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Perspectives of pre-combustion CCS systems for central Europe

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PERSPECTIVES OF PRE-COMBUSTION CCS SYSTEMS FOR CENTRAL EUROPE

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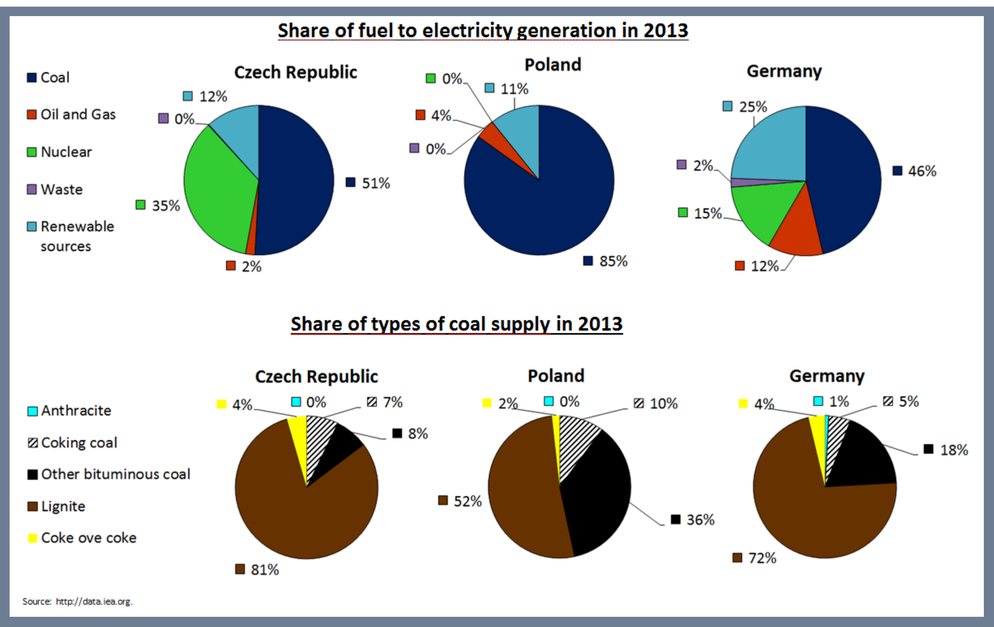
INTRODUCTION

Carbon Capture and Storage (CCS) has a potential to play a significant role in the future of power generation in Europe, at least in a short to intermediate term. CCS technologies however mean inevitable technical, energy and economic penalty, especially since the most common fossil fuel for power generation in the Central Europe is lignite.



CZECH LIGNITE SUITABLE FOR GASIFICATION PROCESS

Basic specifications of lignite
for the gasification proces (see table right)

Basic properties of ash (see table below)

Parameter	Name	Unit	Value
DT	Deformation point	°C	1 325
ST	Softening point	°C	1 425
HT	Hemisphere temperature	°C	1 525
FT	Flow temperature	°C	1 550

Parameter	Unit	Fuel – raw
LHV	MJ/kg	16.50
W_t^r	wt%	31.00
A^d	wt%	13.00
Volatile matter		
C^{daf}	wt%	70.4
H^{daf}	wt%	6.1
N^{daf}	wt%	1.0
O^{daf}	wt%	20.89
S^{daf}	wt%	1.61

PROJECT INTRODUCTION

„Study of CCS Pilot Technologies for Coal Fired Power Plants in the Czech Republic“ is current project in collaboration with Norwegian partner (SINTEF Energi) and supported by Norway Grants 2009-2014.

The main project goal is to create a comprehensive technical and economic assessments of three basic methods for CO_2 capture (post- and pre-combustion, oxyfuel) integrated into the fossil power plant in the Czech Republic.

The analysed pre-combustion CCS in Integrated Gasification Combined Cycle (IGCC) systems are based on gasification of central European lignite and different capture technologies namely modifications of solvent capture (based mainly on **Rectisol wash** using chilled methanol), **low temperature capture** and capture using various **CO_2 permeable or H_2 permeable membranes**.

