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Efficient pellet plant for various types of biomass

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Abstract

The aim of this research is to highlight the potential for using biomass as a renewable energy source. The results will point out the effects that new technologies offer, with showing efficient plant for pelleting of various types of biomass.

Goal is to show the principles of operation of most modern machinery and equipment in this field in the world, with clear indications on key points that need to be addressed when designing a plant and in calculating the cost of this type of production. Renewable energy provides an excellent opportunity and a chance for the development of enterprises in Serbia, and only systematic approach to the production is a precondition for successful performance in the domestic and foreign market, with huge potential for the level of competition.

Key words: *pelleting biomass, renewable energy, machinery and equipment plant design*

1. RENEWABLE ENERGY

Excessive use of fossil fuels has created a major imbalance in the amount of these resources in the future and how the amount of fossil fuels is approaching its end point, so will the price of it, grow rapidly. This is precisely the reason, for the emergence of a new movement in the 1970s, which relies on the use of renewable energy sources.

Clean energy is significant due to environmental standards, and we are all witnesses of negative impact of the effect "greenhouse" and "global warming", to the climate and the lives of people, which was created primarily due to the enormous carbon dioxide emissions in the Earth's atmosphere [1].

According to estimates, by 2050 renewable and clean energy should participate in the total energy from 50%, so that by 2100 the total energy requirement would be from renewable, alternative and clean energy sources [2].

The use of renewable, alternative, energy sources is a necessity today, only on the basis of two facts:

• Reserves of fossil and nuclear fuels are almost exhausted and on these fuels can no longer be counted further from 2090.

• Need to urgently reduce the use of fossil fuels due to excessive carbon dioxide emissions in the atmosphere and to reduce the incomprehensible negative climate change on Earth.

As sources of clean, and at the same time renewable energy, the following energy sources are considered:

• Sun energy
• Wind Energy
• Hydropower energy
• Geothermal energy
• Energy obtained from various forms of biomass [3].

Developed and rich countries have been planning and organizing significant preparations for the emerging new time, through the implementation of significant pilot projects and investing in commercial projects related to the use of alternative energy sources. Many of these developed countries in the European Union and America have found, that in the coming years, alternative energy sources will reach 35% of the country's total energy, although some Nordic countries are very close to achieving this already in 2017. Development plans are realized with significant state funding in the development of new technologies and in alternative energy sources. The financial participation of the states in these projects, on average, is around 30%, in the form of grants [4].

Many developed countries have almost already exhausted their energy potential in renewable sources, so they have directed their strategic projects in this area, to other countries, often underdeveloped countries that have such potentials.

The underdeveloped countries, which most often do not have the strategy of using their own alternative energy sources, in this way directly distort and weaken their economy in relation to the developed countries.

Financial stimulations have enabled developed countries to invest in underdeveloped countries that have raw materials, for example in biomass or biodiesel oilseeds, provided that the produced fuels are delivered to the investor at a certain price. Today, developed countries are solving their energy problems, by importing renewable energy in various forms from underdeveloped countries that do not have for example strategy for biomass and its use. Undeveloped countries continue to import oil, gas or electricity. Unfortunately, as a result of this, there is an even bigger gap in the economies, between underdeveloped countries and wealthy countries.

Today energy pellets are treated as energy fuels traded on stock exchanges and imported into developed countries where they are used in household heating or as a fuel in large power plants. Energy pellets are used as fuel in many modern and technically sophisticated energy systems.

Smaller furnaces and boilers for energy pellets are used in heating systems for residential, but also for many production facilities, such as: dryers, greenhouses etc. The use of pellets as fuel has numerous technological improvements and it is currently achieving comfort, as well as with natural gas or liquid fuel.

Scandinavian countries and some countries of Northern Europe are still relatively rich in forests today. At the same time, these are the countries where the awareness of the need for environmental protection is already being developed in every place. These moments led to the fact that these countries first came to the development and relativization of complex systems of valorization of low-value forest assortments and wood waste, formed in the wood and paper industry.

