Ημερίδα ΙΕΝΕ - Νομαρχία Κοζάνης
«Προοπτικές για την δέσμευση & αποθήκευση CO_2 στην Ελλάδα»
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Δέσμευση CO_2 στην Ελλάδα - CO_2 Capture in Greece

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Contents

- EC Directives – CCS European Market
- Carbon Capture technologies for low-quality coal
  - Reference Power Plant
  - Oxyfuel Lignite-fired Power Plant
  - Power Plant with MEA CO2 post-combustion capture
- Economic evaluation of CO_2 Capture Power Plants
- Conclusions

EC Directives ETS 1/4

Directives of European Parliament and of the Council for the Post - Kyoto period

- Directive 2009/29/EC amending Directive 2003/87/EC so as to improve and extend the greenhouse gas emission allowance trading scheme of the Community (23.4.2009)

- Directive 2009/31/EC on the geological storage of carbon dioxide and amending Council Directive 85/337/EEC, European Parliament and Council Directives 2000/60/EC, 2001/80/EC, 2004/35/EC, 2006/12/EC, 2008/1/EC and Regulation (EC) No 1013/2006 (23.4.2009)

EC Directive ETS 2/4

Elements of 2009/29/EC Directive for GHG emission allowances trading

- Commitment for reduction of total GHG emissions by 20% in 2020 compared to 1990. The reduction can be up to 30% in case of relevant commitments from others developed countries. Allocated emission allowances will be reduced by 21% with respect to their 2005 emissions by 2020
- Full auctioning should be the rule for electricity generation sector from 2013, without free allowances for CCS and with provision for possible pass of cost
- Allowances auctioning from 2011 for orderly functioning in 2013
- For all other sectors, a linear reduction of free allowances will be made up to 2020. (80% by 2013 up to 30% by 2020)

EC Directive ETS 3/4

- Measures for «carbon leakage» based on free allowances or supporting actions (protection of European Industry)
- Measures in case of excessive price fluctuation
- Measures for the modernization of electricity generation sector based on transitional free allowances
- CCS and innovative RES projects are targeted to be supported in the framework of measures for GHG reduction (electricity, transport, household and forestry sectors). The support includes the use of at least 50% of the revenues generated from the auctioning of allowances.
- By 30/9/2010 the EC shall publish the adjusted Community-wide quantity of allowances.

EC Directive ETS 4/4

According to 2009/31/EC Directive, an amendment of 2001/80/EC Directive will be made as follows (Article 9a) :

Operators of all combustion plants of electrical output > 300 MW and original construction licenses of 23rd April 2009, should have assessed for meeting the following conditions :

- ✓ Availability of suitable CO_2 storage sites,
- ✓ CO_2 transport facilities are technically and economically feasible,
- ✓ It is technically and economically feasible to be retrofitted for CO_2 capture.

The competent authorities shall determine that the above conditions are fulfilled and shall ensure the availability of suitable space for CO_2 capture and compression facilities

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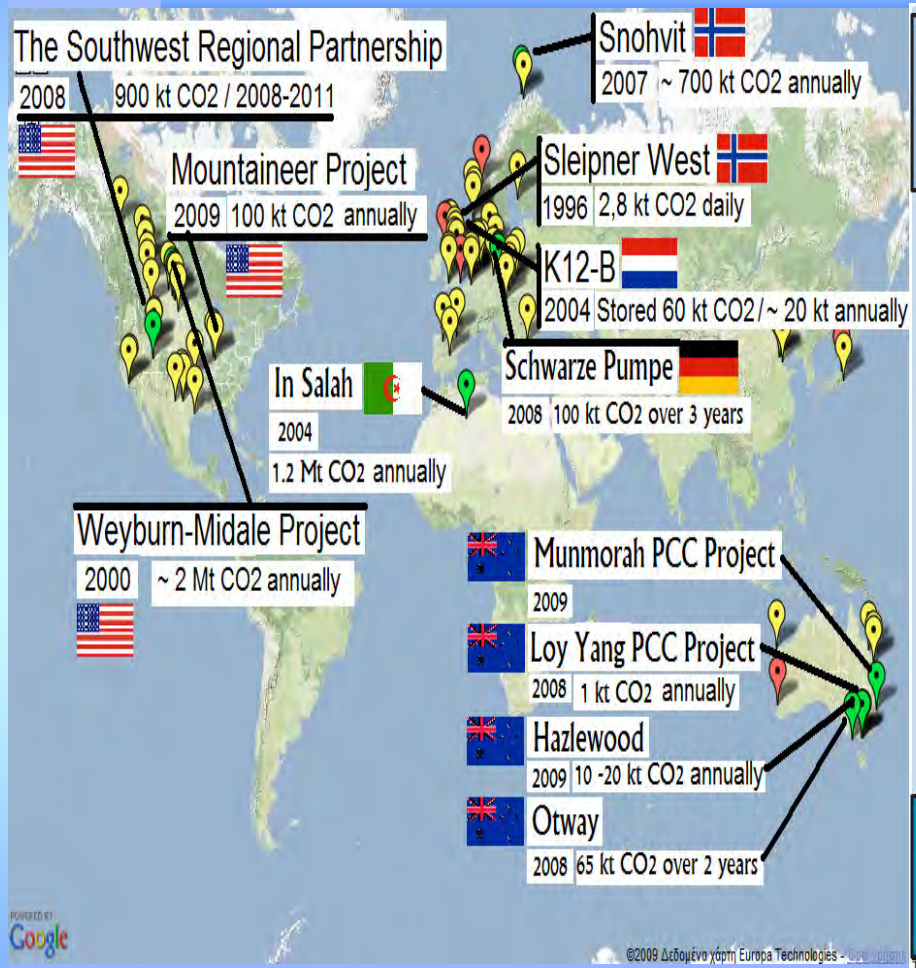
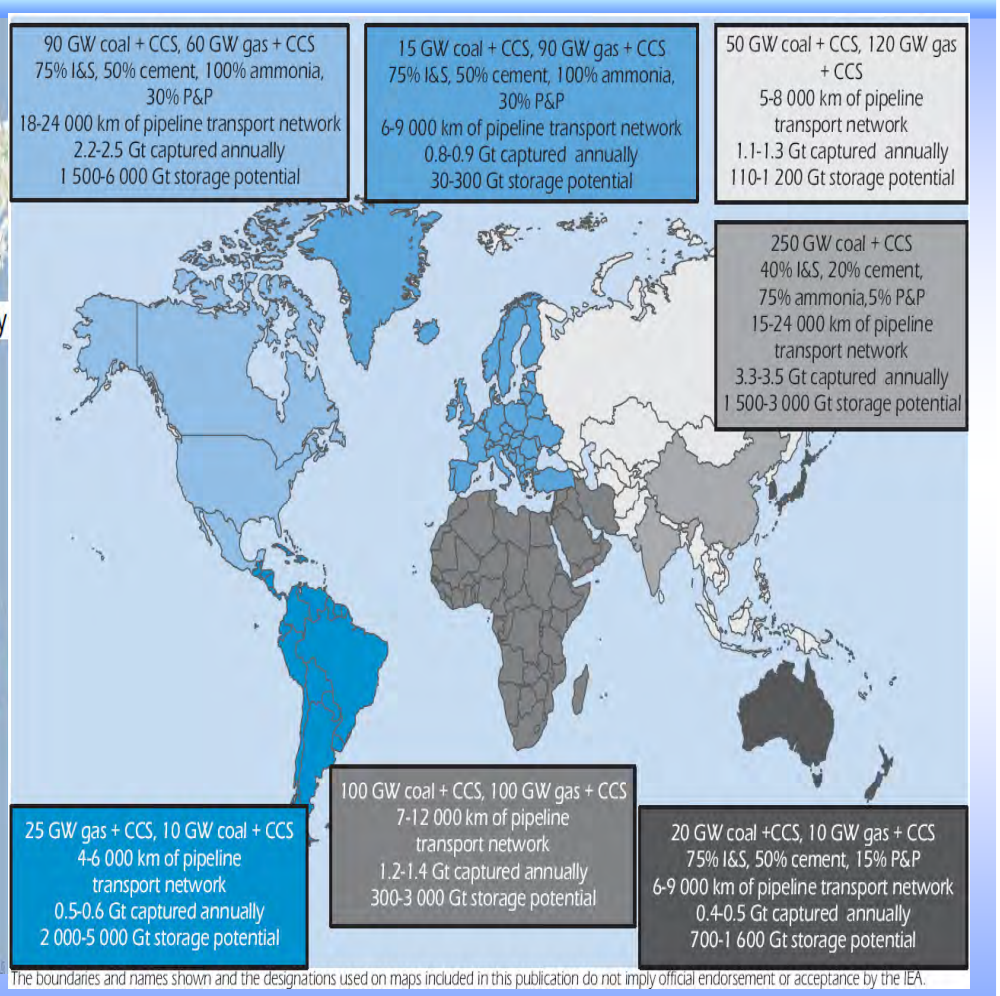
CO_2 Capture and Storage Technologies (CCS)





