Biomass co-firing in existing power plants

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Abstract: - Co-firing is the process of replacing part of the fossil fuel supplied to a power station or boiler with a 'carbon lean', renewable alternative. The article presents the possibilities to use a large perennial grass (Mischantus Giganteus) as a supplemental fuel in romanian large power plants.
In biomass cofiring, Miscanthus can substitute for up to 10% of the coal used in the boiler and it can provide the following benefits: lower fuel costs, avoidance of landfills and their associated costs, reductions in sulfur oxide, nitrogen oxide and greenhouse-gas emissions.

Key-Words: - Miscanthus Giganteus, co-firing, large power plants

1 Introduction

European Union took a leading role in global environmental negotiations, especially by adopting in 2008 the Climate Change package which established the '20:20:20 targets' for 2020 [1]:

- A 20% reduction in EU greenhouse gas emissions from 1990 levels;
- Raising the share of EU energy consumption produced from renewable resources to 20%;
- A 20% improvement in the EU's energy efficiency.

The 20-20-20 targets represent an integrated approach to climate and energy policy that aims to combat climate change, increase the EU's energy security and strengthen its competitiveness.

The climate and energy package comprises four pieces of complementary legislation which are intended to deliver on the 20-20-20 targets:

A. Reform of the EU Emissions Trading System (EU ETS)

The EU ETS is the most cost-effectively key tool for cutting industrial greenhouse gas emissions. The third trading period began in January **2013** and will span until December 2020. Major changes include the introduction of a single EU-wide cap on emission allowances in place of the existing system of national caps. The free allocation of allowances will be progressively replaced by auctioning, starting with the power sector.

B. National targets for non EU ETS emissions

Around 60% of the EU's total emissions come from sectors outside the EU ETS. The Member States have taken on binding annual targets for reducing their greenhouse gas emissions from the sectors not covered by the EU ETS, such as housing, agriculture, waste and transport (excluding aviation).

The national targets, covering the period 2013-2020, are differentiated according to Member States' relative wealth.

C. National renewable energy targets

The Member States took on binding national targets for increasing the share of renewable energy in their energy consumption by 2020. These targets, which reflect Member States' different starting points and potential for increasing renewables production, will enable the EU to reach its 20% renewable energy target for 2020.

D. Carbon capture and storage

The fourth element of the climate and energy package is a directive creating a legal framework for the environmentally safe use of carbon capture and storage technologies. Carbon capture and storage involves capturing the carbon dioxide emitted by industrial processes and storing it in underground geological formations where it does not contribute to global warming.

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In Romania, the GHG emissions dropped by 59,1% in 2010 compared to 1989 but the structure of GHG emissions has almost the same structure, as presented in fig. 1 and fig. 2 [2].

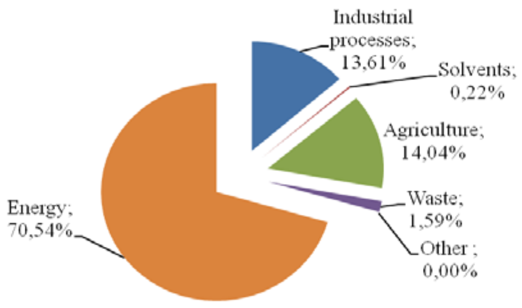

Fig. 1. GHG emissions by sector in 1989

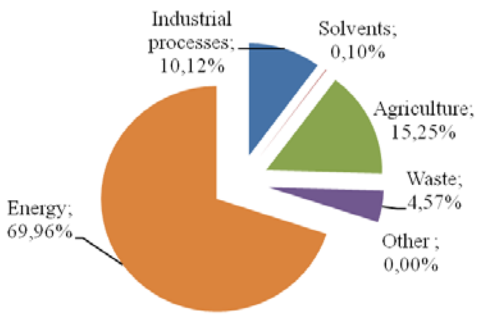

Fig. 2. GHG emissions by sector in 1989

2 Problem Formulation

Energy Complex Oltenia (ECO) is a company founded on 31 May 2012 by the merger of four entities: Energy Complex Rovinari, Energy Complex Turceni, Energy Complex Craiova and National Company of Lignite Oltenia SA. ECO has a share of 25-30% of the domestic electricity market. The total installed capacity is 3570 MW (12 power units) and the steam is produced in coal fired boilers, resulting huge amounts of GHG emissions.

