„Carbon dioxide free“ energy production from fossils fuels – technology and economy

Österreichisches Nationalkomitee des Weltenergierates

Wien 1 April 2004

Lars Strömberg

Vattenfall AB

Group Function Strategy

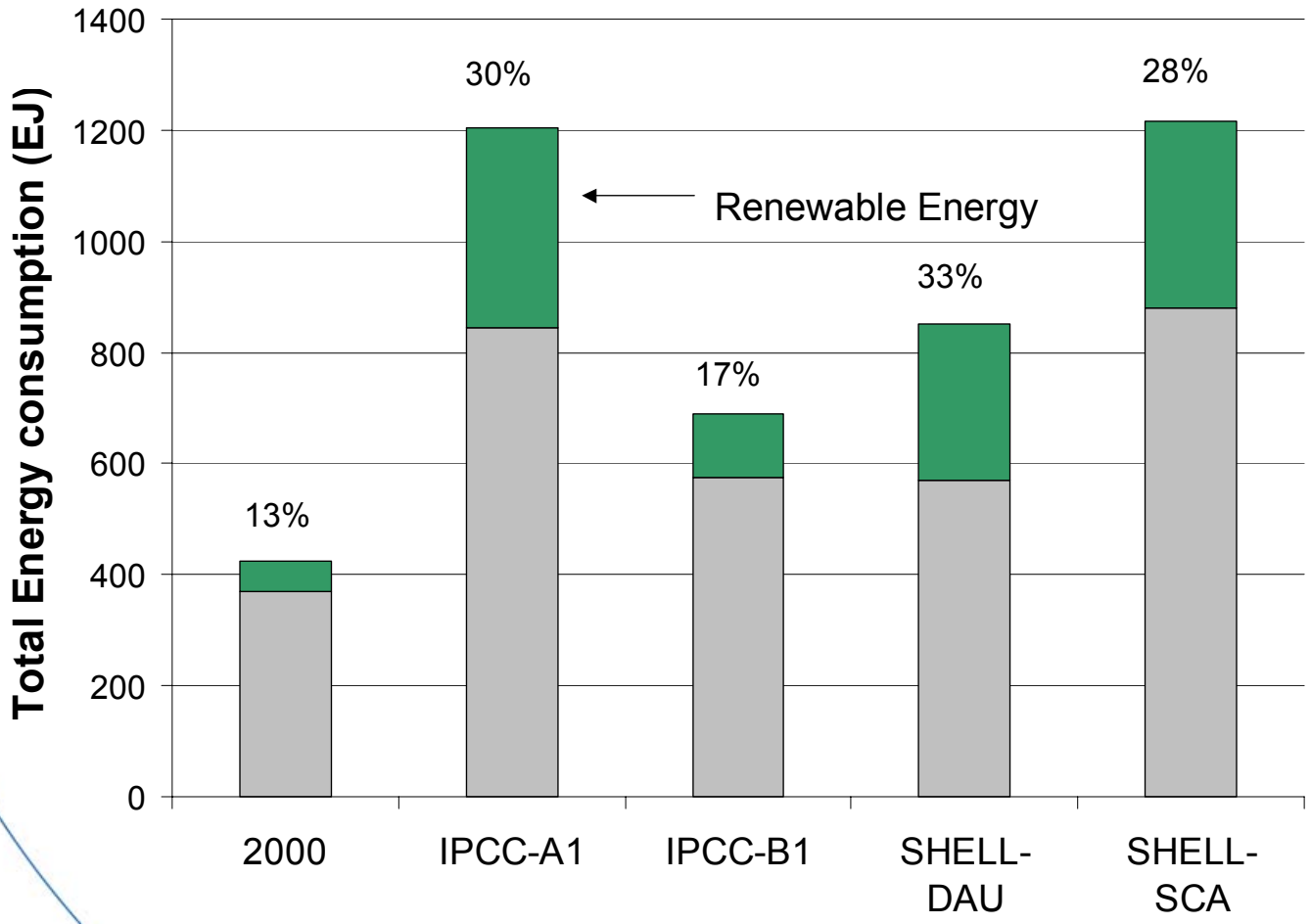
The Vattenfall Group

- Vattenfall sells about 180 TWh electricity, whereof about 160 TWh is produced by ourselves
  - The main part is produced by hydropower, nuclear power, coal and natural gas.
  - A smaller part is produced by biofuels and wind power
  - About 17 TWh is produced in combined heat and power plants
- Vattenfall also sell about 37 TWh heat where all is produced by ourselves
  - The main part is produced by biofuels, coal and gas in cogeneration plants
- Vattenfall emits almost 80 million tons of CO_2 per annum

CO_2 free power plant

Fossil fuels are needed

Scenarios 2030-2050 – renewable energy



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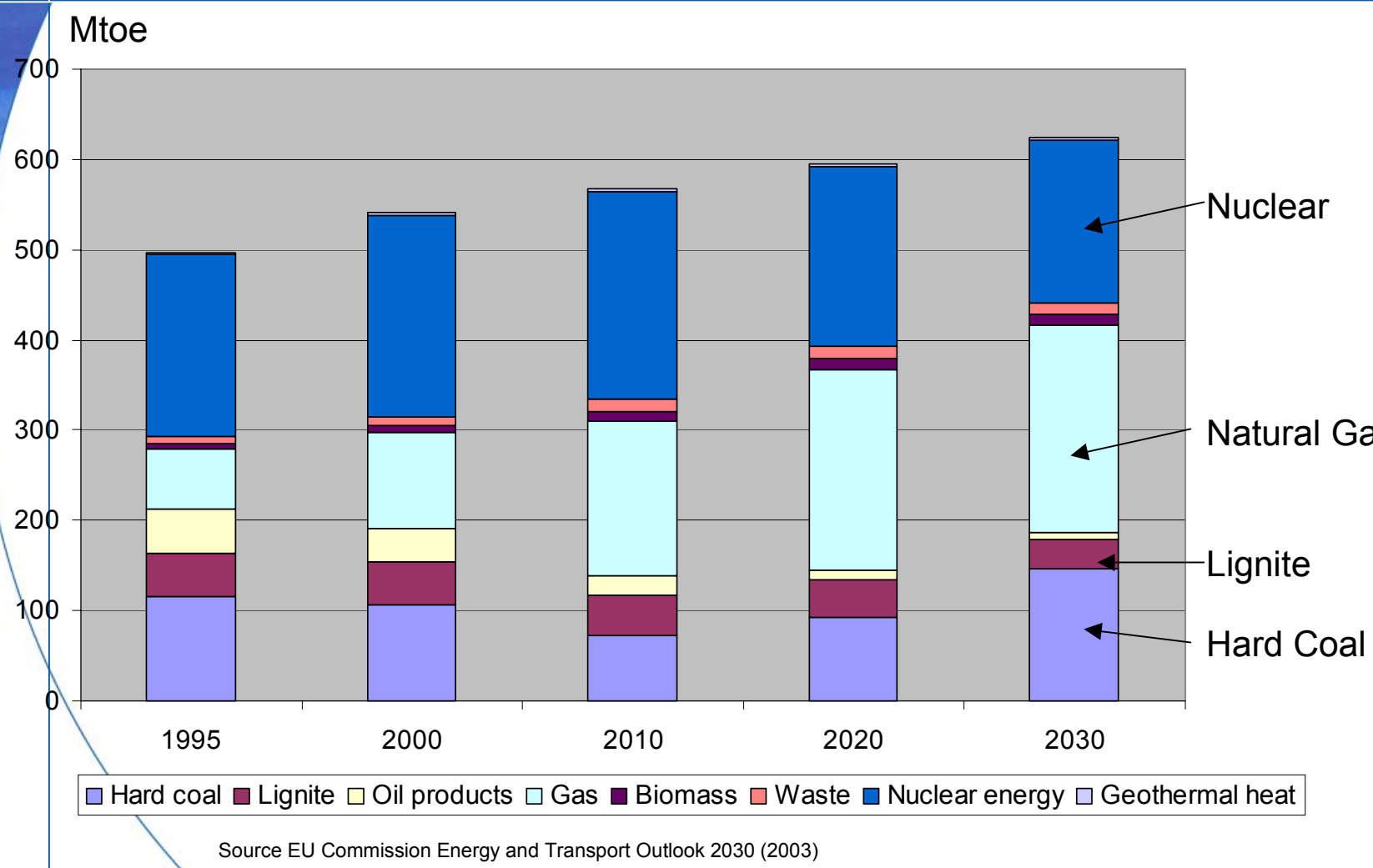
Fuel use for electricity generation EU-15



Source EU Commission Energy and Transport Outlook 2030 (2003)

Emission Trading

Emission Trading sets the commercial framework

The EU emission trading system

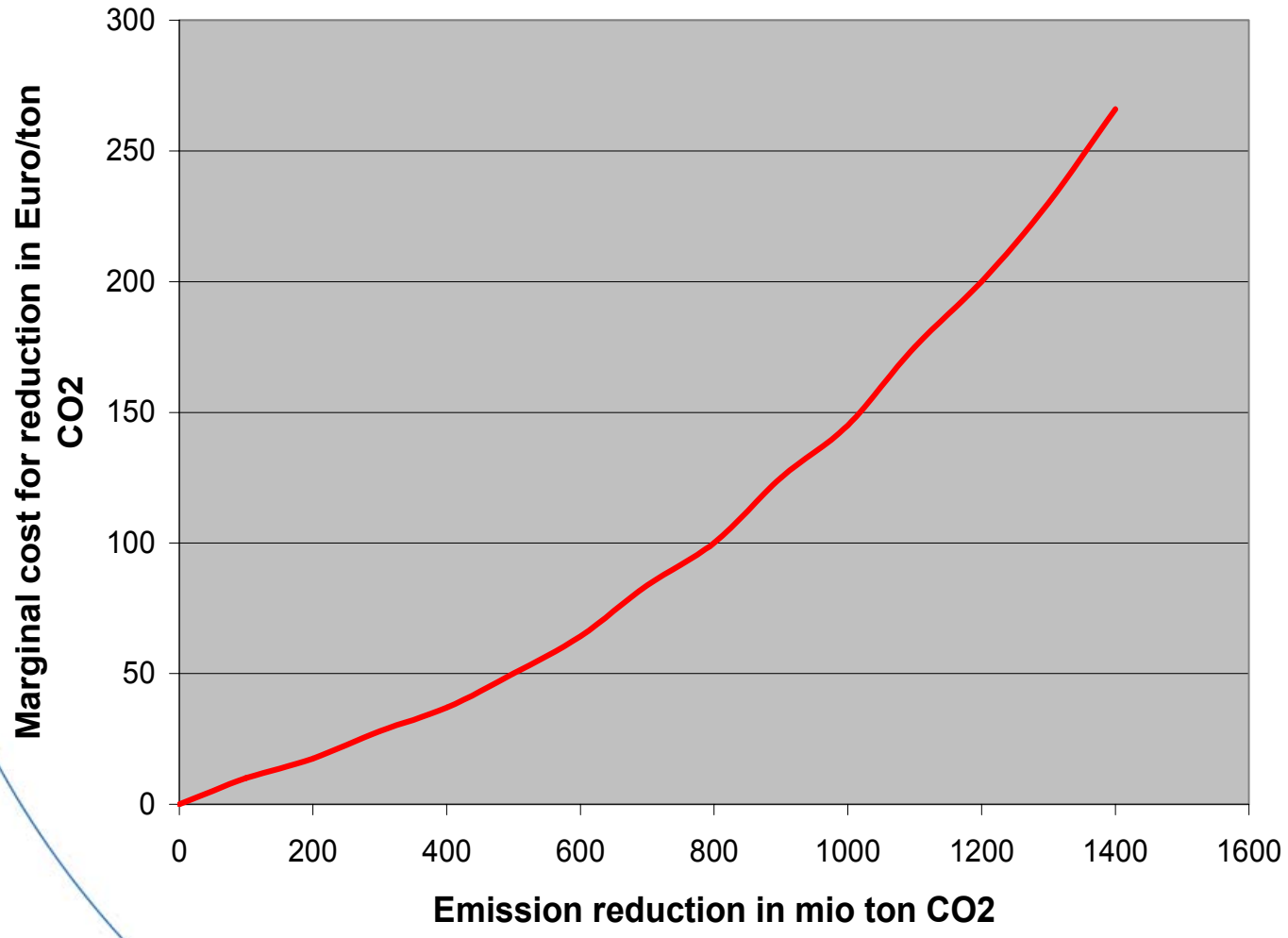
The long term price of the allowances will be set by reduction requirements and the costs of physical reduction

As emission allowances become scarce they will have an increasing value

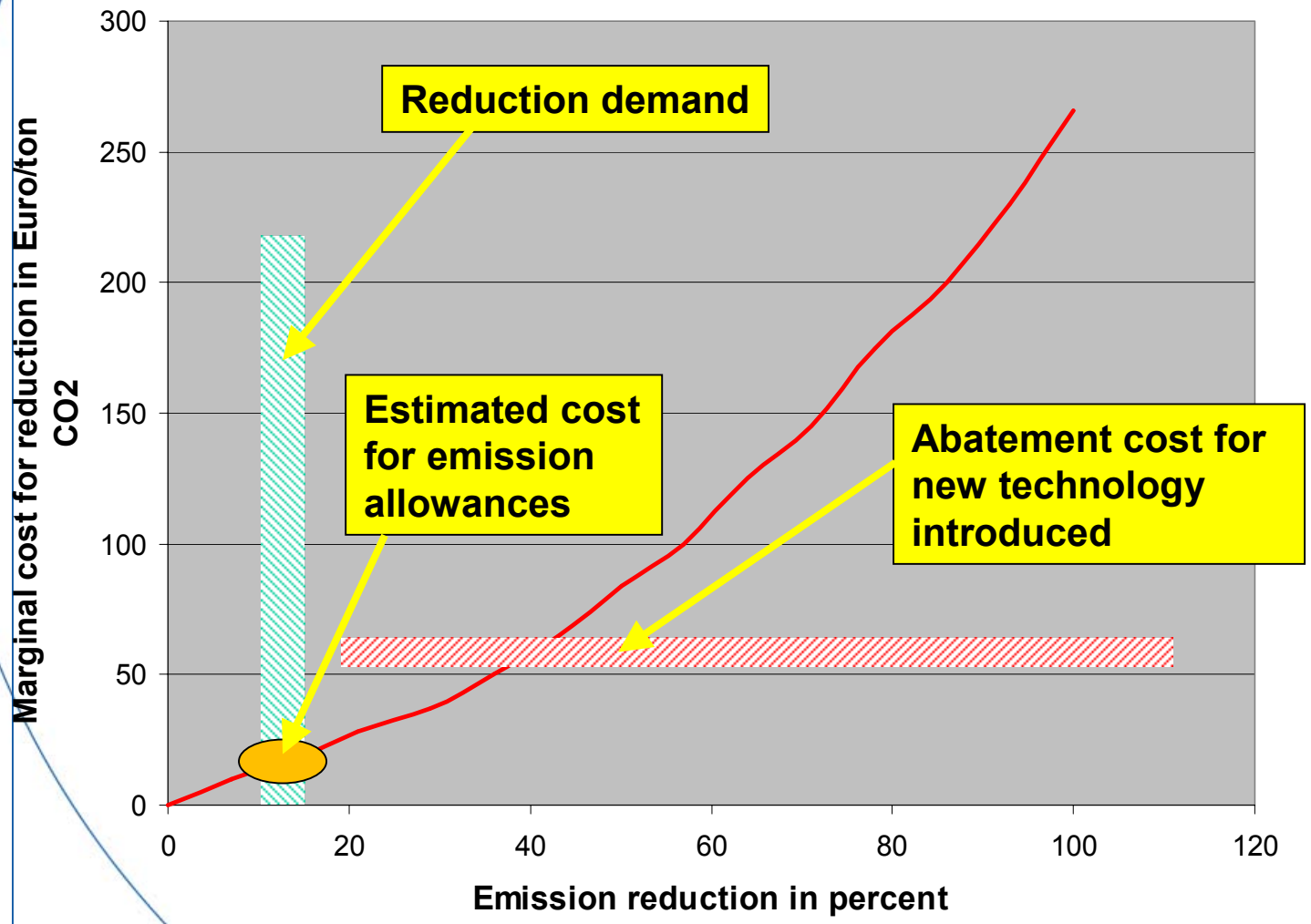
The cost for allowances will be added as a direct marginal production cost and therefore increase the spot price of electricity

