3rd South East Europe Energy Dialogue

"Threats and Opportunities in the Energy Markets in the Current Economic Crisis"

19/6/2009

"Clean Technologies for power production from solid fuels : The European Experience"

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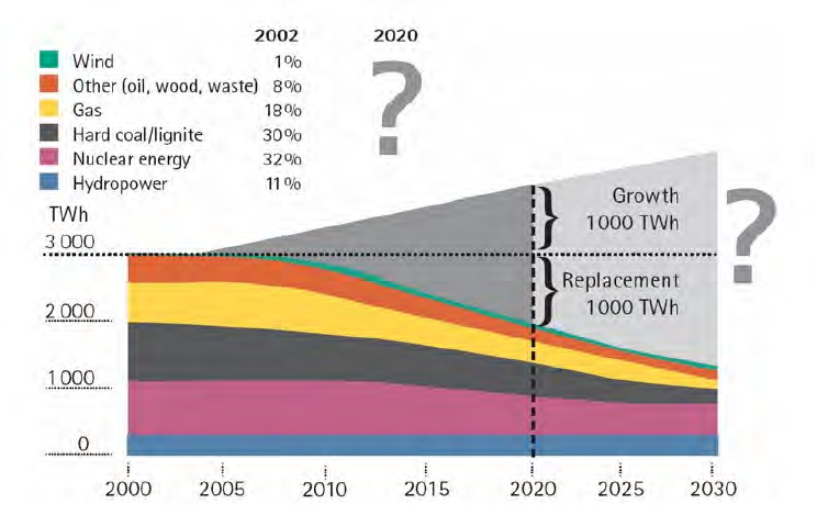
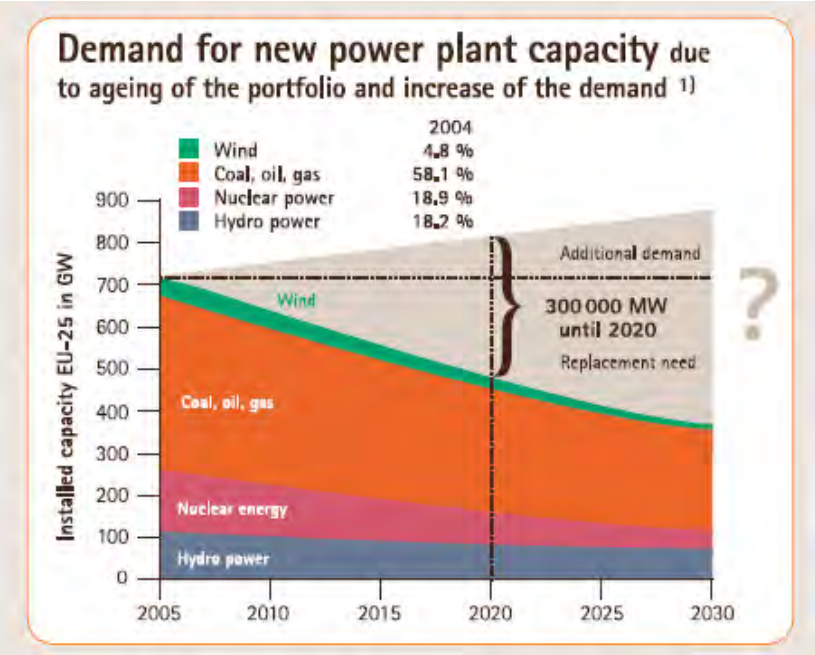
Content

- Evolution of electricity generation sector
- Clean Coal Technologies – Supercritical Power Plants
- Carbon Capture and Storage
- Conclusions

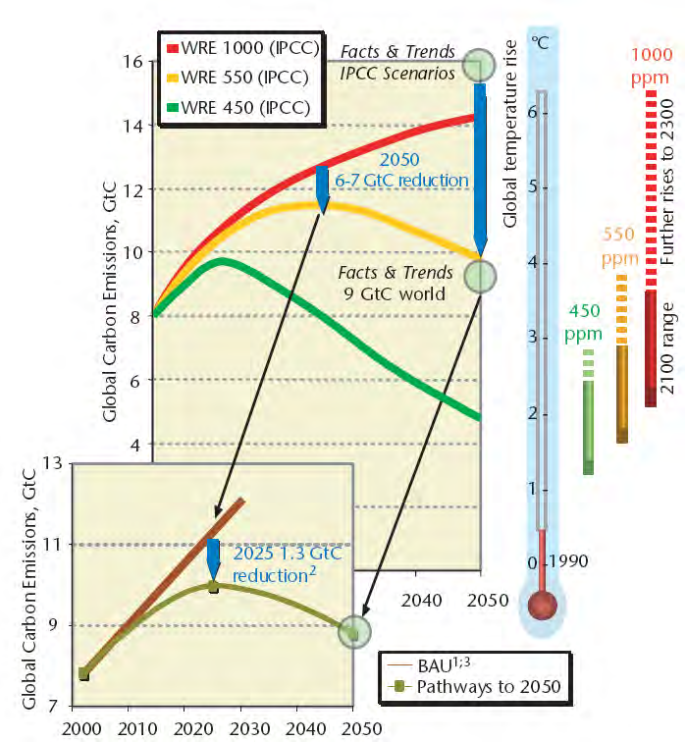
Evolution of electricity generation sector





- The new capacity demand deals with the coverage of electricity consumption increase as well as the decommissioning of old units
- Old units decommissioning refers to 50% of the new electricity production demand
- New capacity is related by 80% to the decommissioning of old units
- The introduction of state-of-the-art technologies into the European electricity system comprise an essential choice

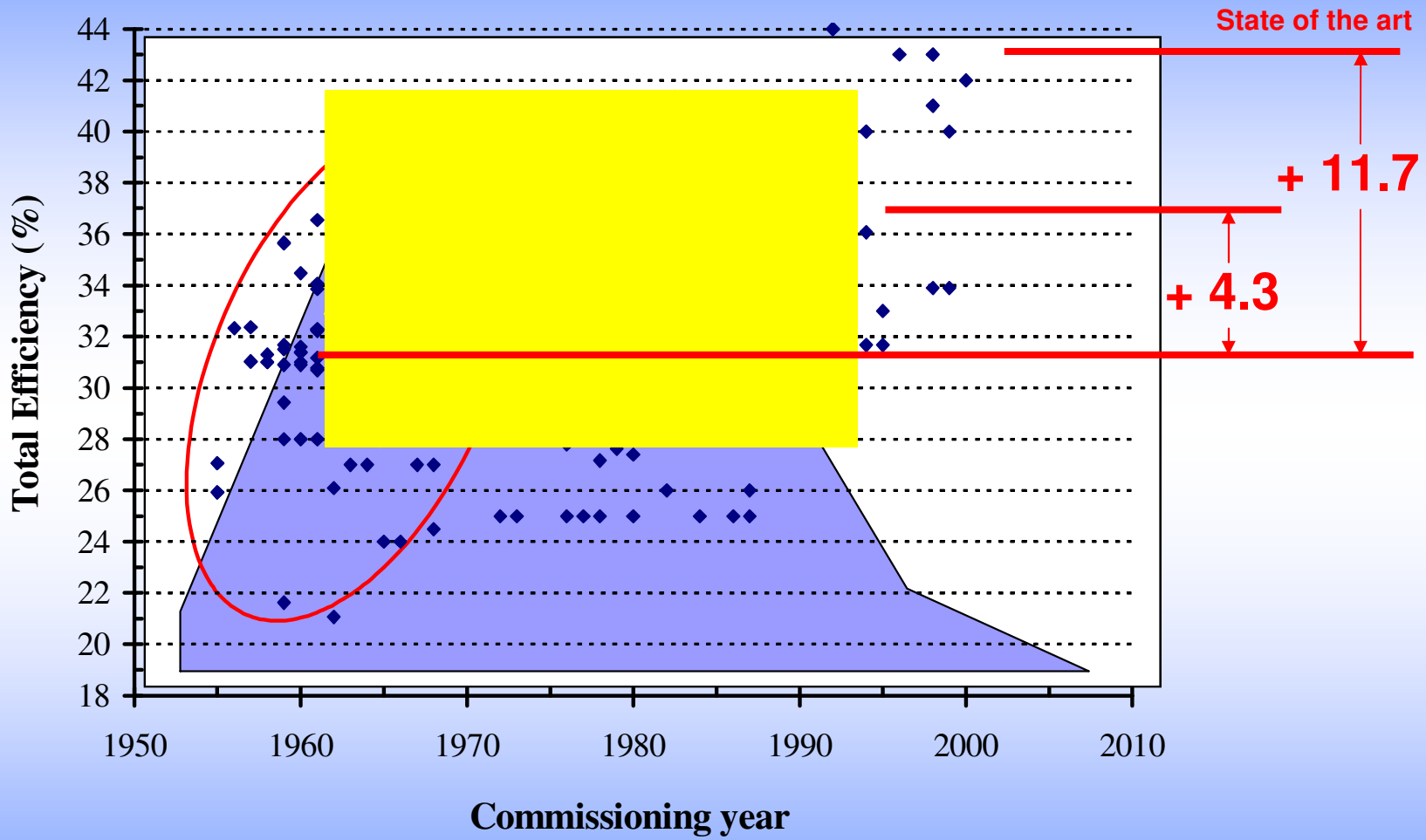
Evolution of electricity generation sector



