BIOMASS FLY ASH POTENTIAL IN POLAND

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Key words: biomass fly ash, energy in Poland, renewable sources in energy production

Abstract. Promising electricity and energy source is a biomass, that is a renewable energy source derived from living/recently living organisms - dedicated energy crops and trees, agricultural food and feed crops, agricultural crop waste and residue, wood waste and residue, aquatic plants, animal waste, municipal waste, and other waste materials. Biomass provides an opportunity to decrease environmental problems such as pollution and depletion of natural resources. It is widely available and regenerates in a relatively short time. The increase in the share of biomass in energy production in Poland is forecast. In addition, numerous, evenly distributed in Poland power plants and central heat plants, which can be converted from burning coal to burning biomass, constitute a local potential for the use of this renewable energy source. As a result of energy production from biomass, large amounts of ashes will be created, which will begin to displace the coal fly ash used in the production of concrete. The forecasted production of concrete for the coming years has a forecast growth exceeding the average forecast growth for the European Union countries. Taking into account the above, it seems reasonable to try to design and use concrete mixtures with the participation of biomass fly ash.

1. INTRODUCTION

Solid biofuels is an umbrella term for all solid organic components to be used as fuels. They include wood, timber industry by-products (wood chips, sawdust, etc.), wood pellets, black liquor from the paper industry, straw, bagasse, animal waste and other solid plant residues including the renewable portion of solid industrial waste [18]. Energy recovery from solid biofuels is mainly used to produce heat (in Poland heat consumption from solid biofuels in 2020 is 5.3 Mtoe [13]) and electricity (in Poland gross electricity production from solid biofuels in 2021 is 6.93 TWh [13].

Promising electricity and energy source is a biomass, that is a renewable energy source derived from living/recently living organisms - dedicated energy crops and trees, agricultural food and feed crops, agricultural crop waste and residue, wood waste and residue, aquatic plants, animal waste, municipal waste, and other waste materials. Biomass provides an opportunity to decrease environmental problems such as pollution and depletion of natural resources. It is widely available and regenerates in a relatively short time. There are many possibilities of biomass processing, e.g., agricultural residues and municipal solid residues for biogas and biofuel production, the use of organic waste for vermicomposting, as a supplement during combustion with hard or brown coal or use of agricultural, urban, woody and industrial pyrolyzed residues to improve soil quality [15]. Biomass is defined as carbon neutral, so the use of fly ash released after the biomass combustion process are brought into the economy, especially concrete production, without affecting the environment. Unlike the commonly used coal fly ash, which can be also problematic soon due to the tightening of environmental standards in the EU. Coal fly ash (CFA) and municipal solid waste incineration ash (MSWIA) are major anthropogenic sources of heavy metals [8][14]. In addition, CFA may contain organic pollutants and radionuclides. In this study, the level of biomass and biomass fly ash usage and potential in Poland was examined.

2. CURRENT SITUATION IN POLAND

Electricity production in 2021 was the highest in Polish history at 179.4 terawatt hours (TWh) (Figure 1). Electricity demand was also a record 180.3 TWh [13]. Net imports of electricity were the lowest in 5 years, as much as 99.5% of electricity demand was met by domestic generation [13]. Poland still produces 83% of its electricity from fossil fuels, whereby 72% of the country's power in 2021 was from coal and this share decreased by almost 15% in a decade. Only 17% of Polish electricity comes from renewable energy sources, with the growing importance of renewables in the Polish energy mix from 2014 [13]. The combustion of coal, however, adds a significant amount of carbon dioxide to the atmosphere per unit of heat energy, more than does the combustion of other fossil fuels. Being a top CO_2 emitter, Poland needs to make a rapid policy turn towards clean energy, otherwise the 2030 climate targets of the whole EU will be at risk. The use of renewable energy sources (e.g., woody biomass), which are by definition carbon-neutral, may significantly reduce greenhouse gas emissions.