Today

Scottish Centre for Carbon Storage

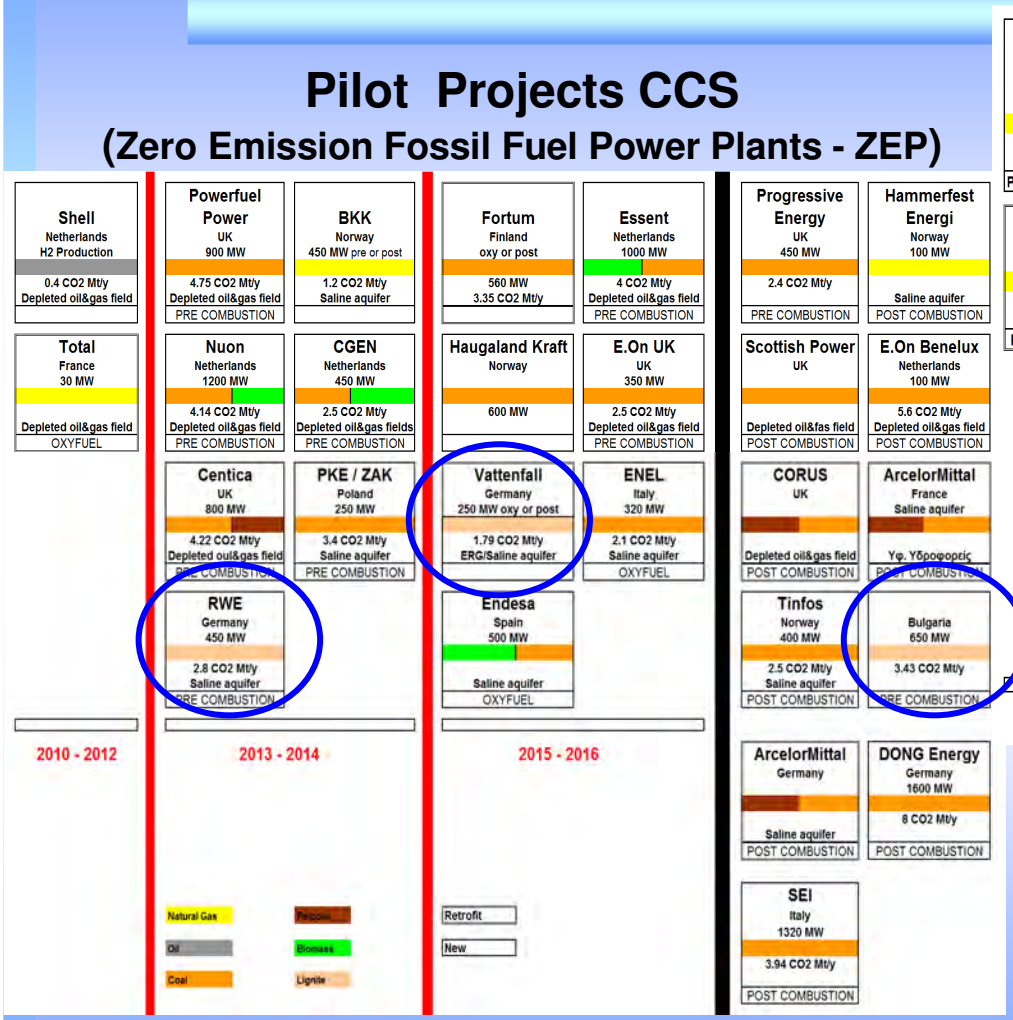
Scenarios/ Implementation Axis for 2050

IEA, CO_2 Capture and Storage : A Key Carbon Abatement Option (2008)

