Methodology for the calculation of LCOE (Levelized Cost of Electricity) for electricity produced by combustion technology of biomass.

MSC.ING.ADI SHAMKU[1]; PROF.DR.ING.ANDONAQ LONDO[2]; PROF.AS.DR.ING.MAJLINDA ALCANI[3]

[1]Author / Agriculture University of Tirana ; Ph.D candidate

[2] Co author; Polytechnic University of Tirana / Sheshi " Nene Tereza " No.4 Tirana-Albania

[3] Co author; Polytechnic University of Tirana / Sheshi " Nene Tereza " No.4 Tirana-Albania

**Corresponding author; E-mail: shamkua@yahoo.it*

Abstract

Biomass waste management systems with low environmental impact, which are able to protect the health and safety of inhabitants , are now gaining global attention. There is currently an increasing interest in new renewable energy generation methods, where its production from biomass is constantly growing. Burning or incineration is a known method for disposal of biomass residues. One of the main objectives of the National Energy Strategy for 2018-2030 for Albania is to provide incentives for implementing the necessary climate change policies, such as achieving renewable energy (RES) and efficiency energy targets and reduce negative environmental impacts. The article presents a methodology on the biomass energy assessment and the determination of the electricity price produced by biomass.

Keywords: *Biomass, electrical energy, renewable energy source.*

1. Introduction

Problem Spreading

According to the IRENA, the energetic sources consumption today has surpassed 12 billion TOEs, mainly compound of fossil's burning fuels of 15 billion tons of carbon, oil and natural gas. [1], [2], [3]

The Interest in the usage of renewable energies has increased significantly during the latest years, mainly as a response to the concerns related with the impact at the environment during the usage of fossil's burning fuels and nuclear subjects.

Many of the renewable energies originate from the *solar radiation*, including the direct usage of solar energy for heating and electricity generation and indirect forms such like *wind energy, waves, running water*, and energy obtained from *herbals* and *animals*. This category of renewable energy is present mainly in the "Third World", where it provides about 40% of the energy needs. Enerrgy from wastes is often considered under the title *of biomass* as much as paper wastes, food wastes and sewages (black waters).

Among to a number of advantages, the biomass gives interest especially on its great energetic potential. The biomass characterizes a very broad term to describe a large range of organic matters, including fertilizers, wastes, and herbals for energy. Any kind of organic matters (subjects) can theoretically be used as raw material for an electric power plant supplied by the biomass.

The technical processes to generate energy from the biomass are diverse. Direct burn of biomass is the earliest electric power transformation process used by humanity. Today, the modern systems for the burning of herbal matters are as diverse as these latest ones themselves, being classified in sizes from the small boilers designed to save fuel and up to the large boilers with heating output in many megawatts.

The qualities of fuels, play an important role at the combustion and gasification process. The content of fuel moisture is an important parameter. The energy required for water vaporization must be provided within the gasification or combustion reactor. Therefore, the distribution of temperatures and as a result, the mode of fuel conversion and reactor efficiency affects directly. If a pre-drying of fuel is required, then a pre-treatment and extra drying power is required, which is directly reflected in the total cost increase.

The content of ash and its composition should be taken into account in terms of thermal conversion processes. The energy that the ash carries out to feed the reactor, which is inevitable, must be beard in mind, as well as the fact that the ash must be removed continuously from the reactor. The composition of ash in interaction with the gaseous phase (oxidizing or reducing conditions) is responsible for the behavior of ash melting and as result consequently causes problems during the usage, such as crushing and contamination. Particularly in “fluidized bed” technology, melting and smoothing temperatures are important parameters [4]; [5]

Therefore the recognition of the relationship between the temperature and the quantity of vapored matter released is important for the final design of the process.

The calorific power of the fuel sets out the capacity of the plant. The heating capacity of the fuel is a decisive parameter (determinant) for the detailed design (projection) of the reactor. The specific conditions of reactor and plant performance conditions are at most related with the calorific power of the fuel used. However, the calorific value of the raw material depends on the moisture content and the ash content. Unstable (vaporable) matter during pyrolysis is the most important feature of the design of construction, as well as for processes such as the new multi-phase process of gasification, which is undergoing a major development nowadays.

2. MATERIALS AND METHODS

The Energetic Situation in Albania

2.1 Primary Energy Consumption

Modern societies and especially the industrial ones are already fully dependent from the great usage of energy, mostly in the form of fossil fuels, in almost all aspects of life. Future energy supply is a concern for all states. Interaction of security probabilities that is cost, technology and sources, constrains the demand (consumers’ preferences, population, incomes and technology) and forms the energy’s usage and fuel combustion for each country (Edmonds, 1985).