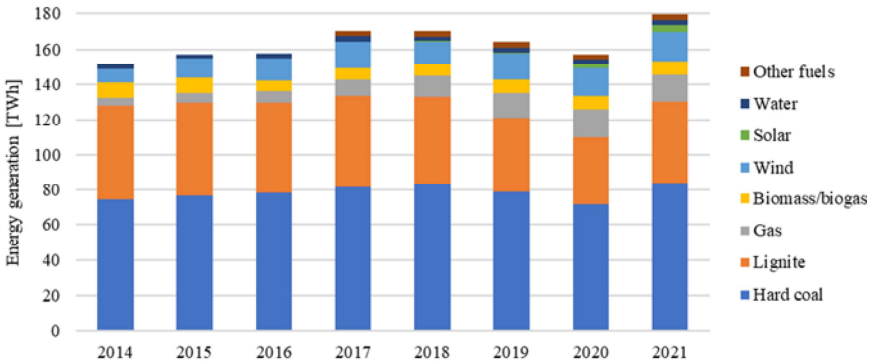

Fig. 1. Energy generation in Poland from 2014 to 2021, by technology (in terawatt-hours) [13]

2.1. The use of non-renewable sources in energy production

In 1990, 13 Member States of the current EU were producing hard coal, while in 2021 there were only two left: Poland and Czechia. Poland produced 55 million tons of hard coal which was 96 % of the total EU production (Figure 2). The country is also accounted for 42% (about 70 million tons per year) of the total hard coal consumption of the EU in 2021 (Figure 3).

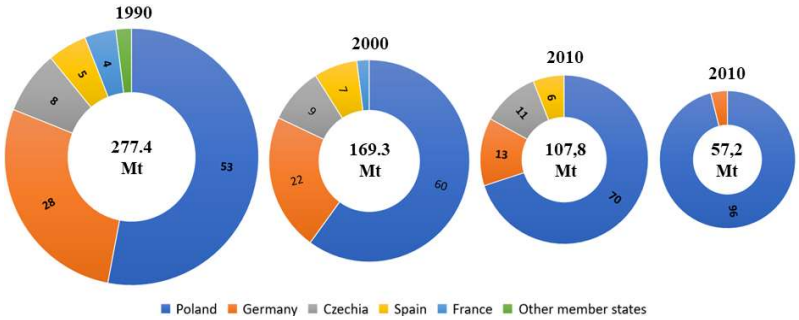

Fig. 2. Inland production of hard coal by Member State, EU, 1990-2021 (million tons) [9]

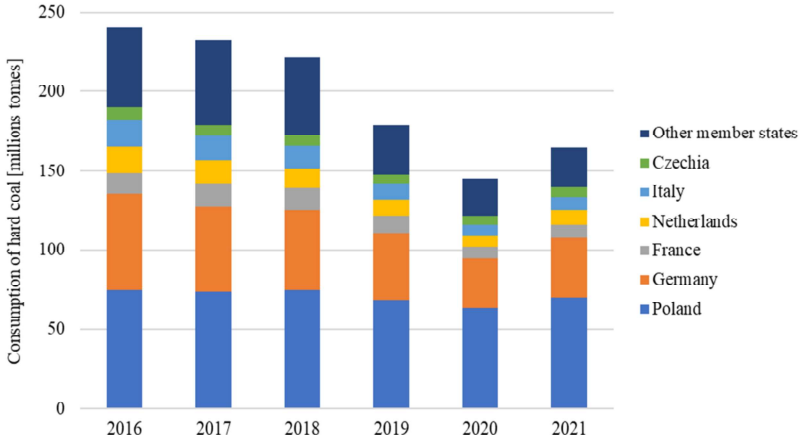

Fig. 3. Inland consumption of hard coal by Member State, EU, 2016-2021 (million tons) [9]

The brown coal production trend in all EU countries is very similar to its consumption trend, because brown coal is mostly produced in the countries of the consumption, while imports and exports are negligible. Generally, Poland was the second biggest consumer of brown coal in the EU in 2021 and represented 19% of the total consumption (about 53 million tons) (Figure 4).

