POLITYKA ENERGETYCZNA – ENERGY POLICY JOURNAL
2020 ✦ Volume 23 ✦ Issue 1 ✦ 87–102
DOI: 10.33223/epj/118781

Natalia Generowicz[1], Zygmunt Kowalski[2]

Cascade use of post-production waste from the wood industry

Abstract: The circular economy model is based on several priority areas, including biomass and bio-based products. Focusing on them and their use should certainly take their cascading into account use, including how energy from waste from the wood industry is managed. Biomass is one of the most frequently used renewable energy sources in Poland, and in the European Union it satisfies 6% of primary energy. The CE (Circular Economy) model assumes that the reuse, processing and regeneration of a product requires less resources and energy, and is more economical than conventional material recycling, as low quality raw materials. The current model of waste management must take energy recovery into account, without which it is impossible to close the balance sheet of management of many groups of waste. This is also important from the economic point of view. Chemical energy, which is contained in a large part of waste, can be used for energy purposes, including the production of electricity and heat.

Reducing the use of raw materials is the most effective environmental approach to solving the waste problem. However, this requires reducing the extraction and consumption of materials, challenging existing production and consumption patterns. In the circular economy model there is a huge dif-

✉ Corresponding Author: Natalia Generowicz; e-mail: ngenerowicz@min-pan.krakow.pl

[1] Mineral and Energy Economy Research Institute of the Polish Academy of Sciences, Kraków, Poland; ORCID iD: 0000-0002-1389-8628; e-mail: ngenerowicz@min-pan.krakow.pl

[2] Mineral and Energy Economy Research Institute of the Polish Academy of Sciences, Kraków, Poland; ORCID iD: 0000-0003-2884-710X; e-mail: zkow@min-pan.krakow.pl

ference in approach to recycling leading to new products that create transport and production, new jobs and possible GDP (Gross Domestic Product) growth.
The aim of the study is to analyze the use of waste from the wood industry and to present possible solutions for its cascade use, taking the currently implemented circular economy model (CE) into account.

Keywords: biomass, wood industry, circular economy, waste

Introduction

At the end of 2015, the European Commission presented its Communication "Closing the Cycle – an EU Action Plan for a Circular Economy". These are proposals to be implemented in the European Union in the coming years. It includes actions taking all stages of the life cycle into account and focuses on several priority areas such as: plastics, food waste, critical raw materials, demolition and construction waste as well as biomass and bio-based products. At the same time, the communication highlights the role of innovation in building a circular economy. Some of these proposals are already being introduced or are under discussion between stakeholders.

The circular economy CE is by definition reproducible and renewable. It is based on the assumption that it is a continuous development cycle that preserves and enriches natural capital, optimizes profits and minimizes systemic risk through appropriate management of non-renewable and renewable material streams (COM 2014; Ellen MacArthur Foundation 2015; Nilsen 2017). The CE's objective is to consistently maintain the highest value and usability of products, components and materials in separate cycles: biological and technical (Blomsma and Brennan 2017; Korhonen et al. 2018). The model of a circular economy uses the concept of sustainable development, i.e. development that meets current needs without compromising the ability of future generations to meet their needs (Broman and Robert 2017; Ingebrigtsen and Jakobsen 2007).

The CE model assumes (Ingebrigtsen and Jakobsen 2007; Broman et al. 2017; Kirchherr et al. 2017) that the reuse, processing and regeneration of a product requires less resources and energy, and is more economical than conventional material recycling, as low quality raw materials. The materials should first be recovered for reuse, refurbishment and repair or reclamation, and only as a last resort should they be used as raw materials that have so far been the main subject of traditional recycling. According to the CE, incineration for energy recovery should be the penultimate option, while landfilling is the last. In this way, the life cycle value chain maintains the highest possible value and quality for as long as possible and is also as energy efficient as it can be (Ghisellini et al. 2016; Bilitewsky 2012).

As already mentioned above, the CE model is based on several priority areas including biomass and bio-based products. Focusing on them and their use, their cascade use should certainly be taken into account, including how energy from waste from the wood industry is used. The current waste management model must take energy recovery into account, without which it is not possible to close the management balance of many waste groups. This is also important from an economic point of view. Chemical energy, which is contained in a large part of waste, can be used for energy purposes, including the production of electricity and heat in various technological variants of thermochemical conversion (Wasilewski and Bałazińska 2018).

Moreover, in March 2007, the European Council adopted the so called 3×20 target, i.e. the "3×20" objective as the general objectives of the energy and climate policy of the European Union until 2020:

- achieving a 20% reduction in greenhouse gas emissions,
- to increase to 20% the share of energy from renewable sources (RES) in total energy consumption in the European Union, including an increase in the share of biofuels in total consumption of petrol and diesel in transport within the European Union to at least 10%,
- increase in energy efficiency by 20%.