Wooden chips, sawdust, wood bark and wood pellets in these countries participate significantly, with a high percentage, which is up to 35% today, for example in Finland [5].

From the European countries in the south of Europe, the most significant step in the use of biomass as renewable energy was made by Italy [6].

Further work, will deal with alternative renewable energy sources, focusing on lignocellulosic residues (wood) and harvesting residues (straw), and their combination use, and conversion into energy fuel in the form of energy pellets.

2. BIOMASS PELLET PRODUCTION AND DESCRIPTION OF TECHNOLOGICAL PROCESS

Pellet production in Europe and North America was started as an idea, when the oil crisis happened in 1973 and 1979. Wood pellet attracted people's attention on that time as it had high quality and could be an alternative for oil. But as soon as the price of oil recovered, the price of wood pellet rose relatively and at the result of that, users of wood pellet were decreased, and wood pellet had not been produced so much. But wood pellet production has been prosperous again since 90's. Because some countries encouraged to use wood pellet through their policy (green tax, supporting introduction of equipment and public education, etc.) as countermeasures against global warming, energy security and rise of oil price, and it has proved good effect.

Even in case a government doesn't encourage, wood pellet's market is rapidly growing by its green image and advantage in price, and it can clearly be seen in the world trading of wood pellet fuel. At present, wood pellet fuel is in fierce price competition with natural gas in many countries. But the demand is steadily increasing because of its advantages such as environment concern, high quality and easiness to use.

First wood pellet production started in Sweden, with the decision to build a pellet plant in Mora. The plant started production in November 1982 and immediately ran into problems because costs were much higher than had been calculated. Equipment was developed for converting oil boilers to pellet-fired boilers. In practically all cases, however, they were highly inefficient, not least because of the poor pellet quality. During this first year the raw material was usually bark. Pellets often had an ash content of 2.5% to 17%. The plant in Mora was closed 1986. In 1984 a pellet plant was built in Vårgårda. The plant’s last owner was the Volvo group. It was closed in 1989. In 1987 the first plant for pelletizing dried material was built in Kil. It was designed for an output of 3,000 metric tons a year. This plant is still in operation and is the oldest commercial plant in Sweden. In the early 1990s the Swedish government came up with a proposal for taxation of mineral fuel. At this time it also limited carbon dioxide emissions. In a short time period the prospect of burning fossil fuels became unprofitable with biofuels stepping in to fill the energy void. This marked a turning point and the use of wood pellets started to grow rapidly [7].

Similarly ambitious clean energy programs emerged elsewhere in Europe. As a result, Europe leads the world in biomass pellet consumption to this day. The level of sophistication has risen on the continent to such an extent that manufactured pellets can be delivered in bulk via tanker trucks and deposited directly in residential storage areas, similar to the way gas stations are restocked with gasoline. In addition to residential heating, European power plants increasingly use biomass pellets to generate electricity as well as for energy in other industrial applications.

In the Netherlands, Belgium, and the UK, pellets are used mainly in large-scale power plants. In Denmark and Sweden, pellets are used in large-scale power plants, medium-scale district heating systems, and small-scale residential heat. In Germany, Austria, Italy, and France, pellets are used mostly for small-scale residential and industrial heat [8].

In Austria, the leading market for pellet central heating furnaces (relative to its population), it is estimated that 2/3 of all new domestic heating furnaces are pellet burners. In Italy, a large market for automatically fed pellet stoves has developed. Italy's main usage for pellets is small - scale private residential and industrial boilers for heating [9].

In 2014 in Germany the overall wood pellet consumption per year comprised 2,2 million tones. These pellets are consumed predominantly by residential small scale heating sector. The co-firing plants which use pellet sector for energy production are not widespread in the country. The largest amount of wood pellets is certified with DINplus and these are the pellets of the highest quality. As a rule, the pellets of lower quality are exported [10].

Some companies import European-made boilers. As of 2009, about 800,000 Americans were using wood pellets for heat. It is estimated that 2.33 million tons of wood pellets was used for heat in the US in 2013 [11]. The US wood pellet export to Europe grew from 1.24 million ton in 2006 to 7 million ton in 2012, but forests grew even more [12].

