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Review Article

Towards Sustainable Use of Peat and Wise Management of Peatlands: Bog and Peatland Research in Latvia During a Century

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Abstract

Peatlands (bogs and mires) cover >10% of the territory of Latvia, they are essential element of landscape and traditionally have been used for extraction of peat. Peat was identified as a resource of national significance after foundation of Republic of Latvia in 1918 and intensive research on peat composition and evaluation of its resources started. In 1936 Peat Institute was founded. After II World War research of peat expanded and new applications was elaborated. During last 30 years the peatland research in Latvia has concentrated in following directions: 1. Studies on peatland ecosystems and development of their protection system; 2. Restoration of abandoned peat mining sites. Development of sustainable peatland management strategies and applications; 3. Paleoecology of peatlands, studies of climate variability, hydrological regime, human pollution impacts on peat composition. Peatland fire impacts; 4. Greenhouse gas emissions from peatlands; 5. Applied research of peat mining technology development. New peat applications and products. Peat mining economy; 6. Innovation in peat applications: peat for production of sorbents, peat humic substances, peat activated carbon, use of low moor (black) peat. Peatland and peat research support sustainable management of peatlands as well as innovation in peat application with reduced environmental impact and possibilities to further develop use of this important resource.

Keywords: Peat; Growing media; Horticulture; Energy; Export

Peat as a Resource of National Significance in Latvia

In Latvia, peat is a national treasure. There are 11.3 billion cubic meters (1.7 billion tons) of peat in Latvia's peatlands, which span 9.9 percent of the country's land area [1,2]. Peat was an important aspect of the national economy in the 20th century, and it is still widely used today. There have been substantial social, economic, and political changes in Latvia between 1920 and 2020 that have resulted in a significant shift in the country's peatland use from extraction to other uses (LKA, 2019). Peat has been used as a fuel in homes since at least the Roman era, when it was mentioned. During the 12th century, peat became a major source of energy in Europe, particularly in countries like Ireland and Scotland where trees were rare. Germany invented a method for gathering and crushing peat into little bricks in the nineteenth century, and it is still in use today in many nations.

When Duke Jacob ordered peat to be used as a fuel in addition to firewood to save trees, peat extraction in Latvia is generally thought to have begun in the late 17th or early 18th century, according to historical records. In the early part of the twentieth century, however, large-scale peat extraction was initiated for the purpose of heating and bedding [3,4]. There were seven million tons of peat gathered between 1960 and 1990. In addition to other uses, peat was utilized as an energy source for the operation of the peat-fired thermoelectric power plant TEC-1 erected in Riga in 1958, which was heated with peat [5,6].

When Latvia's socioeconomic system shifted in 1991, state farms and collective farms were disbanded, having a significant impact on the peat extraction business, they were abolished. Due to lack of demand and antiquated gear, the amount of peat extracted dramatically decreased. Former state-owned firms were privatized and ways were explored to modernize peat mining and processing technologies, to seek new markets, and to attract foreign investors. As a result of the demands and requirements of the European peat market in the 1990s, the industry began to use peat for horticulture applications. In 1993, the amount of peat removed began to rise, and by 2003, exports of peat had surpassed domestic consumption.

The transition to a "green economy" and the implementation of climate change mitigation measures are having the greatest impact on the peat extraction industry right now. Currently, the EU's Paris Climate Agreement sets a 2030 goal of at least a 40% decrease in greenhouse gas (GHG) levels compared to 1990. It is now expected that emissions will be cut by 50% in 2030 and totally eliminated in 2050 as part of the European Green Deal framework.

The extraction of energy peat is a high-emissions activity in the peat extraction sector. There is a worldwide trend to stop extracting peat for the energy industry and instead extract peat for horticulture and high-value-added product reasons. Reorganization and restructuring are needed in many countries that have primarily exploited peat for energy purposes. While socioeconomic and political situations in Latvia have changed over the past century, this study tries to describe the peat industry and peat research progress in Latvia.

