

## EXPERIMENTAL RESULTS CONCERNING THE CO-COMBUSTION OF BIOMASS IN A STATIONARY FLUIDISED BED PILOT WITH BIOGAS SUPPORT AND CO<sub>2</sub> CAPTURE

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**ABSTRACT:** The paper focuses on the main problems of environmental benefits achieved by using biomass as energy resource. Thus one presents the technology of biogas obtaining from agricultural waste biomass and its use as support in a stationary fluidized bed combustion facility for the sawdust co-firing with coal. The flue gases are cleaned up and further on the CO<sub>2</sub> is retained by means of the capture in metal-amines. One gives details about the outfit of the biogas facility. By resuming, one presents a global clean technology, CO<sub>2</sub> neutral, using agricultural waste biomass.

**Keywords:** biomass/coal co-firing, sawdust, biogas, CO<sub>2</sub> emission reduction, flue-gas cleaning, emission reduction, innovative concept, sustainable use of biomass.

### 1 INTRODUCTION

In the long term, 'renewable energies' will inevitably dominate the world's energy supply system. The reason is at same time very simple and imperative: there is no alternative. Mankind cannot indefinitely continue to base its life on the consumption of finite energy resources. Today, the world's energy supply is largely based on fossil fuels and nuclear power. These sources will not last forever and have proven to be one of the main causes of the ever growing environmental pollution.

Environmental impacts of energy use are not new, but they are aggressive and increasing, they range from de-forestation to local and global pollution. In less than three centuries since the industrial revolution, mankind has already burned roughly half of the fossil fuels accumulated under earth's surface during hundred of millions of years. Nuclear power is also based on a limited resource and its use creates also incalculable risks.

Renewable sources of energy are in line with overall strategy of sustainable development. They help to reduce dependency on energy imports, or do not grow a dependency, they help also to industrial competition and, on long term, may have a positive impact on regional development and employment. Combined with improvements in energy efficiency and the rational use of energy, RES can provide everything fossil fuels currently offer in terms of energy services.

The recent EU membership of Romania and the research directives in Europe and all over the world bring a new opportunity for the development of biomass co-firing, due to the coal combustion infrastructure already installed, the land availability for energy crops and the current dependency on imported fossil fuels.

Biomass co-firing represents, compared to other technologies based only on renewable sources, a technically feasible option, having a real potential of contributing to the EU energy supply, meanwhile ensuring sustainable development.

Thus a pilot plant running co-combustion of coal and biomass waste will be presented and results of several tests will be indicated. As one desired to generate a lean CO<sub>2</sub> emission technology, one added specific devices as well: (i) CO<sub>2</sub> capturing device and (ii) low NO<sub>x</sub> burner using self produced biogas from waste materials of agricultural (biomass) origin delivered from (iii) another pilot.

Complementary, a simulation of the co-burning process is realized in Fluent code, with the scope to observe the main characteristics of the parameters involved in co-burning and the different processes that are taking place.

As result a flue gas composed of the main known pollutants (CO, NO<sub>x</sub>, SO<sub>2</sub>, particles) in addition to N<sub>2</sub>, CO<sub>2</sub>, O<sub>2</sub> and other trace species is resulting. The CO<sub>2</sub> is partially reduced by the amount of the biomass share in the blending fuel used in the co-combustion.

In order to further reduce the CO<sub>2</sub> exhaust one started also to test the capability of reducing it further, by means of a post combustion capturing technology Carbon dioxide capture is already an industrial technology, used today notably to process natural gas. Because it would be out of the question to seek to compress the CO<sub>2</sub> for storage, from the stand point of energy and storage capacity, separation methods are thus required so as to trap CO<sub>2</sub> preferentially.

Also, in the paper one will be presented some details regarding the biogas producing installation that is used in order to feed the co-burning installation.

### 2 GENERAL DESCRIPTION OF THE CO-BURNING INSTALLATION

In this paragraph one will presented the general characteristics of the fossil coal from Valea Jiului basin and the biomass used in the co-burning process and also the schematics for the co-burning installation. One used for experiments sorts of agricultural biomass, available at low price in

comparison to coal, for an acceptable and comparative energy offer.

### 2.1. Biomass characteristics

Tables I, II and III present general characteristics for the used pit coal and the different types of waste biomass.

One remarks the major S content in the coal and only the small amount in the biomass. This contributes directly also to the SO<sub>2</sub> reduction in the flue gases, by same thermal input.

**Table I:** Main characteristics for corn cob

Characteristics (dry basis)	Symbol	IS unit	Value
Carbon	C <sup>i</sup>	%	44.62
Hydrogen	H <sup>i</sup>	%	5.37
Sulfur	S <sup>i</sup>	%	0.05
Oxygen	(O) <sub>by dif.</sub>	%	39.57
Nitrogen	N <sup>i</sup>	%	0.41
Ash	A <sup>i</sup>	%	8.50
Chlorine	Cl <sup>i</sup>	%	1.48
Inferior heating value	H <sub>i</sub> <sup>i</sup>	kJ/kg	16,509

**Table II:** Main characteristics for maize

Characteristics (dry basis)	Symbol	IS unit	Value
Carbon	C <sup>i</sup>	%	47.79
Hydrogen	H <sup>i</sup>	%	5.64
Sulfur	S <sup>i</sup>	%	0.01
Oxygen	(O) <sub>by dif.</sub>	%	44.71
Nitrogen	N <sup>i</sup>	%	0.44
Ash	A <sup>i</sup>	%	1.20
Chlorine	Cl <sup>i</sup>	%	0.21
Inferior heating value	H <sub>i</sub> <sup>i</sup>	kJ/kg	16,755

The heat value of the biomass is higher in comparison to the coal, despite the different price of purchasing (that is presently gaping but time dependent). In Fig. 1, 2 and 3 are presented the photographs of the fuel sorts used, in order to inform about their outfit and visual aspect.