New technological concepts should ensure :

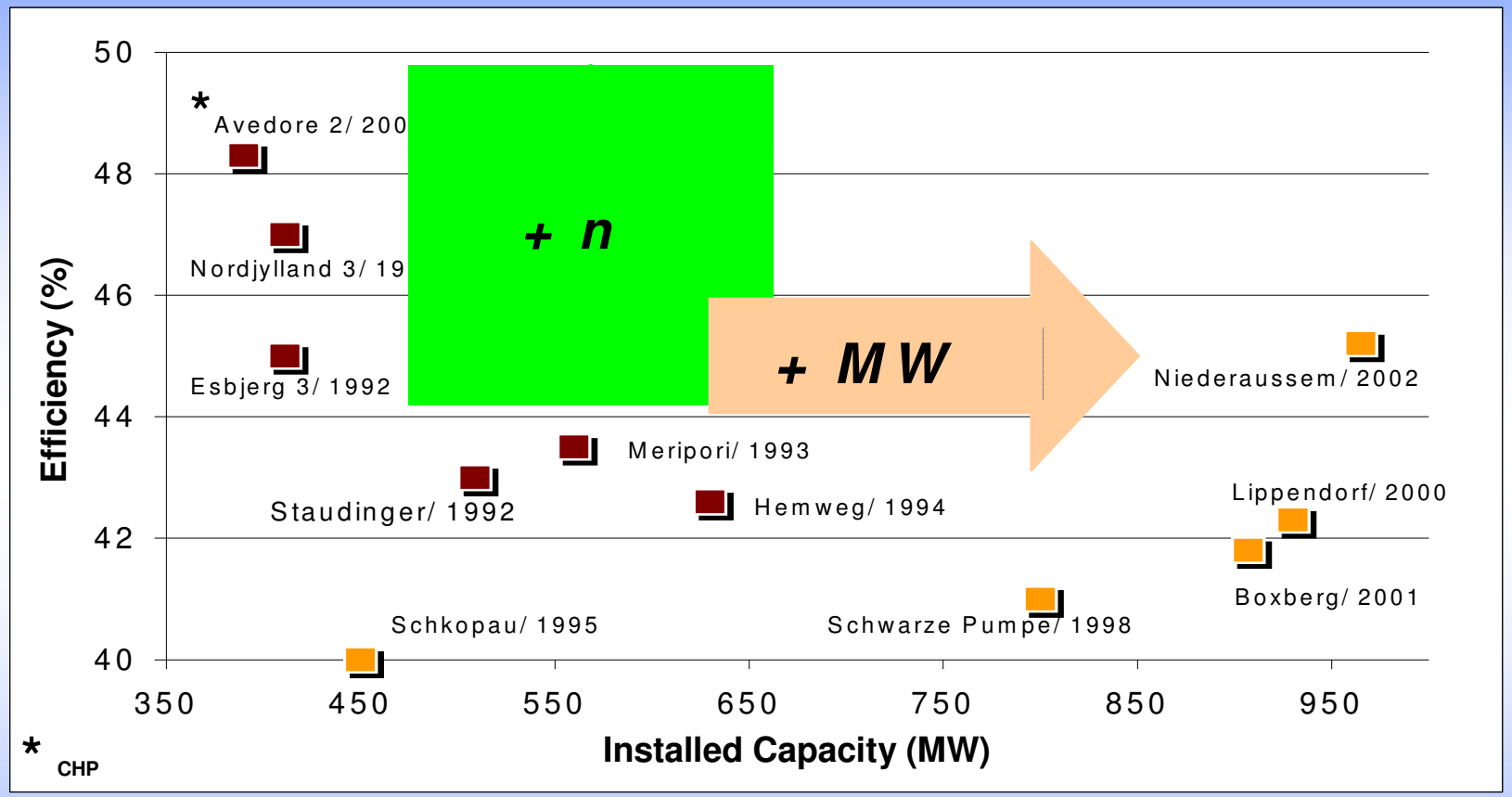
- **Security of supply of the European market**
- **Requirements for Green House Gas emissions mitigation, according to Kyoto Protocol**
- **Electricity demand increase with environmentally acceptable terms**
- **Operation of the liberalized electricity market**
- **Electricity grid stability**

Evolution of electricity generation sector



- Today 123 units in operation, of a total capacity of approx. 13 GW, are more than 45 years old in the Enlarged Europe.
- The average capacity of these units is 105 MW

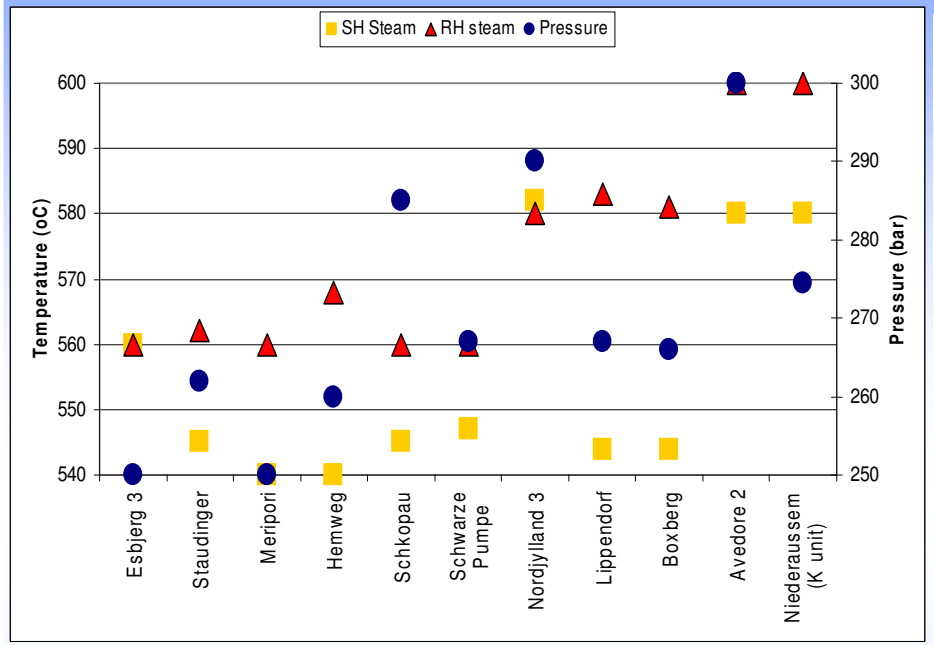
Advanced Supercritical Power Plant Technology

