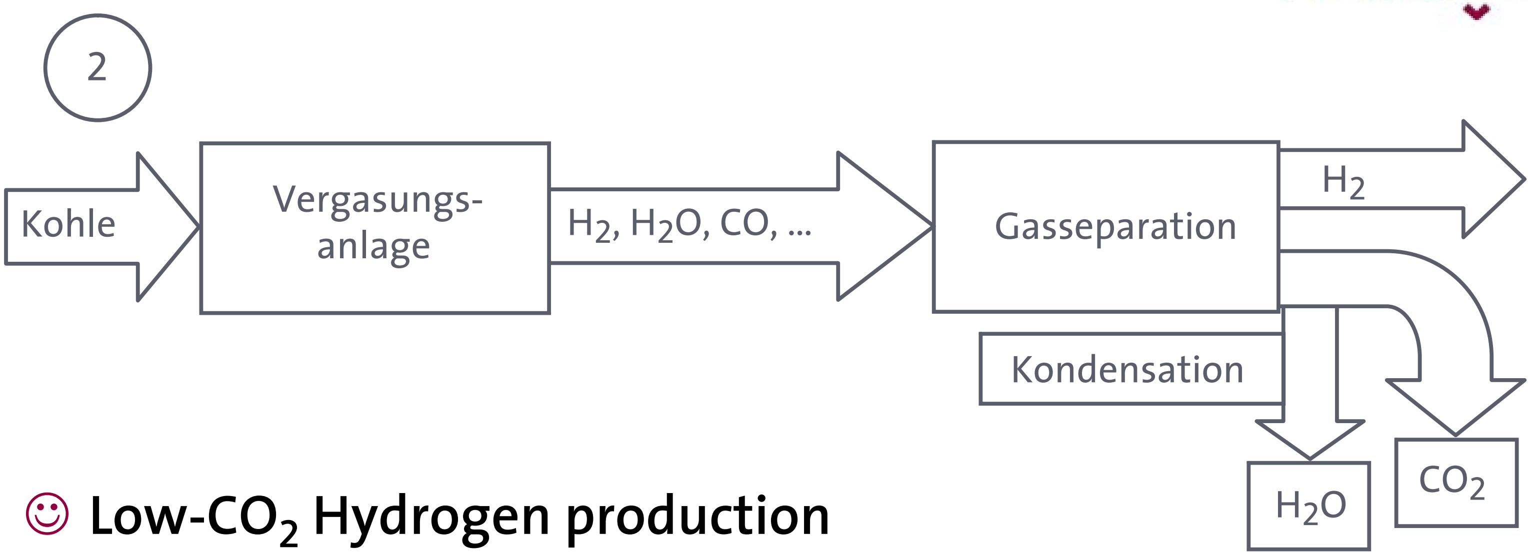
1. Post-Combustion
2. Pre-Combustion
3. Oxyfuel

Post-Combustion



- ☺ **Commercially available process, retrofit possible**
- ☹ **Efficiency of electricity generation drops drastically eg. from 45% to 31-37%, fuel consumption rises by 10-40%**
- ⇨ **Technological challenges: Up-scaling (50 times), development of better solvents, future: selective membranes**