These objectives, as well as the CE model, which is now entering into force and which also addresses the increase of RES use as well as energy efficiency, show how important it is to manage waste and energy properly.

1. Energy recovery from waste from the wood industry

For hundreds of years, biomass has been the primary energy source used by humans. However, when coal, natural gas and oil were discovered, biomass became a much less used raw material despite its significant physic-chemical properties, which could fully satisfy human food needs. According to the literature, biomass is a mass of organic matter contained in plant and animal organisms, which we obtain as a result of photosynthesis reaction (Nadziakiewicz et al. 2007).

Climate change, which is difficult to ignore, although there is no reliable assessment of the direction and scale of these changes, shows how important it is to take action to replace fossil primary energy sources with energy from low-carbon renewable sources. Such actions are already being carried out in Poland as well, and as a result, since 2005 an increase in the amount of biomass used for both electricity and heat production has been visible (Kowalski 2015). Among the most important factors that made the energy sector interested in the use of this fuel, despite many economic, organizational and technological limitations related to the use of biomass, one should mention the possibility of quick technical and technological adaptation of coal installations for biomass combustion and co-combustion and political support for this application, as well as the conviction of the high energy potential of biomass, estimated in Poland at 895 PJ (Jasiulewicz 2010).

Biomass is one of the most frequently used renewable energy sources in Poland, and in the European Union it satisfies 6% of primary energy. In Sweden, a significant, almost 18% increase in the production of energy from biomass was recorded. Since 1991, a significant increase in biomass consumption has been noted – by 71%. The world production of heat from biomass prevails in: Sweden, Germany and the United States (Rogulska 2002). The use of biomass increases local energy security as a result of becoming independent of external suppliers of fossil fuels.

From the beginning, forests were the primary source of energy for mankind. However, at this point in time, about half of global wood harvesting is used for energy purposes. In recent years, technology development has allowed the integration of biomass use into industrial energy systems. The literature of the subject presents the model of biomass in a broad way. While reviewing it, it can be seen that the following forms of biomass are used for energy purposes: waste wood, waste wood packaging, straw (grain), hay, crops from energy plantations, organic waste (slurry), sewage sludge, waste paper, liquid biofuels, biogas from slurry, sewage sludge, municipal landfills (Grzybek 2002).

According to the definition contained in the (RES Act OJ 2015, item 478), the term energy wood is defined as "wood raw material which, due to its quality and dimensional characteristics, has a reduced technical and utility value preventing its industrial use, as well as wood raw material constituting biomass of agricultural origin". The purpose of the draft Ordinance prepared by the Ministry of the Environment is to clarify the definition contained in the Act by specifying the quality and dimensional characteristics (Draft Ordinance of the ME January 8, 2019).

Energy wood is a wood raw material in its form:

- round wood – wood harvested in a round or near-circular state, maintaining the shape of the side of the trunk or crown elements,
- split wood – wood resulting from the separation of round wood along fibers,
- wood residues – wood remaining on the cut surface, associated with the process of felling trees and shrubs and the manipulation of wood material which for quality reasons cannot be assigned to other grades or their harvest is not economically justified, including:
  a) wood with a diameter of not more than 5 cm without bark and 7 cm in bark at the lower end of the unit, irrespective of quality characteristics,
  b) wood with a minimum diameter of at least 5 cm without bark and 7 cm in bark at the upper end of the unit, the length or quality of which does not permit it to be classified in the other ranges of commercial timber, irrespective of quality characteristics,
  c) brushwood, needles, leaves, bark, roots and carp, irrespective of their quality and dimensions,
- carp – raw material derived from carp, which is formed by the root system together with the stump – regardless of the quality and dimensional characteristics,
- production residues, including waste, resulting from the processing of wood – arising from the processing of pure wood: sawdust, shavings, chips, particles, cuttings, chips, beadings, or from the processing of these forms, including briquettes and pellets – irrespective of their quality and dimensional characteristics,
- waste of pure post-consumer wood, originating in particular in from uncontaminated wooden pallets and other uncontaminated wooden packaging – regardless of quality and dimensional characteristics,

- waste other than those listed in points 5 and 6, in particular non-hazardous waste from wood processing and production of panels and furniture, pulp, paper and cardboard, wood packaging, wood waste from renovation and construction, provided that the provisions of the Act of December 14, 2012 on Waste (Journal of Laws from 2018 item 992) are complied with, as regards the eligibility of part of the energy recovered from the thermal transformation of waste – regardless of the quality and dimensional characteristics (Draft Ordinance of the ME January 8, 2019).

