Carbon Dioxide – CO_2

WSF - Meeting

Den Helder – 18.5.2010

Rothkopf-Concept GmbH
Hermann-Ehlers-Str. 16
26386 Wilhelmshaven

Dr. H. W. Rothkopf

Agenda

Introduction

Political Targets

April 2007

- G: Carbon dioxide reduction by 40% until 2020 (Basis: 1990)
- EU: Reduction by at least 20 % until 2020 (80-95% by 2050)

HOW?

Improve share of renewable energies until 2020 (actual in 2005):

Heat:	14 %	(5.4 %)
Electricity:	27 %	(10.2 %) (16 % 2008)
Fuel:	17 %	(3.4 %)

?

AND

- Further option: Carbon Capture and (underground) Storage (CCS)
- Reduction of fossile carbon use and efficiency improvement

Facts and Figures 1

Actual

- 3 000 billion tes of CO_2 (770 billion tes of carbon) are processed within the system „world“
- app. 27 billion tes (1 %) per year are added by emissions
- 45% remain in atmosphere, 55 % absorbed in natural sinks (sea, biomass)
- 870 million tes (3.2 %) per year in **Germany**
- 480 million tes per year by industry and energy production

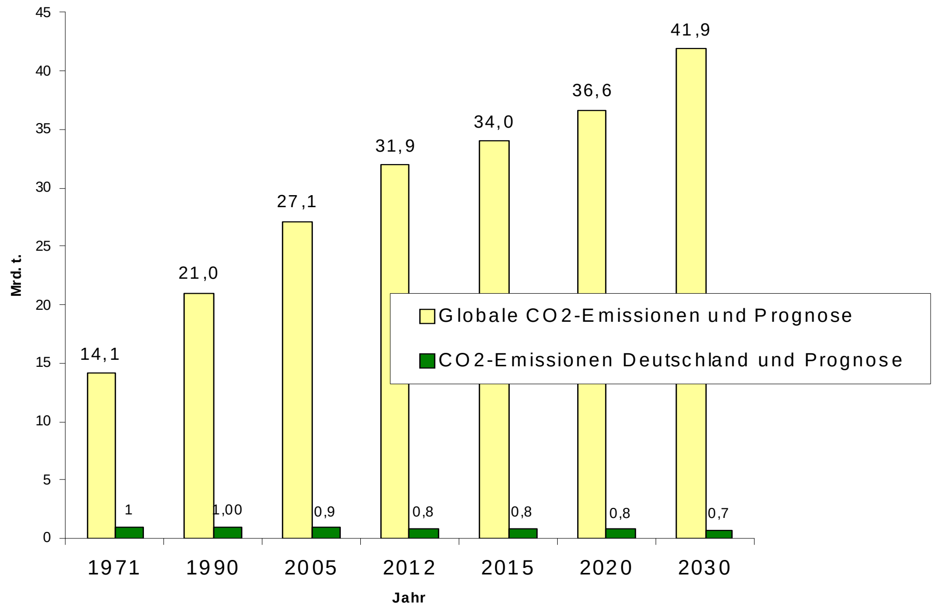
Emissions (tons per capita and year:

Germany:	ca. 10
USA:	ca. 20
China:	ca. 3.5

→ Welfare

Facts and Figures 2

Development of CO_2-Emissions



Source: Bundesministerium für Wirtschaft und Technologie (MR Werner Ressing)

Facts and Figures 3

Conclusion

CO_2 - increase is a global issue and cannot be solved locally

Any achievement on the reduction targets for Germany or EU will be compensated within some weeks!

Responsible allocation of ressources should maximise their return!

Properties 1

Photosynthesis

Carbon dioxide + water + *energy (sun)*

↓

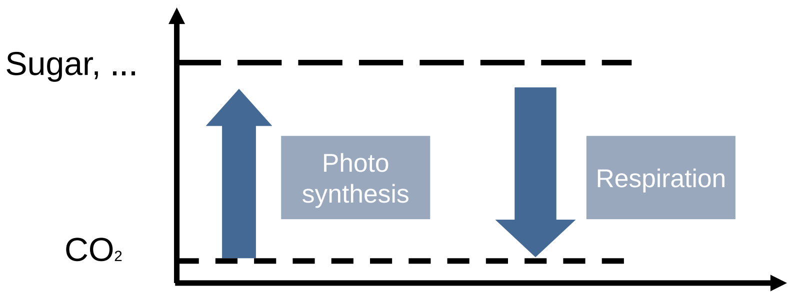
Food, sugar, wood, coal, plants,....

