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Review

Hemp Biomass as a Raw Material for Sustainable Development

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Abstract: Hemp cultivation is becoming increasingly common worldwide, although it still raises many concerns. These plants are gaining popularity due to their versatility and the ability to use virtually every part of them in almost all economic branches. Hemp products are sought after and appreciated by consumers. The cultivation of hemp does not place a large burden on the environment. All this makes hemp an ideal plant in terms of land use, which is closely related to the idea of sustainable development. This paper describes the legal aspects of hemp cultivation in Europe and briefly presents its breeding and cultivation. The possibilities of their versatile use are presented, with particular reference to biofuel production. Moreover, the suitability for ecological cultivation, description of the economic and social aspects of industrial hemp cultivation, as well as future outlooks, are also described.

Keywords: circular economy; plant biomass; biofuels; organic farming

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1. Introduction

Hemp (*Cannabis sativa* L.) has great industrial, medical, ornamental, and recreational potential. For this reason, it is widely cultivated almost all over the world [1–3]. Formally, they are classified according to the phytocannabinoid Δ9-tetrahydrocannabinol (THC) level in the dried flower. Generally, plants containing less than 0.3% THC are considered industrial, and above that, they are classified as medicinal or narcotic. This level varies from country to country [4]. Hemp is an annual, spring-flowering, naturally dioecious, and wind-pollinated plant. However, dioeciousness is not beneficial in terms of cultivation; therefore, numerous studies have been undertaken to breed monoecious varieties [5].

Hemp has been known for many years and cultivated mainly for the textile industry [6]. According to the European Commission data, in recent years the area of hemp cultivation within the European Union has increased by 75%, from 19,970 hectares in 2015 to 34,960 ha in 2019. In the same years, the production of hemp increased by 62.4%, from 94,120 to 152,820 tons. The largest hemp producer in Europe is France, accounting for more than 70% of EU production. The next two countries are the Netherlands and Austria, with production of 10% and 4%, respectively. Hemp cultivation in the EU has dropped minimally to approx. 32,000 ha in 2021 [7] (Figure 1).

Nowadays, the hemp industry is a profitable and dynamically developing branch of the economy. The versatile nature of hemp makes it ideal for the production of reusable, recyclable, and compostable biomaterials, and the market for such materials is now valued at billions of USD. Due to the clear and growing interest of consumers in natural and sustainable fibers and products, an increased demand for hemp raw materials and a significant increase in the acreage of their cultivation are expected in the coming years [8–10]. The article presents an overview of the latest literature and focuses mainly on information

from the European Union. Therefore, new ways to use these plants should be sought, e.g., in the production of biocomposites or biofuels, based on EU documents on sustainable development plans [7,11].

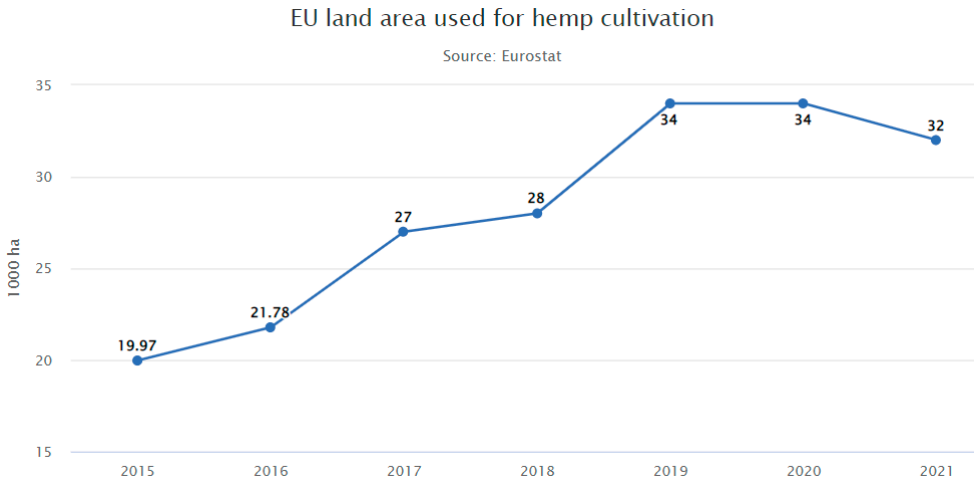

Figure 1. Area of industrial hemp cultivation in EU countries from 2015 to 2021 [7].

2. Hemp Cultivation in Terms of Achieving the Goals of the European Green Deal

The main goal of the European Green Deal (EGD) is to make Europe the first climate-neutral continent. This task is to be achieved by taking the following actions: transitioning the economy and societies, making transport sustainable for all, supporting clean technologies and products, cleaning energy systems, renovating buildings for more ecological lifestyles, coworking with nature and the environment for health and planet protection, and boosting actions for global climate [11] (Figure 2).

