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CCS ECONOMIC INTEGRATION ISSUES IN A STEAM POWER PLANT

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The objective of this work is to achieve a detailed analysis regarding integration CCS technology in a steam power plant, highlighting both the technical and economic aspects. Folioing the 330 MW power plant analysis whit CO_2 capture unit and without showed that CO_2 tax plays a very important role, so for a given trading value over 25 Euro/tone CO_2, becomes profitable CCS technologies.

Keywords: CO_2 tax, electricity price, capture CO_2

1. Introduction

Using industrial scale sustainable fossil fuels will involve the mobilization of substantial financial resources in Europe, in a short period of time. In the view of the European energy strategy 12 coal-fired power plants or natural gas equipped with CCS, 300 MW each, would require at least 5 billion euro's, given current technological costs [1].

The estimated costs for CO_2 capture from production of energy and the estimated costs for further storage can reach 70 euro's per tonne of CO_2, but nevertheless expect technological major improvements through efficiency increasing in new plants and CO_2 capture cost reductions [2,3].

2. Paper contents

Regarding the capital expenditure to capture in the energy there are a lot of factors that affect these costs, namely: plant type (new or existing); plant technology (critical or supercritical parameters); fuel type (lignite, hard coal or natural gas); type of capture technology (post combustion, pre combustion, oxi combustion); solvent type, etc.

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Capital expenditures for CO_2 transport are influenced first by the method of transport chosen: onshore pipelines, offshore pipelines, shipping (including utilities), transportation by tanker trucks, railroad. A second factor defining is the transport distance between the place of CO_2 capture and permanent storage site.

Other factors: pipe wall thickness and material caused by the maximum pressure in line, soil characteristics.

Capital expenditures for CO_2 storage are mainly determined by the location of the field: on shore or offshore.

Other important components are the reservoir type: saline aquifers or depleted oil and gas; the last ones are cheaper than saline aquifers; reservoir size; injectivity; required number of injection wells and not least permeability of the reservoir.

The total cost of CCS, by components are: capture (55 to 80% of total investment), transport (5 to 10% of the total investment and the distance to the storage site), storage (15 to 20% of total investment in depending on storage capacity and providing necessary facilities).

Annual operating cost for the transport of carbon dioxide vary by the length of the pipeline route: for 250 km long pipeline the price is 2.23 ÷ 2.98 Euro/tCO_2, for 100 km long pipeline the price is 0.74 ÷ 1.49 Euro/tCO_2 [4,5].

Operating expenses for CO_2 storage; from the analyzed documents were considered as part of the cost of electricity, which led to an increase from 4.46 to 9.67 Euro / t CO_2 depending on the selected storage site[4]. Storage costs vary between 1-12 euro / ton CO_2 depending on the selected storage site.

In this article, we have analyzed the influence of the cost of CCS technology integration on electricity cost. In this analysis we considered two variants namely a group of 330MW with and without CO_2 capture plant. The fuel used was coal with a lifetime of 6000 h / year. The second option considered, the group of 330 MW was equipped with post-combustion CO_2 capture based on primary amine with CO_2 capture efficiency of the process by 85%.

3. Results and discussion

Transport of CO_2 from the power plant to a permanent storage site was made in the pipe at a distance of 100 km, and storage was made in a saline aquifer. Similar studies on CCS technology and costs involved have been made in the work of Rubin E.S. [6].

In the case of 330 MW analyzed group, it was considered an investment of 300 Euro / kW representing only additional CO_2 cost containment facility is about an existing group [7].

Table 1

Main technical data

Group of 330 MW				
Nr. crt.	TECHNICAL INFORMATION	U.M.	**V1-330MW** without capture $\mathbf{CO_2}$	**V2-330MW** with capture $\mathbf{CO_2}$
1	Electric power	MW	330	330
2	Annual operating	h/year	6000	6000
3	*Gross electricity production*	MWh/ year	1980000	1980000
4	Net power output	MW	310	295
5	Net electricity delivered	MWh/ year	1841400	1787940
6	Fuel annual consumption - Lignite (100 %)	tons/ year	2500000	2500000
7	The Annual quantity of limestone	tons/ year	62640	62640
8	Annual quantity of MEA	tons/ year	n.a	4000
9	Annual Fossil fuel CO_2 emissions	t CO_2	2200000	2200000
10	CO_2 emissions resulting from desulfurization	t CO_2	28188	28188
11	Annual emissions of CO2 captured	t CO_2	n.a	1893960
12	Annual emissions of CO_2 retained after capture	t CO_2	2228188	334228