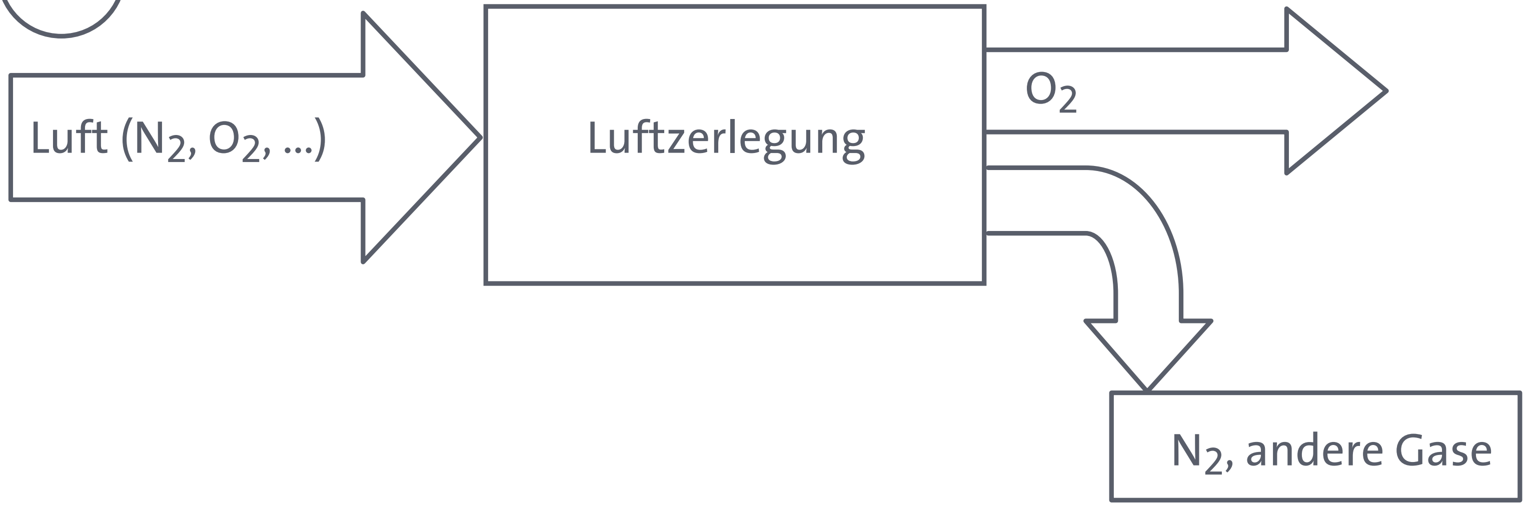
Pre-Combustion



- ☺ **Low-CO_2 Hydrogen production**
- ☹ **Highly complex processes (IGCC)**
- ⇨ **Hydrogen turbines, process integration, membrane methods**