In the paper we analyse a power unit of 330MW (used at Rovinari and Turceni power plants) equipped with a steam boiler of 1035t/h, 195 ata, 540^{o}C/540^{o}C, Benson type once-through boiler with a single gas path and a turbine of 330 MW, 186 ata, 535^{o}C/ 535^{o}C, FIC type, with condensation.

The electricity generated and delivered by the analyzed power unit is presented in table 1. According to coal consumption, the necessary of GHG certificates is presented in table 2. In the same table are shown the number of allocated GHG certificates and the deficit of GHG certificates.

Table 1.

Year	Generated electricity [MWh]	Delivered electricity [MWh]
2010	2.036.980	1.854.399
2011	1.836.469	1.596.244
2012	2.059.868	1.738.778

Table 2

Year	GHG certificates		
	Necessary	Allocated	Deficit
2010	1.889.012	1.211.127	-643.272
2011	1.683.614	1.211.127	-385.117
2012	1.873.538	1.211.127	-527.651

The amounts of pollutants resulted from the coal burning process are presented in table 3.

Table 3

Pollutant	UM	2010	2011	2012
Ash	mg/Nm3	48	36,62	10,63
SO2	mg/Nm3	4765	304,7	252
NOx	mg/Nm3	427,5	486,4	434,8
Slag	kt	522,3	527,5	522,3

In order to meet the deadline set by the European Directive 2003/87/EC for purchasing of CO2 certificates, ECO purchased by November 2012, 3.2 million of GHG certificates [3]. Since certificates lead to more expensive electricity, it is necessary to take rapid measures to reduce emissions in coal fired power plants.

3 Problem Solution

3.1 Renewables support scheme

Romania implemented the first support scheme for renewables in 2005 [4]. This was based on a combination between quota obligations and tradable green certificates. The initial support scheme was improved periodically with some enactments, such as:

(1) Law no. 220/2008 on the promotion of renewable energy sources, as subsequently amended that transposes the provisions of the Directive no. 2009/28/EC of the European Parliament and of the Council on the promotion of the use of energy from renewable sources;

(2) Government Decision no. 1479/2009 establishing the system for the promotion of electricity from renewable energy sources;

(3) Emergency Ordinance no.88/2011 regarding the establishment of the promotion system for the production of energy from renewable energy sources

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In contrast to the provisions of the former Law no. 220/2008, the Government Emergency Ordinance no.88/2011 reduces the number of green certificates from 3 certificates to 2 certificates for the electricity obtained from geo-thermal energy, biomass (other than that coming from energy cultures), bio-liquids, bio-gas and from 3 to 1 for the gas from processing the wastes and fermenting gas from mud.

Due to the generous promotion scheme for green energy technologies, Romania became a favorite location for international projects. There are substantial growth projections for installed capacity of solar power in 2013, as seen in table 4 [5].

Table 4

Renewable source	Running Pi [MW]	Planned Pi [MW]
Wind	1716	2105
Hydropower Pi<10 MW	145	123
Biomass	28	28
Solar	41	371

According to [5], the Romanian Energy Regulator **(**ANRE**)** will propose the government to reduce the green certificates allotted for photo-voltaic projects, wind and small-hydro power plants, as these investments become profitable faster – table 5.

Table 5.

Renewable source	Green certificates/MW	
	According to law	Proposed by ANRE
Wind	2	1,5
Hydropower Pi<10 MW	3	2,3
Solar	6	3

These changes could redirect the investors to biomass projects.

3.2 Biomass co-firing

Biomass is defined as all materials that are derived, directly or indirectly, from contemporary photosynthesis reactions. This includes all vegetal matter and their derivatives; wood fuel, wood-derived fuels, fuel crops, agricultural and agro-industrial by-products and animal by-products [6]. Biomass is considered a renewable energy source as long as it is based on sustainable utilization. If consumed at the same rate as new biomass is grown, there is no net atmospheric CO_2 emission connected to the consumption of biomass materials.

Compared to fossil fuels, biomass is more evenly dispersed over the earth's surface and is thus suitable for distributed local energy production. Energy production from biomass is also in general regarded cleaner than fossil fuels in terms of environmental pollution [7].

Co-firing is the combustion of two different fuels at the same time. One of its advantages is that an existing installation can be used to burn a new fuel, which could be cheaper and more environmentally friendly.

Energy production in coal-fired power plants by partial substitution of coal as the main fuel with biomass feedstock is called co-firing. However this report focuses on systems where a part is substituted for coal with biomass (residues and energy crops).

There are three basic types of technological configurations for biomass co-firing power plants: direct co-firing, parallel co-firing and indirect co-firing [8].