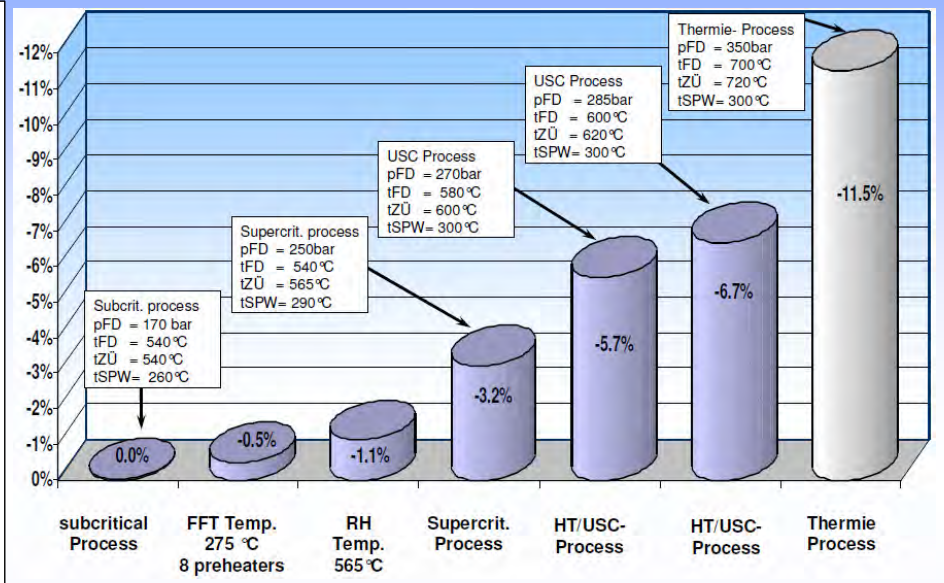


The evolution of supercritical steam technology results into the efficiency increase as well as to power plants' capacity increase

The are choices for the different types of solid fuels

Advanced Supercritical Power Plant Technology

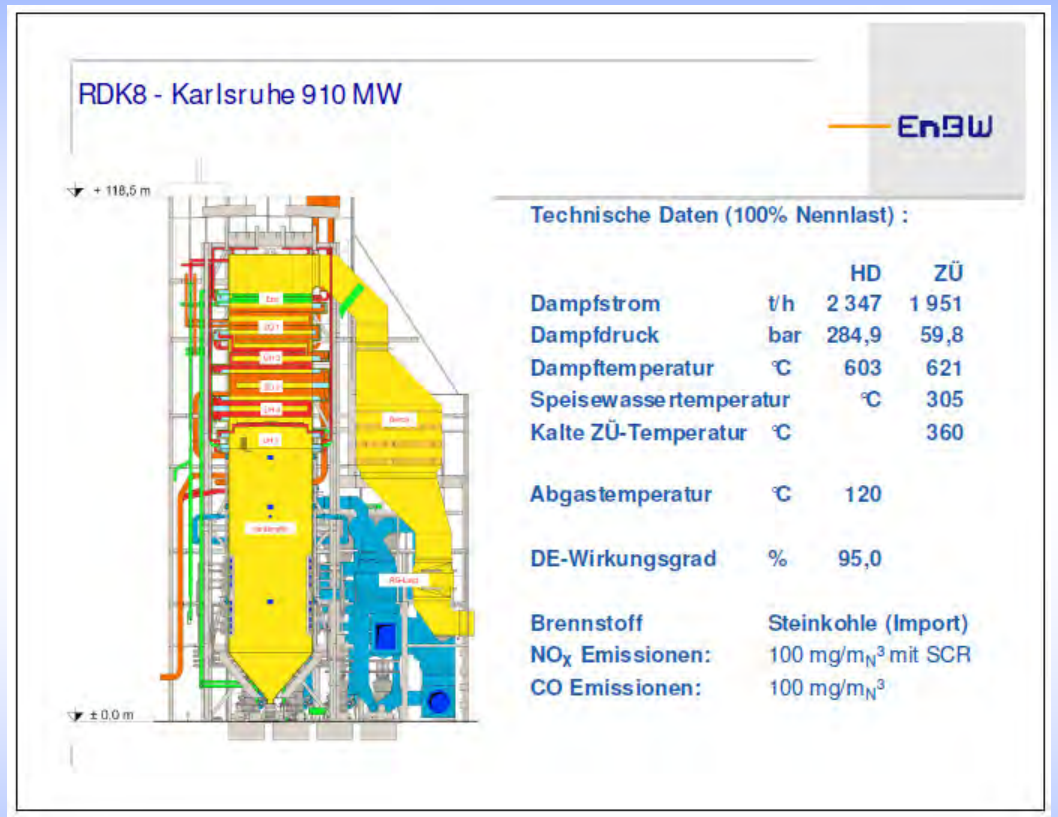


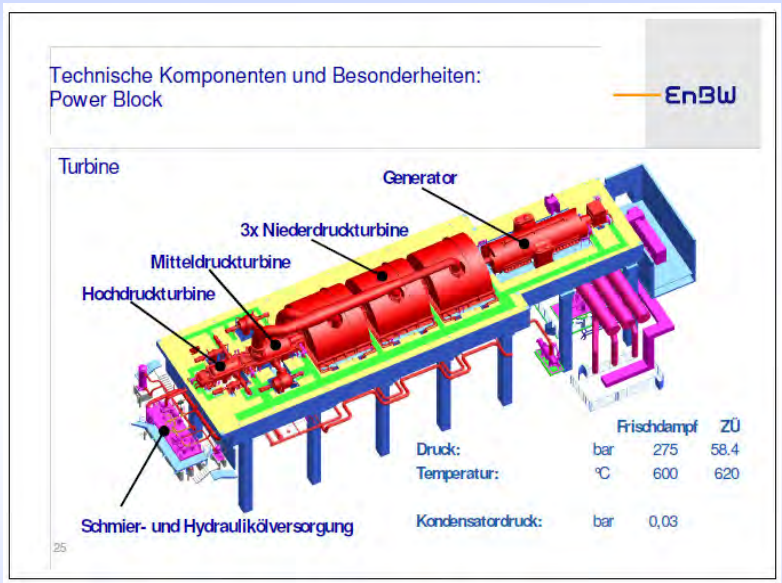


Improvement of specific heat consumption [%] with respect to the evolution of technology

- **Todays industrial practice leads to Power Plants of 600 °C Reheated steam. The existing fleet (since 1992) comprise of 27 units worldwide with total capacity of 20 GW.**
- **15.6 GW refers to 21 coal units [Average installed capacity 740 MW (390 - 1050 MW), Average efficiency 43.5%]**
- **4 GW refers to 5 lignite units [Average installed capacity 810 MW (450 - 965 MW), Average efficiency 42%]**