The following quality and dimensional characteristics of energy wood in the form of round or split wood are defined:

- the top diameter of the wood should be less than 7 cm in bark or 5 cm without bark – for wood lengths up to 3 m,
- the unilateral curvature of the wood should be a minimum of 12 cm per running meter or the multilateral curvature of the wood should be a minimum of half the unilateral curvature of the wood,
- the soft rot of the wood should together amount to a minimum of 30% of the cross-sectional area of both wood fronts or a minimum of 50% of the cross-sectional area of one of the wood fronts,
- brown rotor and scalding should cover a minimum of 50% of the cross-sectional area of one of the wood fronts,
- the presence of foreign bodies in the wood,
- presence of carbonization (Draft Ordinance of the ME January 8, 2019).

2. Cascade use of woody biomass

Cascade use means the resource-efficient use of any biomass in a circular economy. The forest-wood sector includes, among others:

- the woodworking industry, which produces wood materials and products that are clearly identifiable as derived from wood,
- pulp and paper production and processing industry,
- multi-product integrated bio refineries.

Thanks to technological innovations in the management of woody biomass, new materials, chemicals and fuels can be produced, thus replacing fossil resources and avoiding greenhouse gas emissions associated with their use. Forests and the forest-wood sector are of interest to many different policy areas, such as: forestry, agriculture, energy, environment (EC 2019).

Forestry

The European Union's 2013 Forestry Strategy states that cascade use supports the objective of resource efficiency by using 'forest resources in a way that minimizes environmental and climate impacts and prioritizes forestry products with higher added value, creating new jobs and contributing to a better carbon balance' (COM 2013).

Agriculture

The rural development policy under the common agricultural policy supports the introduction of sustainable forest management. Between 2014 and 2020, total public expenditure on the forestry sector amounted to EUR 8.2 billion and was used to modernize technologies, support the bio economy, combat climate change and protect forests (EC 2019).

Energy

Wood as a renewable source of energy also plays an important role in the abandonment of fossil fuels. The EU Renewable Energy Directive (Directive 2009/28/EC) sets European and national targets for increasing the share of energy from renewable sources by 2020 and allows Member States to implement support schemes for renewable energy sources, including wood. In 2015, the Directive introduced some changes to the issue of indirect land use change. An updated Renewable Energy Directive for the period after 2020 (RED II) streamlines the EU sustainability criteria for bioenergy, taking into account not only biofuels for transport but also solid biomass and biogas for heating and cooling and electricity production in plants above 20 MW. The RED II also requires that large-scale electricity generation from biomass (above 50 MW) meets minimum efficiency standards or is based on high-efficiency cogeneration technology (Balcerzak 2014).

Environment

The European Union Timber Regulation (Regulation 2010) regulates the placing on the market of most types of wood and wood-based products in the EU. It combats illegal logging worldwide, which is regulated by prohibiting the placing of illegally harvested timber and products made from illegally harvested timber on the EU market. It also requires operators to show due diligence with regard to legally harvested timber, i.e. it should have an identifiable source, either within the EU or in third countries, and be traceable on the downstream markets through traders. That Regulation therefore empowers the competent authorities of the Member States to carry out checks on operators, traders and monitoring organizations that can assist them.

The Waste Framework Directive (Directive 2008/98/EC) and the Packaging and Packaging Waste Directive (Directive 94/62/EC) set targets for separate collection and recycling of wooden packaging in the European Union Member States of 25% by 2025 and 30% by 2030. This will facilitate further cascade use thanks to reuse and recycling and longer maintenance of the material in the economy.

3. Ways of cascading use of waste from the wood industry

3.1. Principle 1: Sustainable development

All cascade solutions promoting the highest economic added value must take into account its impact on the other two pillars of sustainable development, i.e. the social aspect and the environmental aspect.

Sustainability means balancing economic, social and environmental aspects considered from a long-term and intergenerational perspective. The assumption that cascade use is always appropriate can be misleading. It is important to remember that the implementation of such use should optimize the synergy between the cascading use of biomass and the externalities of this use in each specific case, e.g. emissions, environmental damage, loss of biodiversity or other effects (EC 2019).