In Europe, the primary energy consumption in 2020 can be estimated at about 4.4 EJ.

Generally, the world has an increase in energy consumption thanks to population and economic growth in developing countries.

Over the past few decades, the oil has been the main source of primary energy consumption in the world and is expects to remain in these positions during the period between 2001 and 2025. Though industrialized countries continue to consume most of the world's oil products, the gap is expected to narrow significantly in the planned period. Almost 55% of the coal consumed extensively is used for energy production and its role is expected to decline due to its negative impact into the environment. According to International Energy Outlook (EIA, 2003), fossil fuels will have a crucial role in primary energy consumption by at least up to the year 2025. However, an increase in the use of renewable energy for energy production is expected, not for dominated the energy market but if we consider that they are very favorable in the environment and some of them, such as biomass, are the main fuels in different states, then a change of situation is expected.

2.2 Energy situation in Albania

At present, Albania has an energy production and consumption structure mainly dependent on oil and electricity. For the time being discussed, oil and electricity consumption covers over 80% of all energy sources, while the gas consumption covers about 1-2%.

Albania has a great hydro-power potential, of which only 35% are used. Furthermore, Albania has a sensitive potential of hydrocarbons (oil and gas) as well as large coal reserves, which is of low calorific power.

Coal is one of the most important energy sources in Albania, but most of the sources are coal-brown or low-quality lignite, high-sulfur and very hi-humid. From a historical peak of 3.3 MTOE (Mega Ton Oil Equivalent) in 1989, the main energy sources fell to 2 Mtoe (almost 40%) during the period 1990 and 1992. Since 1992, these sources remained constant at the level of 2.2-2.3 Mtoe. Coal consumption has dropped from 2 Mt (0.5 MTOE) or 19% of primary energy supplied in 1990 to 2075 ktoe or 4% of this value in 1995.

Gas production decreased from 200-250 Mm3 / year to 1989-90 to 20-25 Mm3 in the following years, mainly due to investment shortages to keep production levels. Oil and gas production declined rapidly from the level of 1 Mt of diesel and 200 Mm3 of gas in 1990 to 600 kt diesel and less than 100 Mm^3 (100,000 toe) gas in 1992.

2.3 Renewable Energies in Albania

About 95% of Albania's electricity is produced from the hydric energy which is considered Renewable Energy (E.R. in Albanian language). Renewable energies and especially solar energy are of great importance thanks to the favorable position of the climate that our country has.

Albania has a relatively large biomass potential that can be used as a source of energy. Of particular importance are forest debris, straw, agricultural waste, organic wastes from homes (sewage, plant waste) as well as urban wastes.

At present, urban wastes do not have any thermal treatment and if this would have been accomplished then the problem of their removal, which is known to be a troubling problem, would be solved. This is important in terms of energy and environmental pollution because it is currently impossible to bury all those wastes.

A significant source of renewable energies in our country is also the wind energy.

2.4 Energy Potentials of Biomass in Albania

Tab.1 is given the energy potential of biomass in Albania. (AAE)

Biomass	Theoretical potential (ktoe)	National energy balance (%)	Technica Potentials (ktoe)	National balance (%)	Technical electricity potential (ktoe)	Theoretical potential in the national energy balance (%)	Possible potential future economic potential (ktoe)
Forests (woods)	263.6	1.07%	234.4	0.95%	70.3	1.07%	315.1
Sub-products from agriculture	1521.1	6.17%	979.8	3.97%	293.9	4.45%	1316.8
Urban Wastes	1576.4	6.39%	1276	5.18%	382.8	5.80%	1446.6
Trees (woods) Wastes	168.1	0.68%	142.9	0.58%	42.9	0.65%	207.5
Cattles (Herds, Flocks) Wastes	585.25	2.37%	521.6	2.12%	156.50	2.37%	701.5
Energetic plants (vegetable)	62.34	0.25%	57.1	0.232%	17.13	0.260%	76.72
TOTAL	4176	16.9%	3212	13.0%	963.6	14.6%	4064.2

In another study by the Austrian Energy Agency in 2010, high forests cover about 47-50% of total biomass resources. The bushes represent 29-30% of the biomass wood reserves. The table below presents an estimate of the forest area in Albania presented by the National Agency of Natural Resources (AKBN).