Peat Mining Industry in Latvia and its Development

It was discovered in a study that the average annual accumulation in the Baltic region during the last 200 years was roughly 2millimeters [7]. Since 1991, the country's peat resources have increased on average by 0.79 million tonnes per year and 22.91 million tonnes since the beginning of the study (1991-2019), which means that the country's peat resources have increased on average by 0.79 million tonnes per year and 22.91 million tonnes since the beginning of the study (1991-2019). Peat is abundant in Latvia and is critical to the country's economy. It has been used for a variety of purposes over the years. Peat has been used in Latvia for heating, bedding, dry toilets, product storage, insulation materials, and agriculture since the 16th century, according to recorded evidence [5,6]. Peat is now employed in health, beauty care, textiles, paper manufacture, biosorbents, feed additives, building, art, and more.

Latvia became aware of this issue as peat litter production increased in Western Europe during the 1880 and 1890s. As a result, litter peat and litter production enterprises were established in 1912, and the cutting of peat for litter manufacturing developed [8]. After Latvia gained its independence, the Peat Utilisation Board was formed, and large-scale peat production for energy began [9]. After Latvia got its first dredging machine from the United States in 1924, extensive river control and excavation of main ditches began in all major river basins, the extraction of bigger volumes of peat began [8].

Latvian mires were nearly solely owned by the state at the time. Long-term or annual leases were preferentially offered to enterprises and private people. In 1936, a firm in Ploi Mire began making peat insulation boards [10] . Bedding and fuel peat were the two most popular uses of peat in the years prior to 1940 [11]. The amount of peat extracted increased greatly between 1960 and 1990, as demand for electricity peat and agricultural peat rose dramatically (Figure 1).

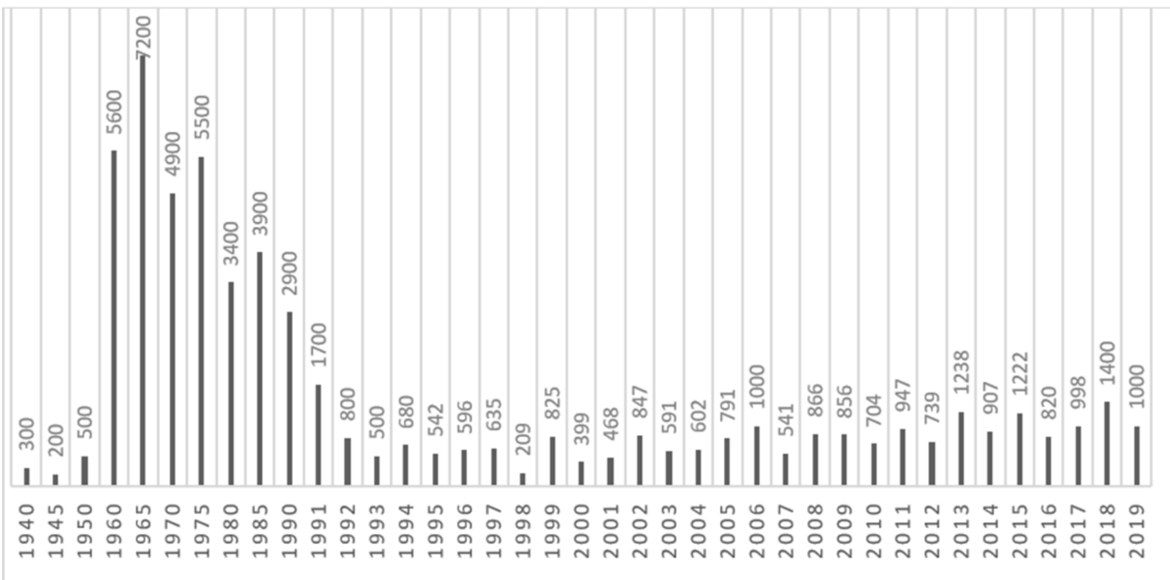

Figure 1: Amounts of peat extracted in Latvia from 1940 to 2019, thousand tonnes per year.