Advanced Supercritical Power Plant Technology

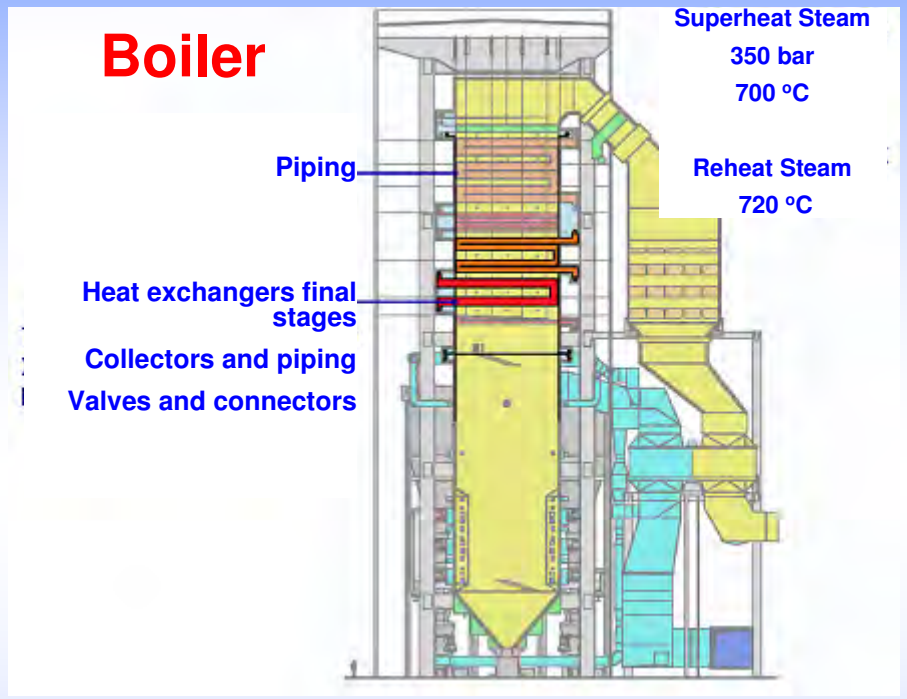




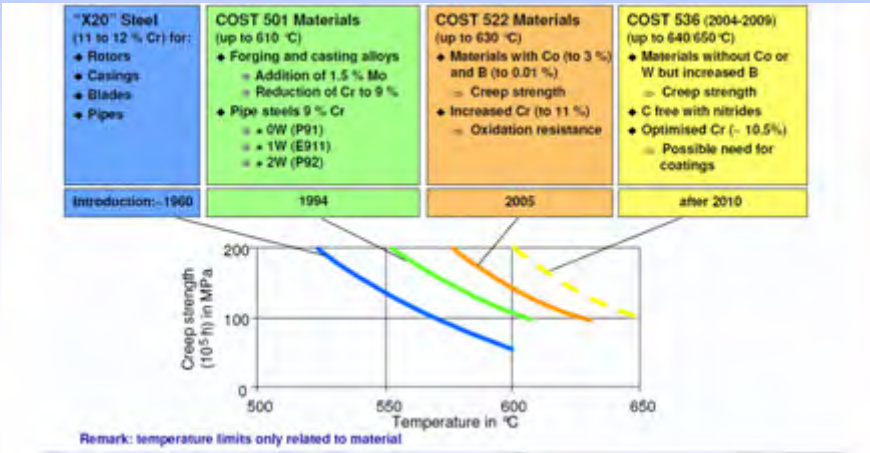
- Unit RDK 8 of 912 $MW_{el, gross}$ capacity (275bar/600°C,620°C) with CHP 220 MW_{th} (utilization up to 58%)
- Foreseen efficiency greater than 46%
- Expected Commercial Operation in 2009 - 2011

Advanced Supercritical Power Plant Technology

Boiler

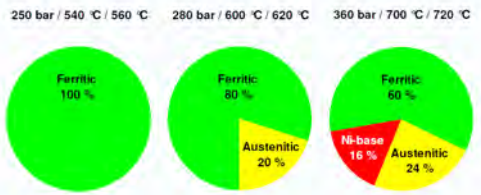


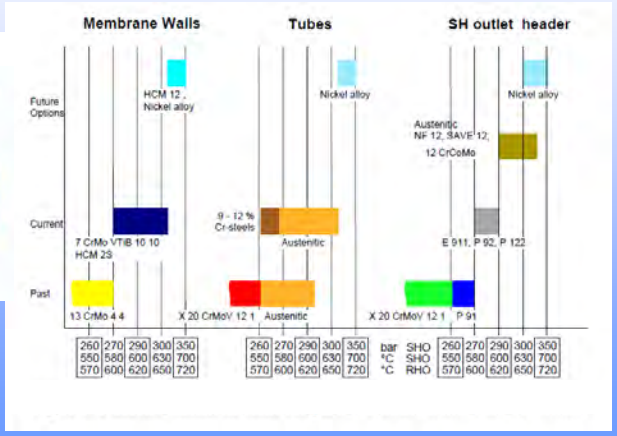
SteamTurbine



ALSTOM

Materials Comparison (400 MW, Single Reheat)





Evolution of Technology

Use of new austenitic and Ni–base materials in critical pressure parts

Materials of 9-12% Cr in steam turbine
New titanium blades LSB
Advanced design blades
Improved seals

New Greek Lignite fuelled Unit

Plans for the introduction of a new Lignite Unit in Ptolemais

- **Capacity 550 – 660 MW**
- **Steam characteristics (605°C, 610°C, 280 bar)**
- **Net efficiency 41,5% ($n_{gross} \geq 45\%$)**

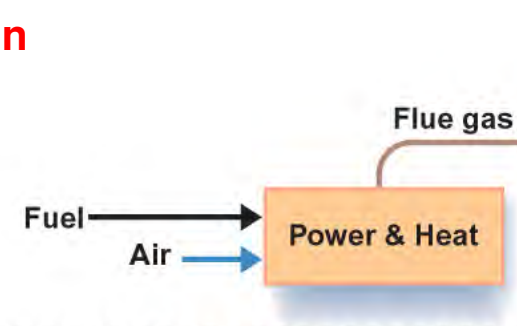
- **will be equipped with :**
  - **Flue Gas Heat Recovery system**
  - **Flue Gas Desulphurization facility**

- **will achieve emission (6% O_2, dry)**
  - **NOx** **< 200 mg/Nm³**
  - **Particulates** **< 10 mg/Nm³**
  - **SO_2** **< 150 mg/Nm³**

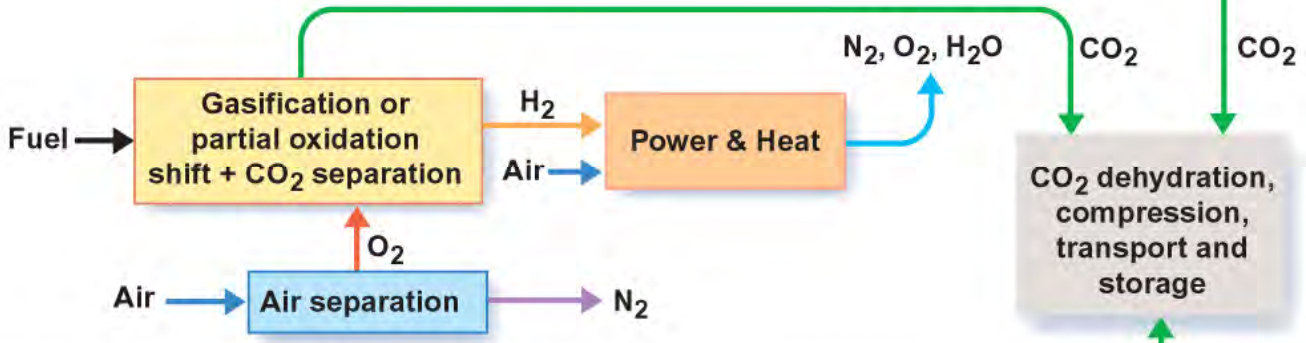
Carbon Capture and Storage Technologies (CCS)