In our country, where roughly one third of the territory is occupied by bushes and forest trees, there are about 3200 species of plants and trees. Of these 29% are part of the European flora, so are known in the EU, and about 47% of them are flora which is also found in the Balkan region.

The biomass as a source of energy is widely associated with forest wastes, agricultural wastes, various agricultural processes, animal wastes and, ultimately, but not by importance and potential, are the urban wastes. The contribution of biomass to the primary energy supply in our country is in the level of 6250 GWh where the main place at it occupies the timber from the forests. It is claimed that the contribution of biomass to this prism is even greater.

Biomass consists mainly of these four sources:

- Wastes from agricultural products;
- Wastes from forest products and its industry;
- Animal wastes;
- Urban wastes.

According to an assessment by the Ministry of Agriculture, the land in our country is made up of: Arable land 24%, Forests 36%, Pastures 15%, other 25%. As it can be seen, our country has a limited potential for utilizing the yield of the Arable land compared to the neighboring (Balkan's) and EU countries.

According to a study conducted by the Ministry of Agriculture in the field of renewable energies and concretely in evaluating the potential of biomass in our country, it is concluded that, the biomass represents a considerable source which is not yet fully exploited.

Our country has a stable annual output of about 4.8 million tons of dry biomass, given this for 2005. We may consider that this figure is slightly higher on today. Animal wastes contribute by about 49% at the total biomass in the country, while agricultural wastes by about 25%, forest wastes by about 19% and urban waste by around 7%.

Albania has approved a friendly policy with regard to renewable energy sources, including the biomass too. In the districts taken into consideration, at the first place for wood surface is Korca with around 54,000 ha forests and shrubs (bushes). In the second place is Tirana with 48,000 ha of forests and then Kolonja with 35,000 ha of forests.

2.5.Calorific power

The biomass suitability for energy purposes is based on the inherent energy of the elementary components, the density and the moisture content of the material as well. [6]

A common measure of energy in fuel is the combustion heat, which is a measurement of energy released by a measurement unit during full combustion (oxidation). The wood consists mainly of cellulose, hemi-cellulose and lignite (brown coal). The table 2 below gives typical values of the high combustion heat of these components.

Tab.2 Heat of combustion of wood components. (Saez, 1998; Sipila, 1998).

Components	**Value (MJ/kg)**
Cellulose/Hemi-cellulose	17.30
Lignite (Brown Coal)	26.60
Ether Extracts	32.2-35.5
Wood	19.3-19.4
Barks	21.4-23.9

The internal heat of wood burning is influenced by these ingredients. The volatile extracts have about double the value of heat than the cellulose and hemi-cellulose; so we can say that the volatile extracts have a major effect at the heat of combustion of wood especially when they are in great percentage [4]; [5]. The materials with high burning heat and low ash content have an almost perfect burn.

The heat values shown in the diagram are the high combustion heat which have a measurement difference compared with the low combustion heat. As it can be seen in the diagram, it is understood that the natural gas has the highest combustion heat and even higher then oil. However, the idea is that these values were compared with other fuel-like woods where its combustion heat is estimated at about 28 MJ / kg and this value is about twice as large as that of straw. (Sipila, 1998)

3. Results and Discussion

3.1 The energy earned from burning the remains of the sage

The net energy output from sage burning is calculated using the following formula:

$E_{net} = E_{tot.sage\ entry/year} - E_{sage\ drying\ /year}$ (kJ /year)

Where:

E_{net} - The net energy produced by sage burning (kJ / year)

$E_{tot.sage\ entry/year}$ - Total annual energy released from sage burning (kJ / year)

$E_{sage\ drying\ /year}$ - Energy required for drying the sage during burning (kJ / year).

$E_{tot.sage\ entry/year}$ - calculated using the following formula:

$$E_{tot.sage\ entry/year} = m\ (kg/\ \text{year}) \times Q_u^p\ (kj/kg) \qquad \text{(kJ/year)}$$

m - the mass amount of the sage / year pertaining to the combustion process (kg /year).

$\boldsymbol{Q_u^p}$ - Low calorific power of the sage (kJ/kg).

The energy required for drying the sage is calculated by the amount of required energy to raise the water temperature present in the sage from the initial temperature up to the evaporation temperature of 100°C and the energy required to completely evaporate this amount of water in the sera at 100°C, or evaporation heat.

