

## Reducing Pollutant Emissions by Integrating Flue Gas Treatment Systems into a Corn Coal Fired Coating Plant

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**Abstract:** *The European Union's 2020 greenhouse gas reduction targets bring solid biomass to the attention of specialists as one of the renewable energies on which Europe can rely. The technical potential for biomass use is about 8-10% of the primary energies in Europe. The amount of heat from the energy recovery of biomass, in Romania, has different weights in the balance of primary resources, depending on the type of waste used or the destination. The rational use of biomass involves knowledge of the physical-chemical characteristics and knowledge of the technological characteristics without which rational design and exploitation storage, transport and grinding would not be possible.*

**Keywords:** *Biomass, corn cobs, combustion, pilot plant, scrubber, reactor*

### 1. Introduction

The technical potential for biomass use is about 8-10% of the primary energies in Europe [2]. Some very large countries, such as China and India, have significant biomass potential and, as a result, its use for energy purposes would significantly relieve the national and global energy balance.

The amount of heat from the energy recovery of biomass in Romania has different weights in the balance of primary resources, depending on the type of waste used or the destination. Thus, 54% of the heat produced from biomass is obtained from the burning of forest residues or 89% of the heat required for the heating of the dwellings and the preparation of the food (rural area) is the result of the consumption of residues and vegetal waste.

Intensive cultivation of "energy plants" is not recommended because in this case chemical fertilizers are used in the manufacture of which indirect CO<sub>2</sub> is emitted. It is preferable to use biogenic resources and energy plants that develop naturally without the use of chemical fertilizers.

The main categories of biogenetic fuels (biomass) are: containing wood, containing straw, oil plants and animal biomass (sludge, slaughterhouse residues, etc.). While the straw-containing biomass has a cellulosic composition (C<sub>6</sub>H<sub>10</sub>O<sub>5</sub>), the biomass has a composition with a slightly increased carbon content (C H<sub>1,23</sub> O<sub>0,38</sub>), and the biomass with protein and oleaginous content has a low content of carbon, but has N and S in relatively high proportion compared to woody or perennial biomass.

Biomass can be used as fuel in the form of "pellets", which have the advantage of improving ignition and combustion stability [3]. The pelleting technology consists of pre-drying, grinding (if necessary) and then pressing with or without a binder. These, for example those made from wood waste (sawdust, chips, chips, etc.) in Germany, are in the form of small cylinders with a diameter of 6 mm and a length of 24 mm, having density  $\delta_{pel} = 650 \text{ kg / m}^3$ , the calorific power of about  $H = 5,0 \text{ kWh / kg} = 18 \text{ MJ / kg}$  at a moisture content of  $W_{pel} = 8\%$ . The production of pellets, which have a higher energy density than their biomass, contributes to the reduction of transportation and storage costs.

### 2. Potential of biomass as a renewable source

The rational use of biomass involves knowledge of the physical-chemical characteristics and knowledge of the technological characteristics (density, granulometric composition, sliding

capacity, mechanical strength, milling capacity, hardness, self-ignition tendency, etc.) without which rational design and exploitation storage, transport and grinding would not be possible.

Density for biomass can be in the form of real and apparent density, as the mass is related to the volume of fuel including or exclusively pore volume. Next to these two sizes is the density in the heap, which is the ratio between the mass of biomass and its gross volume. Gross volume refers to the volume of non-combustible fuel, including the volume of voids between pieces, grains or dust particles. Density in the heap depends on the type of biomass, its humidity, its granulation and its leaching. Its value is used for the sizing of bunkers or fuel silos.

Of great importance in choosing the burning mode, the type of grate and the biomass preparation machine is its granulometric composition, which indicates the distribution of their weight by size. The method for determining the granulometric composition is standardized and is based on the passage of a representative sample through horizontal screens made of standard mesh woven fabric.

The chemical elements that come into the biomass (in fact, any solid fuel) are: carbon (C), hydrogen (H), oxygen (O), nitrogen (N) and organic sulphur, humidity (W) and non-combustible mineral mass (which also includes sulphide sulphide) from which the ashes result. Mineral mass and humidity form the so - called "ballast" of fuel.