Available Options

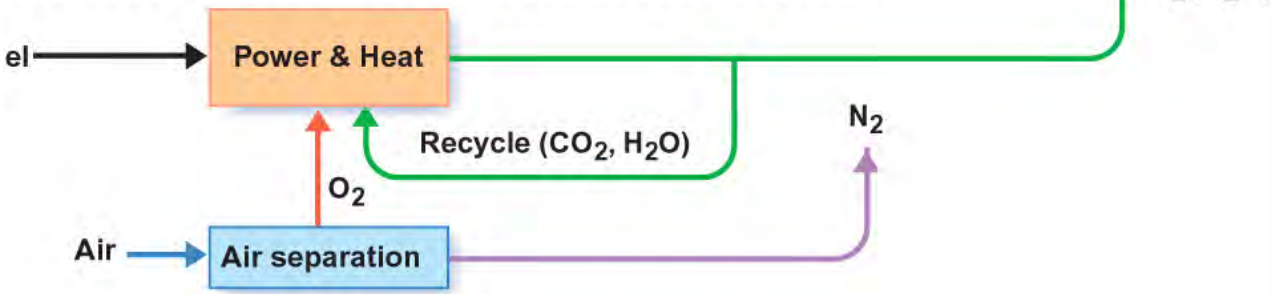
Post Combustion



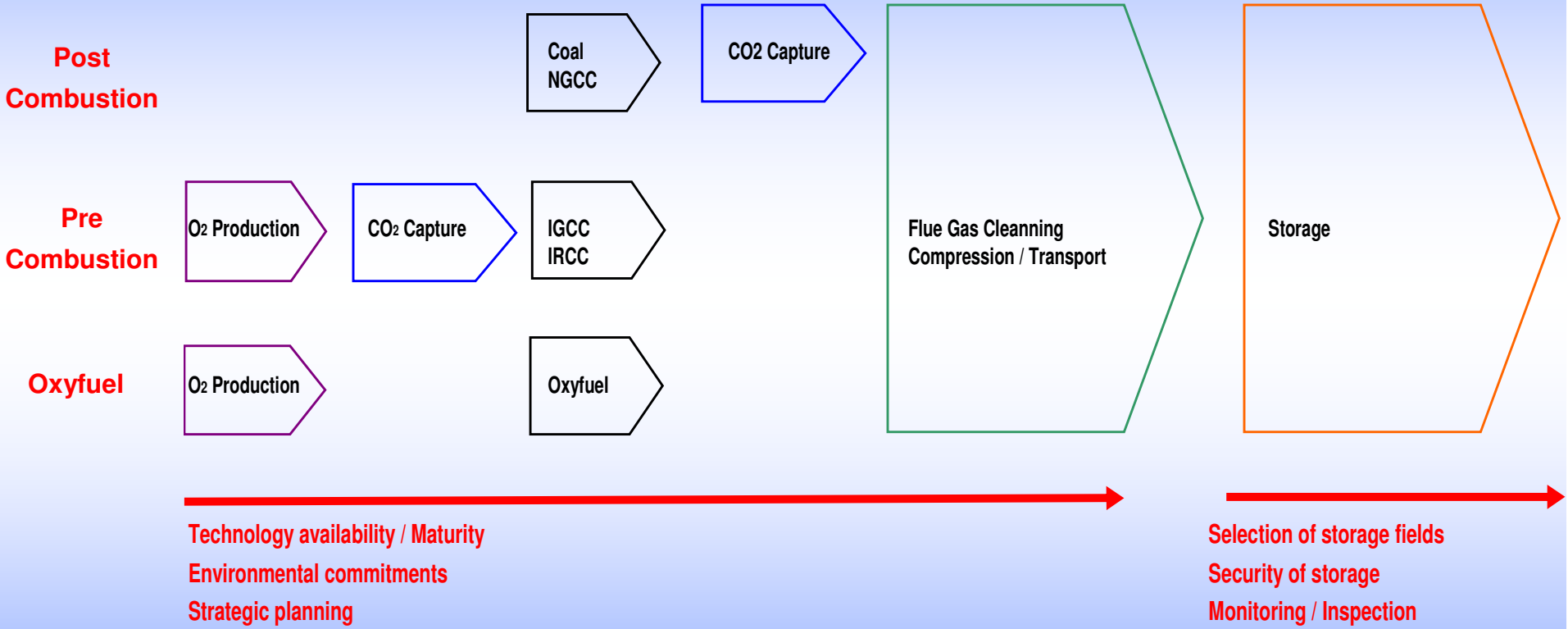
Pre- Combustion



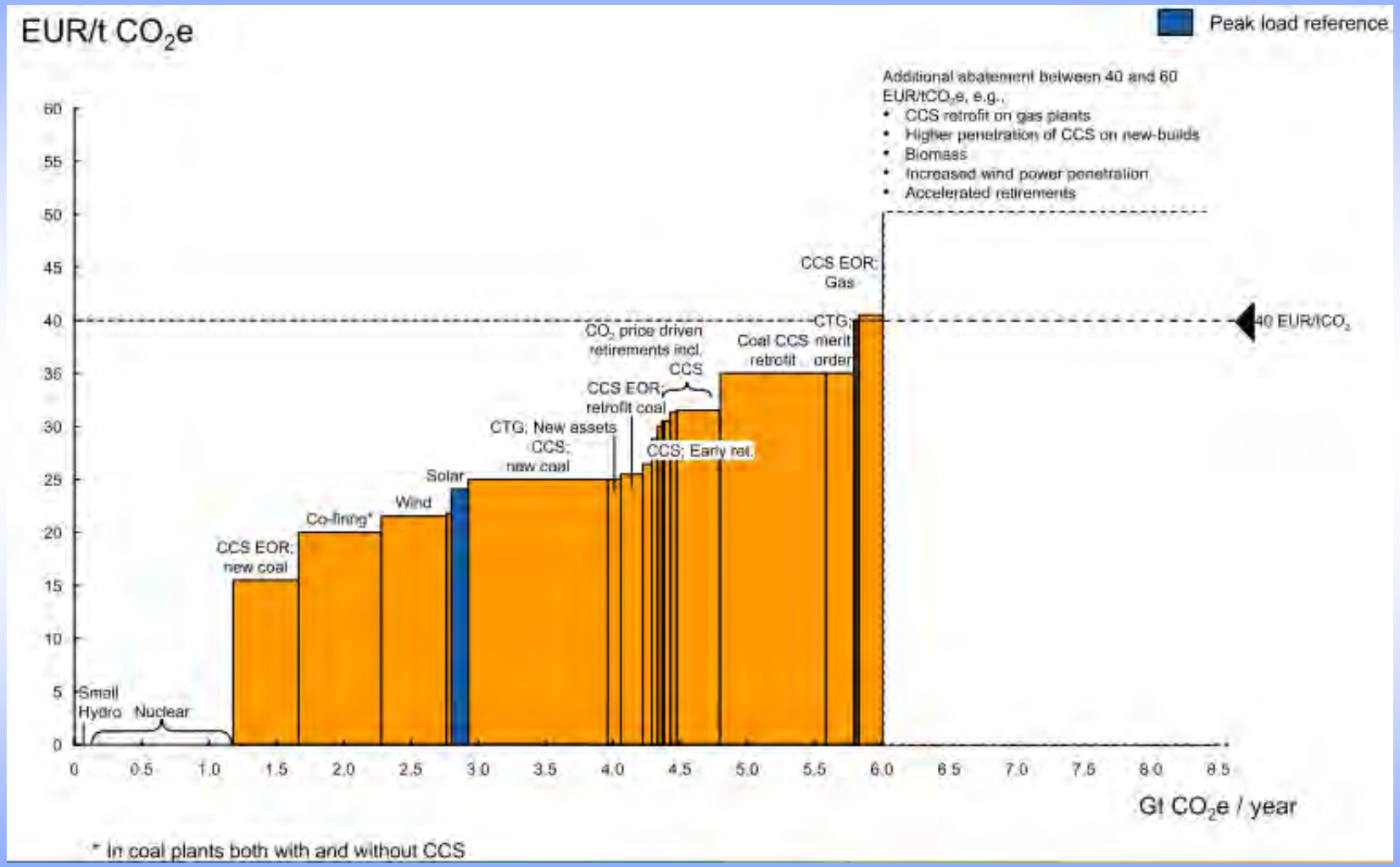
Oxyfuel



Carbon Capture and Storage Technologies (CCS)