3.2.1. Direct co-firing

In this case, biomass is fed into the boiler with coal. For direct co-firing of biomass with coal in large scale boilers, there are possible following options:

• Blending biomass with coal in the fuel storage and transportation of the fuel mixture through the coal dust preparation equipments (crushers, coal mills), being then pulverized in boiler by burners. This is the cheapest and easiest method, but problems may arise due to differences between the characteristics of the two fuels. Some types of biomass can be processed in this way (eg herbaceous biomass is known to cause many problems during shred).

• separate grinding of biomass, mechanical or pneumatic power boiler burning followed by biomass material through existing coal injection system and burners. In this case, there is fuel mixture in the combustion chamber so without affecting fossil fuel delivery system. This solution requires more investment.

• Installing die we only biomass and sometimes separate burners. This solution increases the flow of biomass that can be powered boiler. This type of installation is relatively complex and expensive to install.

In direct co-firing is required a minimum investment but may face various deficiencies resulting from differences between the properties of the fuel mixture.

3.2.2. Parallel co-firing

In this case, biomass is separated from the coal burned] into a new boiler, providing steam to a common pipe. There is no technical possibility to supply boilers burning biomass fuels, as fuel and food preparation are physically independent.

Under this option, potentially limiting factor in power plants can be retrofitted to existing infrastructure capacity, downstream, such as steam turbine. Amount of biomass that could be co-fired capacity could be limited by the steam generator, so you should ensure that there is enough excess capacity steam turbines to match the extra power from biomass burning (or which is activated coal boiler capacity below).

Since coal and biomass are burned in boilers different, may be an optimal choice for each fuel. Investing for the co-firing systems in parallel, significantly higher than the direct option, but the ability to optimize the combustion process, using fuels with high chlorine and alkali content and ash separation are possible benefits.

3.2.3. Indirect co-firing

In this case, biomass is gasified gas produced separately and is injected and burned in boiler coal. Indirect co-combustion disadvantage is the relatively high unit investment costs.

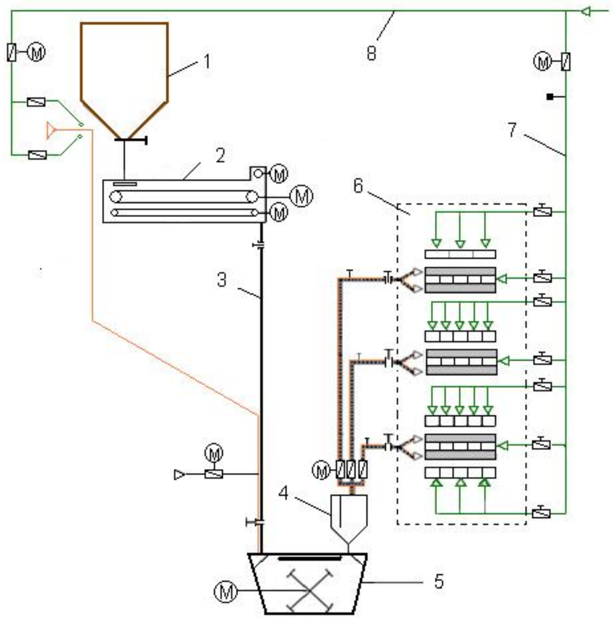
Direct co-firing biomass and coal is the most widely used solution for co-firing in Europe today, especially because of the relatively low cost investment to transform power plants. Parallel co-firing units are used, especially in power plants pulp and paper industry. Indirect co-firing options are currently considered to be too expensive for European markets. However, when considering future prospects for co-firing, the tendency is to increase the rate of biomass / coal, and be able to use a range of different biomass fuels, including fuel mixtures. Therefore, it may be in the future, that greater investment in advanced co-firing configurations would pay back better usability and flexibility of the system.

3.2. Systems for coal and biomass combustion

In general, three types of combustion systems can be identified:

- Fixed bed combustion (burning on the grill)
- Fluidized bed combustion (bubbling and circulating)
- Pulverized fuel combustion (flue dust)

Taking into account the type of existing boiler (see fig. 3), it's cheaper and easier to use the existing coal burners for direct co-firing of biomass and coal.



Fig, 3, Technological scheme of the coal preparation and combustion installation
1 coal bunker, 2 - coal feeder, 3 - coal pipe, 4 – coal separator, 5 - coal mill, 6 - coal dust burner 7 - secondary air pipe, 8 - primary air pipe

In Romania, there are huge areas of land available for energy crops plantation. The potential for dedicated energy crops may total 800 PJ [9]

Perennial rhizomatous grasses, as miscanthus, are generating much interest in Europe, as new sources of biomass for energy production.