### 2.2. The co-combustion pilot

Details about the components and main characteristics are given in [1], [2], [3], [4], and [5].

**Table III:** Main characteristics for pit coal Valea Jiului

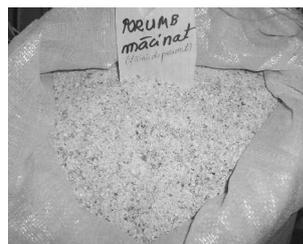
Characteristics	Symbol	IS unit	Value
Carbon	C <sup>i</sup>	%	37.20
Hydrogen	H <sup>i</sup>	%	2.43
Sulfur	S <sup>i</sup>	%	1.10
Oxygen	O <sup>i</sup>	%	9.00
Nitrogen	N <sup>i</sup>	%	1.00
Ash	A <sup>i</sup>	%	40.30
Humidity	W <sup>i</sup>	%	8.97
Inferior heating value	H <sub>i</sub> <sup>i</sup>	kJ/kg	15,894



**Fig. 1:** Pit coal from Valea Jiului basin



**Fig. 2:** Corn cob



**Fig. 3:** Maize

Also the advantages of fluidized combustion are notable, as [6] also indicates and pointed out also by results from a national research project [7], being specific to a larger game of fuel variety and also simultaneous avoiding, by temperature control the NO<sub>x</sub> mechanism. One mentions also that the technique of coupling the waste incinerator to an existing boiler is another option, best applicable in case that no infrastructure for heat and electrical energy generation and transportation and utilization exists, on spot [8]. Special components such as chlorine, fluorine have been controlled,

and one remarks that a special technology to reduce and extract such pollutants is of major importance, as [9] indicates. For researching the deposit formation in cohesion to the material behavior of the furnace one started a range of tests, according to the special indicated techniques from [10].

The main burning system is presented in a general view by Fig. 4 and the components are:

- The furnace, parallelepiped shape with truncated pyramid base,
- The air distributor, air nozzles for injection of fluidization air/main burning air,
- The air feeding system – air blower, adapting pieces,
- The fuel bunkers, starting/post combustion burner working with natural gas,
- The furnace connection allowing the heat transfer system (convective case),
- The measuring equipment for temperatures, pressures, flows and observation holes.

The heat transfer subassembly consists of:

- A convective case, parallelepipedic-shaped,
- A convective case connection with furnace and dust collecting system,
- A heat transfer serpentine cooler with a water pump,
- The measuring equipment.

In addition one remarks the fact that for starting a low  $\text{NO}_x$  burner (Fig. 5) was mounted.

The flue gases particle removing subassembly consisting of a cyclone dust separator, having a cylindrical body in vertical position and a main two parts flue gases cleaning system for  $\text{NO}_x$  and  $\text{SO}_2$  and other components. In addition a scrubbing tower with Raschig rings, having a cylindrical body in vertical position with a cone-shaped base, is mounted.

The principal characteristics of the functional facility have vary as follows:

- Thermal energy: 0.21– 0.42 MJ,
- Electrical power consumption: 2 – 4 kWh,
- Flow of the water system: 2 – 4  $\text{m}^3/\text{h}$ ,
- Flow of combustion / fluidization air: 200 – 300  $\text{m}^3_{\text{N}}/\text{h}$ ,
- Flow of compressed air for flue gases cleaning pumps: 0.5 – 1  $\text{m}^3_{\text{N}}/\text{h}$ ,
- Flow of natural gas for the start: 2 – 5  $\text{m}^3/\text{st}/\text{h}$ ,
- Mass flow of coal: 25 – 50 kg/h,
- Mass flow of biomass: 15 – 30 kg/h,
- Flow of the washing liquid ( $p = 2$  bar): 0.2 – 0.6  $\text{m}^3/\text{h}$ ,
- Mass flow of the resulted ash: 10 – 20 kg/h.

In order to reduce the pollutant concentrations in the flue gases, especially  $\text{NO}_x$  and  $\text{SO}_2$ , in correspondence, reagent proportioning was made as follow: alkali solution with 2.5% sodium hydroxide with 1 l spraying liquid/ $\text{m}^3$  gas flow rate using a metering pump. The achieved denox-efficiency is over 50 %, the desulphurization over 99 % (see Figures 6 and 7) and the particle removal efficiency is 99.7 %.