The locations of power plants in Poland depend primarily on the presence of coal (Figure 5). One-third of Poland's energy comes from coal mining based in Upper Silesian Industrial Region, where the most important power stations are Rybnik and Jaworzno. The second factor is a close proximity to a water source for cooling purposes; the larger the power plant the greater the amount of water is needed for cooling. For this reason, power plants are located near large volume rivers, like power plants in Połaniec, Kozienice, and Ostrołeka.

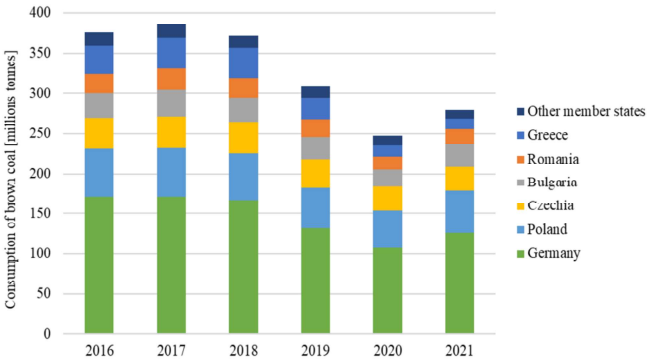

Fig. 4. Inland consumption of brown coal by Member State, EU, 2016-2021(million tons) [9]

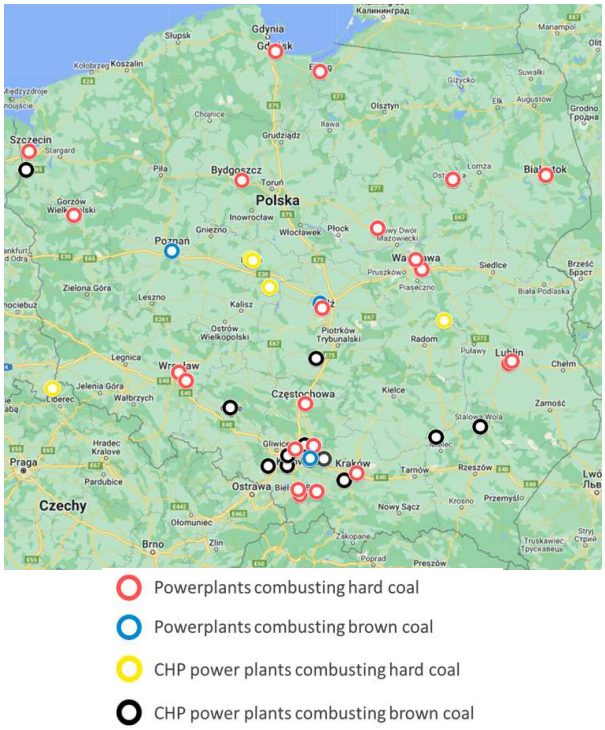

Fig. 5. Localization of coal power plants and CHP power plants in Poland [11]

2.2. The use of renewable sources in energy production

Energy from renewable energy sources is energy generated from renewable non-fossil sources, including wind energy, solar radiation, aerothermal, geothermal, hydrothermal and ocean, hydropower, energy obtained from biomass, as well as from gas coming from landfills, sewage treatment plants and biological sources (biogas) [6].

The most important renewable energy sources in Poland is wind energy and biofuels, liquid and solid. In 2021 55% of renewable energy in Poland was generated from wind power, followed by biomass and water, solar, and biogas (Table 1). Poland's wind generation capacity development was restricted in 2016, when President Duda signed a bill making it illegal to build turbines within 2 km of other buildings or forests, ruling out 99% of Poland's land area. Due to these changes, wind generation capacity only grew by 0.8%. Since then, the government has made plans to revise parts of the bill hindering wind energy development and that created several investment disputes between Poland and international investors. It is worth noting that despite the large installed capacity of solar energy source, which accounts for 52.1% of the total capacity of RES in Poland, the share in energy production is small and amounts to 6.9%. This is because solar energy is dependent on the weather and is not a stable source of energy. Biomass is a stable source of energy and thanks to this, despite the small installed capacity, 5.8% accounts for as much as 23.2% of the total energy generated from RES.