2.1 **Wood pellet production process**

The process of wood pelleting starts with the storage of wood and depends on the type, shape and granulation of wood. If it is a cellulose tree (wood logs) or it is a fire wood, both should be debarked before further processing, and for process od debarking it is advantage, if the wood logs are in the lengths of minimum 3 meters, which ensures greater productivity of the debark device.

Since the raw material has been debarked, it switches to the process of preparing the cutter - wood (wood chips) with a mill for wet grinding. The main goal of this preparation is to achieve granulation, optimal for the operation of the dryer. It is a particle size up to 15mm in length and 1.5mm in diameter. In the line there are devices for extracting foreign objects, which may have come into the material, such as stone, sand, metals etc.

After the crushing of raw materials and wet grinding, the material goes further to the drying line, where output moisture content is from 10-12%. There are several types of dryers used for the production of pellets, and most often they are rotary driers, belt driers and fluid-lift driers.

The dried material goes after drying into a process of fine, dry grinding, where all the granulation is on output below 4 mm, and then the material is ready for the pelleting process.

The pelletizing and cooling line itself is the heart of every pellet production plant and consists of:

• Dosing screw and conditioner for raw materials with the possibility of adding water or stem or binder.

• Pellet press.

• Pellet cooler and vibro screen.

• Aspiration system, which extracts fine dust in the pellet line, in order to ensure a reduced risk of explosion and dust fires and due to the EU environmental standards (dust emissions).

After pelleting and cooling, the pellet goes further to the packaging line.

Essentially, all wood pellet production lines work on the same principle (Figure 1). The material is crushed, milled and dried until granulation of raw material is below 4 mm and moisture content is from 10-12%, prior to the entrance to the pellet press where it is pelleted.

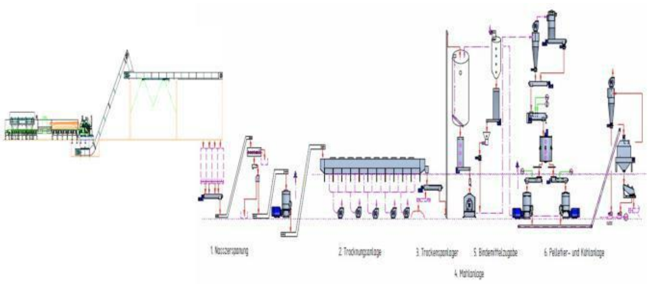

Figure 1. Technological scheme of the line for wood pelleting [13].

Due to the low densities of wood material (120-200 kg/m3), pelleting process is quite difficult, because pelleting represents a combination of sequential operations in which the biomass is compacted under high pressure. However, this problem is solved through densification at high pressures, resulting in the increase of bulk density, which reduces the technical limitation in feeding, storing, handling and transport processes [14], [15].

Final product pellets for domestic use have a diameter of 6-8 mm. For industrial use pellets have diameter of 10-12 mm, with length ranging from 5-40 mm. Total moisture of pellets is usually less than 10% by weight of the raw material [16].

Bulk density of wood pellets is approx. 550-650 kg/m3 so 5-6 times greater than the biomass from which they are made [17].

2.2 **Straw pellet production process**

Agricultural and grass straw have even lower bulk density than wood (80-150 kg/m3), and this type of material is also difficult for pelleting [18].

Raw material reception is the first technological process in the straw pellet process and begins with the delivery of straw bales. Bales should be square-shaped or roll-bales with a maximum moisture content of 15% in the bales, in order to have a successful further process and quality finished product.

After the reception, the bales are placed on the conveyor, which further leads them to the technological process of splitting and shredding, in order to break the straw into the granulations of 50 - 100 mm.

After the technological process of splitting and shredding, the chopped straw is further led to a technological line for the removal of impurities, with the goal of releasing material from rocks, and metals, which are often present in harvest residues. The present stones and metal are removed by means of grabbing stones in stone trap and metal by magnet. This avoids damage to the equipment in the further course of the technological process of pellet production.