3.1.1. Maximizing the potential of cascading activities to minimize climate changes

Cascading the use of wood biomass can be a tool to support the transition to a low-carbon economy. By using wood biomass as a material throughout its life cycle, carbon dioxide is still stored, not emitted into the air. In addition, the cascading of biomass increases the availability of renewable materials that can be substitutes for fossil resource-based products such as biodegradable plastics of biological origin or advanced biofuels. Maximizing the efficiency of material processing and the generation and distribution of heat and electricity also minimizes total emissions. Sorting and recycling of wood waste reduces emissions by returning material to biomass resources and reducing the amount of waste burned or landfilled. This is a cascade use in operation. When no other use of wood biomass is economically viable or environmentally appropriate, energy recovery reduces energy production from non-renewable sources.

Example: Construction using wood

The industrial pre-fabrication, the use of highly processed wood products and the growing standardization of timber construction currently allow for the construction of buildings which are much higher and more durable and can be built from lower quality wood.

This construction method can reduce emissions in many ways:

- the wood used for construction stores carbon dioxide throughout the life cycle of the building, and can be easily recycled after proper dismantling,
- wood is one of the lighter construction materials; this reduces the need for foundations and enables fuel savings and emissions during material transport,
- houses made of wood have good energy characteristics.

Thanks to the invention of new, standardized products with predictable properties, such as cross-laminated timber, laminated veneer and laminated timber, and improved assembly techniques, larger and more durable timber structures can now be built. Prefabricated building elements, in which these highly processed wood products are used, can be produced as an additional activity of sawmills and according to architects' guidelines.

Highly processed wood products – structurally more durable than traditional sawn timber and suitable for modular construction – can often be produced from low quality small size timber from species that could not otherwise be used for construction. Highly processed wood products generally require fewer construction workers and improve occupational health and safety (e.g. due to reduced dust). Modular wooden buildings are much easier to demolish, as they can be designed and built in such a way that they can be easily demolished for recycling, thus keeping them in the material cycle for longer.

The environmental benefits of using wood in construction are also important: longer carbon storage, lighter weight and therefore lower fuel requirements for transport and reduced need for foundations, good acoustic properties, good energy efficiency in use and reuse, recycling or biodegradability at the end of its life. The development of wooden construction has also been greatly influenced by advances in many areas: glue production, non-toxic treatment, processing and quality assessment technologies.

Example: Green Deals – creating opportunities for new business models

Green Deals (The Netherlands) is a program that allows non-financial government support for sustainable initiatives. It is a system in which different businesses, civil society organizations, local and regional authorities and interest groups work together to achieve green growth and solve social problems. Green Deals enables the implementation of environmentally friendly processes and innovations. The program complements existing instruments such as legislation, as well as market and other incentives.

3.2. Principle 2: Raw material efficiency

Promoting raw material efficiency by focusing on applications with the highest economic added value and promoting a market-based approach. In order to increase raw material efficiency as much as possible, the focus should be on using wood biomass in the material cycle for as long as it is economically viable and technically possible (EC 2019).

3.2.1. Preventing and minimizing waste

The raw material efficiency approach enables an easier implementation of the waste hierarchy, which includes waste prevention, reuse, recycling as well as energy recovery and landfill.

Innovations are moving towards a more resource-efficient use of resources, and new technologies can lead to better treatment of resources, resulting in less by-products and less waste from the outset, and new applications can be found for by-products with a higher added value than their predecessors. However, it should be taken into account that there are already many known by-product applications that make sense from both an economic and an environmental point of view. For example, in the wood-based panel sector, not only small industrial round wood, but also chips, sawdust and recovered wood are used as the most important raw material for a wide range of products.

Modern bio refineries can make a variety of products from almost all parts of trees, including those parts that would previously have been treated as waste because it is difficult to process them. However, some products that can be obtained from these residues have a high market value.

Example: Bark as an example of turning waste into a resource

Bark has three main uses: as animal bedding, for energy recovery and for mulching (in horticulture and landscape architecture). The applications are generally not as valuable. Especially when compared to new ideas. The bark contains 30–40% of extractable ingredients such as: tannin, suberine, stilben, lignan, taxi, salicin, polyphenols, pectin and starch. The bark is about 10–20% of the total weight of the tree trunk, while in the case of small branches, the bark can make up to 60% of the weight. Wood waste from sawmills, especially bark, is rich in nutrients and is a good breeding ground for medicinal plants and fungi. In typical weather conditions, the nutrients are washed out into the soil in stages instead of being released quickly, as is the case with fertilizer.

Today, new opportunities for the industrial use of bark are increasingly emerging. For example, bark from the fir tree can be used to produce dietary supplements that have a stress -relieving effect. The bark of the European silver fir is rich in vitamins, minerals and special natural polyphenolic substances that can be easily absorbed by the human body. The polyphenols from the bark of this tree are strong antioxidants that are most effective at the cellular and intercellular level. The polyphenol-rich water extract from the bark of the fir tree has a strong protective effect on the heart and protects against atherogenic, diet-induced damage to arterial walls.