In 1958, Riga's TEC-1 plant was completed, which required peat for its functioning. There were a number of factories built (in Seda, Struni and Zilaiskalns) for the extraction of energy from peat as a result. The Sloka pulp and paper mill was the second-largest consumer of milled peat [5]. Additionally, agricultural peat was increasingly being extracted in the early 1960s for use in bedding and fertilizer formulations. Peat extraction was well established in the 1970s, with more than 100 deposits being exploited. A total of 4.3 million tonnes of peat was harvested each year, which was utilized for bedding as well as compost and as a fuel.

State and collective farms, Latvia's major peat consumers, were gradually phased out, causing a steep collapse in the country's peat extraction industry in 1991. Peat companies were privatized as part of a reorganization of the state. A shift to peat extraction for horticulture reasons began in the late 1990s. It takes a long time to turn a profit in the peat extraction industry since it requires significant upfront expenditure. A large number of foreign investors came to Latvia during this period, with experience in the horticultural peat trade, as well as the ability to invest and begin mining agricultural peat.

Peat extraction began to rise again in 1993. A stabilization of the industry has taken place over the past 20 years, and today fluctuations in peat extraction are largely influenced by weather and precipitation levels during the season. TEC-1 was reconstructed in 2003 and no longer relies on peat for its functioning, causing a significant drop in the use of peat for energy in that year. The vast majority of peat collected in Latvia since 1998 has been used for agricultural uses (mostly horticultural) (Figure 2).

Extraction volumes and use kinds from 1990 to 2019 are shown in Figure 2 (thousand tonnes). The peat consumption market evolved along with the industry's shift in focus. Extracted peat was used locally until 1993 when export markets began to grow and by 2000 more than 90% of the peat resources extracted in Latvia were exported. Export volumes began to surpass extraction volumes in 2003, showing an increase in expanding media production. Instead of relying on energy peat extraction in the same way as other peat-extraction countries such as Estonia, Finland, Sweden and Ireland, Latvia first restructured its peat extraction sector. The vast bulk of peat is still mined in the aforementioned nations for energy purposes (Table 1).