The elemental composition of a biomass sample, expressed as a percentage by mass, is reported under the following conditions [4], [5], [6], [7]:

- initial state:

$$C^i + H^i + O^i + N^i + S_c^i + A^i + W_t^i = 100 [\%] \quad (1)$$

- dry air condition:

$$C^u + H^u + O^u + N^u + S_c^u + A^u + W_h^u = 100 [\%] \quad (2)$$

- state of analysis:

$$C^a + H^a + O^a + N^a + S_c^a + A^a + W_a^a = 100 [\%] \quad (3)$$

- anhydrous state:

$$C^{anh} + H^{anh} + O^{anh} + N^{anh} + S_c^{anh} + A^{anh} = 100 [\%] \quad (4)$$

- fuel state:

$$C^{mc} + H^{mc} + O^{mc} + N^{mc} + S_c^{mc} = 100 [\%] \quad (5)$$

- organic state:

$$C^o + H^o + O^o + N^o + S_o^o = 100 [\%] \quad (6)$$

- total sulphur:

$$S_t = S_c + S_{SO_4} [\%] \quad (7)$$

The total moisture content of the biomass composition is divided into humidity and hygroscopic humidity.

Humidity or external moisture  $W_i$  represents the amount of water lost by drying in the oven at 50°C for about 3 hours or at room temperature of 20°C for about 24 h to a practically constant weight. If the mass of the initial sample is  $m$  [kg], and after drying it reaches  $m_1$  [kg], the moisture content is given by:

$$W_i^i = \frac{m - m_1}{m} 100 [\%] \quad (8)$$

Humus hygroscopic or internal ( $W_h^u$ ) moisture originates from the water found in plant capillaries and cells (biomass).  $W_h^u$  is determined by drying in the oven at 105°C to practically constant weight. If  $m_1$  is the initial mass and  $m_2$  of the final mass, hygroscopic humidity results from the relationship:

$$W_h^u = \frac{m_1 - m_2}{m_1} 100[\%] \quad (9)$$

If the dry state of the air coincides with the state of analysis, then obviously  $W_h^a = W_a^a$ .

### 3. Biomass preparation and combustion concept

Generally, biomass, due to its properties, falls into the category of solid fuels with medium calorific value, low ash content and high moisture content. As a result, it can be burned in installations used to burn coal, especially the lower ones, with some constructive and functional adaptations.

Due to the low energy density of biomass compared to conventional fuel, it is desirable to use it at the place of production or in small installations, with long-distance transport being economically inefficient.

Ash deposition on heat exchange surfaces when biomass is burned can occur to a greater or lesser extent than coal combustion. When combustion of the biomass and coal mixture, ash deposition occurs to a lesser extent than the combustion of only one of the fuels. The adherence and hardness of biomass burning deposits are higher than those encountered during coal combustion.

For these reasons it is recommended to co-incinerate biomass together with a fossil fuel. The participation of biomass in energy plants where it is burnt together with coal can reach up to 20% of the nominal power of the energy group.

There are three situations of co-incineration of biomass with a fossil fuel:

- 1) Combustion in the same furnace [8], [9], [10], [11], [12], [13], [14] when the resulting combustion gases cede the heat of a working fluid (usually water) which turns into steam, in turn being released into a turbine that drives an electric generator or is used for district heating. This process is used in high-power power plants.
- 2) Combustion in different flames when the combustion gases mix after exiting the furnace, their energy being used as in the previous case. The advantage of this process lies in better combustion and safer operation;
- 3) Combustion in different installations operating in parallel, the electrical and / or thermal energy being supplied together. In this case the costs are higher than in the first two, but there is the possibility of simultaneous or consecutive use of the two installations depending on the energy demand (electrical or thermal).

As far as fuel preparation is concerned, they were milled with a knife mill after grinding of between 0 and 4 mm. The Fig.1 show the type of waste biomass analysed, before and after grinding.