Table 2

Economic Data

Nr.crt.		U.M.	V1-330MW without capture CO_2	V2-330MW with capture CO_2
1	Specific investment i_{sp}	$€/kW$	1200	1500
2	Fixed operating and maintenance cost $c_{0+M,f}$	$€/kW$	4	7
3	Variable operating and maintenance cost $c_{0+M,v}$	€/MWh	10	13
4	Fuel price	$€/t$	20 ÷ 30 [8]	
5	Tax CO_2	$€/t$	15 ÷ 60	
6	Price *$CaCO_3$*	$€/t$	71,7	
7	Cost MEA,DEA,TEA	$€/t$	1400-1800 [8,9]	
8	*CO_2* transport cost	$€/t$	(0,5-4)1,5 [4]	
9	*CO_2* storage cost	$€/t$	(1-12) 4 [4]	
10	Consumption *on MEA* between *1-4kg MEA per ton CO_2* [10,11]			

Table 3

Calculation formulas

Nr.crt.	Types of costs	Formula
1	Fuel costs	$C_B = P_c \text{ x } B_{an}$
2	Investment costs	$I = i_{SP} \text{ x } P_B$
3	Amortization costs	$C_I = \frac{I}{nr.ani}$
4	Fixed operating and	$C_{0+M,f} = c_{0+M,f} \text{ x } P_B$

	maintenance cost	
5	Variable operating and maintenance cost	$C_{0+M,v} = c_{0+M,v} \text{ x } E_{an}^{P}$
6	Total costs without capture CO_2	$\boldsymbol{C_{T,ref.} = C_B + C_I + C_{O+M,f} + C_{O+M,v} + Tax\check{a}_{CO_2}}$
7	Total costs with capture CO_2	$\boldsymbol{C_{T,CCS} = C_B + C_I + C_{O+M,f} + C_{O+M,v} + C_T + C_S + Tax\check{a}_{CO_2}}$
8	Energy cost	$\boldsymbol{C_{EE} = \frac{C_{TOT}}{E_{an}^{neta}}}$

The main technical and economic indicators that influence the final price of electricity are: greenhouse certificate costs, emission factor of fossil fuel, fuel price, new power plant efficiency, reduce power plant efficiency through the implementation of CCS technologies, CO_2 capture efficiency, additional cost of investment in CCS, recover the investment, CO_2 transport costs, CO_2 storage costs. Information on the investment and operating costs for capture, transport and storage of carbon have at present as source studies and pilot projects.

The carbon tax plays an important role in the decision to equip or not a power plant with CO_2 capture. The CO_2 tax amount is higher the more profitable it becomes to opt for integration CO_2 separation unit, this is reflected in the cost of electricity, which becomes larger when the CO_2 tax is paid.

Further was presented the factors that influence the amount of CO_2 tax for wich energy produced without CO_2 capture cost is higher than the energy produced with capture installation.

In the Fig. 1 was observed shift of the critical point for which the amount of CO_2 increases from 20 to 25 Euro/ton CO_2 and the cost of electricity grew by 14% compared to the version above.

In Fig. 2 was analyzed variation in the cost of CO_2 tax, provided that account is taken of the costs of transport and storage of CO_2.

In Fig. 3 was analyzed variation of CO_2 tax on the price of fuel which was varied between 20 and 35 Euro/ton coal without taking into account the costs of CO_2 transport and storage. The increase of fuel prices lead to a significant increase in cost of electricity.