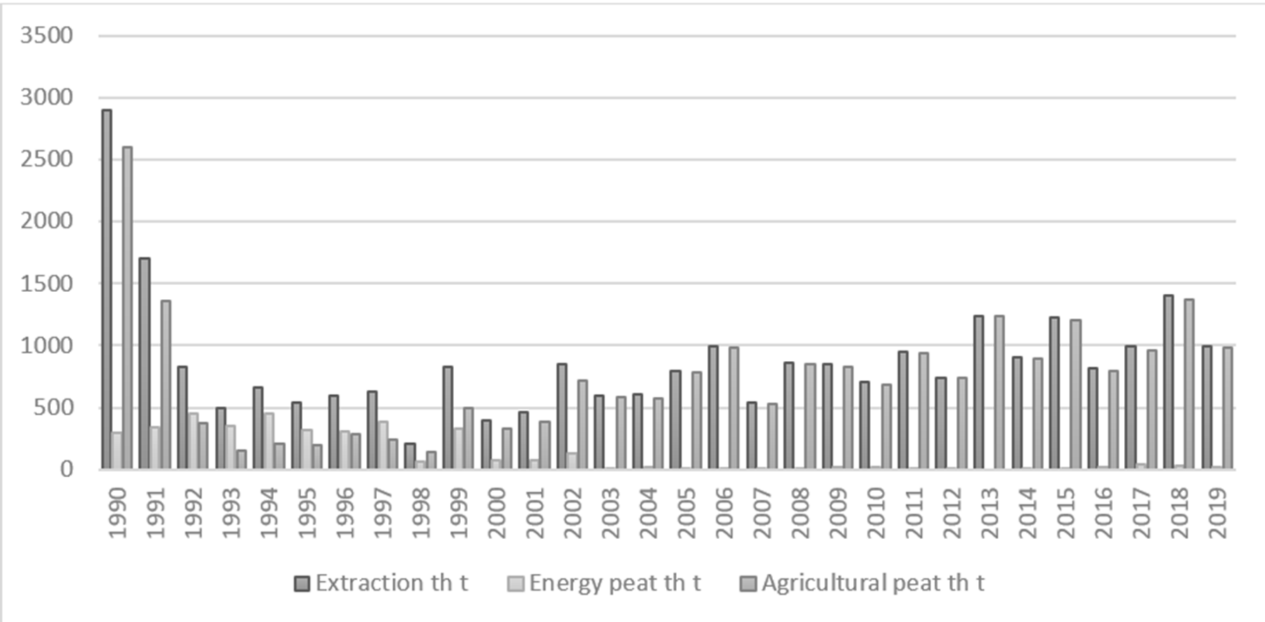

Figure 2: Volumes of peat extraction and types of use from 1990 to 2019 (thousand tonnes).

Table 1: Peat extraction volumes and purposes in 2017 in various EU countries.

Country	Peat Extraction, thous. m^3	Horticultural Peat, thous. m^3	Energy Peat, thous. m^3
Ireland	17,100	4,100	13,000
Sweden	3,100	1,700	1,400
Finland	11,097	1,000	9,500
Estonia	3,784	2,648	1,135
Latvia	4,988	4,900	88
Lithuania	2,500	1,788	712

An estimated 55% of European Union peat extraction was used for energy production, 37% for horticulture, and 8% for other uses in 2017, according to the International Peat Society (Figure 3). In 2019, 95% of the peat harvested in Latvia was used for horticulture, 4% for energy production, and 1% for other reasons. in Latvia Because of the global trend toward reducing greenhouse gas emissions, the use of peat for electricity has historically been favorable for Latvia's peat extraction industry. European Union energy regulations classify peat as a fossil fuel source. Because of this, countries have agreed that the use of peat as a source of energy must be gradually phased out in order to limit greenhouse gas emissions. In nations where peat is primarily used for energy, this has a significant impact.

Figure 3: Use of peat extracted in the EU (A) and in Latvia (B) in 2019.

Due to a shift in its economy at the dawn of the new century, Latvia has the best prospects for generating peat. We now solely extract horticultural peat, which is used for growing food, ornamental plants, and other crops.... Plants grown in peat-growing media (peat substrates) trap GHG emissions that would otherwise be released as a byproduct of peat use. Peat can be used to grow 6,000 seedlings of trees, which can be used to plant 3 acres of forest and capture 1110 metric tons of CO_2 over the course of 50 years. Peat substrates can be utilized to enrich the soil after they have been employed in plant culture, allowing for greater plant development and absorbing more GHG emissions.

To some extent, the abundance of energy peat in countries where it is mined may account for statistics inaccuracies that have harmed EU member states as well as EU and international rules. As a result, climate policy documents that view peat primarily as an energy source may be affected. Peat is classified as an energy product by the Combined Nomenclature (hence – CN) when it comes to international trade data ("Chapter 27. Mineral Fuels, Mineral Oils and Products of Their Distillation; Bituminous Substances; Mineral Waxes", code 2703). Peat and coal are mentioned in the CN's description. As there is no other nomenclature in this nomenclature, enterprises exporting peat and peat products (substrates) must declare these exports using this nomenclature. Current data on peat use in Latvia, the EU, and internationally is inaccurate. There is therefore no fulfilment of the CN's objective, which was to provide internationally comparable statistics on international trade.

History of Peatland and Peat Research in Latvia and Current Tendencies

The peatlands in the territory of Latvia have been studied already before the First World War, however, the wider research of peatlands started in 1919, when the at Agriculture faculty at the University of Latvia was established the Department of Peatland and Peat Use was established. Systematic research of Latvian peatlands was started in 1926 when the Peatland and peat research laboratory of the University of Latvia started systematic surveys of the largest peat deposits. The research mainly covered bogs with an area of >50ha. Already in the field studies, all peat profiles were studied by using the L. von Posta scale, determined the main peat properties-moisture, colour and the degree of decomposition, but in the laboratory were determined the peat botanical composition, the degree of ash content and pH [12,13]. During the study, coring and sampling were performed to determine the properties of the peat.

