University of Sopron
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PhD Thesis Summmary

ECO-ENERGY ASPECTS OF PRODUCTION AND UTILIZATION OF ENERGETIC PELLETS

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INTRODUCTION

The opportunities among the renewable energies in Hungary largely lies in the utilization of biomass, due to the characteristics of its agricultural industry large amounts of herbaceous residues are available. Straw and various agricultural and wood industry by-products can be used as the raw materials for pellets. Common complications of the various by-products used in pellet production are the ability to store and manage them, in addition to their combustion. Therefore it is important to create pellets that will reduce the energy put into transportation and improve the combustion parameters. The demand for wood pellets is stedily increasing in the European Union, however wood stocks are limited. It is therefore increasingly used for round logs or wet timber in pellet process, thus significantly altering the energy balance. During my work I dealt with carbon and energy balance of different pellet producing processes, emphasizing the excessive consumption of primary energy. Another part of the job energy and mechanical properties of the pellets were examined. In the studies I dealt with the biodiesel production generated from the by-product of rapeseed stalk. Utilization of rapseed-stalk pellets are significantly changes the energy balance of biodiesel production. The raw material base of pellet production can be upgraded with industrial waste or by-product. Paper sludge, pyrolysis carbon black and wood blend pellets were produced on which energy laboratory investigations were performed.

THE RELEVANCE OF THE RESEARCH TOPIC

Based on the meteorological measurements of the last fifty years, the global average temperature is increasing considerably and it is worrying that the degree of upsurge and, in this context, the melting of polar ice cover has accelerated over the past 15 years [National Atmospheric Administration 2015]. According to 97% of climate researchers, human activity is responsible for global warming. Recognizing the importance of the problem, policy guidelines are formulated for the reduction of greenhouse gases in the European Union and around the world. Hungary complied with the EU requirements, the 14.65% renewable energy share by 2020 is determined by the National Action Plan. Thanks to the soil and climate conditions of our country, the utilization of biomass in renewable energies is of paramount importance. A common feature of agricultural and wood by-products that are difficult to handle and firing, they have a low bulk density in original condition. Therefore, pelleting is a potential alternative for the energetic utilization of these materials. Production and trading of wood based pellets have increased significantly since 2008 [Eurostat 2015, Pell. Atlas 2014]. The United States and Canada are the main producers and exporters, primarily to the European Union. The EU wood pellets "dependence" is caused by the political directives to reduce greenhouse gas emissions and increase the share of renewable energies. Many European electricity generators, power plants have converted or are in the process of replacing coal and gas with biomass, often with wood pellets. The examined domestic pellet plants 85-90% of produced pellets are sold in Italy. Based on the 2015 data of the Hungarian Pellet Association, 80% of the wood pellet

manufacturers exported to Italy and Austria, mainly to meet domestic heating, pellet furnaces and boilers lower raw material demand. The increase in multilateral demand for wood pellets has resulted the involve of wood of different quality, size and composition into pelletization, wood and sawdust residues from the wood industry does not cover the need. Since the timber industry stocks are limited, priority is therefore to expand the raw material base of the pelleting process with different materials, industrial pellets and agropellets also get an increasing role in the future.

Another important issue is the extension of the energy balance examination, with delivery of the finished product, the primary energy demand of production and efficiency of the use. A number of studies dealing with the energy balance of pellet production [Jannasch et al. 2001, Pastre 2002, Sokhansaj 2006, Adapa et al. 2011, Hagberg L. 2009, Mann M. 2004, Kocsis Z. 2014, Németh 2016, Szamosi 2014, Papp-Marosvölgyi 2011] however, only a few of them examined the energy needs of deliver the raw material and to transport the pellet to the user's place. Another problem is that in many cases, primary energy needs are not taken into account, which in my opinion is one of the most important issues to consider a process as a whole. The EROEI tests of the production processes, which mainly refer to wood pellets and wheat straw for agripellets, do not take into account the efficiency of pellet firing and the energy requirements of pellet burning. Therefore, I consider to extend of the energy balance studies, since environmental point of view, this is the most important.

OBJECTIVES, METHODS OF RESEARCH

During my doctoral work I carried out a number of energetic investigations on raw materials containing wood, herbaceous and industrial by-products of different composition and on the compressions produced therefrom. I would like to summarize research studies as the basis for the formation of standards, some of which engaging in eco-energy research was carried out by University of West-Hungary, Forestry and Environmental Engineering Institute and Technology lab of the Cooperative Research Center. The mechanical properties of the pellets were tested in the energy laboratory of the University of West-Hungary SKK Wood Engineering Institute.