Example: Biocarbon as a high quality soil improvement

Minor residues of wood biomass, such as branches or felling, are common by-products of forest wood processing or gardening and maintenance work in urban parks. Usually these small residues of wood biomass are burnt or composted. Both of these processes nevertheless release stored CO_2 in a short time.

Another possible solution for wood waste is biocarbon, i.e. a product obtained by pyrolysis or torsion of wood biomass residues. Biocarbon is used in the soil reduces the need for energy-intensive soil fertilizers because it provides plants with the right nutrients in the right form and can also replace peat as a growth medium and water retention. Such properties are also very beneficial for the reclamation of old mining areas, as biocarbon mixed with clay stimulates vegetation growth.

As biocarbon can be produced at local and regional level, it enables the creation of new local jobs and easy to implement initiatives for many applications in different sectors, leading to lower transport and storage costs. Less densely forested land can also be used to grow fast-growing trees, such as: willows, for local biocarbon production.

Example: Precision wood cutting method

The most modern sawmills use three-dimensional and X-ray technology to properly select the logs according to quality and determine the subsequent changes in the position of individual logs during cutting in advance. This technology, combined with thinner saw blades, generates less by-products and much less waste during the cutting stage.

3.2.2. Innovations to find more efficient ways of using wood biomass

The most important innovations in the sawmill sector are related to technological progress, which leads to the optimization of the use of wood biomass and to new techniques of non-toxic wood processing. Similarly, the advanced technology of sorting recycled wood enables its increased use in the production of wood-based panels.

The forest-wood sector is capital-intensive and has long investment cycles. Therefore, innovation to find better solutions also means finding the best ways that are sustainable and allow a long-term return on the investment.

Example: Furniture made of recycled materials

Italy is the third largest producer of wooden furniture in the world, although it has some of the most limited commercial forest resources in Europe. The solution here is consumer and post -industrial wood waste and innovation. About 80% of Italian furniture is made of particleboard, which is mostly made of material that would be considered wood waste if it were not separately collected, sorted, cleaned and then reintroduced into the wood-based panel production cycle. Gruppo Mauro Saviola has been a leader in this field since the 1980s. It started using recycled biomass and marketing its products as “green panels”. Since the beginning of the 21st century, all Saviola particleboards are made exclusively from recycled wood.

Example: Production of ethanol from sawdust

Sawdust ethanol production started at the Cellunolix plant in Kajaani, (north-east Finland) at the end of 2016. It is the world’s first such production on an industrial scale. This factory was built in cooperation with a retailer’s cooperative and an energy company. Sawdust is delivered to it from a nearby sawmill.

The regulatory and infrastructural framework should enable favorable conditions for innovation in terms of the efficient use of wood biomass. The research and innovation policy as well as public and private investment in innovation have an important role to play in supporting research, innovation and technology deployment as well as promoting the implementation of more efficient measures and technologies.

In these times of increasing interconnection, the best available technologies can come from all sectors. Large data collections and digitization are an asset for the entire wood-based value chain, from forest to recycling. Block chain technology could be used in the future on market platforms to facilitate transactions.

3.3. Principle 3: Circular economy in each stream and at each stage

The aim of this principle is to keep each stream of wood biomass used in different resource-efficient applications in accordance with the previous principle in circulation. An appropriate regulatory environment with regard to innovation, technology deployment and investment is key to achieving progress in the use of wood biomass in a closed cycle (EC 2019).

3.3.1. Life cycle design

Materials and products that have been designed with a view to their further possible use are easier to recycle or up-cycle at the end of their life. Life cycle thinking includes the consideration of what wood should be used at the beginning and what treatment and mix of materials should be used. It is also important to consider the system in which the product will be placed and the availability of the collection systems after use.

Example: Wooden pins

The use of typical metal pins makes it difficult to recycle wood, especially high-quality construction timber, due to the fact that it is not always possible to separate the two materials and that woodworking equipment can be damaged by hitting the metal. With proper hardening it is possible to form wooden pins that are as strong as aluminum pins but are much better suited for wood reuse or recycling. Furthermore, the advantage is that these pins do not contribute to the coloring or discoloration of the wood surface and are virtually invisible.

Example: Woodworking and wood biomass

Treatment methods that are not toxic enable the wood to increase its strength in a sustainable and harmless way. For example, natural adhesives and protective agents (e.g. adhesives) obtained from wood provide the required stability and protection. They can be used on different types of wood, such as plywood or combined with it, replacing the more commonly used toxic chemicals. This non-toxic treatment enables a closed circuit.