The works were supervised by the outstanding Latvian scientist academician prof. Dr P. Nomals (1876-1949), who spent 40 years of his life researching Latvian peatlands. P. Nomals studied bog chemistry and stratigraphy, water regime, drainage potential, peat composition, peat agronomic and technological properties, as well as bogs and peat usage problems. He did his research results have been compiled in many scientific works, including in his doctoral dissertation "The quantity and grouping of water, minerals and nitrogen in Latvian peatlands", which became the basis for future Latvian bogs and their deposit research [4]. The results of these research have not lost their relevance today. Within the framework of the Institute of Peatlands and the Institute of Marshs of the Academy of Sciences of the Latvian SSR, versatile research was carried out, including topographic surveying, sounding and sampling of peat deposits in a regular network, and laboratory research into the possibilities of mire drainage. The purpose of the research was to prepare projects for the extraction of peat [10]. The obtained data was collected, and a Peat Fund of Latvia was prepared in 1948 and then and then the second supplemented edition in 1962, which includes information on all surveyed deposits. and contains a description of the peatlands and a map of the peat deposits [14].

Due to the expansion of the use of peat in collective farms, in 1950 the government of the Republic instructed the Latvian Hydrotechnical and Amelioration Research Institute (then the Amelioration Institute of the Academy of Sciences) to identify peat deposits of agricultural significance. The task was performed by conducting systematic surveys of the republic's peatlands, performing peat search routes. During the works, deposits with an area of more than 1 ha were inspected [3].

In 1978, the Peat exploration department was established in the Geological Survey under the Complex Geological Survey Expedition to search for peat deposits, audit and identify peat forecasting resources by administrative districts throughout Latvia. The works in most districts have been performed according to a common methodology [3].

In addition to applied research for the needs of the peat extraction industry, research carried out at the University of Latvia, which includes both classical physical and chemical, lithological and paleobotanical methods, uses a wide range of interdisciplinary scientific methods in the research of Latvian bogs [15-17]. Based on the data of peat botanical composition and spore-pollen analyzes, which generally well reflect the vegetation of the time, its peculiarity, the stratigraphic division of bog deposits and the sequence of the most important paleo-geographical events, the nature of environmental conditions at that time, which affects the nature and intensity of deposit formation. Many studies were paid to the nature of the development of raised bogs and the processes of microrelief formation, as well as the dynamics of peat accumulation [7,15,16,18].

One of the directions of such complex research is archaeological-paleogeographical-paleoecological research projects, in the framework of which Stone Age settlements are found and studied to find out how ancient man lived according to nature, what their interactions have been. The Middle Stone Age (Mesolithic) and Late Stone Age (Neolithic) people were characterized by the lifestyles of hunters, fishermen and plant collectioners, so they chose to live near the waters that provided them with food for fish, animals and waterfowl, as well as forage [19,20].

Research on peatlands is unthinkable in the future without the use of interdisciplinary methods and interdisciplinary cooperation between them, the aim of which is to promote research into a natural resource important to Latvia - peat, by effective peat mining technology development, new peat applications and products, peatland recultivation and developing innovative solutions for its use [21,22].

In recent decades, with the rapid development of peatland and bog research, a significant number of specialists have been trained to defend their dissertations (for example, I. Silamiķele, J. Krūmiņš, I.Ozola, O. Purmalis, etc.) as well as to participate in both local and international projects, including "Interdisciplinary team of young scientists for research of bog resources, sustainable use and protection in Latvia (PuReST), ERDF Project „Innovation in Peat Studies for Development of New Applications", Latvian Environmental Protection Fund project "Analysis of the quality of data on peat deposits data in Latvia, preparation of recommendations for their improvement and use in preparation of the basic strategy documents", etc. Since 2019 the project "Investigations of the environment affected by bog fires and the intensity of bog regeneration" is ongoing. The results of the research have been published both in highly indexed international journals and in collections of articles, e.g. "Peat and sapropel - synergy of production, science and environment in the context of effective resource use" [23].