IGCC POWER PLANT W and W/O CCS

Process flow diagram of IGCC plant is designed based on similar plants around the world, assumptions and theoretical analyses for CCS systems and according to the recommendations acquired from the experience of operation in IGCC plant Vřesová in Czech Repubic.

The main proces technology

- 2 stage milling units with integrated WTA dryer
- ASU unit for oxygen and nitrogen production
- Shell gasification technology (1600 °C, 3 MPa, max. W 12%) with integrated recycled syngas quench (250 °C)
- High temperature HRSG – syngas cooling system (saturated steam HP 12,5 MPa, MP 4,5 MPa = process steam)
- Bag filters or cyclone for ash separation process
- Gas turbine - SGT-2000E (nominal power output 187 MWe)

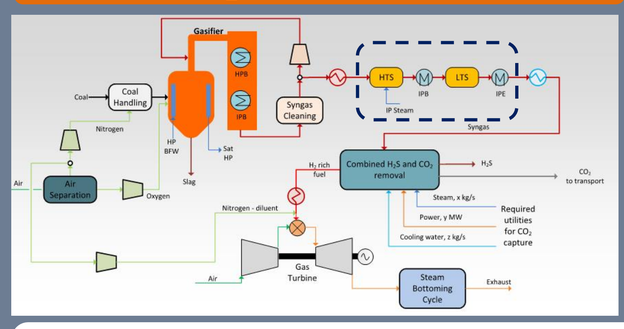
CSS technology implementation shows the necessity of the integration of new or modifying existing systems:

- CO shift integration => water/steam utilization (increase LP steam consumption up 36 kg/s)
- GT modification
  - Air compressor
  - Nitrogen compressor modification
- DeNOx technology integration into HRSG
- Increase of the cooling capacity of the system (based on low-potential heat)

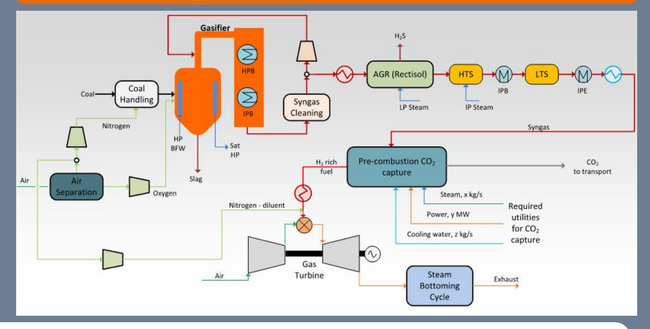
BASIC INPUT OPTIONS

The analysis was performed to design power plant of 250 MWe output, CCR 90% , or 85% by pre-combustion technology (loss of CO2 in AGR unit and limitations of capture technologies).

SOLVENT CO_2 CAPTURE



OTHER CO_2 CAPTURE



To eliminate the loss of CO_2 (8%->1.5%) in the system of separation of H2S (based on Rectisol – AGR unit) were proposed two options for integration the CO shift process into scheme of power plant.
Cases with CO_2 capture technology based on solvents are using sour CO shift process integrated before AGR unit. Cases with other CO2 capture technology (membrane etc.) use CO shift process integrated after AGR unit.

RESULTS

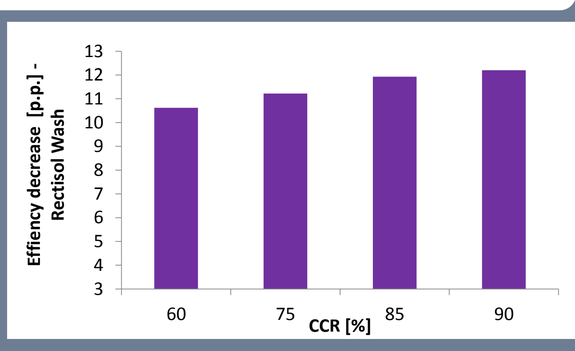
Integration of the selected technologies will reduce the efficiency of IGCC power plant to 10.5 - 23%.