Fig. 4: Photo of the fluidized bed co-combustion



Fig. 5: Low  $\text{NO}_x$  burner using biogas

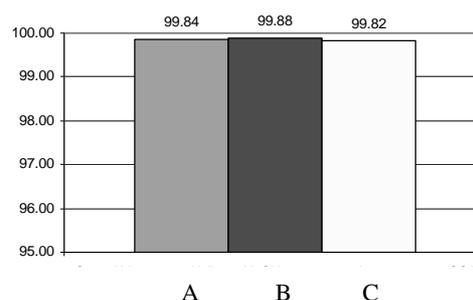


Fig. 6:  $\text{SO}_2$  retention factor for the three types of fuel mixtures (A – Corn cob + pit coal, B – Maize + pit coal, C – Sunflower seed + pit coal)

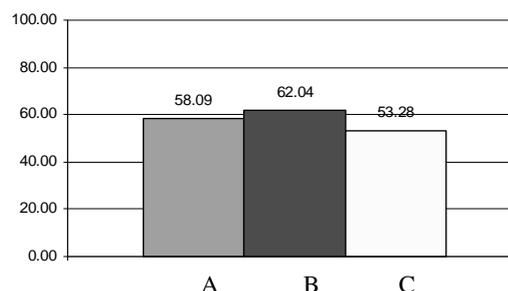


Fig. 7:  $\text{NO}_x$  retention factor the three types of fuel mixtures (A – Corn cob + pit coal, B – Maize + pit coal, C – Sunflower seed + pit coal)

### 3. SIMULATION OF THE PROCESS IN THE CO-BURNING INSTALLATION

#### 3.1. Hypothesis adopted

A Lagrangean model was selected to be used. The combustible phase was charged like solid combusting particles in the fluid oxidant phase. By using PDF

model, it is indispensable that the combustible flux must consist of the combusting particles, and thus it is introduced as dispersed solid phase injections. The fuel with empirical defined analysis was accomplished in FLUENT only at dry, ash free (DAF) level mass, and not at humid one (RAF). The mineral matter was considered as a fuel with a zero content of volatile matter and char (meaning it does not release combustible matter, and does not influence the combustion), but characterized by an ash density, specific heat and conductivity value. Tables IV and V give results for the basic numerical input data used.

**Table IV:** Calculated values for the simulation

Parameter	IS units	Value
RAW mass combustible flow	kg/s	0.011879
DAF mass combustible flow	kg/s	0.004496
Low heating value of the RAW mixture	kJ/kg	6,435
Low heating value of the DAF mixture	kJ/kg	17,000
Reduced low heating value of the DAF mixture by moisture vaporization	kJ/kg	13,800
Combustion air mass flux	kg/s	0.0478
Air moisture mass flux, including the fuel moisture	kg/s	0.0057
Post combusting air mass flux	kg/s	0.0146

**Table V:** Global values related to domain boundary conditions

Parameter	IS units	Value
Air + moisture mass flux at inlet	kg/s	0,05356
Post combusting air mass flux	kg/s	0,01452
Flue gas temperature at outlet	°C	1189
Mole fraction of CO <sub>2</sub>	%	9,75
Mole fraction of O <sub>2</sub>	%	4,88
Mole fraction of CO	ppm	1,23
Mole fraction of NO	ppm	416

For simulation following phases were adopted:

- The combustible phase, consist from injections of solid particles of DAF mixture, as dispersed phase.
  - The distribution of particles is considered Rosin-Rammler type (RR);
  - The oxidant phase consists from the air and the fuel moisture;
- Concerning the combustion model for ash a separate phase is not necessary.

Concerning the selection of the model, one used according to [11], [12]:

- the Solver characterized by being segregated, implicit, 3D, and steady,
- velocity formulation considered absolute;

- energy used as enabled;
- turbulence model: k-ε standard;
- radiation: DO (discrete ordinates);
- discrete phase: enable, allowing the interaction with continuous phase by radiation; multiphase: off.

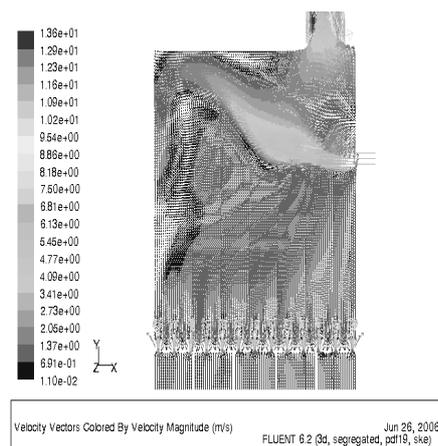
### 3.2. The boundary conditions

Concerning the inlet and fuel injections boundary conditions one generated an input data range, consisting of a series of the fuel mixtures. As fuel mixture one calculated a share of biomass (B) with Coal (C), by mass fractions:

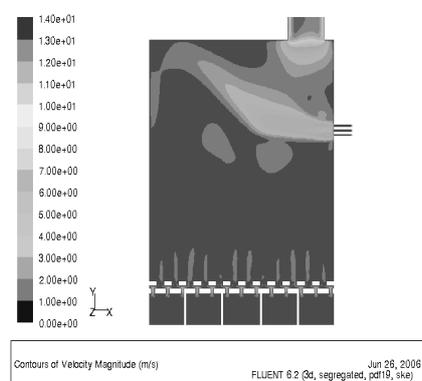
- 10 % biomass + 90 % coal (10B+90C),
- 20 % biomass + 80 % coal (20B+80C),
- 30 % biomass + 70 % coal (30B+70C) and
- 40 % biomass + 60 % coal (40B+60C).

### 3.3. Simulation results

In the next FLUENT simulation results are presented taking the second from above mentioned share into account. Figures 8 to 19 gives cross section flow and concentration fields, as specific for the fluidized bed combustor, running coal and biomass waste, in a share of 20 % by mass.