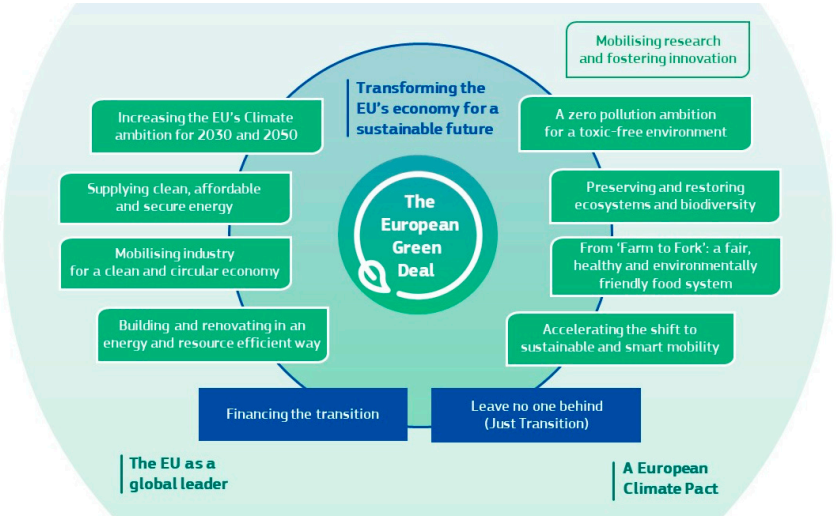

Figure 2. Various elements of the European Green Deal [11].

Production of hemp offers wide possibilities for farmers, industry, and consumers in the EU and has a number of environmental benefits directly related to the assumptions of the EGD. The main ones are storage of carbon, breaking the disease cycle, prevention of soil erosion, biodiversity, and low or no use of pesticides [7,11].

A vital element of the EGD is the agri-food system, supported by the Common Agricultural Policy (CAP). The pro-ecological properties of hemp are appreciated in CAP, and their cultivation is promoted. Hemp farmers can receive direct area payments under the CAP. They must meet the standard conditions for eligibility for subsidies and additional

requirements for hemp cultivation so that no illegal crops receive support under the CAP. The THC level in cultivated hemp must not exceed 0.3%. Farmers are required to use certified seed varieties listed in the EU common catalog of varieties of agricultural plant species. There are 75 different varieties of cannabis registered in this catalog. Under certain conditions, individual EU countries can additionally voluntarily support hemp production. This aid is currently implemented in France, Poland, and Romania [7].

Hemp growers can also benefit from support through the rural development measures available under the second pillar of the CAP. The appropriate types of support are to facilitate investment, knowledge building, business start-ups, innovation, supply chain organization, organic farming, environmental protection, and climate action [7,11].

Hemp cultivation and hemp products fit perfectly into the EGD and CAP assumptions, which will be described in more detail below in this article.

3. Cultivation of Industrial Hemp

Industrial hemp is suitable for organic farming. It responds very well to organic fertilization and whenever possible, it is recommended to use natural fertilizers (e.g., manure) for autumn plowing or forecropping [12]. It is usually not necessary to protect hemp from weeds on industrial plantations. These plants grow quickly, and with dense sowing, they quickly cover the surface of the field and drown out the weeds [13,14]. Hemp is believed to be a disease- and pest-resistant species. However, in unfavorable cultivation conditions—high humidity and temperature, dense crops, and over-fertilization with nitrogen—plants are infected with diseases and pests. Chemical protection of hemp plantations is difficult due to the fact that the plants quickly reach a considerable height, which makes it impossible to perform the treatment. In addition, there are few registered plant protection products for this species (in Poland, there are 67 products—a total of fungicides, herbicides, insecticides, and growth stimulators dedicated for agricultural plantations and professional use). For comparison, over 300 products are registered for maize, around 1500 for wheat, and over 100 for rapeseed. For flax, which is in the same group of agricultural crops as oil plants and fiber plants, around 100 plant protection products are registered. These numbers refer to products under various trade names, and there are only five registered active substances for fungicides and four for insecticides and herbicides [15].

Therefore, it is crucial to regularly inspect the plantation and provide non-chemical protection by performing the recommended agrotechnical treatments, in particular balanced fertilization (especially nitrogen fertilization), appropriate spatial isolation from hop and other hemp plantations, weed control, crop rotation, soil liming, and introducing post-harvest crops. Biological protection and beneficial organisms such as *Coccinellidae*, *Syrphidae*, *Chrysopidae*, and *Araneae* are also worth attention. In order to provide plantations with this type of protection, special attention should be paid to preserving and creating biodiversity [14].

Hemp is a dioecious plant by nature. However, this feature is not desirable in industrial crops due to lower profitability—e.g., lower grain yield [16]. Therefore, breeding work was undertaken to obtain monoecious varieties. Currently, in Poland, 11 varieties are registered in the Research Centre for Cultivar Testing, of which only one—Matrix—is a dioecious variety [17]. Hemp is a plant that varies significantly in height. There are varieties that grow up to over 4 m in height, e.g., Tygra and Rajan, but also those with a height of about 1–1.5 m, e.g., Finola. Breeding work is aimed not only at creating monoecious varieties, but also, for example, at improving the quality of fiber or increasing grain yield [18,19]. A perfect example of such activities is the cultivation of the Henola variety at the Institute of Natural Fibers and Medicinal Plants—National Research Institute in Poznań (Figure 3). As a result of breeding work carried out using natural selection methods, by selecting the lowest plants with well-developed inflorescences and a short growing season, a cultivar with approx. 50% shorter technical plant length, a shorter vegetation period, and significantly larger inflorescences was identified as fibrous hemp of the Białobrzeskie variety (Figure 4) [13].

Figure 3. A mature field of monoecious hemp of the Henola variety.