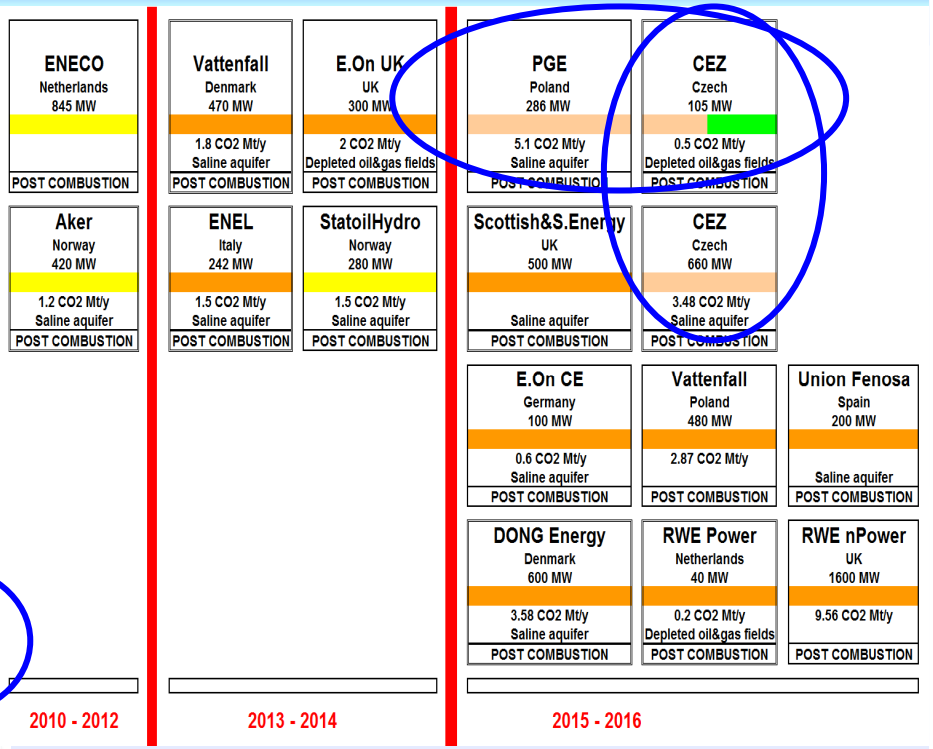
CO_2 Capture and Storage in the European market 1/2

Pilot Projects CCS

(Zero Emission Fossil Fuel Power Plants - ZEP)



CO_2 Capture with Oxyfuel / pre-combustion options



CO_2 Capture Post-Combustion options

- ✓ 6 of 43 projects on lignite
- ✓ All technological options are involved
- ✓ Most selected solution is post combustion

CO_2 Capture and Storage in the European market 2/2

Evaluation of Proposed Demonstration Projects (CCS) in EU

Member State	Σταθμός		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		?	
Iltaly	Porto Tolle		660	PC		?	100
France	Florange		50	Application for CO_2 transport from steel industry	?		50
						Total	1050

Proposal of Presidency to European Council (20/3/2009) related to European Economic Recovery Plan and call for proposals of May 2009

Carbon Capture technologies for low-quality coal

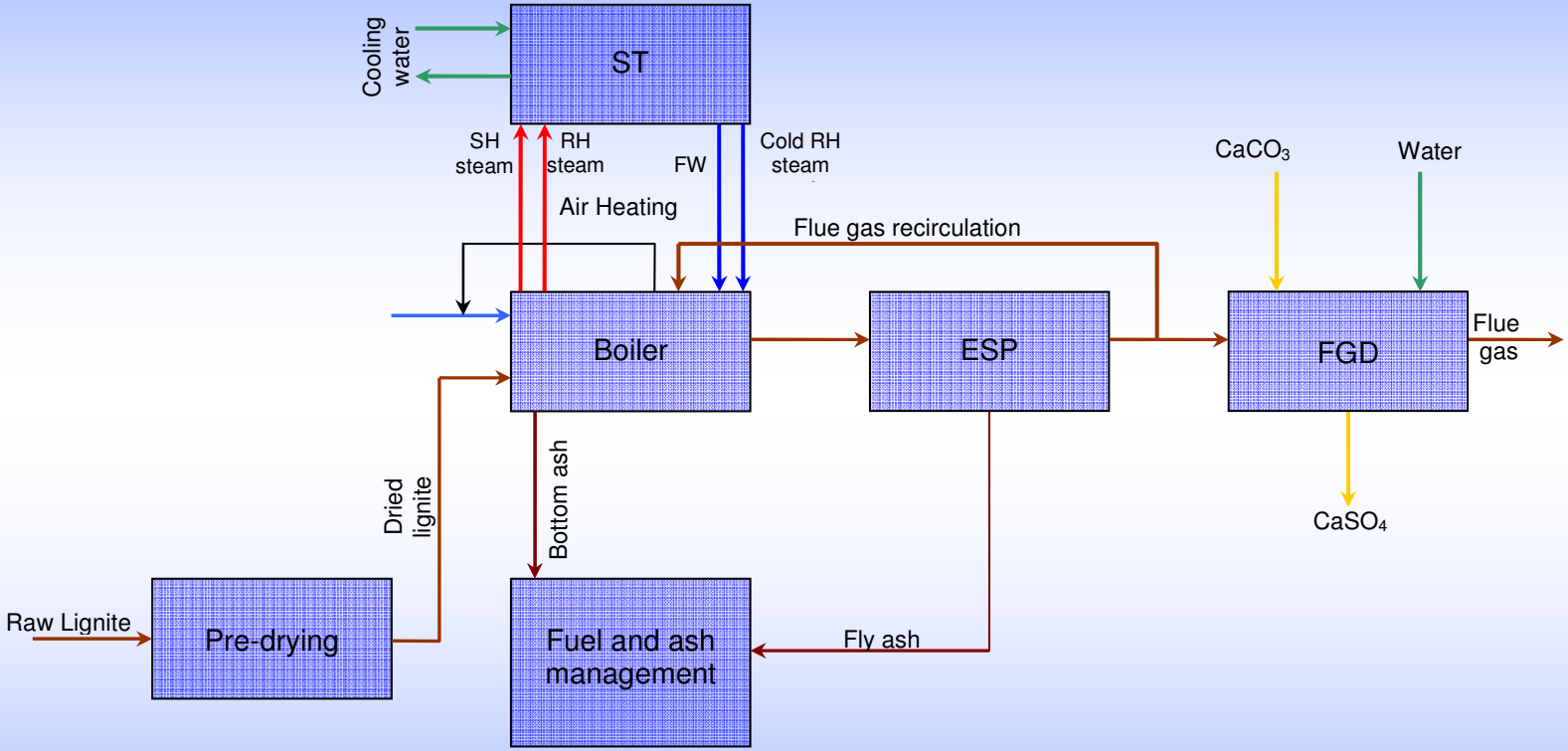
- The application of CO_2 capture technologies in the Greek electricity generation sector has been examined, for a modern Greek lignite-fired power plant incorporating pre-drying.