**Fig. 8:** Velocity vectors.



**Fig. 9:** Velocity magnitude [m/s]

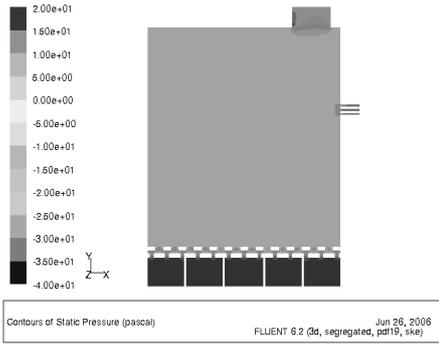


Fig. 10: Static Gauge Pressure [Pa]

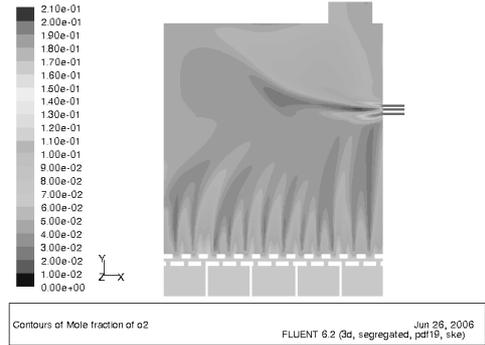


Fig. 14: Mole fraction of O<sub>2</sub>

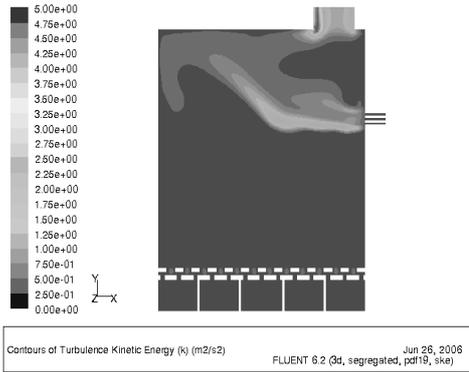


Fig. 11: Turbulent Kinetic Energy (k)

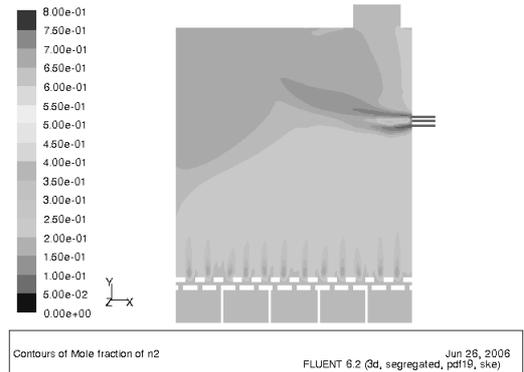


Fig. 15: Mole fraction of N<sub>2</sub>

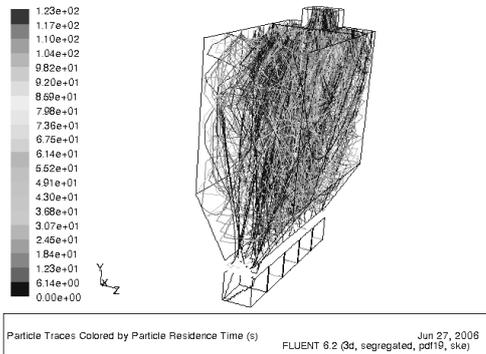


Fig. 12: Particle Traces

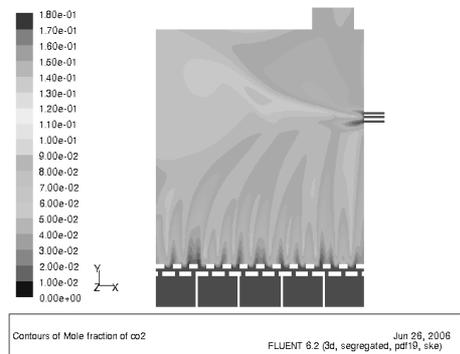


Fig. 16: Mole fraction of CO<sub>2</sub>

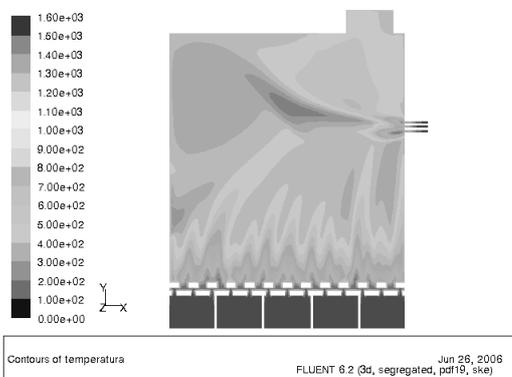


Fig. 13: Temperature field [°C]