Oxyfuel

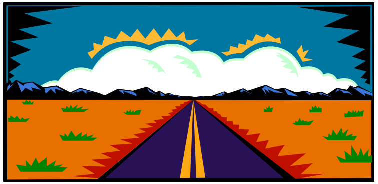
3



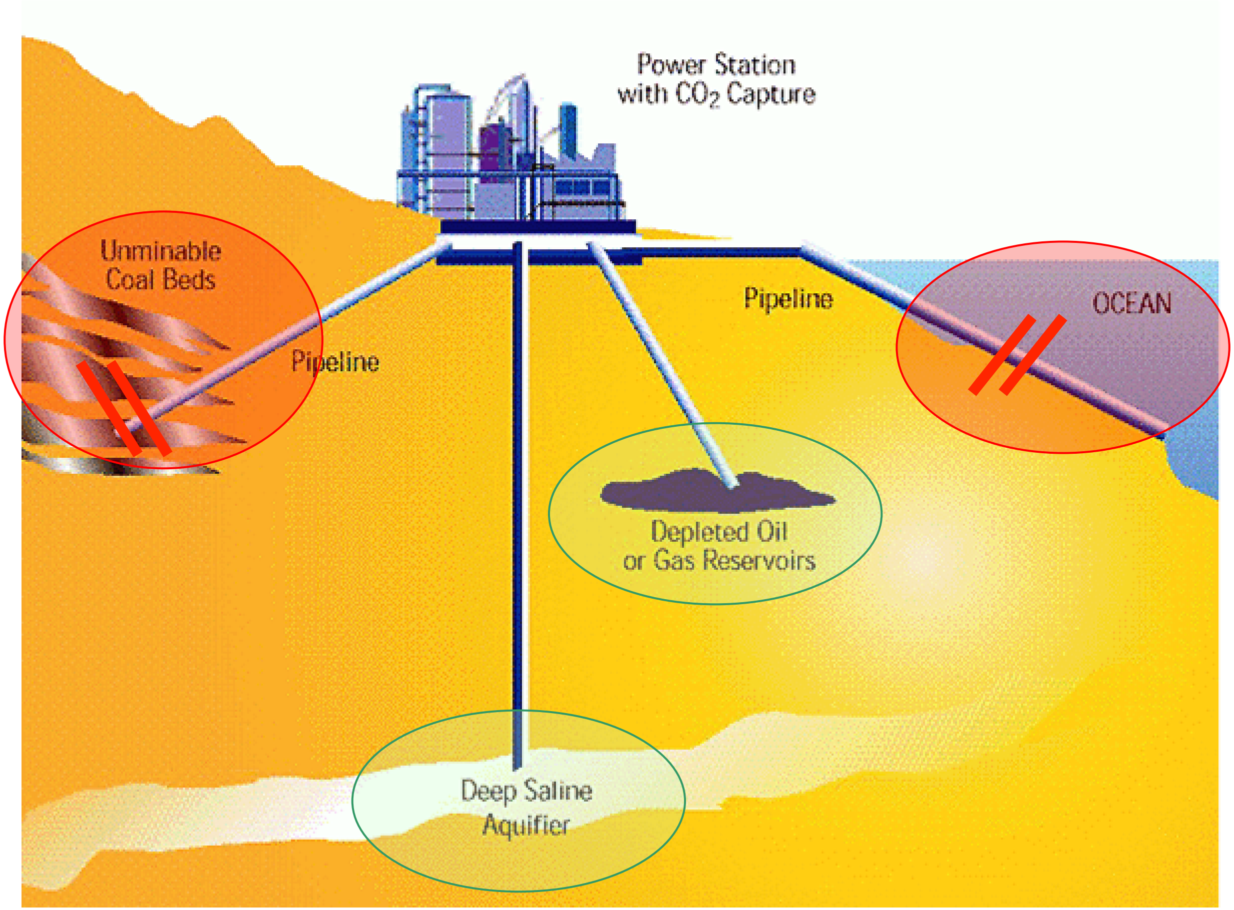
- ☺ Less effort and costs for CO_2-Capture
- ☹ Energy consumption for Oxygen production, impurities in the CO_2 could be a problem
- ⇨ Membrane methods, process integration

CO_2 Conditioning and Transport

- Deal with big streams of CO_2 (eg coal power plant $1000MW_{el} \rightarrow$ 5 Mio t/a)
- Transport by: Pipeline, Ship
- CO_2 has to be liquefied (or „supercritical“) (needs energy)
- Open questions
  - Corrosion resistant materials
  - Role of impurities
  - Build-up of Infrastructure (regional planning)