Table 1.
Renewable energy sources in Poland in 2021 [9][13]

RES type	Installed capacity, MW	Installed capacity, % in RES	Energy production, GWh	Energy production, % in RES
Water	978	4.8	2936	10.2
Wind	7521	37.0	15800	54.8
Biogas	268	1.3	1410	4.9
Biomass	968	4.8	6700	23.2
Solar	10586	52.1	1990	6.9
Total	20321	100.0	28836	100.0

The second most used renewable energy source in Poland in 2021 was biomass (23% of total production). Biomass is widely available in Poland and has a large potential for development due to surplus straw, which is a by-product of the developed agricultural industry. In Poland about 60% of all land is agricultural land, of which 40% is arable land. This means that biomass supply is high.

Generating energy by burning solid fuels such as wood and straw are of great interest, as energetic biomass resources in Poland have been estimated at about 30 million tons per year [10]:

- 9 Mt – wood and wood waste from the forests and orchards,
- 8 Mt – cereals straw,
- 6 Mt – various types of biowaste,
- and other materials (usually not often used).

Since 2010, the share of energy obtained from biomass in Poland has been between 3÷6% [13][19]. The lowest share of biomass as an energy source was in 2017 (3.19%). Which coincided with the decrease in biomass consumption in the rest of the European Union [13]. Since then, there has been an increase in the use of biomass as an energy source (Figure 6). In 2021 6.7 TWh was obtained from biomass combustion, which accounted for 3.73% of the record high total energy produced. The localization of elements of the biomass energy production in Poland is presented in Figure 7.

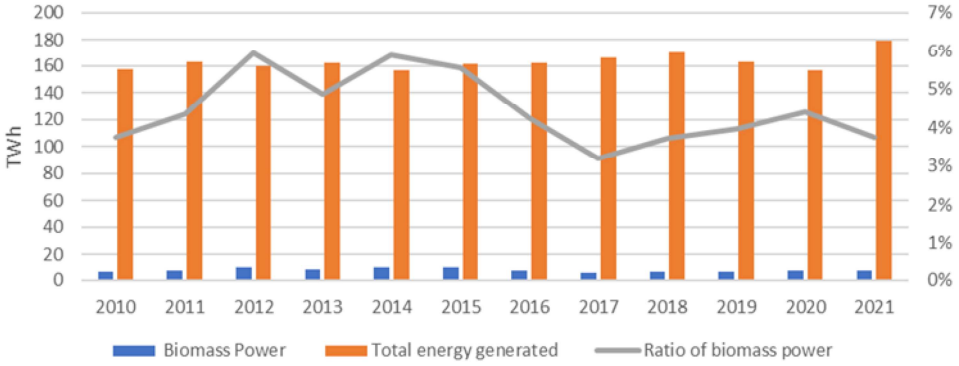

Fig. 6. Biomass usage as an energy sources in Poland [13][19]