↓

Respiration / Combustion

Carbon dioxide + water + *energy*

Energy level



Properties 2

Carbon dioxide properties

Carbon dioxide‘s energy level is extremely low

→ Carbon dioxide is an extremely unreactive molecule

→ ANY technical / physical / chemical treatment, reaction or storage will require

- Significant additional energy input

and hence

- Significant costs

Without Greenhouse Gases the average temperature on earth: - 15 °C !!

Properties 3

Carbon dioxide properties

- Natural gas, colourless, odourless
- Ambient air approx. 390 ppm (0,039 %)
- Breathable air approx. 4 %
- Acidic taste - carbonic acid – mineralisation processes
- Specific weight higher than air (Factor: 1.5)
- Toxicity
  1. Due to displacement of oxygen in breathable air
  2. At higher concentrations (> 8%) respiratory paralysis
- No acute toxicity (compared eg. to carbon monoxide)

Properties 4

Sources - System

870 million tes per year in **Germany**
480 million tes (56 %) per year by
industry (10 %)
energy production (46 %) POINT SOURCES

390 million tes p.a. by
traffic
private households / use DIFFUSE SOURCES

→ Only point sources (industry, energy production) can be used for CO_2 separation (and use):

→ Transfer diffuse sources (e.g. cars) into point sources (electricity for cars)

→ Scientific / practical problem: Where are the system bounderies for setting up a modell for a „CO_2 –neutral or friendly area“?

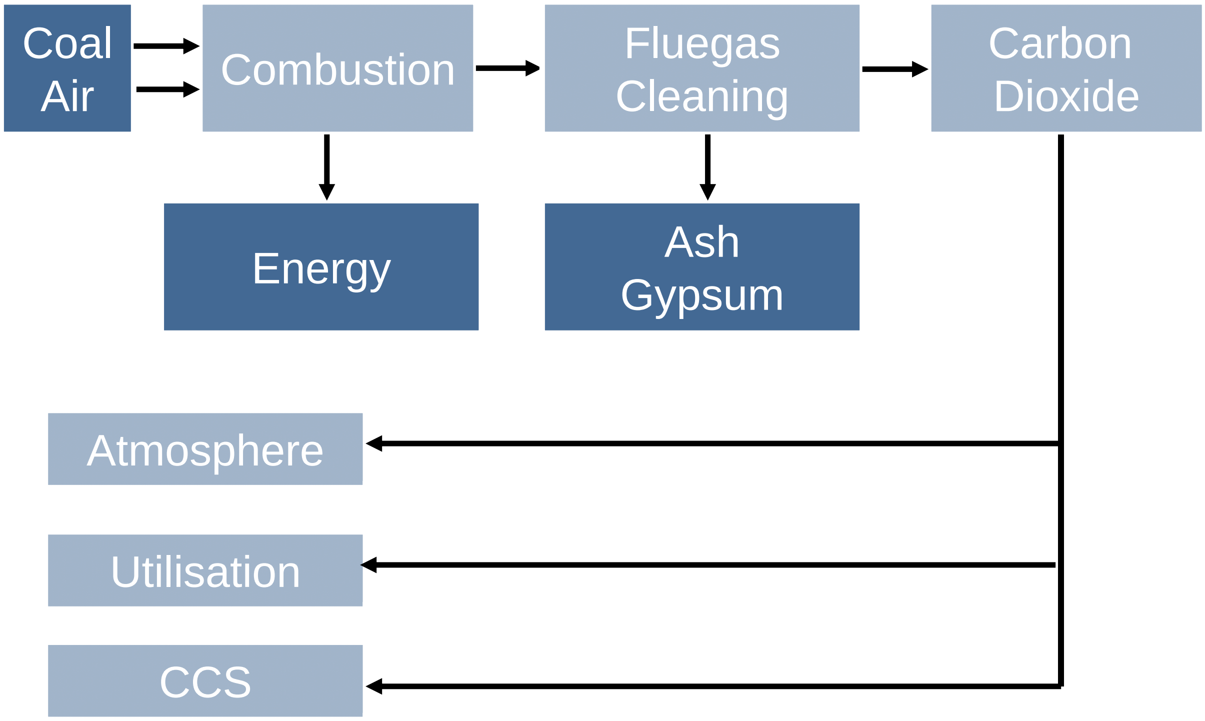
Ways Forward

- Improve the use of renewable energies (incl. necessary infrastructure)
- Improve efficiencies of existing / future „CO_2 producing systemes“
- Remove CO_2 by capture and storage methods → CCS
- Reuse of CO_2 as input material (instead of waste) → CCU
- Save carbon systems for better use
- Improve trading of emission certificates
- Gas, Nuclear necessary for some time