- **Lowest negative impact** technology **has low temperature (cryogenic)** and Rectisol wash (the difference between the two technologies is about 1%).
- Purest CO_2 stream for transport/utilization has a system based on Rectisol wash.
- The lowest CO_2 losses in capture process achieves cryogenic technology (0.03%) - about 10 times lower than Rectisol wash (0.3%).
- The membrane processes exhibit high losses of H_2 in the separation process.

Cases	IGCC plant				
	w/o CCS	with CCS (CCR 85%)			
		Rectisol wash	Cryogenic	CO_2 membrane	H_2 membrane
Gross Power output [MWe]	306 717	252 125	254 036	246 369	227 761
Electricity consumption [%]	13%	22%	21%	45%	48%
Syngas flow to GT [kg/s]	46.7	17.5	19.5	18.5	17.2
Efficiency [%]	43.25%	31.70%	32.88%	22.78%	21.06%
Efficiency decrease [p.p.]	x	11.55%	**10.47%**	20.57%	22.29%
CO_2 capture mixture - composition - main elements					
CO_2	-	**98.39**	95.45	94.35	82.87
CO	-	0.03	3.25	2.65	2.33
H_2	-	0.45	0.03	2.66	**13.14**

Reducing the capture factor (CCR) has a relatively low contribution for reducing of the negative impact of the integration of CCS than we expected.

CCR **increase of about 1%** efficiency drops by **0.2 p.p.** for Rectisol wash.

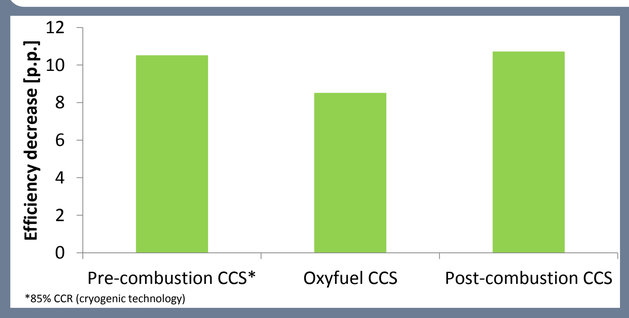


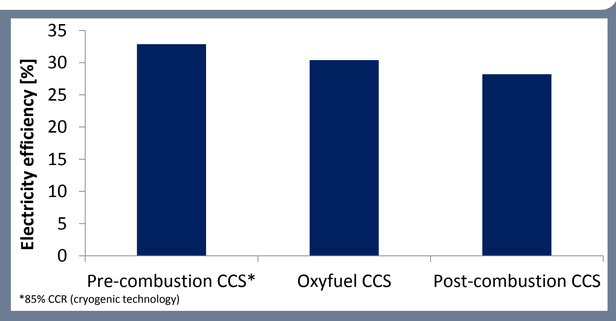
COMPARISON WITH OTHER CCS TECHNOLOGIES

Conclusions obtained for technology oxyfuel and post-combustion taken from the project *FR-TI1 / 379 and reports UJV 14545
The results show:

- **maximum economic benefit** has oxyfuel CCS technology
- **the lowest decrease in efficiency** has oxyfuel CCS (without waste heat recovery)
- **the highest efficiency of electricity** production achieves pre-combustion CCS technology

	Oxyfuel CCS*	Post-combustion CCS - amoniak*	Pre-combustion CCS
CAPEX increase	50%	58%	50%
LCOE increase	42%	50%	45%
CO_2 capture cost [USD/t]	25	28.5	35





CONCLUSION

The first results of the analysis of pre-combustion technology (cryogenic, Rectisol wash) demonstrate potential applicability within the energy system of the Czech Republic. This technology achieves the highest efficiency of electricity production within analyzed technologies, despite the higher absolute value of the reduction in efficiency. Capture technology using membranes is shaping up to be unsuitable for this system.

Information about project NF-CZ08-OV-1-003-2015
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