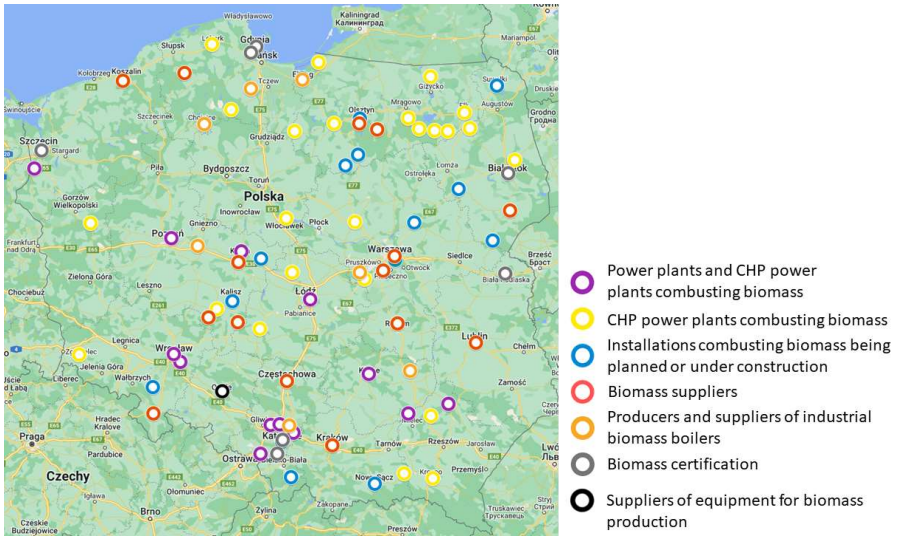

Fig. 7. localization of elements of the biomass energy production in Poland [11]

However, Poland's bioenergy sector remains below the expected level of development, with fewer than 300 biogas installations, approximately 100 of which are designed for agricultural substrates. Meanwhile, approximately 100,000 farms exist within Poland that are 20 ha (49.4 acre) to 50 ha (123.6 acre) in size and would, therefore, be suitable for small container biogas installations [5].

The flow of biomass in Poland in 2020 [2] is presented at Figure 8. The largest share in biomass produced in Poland is held by agriculture, followed by forestry. Almost half of the biomass produced in Poland from forestry is used as biomass for energy. Biomass used for the production of energy in Poland accounts for almost 14% of total biomass production.

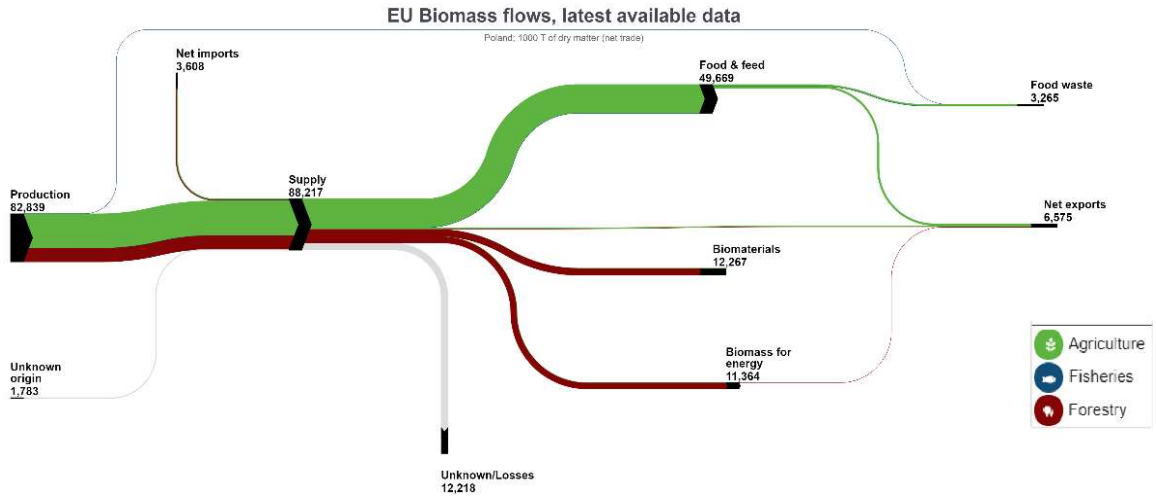

Fig. 8. Biomass flow in Poland in 2020 **Błąd! Nie można odnaleźć źródła odwołania.**[2]

3. BIOMASS POTENCIAL IN POLAND

3.1. Production of electricity and heat from biomass

The potential of biomass in Poland should be considered from two aspects of utilisation. The first is the potential for use in the production of electricity and the second in the production of heat.