Chopped straw continues on the technological line of grinding in hammer mill. In order to obtain high quality of finished pellets, it is necessary to additionally mill the precut straw to a size of 4-7 mm. Hammer mill has an integrated sieve with openings Ø 7-10 mm in order to fulfill conditions for further processing. With this process of milling, straw is suitable for the conditioning.

Conditioning is the technological process of treating straw with plain water, or a high temperature steam (90-100 ° C) in a conditioner in order to activate the lignin present in the straw.

After the conditioning process, material is further led to the pelleting line. Pelleting represents a technological process of compression, in which straw under pressure is treated by forming a pellet from it.

Straw pellets continue to run on the cooling line, with the aim of cooling at ambient temperatures around 25 ° C. In cooler pellets are placed on the belt and pellets are cooled by strong air currents.

After the technological process of cooling, the cooled pellets are further led to the line of screening, so that the finished whole pellets can free from fines, the small and broken pieces of pellets. At the output there is two fractions:

• First fraction is the whole pellets

• Second fraction is small and broken pieces of pellets

The finished whole pellets are going further on the packaging line, and the small and broken pieces of pellets are returned to the pelleting process again.

Essentially, all straw pellet production lines work on the same principle (Figure 2).

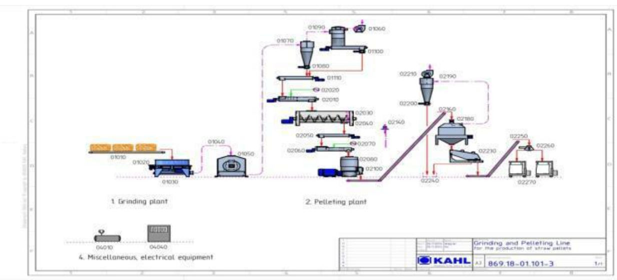

Figure 2. Technological scheme, pellet plants for a production of straw pellets [19].

3. COMBINE PELLET PLANT FOR VARIOUS TYPES OF BIOMASS

In order to maximize the customers profit and increase the degree of flexibility, more and more are being mentioned about combined pelletizing plants for various types of biomass (wood, harvest residues, Miscanthus Gigantheus, Paulownia etc.). The idea is that plant design allows the use of both input materials, wood logs, wood chips, wood residues and harvest residues on a single pelletizing plant line.

In order to successfully realize the concept of a combined plant, it is necessary to consider the technical feasibility, location of the plant, the reliability of the plant and analyze the sensitive points of this process.

For process of selecting a location, it is necessary to see where the plant would be installed, because there is noticeable increase in the cost of transporting raw materials and transport of pellets (Figure 3).

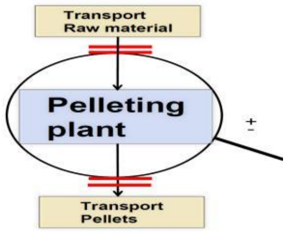

Figure 3. Defining the location of the plant

When it comes to delivering of wood to the pelletization plant, the location of the plant needs to be within the radius of the raw material source up to max. 80 kilometers. When it comes to transporting of straw bales (harvest residues) due to volume nature, the location of the plant is required to be within a radius of 50 km, in order to avoid high transport costs and therefore the cost of the input material [21] [22].

After defining the location of the plant, the next major point is defining the cost of production (Figure 4). It is clear from the picture that the price of the input material is the biggest impact in the production cost of pellets.

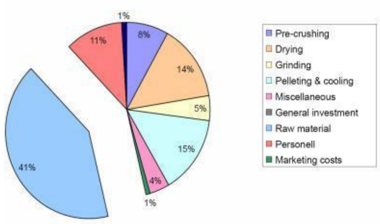

Figure 4. Production cost [20].

Combining different raw materials carries with it another risk, which is a change in the quality of pellets. At the selling price of pellets, one of the most important data determining the quality of pellets, and therefore its price, is the content of ash. In the wood logs, naturally there are many less non-combustible matter (ash) than in the straw from harvesting residues.