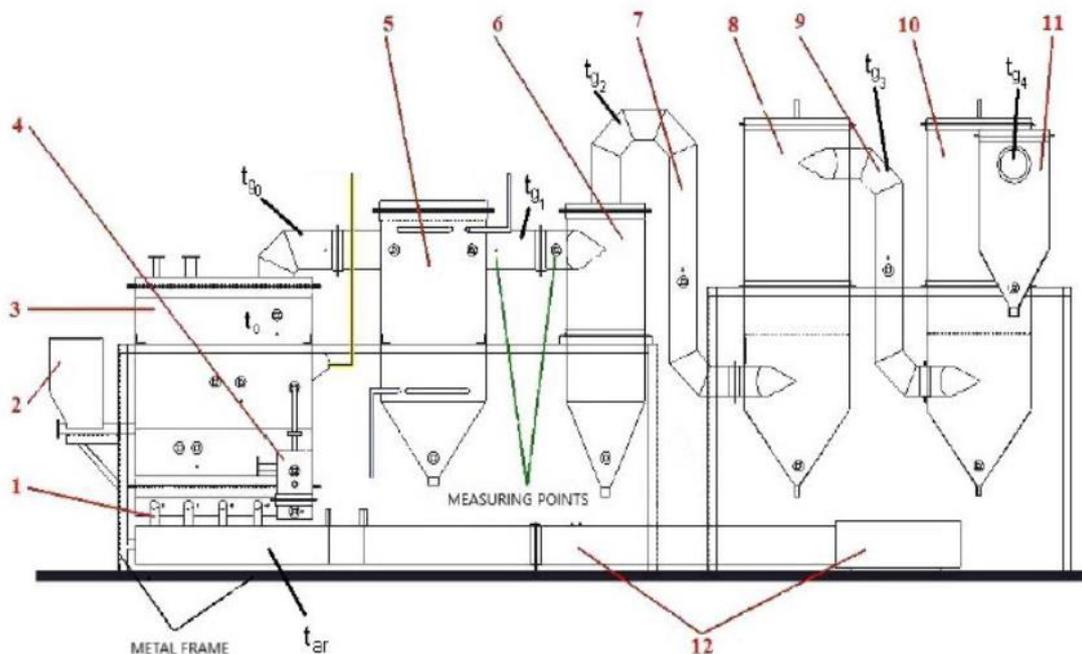
Fig. 1. Corn stalks forward (left) and after (right) grinding

Corn stumps, the waste biomass used to carry out the measurements, has a density of 337 kg/m<sup>3</sup>.

#### 4. Integration of the scrubber and reactor into the fluidized bed combustion plant

The pilot plant of the Multifunctional Laboratory of Thermal Machines and Unconventional Laboratories from U. P. Timișoara presented in Fig. 2 has the following components:

- stationary fluidized bed combustion of solid fuel particles (biomass, coal) equipped with a fluidised air distributor, an ash cooler, two solid fuel systems with adjustable speed springs, a natural gas burner a burner outlet, and a pressure measuring outlet;
- the convective body in which there are mounted coils of pipes through which the cooling water circulated with the circulation pump from a cooling tank;
- the cyclone in which it occurs most of the dust reduction from the combustion gases;
- the scrubber, which defines the process of degreasing the combustion gases by washing them with industrial water dispersed by means of a sprayer mounted on the top cover;



Scrubber



Reactor

**Fig. 2.** Pilot Station Principal Scheme

- 1 - Air distributor, 2 - Fuel hopper, 3 - Fireplace, 4 - Cooler, 5 - Convective body, 6 - Cyclone, 7 - Cyclone-scrubber connection, 8 - Scrubber, 9 - Scrubber reactor connection, 10 - Reactor, 11 - Drop separator, 12 - Air supply system, 13 - Smoke chimney connection

- a reactor with a 100 mm thick bottom layer of glass Rasching rings, permanently wetted with a water solution having, where appropriate, a certain concentration of the active substance for desulphurisation of the flue gases such as calcium hydroxide  $\text{Ca}(\text{OH})_2$  or sodium hydroxide;
- the separator of droplets trapped by the waste gas stream upon leaving the reactor;
- the chimney with a height of 15 m and a diameter of 150 mm.

Where:

$t_{ar}$  - the temperature of the air introduced into the furnace;

$t_0 = t_{g0}$  - the temperature of the combustion gases when leaving the furnace [ $^{\circ}\text{C}$ ]:

- at the out of the furnace:  $t_0 = t_{g0} = 900\text{ }^{\circ}\text{C}$ ;
- the temperature of the combustion gases when leaving the convective body:  $t_{g1} = 300\text{ }^{\circ}\text{C}$ ;
- the temperature of the flue gases at the cyclone outlet:  $t_{g2} = 290\text{ }^{\circ}\text{C}$ ;
- the temperature of the flue gases at the outlet of the scrubber:  $t_{g3} = 90\text{ }^{\circ}\text{C}$ ;
- the temperature of the combustion gases at the reactor outlet:  $t_{g4} = 70\text{ }^{\circ}\text{C}$ ;
- the temperature of the flue gases to the chimney:  $t_{gc} = t_{g4} = 70\text{ }^{\circ}\text{C}$ .