Figure 4. Comparison of hemp plants of the Białobrzeskie and Henola varieties [20].

A large number of varieties of industrial hemp and their diversity make it possible to cultivate it in many countries in Europe and around the world. Resistance to drought, low fertilization requirements, and low susceptibility to pests and diseases make these plants suitable for cultivation by both experienced and less experienced growers. They are also an interesting alternative in places where more demanding species do not yield satisfactory crops. In this case, the variety of hemp and the intended use of the crop should be selected properly.

4. Various Uses of Industrial Hemp

The figure below shows the possibilities of using every part of hemp biomass (Figure 5).

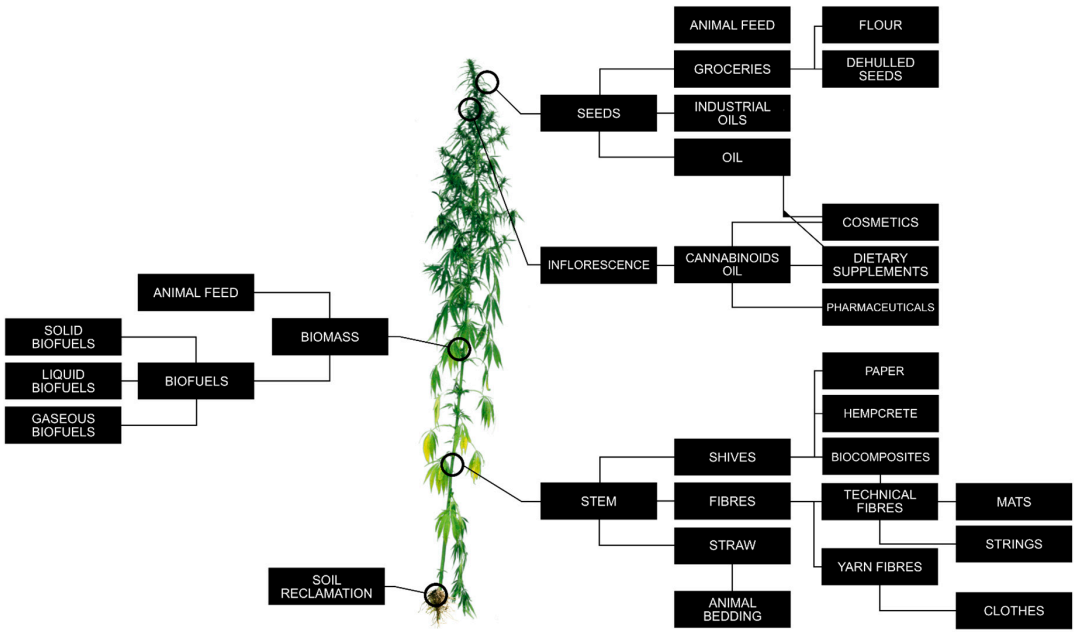

Figure 5. Possibilities of using individual parts of the hemp plant.

Originally, hemp was mainly used for textile purposes. Currently, the textile industry, which is based on cotton, is one of the most polluting to the environment, so more sustainable alternatives are being sought. One of them is the return to the cultivation of fibrous hemp varieties, which are a high-yielding crop. Hemp cultivation yields three times more metric tons of fiber per hectare, and the cultivation process reduces agricultural costs by 77.63% compared to cotton [21]. This makes the acquisition of hemp fiber profitable, and this raw material can be environmentally friendly, successfully replacing cotton and synthetic fiber [22,23]. Additionally, in other branches of the economy, hemp products can successfully compete with artificial materials.

Over the past 20 years, there has been a resurgence of interest in hemp seeds for their nutritional and pharmaceutical value. They were initially considered a by-product of the fiber extraction process. Currently, there is a growing interest in growing them for seeds, as they are widely regarded as one of the most complete sources of nutrition. They usually contain 25–35% lipids with a unique and perfectly balanced composition of fatty acids, 20–25% easily digestible and rich protein in essential amino acids, and 20–30% carbohydrates, a significant part of which is dietary fiber, mainly insoluble, as well as vitamins and minerals. However, this proportion is different for different varieties of cannabis. The seeds can be eaten whole, dehulled, or used to produce, e.g., cooking oil, flour, or hemp protein [24,25].

Plant oils are widely used in the cosmetics industry. In the whole group, industrial hemp seed oil is highly valued for its special health-promoting properties and multidirectional action. It has a positive effect on the skin and the whole body. Polyunsaturated fatty acids contained in hemp seed oil have a strong ability to penetrate the skin and have sunscreen and antioxidant effects, as well as improving skin nutrition and elasticity [26,27].

Due to its antibacterial and anti-inflammatory properties, essential oil obtained from hemp also enjoys the attention of the cosmetics and pharmaceutical industries. It includes, e.g., shampoos, soaps, creams, cosmetics against acne, facilitating wound healing, and reducing swelling, as well as massage and aromatherapy products and insect repellents. In addition, due to its antibacterial and antifungal properties, it can be used as a natural substance supporting the preservation of cosmetics [28–31].