$E_{sage\ drying\ /year}$ can be calculated by the expression:

$E_{sage\ drying\ /year} = Q_l + Q_{evaporation}$ (kJ/year)

$Q_l = m_{water} \times Cp \times \Delta T$ (kJ/year)

$Q_{evaporation} = m_{water} \times r_{av}$ (kJ/year)

Q_l - The heat required to increase the water temperature present in the sage from

the ambient temperature, assumed at 25°C to 100°C,

m_{water} - Water mass in kg

$$\mathbf{m_{water}} = m_{sage} \times \text{ the moisture content in the sage}$$

$$\mathbf{m_{water}} = 500{,}000\ \text{kg/year} \times 0.1 = 50\ 000\ (\text{kg/year})$$

$\mathbf{C_p}$ - Specific water heat, equal to: $C_p = 4.1868$ (kJ/kg°C)

ΔT- It is the temperature change, equal to: $\Delta T = (100 - 25) = 75$ (°C)

r_{ev} - Latent water heat, equal to: $r_{ev} = 2445$ (kJ/kg)

Replacing the corresponding values in the formulas above we get:

$$E_{tot.sage\ entry/year} = m\ (kg/year) \times Q_u^p\ (kj/kg) = 500{,}000 \times 9000 = 45 \times 10^8 (kJ/year)$$

$E_{sage\ drying\ /year} = Q_l + Q_{evaporation} = (m_{water} \times Cp \times \Delta T) + (m_{water} \times r_{ev}) =$

$= (50\ 000 \times 4.1868 \times 75) + (50\ 000 \times 2445) = 1.6 \times 10^7 + 12.2 \times 10^7 = 13.8 \times 10^7$ (kJ/year)

$$E_{net} = E_{tot.sage\ entry/year} - E_{sage\ drying\ /year} = 45 \times 10^8\ (kJ/vit) - 13.8 \times 10^7\ (kJ/\ year)$$

$$= 43.6 \times 10^7\ (kJ/\ year)$$

Net Power in Entrance (kJ/sek = kW) = *[Net Energy in Entrance* (kJ/year) *] / [(7500 (hrs/year)) × (3600 (sek/year))]* = $43.6 \times 10^7 / 7500 \times 3600 = 16.9$ kW

The output power produced in the Electrical Energy form, for the Proposed Rendiment 24% :

$$N_e = N_{net\ in\ entrance} \times \text{ Rendiment of the Electrical Energy production } (\boldsymbol{\eta_e})$$

$$N_e = N_{net\ in\ entrance} \times \eta_e = 16.9\ kW \times 0.24 = 4056\ kW \text{ or } 4.056\ MW$$

3.2 Costs for energy production

The plants' costs for the Sage burn are commonly compound from the:

1) Investment Costs, I (USD);

2) Operation and Maintenance Costs, $C_{O\&M}$ (USD /year)

a. We calculate the investment costs, I (in USD):

Accordingthe IRENA: *The total installed costs of biomass power generation technologies varies significantly by technology and country.*

Thus, as per this study:

$$I = (4260\ USD/kW) \times 4056\ kW = 17.278560 \text{ Million USD/year.}$$

b. We calculate costs of O&M (Million USD/year):

$C_{O\&M} = C_{fix\ (O\&M)} + C_{variable\ (O\&M)} = I \times (5\%/100) + (0.005\ USD/kWh) \times$ Produced Energy (kWh/year)

Produced Energy in a year = Net power × (7500 hrs/year) = 4056 (kW) × 7500 (hrs/year) = 30 420 000 (kWh/year)

$C_{O\&M}$= (17.278560 Million USD/year) × 0.05 +0.005/1,000,000 (USD/kWh) × (30 420 000 kWh/year)

$C_{O\&M}$= 0.863928 Million USD/year + 0.1521 Million USD/year =1.016028 Milion USD/year

3.3 Levelized Cost of Electricity **(LCOE)**

LCOE is calculated by applying the belowing formula:

$$LCOE = \frac{\sum_{t=1}^{n} \frac{I_t + C_{l.burn,t} + C_{O\&M,t}}{(1+r)^t}}{\sum_{t=1}^{n} \frac{E_t}{(1+r)^t}}$$

where:

I_t - is the investment cost in year t;

$C_{O\&M}$ - is the cost of operation and maintenance in year t;

$C_{l.burn,\ t}$ - is the cost of fuel in year t;

E_t - It is the electricity generated in year t;

r - It is the actualization rate;

n - It is the life span of the plant.