One of the reasons for this situation is that in season of harvesting, the baler is deliberately set to a lower level (in order to balance the larger mass), and in addition, the machine also purchases earth, sand and silicates in addition to straw. These materials eventually goes in to the pellet and these particles do not burn in the boiler and the ash occurs.

Today is the validly accepted ENplus certification scheme, which defines the quality of pellets in three classes (Table 1).

Based on classes of ISO 17225-2, the titles are as follows:

1. ENplus A1- can be achieved only from the debarked wood.

2. ENplus A2-can be achived from wood with bark.

3. ENplus B - is an industrial pellet and can be obtained from harvest residues, waste wood, waste saw dust wood with bark etc.

Table 1. Threshold values of the most important pellet parameters [23].

Property	Unit	ENplus A1	ENplus A2	ENplus B	Testing standard [11]
Diameter	mm	6 ± 1 or 8 ± 1			ISO 17829
Length	mm	3,15 < L ≤ 40 [4]			ISO 17829
Moisture	w-% [2]	≤ 10			ISO 18134
Ash	w-% [3]	≤ 0,7	≤ 1,2	≤ 2,0	ISO 18122
Mechanical Durability	w-% [2]	≥ 98,0 [5]	≥ 97,5 [5]		ISO 17831-1
Fines (< 3,15 mm)	w-% [2]	≤ 1,0 [6] (≤ 0,5 [7])			ISO 18846
Temperature of pellets	°C	≤ 40 [8]			
Net Calorific Value	kWh/kg [2]	≥ 4,6 [9]			ISO 18125
Bulk Density	kg/m³ [2]	600 ≤ BD ≤ 750			ISO 17828
Additives	w-% [2]	≤ 2 [10]			-
Nitrogen	w-% [3]	≤ 0,3	≤ 0,5	≤ 1,0	ISO 16948
Sulfur	w-% [3]	≤ 0,04	≤ 0,05		ISO 16994
Chlorine	w-% [3]	≤ 0,02		≤0,03	ISO 16994
Ash Deformation Temperature [1]	°C	≥ 1200	≥ 1100		CEN/TC 15370-1
Arsenic	mg/kg [3]	≤1			ISO 16968
Cadmium	mg/kg [3]	≤ 0,5			ISO 16968
Chromium	mg/kg [3]	≤10			ISO 16968
Copper	mg/kg [3]	≤10			ISO 16968
Lead	mg/kg [3]	≤10			ISO 16968
Mercury	mg/kg [3]	≤ 0,1			ISO 16968
Nickel	mg/kg [3]	≤10			ISO 16968
Zinc	mg/kg [3]	≤100			ISO 16968

According to the quality of the pellet, the price is, for ENplus-A1, A2 from 150-200 Eur / t, while for the industrial pellet ENplus-B price is 100-140 Eur / t.

After looking at the location, the accessibility of various types of raw materials and their transportation costs and the selling price of the finished product, it is necessary to consider, how increasing the diversity of raw materials influences the design of the pellet plant itself.

An overview is given in the course:

• Mono-component plants - only wood logs, or only wood chips, or only sawdust or just straw from harvest residue, etc.

• Raw material mixing - only wood (but different input, i.e. granulation of input material, for e.g. wood logs and wood chips) or only harvest residue.

• Combined plants - using different components and different raw materials, in terms of seasonal and price differences in raw materials.

In the previous chapter, a technological scheme for pelleting of wood (Figure 1) and pelleting of harvest residues (Figure 2) was shown. If we compare both technological schemes, it is quite clear that the lines of grinding, conditioning, pelleting, cooling, and storage and packaging lines are completely identical.

It is necessary to conclude that for combined pellet plant, it is need beside this identical lines only special preparation lines. For wood in the form of chipper and mill and in particular a preparation line for harvest residues, straw shredder and hammer mill. This is shown in technological schema for pellet plant for various types of biomass (Figure 5).