In the chemical industry, hemp can be used to remove pollutants from industrial wastewater. Hemp-based felt is an efficient bio-sorbent for heavy metals [32]. In the chemical industry, hemp can be used to remove pollutants from industrial wastewater. Hemp-based felt is an efficient bio-sorbent for heavy metals. Hemp biosorbents ensure the effective and permanent reduction of pollutants and the improvement of wastewater management. Traditional treatment methods have limitations that hemp biosorbents do not have and, at the same time, provide similar efficiency and greater durability. Lead(II) contamination is extremely dangerous due to its toxic and carcinogenic effects, and its removal from the environment has been a serious problem. So far, it has been removed with synthetic single-exchange resins. Biosorbents based on hemp straw can successfully replace them and remove lead(II) from water systems, which is a sustainable and economically viable alternative [33,34].

The paper and pulp industry is also returning to the use of hemp as a resource in industrial paper production. After developing appropriate technology and selecting optimal operating conditions for an industrial installation producing cellulose pulp, hemp can be a raw material for paper production [35]. Hemp shives, which are a hemp fiber by-product, can be used to make tissues and toilet paper. The research of the Naithani [36] team has shown that hemp shives processed using a non-chemical method of autohydrolysis can successfully replace some of the chemically processed wood fibers and provide the same or even better properties. Thanks to this technology, many environmentally friendly tissue products can be created that are both highly energy-efficient and do not require chemical treatment.

Hemp is also used in the construction industry. Hemp shives combined with lime mortar form the so-called hempcrete, which has become increasingly popular in recent years. Construction materials based on hemp concrete are used in non-load-bearing walls, as finishing plasters, and as insulators for floors and ceilings. It is a material with many ecological values, and its thermal and humidity properties ensure a healthy microclimate in the room. The results of numerous experiments show that hemp shives can be an excellent and ecological substitute for raw materials in precast concrete elements [37–39]. Over the past two decades, there has been a revival of interest in hemp seeds for their nutritional and pharmaceutical value. They were initially considered a by-product of the fiber extraction process. Currently, there is an increasing interest in growing hemp for seeds, as they are widely regarded as one of the most complete sources of nutrients [20].

Hemp undoubtedly owes its popularity to the presence in its composition of compounds called cannabinoids: tetrahydrocannabinol (Δ9-THC) and cannabidiol (CBD). Due to the content of these two substances, hemp can be divided into three groups: narcotic (cannabis), intermediate, and hemp (fibrous, industrial) (Table 1) [40–42].

Table 1. Δ9-THC and CBD content for individual cannabis chemotypes [40,43,44].

Chemotype	Δ9-THC [%]	CBD [%]
Cannabis	1–20	<0.5
Intermediate	0.3–2.0	>0.5–2.0
Hemp	<0.3	>0.5

Cannabinoids are organic compounds that act on special cannabinoid receptors in the endocannabinoid system in the human body [45]. It is an important system involved in many physiological processes, responsible, among others, for the regulation of energy management, neurohormonal and neuroimmunological connections, affects mood, motivation, motor activity, hunger, and regulates carbohydrate and lipid metabolism [46,47]. THC is the main psychoactive substance in cannabis and is soluble in fats and alcohols [48]. It exhibits antipsychotic properties and can reduce the symptoms of anxiety [49,50]. Although research on the properties of cannabinoids and their impact on the human body is still ongoing, their metabolism, properties, and interactions with other drugs are not

fully understood [51,52]. THC and CBD, along with dozens of other cannabinoids, are increasingly used in medicine, including the production of medicines [53,54].

A relatively new but increasingly popular topic is the use of hemp products in broadly understood gardening (vegetable production, orchards, green areas, and hobby gardening). Hemp shives are used as mulch, successfully replacing the bark. Such mulch, similarly to the traditional one, maintains moisture in the soil and prevents the growth of weeds. Hemp shives have a neutral pH, are fully biodegradable, and decompose, enriching the soil with humus [55,56]. Mats made of technical, or waste, hemp fiber also have similar properties. Just like hemp shive mulch, they are used in flowerbeds or in rows of trees in an orchard, protecting the soil against drying out and weed growth, replacing polypropylene mats. Hemp fiber mats also have thermal insulation properties, which help to heat the soil in the spring and protect against freezing in the winter. They can be used on slopes, additionally preventing erosion. These mats are also biodegradable [57,58].

Another application of hemp, which is becoming very important due to the growing demand for innovative and sustainable products and technologies, is the use of raw hemp material for the production of bioplastic. Plastic is produced from petroleum-derived materials, which, due to their expected depletion and environmental protection, have been intensively tried to be replaced with natural products, preferably completely biodegradable, in recent years. Plastic is used in virtually every industry and in every area of life, but mostly as all kinds of food packaging—almost 40%; in the construction industry—over 30%; and in the automotive industry—approx. 15% [59].

However, there are possibilities to replace this unfriendly and non-degradable product with a much more sustainable and fully degradable bioplastic. It can be made from plants such as potatoes, rice, wheat, corn, bananas, and sugarcane, which are rich sources of starch. Numerous researchers have also undertaken experiments related to the production of plastic from hemp-derived material, creating various types. Additionally, "traditional" plastic in packaging materials can already be replaced with hemp paper laminated with xylan, PEG, glycerol, and citric acid [60,61].

A biodegradable, biocompatible, and non-toxic polymer—poly(3-hydroxybutyrate)—was also created. The possibility of its production using hemp shives as a source of carbon from sugar hydrolysates was examined. Researchers believe that this polymer can be competitive with plastics derived from fossil fuels, and the method of its production can be easily adapted to an industrial scale [62]. Bioplastic is used, for example, in packaging materials or in the production of gardening equipment [63].