I studied the energetic and mechanical properties of pellets made from various woody, herbaceous and industrial by-products, which produced in pellet plants and laboratory conditions. One area of the research is to involve new materials in the pelletisation to expand the feedstock base. Pellet mixes from various agricultural by-products, wood and industrial by-products are produced by laboratory pellet equipment, the most important energetic characteristics were examined. Paper sludge from papyrus waste and pellets from the pyrolysis by-products of the rubber were also pelletized and blend pellets were prepared by adding wood material. Due to the material composition of paper sludge, the high inorganic content significantly increased the ash content of the mixture pellets. I assumed a linear relationship between the mixing ratio and the ash content, which was confirmed by the regression equation. A large amount of contaminated by-products are

also present in the wood industry, surface-treated materials, glue, paint residues which can not be wood-pellet raw materials according to EN-14961-1 but can be used as industrial pellet raw materials. Rubber pyrolysis carbon black (up to 20% mixing) and paper sludge with this contaminated wood could be used as blend pellets. I studied the energetic and mechanical properties of the various blend pellets, in which different mixing ratios showed significant differences in pellet length, calorific value and ash content.

Another part of the research, I studied the properties of wood and agripells produced under operating conditions, where the calorific value, the moisture content and the ash content of the raw materials and finished products were of paramount importance. I also dealt with the mechanical properties of the pellets, most important of which were diameter and length, the bulk density, fine fraction and the mechanical strength. One of the important areas of research is the energetic analysis, where first tests are performed on the least energy consumption of wood pelleting and agripellet production without the need for delivery to the user site. The examinations were carried out two wood-pellet, and two agripellet facilities. To determine the energy balance, I determined the primary electricity demand of the manufacturing technology and the energy consumption of the machines of the material handling with reference to a unit weight of pellets. In order to give the EROEI value of the basic manufacturing technology, that is, the amount of energy input and recoverable, the calorific value of the pellets of different materials and calorimeter measurements were always performed. In the examination of recoverable energy, I also considered the efficiency of pellet combustion equipment, which was determined from the literature data and from my own measurements in the case of small pellet firing system. It was one of aims of research to extend the energy balance tests based on the typical examples of the operation pellet plants in Hungary, the different technological processes and the energy demand for the delivery of the finished product. During my work, I would like to demonstrate, on the basis of domestic examples, how the weaker and weter material is transformed into the primary energy demand of basic manufacturing technology. There are more and more examples of using pallets of wood or wood chips as pallet raw material. This translates into a significant increase in energy from raw material crushing, which not only increases production costs, greatly alters energy and carbon balance. The energy balance is also significantly influenced by the distance between the raw material to the pellet plant. Chip with low volumetric density, while in the case of agripells, the delivery of bales requires considerable energy and further degrades the energy balance if wet raw material is delivered. Based on domestic examples, I present how the energy demand of a unit weight mass of pellets changes by increasing supply distances.

In my opinion, from an environmental point of view, the examination of a complex production and utilization process is the most important. However, only few cases come from the primary energy demand of production or delivery and CO_2 emissions compared to this. It should not be overlooked that the efficiency of automated pellet stoves and boilers also varies and the use of electricity is used during their operation. Based on the flue gas analysis measurements carried out on a small pellet furnace, I studied the change of efficiency in the combustion of pellets with different base materials.

In Hungary, the pellet heating due to the decrease in the price of gas is no longer competitive. Taking into account current wood pellets and gas prices, heating with gas is currently cheaper than wood pellets. If we calculate the prices of pellet boilers and stoves, which are much more expensive than a gas boiler, it is easy to see that no increase in demand is expected in the domestic retail sector without subsidies. With this, domestic manufacturers are increasingly export-oriented, with an economically profitable business line being created, but due to the long delivery route of the finished product, fuel consumption is environmentally questionable. During my work, I determined the energy consumption and the CO_2 emission of the user to the point of view, taking into account different transport distances. At the end of the research, I determined the primary energies of different production processes, different materials, transport distances and pellet firing. I have pointed out that, unfortunately, in the process, pellet production and utilization raise many issues, and with the whole process, greenhouse gas emissions are also significant.

For the determination of the energy balance of agripellets, I investigated more closely the analysis of the rapeseed-stalk pellet. During my work I produced with a small pelletizer for rape-seed pellets, which I analyzed its energetic properties. Rape seed production has grown considerably over the last ten years due to the production of biodiesel. By utilizing the rapeseed straw as pellet, the energy extracted from the unit area is significant and significantly alters the biodiesel energy balance.

Flue gas analyzes carried out with rape stalk pellet in small pellet burners revealed burning problems. The efficiency did not reach 60% and CO ppm also provided high values. Therefore, I tested the flue gas analyzes of pellet and wheat straw made from different raw material mixes produced in the plant of Szentes, T & T Technik Ltd. During the processing of the measurment data, Student-test, t-test in the SPSS and Statistics programs, a pair and two-sample t-test were used to compare the different rape and wheat straw mix pellets. The mixture pellet combustion properties were significantly better than those of pure rapeseed stalk pellet.