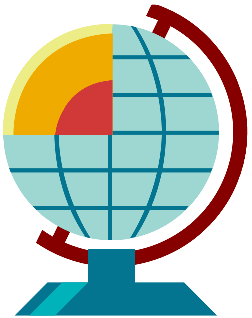
CO_2-Storage



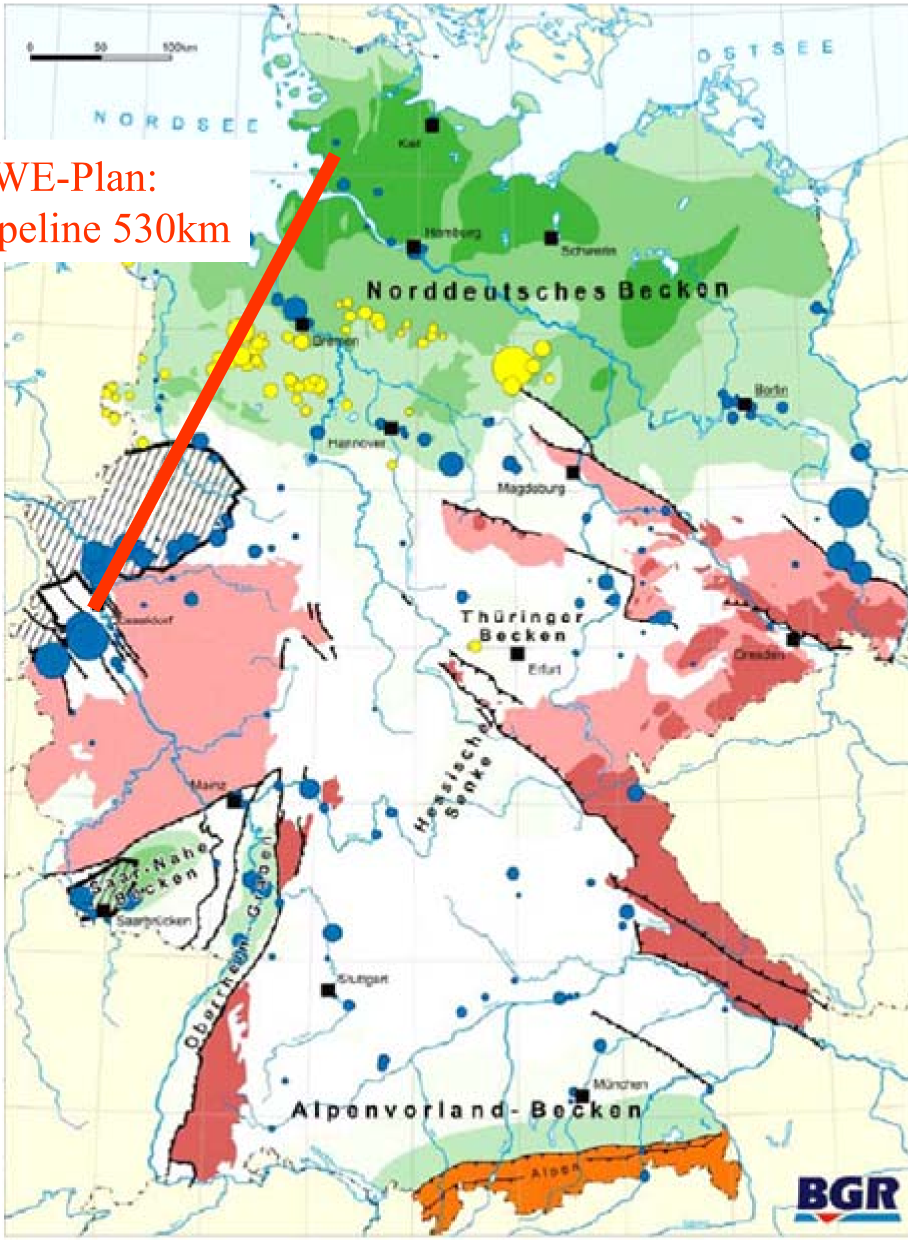
Quelle: IAE GHG

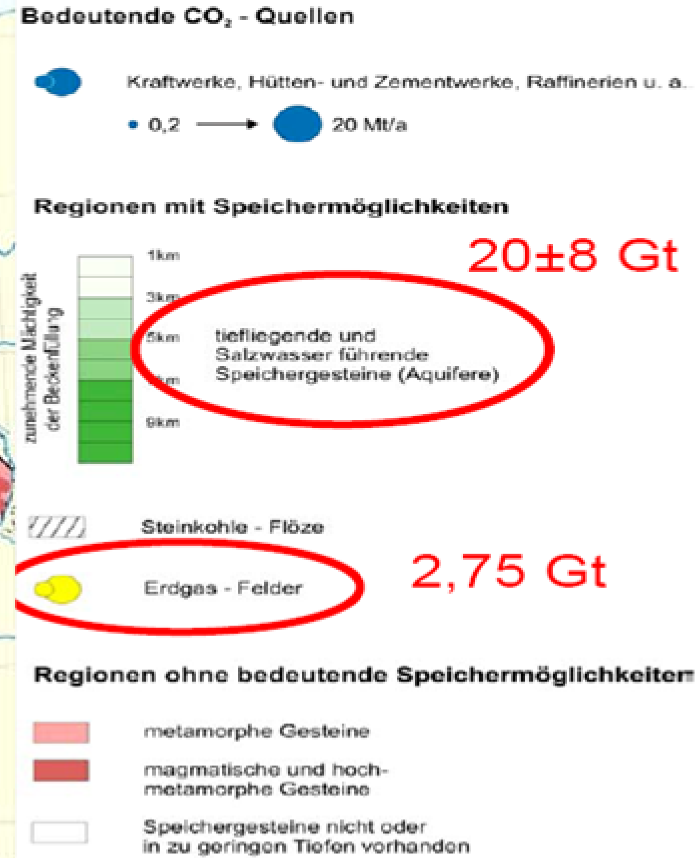
Storage Potential

- Estimations of worldwide storage potential show an enormous spread
  - 100 bis 200.000 Mrd. t CO_2
- In Germany they amount to about 40- to 130-times the annual CO_2-Emissions of all power plants
- Geographical distribution: mainly in northern Germany
- Not all possible storage formations will be usable
- Restrictions:
  - geologic details, competing usages (eg geothermal energy), economic, legal and political framework



Storage potentials





➔ BGR develops currently a register of storage sites (finish 2010)