Biomass, as a stable source and additionally thanks to low conversion costs, can complement heating mixes. Biomass allows for flexibility in choice, you can decide when to produce electricity or heat from this source, while in the case of solar and wind energy, significant storage costs must be added to be able to power the system "on demand" [16]. This means that storage losses and capital costs must be taken into account. In Poland, we see a clear increase in interest in biomass on a macro and micro scale. Pellet has become a full-fledged fuel in households. District heating sees biomass as an alternative to coal as a solution to reduce the effects of the increasing burden on CO_2 emissions charges resulting from EU regulations. By 2050, biomass will play a significant role in achieving climate neutrality. As McKinsey [20] forecasts, the process of decarbonizing the district heating network will require the implementation of solutions that use two-thirds of cogeneration from biomass and waste [17].(Figure 9).

In turn, according to Forum Energies' calculations, in order to increase the share of RES in heating to 40%, the total installed capacity of biomass boilers in district heating should increase by 3.2 GW by 2030, and biomass cogeneration systems by 665 MW [14].

Projects to convert coal-fired power plants and combined heat and power plants to biomass enable continued cost-effective operation with existing supply, generation and grid infrastructure. Unlike wind and solar power, biomass is not dependent on grid expansion. This makes biomass a viable and attractive complement to the changing renewable energy resources. In addition, coal assets are a very important source of employment. Conversion to biomass preserves jobs both in the power plant and in the supply chain. The example of woody biomass shows that energy security and sustainability are not mutually exclusive. Biomass produced sustainably on a large scale can provide the security of supply that is essential for large-scale processing, while creating enough demand to benefit local pellet producers as well [16].

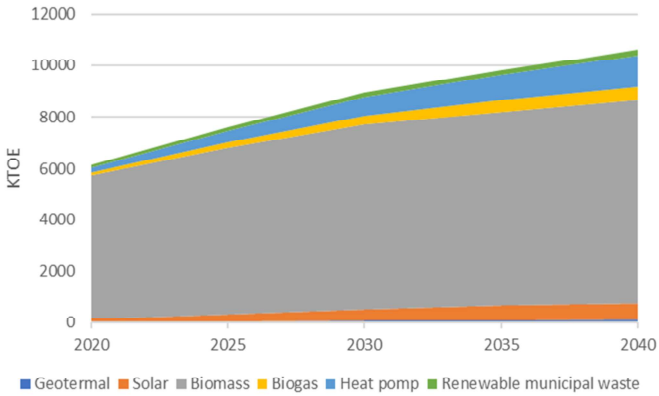

Fig. 9. Projection of gross final energy consumption from RES in heating [17]

In Poland, the largest resources are solid biomass, which consists mainly of waste wood from forests, post-consumer wood and straw. The purchase of biomass for the production of electricity can support agriculture and the national budget through the activities of the State Forests. According to PEP 2040, the energy use of biomass – both thermal (forest biomass) and anaerobic in biogas plants and for the production of biofuels – will be increased. In the energy sector, biomass can be converted into a wide variety of energy carriers. The potential of exploitation – biomass from large-scale production of

pellets from wood biomass – is not recognized in Poland. Examples of European countries point to significant benefits for the energy and heating system when such a source is used. In many cases, biomass can be converted into drop-in fuels, which cause small changes in existing infrastructure and end-use technologies- the so-called biomass conversion. Applications where biomass can extract fossil fuels include electricity generation, liquid fuels in transport, and heat in buildings and industrial processes. We anticipate that in the future it will be possible to use bioenergy with carbon capture and storage (BECCS) to produce energy, heat, hydrogen and/or biofuels. This will pave the way for long-term carbon storage, which will provide the negative emissions required to achieve global climate goals, as well as provide important services within the energy system (e.g. by providing baseload power or hydrogen for balancing) [1] [16].