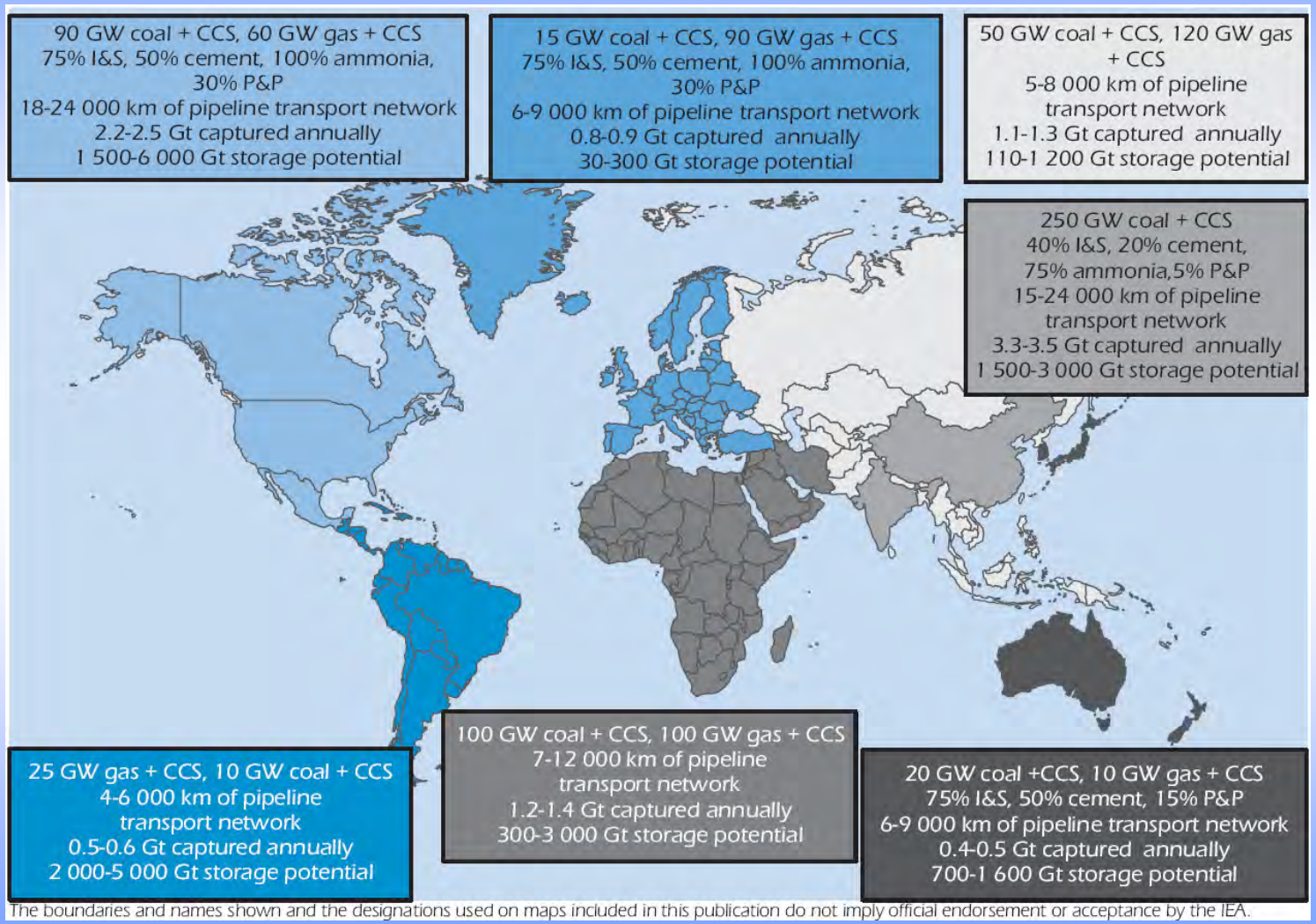
Carbon Capture and Storage Technologies (CCS)



Avoidance cost in energy sector for 2030

Carbon Capture and Storage Technologies (CCS)

Scenarios / Axis of implementation CCS



IEA, CO2 Capture and Storage : A Key Carbon Abatement Option (2008)

Carbon Capture and Storage Technologies (CCS)

Shell
Ολλανδία
Παραγωγή H2
0.4 CO2 Mt/ετ.
Εξ. Ταμιευτήρες

Total
Γαλλία
30 MW
Εξ. Ταμιευτήρες
OXYFUEL

Powerfuel Power
Ην. Βασίλειο
900 MW
4.75 CO2 Mt/ετ.
Εξ. Ταμιευτήρες
PRE COMBUSTION

BKK
Νορβηγία
450 MW pre or post
1.2 CO2 Mt/ετ.
Υφ. Υδροφορείς

Nuon
Ολλανδία
1200 MW
4.14 CO2 Mt/ετ.
Εξ. Ταμιευτήρες
PRE COMBUSTION

CGEN
Ολλανδία
450 MW
2.5 CO2 Mt/ετ.
Εξ. Ταμιευτήρες
PRE COMBUSTION

Centica
Ην. Βασίλειο
800 MW
4.22 CO2 Mt/ετ.
Εξ. Ταμιευτήρες
PRE COMBUSTION

PKE / ZAK
Πολωνία
250 MW
3.4 CO2 Mt/ετ.
Υφ. Υδροφορείς
PRE COMBUSTION

RWE
Γερμανία
450 MW
2.8 CO2 Mt/ετ.
Υφ. Υδροφορείς
PRE COMBUSTION

Fortum
Φινλανδία
oxy or post
560 MW
3.35 CO2 Mt/ετ.

Essent
Ολλανδία
1000 MW
4 CO2 Mt/ετ.
Εξ. Ταμιευτήρες
PRE COMBUSTION

Haugaland Kraft
Νορβηγία
600 MW

E.On UK
Ην. Βασίλειο
350 MW
2.5 CO2 Mt/ετ.
Εξ. Ταμιευτήρες
PRE COMBUSTION

Vattenfall
Γερμανία
250 MW oxy or post
1.79 CO2 Mt/ετ.
ERG/Υφ.Υδροφορείς

ENEL
Ιταλία
320 MW
2.1 CO2 Mt/ετ.
Υφ. Υδροφορείς
OXYFUEL

Endesa
Ισπανία
500 MW
Υφ. Υδροφορείς
OXYFUEL

Progressive Energy
Ην. Βασίλειο
450 MW
2.4 CO2 Mt/ετ.
PRE COMBUSTION

Hammerfest Energi
Δανία
100 MW
Υφ. Υδροφορείς
POST COMBUSTION

Scottish Power
Ην. Βασίλειο
Υφ. Υδροφορείς
POST COMBUSTION

E.On Benelux
Ολλανδία
100 MW
5.6 CO2 Mt/ετ.
Εξ. Ταμιευτήρες
POST COMBUSTION

CORUS
Ην. Βασίλειο
Εξ. Ταμιευτήρες
POST COMBUSTION

ArcelorMittal
Γαλλία
Υφ. Υδροφορείς
POST COMBUSTION

Tinfos
Δανία
400 MW
2.5 CO2 Mt/ετ.
Υφ. Υδροφορείς
POST COMBUSTION

Βουλγαρία
650 MW
3.43 CO2 Mt/ετ.
PRE COMBUSTION

ArcelorMittal
Γερμανία
Υφ. Υδροφορείς
POST COMBUSTION

DONG Energy
Γερμανία
1600 MW
8 CO2 Mt/ετ.
POST COMBUSTION

SEI
Ιταλία
1320 MW
3.94 CO2 Mt/ετ.
POST COMBUSTION

2010 - 2012 | 2013 - 2014 | 2015 - 2016

Pilot Projects CCS
(Zero Emission Fossil Fuel Power Plants - ZEP)

Φυσικό Αέριο
Πετρέλαιο
Ανθρακας
Petcoke
Βιομάζα
Λιγνίτης

Μετασκευή
Νέο

Carbon Capture and Storage Technologies (CCS)

Pilot Projects CCS
(Zero Emission Fossil Fuel Power Plants - ZEP)