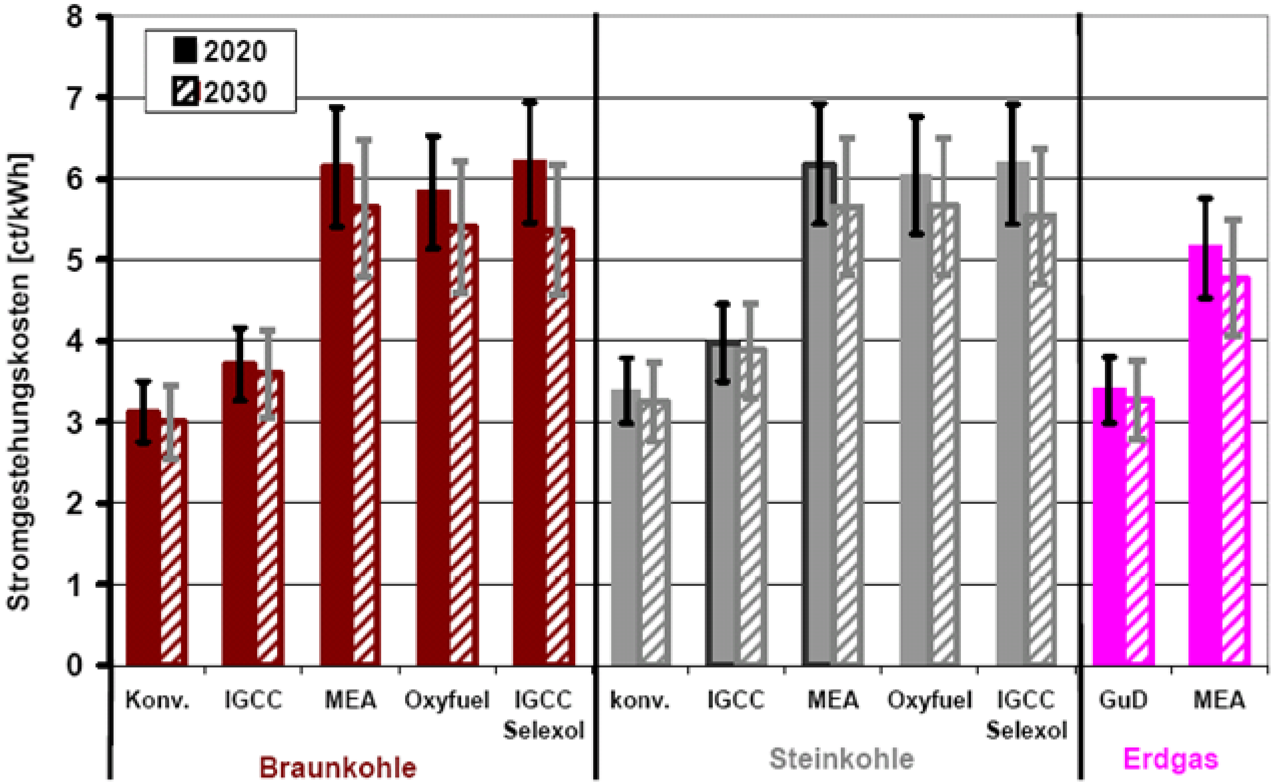
Safety, Risks, Environmental Impacts

- Focus of risk discussion: Geologic Reservoirs
  - Storage permanence: at least 1.000 to 10.000 years
- Safety and permanence of CO_2 storage could be compromised by:
  - Dissolution of rock by CO_2/water-mixture (carbonic acid!)
  - Pressure induced enlargement of existing fractures and rifts
  - Leakage through existing old boreholes
- Generic conclusions with respect to the safety of specific storage formations have limited validity
- Each reservoir has to be examined individually
- Minimise risiks by
  - Suitable regulation
  - Continuous Monitoring

Costs

- Cost breakdown
  - CO_2-capture is dominant cost factor: ca 26 - 37 /t
  - Transport: ca 2 /t (typical case: 250km, 5 Mt/a, easy terrain)
    Can be 10 times higher eg in urban areas
  - Storage: -10 /t (for EOR) to 10 /t
    (depends strongly on geological details)
  - Other cost components: Monitoring, liability/insurance, restoration
- Electricity generation costs increase to 5-7 ¢/kWh (in 2020)
  - Many renewable energy technologies could reach a comparable cost level
  - Cost projections depend on a number of assumptions
  - It is evident that CCS does not enjoy a unique selling position
- CCS only attractive if financial incentives for CO_2-mitigation is big enough (eg price for EU-Allowances)

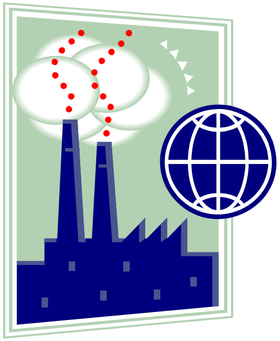
Electricity generation cost with and without CCS



Source: Linßen et al. 2006

Integration into the Energy System

- Availability of CCS-Technology is expected around 2020
- Considerable need for renewal of power plants in the next years
- If the modernisation cycle is finished, structure of power generation is fixed for centuries to come
- The „window of opportunity“ is narrow and starts closing after 2020
- If the „Capture Ready“-concept is credible is still an open question



International Perspective

- CCS-Technology could be attractive for countries that
  - are sceptical about climate protection (USA, Australien)