Mischantus Giganteus is a large perennial grass used primarily for combustion in power plants. In addition to providing clean and affordable energy, Mischantus is an environmental friendly crop. Miscanthus is a warm-season grass but it can grow even at relatively low temperatures. Maximum dry matter yield is reached in late-summer but harvest is typically delayed until winter or early spring. This allows nitrogen to move into the rhizome for use by the plant in the following season. Miscanthus is a sterile plant so is less likely to be invasive.[10]

Miscanthus has a growing cycle of 15 years or longer. Yield increases until the third year of growth after which it stays roughly constant until the 15th year. The biomass yield tends to decline after that although some miscanthus stands produce acceptable yields beyond 15 years [11].

The experiments were carried out on miscantus giganteus. Because we harvested the plants just one year after planting, the moisture content was high – 52,38%. We dried miscanthus, chopped it and we performed the ultimate analysis. The results are shown in table 6.

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Table 6

Parameter	Value
Moisture content	0,8
Carbon content	45,5
Hydrogen content	5,7
Ash content	3,3
Oxigen content (by difference)	44,5
Sulfur content	0,0
Nitrogen content	0,2
Lower heating value [MJ/kg]	17,57
Volatile matter content	72,3

The total coal reserves of Romania amount to approximately one gigatonne of hard coal and 3 gigatonnes of brown coal and lignite and they are sufficient to cover power generation needs for 70 years. More than 90% of the Romanian coal reserves are in the Oltenia Region and could be efficient exploited in open pits [12].

Lignite, also known as brown coal, is the lowest grade of coal and shares some characteristics with peat. It tends to have a carbon content of 21-26 per cent and high levels of moisture and an ash. The average characteristics of lignite from Oltenia Region are indicated in table 7, where: AR – as received, DB – dry basis.

Table 7

Parameter		Value
Adventitious moisture content		36,21 ÷ 43,21
Inherent moisture content, AR		3,18 ÷ 5,45
Total moisture content		41,35 ÷ 46,29
Ash content, AR		13,60 ÷ 25,29
Ash content, DB		25,12 ÷ 43,12
Sulfur content	Combustible, AR	1,09 ÷ 1,42
	Total	1,26 ÷ 1,72
Nitrogen content, AR		0,49 ÷ 0,65
Oxygen content, AR		7,03 ÷ 8,85
Hydrogen content, AR		1,84 ÷ 2,48
Carbon content, AR		21,98 ÷ 25,86
Lower heating value		6,92 ÷ 9,06
Volatile matter content		15,25 ÷ 21,19

By comparing tables 8 and 7, one can see that the lower heating value of dried miscanthus is about two fold greater than that of lignite.

The annually fuel consumptions for the considered power unit are presented in table 8.

Table 8

Consumption	2010	2011	2012
Coal [t/year]	2.571.648	2.328.901	2.482.112
Oil [kg/year]	176.250	11.600	203.200
Natural gas [m^3/an]	814.769	765.881	1.320.537
Specific [gcc/kWh]	321,17	321,31	303,48

Given the ratio of the calorific value for the two fuels, to replace 10% of coal, about 120000 tones of miscanthus annually are required.

According to former case studies [11,13,14,15], planting density, soil type, sunshine and rainfall are the key determinants of yield. The yields of miscanthus were found to range between 4 and 44 tones of dry matter per hectare.

As adverse environmental conditions near the power plant, we expect a lower yield of miscanthus, of 13 tones of dry matter per hectare.

To provide the annually amount of biomass, an area of almost 10000 ha of land is required.

4 Conclusion

Romanian power plants generate huge quantities of greenhouse gas and they must buy CO_2 certificates, resulting in an increase of electricity price.

According to the European Union requirements, the power and heat generation for industry and household sectors have to gradually glide from fossil fuels to renewable sources of energy. Biomass is an auspicious source of energy for the future, especially as the number of green certificates allotted for wind, water and solar plants will be reduced.

Mischantus Giganteus is one of the perennial rhizomatous grasses that could be used for combustion in power plants.

Miscanthus could be use in direct co-firing with coal, the mixture being pulverized into the boiler. Because of the large consumption of fuel, important quantities of Miscantus are required. Even Energy Complex Oltenia owns enough land for planting Miscanthus, transport, storage, drying and chopping of large quantities of Miscanthus may cause problems.

Mischantus provides clean and affordable energy, and its lower heating value is almost double than that of lignite.

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