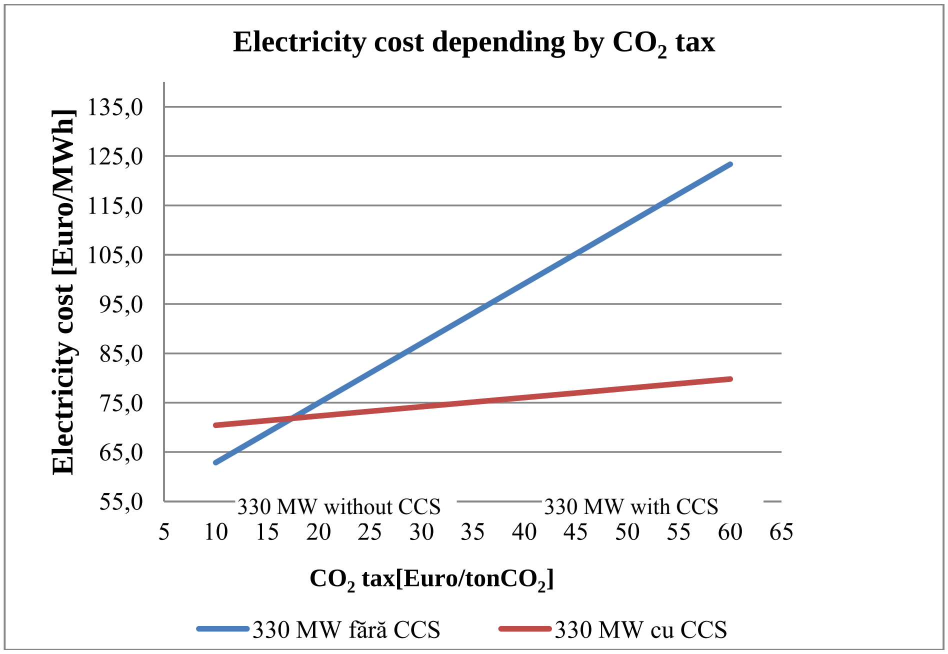

Fig.1. Electricity cost depending by CO_2 tax for a group with and without capture CO_2

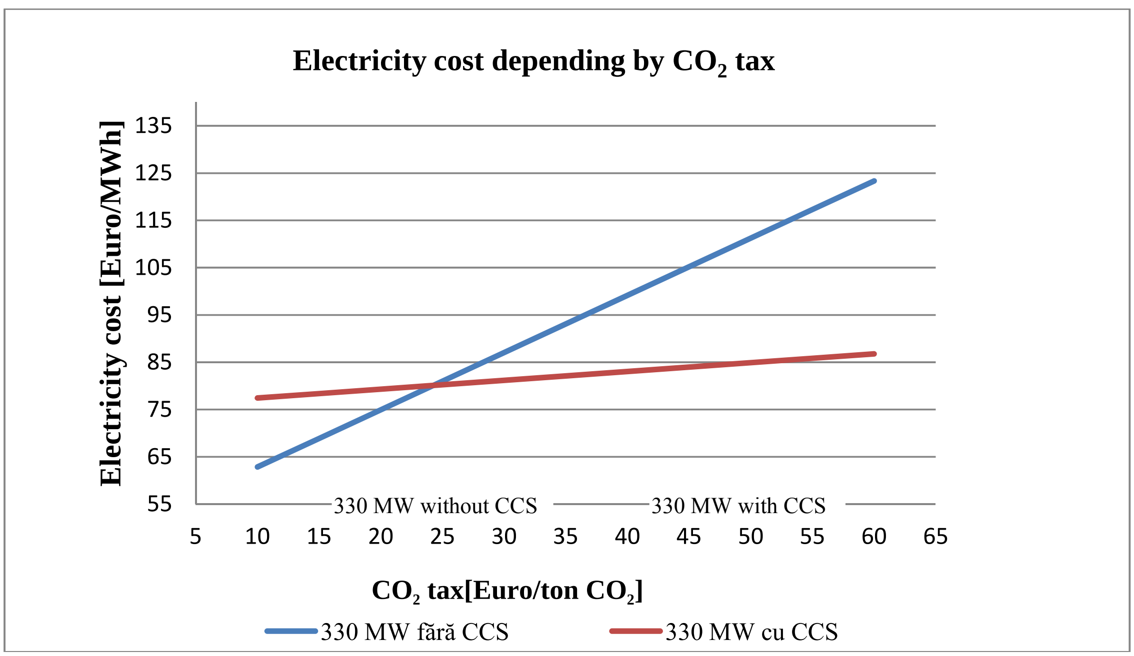

Fig.2. Electricity cost depending by CO_2 tax for a group without capture CO_2 and with CCS