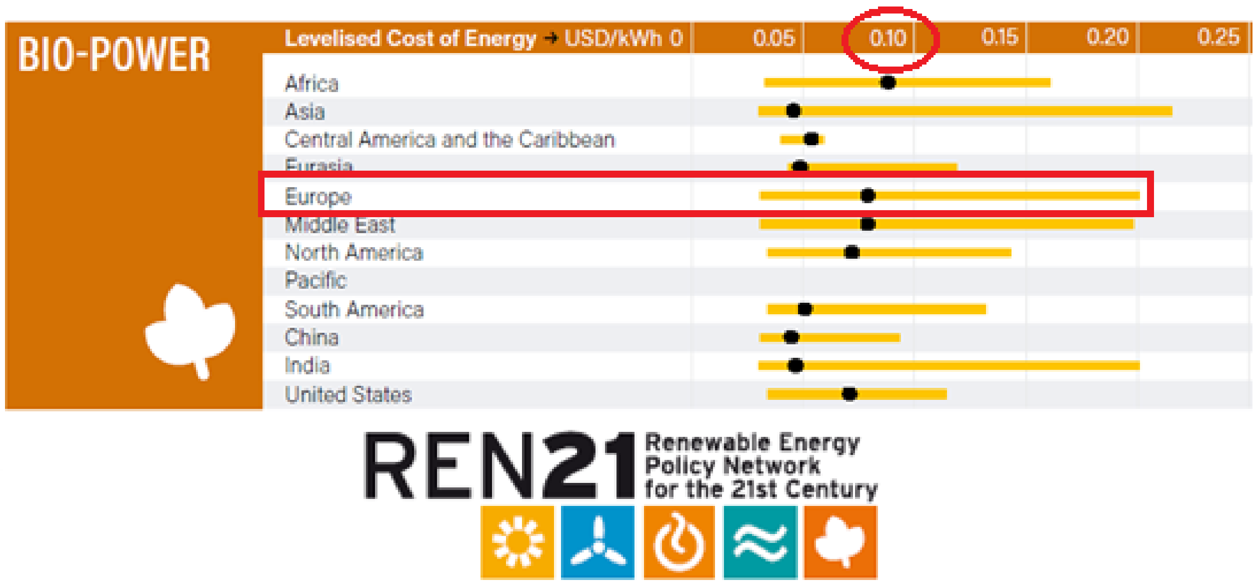
LCOE (USD/kWh) = 27,423,733 / 274,888,835 = 0.0997 (USD/kWh)

Tab. 3 The cost of energy produced from sage waste in kWh / year (LCOE)

Year	Initial Investment (Million USD)	Costs $C_{O\&M}$ Million USD/Year	Interest rate (10 %)	$1/(1+i)^n$ = $1/(1.1)^n$ per n = 0-20	Actual Costs (USD) $C_{O\&M}/(1.1)^n$	Produced Energy kWh/year	Energy $E/(1.1)^n$ kWh/year
0	17,278,560		0.1	1	17,278,560	0	0
1		1.016028	0.1	0.90909	923,661	30,420,000	30,420,000
2		1.016028	0.1	0.82644	839,692	30,420,000	27,654,545
3		1.016028	0.1	0.75131	763,356	30,420,000	25,140,495
4		1.016028	0.1	0.68301	693,960	30,420,000	22,854,996
5		1.016028	0.1	0.62059	630,873	30,420,000	20,777,269
6		1.016028	0.1	0.56445	573,521	30,420,000	18,888,426
7		1.016028	0.1	0.51315	521,383	30,420,000	17,171,296
8		1.016028	0.1	0.46656	473,984	30,420,000	15,610,269
9		1.016028	0.1	0.42413	430,895	30,420,000	14,191,154
10		1.016028	0.1	0.38552	391,723	30,420,000	12,901,049
11		1.016028	0.1	0.35054	356,111	30,420,000	11,728,226
12		1.016028	0.1	0.31861	323,737	30,420,000	10,662,024
13		1.016028	0.1	0.28970	294,307	30,420,000	9,692,749
14		1.016028	0.1	0.26335	267,552	30,420,000	8,811,590
15		1.016028	0.1	0.23948	243,229	30,420,000	8,010,536
16		1.016028	0.1	0.21763	221,118	30,420,000	7,282,306
17		1.016028	0.1	0.19782	201,018	30,420,000	6,620,278
18		1.016028	0.1	0.17981	182,741	30,420,000	6,018,434
19		1.016028	0.1	0.16359	166,1286	30,420,000	5,471,304
20		1.016028	0.1	0.14867	151,026	30,420,000	4,973,913
Total					**27,423,733**		**274,888,835**

Comparing the produced energy cost in kWh /year (LCOE) with the production value of energy taken fromm biomass energy measured in Europe, we can say that at the process the sage wastes from the Maminas (Durrës) Refining Factory, the cost for energy production LCOE (USD/ kWh) from the sage burn is at an acceptable and competitive value for the future in Albania.