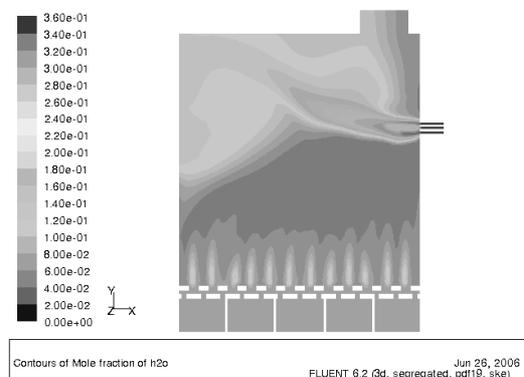


Fig. 17: Mole fraction of H<sub>2</sub>O

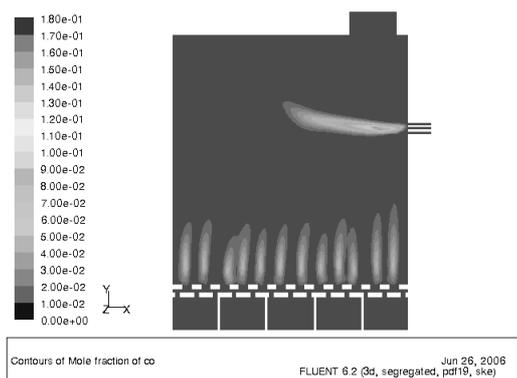


Fig. 17: Mole fraction of CO

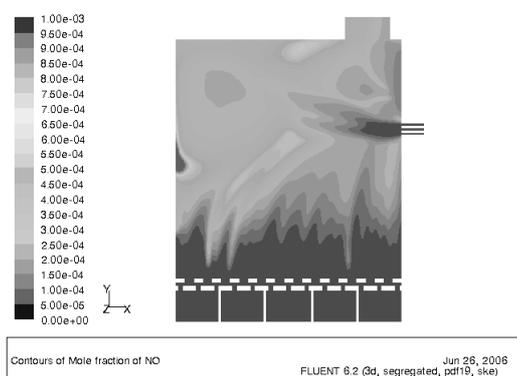


Fig. 19: Mole fraction of NO

#### 4. CO<sub>2</sub> CAPTURE INSTALLATION

In this paragraph one presents the schematics for the designed and used CO<sub>2</sub> capture installation and some particularities of the process, including results.

##### 4.1. General aspects regarding CO<sub>2</sub>

Emissions of greenhouse gases are charged to cause climate change. The main greenhouse gas is carbon dioxide (CO<sub>2</sub>) and the major source of it is the combustion of fossil fuels (coal, oil and gas) to supply energy under different forms, such as heat, electricity, mechanical work, etc. Global emissions of CO<sub>2</sub> from fossil fuel combustion increased from 20.7 billion tones (Gt) in 1990 to 24.1 Gt in 2002 (i.e. an increase of 16 % in comparison to 1990), as [13], [14], and [15] status.

Also, it is known that only by the integration of all new admitted countries in the biomass co-firing pathway, the European Union will be able to reach its own targets of reduction of CO<sub>2</sub> and increasing of renewable source share by the year 2010. Carbon dioxide capture is already an industrial technology. The main problem is generally the low concentration of CO<sub>2</sub> in the flue gas.

Three main categories for CO<sub>2</sub> capture are recognized according to [16] Figures 20, 21 and 22:

- Post-combustion capture;
- Oxy-fuel combustion;
- Pre-combustion.

**Post-combustion capture** is designed to extract the CO<sub>2</sub> that is diluted in the combustion flue gas. It can be integrated into the existing facilities without demanding any major modifications. The most common process is CO<sub>2</sub> capture by solvents, generally amines.

Other processes are under consideration involving the calcium cycle and cryogenic separation. The former consists in quicklime-based capture that yields limestone. This is then heated, thereby releasing CO<sub>2</sub> and producing quicklime again for recycling. The cryogenic process is based on solidifying CO<sub>2</sub> by frosting to separate it out.

The **technology of oxy-fuel combustion capture** is not a CO<sub>2</sub> capture process in the true sense of the term. Here, the process is applied at the input as opposed to the output stage: the objective is to obtain flue gas with a 90 % CO<sub>2</sub> content by performing combustion in the presence of pure oxygen. Because it recycles part of the CO<sub>2</sub> as a substitute for the nitrogen in air, oxy-combustion is particularly well suited when an existing facility is being retrofitted.

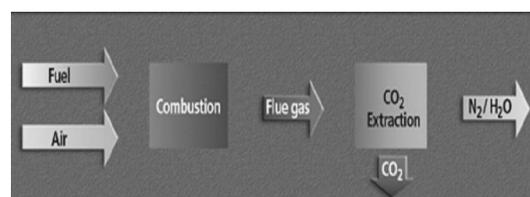


Fig. 20: Post-combustion capture [16]

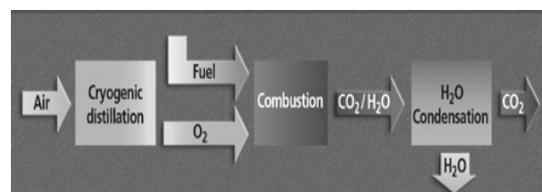


Fig. 21: Oxy-fuel combustion [16]

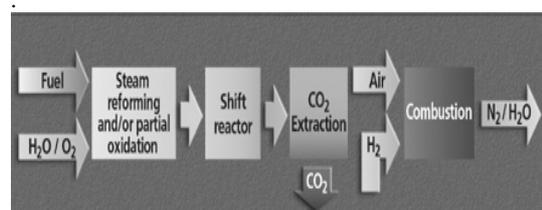
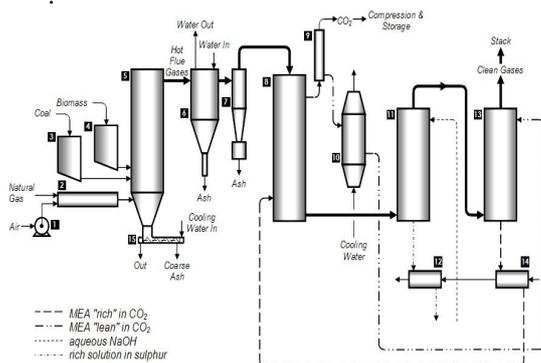


Fig. 22: Pre-combustion capture [16]