Marginal cost vs. Reduction of CO2 emissions in EUR/ton CO2

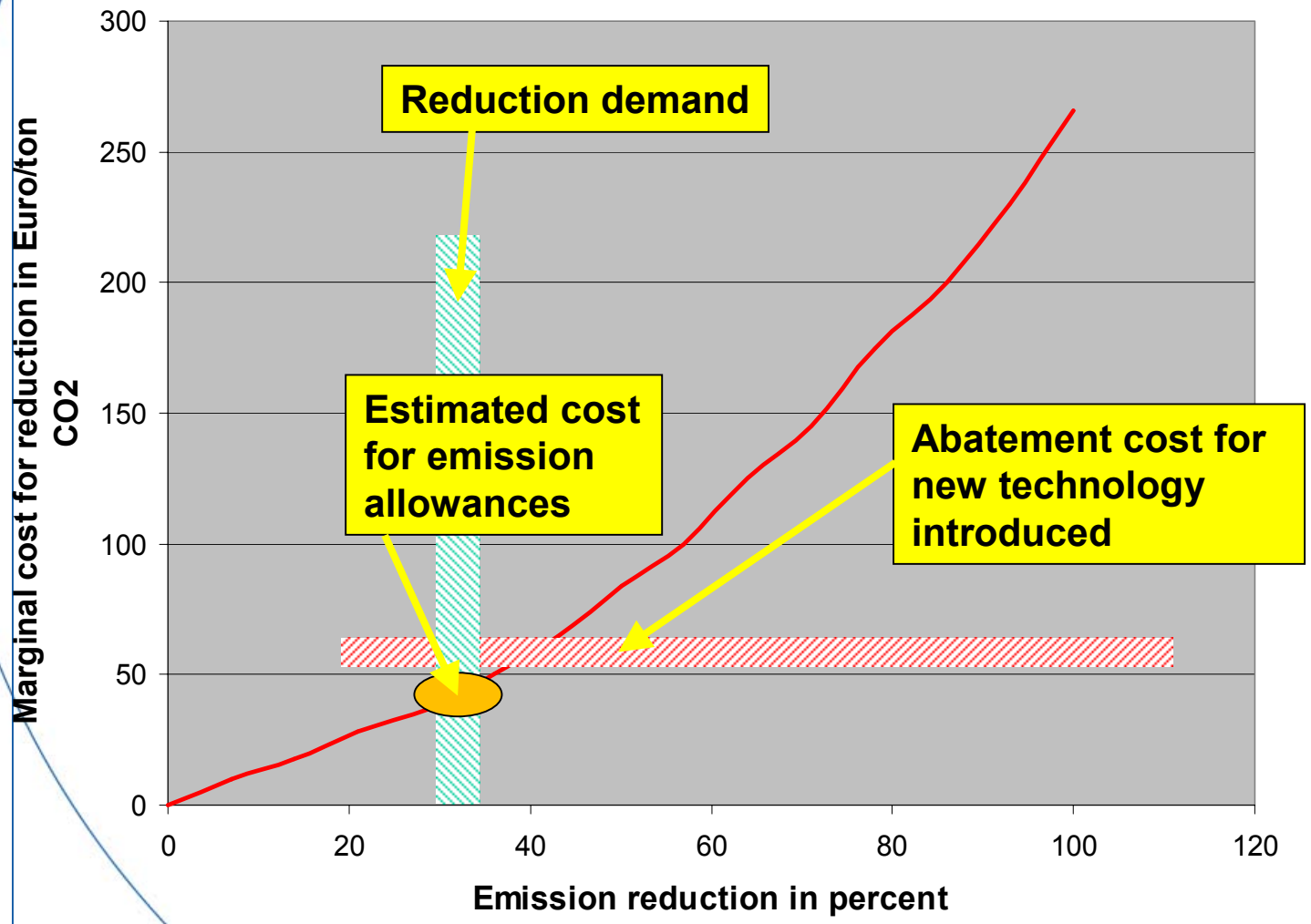
Source: ECOFYS Economic evaluation of sectorial reduction objectives for climate change



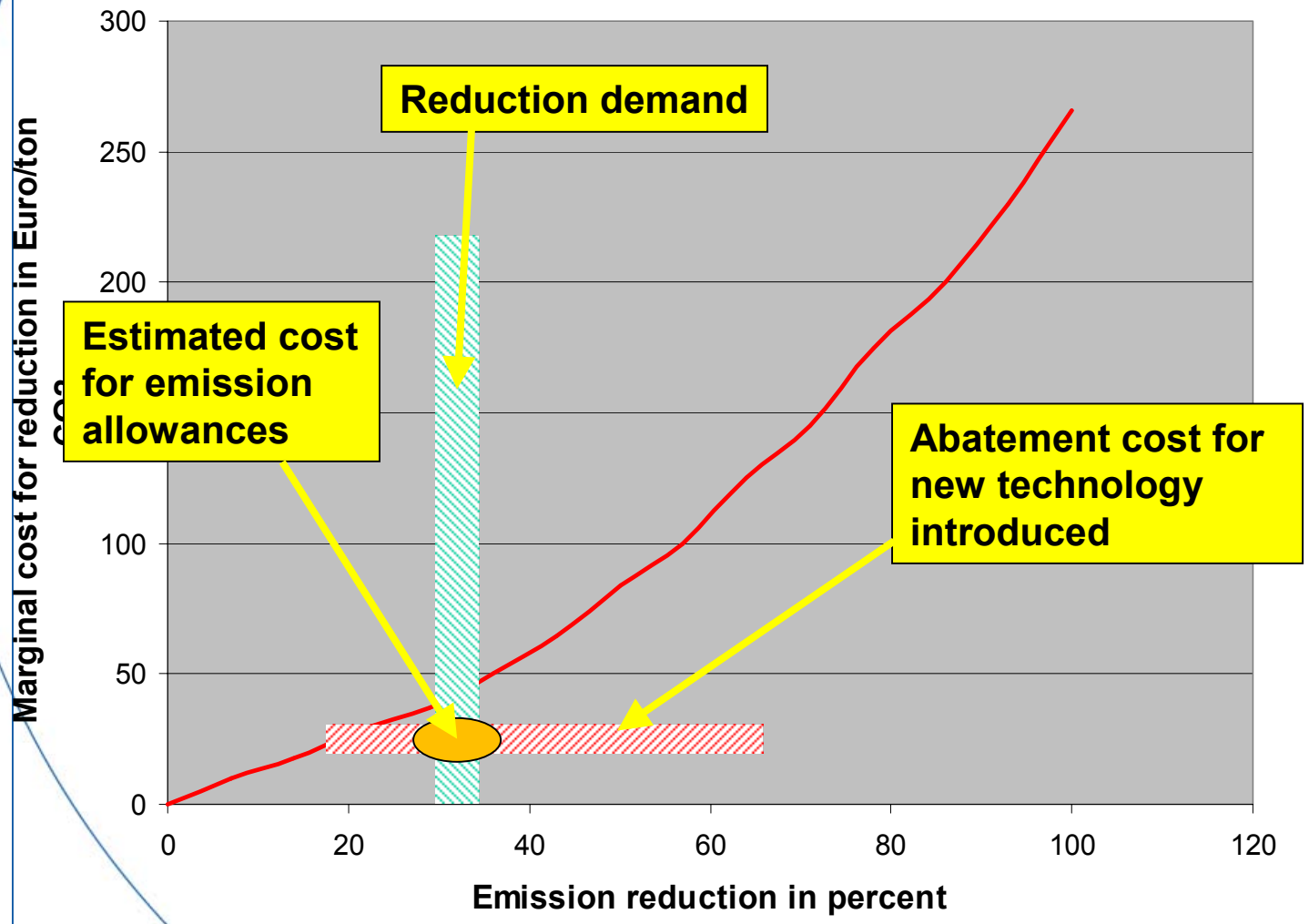
Marginal cost vs. Reduction of CO2 emissions in EUR/ton CO2



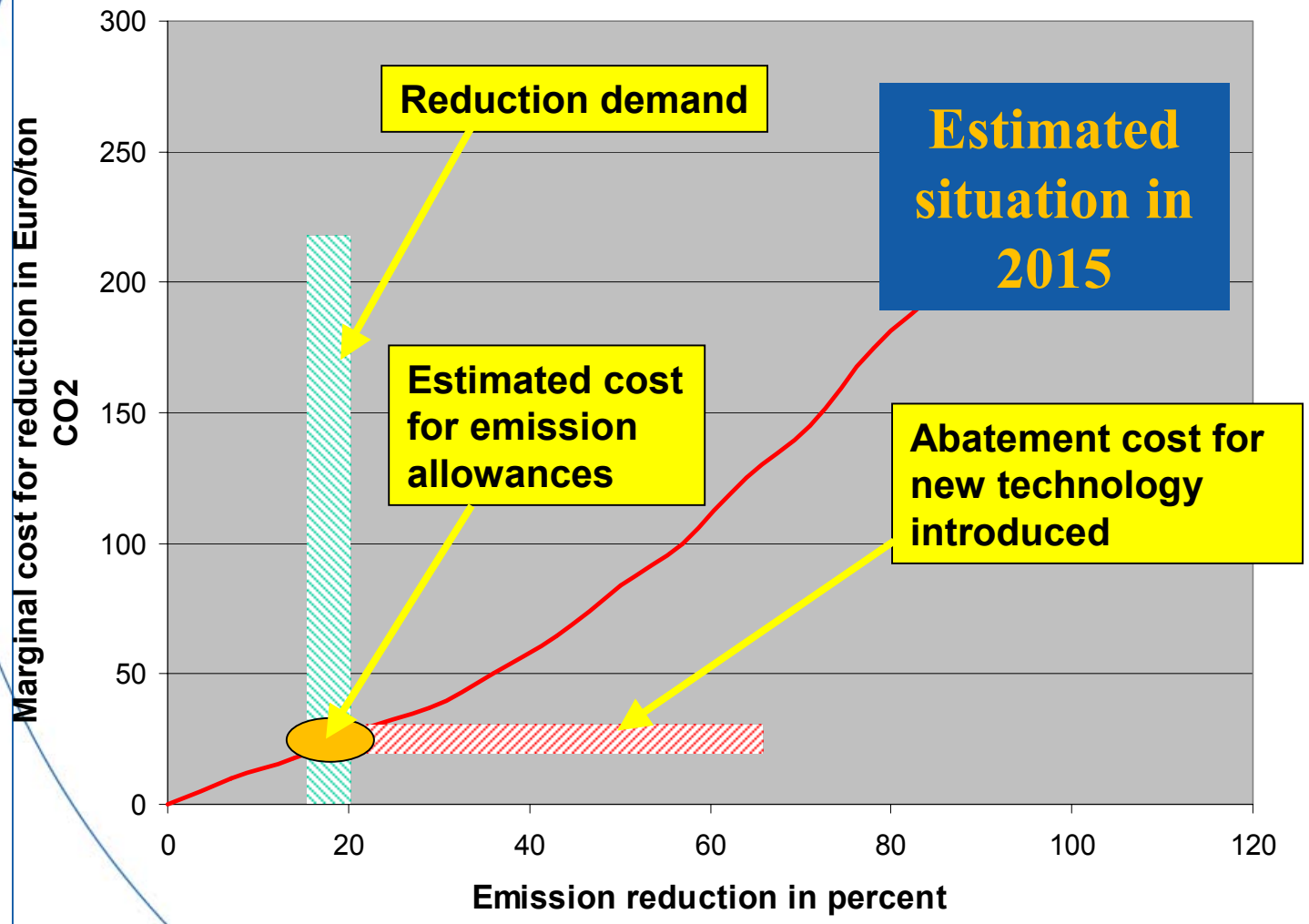
Marginal cost vs. Reduction of CO2 emissions in EUR/ton CO2



Marginal cost vs. Reduction of CO2 emissions in EUR/ton CO2



Marginal cost vs. Reduction of CO2 emissions in EUR/ton CO2



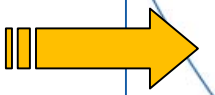
Analyses show that…

by 2010 …..

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

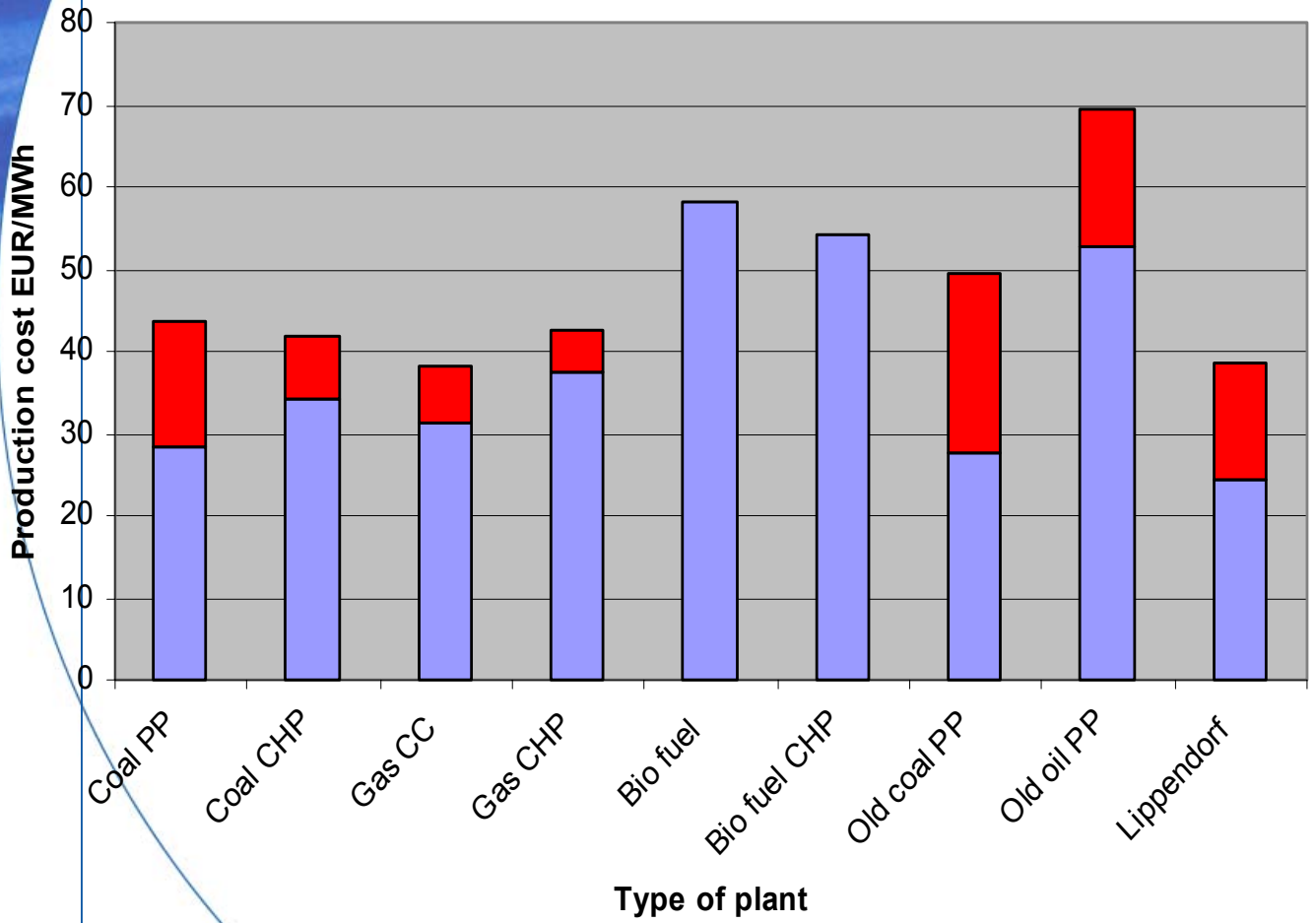
but in 2015….