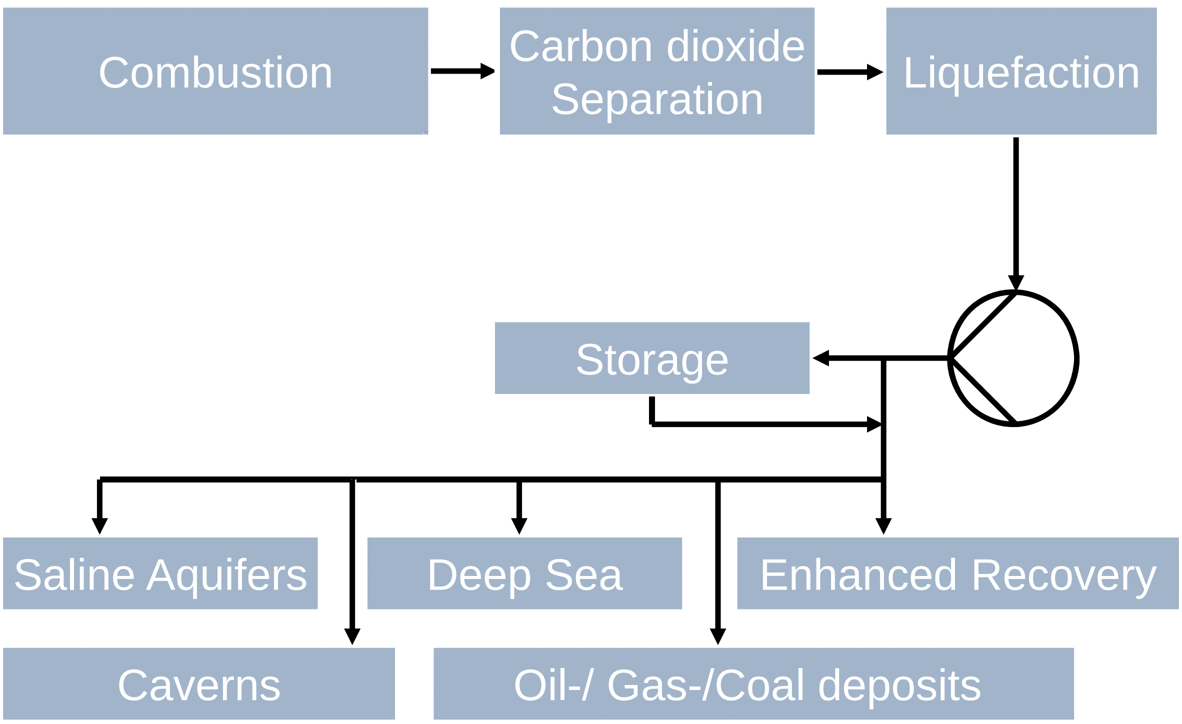
Carbon Capture and Storage CCS

- CO_2 – Separation
- CO_2 - Transport
- CO_2 - Storage

CCS 2


Coal
Air
Combustion
Fluegas Cleaning
Carbon Dioxide
Energy
Ash
Gypsum
Atmosphere
Utilisation
CCS

CCS 3


Combustion
Carbon dioxide Separation
Liquefaction
Storage
Saline Aquifers
Deep Sea
Enhanced Recovery
Caverns
Oil-/ Gas-/Coal deposits

Carbon Capture and Storage: Test and Demonstration

13.4.2011 / Evaluation in 2017

Deals with: Separation, Transport und Storage of Carbon dioxide

Political Targets:

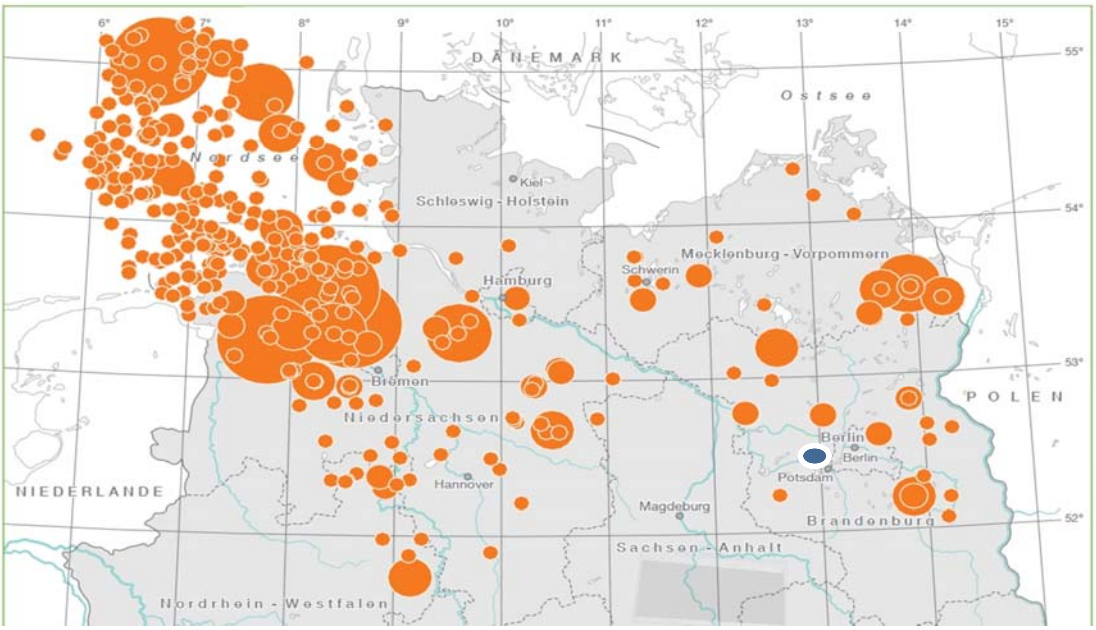
- Comply with European legislation (CCS-RL Jan. 2008)
- Test / Demonstration of the necessary technical issues in pilot plants
- Exploration of suitable (geological) deposits
- Secure improvement/revamp of existing energy plants (coal / lignite)
- Secure environmental friendly energy supply based on coal / lignite
- Reduce dependency from foreign energy suppliers
- Secure technological leadership for future engineering demands
- Clarification of future responsibilities / liabilities for the safety of the storage facilities