However, separating out the oxygen from air, performed mainly using the cryogenic principle, is both costly and energy-consuming. To give an idea, the energy consumption involved in supplying pure oxygen to a 500 MW coal-fired power station that operates 8000 hours a year would represent 15 % of the electricity it generates annually. To avoid the cost of separating out the oxygen from air, a promising technology is under consideration: **chemical looping combustion**. It consists in bringing the oxygen in the air into contact with a metallic medium that, when it circulates, transfers the oxygen

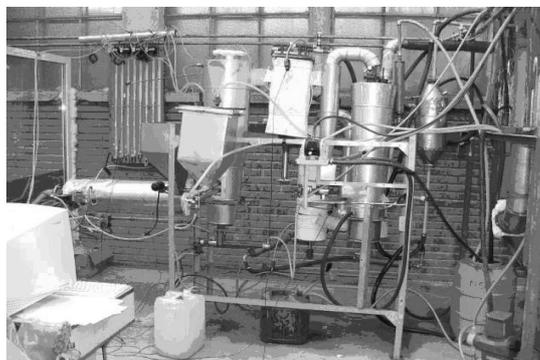
With the *pre-combustion capture*, the goal is to trap the carbon prior to combustion: the fuel is converted on entering the installation into synthesis gas – a mixture of carbon monoxide (CO) and hydrogen. The two main techniques are steam reforming of natural gas in the presence of water and partial oxidation in the presence of oxygen. The CO<sub>2</sub> is separated from the hydrogen, which can then be used to produce energy (electricity or heat) without giving off CO<sub>2</sub>.

#### 4.2. CO<sub>2</sub> capturing pilot



**Fig. 23:** Co-combustion of biomass with coal in fluidized bed with flue gas post-treatment, including flue gas desulphurization and carbon dioxide capture: 1-air fan, 2-combustion air pre-heater, 3-coal feed, 4-biomass feed, 5-combustion chamber, 6-heat exchanger flue gas-to-water, 7-cyclone, 8-desorber, 9-CO<sub>2</sub> separator, 10-heat exchanger MEA-to-water, 11-FGD (flue gas desulphurization unit), 12-cooler, 13-CO<sub>2</sub> absorber, 14-cooler, 15-bottom ash cooling screw.

In figure 23 one presents a schematics for the CO<sub>2</sub> capture installation and in figure 24 a photo of it. During the process of combustion, the coarse ash is removed from the combustor by means of a screw, located at the bottom of the combustor. From the top of the combustion chamber, the hot combustion gases with temperatures up to 900 °C (due to a separate post combustor running gas situated at the end of the furnace) are passed through a heat exchanger, where they are cooled down to the temperature levels required for the removal processes

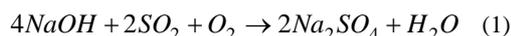


**Fig. 24:** Photo of the CO<sub>2</sub> capture installation

After transferring the specific heat, the gas enters tangentially a cyclone, where particulates are separated and removed from the bottom of the device, while the cleaned flue gas leaves at the top.

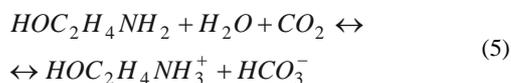
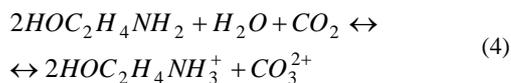
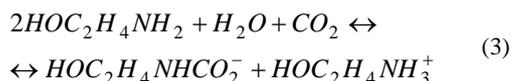
The amount of fly ash depends mainly on the ash content of the fuel, which is in case of Romanian Lignite considerable (at least 30-40 % by mass on humid basis). After leaving the cyclone, the flue gas with low ash content flows through a desorbing device. Here, the flue gas having appropriate temperature gets in counter heat exchange with the solution of amine "rich" in carbon dioxide. The flue gas temperatures measured during the test were around 255 °C before entering the desorbing unit. After the flue gas pre-treatment, a flue gas desulphurization process follows.

The co-combustion test installation was equipped with a "wet" scrubber, in which appropriate aqueous solutions of NaOH or Ca(OH)<sub>2</sub> were selected as active washing fluids [3]. Prior to be introduced, sodium hydroxide or calcium oxide were dissolved in water forming a strongly alkaline solution, the mass ratio of NaOH to H<sub>2</sub>O was 1:100, respectively the molar ratio Ca:S was 1.5:1. In the FGD unit, the flue gases get into direct contact with the selected aqueous solutions which are pumped to the scrubber with a flow rate of 2 l/h. Sulfur dioxide reacts with sodium hydroxide and forms a mixture of sodium sulfite (Na<sub>2</sub>SO<sub>3</sub>) and water. After that, sodium sulfite absorbs additionally sulfur dioxide, resulting in a chemical compound of sodium hydrogen sulfite (NaHSO<sub>3</sub>). It is important to note that, the solution of sodium hydroxide also reacts with other acid gases. For example, carbon dioxide reacts with aqueous sodium hydroxide to yield sodium carbonate (Na<sub>2</sub>CO<sub>3</sub>). In case of injecting calcium hydroxide as additive in the FGD, the solid calcium carbonate is formed finally. The absorption processes occur as follows:



After the removal of sulfur dioxide, the flue gas is sent to the CO<sub>2</sub> absorption unit. The CO<sub>2</sub> is removed from the flue gas by means of a chemical solvent. As a solvent, there was selected an aqueous solution of mono-ethanol-amine, with concentration ranging between 30 and 40 wt%. Flue gases with low sulfur content enter the CO<sub>2</sub> absorption tower and come into counter-flow contact with "lean" solution of MEA, which chemically absorbs the CO<sub>2</sub>-gas. The fundamental reaction between carbon dioxide, a weak acid, and mono-ethanol-amine, a weak base, is reversible under specific thermal conditions. Under these circumstances, if aqueous MEA is cooled to the temperature levels of 40-60 °C, then the chemical solvent retains the CO<sub>2</sub>. Opposite to this procedure, when the MEA is heated up to 120-140 °C, it releases the CO<sub>2</sub>-gas and the regeneration of the chemical solvent takes place.