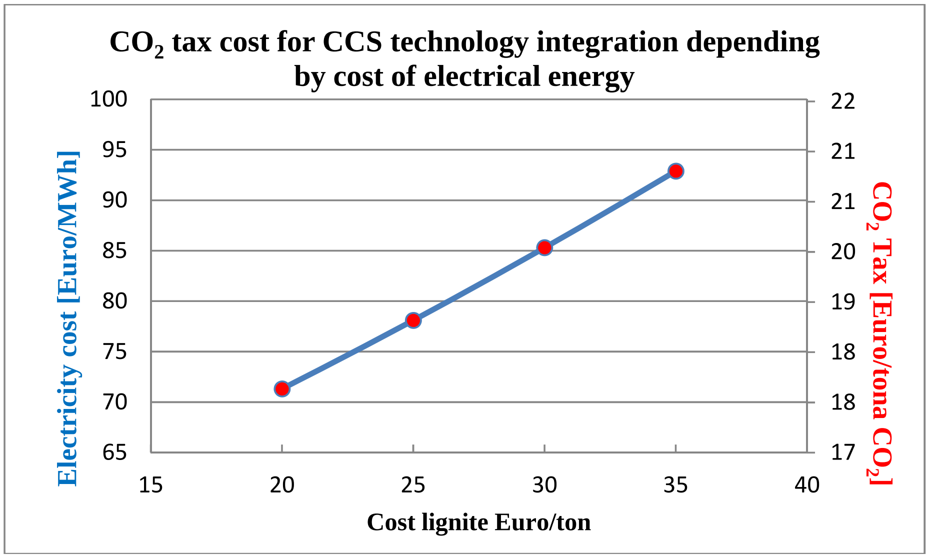

Fig.3. CO_2 tax cost for CCS technology integration depending by cost of electrical energy, if fuel prices grown

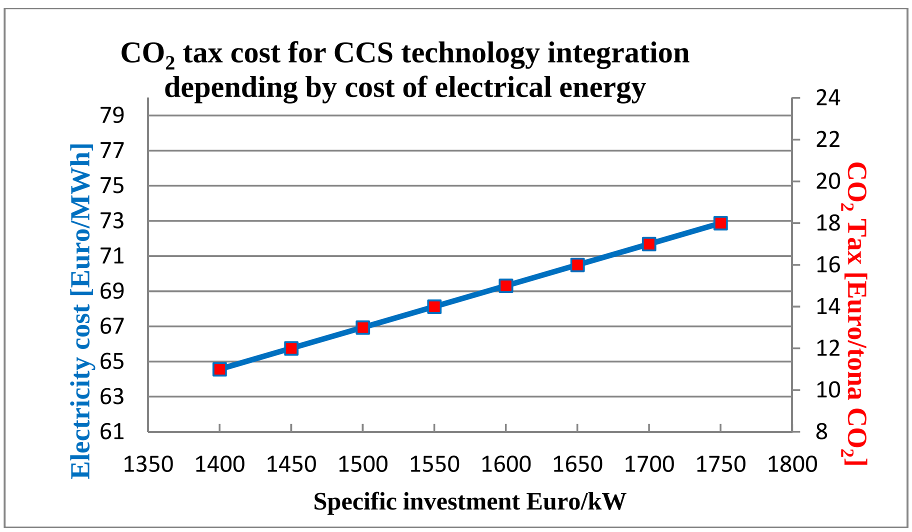

Fig.4. CO_2 tax cost for CCS technology integration depending by cost of investment CCS technology

In the case of investment variation (Fig. 4) in CO_2 capture technology was observed that an increase of 3.5% on investment from 1400-1450 Euro/kW, led to a sensible change of energy cost with 3.12% and increase of 9% CO_2 tax.

The amine type is another important parameter that influences the cost of electricity for CO_2 capture unit integration as directly affects the amount of energy that is produced by energy consumption for solvent regeneration process.

Depending on the type of amine, primary, secondary, tertiary or mixture the amount of energy necessary for the regeneration of the solvent may vary as shown in Fig. 5. and 6.