- 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.



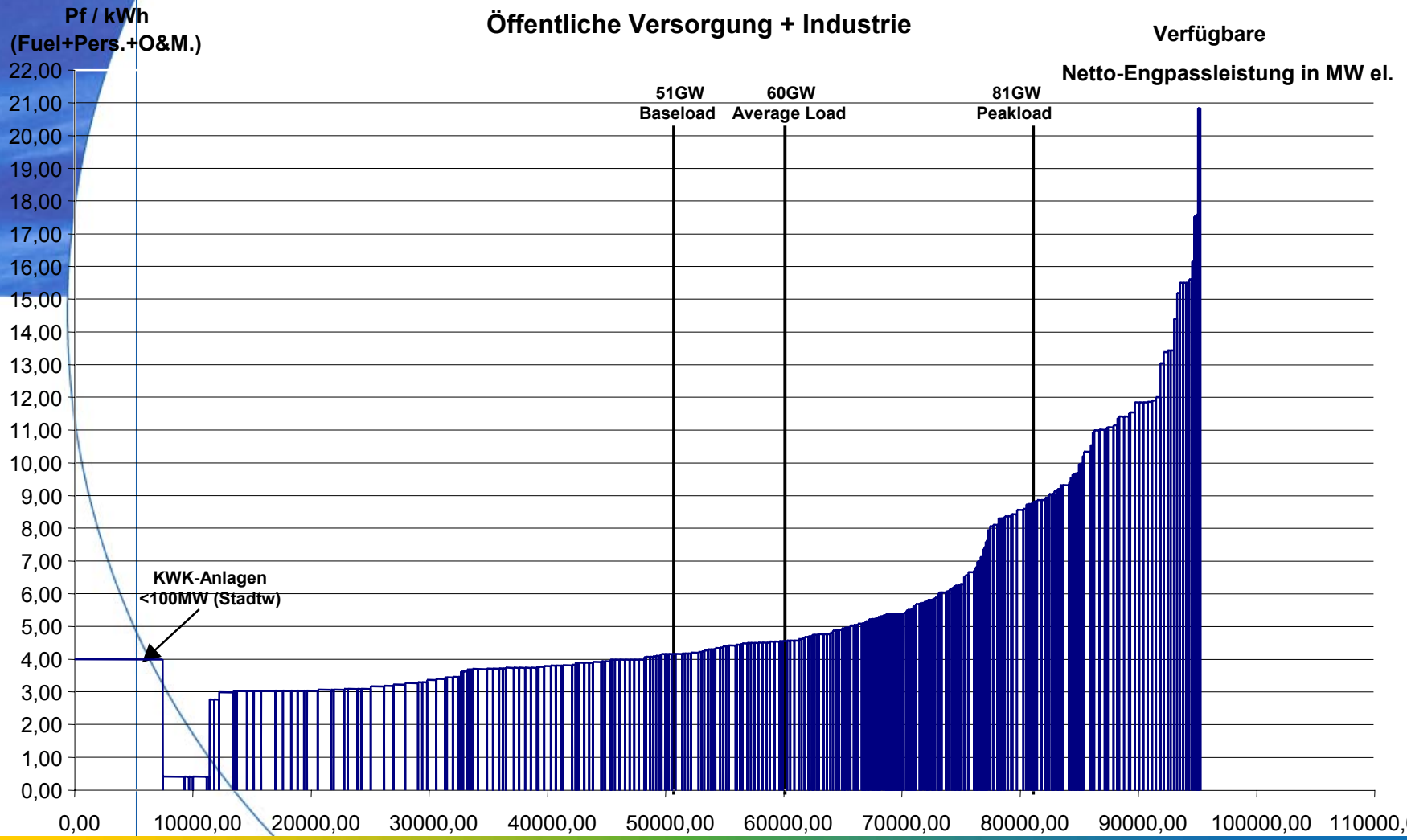
This is the target to be met by new ”zero emission” technology

Influence on total production cost
CO2 penalty of 20 EUR/ton CO2



SUPPLY CURVE GERMANY 2000

Longterm variable costs



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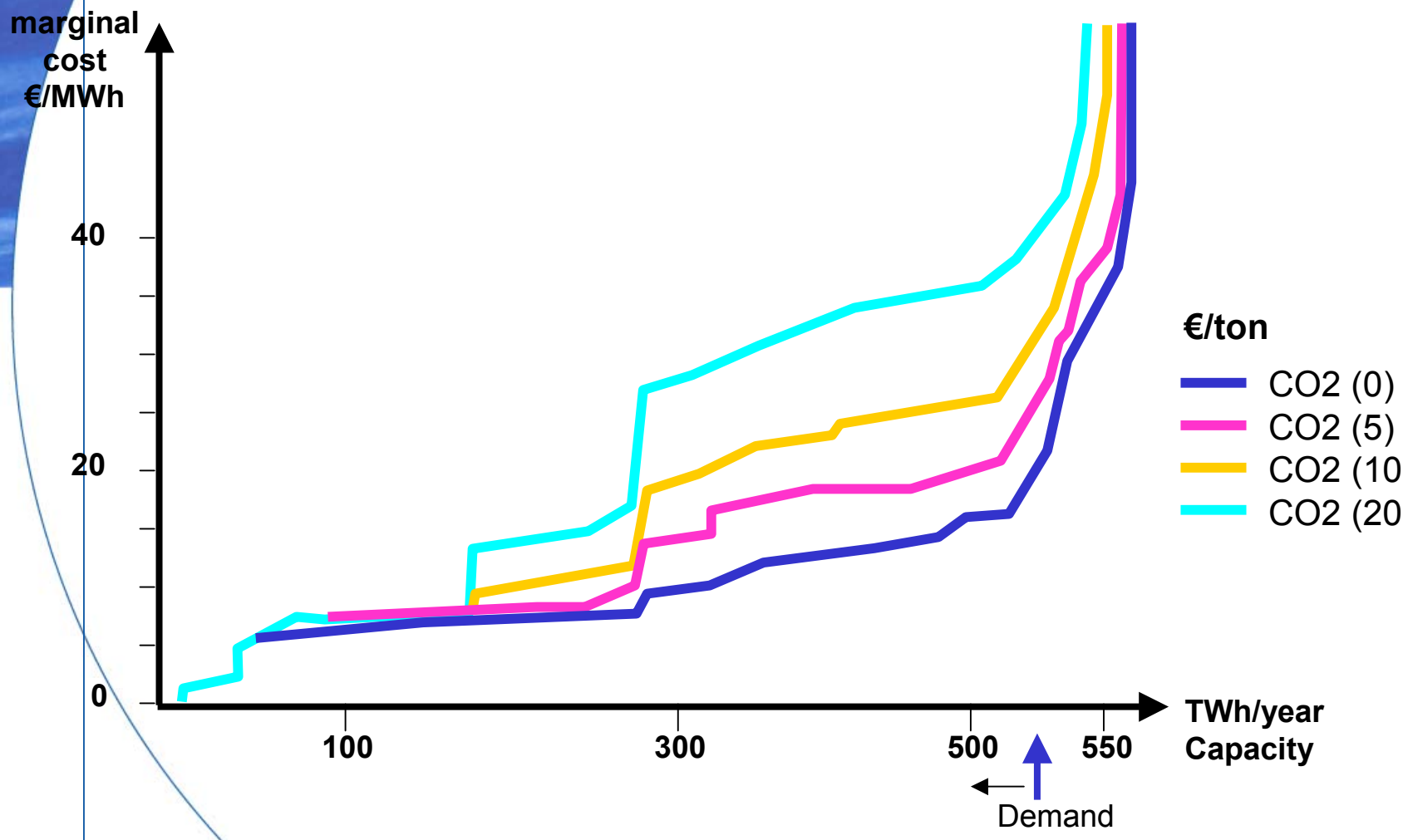
Supply and Demand in Germany



Capture and storage of CO_2

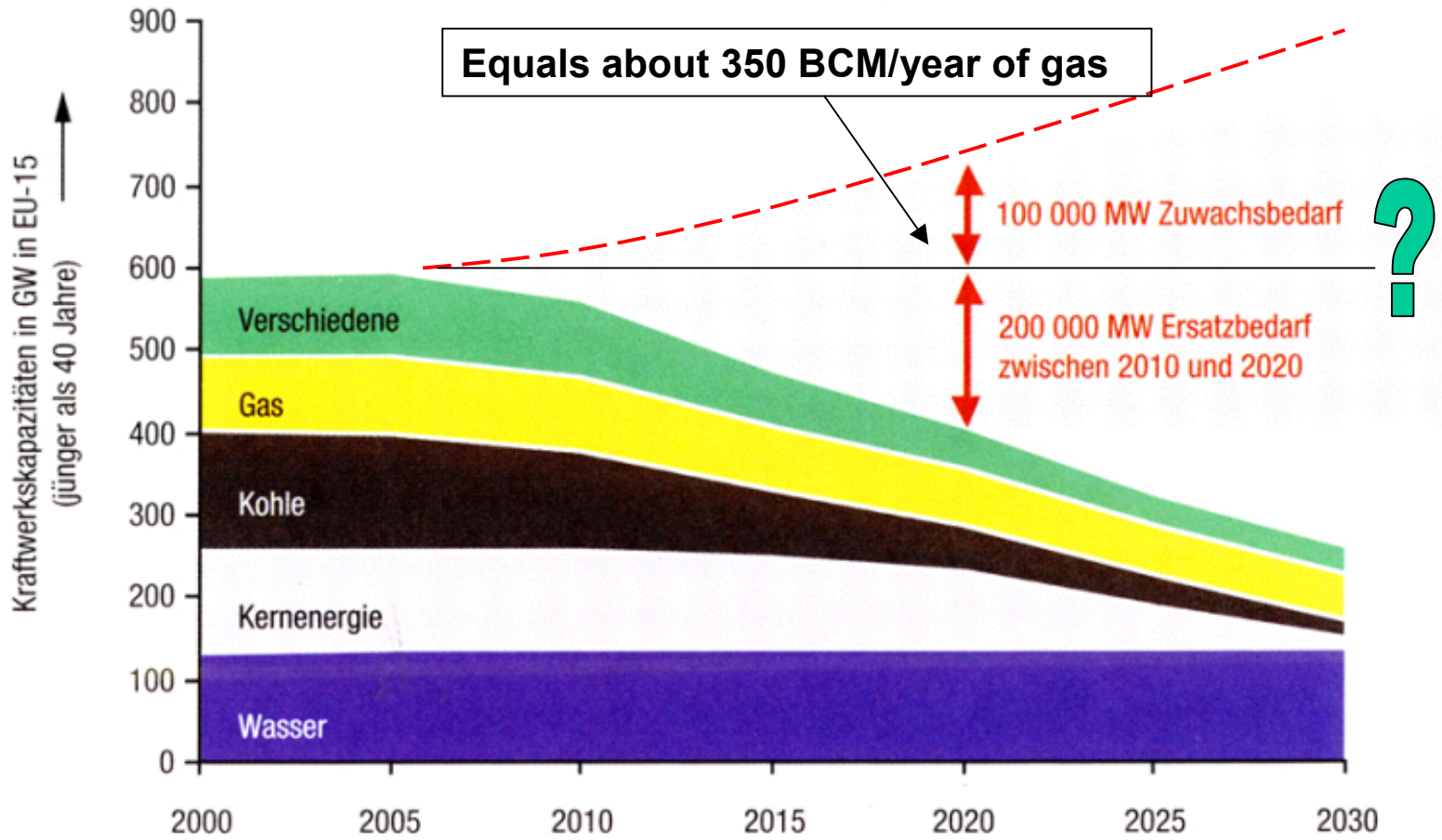
Options to reduce the CO2 emissions

Options to reduce CO_2

- The options available to reduce the CO_2 emissions from fossil fuelled plants are:
  - To increase the efficiency. Example: The 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, or to biofuels which is renewable.
  - Capture and permanent storage of CO_2

Vattenfall works with all options

Need for new capacity in Europe (EU 15)



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

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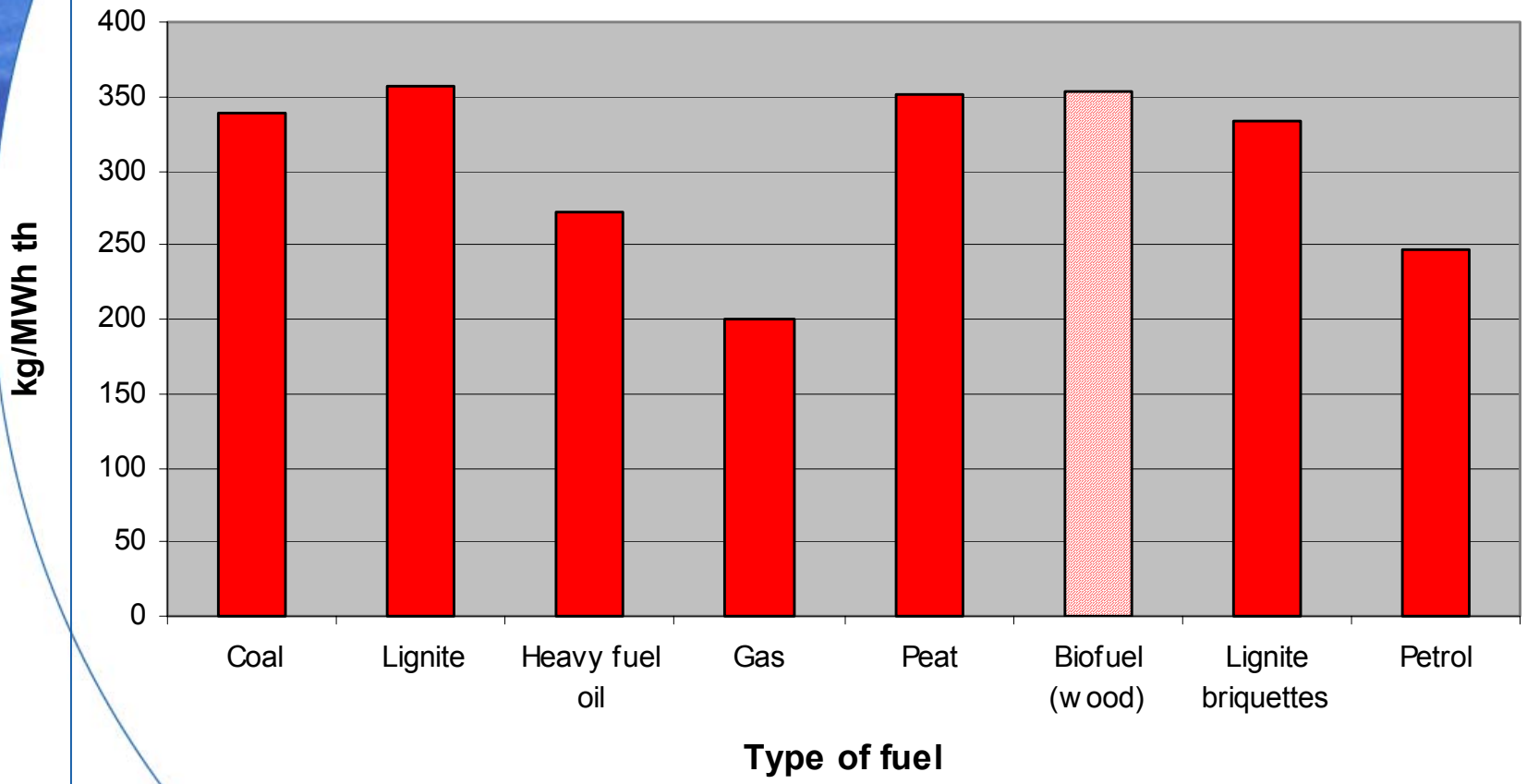
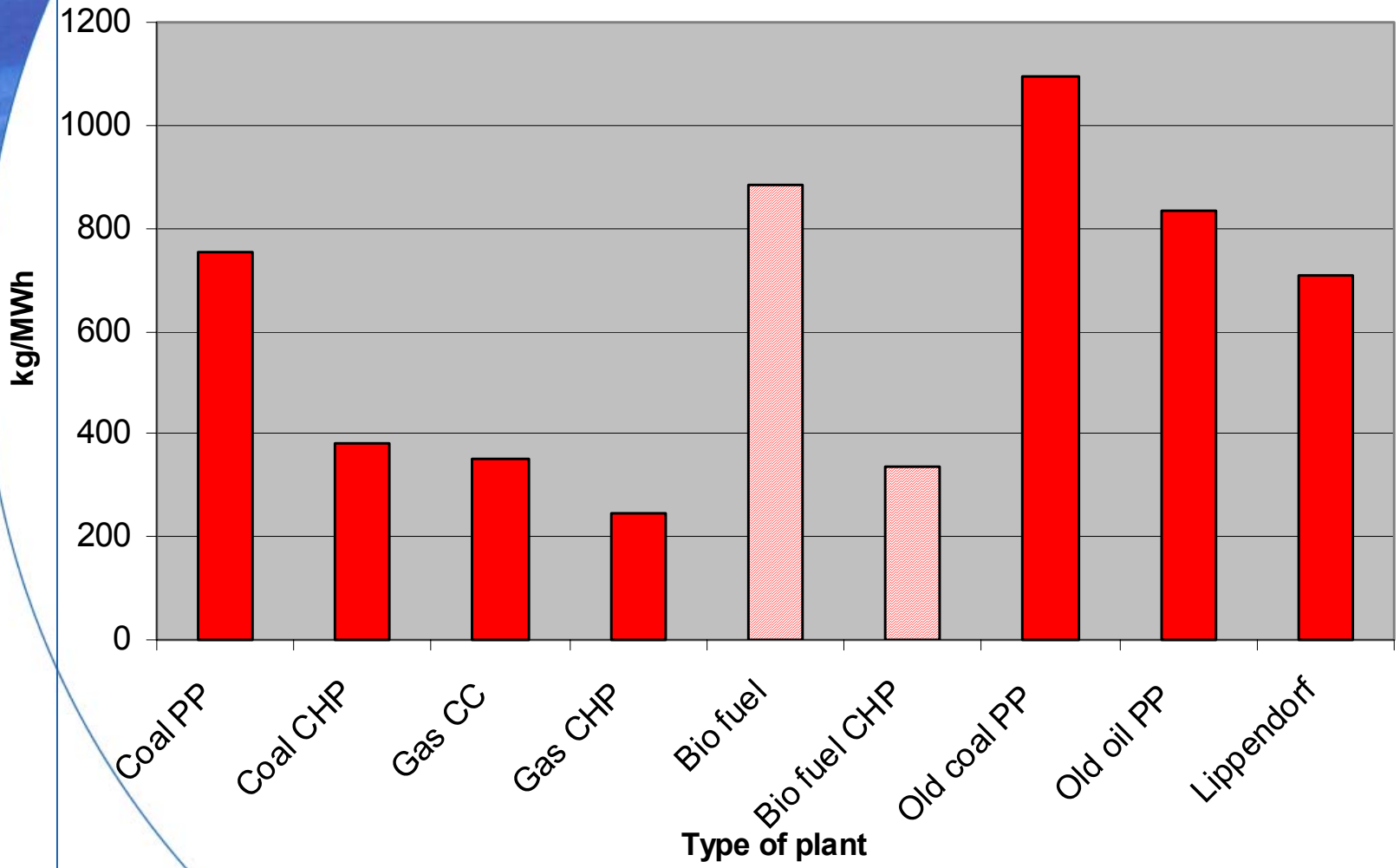
CO_2 release from combustion of different fuels