ENECO
Ολλανδία
845 MW
POST COMBUSTION

Aker
Νορβηγία
420 MW
1.2 CO2 Mt/ετ.
Υφ. Υδροφορείς
POST COMBUSTION

Vattenfall
Δανία
470 MW
1.8 CO2 Mt/ετ.
Υφ. Υδροφορείς
POST COMBUSTION

E.On UK
Hv. Βασίλειο
300 MW
2 CO2 Mt/ετ.
Εξ. Ταμιευτήρες
POST COMBUSTION

ENEL
Ιταλία
242 MW
1.5 CO2 Mt/ετ.
Υφ. Υδροφορείς
POST COMBUSTION

StatoilHydro
Νορβηγία
280 MW
1.5 CO2 Mt/ετ.
Υφ. Υδροφορείς
POST COMBUSTION

PGE
Πολωνία
286 MW
5.1 CO2 Mt/ετ.
Υφ. Υδροφορείς
POST COMBUSTION

CEZ
Τσεχία
105 MW
0.5 CO2 Mt/ετ.
Εξ. Ταμιευτήρες
POST COMBUSTION

Scottish&S.Energy
Hv. Βασίλειο
500 MW
Υφ. Υδροφορείς
POST COMBUSTION

CEZ
Τσεχία
660 MW
3.48 CO2 Mt/ετ.
Υφ. Υδροφορείς
POST COMBUSTION

E.On CE
Γερμανία
100 MW
0.6 CO2 Mt/ετ.
Υφ. Υδροφορείς
POST COMBUSTION

Vattenfall
Πολωνία
480 MW
2.87 CO2 Mt/ετ.
POST COMBUSTION

Union Fenosa
Ισπανία
200 MW
Εξ. Ταμιευτήρες
POST COMBUSTION

DONG Energy
Δανία
600 MW
3.58 CO2 Mt/ετ.
Υφ. Υδροφορείς
POST COMBUSTION

RWE Power
Ολλανδία
40 MW
0.2 CO2 Mt/ετ.
Εξ. Ταμιευτήρες
POST COMBUSTION

RWE nPower
Hv. Βασίλειο
1600 MW
9.56 CO2 Mt/ετ.
POST COMBUSTION

2010 - 2012

2013 - 2014

2015 - 2016

Φυσικό Αέριο
Πετρέλαιο
Ανθρακας
Petcoke
Βιομάζα
Λιγνίτης

Μετασκευή
Νέο

European Strategic framework for Energy

EU energy security and solidarity action plan

- **In compliance with the targets of :**
  - **the reduction of Green House Gas emissions by 20%**
  - **the increase of the share of RES to the energy consumption to 20%**
  - **the improvement of the energy efficiency by 20%**

- **Proposals for :**
  - **Infrastructure development and diversification of energy supply**
  - **Developments of energy international relations**
  - **Revisions on improved oil and gas stocks and crisis response mechanism**
  - **Development of regulatory framework for energy efficiency**
  - **Advanced utilization of indigenous energy sources (RES, low carbon technologies, CCS)**

European Strategic framework for Energy

Carbon Capture and Storage (CCS) Projects

Member State	Station		Capacity (MW)	Technology	Saline Aquifers	Oil / Gas fields	Envisaged EC contribution M€
Germany	Huerth	Coal	450	IGCC	√		180
	Jaenschwalde		500	OxyFuel		√	
The Netherlands	Eemshaven		1200	IGCC		√	180
	Rotterdam		1080	PC		√	
	Rotterdam		800	PC		√	
Poland	Belchatow		858	PC	√		180
Spain	Compostilla (Leon)		500	OxyFuel	√		180
United Kingdom	Kingsnorth		800	PC		√	180
	Longannet		3390	PC	√		
	Tilbury		1600	PC		√	
	Hatfield (Yorkshire)		900	IGCC		√	
Italy	Porto Tolle		660	PC		√	100
France	Florange		50	Application for transport of CO2 from steel industry	√		50
						Total	1050

Proposal of Presidency to European Council (20/3/2009) related to European Economic Recovery Plan

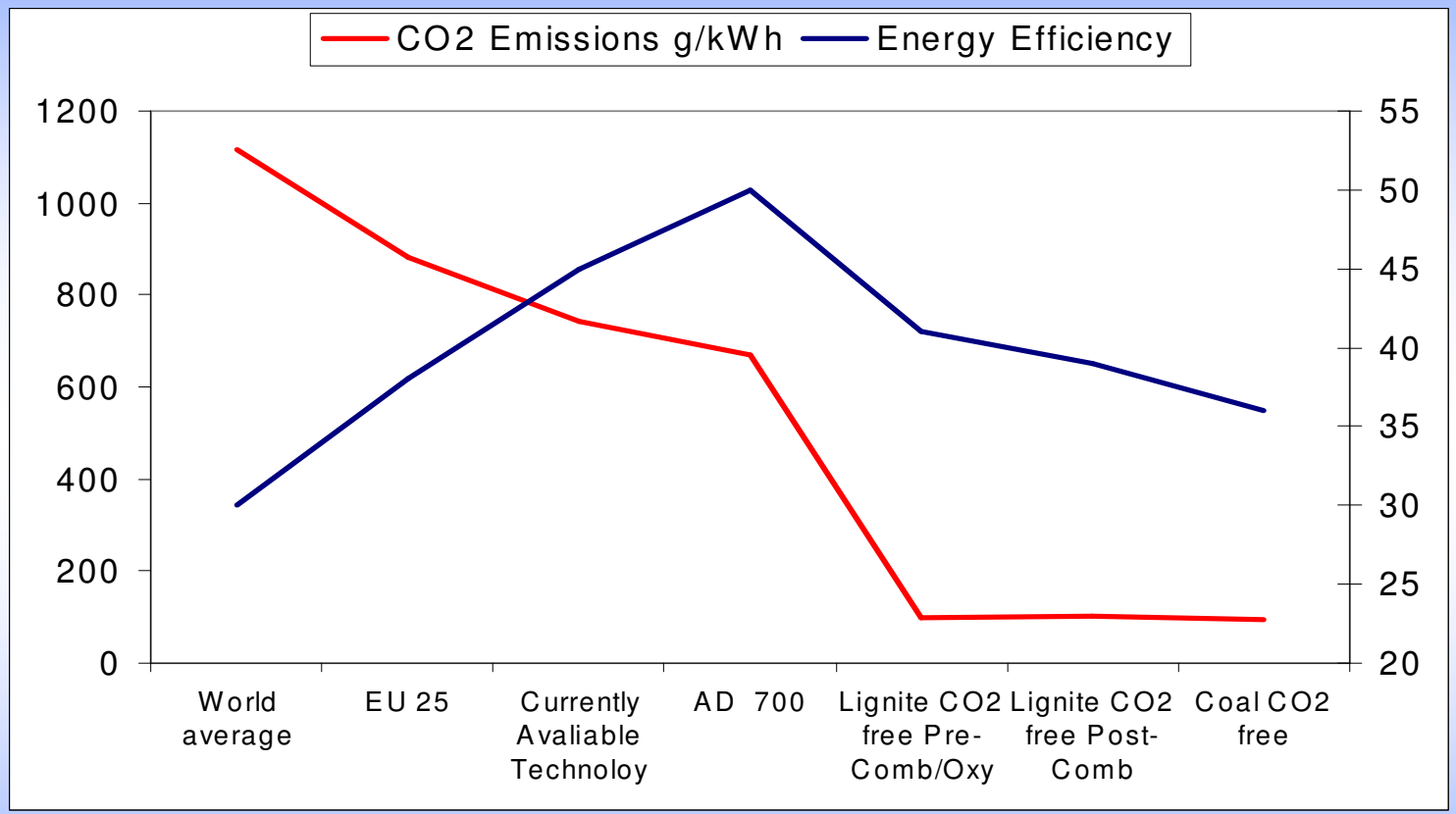
European Strategic framework for Energy

Eligibility requirements :

- **The projects should :**
  - **demonstrate the ability to capture at least 85% CO_2**
  - **implemented in industrial installation of at least 300 MW_{el}**
  - **demonstrate the ability of secure transport and geological storage of CO_2**
- **The project promoters should :**
  - **declare that the generic knowledge gained, will be available to wider industry**
  - **contribute to the Strategic Energy Technology Plan for Europe**

Proposal of Presidency to European Council (20/3/2009) related to European Economic Recovery Plan

Carbon Capture and Storage Technologies (CCS)