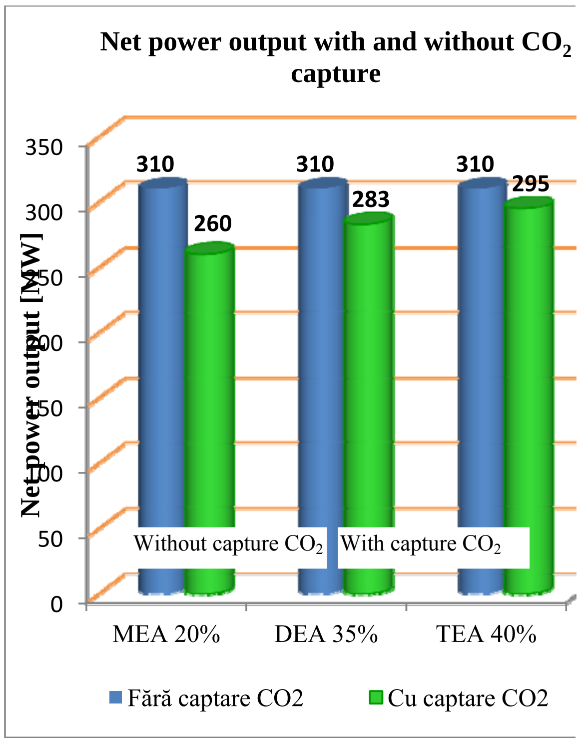

Fig.5. Net power decrease for a group 330 MW equipped with CO_2 capture plant

In Fig. 5 is presented the influence wich amine type can have on electricity price but also on CO_2 tax for wich the cost of energy produced in a power plant with CO_2 is higher than that produced in a plant equipped with CCS.

Choosing a type of amine requiring a high energy 4.2 GJ/tCO_2 (MEA 20%) for the regeneration of the solvent will result in a lower production of energy at a higher cost, while establishing a higher CO_2 price of 23 Euro/tCO2 certificate.

This value of CO_2 tax is the price that would be paid for CO_2 emissions if the system is not equipped with CO_2 capture plant and the cost of energy from start to exceed the cost of energy produced in the same plant fitted with CO_2 capture plant.

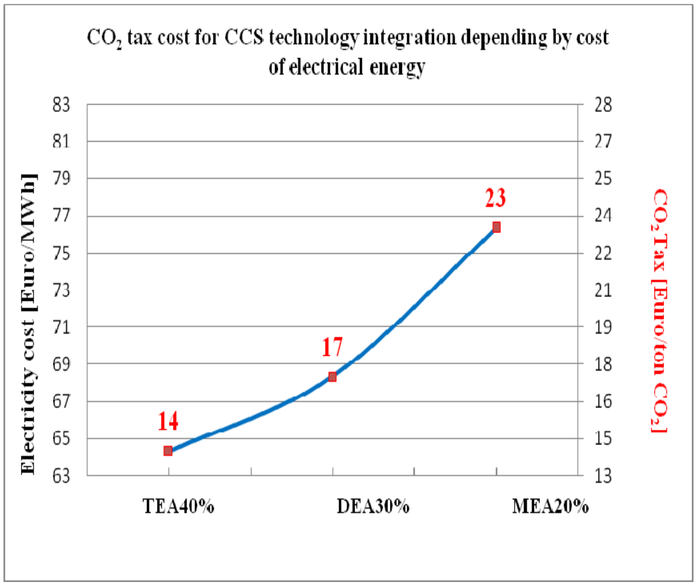

Fig.6. The influence of amine type on the cost of electricity and the CO_2 tax

Energy consumption for solvent regeneration significantly affect the cost of electricity so when we use TEA at 40% which has a very low energy consumption of 1,2 GJ/CO_2 TEA at DEA 30% with a consumption of 2,8 and 4,2 for MEA20% energy cost increases by 6.25% and 20% reaching 76 Euro / MWh.

4. Conclusions

In conclusion the rising of fuel price is the main factor wich influence the cost of electric enrgy both in the case of a plant equipped with CO_2 capture installation but also in the other case when the plant is not equipped with capture instalation. Increasing the price with 75% from 20 to 35 EUR/t lignite led to increased energy cost with 32% reflected also in the cost of CO_2 tax wich also increased from 18 to 21 euro/ton.

Investment in CO_2 capture unit represent a growth factor whose increasing by 350 EUR/ KW cause an increase in the cost of energy by 10% ranging from 64-71 Euro / MW, at the same time causing an increase in CO_2 tax cost from 11-18 Euro/tCO_2 for the cost of energy from a unit without CO_2 capture is greater than the cost of product in a facility with CO_2 capture.

Solvent cost is not a factor that greatly influence the energy cost so it is recommended to use solvents more expensive but with better properties. Following the study, tertiar amines (40% TEA) turned to have the lowest regeneration energy consumption.

Energy consumption for solvent regeneration proved to be a very important factor that can influence up to 20% cost of electrical energy and therefore CO_2 tax cost.

CO_2 tax price plays a very important role in determining the cost of electrical power and the decision to equip a plant with CO_2 retention unit.The critical point for which the amount of CO_2 tax necessary to provide a capture unit are 23 Euro/t CO_2 for primary amine. Increasing CO_2 tax is to encourage and determine to install CO_2 retention unit.

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