  - want to use domestic coal resources (China, India)
- In China between 1995 bis 2002 about 100.000 MW fossil fuelled power stations (mostly coal) have been built.
- For 2002 to 2010 additional 170.000 MW are expected
- If this trend continues international efforts for climate protection would be seriously dwarfed

Public Opinion and Acceptance

- Technologies like CCS („big“, „under ground“, „waste“) are prone to trigger public concern and opposition
- Lack of public acceptance can be a potential „Show Stopper“
- Securing a high degree of acceptance must be a high ranking objective

- Nation-wide discourse and participation process should be initiated before concrete siting decisions have to be taken (NIMBY!)

Regulation

- Regulation has to pursue three objectives
  - Assure that CCS is permissible
  - Provide incentives that investments in CCS are realised
  - Ensure that CCS does not fail because of lack of acceptance
- There is urgent need for action because planned Pilot- and Demonstration-Projects need legal basis
- The awareness for urgency seems to have been established
  - EU CCS-Directive was adopted in record-breaking time
  - German CCS-law is up for decision in the next few weeks

The Way Forward (1)

- 10-12 Demonstration plants in Europe
  - 300 Mio. allowances from EU Emission trading scheme (equivalent to 6-9 Mrd. Euro)
- Exploration and field tests for storage in different geological formations
- Broaden the science-base – Close critical knowledge gaps
  - Interactions of CO_2 in the ground
  - Determination of suitability and capacity
  - Competing usage
  - Capacity Building and technology transfer to emerging countries (China, India)

The Way Forward (2)

- Integrate social and environmental accompanying research
- Align Technology development with criteria of sustainable development
- Provide decision-relevant knowledge concerning economic, ecologic and social impacts
- Initiate public debate and develop acceptance
  - Develop and implement a nation-wide communication, information and participation strategy