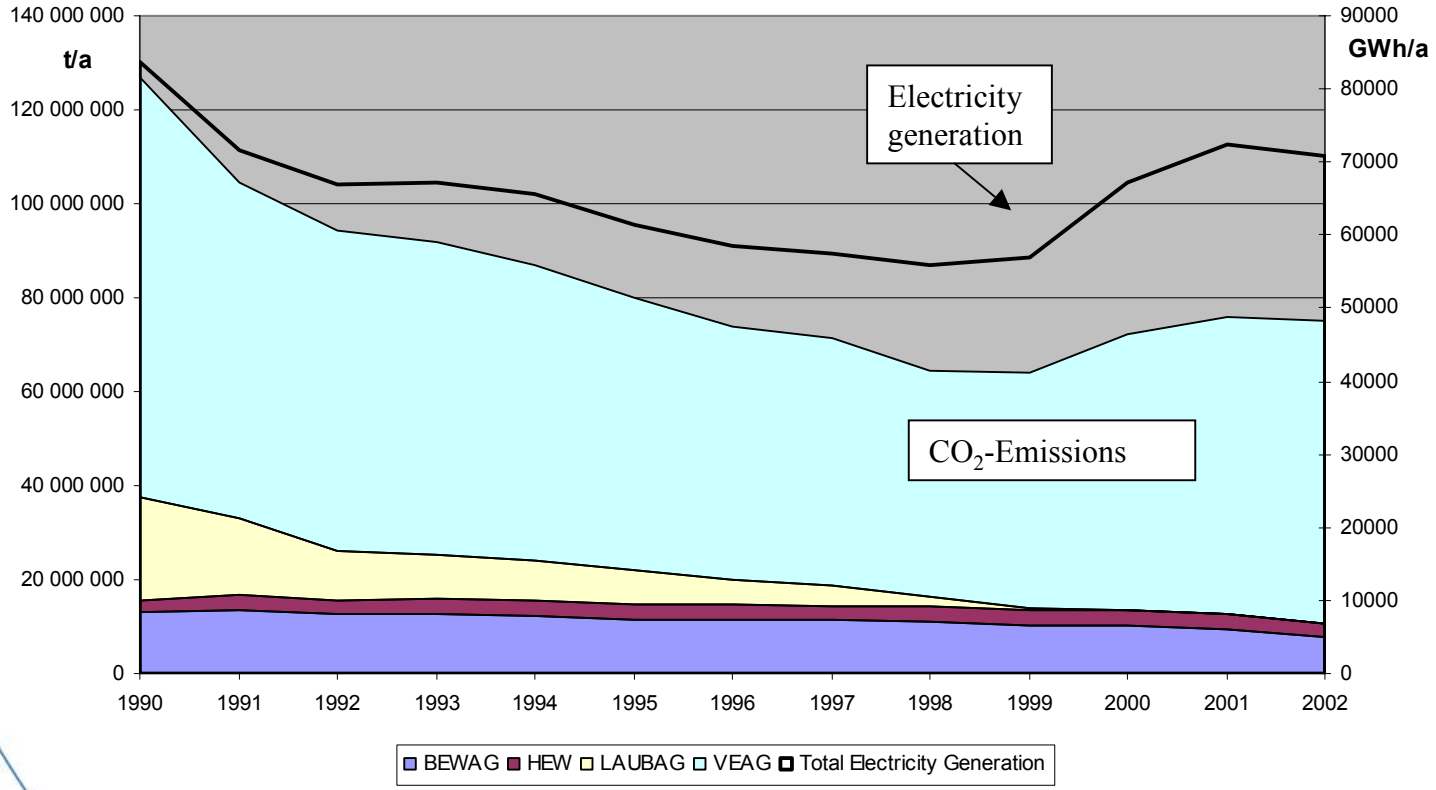


CO_2 emissions from different power plants



Schwarze Pumpe power plant

CO_2-Emission Reductions and Electricity Generation in North Eastern Germany



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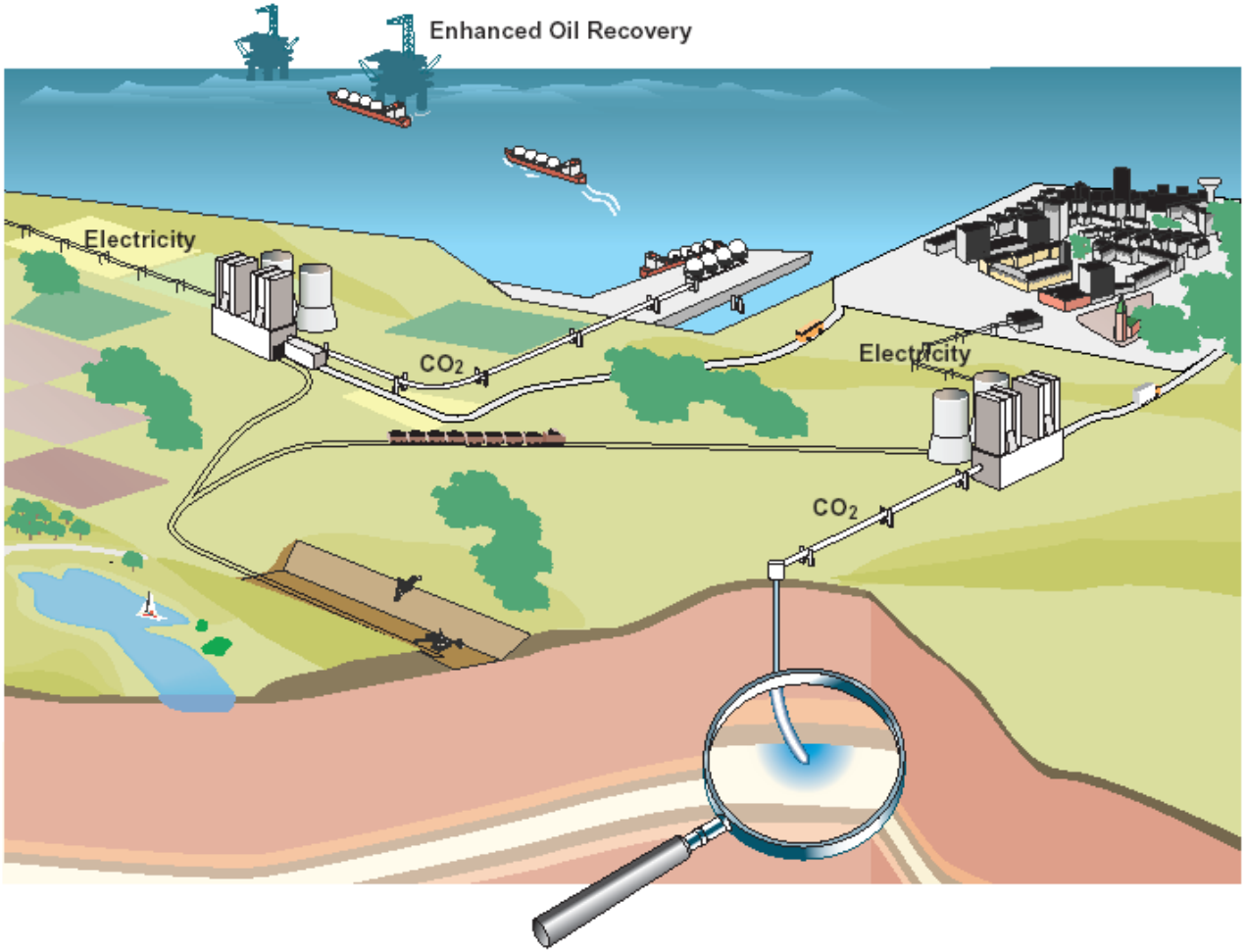
Capture and storage of CO_2

Capture and storage

CO_2 Capture and storage



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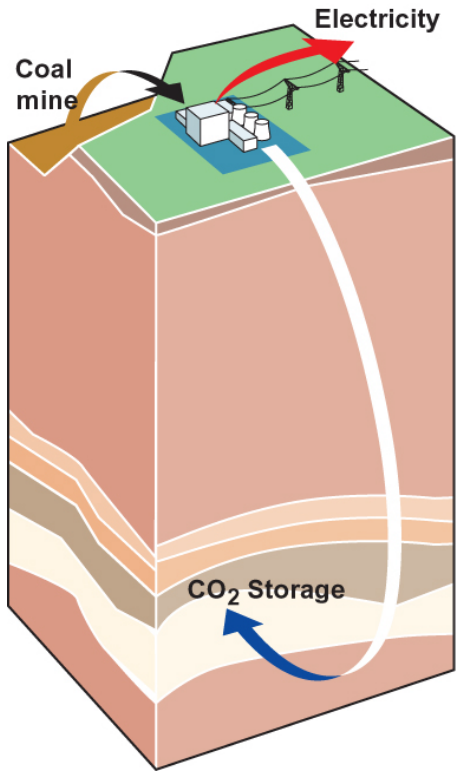
CO_2 free power plant

Storage

Storage in Saline Aquifers

Method:

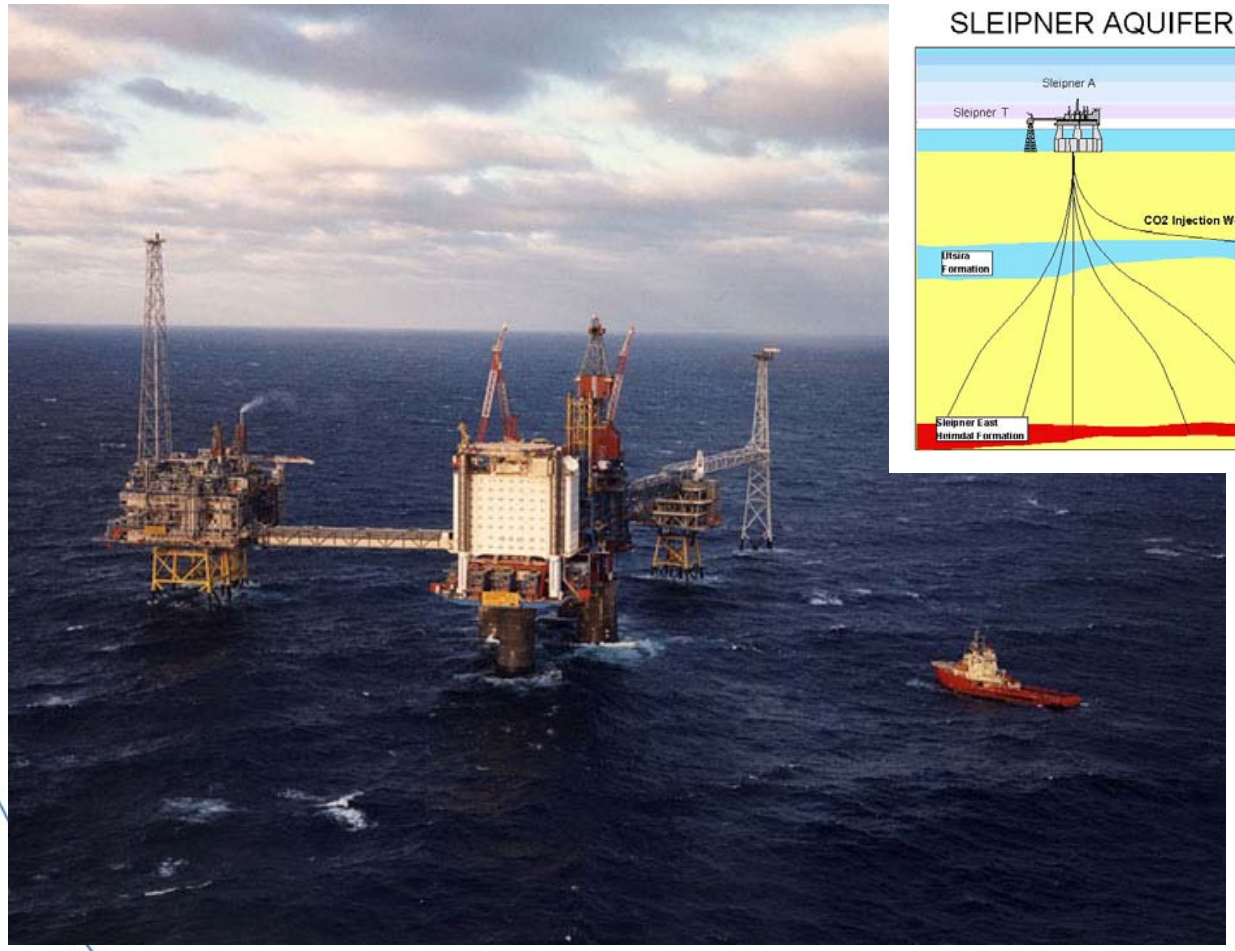
- Liquid (supercritical) Carbondioxide is pumped down replacing the salt water present in an Aqiufer > 700 m deep.
- This water cannot be used for watering or drinking due to high mineral content – up to 40%
- This storage option has a very large potential for captured CO_2