WOOD-FLARETCOAT is a Horizon 2020-funded project which aims to address the problem of producing better flame retardant coatings for wood products (https://cordis.europa.eu/project/rcn/111259_pl.html).

The SustainComp project, funded under Horizon 2020, aims to develop a range of completely new and sustainable wood-based composite materials for use in a wide range of market sectors, from the medical, packaging and transport to construction (https://cordis.europa.eu/project/rcn/89321_pl.html).

3.3.2. Encouraging collection, recycling and reuse

A CE depends on programs that keep materials in circulation. The successful operation of these programs depends on public support for adopting a circular approach as well as on individual consumers having adequate knowledge of the specific products and services. A targeted collection system or extended producer responsibility system helps to keep materials in circulation and make recycling or upcycling easier and more cost-effective. In addition, transparent and clear information on the environmental impact of products and services during their life cycle allows consumers to make more informed choices.

Some wood biomass sub-sectors are more developed than others in terms of collection and recycling rates. The use of paper and board in a closed circuit is based on a very efficient collection system introduced in the Member States.

Digitization plays an important role in effective collection, recycling and reuse. IT programs make it possible to locate the material and its potential future destination as well as to provide consumers with information on the available options for using the material in a closed circuit.

Example: Recycling of cardboard packaging by ACE (Association for Beverage Cartons and the Environment)

Beverage carton packaging is made of combined layers of cardboard and polymers, and sometimes a thin layer of aluminum. Although this combination makes it possible to create very durable, hygienic and lightweight packaging for storing and protecting beverages, it still contributes to the technical challenge of recycling cartons after use. Therefore, beverage carton manufacturers and their suppliers have developed a special recycling system, including polymer and aluminum extraction.

One of the prerequisites for any recycling is collection. Therefore, a mandatory separate collection of beverage cartons (e.g. together with lightweight packaging or paper) increases the amount of material available for recycling. This, in turn, can lead to a more stable investment in sorting technologies, recycling and new materials and thus develop green jobs in Europe.

Manufacturers and suppliers of beverage carton packaging and their suppliers use paper recycling processes that separate paperboard from the polymer and aluminum layers of cardboard packaging, thus allowing the use of high quality fiber optics.

3.4. Principle 4: New products and new markets

The search for new economic applications with high added value is now part of the activities of biomass-based businesses. high rates of investment in research and maintaining flexibility in production so that new technological developments can be exploited are among the success factors in this sector.

Measures to increase the scale of innovation are important here. This includes developing appropriate standards, ensuring availability of funding and cooperation. In many cases, new products based on wood biomass can be competitive in terms of functionality, but not cost. Economies of scale are also needed to achieve price competitiveness (EC 2019).

3.4.1. Innovations to use new technologies to transform by-products and waste streams into new products

Progress can be seen in all value chains: in the woodworking industry, in pulp, paper and board production and especially in multi-product bio-refineries. Wood biomass can be processed to obtain the same chemical base elements as those obtained from oil. However, this biomass may also be processed to obtain new, better for the environment, basic elements or completely innovative basic elements which may be used for the manufacture of medicinal products.

Example: Use of wood bark for adhesives, cosmetics and pharmaceutical products

The bark residues from pulp and paper production have a fairly high calorific value, so they are usually burned to produce bioenergy. However, there are more industrial opportunities in terms of using wood bark for the production of new products. Since bark is rich in minerals, the pharmaceutical company Ars Pharmae d.o.o. in Slovenia already uses it for the production of food supplements.

Another use is for the production of adhesives and insulation materials. Wood adhesives made from substances obtained from bark, such as tannin and lignin, have already been used in timber construction and panel production.

Conclusions

The energy use of biomass – both thermal and anaerobic in biogas plants and for the production of biofuels – will increase due to the increasing flow of bio-waste resulting from growing consumption, as well as tightening waste management regulations which gradually prevent bio-waste from being landfilled. This solution also fits in with the idea of a circular economy.

The energetic use of waste from wood biomass gives measurable ecological benefits, related to the reduction of the amount of stored waste, as well as economic benefits resulting from the saving of ever smaller fossil fuel resources. The recovery and sale of energy from waste containing the biodegradable fraction may bring additional effects in the form of including it in part or in whole in the energy coming from renewable sources, as well as participation in the system of greenhouse gas emissions allowance trading.

Agricultural biomass will continue to play an important role in meeting the demand for raw material, and it is crucial that there is no competition for raw materials between energy and agriculture, the agri-food industry and the processing industry. Furthermore, biomass should be used as close as possible to its origin so that its transport and related costs do not adversely affect the environmental and economic effect.