The following chemical reactions take place when CO<sub>2</sub> is absorbed by MEA:



During the absorption process, the reactions proceed from left to right.

From the bottom of the column, the "rich" MEA solution, which contains the chemically bound CO<sub>2</sub>, is passed through a cooler. Afterward, it is pumped to the desorber where it is heated in counter flow up to 120-140 °C by the flue gas stream, in order to be able to release almost pure CO<sub>2</sub>.

During regeneration, the reactions proceed from right to left, thus CO<sub>2</sub> and H<sub>2</sub>O evolve separately from the amine solution. The captured CO<sub>2</sub> leaves through the top of the separation device (10). It is then compressed and stored. The "lean" solution of MEA, containing far less CO<sub>2</sub>, is cooled down to 40 °C in a cooler, and recycled back to the absorber, for further additional CO<sub>2</sub> capture and continuity of the global process. More details are given in [17].

#### 4.3. Results concerning CO<sub>2</sub> capture

The test have been organized in order to fit to general and minimal conditions, such as described by [18], [19].

Temperature behavior inside the combustor is shown in Figure 25. During operation the highest temperature received was 980 °C (for few seconds expecting higher NO<sub>x</sub>). No other major operational difficulties were observed during temperature variation. The decrease of the gas temperature was caused by the fuel feeding interruption.

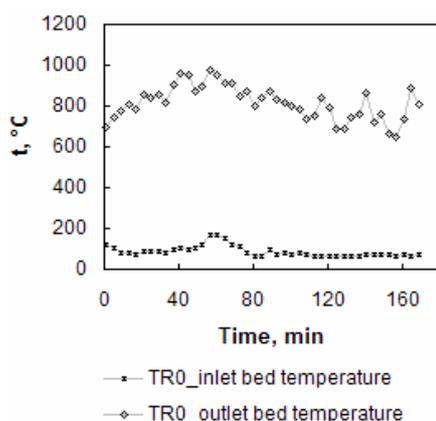


Fig. 25: Temperature profile inside the combustor

Figure 26 shows the concentration of SO<sub>2</sub> in the flue gas before and after the scrubber, using a strong alkaline solution of 1 wt % and 2 wt % NaOH. After leaving the scrubber the

concentration of SO<sub>2</sub> was in the range of 50-75 ppm.

CO<sub>2</sub> absorption into 35 wt % MEA was relatively good with an overall absorption efficiency of 66 %.

It should be taken into account that the acceptable concentrations' levels of SO<sub>2</sub> and NO<sub>x</sub> in the flue gas before the absorber are recommended to be in the range from 10 to 50 ppm, as described by Metz and al. (2002).

Using a 2 wt % NaOH concentrated solution it was possible to achieve 50 ppm of SO<sub>2</sub>. But in case if NO<sub>x</sub> are not controlled the ability of the MEA solvent to capture more CO<sub>2</sub> decreases. During operation one measured as well high NO<sub>x</sub>, 280-340 ppm. Figures 27 and 28 depict the efficiency of the CO<sub>2</sub> removal process, ranging from 66 % up to 91 %. One notes the synergy influence of the SO<sub>2</sub> presence on the quality and efficiency of the MEA and entire process.

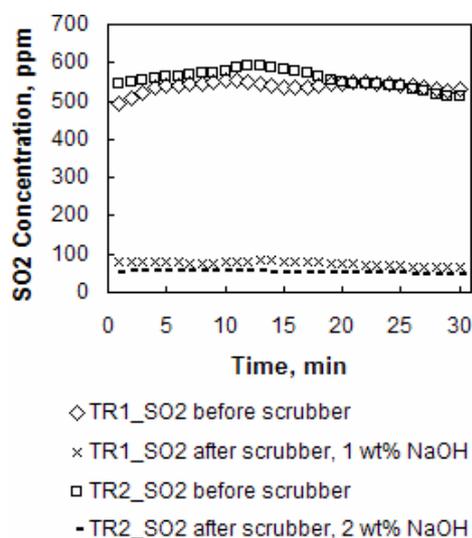


Fig. 26: SO<sub>2</sub> concentration profiles (TR1: 1 wt % NaOH, pH=13; TR2: 2 wt % NaOH, pH=13.3)

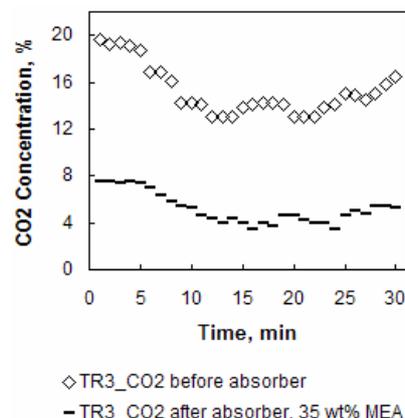
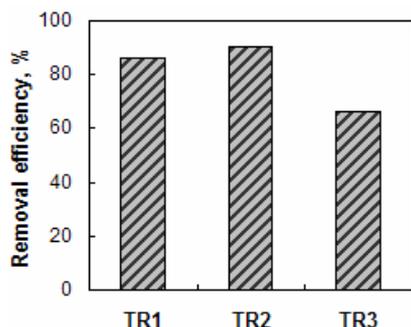