- Two basic CO_2 capture technological options were assessed:
  - Oxyfuel capture
  - Post-combustion CO_2 capture with MEA scrubbing

- The technical characteristics of the CO_2 capture power plants have been determined according to the reference power plant.

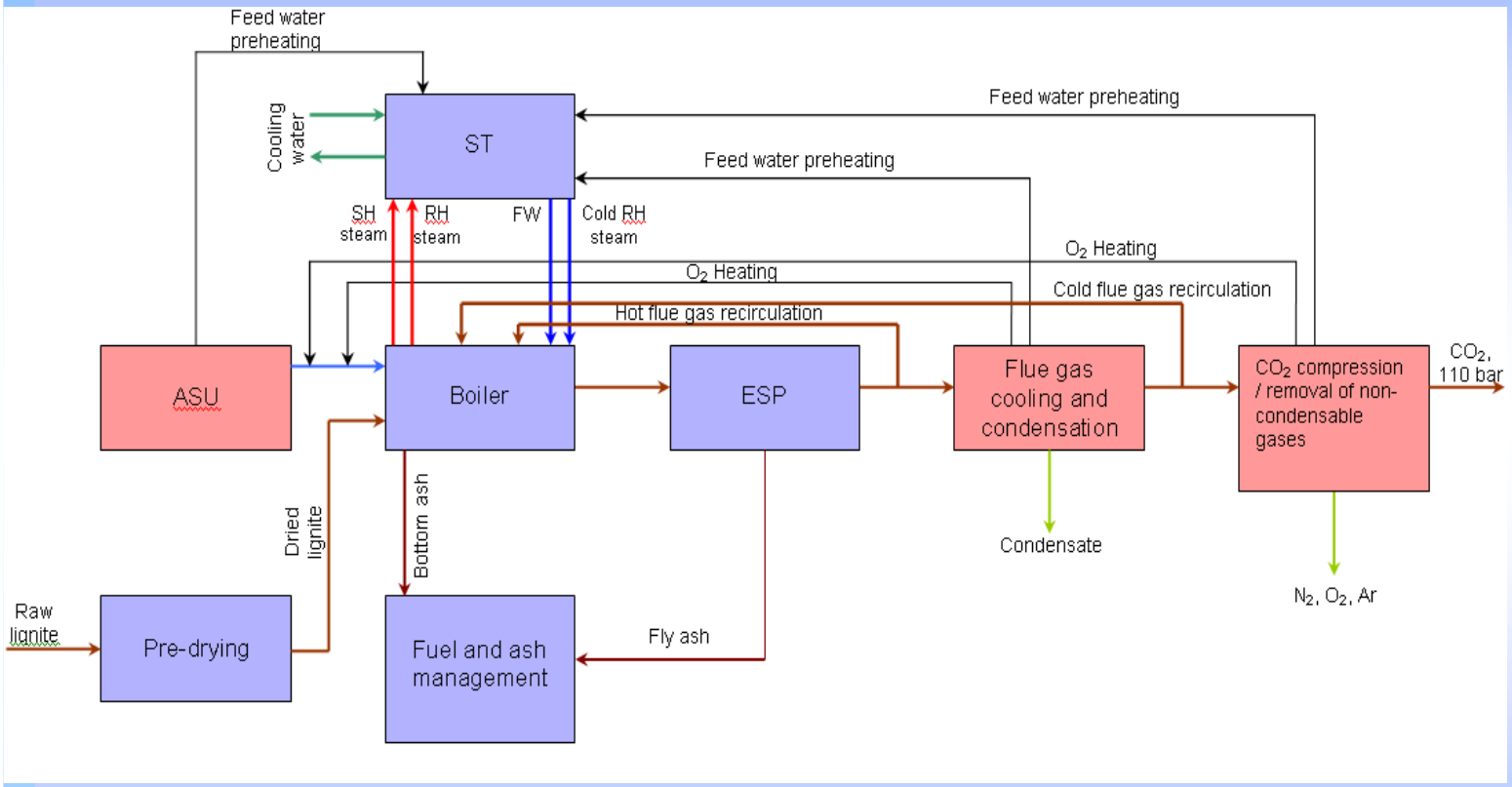
- The configuration of the CO_2 capture PP's has been optimized in terms of heat integration of new components (ASU, amine scrubbing unit, CO_2 compression unit etc).