Determination of the composition of the combustion gases is made in three points: before and after the scrubber, respectively after the reactor. For this purpose, three TESTO 300 gas analysers are used to determine the volumetric or mass content (as adjusted) of the components ( $\text{O}_2$ ,  $\text{CO}$ ,  $\text{NO}$ ,  $\text{NO}_x$ ,  $\text{SO}_2$ ,  $\text{CO}_2$ ) in the dry combustion gases. The concentration of dust in the flue gases is determined using the Ströhlein STE 4. The construction and operation of these measuring devices are presented in [15], [16].

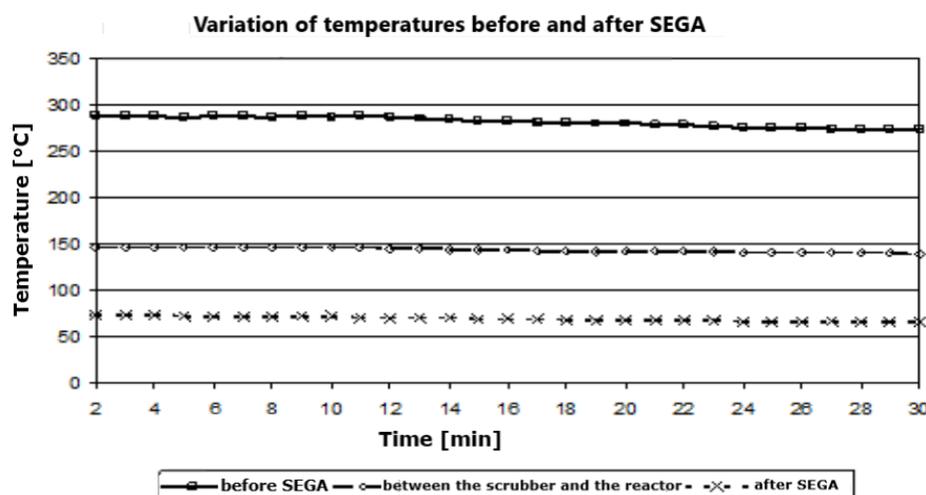
## 5. Experimental results and conclusions on pollutant emissions before and after the integration of exhaust gas cleaning elements in the pilot plant

Experimental measurements were made using corn cob biomass. The sampling and determination of the concentration of noxes from combustion gases, resulting from the burning of corn cobs, was carried out using the TESTO 300XXL gas analyser.

For the type of fuel used, in terms of gas emissions, measurements were made at three distinct points, namely:

- before the flue gas treatment system (ante SEGA);
- between the scrubber and the reactor (intermediate point);
- after the flue gas treatment system (post SEGA).

The results were recorded for a period of 30 minutes, in every minute, from the moment the plant has entered the stationary thermal operating regime. The measurements obtained for the fuel used are shown in Fig. 3. Only the variations for temperature, carbon monoxide, nitrogen oxides and sulphur dioxide are considered to be the most representative [1].