The above short summary demonstrates only a part of the uses of hemp, but at the same time, it shows how versatile plants are and in what diverse industries they are used. It also shows that any part of the plant can be used. In addition to the main purpose for which the plants are growing, other products—parts of the plant that would be wasted—can be effectively utilized, e.g., for the production of biofuels.

5. The Use of Hemp Biomass for Biofuels Production

The need for rational use of energy resources and a significant reduction in fossil fuel consumption in favor of sustainable renewable sources has been noticed for years and is reflected in legislation, both EU and national. Biofuels derived from plant biomass are mentioned in many documents and legal acts concerning long-term energy strategies. Therefore, it is highly justified to search for and develop solutions leading to the most effective use of this source of green energy.

Biomass, both plant and animal, is regarded as an alternative energy source to fossil fuels. Even though significant amounts of energy are needed for their production and processing, their energy management is less inconvenient for the environment than the use of petroleum, lignite, or hard coal [64–66]. This is due to its absorption of CO_2 during plant growth, which significantly reduces the overall balance of the impact of biomass production on the ecosystem [67,68]. Plant biomass can be used to produce solid, liquid, and gaseous biofuels (Figure 6).

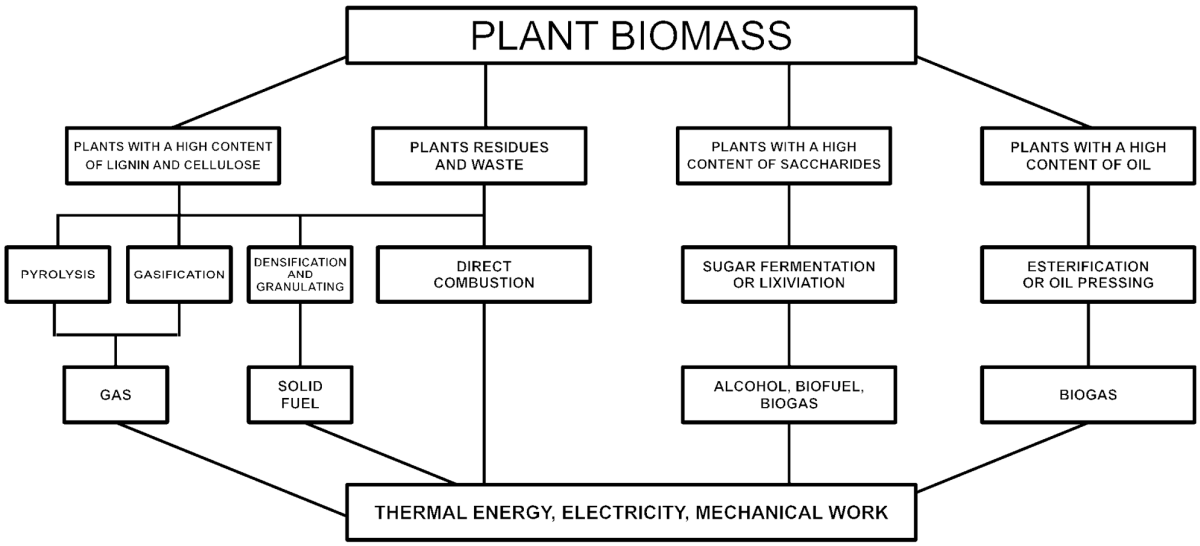

Figure 6. Schematic of using hemp biomass for energy purposes [69].

The figure below shows the structure of industrial hemp cultivation in Europe (Figure 7).