THESES, NEW RESEARCH RESULTS

The conclusions of the doctoral candidate's work can be summarized in the following theses:

1. During the doctoral thesis of the candidate, through domestic examples, how to change the EROEI values of the base wood pellet manufacturing technology between 11-13 to take into account the primary energy needs extended to different technological processes. With regard to delivery distances, possible drying, pre-grinding, primary energy expended on the delivery and use of the finished product, the extended energy balance values are only between 2.5 and 3 EROEI values.

1/a

The lower quality, moist material makes the primary energy requirement of basic wood pellet manufacturing technology considerably higher. There are more and more examples of using pallets of wood or wood chips as pallet raw material. This also significantly improves the energy consumed by the raw material grinding, which not

only increases production costs it significantly alters energy and carbon dioxide balance. The energy balance is also significantly influenced by the distance between the raw material to the pellet plant. Chip with low volumetric density, while in the case of agripells, the delivery of bales requires considerable energy and further degrades the energy balance if wet raw material is delivered.

1/b

According to the candidate, the most important is the examination of a complex manufacturing and utilization process from an environmental point of view. Domestic manufacturers are increasingly export-oriented, with an economically profitable business line being created, because of the long delivery route of the finished product, fuel consumption is environmentally questionable. It should not be overlooked that the efficiency of automated pellet stoves and boilers also varies and the consumption of electricity is used during their operation. Taking into account the efficiency of the pellet combustion equipment and its primary energy demand, the energy and carbon dioxide balance of the process is significantly changed.

2.

The production and utilization of agripellet and wood pellets raise many issues from an environmental point of view, and with the whole process, greenhouse gas emissions are significant. The candidate also said that even taking into account the emission figures of domestic power plants different values are displayed. In the production of wood pellets, taking into account the production and utilization process, 1 tonne of pellet is emitted between 280 and 500 kg CO_2 eq value, while in the examined agripellet plants, the shorter transport distances are slightly more favorable between 200 and 350 CO_2 eq. These values do not yet show the amount of CO_2 released during the firing of biomass, which is added to the data by 2000-2300 CO_2 eq values.

2/a

In the case of agripellets, the use of fertilizer significantly increases the utilization of the projected energy and emission values. The use of fertilizers per unit of mass differs from one species to another, depending on the type of plant, an additional 50-58 kg CO_2 eq emissions per tonne pellet.

2/b

Incorporating the agripellet firing tests in the pellet firing, use the results of energetic measurements, and literature datas are also utilized by candidate in the calculations, due to the different calorific values and efficiencies, there is a significant difference in the EROEI values of the different investigated raw materials (rye, wheat straw, sunflower peel).

3.

Rape seed production has grown caused by biodiesel production over the past ten years. As a by-product, a significant amount of rapeseed stalk is produced which has been tested by the candidate for pelleting properties. The energy characteristics of the pellet produced from the rape straw were adequate compared to the agropellets, but the mechanical properties of the fine fraction and mechanical durability could be a problem.

3/a

By utilizing the by-product rape seed stalk as pellet, the energy extracted from the unit area is considerable and significantly alters the energy balance for biodiesel production.

3/b

Flue gas analyzes carried out with rape stalk pellet in small pellet burners revealed burning problems. The efficiency did not reach 60% and CO ppm also provided high values. Therefore, the candidate has made a mixture of raw material with different proportions of wheat and rape seed straw pellets, and measuments are made by flue gas analyzes. The combustion properties of blend pellets were significantly better than pure pellets.

4.
Wood and industrial by-product blend pellets made from small pelletizing equipment are tested, the candidate examined their major energetic characteristics as pellets. Paper stains appearing as pulp waste and a by-product of rubber pyrolysis are utilized, as well as blends of pellets with the addition of wood. The energy and mechanical properties of various pellets were investigated, with significant differences in pellet length, calorific value and ash content during the various mixing ratios.

4/a

When using paper sludge pellets, high ash content can cause problems by increasing the mixing rate to wood, the ash content has increased linearly and the calorific value decreased.

4/b

In case of pyrolysis of carbon black, up to 20% admixture percentage propose the candidate, problems occur to a greater extent during the compression, the material is burned in the presshole. Increasing the mixing ratio also increased the calorific value, but the blend pellet length are decreased linearly. Due to the environmental pollution and the potentially harmful properties of carbon black, the use of this mixture pellets

can only be carried out in the use of suitable combustion pumps and filtering equipment.

UTILIZATION OF THE DISSERTATION RESULTS

During the research, I pointed out the primary energy needs during the pelletization process and utilization in different production and delivery processes. In the case of agripellets there were significant differences in the calorific value of the various plant residues and the efficiency of the combustion, so I received different results for the energy balance as a function of the raw materials. The combustion of wheat straw blend pellets had significantly better combustion properties than pure rape seed straw pellets, so I suggest the production of blend pellets, which is made possible by the availability of raw materials.

Expansion of the pelleting raw material base is a priority issue. I examined the energetic and mechanical properties of pellets made from various materials, industrial by-products, which results can be applied in practice, thereby expanding the range of useable raw materials.