The energy sector should, in particular, use waste biomass (non-agricultural) which is not used in other branches of the economy, e.g. biodegradable municipal waste, residues from forestry, households and the agri-food or processing industry (furniture, paper etc.). High potential occurs in sewage sludge, industrial waste, defined by law as hazardous (including hospital waste) and municipal waste. This process must be carried out in accordance with the principle of hierarchical waste handling, which means that biomass should be recycled first, and if this is not possible, it should be recovered and disposed of, allowing for rational management of the biodegradable fraction.

The use of wood as an energy source on an industrial scale is an extremely complex process with far-reaching natural and socio-economic implications. However, the positive effects of this process on the improvement of the state of the climate cannot conceal the risks associated with the risk of excessive exploitation of the stands or the management of ashes. The use of biomass for energy production has and will have a significant impact on the improvement of agricultural management. However, the extensive use of wood biomass for energy production purposes may have a negative impact on rural development, due to the deterioration of the condition of wood industry branches, which contribute significantly to economic development. The use of wood biomass for energy generation, due to its scale, puts the importance of wood in a new light, defining forest management as a sector supporting the implementation of climate policy. However, policies to minimize climate change require an analysis of all benefits and risks so that their implementation does not interfere with the development of other uses of wood and does not endanger the wood and pulp and paper industries.

References

Balcerzak et al. 2014 – Balcerzak, W., Generowicz, A. and Mucha, Z. 2014. Application of a multi-criteria analysis for selection of a method of reclamation method of a hazardous waste landfill. *Polish Journal of Environmental Studies* Vol. 23, No. 3, pp. 983–987.

Bilitewsky, B. 2012. The circular economy and its risks. *Waste Management* Vol. 32(1), pp. 1–2.

Blomsma, F. and Brennan, G. 2017. The emergence of circular economy: a new framing around prolonging resource productivity. *Journal of Industrial Ecology* 21(3), pp. 603–614.

Broman, G. and Robért, K.H. 2017. A framework for strategic sustainable development. *Journal of Industrial Ecology* 140(1), pp. 17–31.

Broman et al. 2017 – Broman, G., Robért, K.H., Collins, T., Basile, G., Baumgartner, R.J., Larsson, T. and Huisingh, D. 2017. Science in support of systematic leadership towards sustainability. *Journal of Industrial Ecology* 140(1), pp. 1–9.

EC 2013. *Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions, COM(2013) 659 final,* Brussels.

EC 2014. *Towards a Circular Economy: a Zero Waste Programme for Europe*, *COM(2014),* Brussels.

Directive 94/62/EC, European Parliament and Council Directive 94/62/EC of 20 December 1994 on packaging and packaging waste.

Directive 2008/98/EC of the European Parliament and of the council of 19 November 2008 on waste and repealing certain Directives.

EC 2019. *Guidance on cascading use of biomass with selected good practice examples on woody biomass*. Luxembourg: Office for Official Publications of the European Communities (EC), 66 pp.

Ellen Macarthur Foundation, 2015. *Growth Within: a circular economy vision for a competitive Europe*. [Online] https://www.mckinsey.com/~/media/McKinsey/Business%20Functions/Sustainability/Our%20Insights/Growth%20within%20A%20circular%20economy%20vision%20for%20a%20competitive%20Europe/Growth_Within.ashx [Accessed: 2020-02-11].

Ghisellini et al. 2016 – Ghisellini, P., Cialani, C. and Ulgiati, S. 2016. A review on circular economy: the expected transition to a balanced interplay of environmental and economic systems. *Journal of Cleaner Production* 114, pp. 11–32.

Grzybek, A. 2002. The potential and possibilities of biomass utilization in Poland (*Zasoby i możliwości wykorzystania biomasy w Polsce*). *Ekologia i Technika – Ecology and Technology* 10(4), pp. 99–104 (*in Polish*).

Ingebrigtsen, S. and Jakobsen, O. 2007. *Circulation Economics. Theory and Practice*. Bern: Peter Lang AG, International Academic Publishers, 44 pp.

Jasiulewicz, M. 2010. Biomass potential in Poland (*Potencjał biomasy w Polsce*). Koszalin: Wydawnictwo Uczelniane Politechniki Koszalińskiej, 169 pp. (*in Polish*).

Kirchherr et al. 2017 – Kirchherr, J., Reike, D. and Hekkert, M. 2017. Conceptualizing the circular economy: An analysis of 114 definitions. *Resources, Conservation and Recycling* Vol. 127, pp. 221–232.