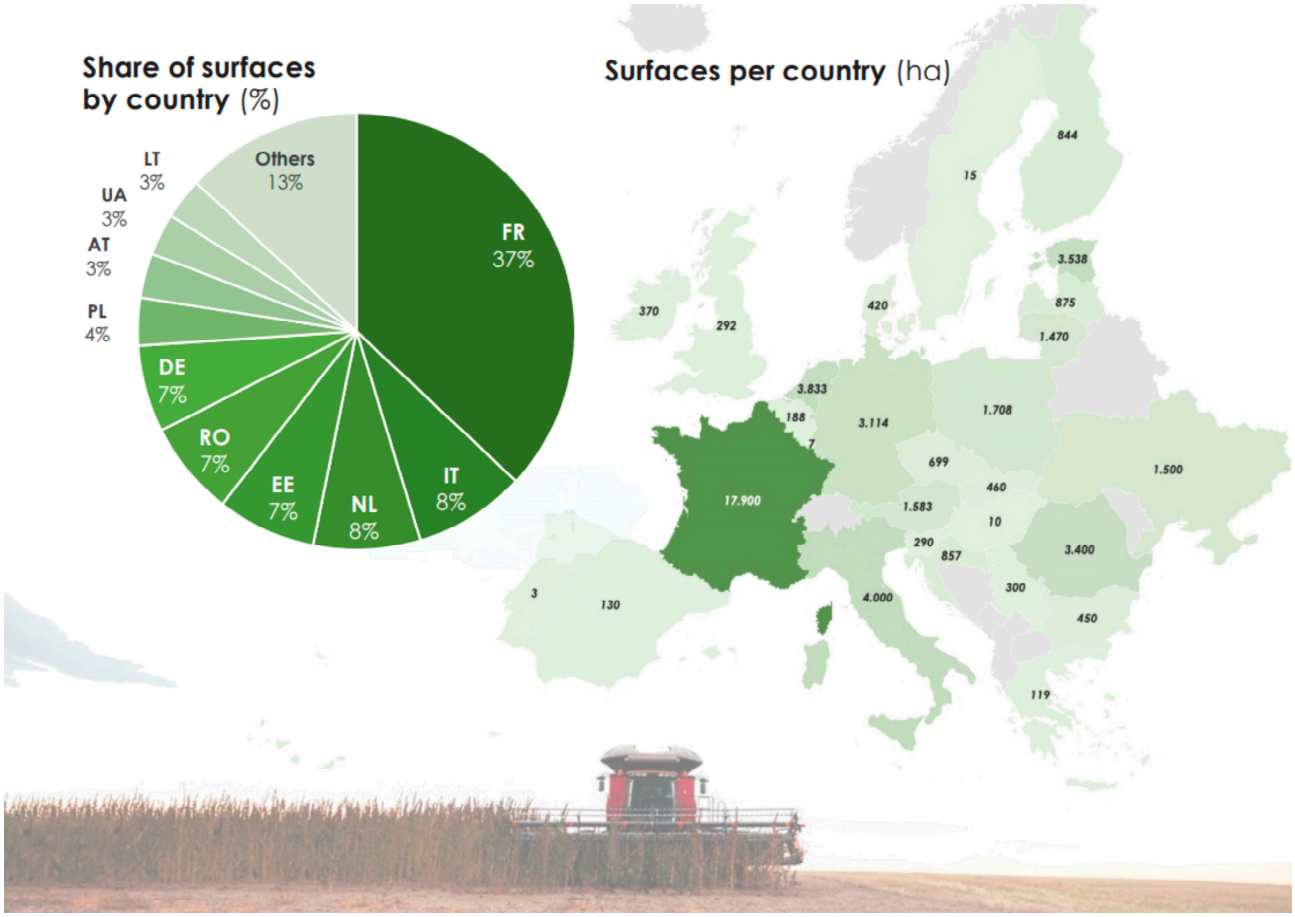

Figure 7. Hemp cultivation area in Europe in 2018 [10].

According to various sources, the average yield of hemp straw, depending on the variety, climatic and soil conditions, and type of plantation, ranges from about 10 to 20 t·ha^{-1} [13,70]. Hemp biomass can be used to produce solid as well as liquid and gaseous biofuels (Figure 8).

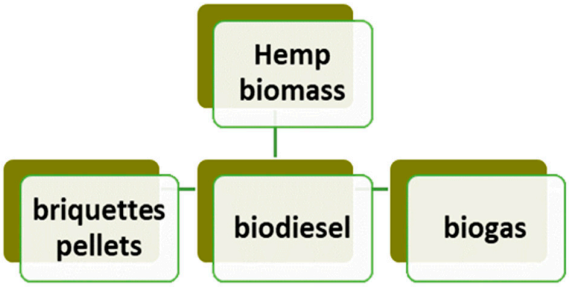

Figure 8. Schematic of the possibility of using hemp biomass for the production of biofuels [71].

For solid biofuel production, waste biomass from various types of processing or from energy crops with a high content of lignocellulosic compounds is usually used. The most commonly produced solid biofuels are briquettes and pellets. They are intended mainly for combustion in household stoves [72–74].

Hemp biomass, which is waste from hemp cultivation for various purposes, e.g., seed, food, cosmetics, or pharmaceuticals, can be successfully used for the production of solid biofuels. For example, in cultivation for seed or grain, whole stalks and threshing are waste; in fiber crops, they are shives, respectively.

The hemp biomass at 8.5% humidity has a high content of cellulose—more than 40%—and hemicellulose—almost 30% (Figure 9), which makes it a valuable material for solid biofuel production, such as pellets or briquettes. In addition, hemp biomass heat of combustion is 18,300 kJ·kg^{-1}, and the calorific value is 17,100 kJ·kg^{-1} [71]. The heat of combustion of hemp biomass is higher than the heat of combustion of other popular energy crops such as *Hibiscus cannabinus* (15,800 kJ·kg^{-1}), *Riparioside hermaphrodita* (17,200 kJ·kg^{-1}), and *Brassica napus* var. *napus* (17,600 kJ·kg^{-1}). Nevertheless, the calorific value is slightly lower than the calorific value of *Triticum* straw (18,700 kJ·kg^{-1}) [75]. Solid biofuels from hemp biomass have a higher energy yield compared to other hemp biofuels such as biogas and liquid biofuels [76]. They can also be produced and used locally, even on individual farms or by small groups of farmers in the vicinity of hemp plantations.