Renewable energy sources remain poorly developed in Poland. However, currently, projects have been initiated to increase the number of wind turbines, hydroelectric power stations, and photovoltaic installations. A significant proportion of the work in this area concerns using biomass for energy production and energy carriers, as well as for producing chemical substances, fertilizers, plastics, and other materials and products according to the bioeconomy approach. Biomass for energy and energy carrier production can be extensively, and intensively, developed in Poland. The extensive approach involves increasing the number of biogas installations from the current hundreds to thousands and increasing the use of fallow land for energy crops. Meanwhile, the intensive approach concerns changing low-efficiency solid biomass incineration technology into advanced processing technologies, such as torrefaction, pyrolysis, and gasification. In addition, it is worth transitioning from the present use of biodegradable organic waste obtained from incineration to the use of anaerobic fermentation. The realistic total energy produced from agriculture biomass in Poland may be up to 245 PJ (5.85 Mtoe), including the contribution of the particular biomass sources [3].

The Role of Renewable Energy Sources in Electricity Production in Poland and the Background of Energy Policy of the European Union at the Beginning of the COVID-19 Crisis [4].

Currently, most of the biomass used for energy production in Poland comes from forest sources. However, regional conditions indicate another possible share distribution of biomass sources. An example of a proportion suggested by [3] is shown on Figure 10. Despite forestry resources, residual organic and straw can also be used to a large extent.

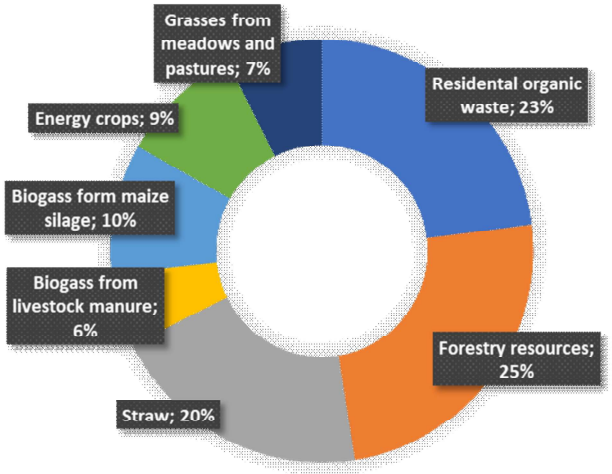

Fig. 10. Potential for energy production from agricultural and residential resources in Poland [3]

3.2. Biomass ash potential

Biomass is defined as carbon neutral, so the use of fly ash released after the biomass combustion process are brought into the economy. It could be used especially in concrete production, avoiding it negative affect on the environment. Unlike the commonly used coal fly ash, which can be also problematic soon due to the tightening of environmental standards in the EU. Since fly ash (CFA) and municipal solid waste incineration ash (MSWIA) are major anthropogenic sources of heavy metals [14]. In addition, CFA may contain organic pollutants and radionuclides.

4. POSSIBILITY IF USAGE BIOMASS FLY ASH IN CONCRETE PRODUCTION IN POLAND

Concrete production in Poland in 2021 amounted to 41 236 thousand tons [13] (Figure 11). According to various sources, in the future it will increase from (0÷6%). According to IBISWorld, in the coming years, the average increase in concrete production in Poland will amount to 6.17% and will be higher than the increase in production in the entire European Union. Concrete manufacturers will strive to reduce their carbon footprint in line with their 2050 Roadmap, as detailed by the Global Cement and Concrete Association. Fly ash is one way to reduce your carbon footprint. Due to plans to reduce coal burning, the availability of coal fly ash will decrease. The solution would be to use ashes from biomass combustion.