Target

Improvement of climate change by reducing carbon dioxide in atmosphere

Potentielle CO_2-Endlager in Deutschland

in Salzwasser führendem Tiefengestein



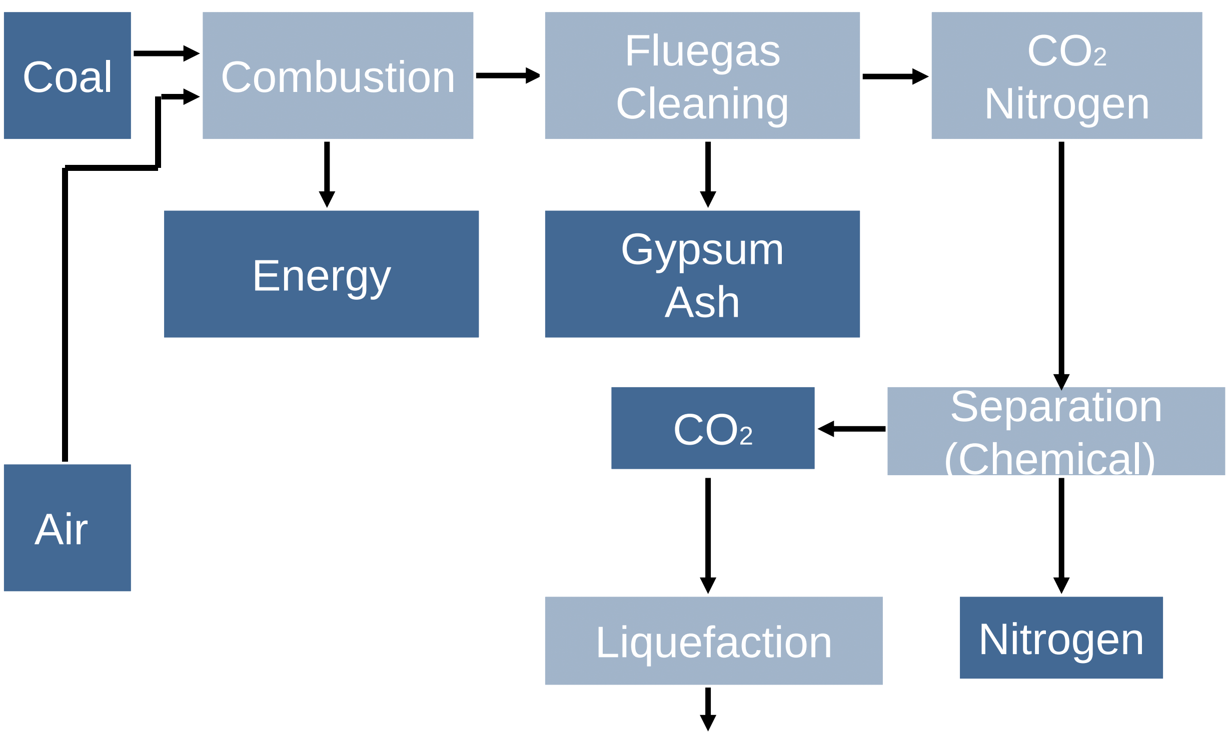
Source: Greenpeace 2011

CCS 6

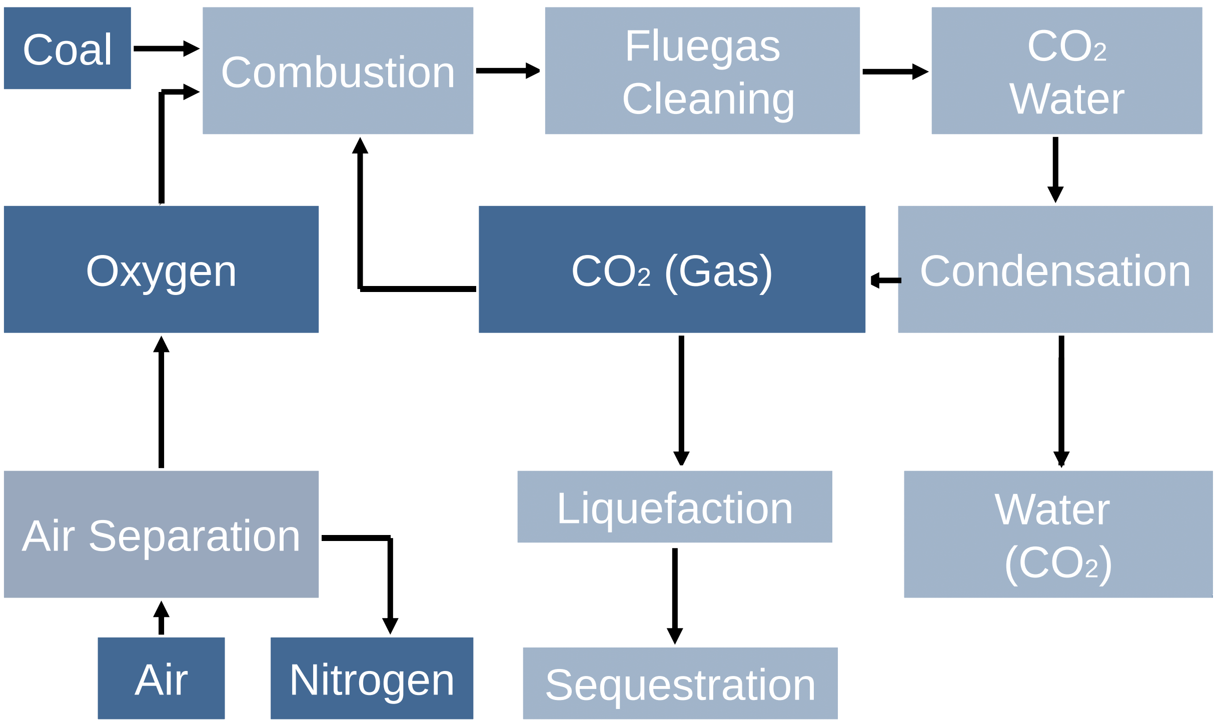
Carbon Capture and Storage Cost

CO_2 – Separation	approx.	50 € / to
CO_2 - Transport		1 – 10 € / to
CO_2 - Storage		10 – 24 € / to