Reference Greek Lignite-fired Power Plant



Reference lignite-fired power plant: Net Power output: **326.6 MW**
Net efficiency: **42.2%**

Oxyfuel Lignite-fired Power Plant 1/2



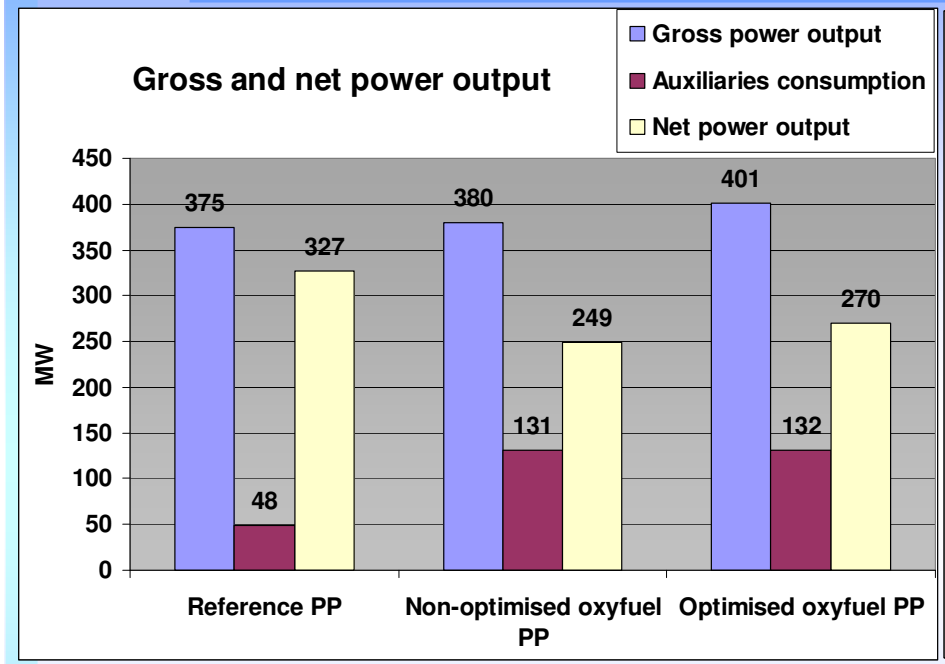
Heat integration

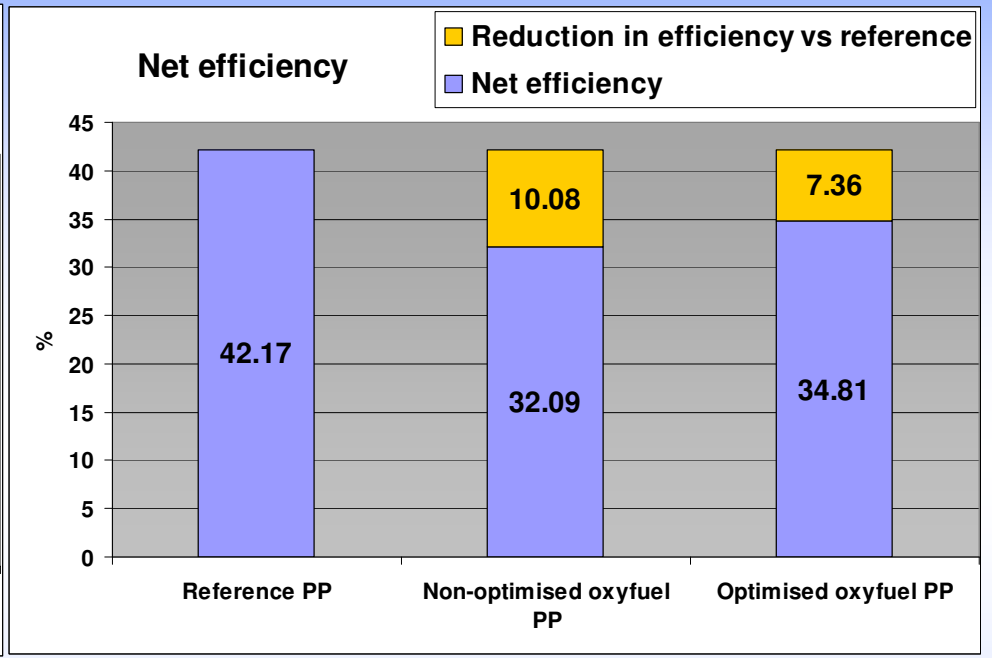
- O_2 pre-heating and heating
- N_2 heating
- FW pre-heating through flue gas cooling and CO_2 compressors inter-cooling