Korhonen et al. 2018 – Korhonen, J., Honkasalo, A. and Seppälä, J. 2018. Circular economy: the concept and its limitations. *Ecological Economics* 143, pp. 37–46.

Kowalski et al. 2015 – Kowalski, Z., Generowicz, A., Makara, A. and Kulczycka, J. 2015. Evaluation of municipal waste landfilling using the technology quality assessment method. *Environment Protection Engineering* Vol. 41, No. 4, pp. 167–179.

ME 2019. *Draft Ordinance of the Minister of Environment on detailed quality and dimensional characteristics of energy wood* (*Projekt Rozporządzenia Ministra* Środowiska *w sprawie szczegółowych cech jakościowo-wymiarowych drewna energetycznego*). Warszawa: The Ministry of Environment (ME), 4 pp. (*in Polish*).

Nadziakiewicz et al. 2007 – Nadziakiewicz, J., Wacławiak, K. and Stelmach, S. 2007. Thermal processes for waste disposal (*Procesy termiczne utylizacji odpadów*). Gliwice: Wydawnictwo Politechniki Śląskiej, 275 pp. (*in Polish*).

Nilsen, H.R. 2017. The Hierarchy of Resource Use in a Sustainable Circular Economy. *University of Oslo Faculty of Law Research Paper* No. 2017-22, pp 1–12.

[Online] https://cordis.europa.eu/project/rcn/89321_pl.html [Accessed: 2020-02-11].

[Online] https://cordis.europa.eu/project/rcn/111259_pl.html [Accessed: 2020-02-11].

RES 2015. Act of 20 February 2015 on Renewable Energy Sources (*Ustawa o Odnawialnych Źródłach Energii*) (U. 2015 item 478) (*in Polish*).

Rogulska, M. 2002. Use of biomass energy in Poland, First National Conference on the Use of Renewable Energy Sources (*Wykorzystanie energii biomasy w Polsce*, *Pierwsza Krajowa Konferencja nt. Wykorzystanie energii źródeł odnawialnych*), Kudowa Zdrój (*in Polish*).

Wasilewski, R. and Bałazińska, M. 2018. Energy recovery from waste in terms of qualification of the electricity and heat generated as a renewable energy source and participation in the greenhouse gas emission allowance trading scheme (*Odzysk energii z odpadów w aspekcie kwalifikacji wytworzonej energii elektrycznej i ciepła jako pochodzących z odnawialnego źródła energii oraz uczestnictwa w systemie handlu uprawnieniami do emisji gazów cieplarnianych*). *Polityka Energetyczna – Energy Policy Journal* 21(1), pp. 129–142 (*in Polish*).

Natalia Generowicz, Zygmunt Kowalski

Kaskadowe wykorzystanie odpadów z przemysłu drzewnego

Streszczenie

Model gospodarki o obiegu zamkniętym opiera się na kilku obszarach priorytetowych, w tym na biomasie i bioproduktach. Skupiając uwagę na nich i na ich wykorzystaniu, powinno się na pewno uwzględnić ich kaskadowe wykorzystanie, w tym również sposób zagospodarowania energii z odpadów z przemysłu drzewnego. Biomasa jest jednym z najczęściej wykorzystywanych źródeł energii odnawialnej w Polsce, a w Unii Europejskiej zaspokaja 6% energii pierwotnej. Obecny model gospodarki odpadami musi uwzględniać odzysk energii, bez którego niemożliwe jest zamknięcie bilansu zagospodarowania wielu grup odpadów. Jest to również istotne z ekonomicznego punktu widzenia. Energia chemiczna, która jest zawarta w dużej części odpadów, może być wykorzystana do celów energetycznych, w tym również do produkcji energii elektrycznej i ciepła.

Ograniczenie stopnia wykorzystania surowców jest najskuteczniejszym podejściem środowiskowym do rozwiązania problemu odpadów. Wymaga to jednak zmniejszenia wydobycia i zużycia materiałów, co stanowi wyzwanie dla istniejących wzorców produkcji i konsumpcji. W modelu GOZ występuje ogromna różnica podejścia do recyklingu prowadzącego do powstawania nowych produktów, które kreują transport i produkcję, nowe miejsca pracy i możliwy wzrost PKB.

Celem pracy jest analiza wykorzystania odpadów z przemysłu drzewnego oraz przedstawienie możliwych rozwiązań ich kaskadowego wykorzystania z uwzględnieniem obecnie wprowadzanego w życie modelu gospodarki o obiegu zamkniętym (GOZ).

Słowa kluczowe: biomasa, przemysł drzewny, gospodarka o obiegu zamkniętym, odpady