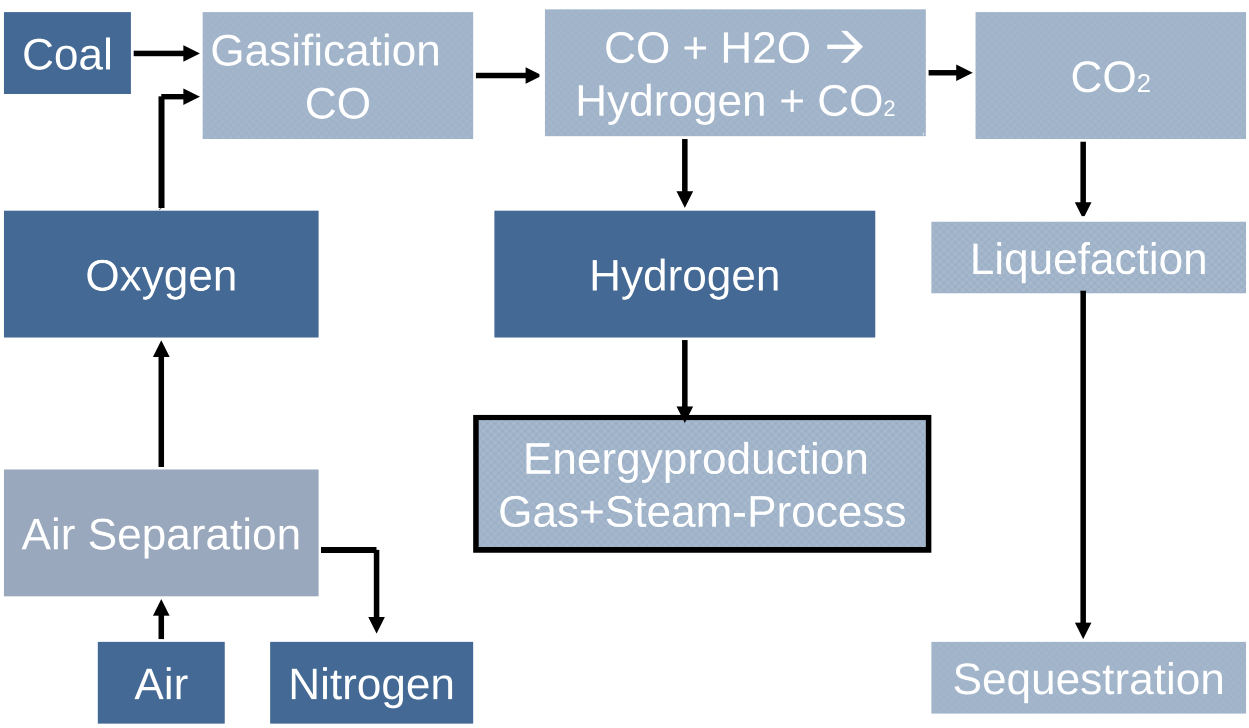
CCS 7 Energy production: Post Combustion CO_2 - Removal



CCS 8 Energy Production Process: Oxy - Fuel Process



CCS 9 IGCC (Integrated Gasification Combined Cycle) / Pre Combustion



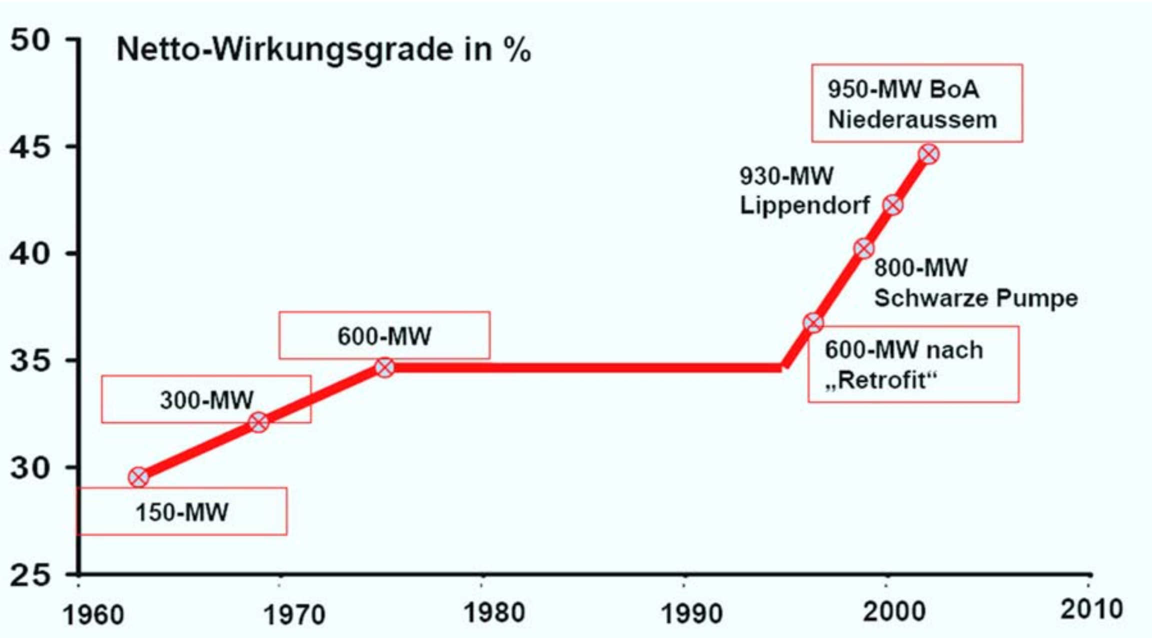
Issues of Sequestration

- Carbon dioxide transport (ship, pipeline, lorry, intermediate storage)
- Exploration of suitable / safe deposits
- Sequestration will not be ready for industrial use within the next 10 – 15 years
- Capacity of geological deposits in Germany is limited (app. 80 years)
- Unknown (long term) behaviour of carbon dioxide in the deposits
- Long term tightness of storage facilities needs to be secured
- Further intense research work necessary