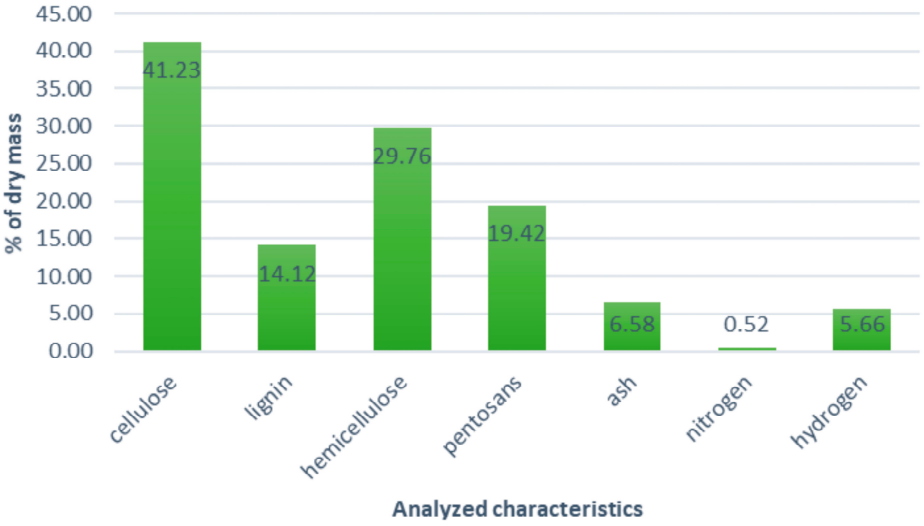

Figure 9. Henola variety biomass chemical composition [71].

Liquid biofuels are substitutes or additives to diesel oil [77]. In Poland, biocomponents are not used themselves [78], due to the low temperatures in winter, which could freeze the fuel in the tanks [79,80]. The use of biofuels may have a lower environmental impact than the use of diesel [81]. Nevertheless, the production of liquid biofuels is energy- and cost-intensive; hence, numerous studies have been conducted in the field of optimizing production efficiency and minimizing bioethanol production costs [82–85].

Due to its high cellulose and low lignin content, hemp has promising potential for bioethanol production. The co-production of ethanol and methane has a slightly reduced yield (163–188 $L \cdot Mg^{-1}$), but it also provides 175–181 $m^3 \cdot Mg^{-1}$ of methane as a by-product. Similar amounts of bioethanol are obtained from hemp as from *Hibiscus cannabinus*, *Panicum virgatum*, and *Sorghum*, but these plants are characterized by greater profitability while co-producing grain [86,87].

The research on the new 'Henola' hemp cultivar showed that the yield of straw ranged from 10.6 $Mg \cdot ha^{-1}$ to 11.3 $Mg \cdot ha^{-1}$—in the case of the control object and using complex fertilization with NPK, respectively. In the analyzed samples, the average content of cellulose was 35.5%, holocellulose was 68%, and hemicellulose was 32%. In turn, the amount of lignin turned out to be independent of the type of fertilization. The lowest bioethanol content, 7.11 $g \cdot L^{-1}$, was found for hemp fertilized with NPK, and the highest, 9.93 $g \cdot L^{-1}$, for hemp fertilized with P and K, for which the ethanol yield converted to straw yield was 2.7 $m^3 \cdot ha^{-1}$ [88]. In other studies about the optimizing chemical and enzymatic treatment of Henola's biomass, an ethanol content of 10.51 $g \cdot L^{-1}$ was obtained [89].

The so-called 'first generation' biofuels, which are produced from starch and sugar, do not seem to be a sustainable solution due to the potential burden that their production places on the food industry. 'Second generation' biofuels, made from inexpensive and abundant plant biomass, are seen as a much more attractive option. However, the full use of their potential still requires overcoming many technical problems [90].

Biogas is produced during the transformation of biomass in anaerobic biological processes [91]. The most frequently used and most effective method of biogas production in industrial conditions is methane fermentation. It is carried out under strictly defined conditions in special reactors [92]. The resulting gas mixture consists of about 2/3 methane and about 1/3 carbon dioxide [75,93]. Many different organic substrates are used for the production of biogas. Biomethane is most often produced from maize silage and animal manure. Increasingly, biowaste and waste plant biomass are also used for this purpose [94,95]. The possibilities of producing fuels from plant biomass are the subject of intensive research and have been implemented for years. The results of this work clearly indicate that this is a prospective direction that already brings measurable benefits to both the environment and agricultural producers. However, it requires further research in order to optimize biofuel production processes as well as search for biomass sources that are most favorable in terms of energy efficiency and at the same time have the least impact on the environment.

Industrial hemp biomass can also be used to produce biogas. *Zea*, ×*Triticosecale*, *Helianthus*, and *Sorghum* are energy crops often used as raw materials for processing in anaerobic fermentation processes, mainly due to their high biogas potential. Hemp cultivation has negative environmental impacts due to changes in land use. Therefore, it is important to look for alternative species with a lower environmental impact that allow the production of comparable amounts of biogas with similar energy efficiency. Industrial hemp is a highly competitive raw material in relation to the currently used energy crops [96]. From one hectare of hemp cultivation of the Henola variety, 630 m^3 to 783 m^3 can be obtained, depending on the sowing density [20].

Worth noting is also the topic of fifth-generation fuels from in vitro cultures. Currently, this method of obtaining biofuels is perceived as one of the most promising and environmentally friendly. The innovative use of industrial hemp callus in research allowed us to obtain a high-quality bio-raw material consisting mainly of ketones and alkenes. The yields of fuels from leaf obtained from in vitro-grown plantlets were, under optimal conditions, 3.17% for light naphtha, 11.1% for naphtha, and 36.03% for biodiesel. The most important advantages of fifth-generation biofuels include the ability to modify the content of lignin in plants, the ability to produce high-quality biofuels from modified calli samples, and the fact that callus cultures do not have a negative impact on ecosystems and the environment because their competition with the food and feed industries and arable land is avoided [97].