Tab. 4 The cost of renewable energyfor thë 21st Century



4. Conclusions

1. Today the technologies that use biomass and wastes in the energy or heat production are of a particular interest. The Biomass has a number of environmental advantages compared with fossil fuels like: "the biomass utilization is a solution to reduce CO2 emission in atmosphere for the energy production".

2. The moisture content, as the main feature studied, shows different values for each material, where it can be easily see the high sage content (65% -80%). The impact of moisture content at the calorific power for sage biomass it is taken by us during the experiment carried out at the AlbKalustyan Maminas Factory (Durrës). Along the moisture content of 10% (which refers to moisture content in sage waste used for combustion), the calorific value is slightly below the limit of 8 MJ / kg, which can be estimated as the possible limit of the sole combustion of this biomass with the respective energy technologies.

3. Both of these impacts reduce the temperature in the combustion chamber under the permissible limit, which is necessary to ensure a continuing combustion.

4. From the point of view of the reduction of humidity from the biomass (sage), we conclude that: the energy drying presents as the only way suitable for its separated burning. The required drying rate we can reach either naturally, for example in wind conditions but it requires long time, or by forced drying which is a fast process, but energetically expensive (costly).

5. Also, through a technical-economic analysis of the energy production from the sage wastes burning at the AlbKalustyan Maminas (Durrës) Factory (plant), we can conclude that by comparing the cost of energy produced in kWh / year (LCOE) with the value of energy production from the biomass in Europe, we might say that from the burning of sage wastes taken at its processing plant, the cost of energy production (USD / kWh) from the burning of sage is an acceptable and competitive value in the future in our country (Albania).

5. References

1. Agency IE. International Energy Agency. Renewables for Albania; 2017, http://www.iea.org/.

2. Alexander, G.; "*Renewable Energy*", Power for a sustainable Future 1996, Oxford. ISBN 0 19-856452-X.

3. Karaj, Sh. & Rehl, T. & Leis, H. & Müller, J., 2010. "Analysis of biomass residues potential for electrical energy generation in Albania," Renewable and Sustainable Energy Reviews, Elsevier, vol. 14(1), pages 493-499, January.

4. Andre, R. N.; Pinto, F.; Franco, C.; Gulyurtlu, I.; Cabrata, I., "*Study of gasification technology to convert biomass and plastic wastes into an economical valuable gas*",1st World Conference on Biomass for Energy and Industry, Sevilla, Spain, 2000.

5. Baird, S.; Hayhoe, H.:"*Energy Fact Sheet*", Originally Published by the Energy Educators of Ontario, 1993. http://www.iclei.org/EFACTS/GLOBWARM.HTM

6. Chartier, Ph.; de Silguy,C.; Defaye, S.; Battais, L.: "*Perspectives for Biomass Energy in the European Union How a 200 % increase can be attained*" Agency for Environment and Energy Management, "Biomass for Energy and Industry" 10th European Conference and technology Exhibition, C.A.R.M.E.N 1998.

7. Hamel, S.: "*Mathematische Modellierung und experimentelle Untersuchung der Vergasung veschiedener fester Brennstoffe in atmosphärischen und druckaufgeladenen stationären Wirbelschichten*", Dissertation zur Erlangung des akademischen Grades DOKTOR-IGENIEUR, 2001; ISBN 3-18-346906-5.

8. M Milani, L Montorsi, M Stefani 2014 . An integrated approach to energy recovery from biomass and waste: Anaerobic digestion–gasification–water treatment . Waste Management & Research, vol. 32, 7: pp. 614-625

9. Bioenergy and Biofuel from Biowastes and Biomass. Samir K. Khanal; Rao Y. Surampalli; Tian C. Zhang; Buddhi P. Lamsal; R. D. Tyagi; and C. M. Kao.© 2010 American Society of Civil Engineers

10. Renewables 2016. Global Status report. REN21(renewable energy Policy Network for the 21 st Century. Marcet and industry trends . Biomass energy . pp 42

11. http://www.ere.gov.al/doc/ligj-nr.-7-dt.-2.2.2017-_RES.pdf. 2017. LAW No. 7/2017. The use of renewable energy in Albania