Ongoing European activities:

- CO_2–storage is made on a commercial basis since 1996 i a saline aquifer in the gasfield Sleipner in the Northsea (Statoil)
- CO_2–storage is planned for the plants Snöhvit (Statoil) and Asnæs-værket (Energi E2)

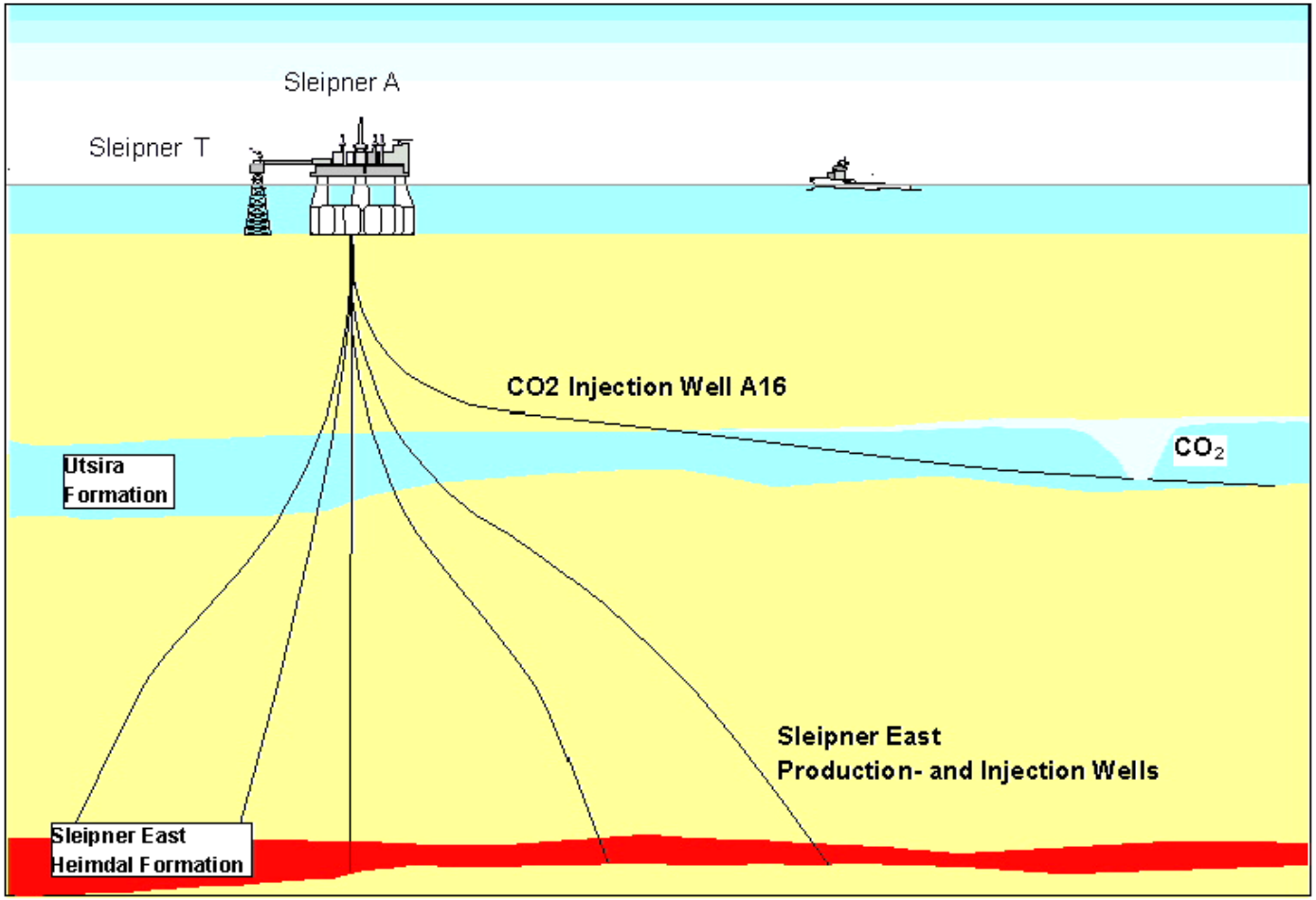
Storage of CO_2 in a Saline Aquifer under the North Sea



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

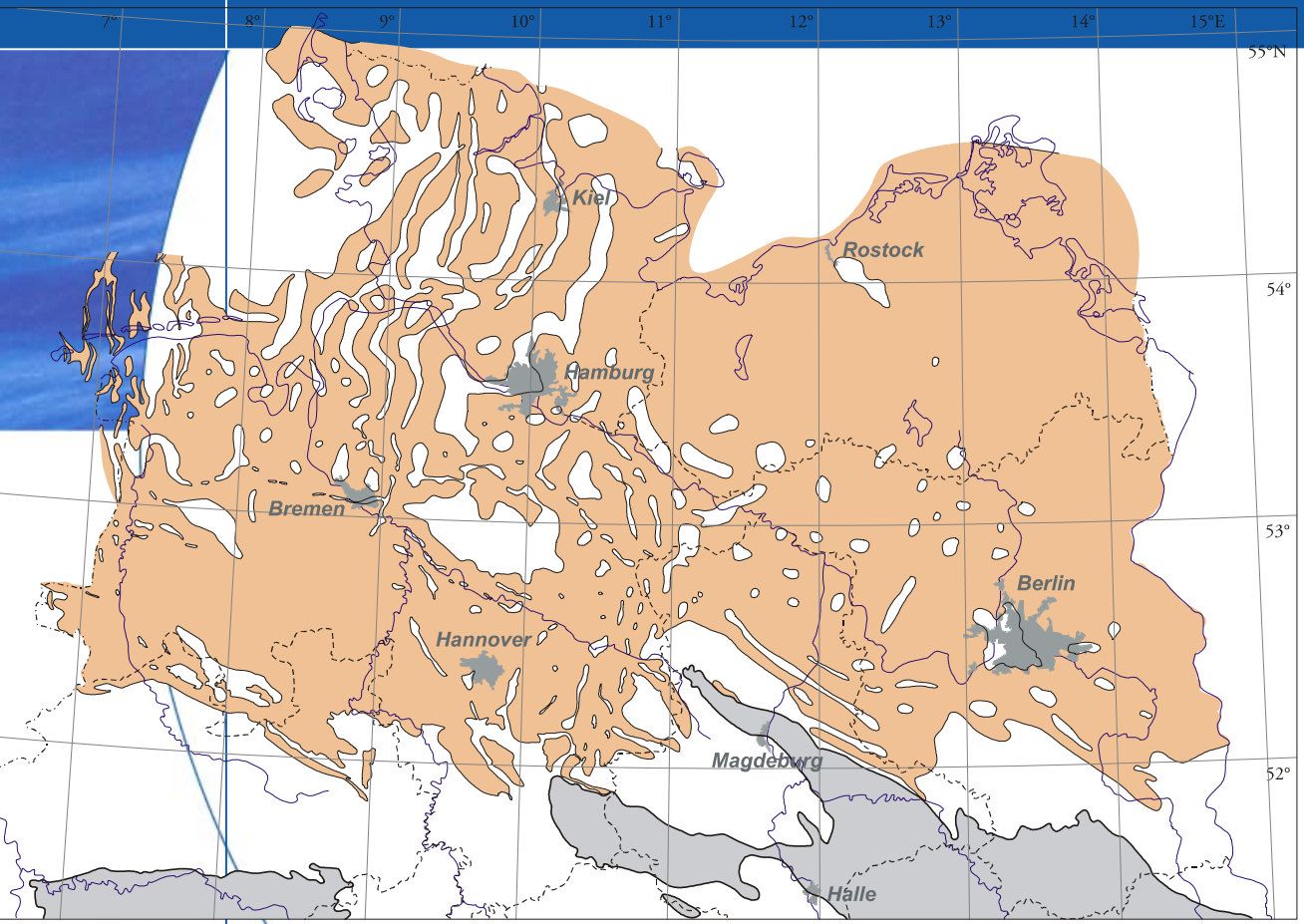
The Sleipner field. Oil and gas production facilities. (Source: STATOIL)

Storage of CO_2 in a Saline Aquifer under the North Sea



Source: Statoil

Storage Capacity, saline aquifers



Distribution of Rhetian Basement below Cenozoic cover

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,

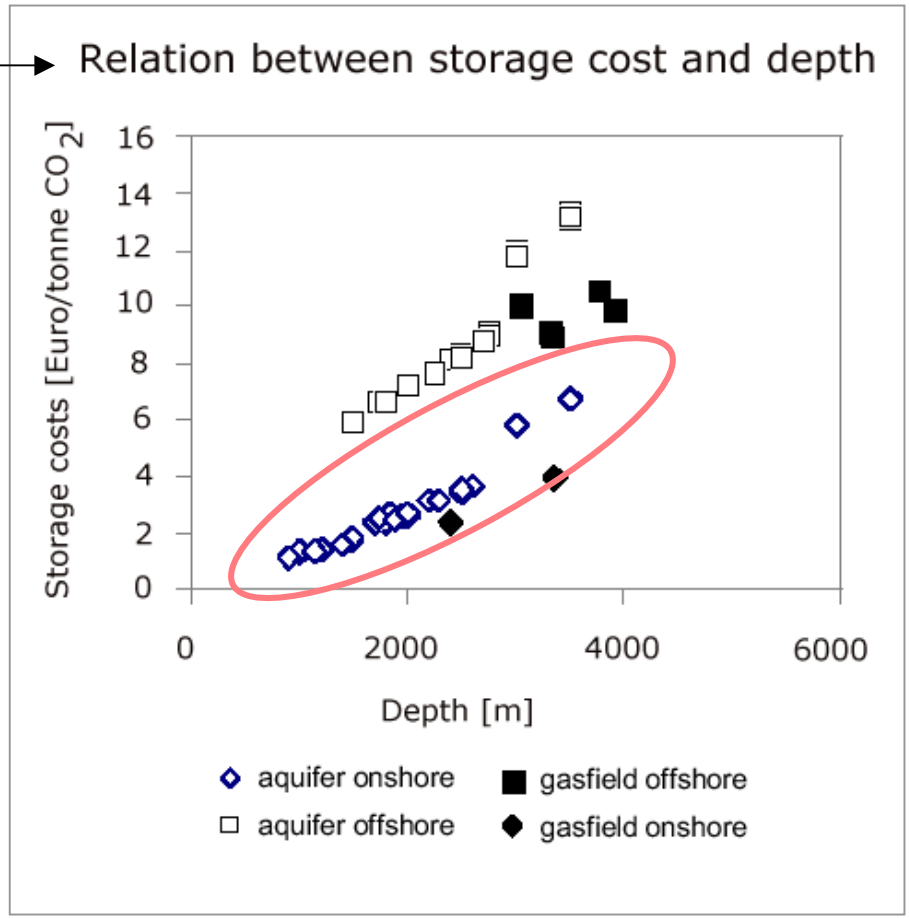
Paul Krull

Bundesanstalt für Geowissenschaften und Rohstoffe, Hannover

Storage cost estimates

Storage in aquifer traps (GESTCO Figures)

- 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 av.



Källa: Christian Bernestone Vattenfall Utveckling

CO_2 free power plant

Transport

CO_2 pipelines in operation in the USA

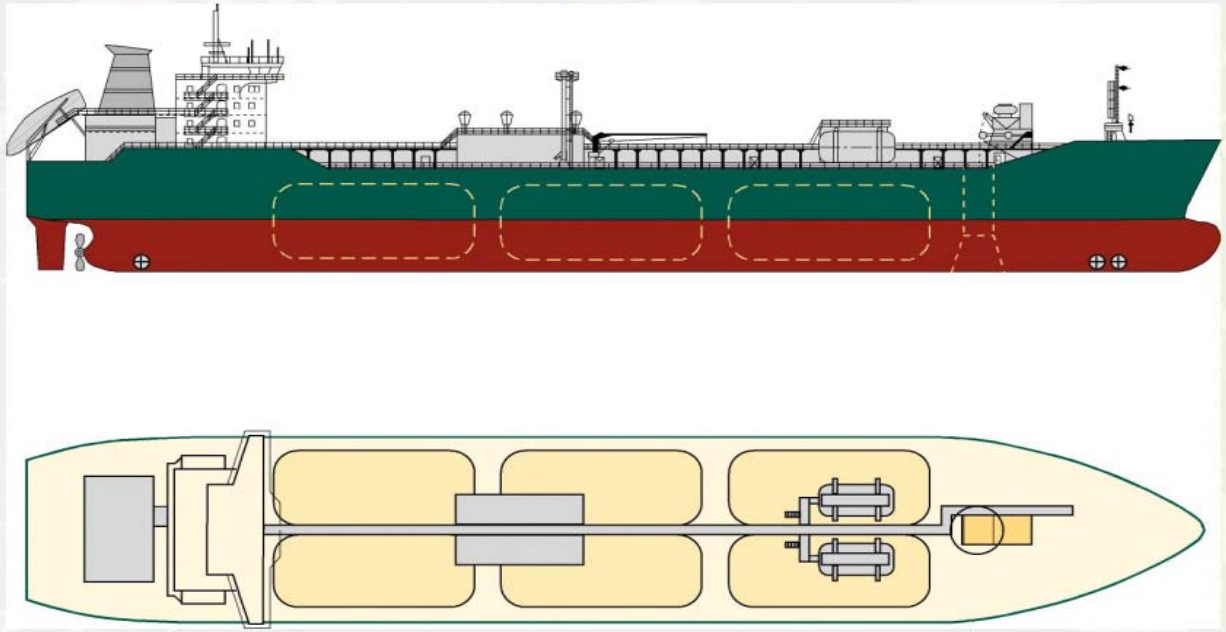
Transportation with water carriers

Transportation of CO_2 in Semi-Cooled Ships.