To sum up, hemp biomass has a very high energy potential and can be used in the production of liquid, gaseous, and solid biofuels. However, a much more cost-effective and sustainable solution is to use waste biomass left over from another type of main crop, e.g., for seed material and grain or panicles to extract CBD essential oil.

6. Social and Economic Aspects of Hemp Cultivation

Agriculture is a special type of economic activity closely related to the natural environment and providing products of strategic importance for the functioning of communities. Farms, apart from their production functions, also have an important role in shaping the natural environment [98]. Fiber plants (including hemp) and herbal plants are a group of alternative crops that facilitate the diversification of agricultural income sources and have a positive effect on long-term crop rotation. Farms oriented toward specialist production may produce hemp under contract or technological cooperation with industrial processing enterprises [99].

According to the authors of the Polityka Insight platform report, in 2019, Polish farmers income from industrial hemp cultivation amounted to over EUR 8 million, and most of it remained in farmers' pockets due to relatively low cultivation costs. The estimated value of revenues of CBD processing companies exceeded almost EUR 49 million in 2019, of which domestic micro-companies accounted for about two-thirds. Smaller companies were primarily involved in the production of simple products such as CBD oils, while larger ones mainly produced cosmetics and food. The hemp industry is highly fragmented. Most processors and sellers are micro-companies employing several people. Companies with a crew of more than 10 people are a rarity, and most of them are in the hands of foreign capital [100].

Nowadays, hemp cultivation is becoming more popular for economic reasons. Hemp plantations are profitable for both large companies and private farmers. Extending cultivation to include processing may significantly improve the financial situation of smaller farms.

7. Current Problems in the Hemp Industry

Currently, one of the major problems is the effective mechanical harvesting of fibrous varieties, which is caused by the thickness and hardness of their stems [101,102]. Another problem is the effective collection of whole plants from the field and their comprehensive use. Farmers picking flowers usually must leave the stem in the field because there is no company nearby that will process it into products made of straw, such as hemp concrete or biocomposites. Local enterprises dealing with comprehensive hemp processing should be established because transporting the stem over long distances is unprofitable.

Each part of the harvested hemp plants can be processed into bioenergy, and this biomass is a valuable raw material for the production of solid, liquid, and gaseous biofuels. The use of agricultural lignocellulosic resources as renewable energy sources is constantly growing. This allows increased development in rural areas and causes their social and economic recovery. However, effective technology for processing lignocellulosic raw materials into biofuels remains a problem. Developing methods of obtaining biofuels from waste hemp biomass should contribute to wasteland management, reduce emissions of greenhouse gases, and provide effective technological solutions, along with improving the stability of fuel prices in the future [71,88,103]. It would also be invaluable to standardize the regulations on the cultivation and processing of hemp in the European Union countries, which would greatly facilitate cooperation between farmers and entrepreneurs or, for example, the creation of hemp cooperatives in border areas.

8. Summary and Conclusions

The diverse nature of hemp varieties allows it to be used in the production of not only food products but also cosmetics, medicines, building materials, and reusable biomaterials suitable for recycling and composting. Hemp is a natural and sustainable source of natural fibers and many other products. Industries from every branch of the economy are interested

in hemp raw materials. As a result, the by-products of hemp cultivation can be used as secondary raw materials, which will significantly reduce the amount of post-production waste generated.

The studies on the possibility of using waste hemp biomass as a raw material for the production of biofuels are the answer to the search for pro-ecological solutions in the economy in the field of plant waste biomass management and the recommendations of the European Union for supporting the development of renewable energy. The results of scientific research indicate that biofuels made from waste biomass have satisfactory energy potential. Moreover, this sustainable use of the raw material is a cost-effective solution that simultaneously improves the environment.

Due to the low agrotechnical and cultivation requirements as well as the specific biological properties of hemp, these plants can be grown almost anywhere. The low demand for fertilizers and plant protection products makes crops environmentally friendly. A large number of varieties with different properties allow for the selection and adaptation of the crop to the farm's capabilities and local market needs. All this makes hemp an excellent alternative to traditional crops and a valuable change in crop rotation.

The essence of the concept of sustainable development is to ensure a permanent improvement in the quality of life of current and future generations through a balance between the development of economic, human, and natural capital. Considering the above, it can be said with certainty that both the cultivation of hemp and the use of hemp raw materials are the right actions to reduce waste production and transition to a circular economy, which perfectly fits into the idea of sustainable development. However, as the LCA has shown, when growing hemp, attention should be paid to the purpose of the cultivation. It is, therefore, appropriate to conduct research on the effective harvesting and processing of hemp and, at the same time, to make efforts to introduce regulations that will make it easier for growers and processors to set up plantations and cooperate toward the effective processing of whole plants. However, their utilization through the production of bioenergy, e.g., biogas or bioethanol, may be a rational and effective option for managing this waste biomass. Moreover, the future outlook for hemp investigation should concern hemp root usage in the bioeconomy. So far, they are mostly unharvested, and they show great potential, for example, in medicine.

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