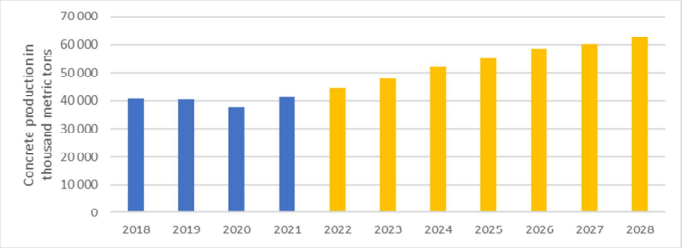

Fig.11. Concrete production current data according to Statista, the prediction is according [12][13]

5. SUMMARY

Following the unprovoked Russian invasion of Ukraine, the need to enhance the transition towards both clean energy and sustainable, resilient, and fair food systems has never been stronger and cleaner. Future implementation of the EU Bioeconomy Action Plan will have to take into account the implications on food and energy prices, as well as prices of energy-intensive products, and global supply chains, and address resulting additional pressure on natural resources within ecosystem boundaries [20].

Therefore, an increase in the share of biomass in energy production in Poland is forecast. In addition, numerous, evenly distributed in Poland power plants and central heat plants, which can be converted from burning coal to burning biomass, constitute a local potential for the use of this renewable energy source. As a result of energy production from biomass, large amounts of ashes will be created, which will begin to displace the coal fly ash used in the production of concrete. The forecasted production of concrete for the coming years has a forecast growth exceeding the average forecast growth for the European Union countries. Taking into account the above, it seems reasonable to try to design and use concrete mixtures with the participation of biomass fly ash.

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POTENCJAŁ POPIOŁÓW ZE SPALANIA BIOMASY W POLSCE

Słowa kluczowe: popiół ze spalania biomasy, energia w Polsce, odnawialne źródła energii

Streszczenie: Biomasa jest aktualnie obiecującym źródłem energii. Biomasa jest odnawialnym źródłem pochodzącym z: dedykowanych roślin energetycznych i drzew, roślin spożywczych i pastewnych w rolnictwie, odpadów i pozostałości z upraw rolnych, odpadów i pozostałości drzewnych, roślin wodnych, odpadów zwierzęcych, odpadów komunalnych i innych materiałów odpadowych. Biomasa daje możliwość zmniejszenia problemów środowiskowych, takich jak zanieczyszczenie i wyczerpywanie się zasobów naturalnych. Jest powszechnie dostępna i regeneruje się w stosunkowo krótkim czasie. Prognozowany jest wzrost udziału biomasy w produkcji energii w Polsce. Ponadto liczne, równomiernie rozmieszczone w Polsce elektrownie i elektrociepłownie, które można przekształcić ze spalania węgla na spalanie biomasy, stanowią lokalny potencjał wykorzystania tego odnawialnego źródła energii. W wyniku produkcji energii z biomasy powstaną duże ilości popiołów, które zaczną wypierać popiół lotny z węgla stosowany w produkcji betonu. Produkcja betonu na najbliższe lata ma prognozowany wzrost przekraczający średni prognozowany wzrost dla krajów Unii Europejskiej. Biorąc pod uwagę powyższe, zasadna wydaje się próba zaprojektowania i zastosowania mieszanek betonowych z udziałem popiołów lotnych z biomasy.

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Andrzej Garbacz, Prof. dr hab. inż. Andrzej Garbacz jest Dziekanem Wydziału Inżynierii Lądowej Politechniki Warszawskiej, członek KILiW PAN, Prezydent International Congress on Polymers in Concrete. Przez całą swoją karierę zawodową związany z wykorzystaniem zaawansowanych metod inżynierii materiałowej, w tym metod nieniszczących, do analizy relacji miedzy mikrostrukturą a właściwościami kompozytów budowlanych. Wiele projektów wniosło istotny wkład w rozwój inżynierii napraw konstrukcji betonowych. Współpracuje z wieloma ośrodkami na całym świecie, m.in. z Kanady, Belgii, Słowenii, Portugalii, Chin, w obszarze nowych rozwiązań materiałowych, ze szczególnym uwzględnieniem zasad zrównoważonego budownictwa. Jest autorem ponad 250 prac naukowych, publikacji i raportów, andrzej.garbacz@pw.edu.pl