Schematic configuration of oxyfuel lignite-fired Power Plant

Net Power output: **269.7 MW**
Net efficiency: **34.8%**

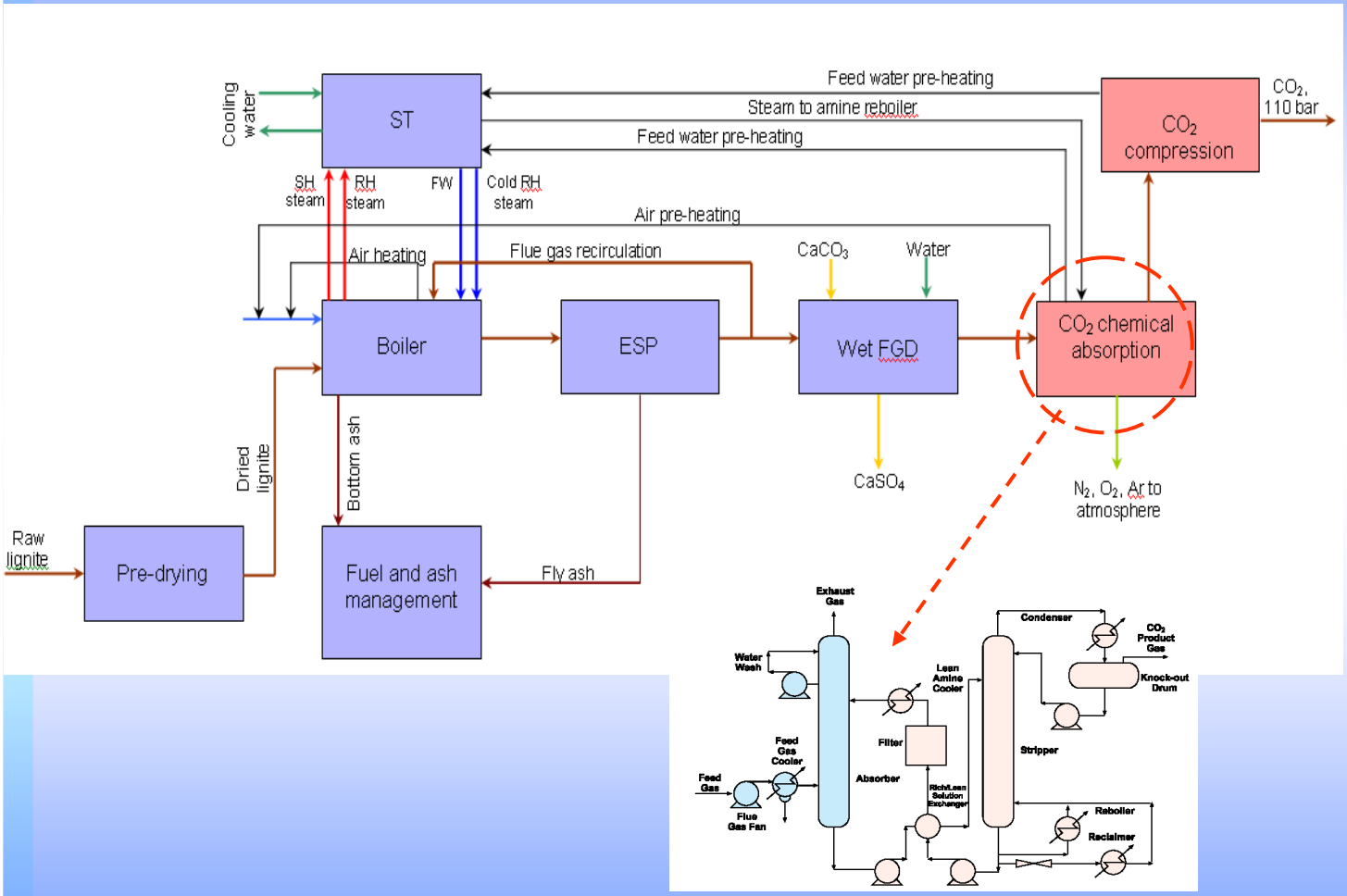
Oxyfuel Lignite-fired Power Plant 2/2





- Possibilities for efficiency increase through heat integration are significant.
- The gross power output is increased with respect to the reference PP due to the increase in boiler efficiency and the reduction of the ST heat rate.
- The net power output is reduced significantly with respect to the reference PP due to the increased consumption of auxiliaries.
- Thus, although the gross efficiency is increased, **the net efficiency is reduced by 7.4 percentage points** with respect to the reference power plant.

Power Plant with MEA CO_2 post-combustion capture 1/2



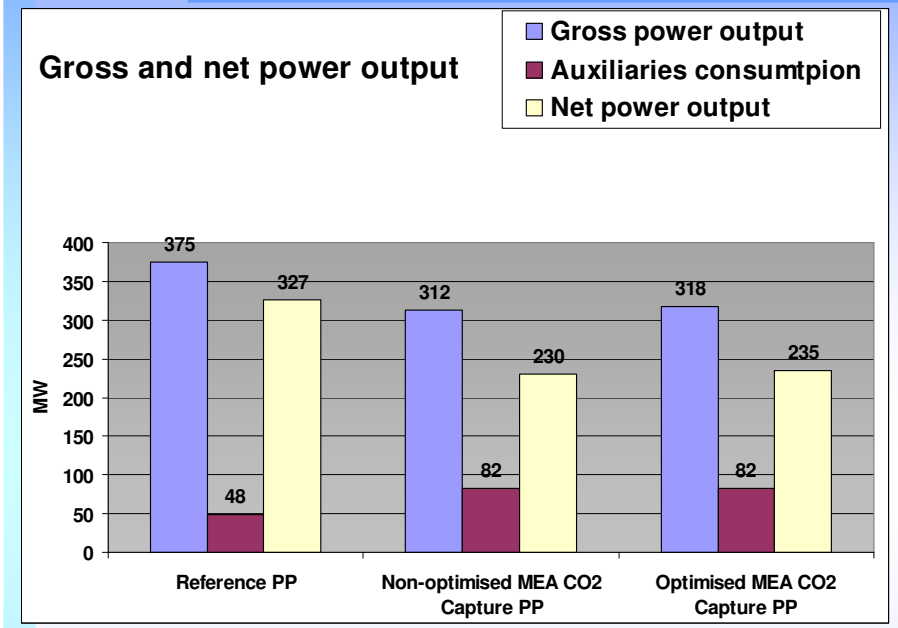
Heat integration

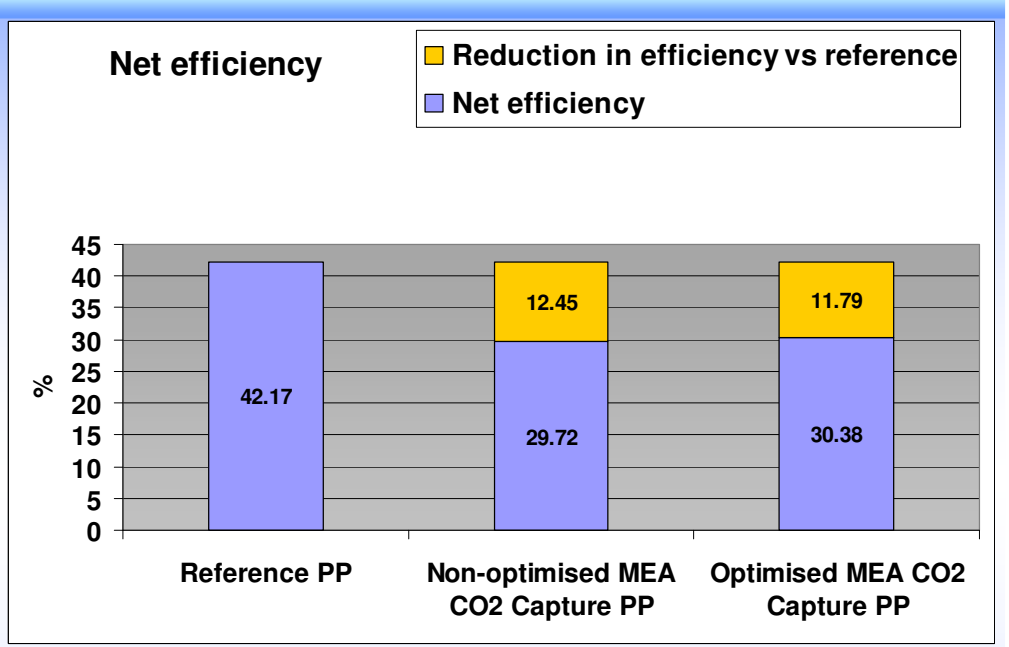
- Air pre-heating using heat from FGC
- FW pre-heating from FCG and CO2 compressors inter-cooling