Consequences

- Loss of efficiency of the energy production units: 6 -15 %
- Additional coal input (up to 20%) to maintain energy output
- Costs for sequestration: 40 (60) – 90 €/t Carbon dioxide
- Subsidies available from EU / G: approx. 1 billion €
- Long term responsibilities / Costs for the deposits („Ewigkeitsproblem“)
- Obstruction of storage capacities/ different usages for future / other purposes
- Acceptance (and KNOWLEDGE about costs involved) by the population

Development of Efficiencies



Consequences

- Billions of € spent for the burial of waste
- Billions of € spent in Germany and in EU for NO SIGNIFICANT REDUCTION
- End-of-pipe technology
- Limited lifetime of deposits
- Partly wrong allocation of ressources and wrong investment into obsolete infrastructure
- Wrong allocation of perception and attitude

CCS is economically not feasible and no sustainable solution!
Nature provides more intelligent solutions.

Alternatives 1

Pragmatic View

Very cold economic reasons are recommending the reduction of CO_2 – emissions

By processes which add value

Uncertainties about the effects and their impacts are demanding
Risk reduction and risk mitigation

Alternatives 2

Intelligent usage of carbon dioxide for the production of value added products

Utilisation by

- Chemical processes
- Biochemical processes
- (Artifical) photosynthesis
- Polymerisation

- Fine chemicals
- Bulk material
- Polymers
- Fuel
- Biogas

Reduce carbon input into energy production systems
More sustainable use of carbon containing ressources (oil, gas, coal)

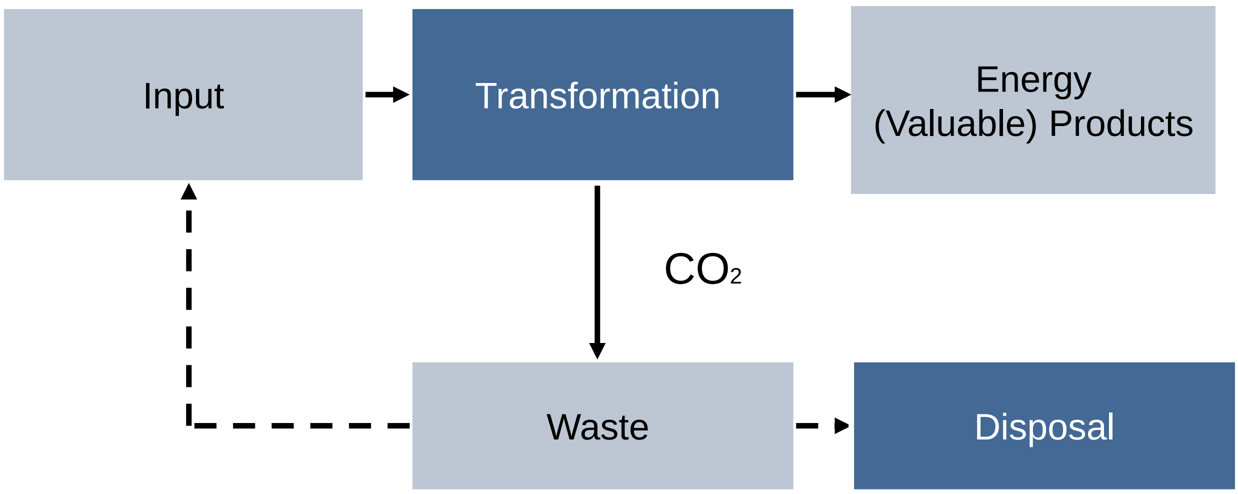
Present energy mix:

•Fossile materials	77 %
•Biomass	11 %
•Other renewable energies	5 %
•Nuclear	7 %

Reserves:

Oil	50 years
	Ressources: 70 years
Gas	65 years
Coal	200 years
Uranium	45 years

Alternatives 3



Alternatives 4

Options for the use of CO_2 (CCU)

- Direct use of Carbondioxide
- Chemical processing
- Biological processing
- Inorganic processing

Alternatives 5

Direct Use

- Enhanced oil and gas recovery (incl. permanent CCGS)
- Recovery of methane hydrate
- Use as industrial gas (or liquid or solid) (Solvent, Food industry, cleaning agent, fridge systems (e.g. automotive industry, ship containers, ..) (20 Mio tons/a CO_2)

Alternatives 6

Chemical Processing 1

- C 1 - Source for bulk / fine chemicals

Already used for: Urea, Salicylic acid, Formic acid… (110 Mio tons CO_2 /a)

Further investigations into possible “Dream reactions”
(e.g. CO_2 + Hydrogenation leading to long chain alkohols,
hydrocarboxylation of ketones (imine),
Production of isocyanates and carbamines (e.g. for polymers)

- C 1 - Source for polymers

Used already for polycarbonates (3 Mio tons/a) (substitution of phosgene)

Potential use for other polymeres, incl. Copolymerization

Chemical Processing 2

Carbon - Source for biofuels (and chemicals)

Already used for the production of methanol, DME etc.