STATOIL

Illustrated ship has a carrying capacity of 20 000 m3

Project participants: Navion, SINTEF, Vigor and Statoil



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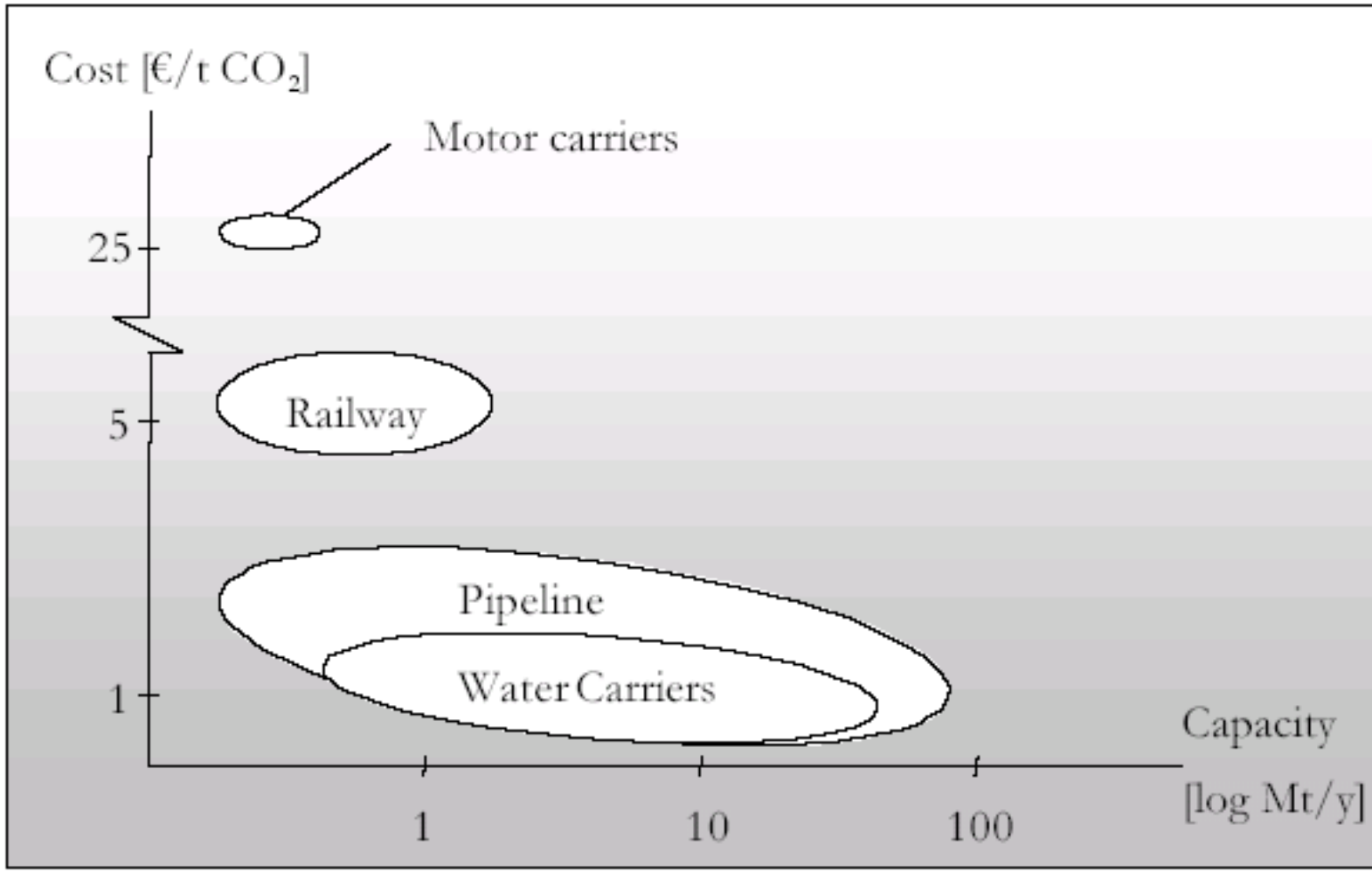
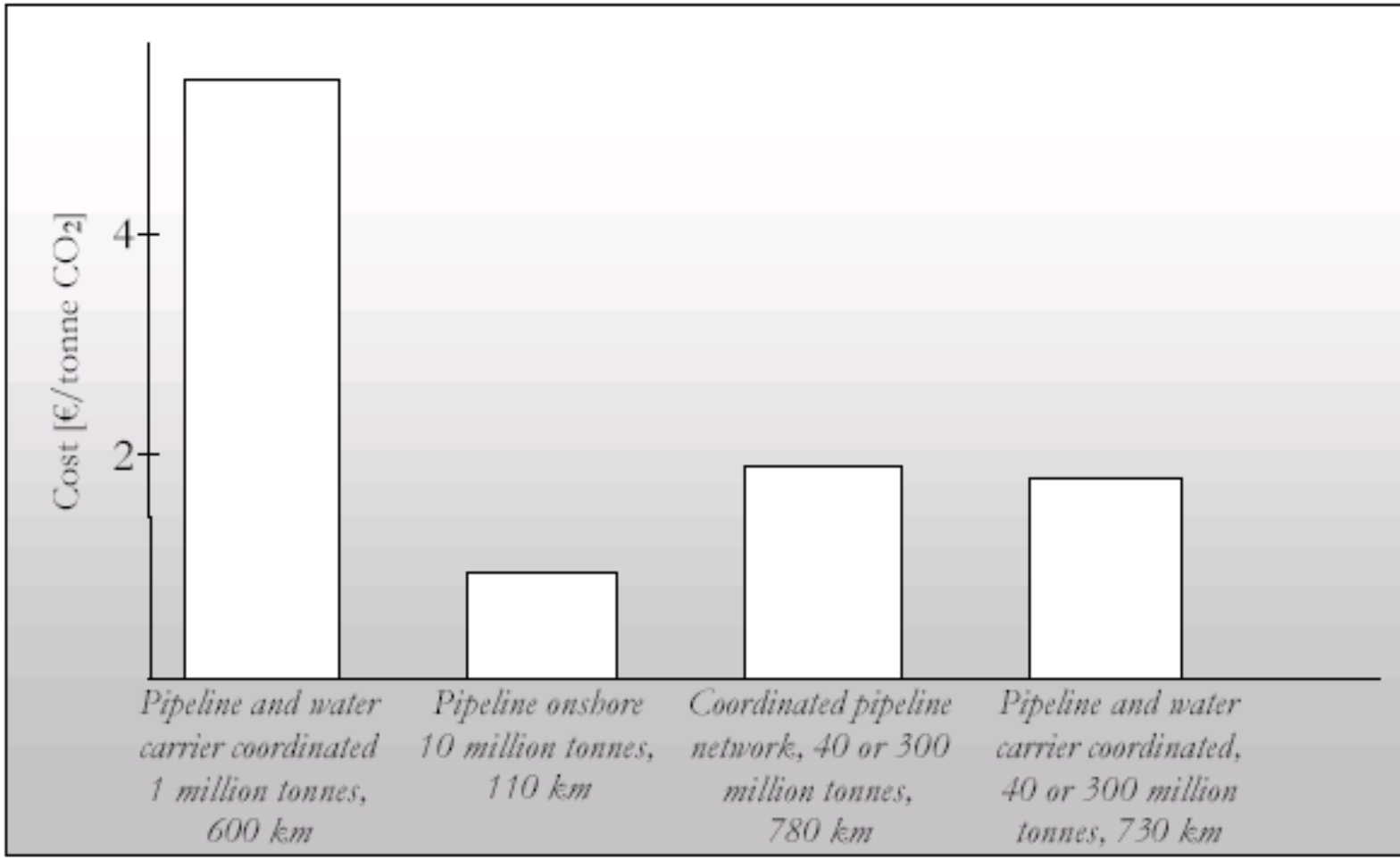
Transport costs for CO2
Cost and capacity ranges



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

Transport costs for CO2

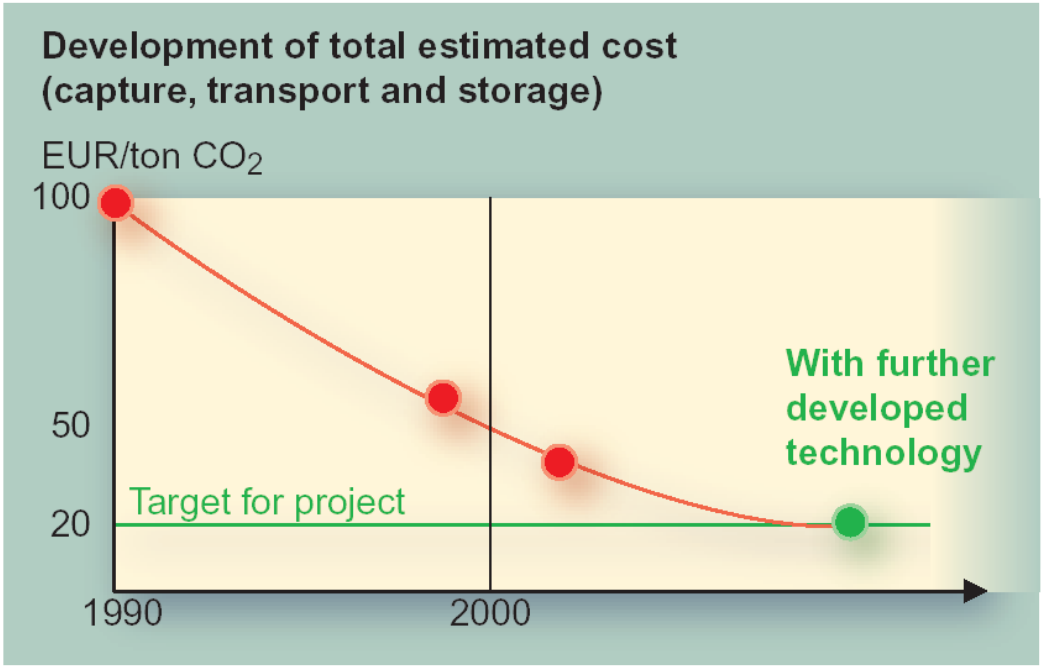


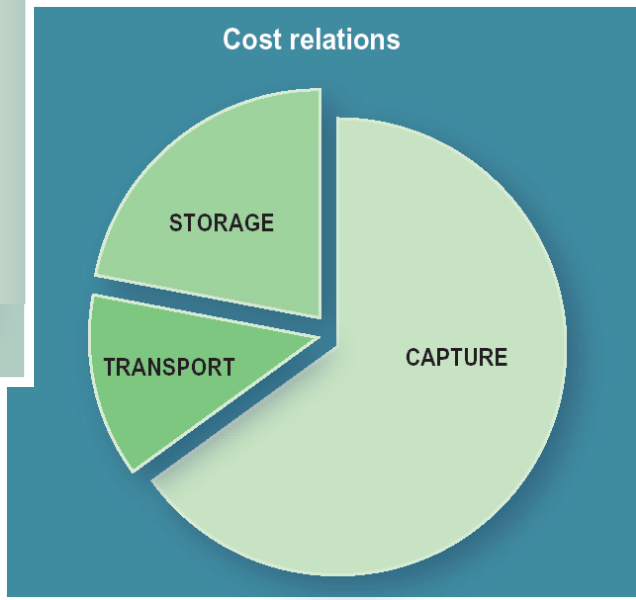
Source: Odenberger M, Svensson R, Analysis of Transportation Systems for CO2, Chalmers, 2003

CO_2 free power plant

Capture

CO_2 capture and storage – cost estimates



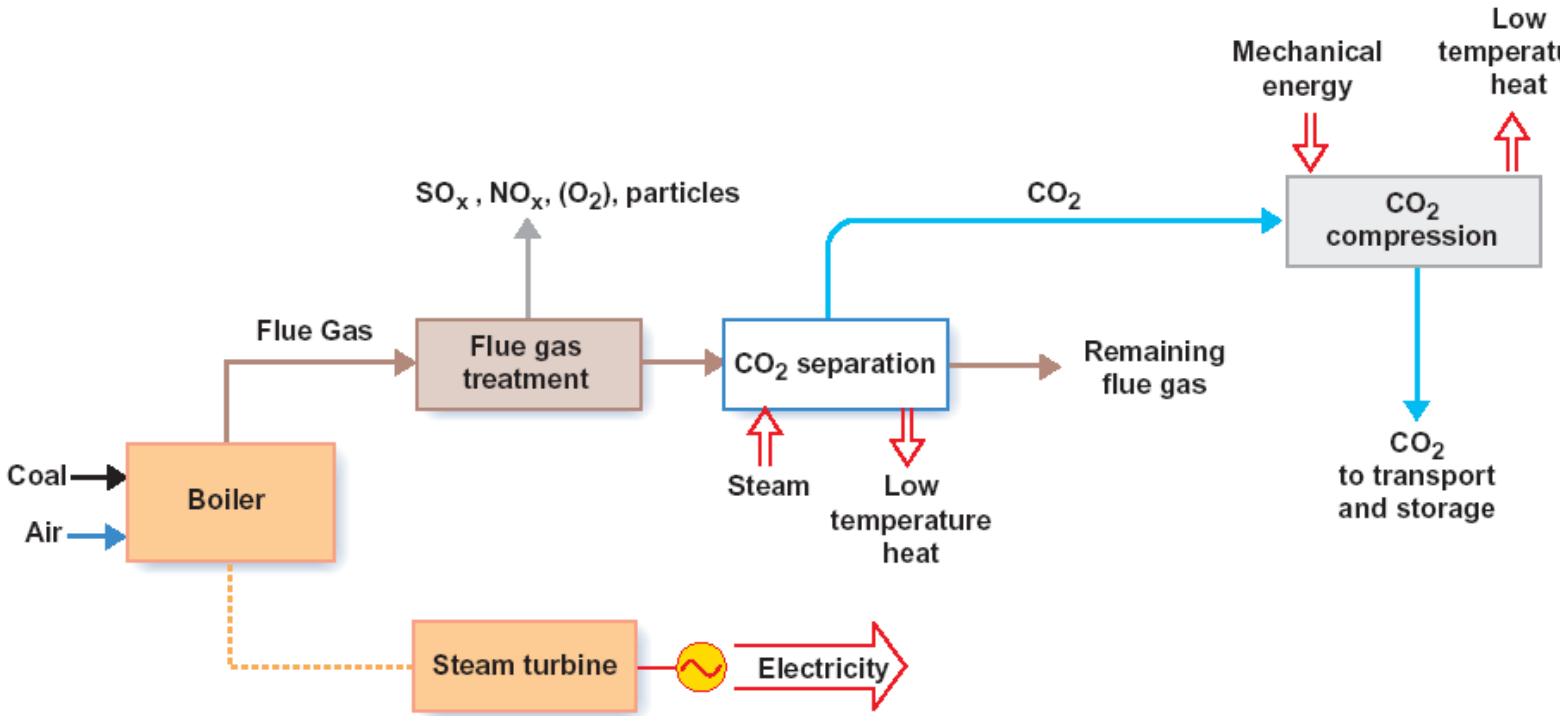


CO_2 free power plant - Capture

- Capture of CO_2 is well established in several industrial processes. In food industry, in oil and gas industry and in chemical industry.

- 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

Post-combustion capture – absorption process



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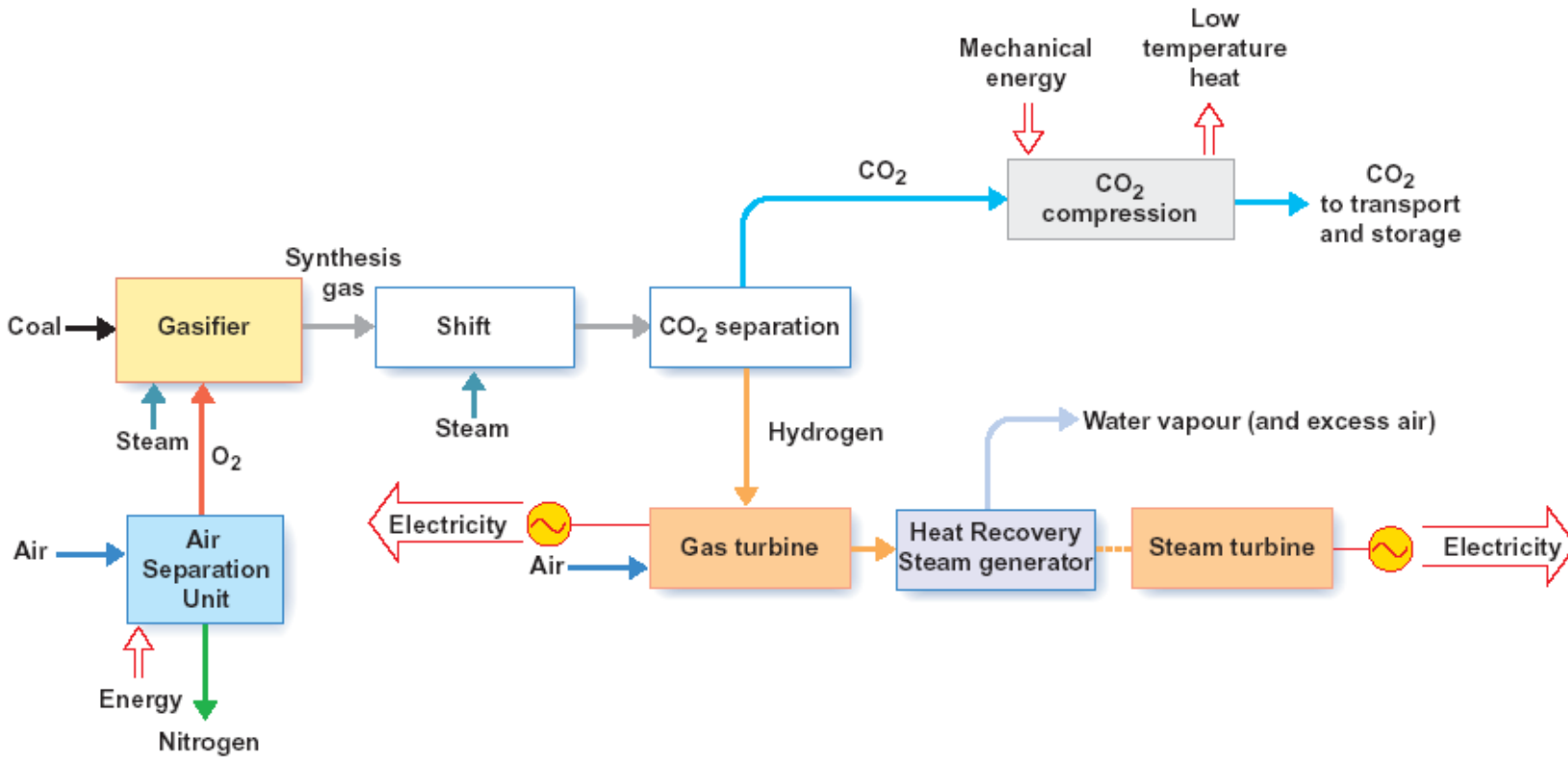
Pre-combustion - decarbonisation capture