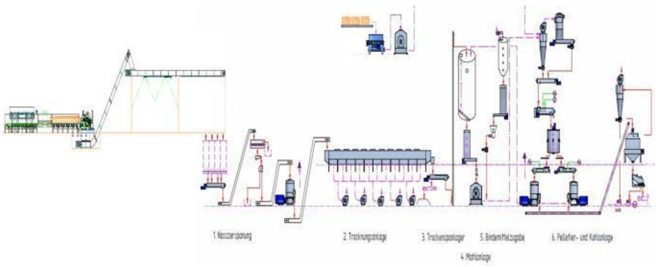

Figure 5. Technological scheme, pellet plant for various types of biomass.

4. CONCLUSION

Biomass pelleting has some important advantages:

- using pellets as an alternative sustainable energy is an effective tool in the fight against climate change; [24].

- reduced handling of biofuel, lower storage and transportation costs [25].

- improved overall biomass quality, stability and durability [26].

- lower dust levels and higher heating values, lower pollution [27].

- reduced deforestation by providing a substitute of wood mass used for fire [28].

Main disadvantages of biomass pelleting are:

- emissions of low quality solid biofuels may damage the combustion plants and cause unwanted effects such as: slugging, corrosion and interference with automatic control of processes [29].

- fine particle content of the pellets, which is influenced by their mechanical durability and also storage conditions, can disrupt the control of automated heating systems or cause interruption of automated supply with solid biofuels in combustion plants [30].

- fine particles burn faster and higher temperatures may favor the melting of ash [31].

- dust generated by disintegration of low quality pellets represents a health risk, and can also contribute to the risk of ignition and explosion during handling, storage and transport [32].

Pellets production has shown a continuous expansion over the years (Figure 6) and is expected to have a faster growth in the near future [33].

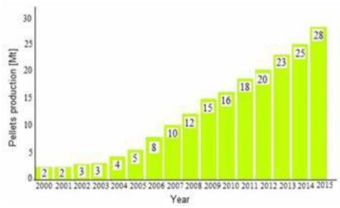

Figure 6. Global production of wood pellets in the period 2000-2015 [34].

Table 2. Presents global production of wood pellets (x millions t/year) in 2010 and 2015, with forecast for 2020 [34].

Regions	2010	2015	2020
North America	4.9	8.5	11
South America	0.1	3	4.4
Western Europe	7.7	10.7	13
Eastern Europe	2.2	2.8	3.3
Russia	0.6	1.4	1.6
Japan and Korea	0.1	0.4	1.1
China	0.6	3	10
Oceania	0.2	0.4	0.8

Table 3. Presents Consumption of wood pellets (x millions t/year) in 2010 and 2015, with forecast for 2020 [35].

Regions	2010	2015	2020
North America	3.4	4.3	5.6
South America	0.05	0.12	0.2
Western Europe	10.8	16.4	23.8
Eastern Europe	0.4	0.6	0.8
Russia	0.03	0.05	0.05
Japan and Korea	0.2	3	5.5
China	0.6	3	10
Oceania	0.03	0.06	0.13

All these results show that pellet production exponentially increases and grows in the coming years.

It should also be noted that in Europe appears energy crops of some foreign species as Paulownia (softwood) and foreign species of grass Mischantus also.

Both types of species fall into rapidly growing, with huge yield per hectare. For example, Paulownia is a softwood, which gives 1 m3 of wood per single log, and achieves a full yield in relation to Europe wood known species, even 2-3 times faster. For biomass energetic use, the planting is in the formation of 2x2 m, which yields approximately 2,300 trees or about 2,300 m3 per hectare. Mischantus has yields 20-40 tons of biomass per hectare, and a typical hectare of corn gives for e.g. 19 tons of biomass. This is huge different per hectare!

In the coming years, it is expected that besides the growth of pellet consumption from biomass and the trend of growth of these types of energy crop, which will serve as an alternative raw material. These types can be used in combination with existing wood raw material and existing straw raw material in combined plants for various types of biomass. By combining these biomass, the ash content of pellets will be reduced, while on the other hand the energetic power of such pellet will increase, and both factors will positively influence the increase in the quality of pellets. This is certainly a future in the field of biomass pelletization and something we can expect in the coming years. Therefore, the aim of this work was to show that there is a technology that can successfully deal with new trends.

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