Schematic configuration of PP with MEA CO_2 post-combustion capture

Net Power output: **235.4 MW**
Net efficiency: **30.4%**

Power Plant with MEA CO_2 post-combustion capture 2/2





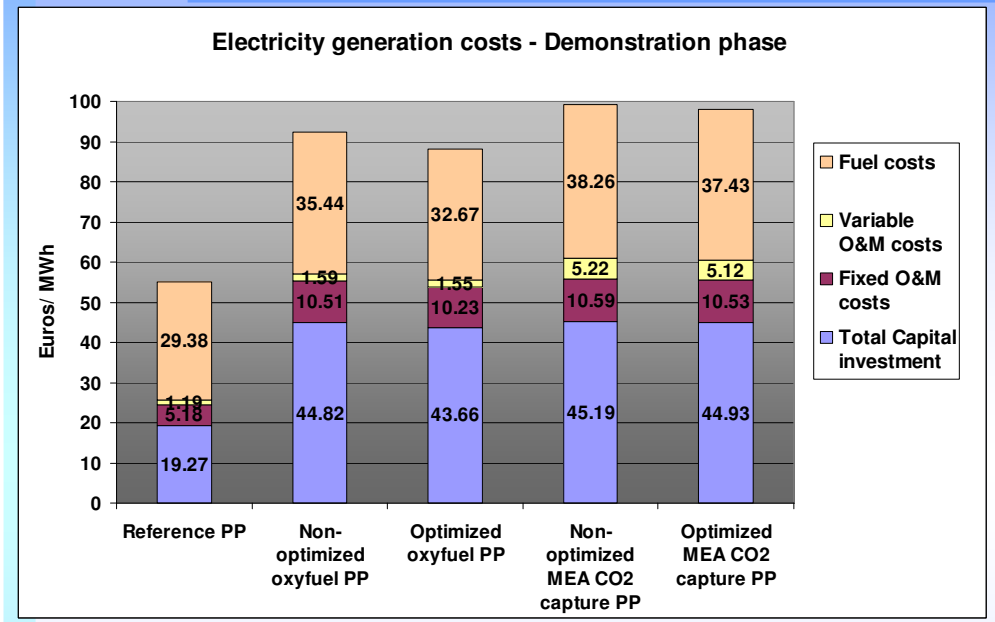
- The possibilities for efficiency increase through heat integration are limited.
- The gross power output PP is decreased with respect to the reference PP, due to the ST heat rate increase caused by the amine steam requirements.
- CO_2 compression consumption is reduced with respect to the oxyfuel PP (22.75 vs 34.40 MWe), due to lower non-condensable gases concentration and CO_2 purification requirements.
- **The net efficiency is reduced by 11.8 percentage points** with respect to the reference power plant.

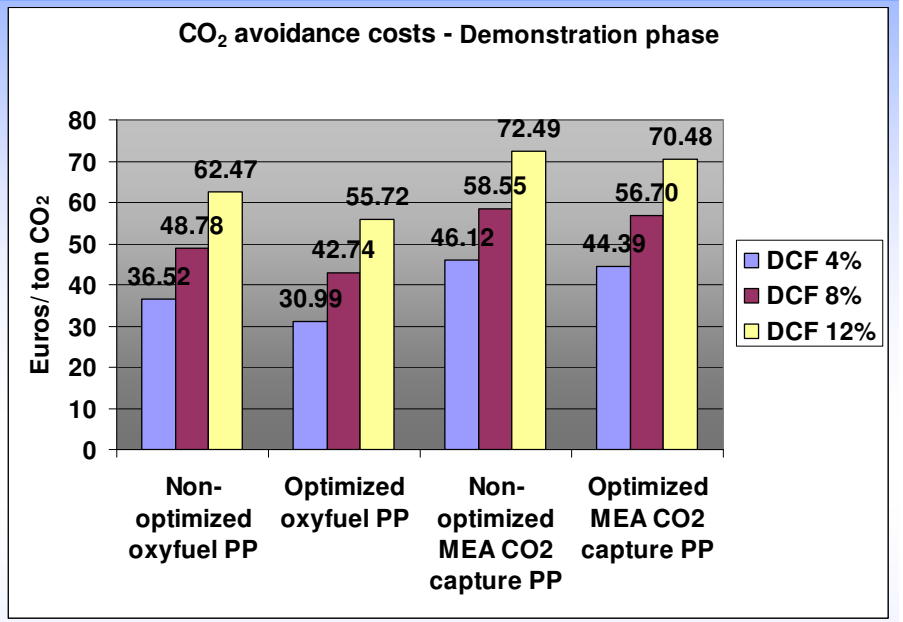
Economic evaluation of CO_2 Capture Power Plants 1/3

	Units	Reference PP	Non-optimized oxyfuel PP	Optimized oxyfuel PP	Non-optimized MEA CO_2 capture PP	Optimized MEA CO_2 capture PP
Investment						
Fixed capital investment	€/ kW gross power	1250	1520	1520	1725	1725
Owner's costs	% of fixed capital investment	10	10	10	10	10
Contingencies	% of fixed capital investment	10	10	10	10	10
Total capital investment	€/ kW gross power	**1500**	**1824**	**1824**	**2070**	**2070**
O&M costs						
Fixed operating costs	% of fixed capital investment	1.3	1.3	1.3	1.3	1.3
Fixed maintenance costs	% of fixed capital investment	1.3	1.3	1.3	1.3	1.3
Variable O&M costs	€/ MWh,gross (MEA) €/ tn captured CO_2	1 -	1 -	1 -	1 3.25	1 3.25
Fuel price						
Average	€/ GJ	1.1	1.1	1.1	1.1	1.1
Max	€/ GJ	1.7	1.7	1.7	1.7	1.7
Min	€/ GJ	0.8	0.8	0.8	0.8	0.8
Technical assumptions						
Gross power output	MW	375.07	379.76	401.31	312.46	317.58
Net power output	MW	**326.72**	**248.65**	**269.74**	**230.26**	**235.38**
Fuel consumption	kg/ s	97.32	97.32	97.32	97.32	97.32
LHV	kJ/ kg	7962	7962	7962	7962	7962
Net efficiency	%	**42.17**	**32.09**	**34.81**	**29.72**	**30.38**
Specific CO_2 emissions	g/ kWh,net	880.65	115.42	106.4	124.95	122.23