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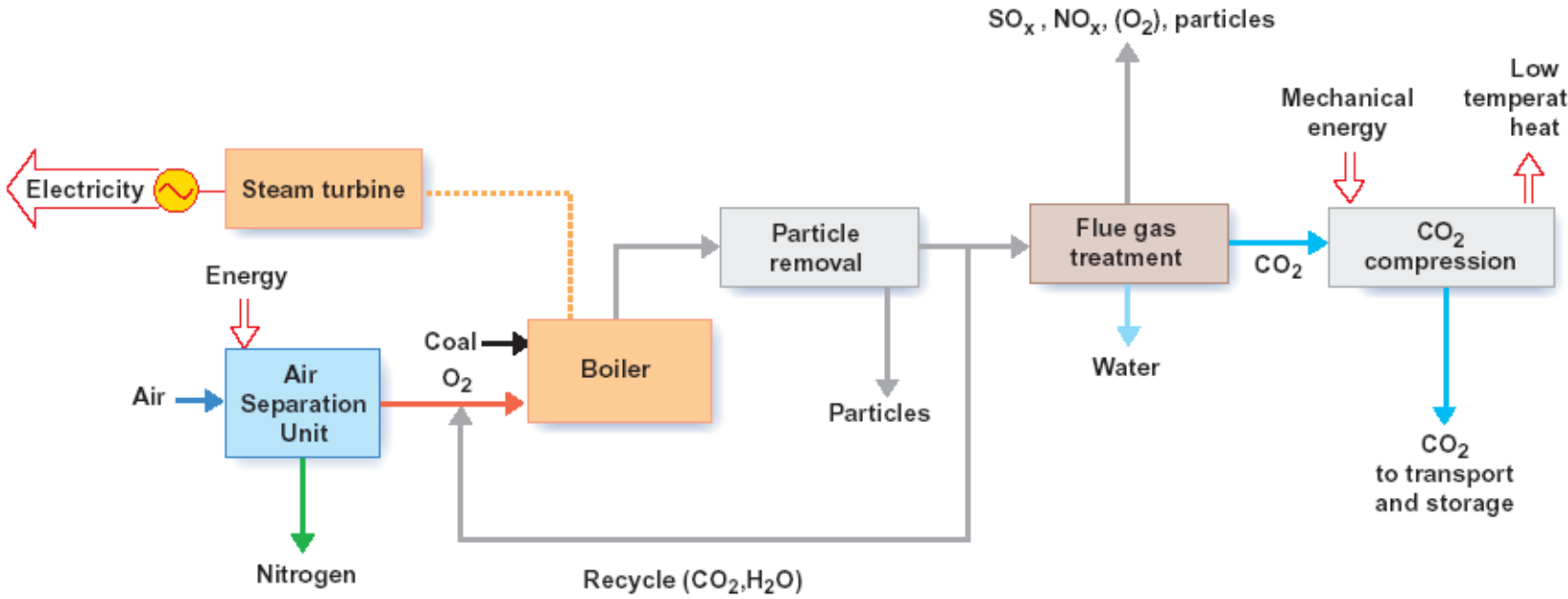
O_2/CO_2 recycle (oxyfuel) combustion capture



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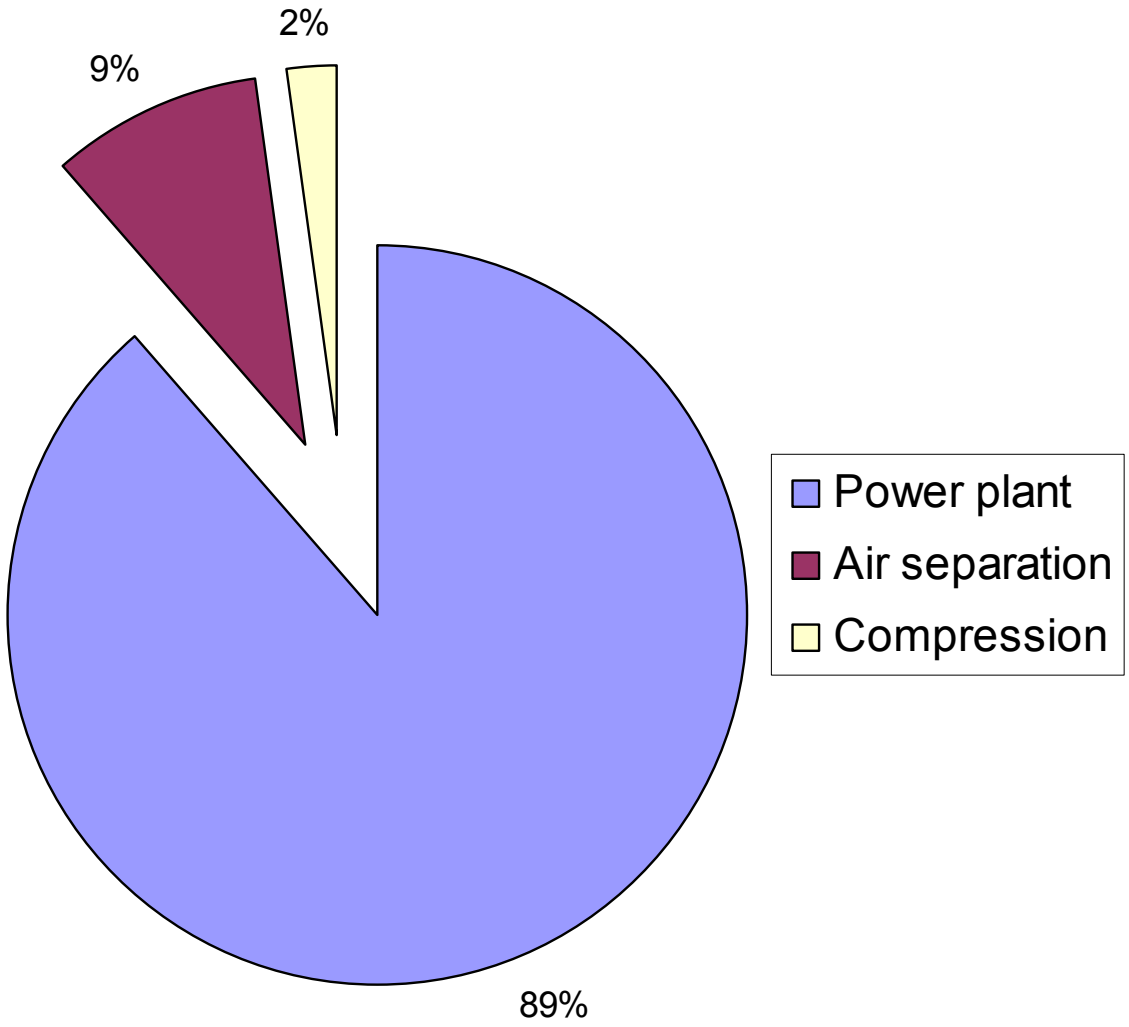
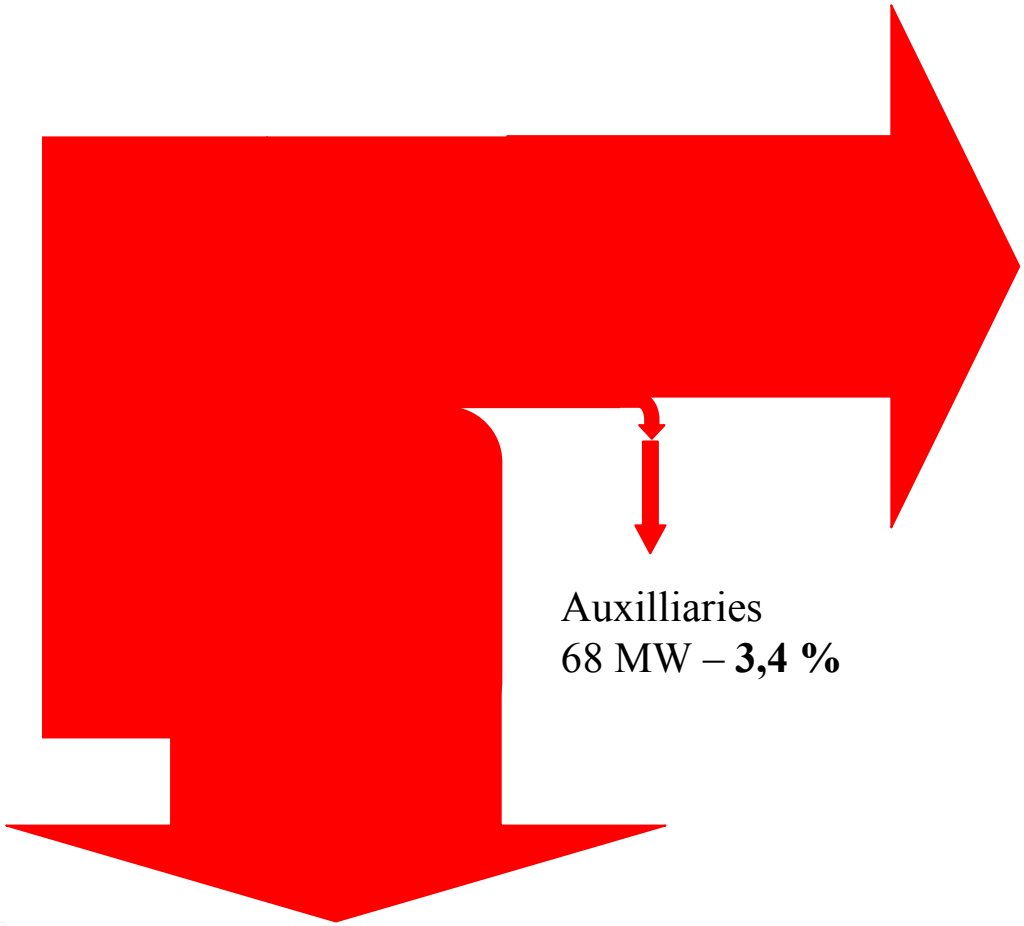
Investment cost for a large lignite fired power plant with O_2/CO_2 combustion



Energy flow diagram for a lignite fired Power Plant



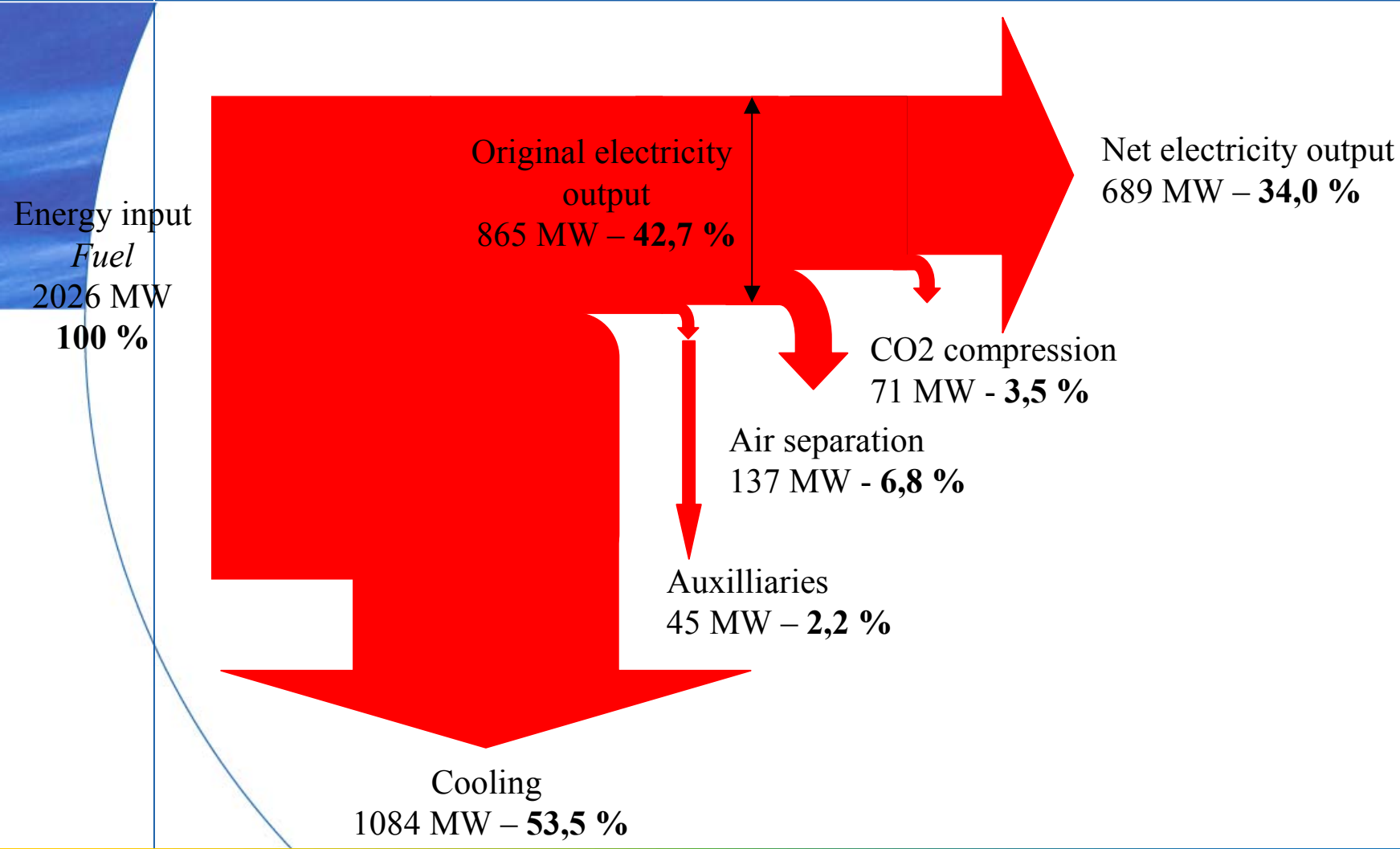
Energy input
Fuel
2026 MW
100 %

Net electricity output
865 MW – **42,7 %**

Auxilliaries
68 MW – **3,4 %**

Cooling
1093 MW – **53,9%**

Energy flow diagram for lignite fired plant with O_2/CO_2 combustion



CO_2 free power plant

Evaluation of the options

CO_2 – Capture
Evaluation of options

A preliminary evaluation of different options for CO_2 capture from coal fired plants has been made.