**Fig. 3. a.** Temperature variation before and after SEGA to burning corn cobs

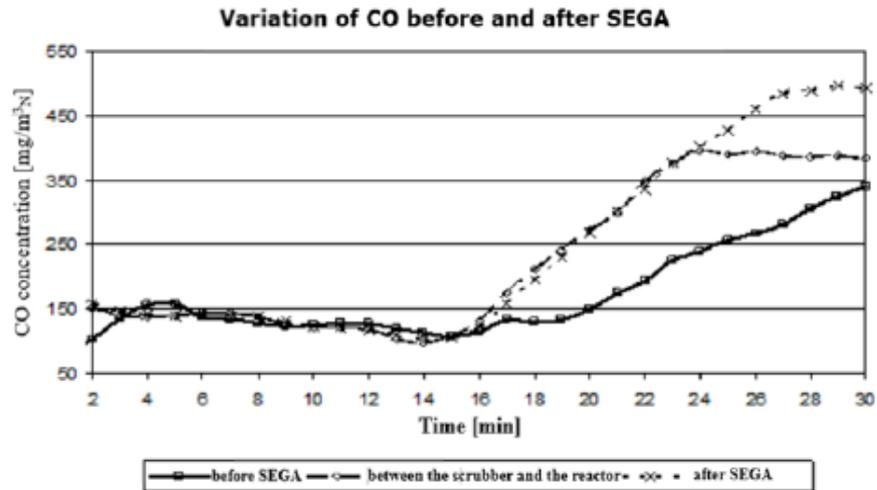


Fig. 3. b. Variation of CO before and after SEGA to burning corn cobs

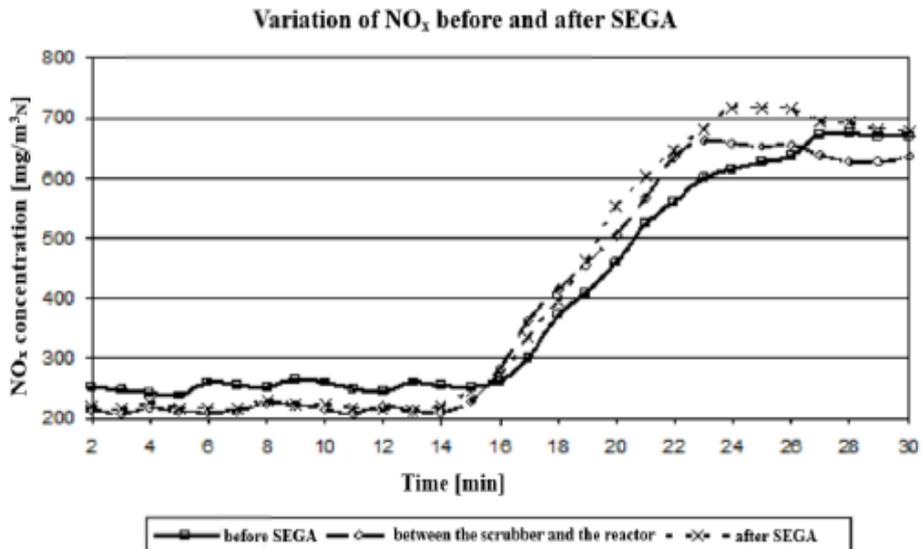


Fig. 3. c. Variation of NO<sub>x</sub> before and after SEGA to burning corn cobs

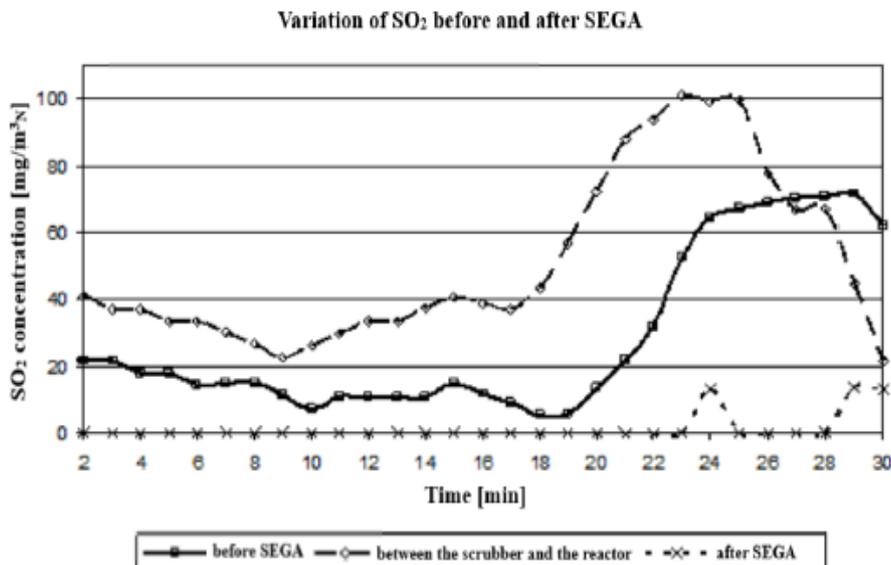


Fig. 3. d. Variation of SO<sub>2</sub> before and after SEGA to burning corn cobs

Current legislation does not provide for limit values related to 11% of reference oxygen for pollutant emissions from combustion gases from combustion of waste biomass, which is why the data obtained from the combustion of waste biomass from corn cobs could not be compared to fixed values.

For corn cobs the CO concentration values are higher, the temperature conditions (760 - 920) °C and the excess air coefficient (1.6 - 2.25) recommended by the literature are not met in the combustion zone.

The reported average values for corn cobs of NO<sub>x</sub> concentrations are between 94.94 and 72.37 [mg/m<sup>3</sup><sub>N</sub>] and for SO<sub>2</sub> between 4.40 and 0.10 [mg/m<sup>3</sup><sub>N</sub>].

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