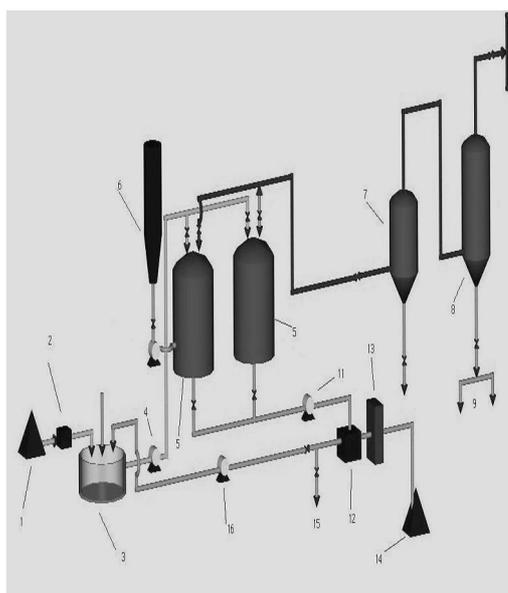
Fig. 27: CO<sub>2</sub> concentration profiles (TR3: 35 wt % MEA, pH=10.7)



**Fig. 28:** SO<sub>2</sub> and CO<sub>2</sub> removal efficiency (TR1: 86 %, 1 wt % NaOH; TR2: 91 %, 2 wt% NaOH; TR3: 66 %, 35 wt % MEA)

## 5. GENERAL INFORMATION REGARDING THE BIOGASS PRODUCING INSTALLATION

In the followings one will shortly present the schematics for the biogas producing installation using waste biomass (sawdust see Figure 32) as initial source, as well. The biogas resulted was used in order to sustain the fluidized bed combustor of the main pilot, as described in paragraph 2.



**Fig. 29:** General schematics for the biogas producing installation using biomass: 1. biomass deposit; 2. mill; 3. tank for the preparation of the biomass suspension; 5. anaerobic fermentation reactor(containing the heating system); 6. tank for the correction agent for the pH; 7. retaining filter; 8. CO<sub>2</sub> absorber and pump; 9.CO<sub>2</sub> desorber and compressor; 10. feeding system of the biogas; 11. pump for the evacuation of the used material; 12. compost filter; 13. compost drier; 14. tank for compost; 15. liquid evacuation; 16. pump for the recirculation material

The concentration in methane obtained in the resulted biogas generated by the installation reached 60 – 65 % by volume. The rest is CO<sub>2</sub>, H<sub>2</sub>S, small

quantities of particulates, CO and O<sub>2</sub>. Literature indicates similar results [19], [20].



**Fig. 30:** Front view of the biogas installation



**Fig. 31:** Saw dust used as biomass in the installation

*The hydrolysis reactor* has a cylindrical shape. It's made of steel and has a cover on it's upper part on which it's installed the agitator.

*The fermentation reactors* have on their upper parts a connection for feeding the biomass and evacuation of the biogas, for feeding the additives, and for measuring the pressure and the pH. *The heating system* is composed mainly from a boiler made for an installation having a calorific value of 18KW/h., enough for heating the biomass at a temperature of 35 - 40°C, and maintaining it there. The temperature inside the reactor will be fixed trough an automatic system which will command the gas flow of the burner. The purification and the processing of the biogas will be realized trough a filter filled with steel material trough which the H<sub>2</sub>S will be eliminated. After the filtering process, a part of the CO<sub>2</sub> is eliminated trough another filter with ceramic components that "washes" the gas of CO<sub>2</sub>. The electric installation will be relatively simple; it consists of an electric panel trough which the pumps of feeding and recirculation of biomass will be commanded.

## 6. GENERAL CONCLUSIONS VERSUS THE GLOBAL TECHNOLOGY PROPOSED

6.1. The biomass participation into combustion had a share of maximum 40 % mass in the mixture, meaning approx. max 25-30 % from the total thermal power input. The facility using fluidized bed combustion technology was adaptable to different sorts of biomass, by only taking sure that first a drying process and

a grinding suitable for fluidized bed combustion are accomplished.

- 6.2. In several important points the temperatures, pressure losses and flow capacities have been recorded on line during operation with the help of a data acquisition system. The temperatures at the combustion zone outlet are above 800 °C, thus, the not cooled walls must be made by a temperature resistant material. By introducing special additives to wash out the flue gases one obtained best retention of NO<sub>x</sub> and SO<sub>2</sub>.
- 6.3. In order to generate a total CO<sub>2</sub> lean global process by CO<sub>2</sub> absorption (through scrubbing with mono-methanol-amine MEA), the CO<sub>2</sub> emission might be also reduced and controlled, of course by paying the price for the supplementary technology. The higher the concentration of CO<sub>2</sub> in the flue gas, the faster it is absorbed by MEA.
- 6.4. One succeeded replacing natural gas used for warming up the fluidized bed by biogas produced from waste biomass, in an extension less than 60-65 % CH<sub>4</sub> by volume, and after the CO<sub>2</sub> capturing process, more than 70-80 %.
- 6.5. In conclusion, one generated a global lean CO<sub>2</sub> technology generating energy on basis of fossil fuel (coal) and biomass.

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