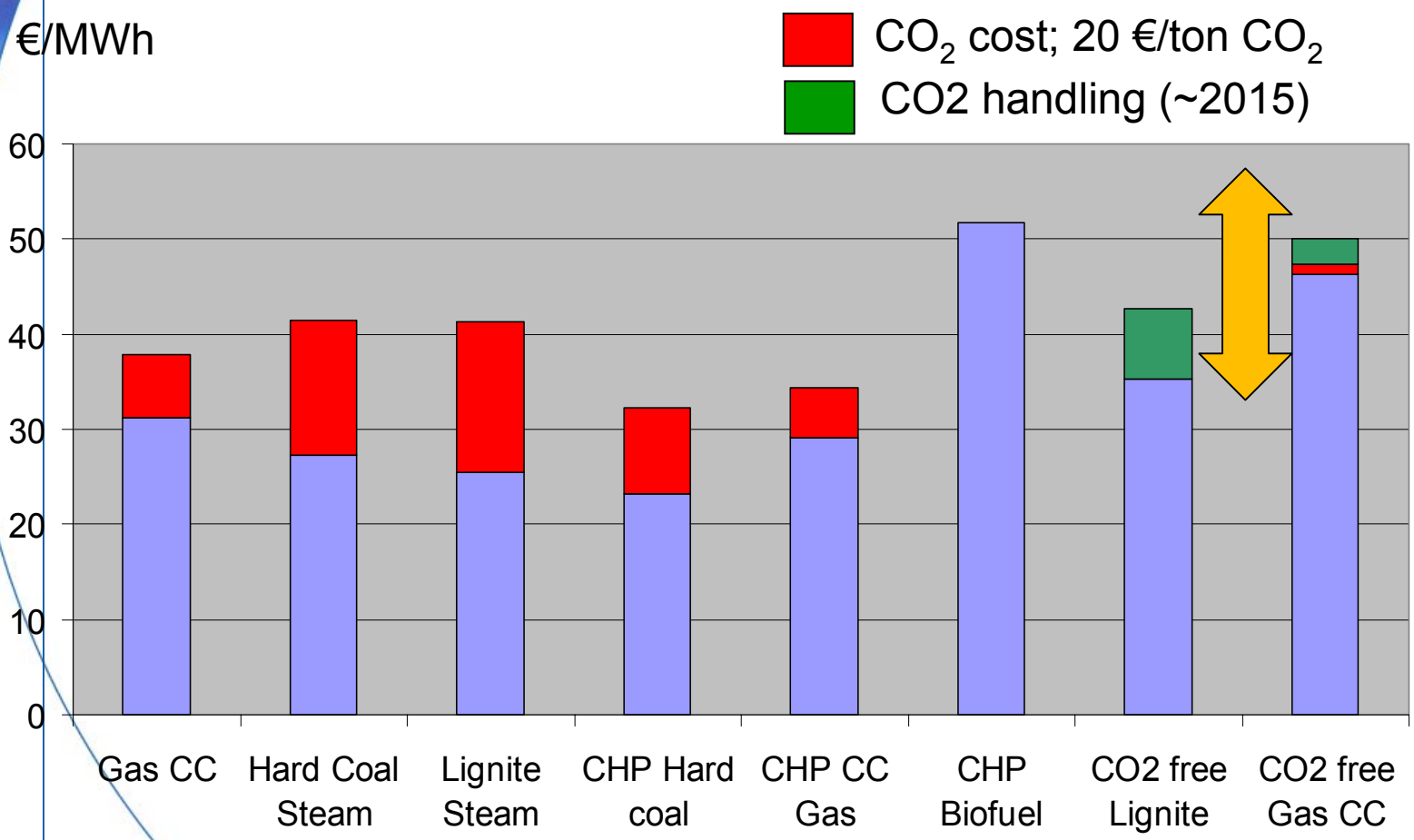
- Major conclusions are:
  - Of the three available technologies, IGCC, O_2/CO_2 combustion and MEA absorption, the first two seems most attractive
  - Vattenfall will continue to study all three options, with emphasis on the two first, and most effort into O_2/CO_2 combustion, due to that others work with the other two.

CO_2 Capture – present technologies
Evaluation of options

Technology	IGCC					O_2/CO_2
Source reference	IEA GHG			EPRI	MIT	Vattenfall / Chalmers
Specification	Dry feed GE F class		Slurry feed GE F class	Slurry feed GE H class	Vario us	*Lippendorf* Wet Lignite
Date for study	2001	2003	2003	2000	2001	2001
Efficiency, % (LHV)						
Without capture	46,3	38,0	43,1	45,2	42,2	*42,7*
With capture	38,2	31,5	34,5	38,8	36,1	34,3
Efficiency difference	8,1	6,5	8,6	6,2	6,1	8,4
Capital cost, EUR/kW						
Without capture	1470	1187	1371	1260	1401	*1272*
With capture	2200	1495	1860	1640	1909	1570

References: IEAGHG: Leading options for capture of CO2 emissions from power plant(2000); EPRI: Evaluation of innovative fossil fuel plants with CO2 removal (2000); MIT: David, J and Herzog, H: The cost of carbon capture (2001)

Electricity generating cost incl. CO_2 cost



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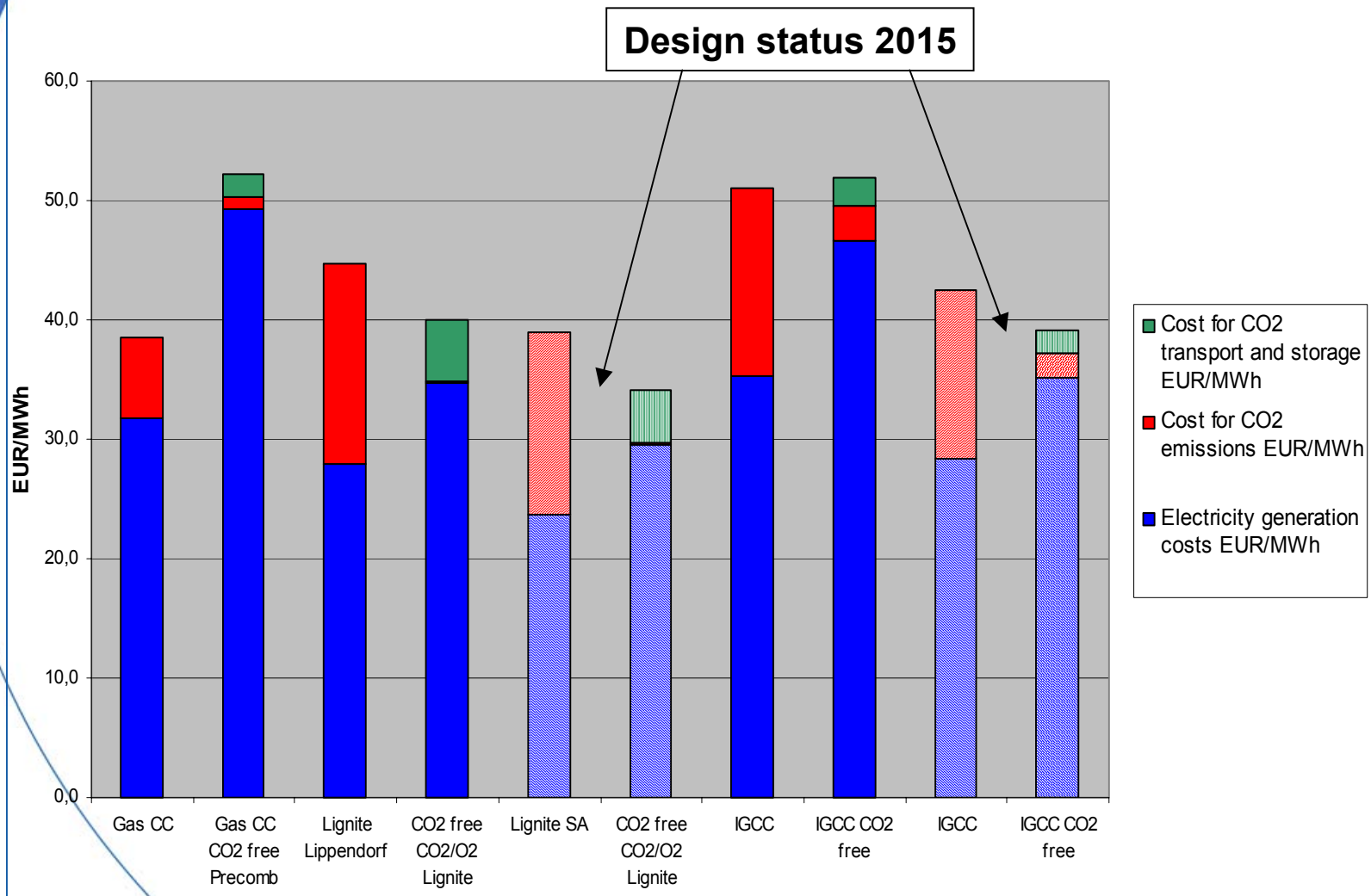
CO_2 Capture
Evaluation of options

	Gas CC	Gas CC CO2 free Precomb	Lignite Lippendorf	CO2 free CO2/O2 Lignite	Lignite SA	CO2 free CO2/O2 Lignite	IGCC	IGCC CO2 free	IGCC	IGCC CO2 free
Reference	Sintef	Sintef	VAB	VAB	VAB	VAB	IEA	IEA	IEA	IEA
Fuel	Gas	Gas	Lignite	Lignite	Lignite	Lignite	Coal	Coal	Coal	Coal
Power output MW	400	392	865	700	500	500	776	676	750	700
Specific Investment cost EUR/kW	625	1430	1272	1570	1005	1366	1371	1860	900	1250
Efficiency %	60	49	42,7	34,3	47	39,8	43,1	34,5	48	43,2
Fuel cost EUR/MWh fuel	12,5	12,5	4	4	4	4	5,8	5,8	5,8	5,8
O&M cost EUR/MWh	2,7	5,8	4,0	5,0	3,4	3,9	6,7	9,5	6,0	7,8
CO2 emitted kg/MWh	335	53	836	7	760	4	786	142	706	102

CO_2 Capture
Evaluation of options

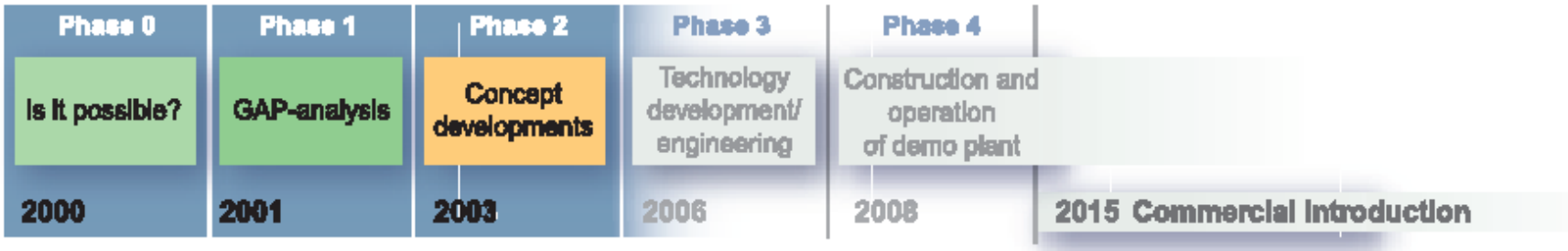


The CO_2-free Power Plant

Vattenfall

A leading role in the development

The CO_2-free Power Plant project



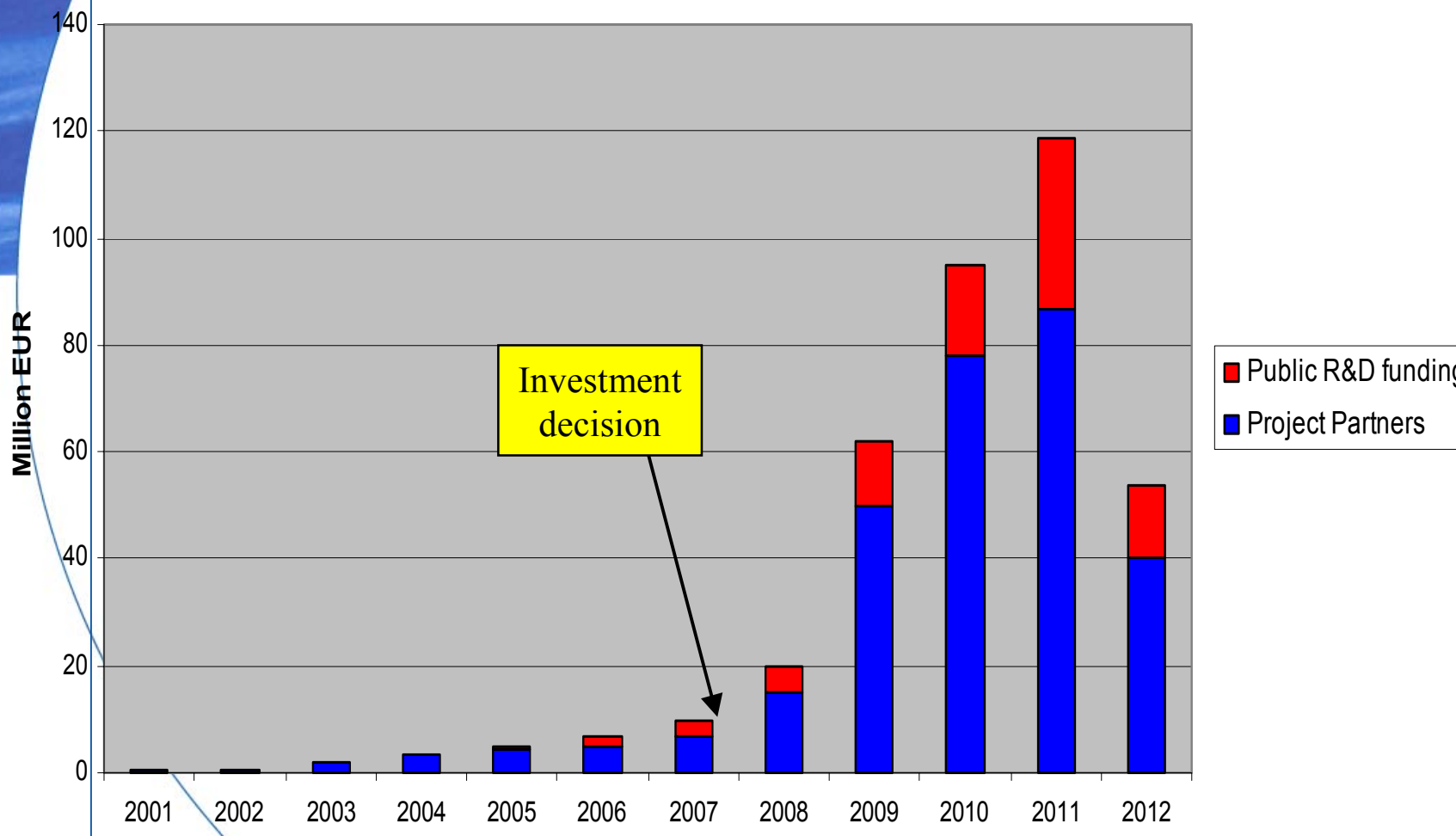
- The project consists of four steps, leading to a base for a large demo plant
- Target is to reduce cost for CO_2 separation and storage below 20 €/ton CO_2
- Vattenfall has taken a leading role in international co-operation, together with the major European industry

  Energy industry: RWE, Vattenfall, Energi E2, PPC, Statoil…..

  Industry : Alstom, Siemens, Linde, BOC, Lurgi ….

  Research : IFP, TNO, Sintef, BGR, leading European Universities ….

CO_2 free Power Plant Demo
Cost distribution



Conclusions

Conclusions

- Fossil fuels are needed many decades yet
- CO_2 capture and storage can enable energy generation at a lower cost than most renewable alternatives, eliminating carbon dioxide emissions to the atmosphere.
- 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 under the upcoming trading scheme.
- ”Carbon dioxide free” energy production from fossil fuels can not be be introduced at a larger scale before 2015.
- Coal will be available for a long time and can create a way to ensure energy supply without severe negative environmental impact, until real, large enough sustainable energy sources, with a reasonable cost, can be developed.