Main assumptions for the economic evaluation

Economic evaluation of CO_2 Capture Power Plants 2/3

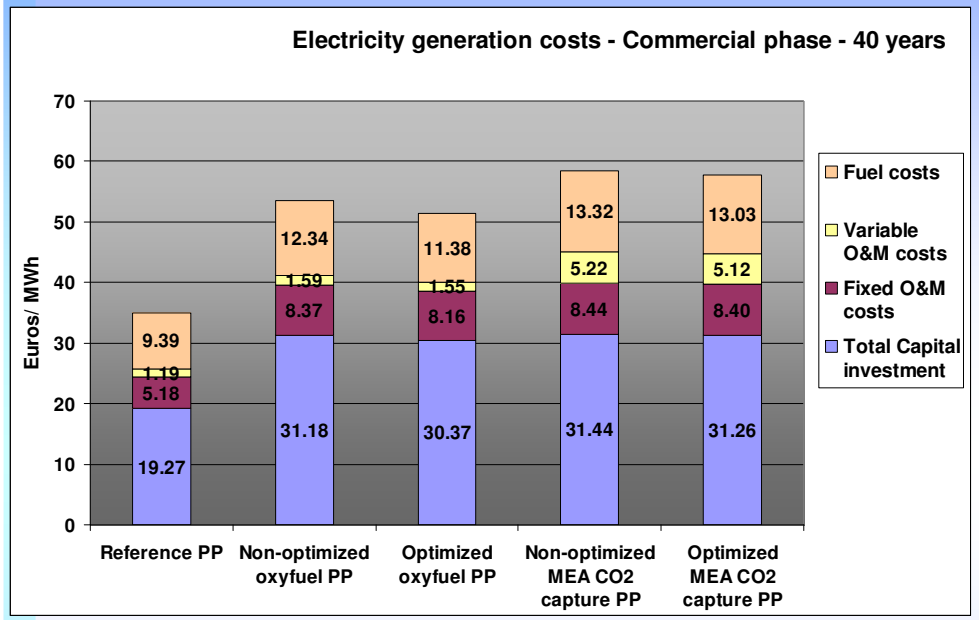


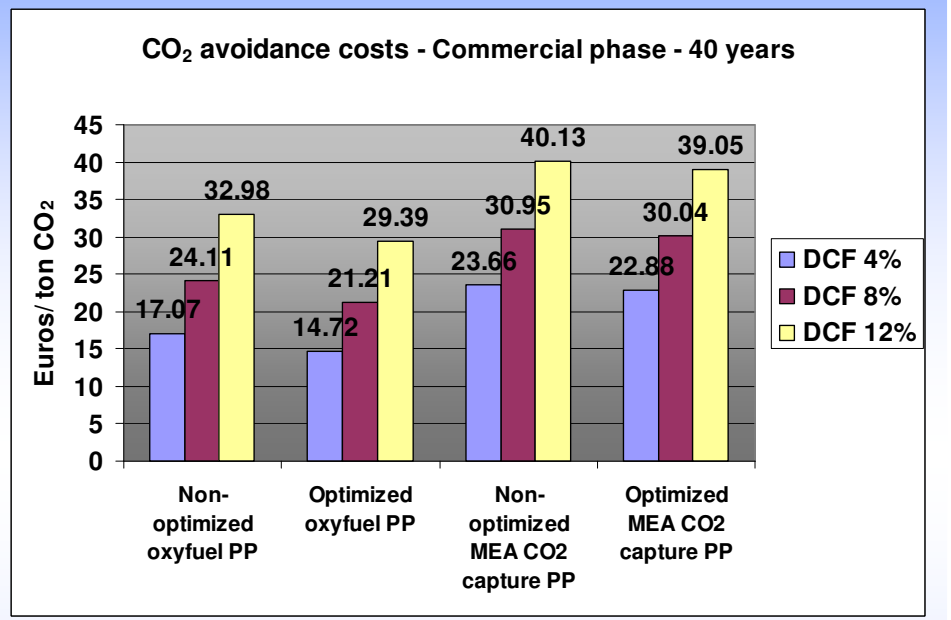


	Units	Reference PP	Non-optimized oxyfuel PP	Optimized oxyfuel PP	Non-optimized MEA CO_2 capture PP	Optimized MEA CO_2 capture PP
Cost of electricity generation	€/ MWh,net	55.02	92.35	88.11	99.26	98.02
CO_2 avoidance cost	€/ ton CO_2	-	48.78	42.74	58.55	56.70
Electricity generation costs increase due to efficiency drop	%	-	46.3	35.1	52.1	49.7

- The capital costs of CO_2 capture power plants during the demonstration phase is increased. Nevertheless, following the installation of a number of PP's, the costs will be reduced (learning effect). The cost reduction rate is assumed 12% for a doubling of the power installed.

Economic evaluation of CO_2 Capture Power Plants 3/3





	Units	Reference PP	Non-optimized oxyfuel PP	Optimized oxyfuel PP	Non-optimized MEA CO_2 capture PP	Optimized MEA CO_2 capture PP
Cost of electricity generation	€/ MWh,net	35.03	53.48	51.45	58.42	57.81
CO_2 avoidance cost	€/ ton CO_2	-	24.11	21.21	30.95	30.04
Electricity generation costs increase due to efficiency drop	%	-	59.6	45.1	62.8	59.7

Conclusions

- A new framework for electricity generation is established dealing with pool auctioning of CO_2 emission allowances after 2013.
- Several CCS projects are in the phase of planning and/or realization.
- The efficiency penalty for lignite power plants with CO_2 capture is 7.4-11.8 percentage points. Electricity production price increases by 47-65%, with an avoidance cost of 21-30 €/ton CO_2.
- Both oxyfuel and post-combustion CO_2 capture are feasible tecnhologies for Greek fuels.