Problem:
Energy for hydrogen production from water must be renewable!
Why: $H_2 + CO_2 \rightarrow$ chemicals ?
If: $H_2 + O_2 \rightarrow$ energy ?

Advantages by using CO_2 :
No interference with crop / food production
Less usage of land
Less logistics

Biological Use

Microalgae

Very efficient and productive, no competition for food production (water resources), can be part of the chemical route

Plants

CO_2 as a fertilizer

Artifical photosynthesis

Bio-mimetic chemistry, sun energy required to initiate the first reaction step to convert H_2O into O_2 and H_2
High selective catalysts necessary
CO_2 - quality might be a limiting factor

Alternatives 9

Inorganic Use

Mineralization

Reaction of e.g. olivine (Mg_2SiO_4) and CO_2 → $MgCO_3$ + SiO_2 + Energy

Same process as CCGS in aquiferes

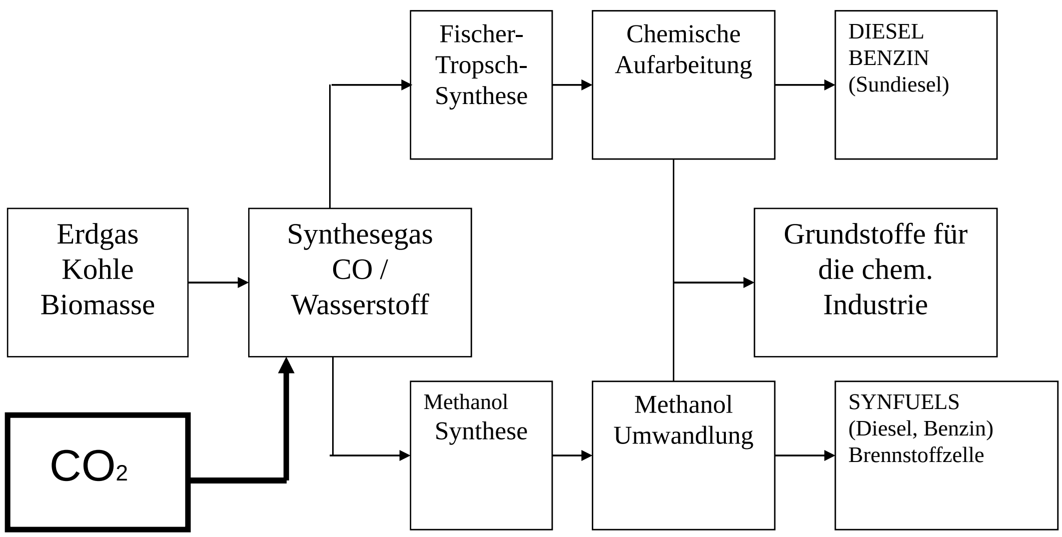
Comparable to the capture of SO_2/SO_3

Advantages: No quality restriction for the flue gas
Input material is available in large quantities all over the world
Output material is easy to dispose or can be reused for construction materials

Disadvantages: Large quantities required, limited by logistics
Very slow reaction

Alternatives 10

Syntheses of the 2. Generation



Summary

- Carbon Capture and Storage in Germany and Europe is a burial of money
- CCS supports a wrong allocation of ressources
- CCS is not sustainable

However, CO_2 – emissions must be reduced because

- the availibilty of fossile raw materials will be limited in the future
- these raw materials will be needed for „non energy processes“

- Carbon dioxide should not be regarded as „waste“ but as valuable input material:
  Carbon Capture and Utilisation

- this will also help to minimise the CO_2 – impact on climate change in the long term

Last but not least:
We will need the appropriate mixture of ressources for energy production, including the construction and the revamp of highly efficient coal based plants!

Thank You For Your Attention

Rothkopf-Concept GmbH

Hermann-Ehlers-Straße 16
26386 Wilhelmshaven

Beraterteam:

Dr. Hans Werner Rothkopf
Dipl.-Ing. Alexander Rothkopf

Kontakt:

T 49 4421 809797
E hans.werner.rothkopf@rothkopf-concept.de