Evolution of CO_2 emissions and energy efficiency with / without CCS

Conclusions

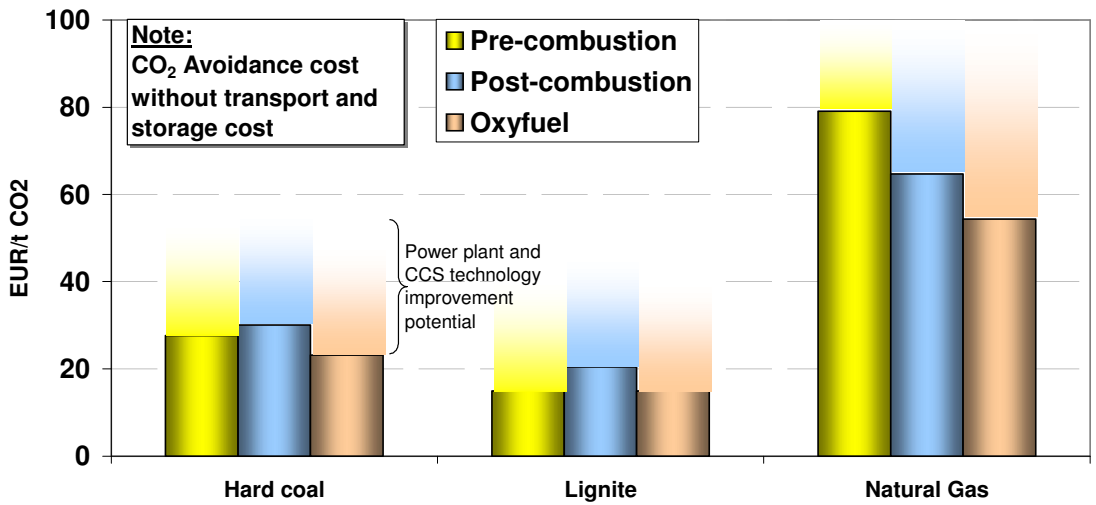
- The commitment for Green House Gas reduction as well as the purchase of CO_2 allowances is expected to surcharge the electricity generation cost, without reference to the implementation of Carbon Capture and Storage.

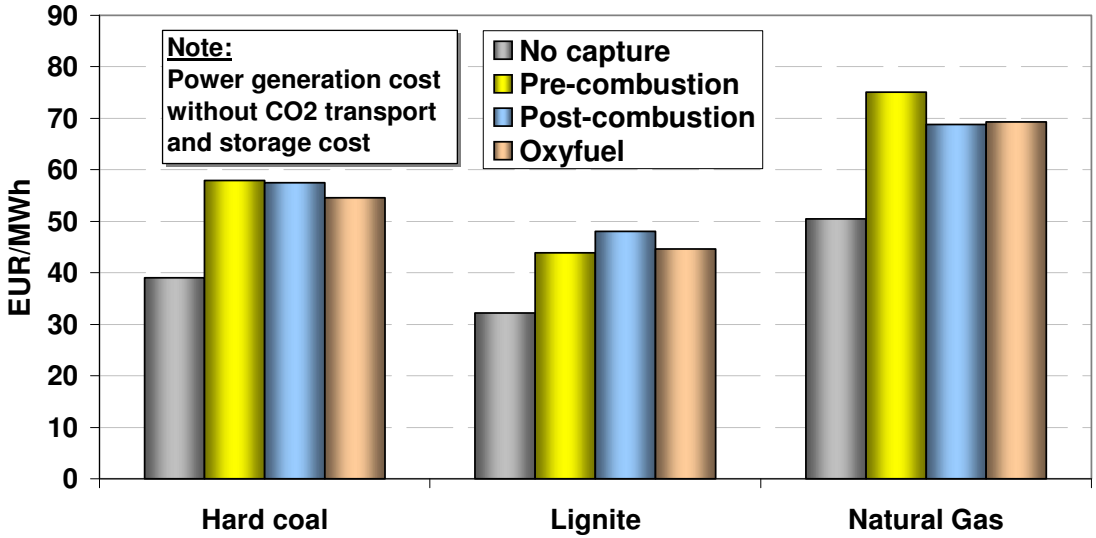
- The Research & Development of the clean technologies for solid fuels utilization is expected to provide options high efficiency options with significantly reduced emissions of CO_2. Compared to expected average avoidance CO_2 cost, lignite cost will be higher due to its quality characteristics.

- Significant projects in the Carbon Capture and Storage sector are proposed, with sort-term schedule for implementation.

- The CO_2 capture cost for solid fuel units is competitive in comparison to natural gas solutions for electricity production.

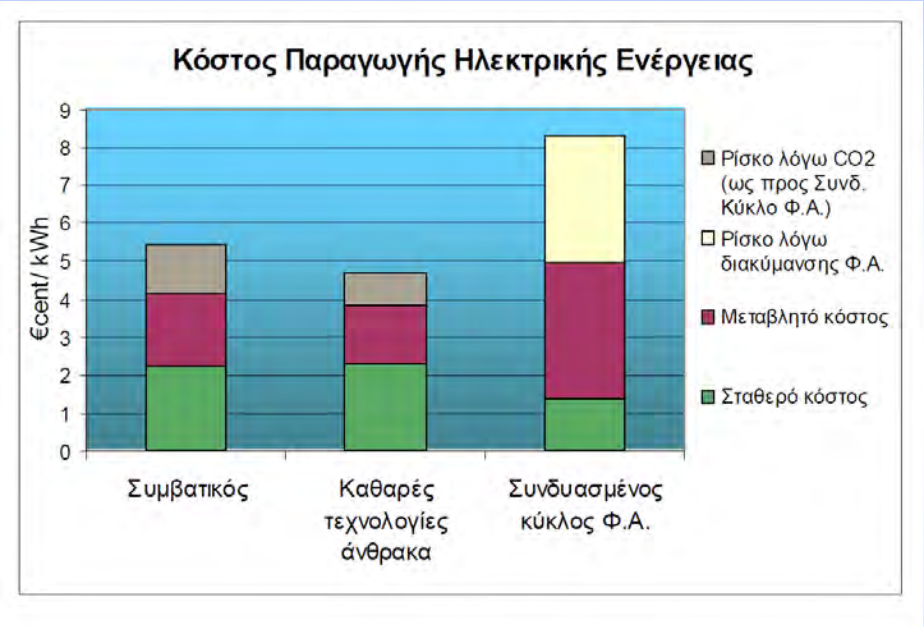
Carbon Capture and Storage Technologies (CCS)

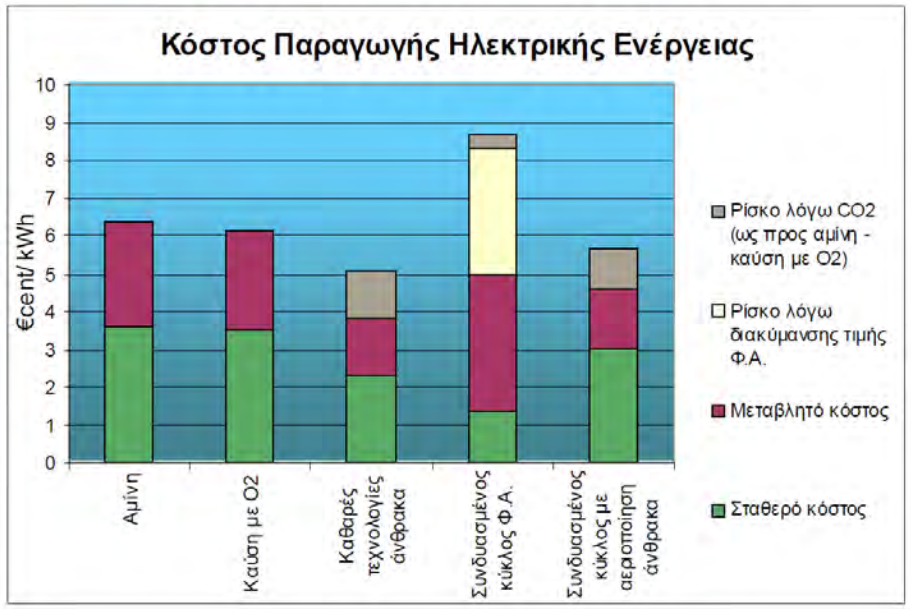




Backup

Carbon Capture and Storage Technologies (CCS)





Backup