Nowadays predictions of climate change suggest that extreme weather events will become more frequent, and this will introduce adjustments in agriculture, water and also peatland management. Therefore, throughout the world, including Latvia, the role of scientific studies and, above all, the role of action for climate change mitigation is increasing. For the first time in Latvia, with the involvement of scientists and practitioners, greenhouse gas emissions from abandoned peatland areas and also former peat extraction sites have been evaluated in EU LIFE programme "Sustainable and responsible management and re-use of degraded peatlands in Latvia" implemented by Nature Conservation Agency and partner organizations is the first project in Latvia under Climate Action sub-programme [24]. During the project, the areas affected by peat extraction in Latvia were surveyed, and the information about degraded peatlands where reclamation is necessary was summarised [25]. For the first time in the Baltic states, national greenhouse gas emission factors were determined. In the framework of the project, several reclamation types in extracted peatlands were tested [26]. Not only conservation of natural mires but also restoration of degraded peatland ecosystems is highly important to preserve the biodiversity and ecosystem services for generations to follow.

Peat studies in Latvia has rich history, they include extensive research in both natural mires and in peat extraction sites and cover not only peat characterization, but also suggests new and alternative fields of peat use [27,28]. Recent peat studies in Latvia are related not only to the raised bog peat, but also to the fen peat research, which is comparatively much less researched topic in the world and therefore is of high scientific interest. In these studies, various fens with varied formation and development conditions in different regions of the country have been selected as the research objects so they could be compared with each other, but at the same time also the general development of fens in the boreal region could be described. In addition, fen peat has been compared to raised bog peat to find out if there are any major differences in their properties, given the significantly different conditions of the formation and development. For instance, fen and raised bog peat have been compared using Fourier transform infrared spectra, differential thermal analysis and thermogravimetry with the results giving obvious indications of a different chemical composition [29,30]. Moreover, peat properties, including fen peat properties, in Latvia have also been studied in regard to its high potential in sorption of hazardous elements and to extract humic substances, benefits of which are known for centuries [31-33].

One of the more extensive studies in regard to fen peat research in Latvia was done in the second decade of the 21st century (from 2011 to 2016), where the influence of peat composition on metallic element accumulation in fens was studied in depth [21,34-37]. This work was associated with a detailed study of fen peat characteristics and metallic element concentration and included the use of new and advanced methods in the characterization of peat. For the first time in fen peat studies, the three-dimensional fluorescence spectroscopy had been used, which gave the opportunity to describe peat organic matter in higher than before detail. This study also included trials with biosorption of metallic elements onto fen peat to evaluate its potential as sorbent material, which gave reasonable results [38].

The latest research on fen peat in Latvia was carried out within the post-doctoral research project 'Fen peat in Environmentally Friendly Technologies' from 2017 to 2020, led by lead researcher Dr. geogr. Janis Krumins. The scientific idea of this project was to explore fen peat and its components in detail in order to promote its use, especially in environmentally friendly applications and technologies [39,40]. In this project, fen peat was studied in depth both in terms of its properties and in terms of the specific characteristics and regularities of fens [41]. In this respect, fen peat formation and further development has been evaluated based on a variety of factors, such as stable carbon and nitrogen isotopes or fluorophores within fen peat humic acids [42]. Another recent aspect of fen peat studies in Latvia and peat research in general included burnt peat studies to evaluate impact of wildfires on further mire development and peat properties [43]. In addition, the legal procedure of peat extraction in Latvia was described in detail. Fen peat research also included recommendations for peat use in high added-value products and applications, such as in agriculture, horticulture, environmental remediation, medical and veterinary applications and others. Furthermore, these studies also included in-depth fen peat humic substance research and application selection, such as in soil erosion control, wastewater treatment or sorbent preparation and many others [44,45]. In addition, due course, numerous advanced research methods, such as three-dimensional fluorescence analysis combined with parallel factor analysis were configured to apply to fen peat studies and offered to students and researchers as a guide in fen peat research methods [46].

Prospects of Peat Industry and Research in Latvia

The peat extraction sector in Latvia has been influenced by political, economic, and ideological reasons. In contrast to other European countries, Latvia only used peat for energy for 30 years before shifting its focus to other sources.

For example, bedding peat's development, use in heating homes and for TEC-1's operation system have had an impact on peat use in the peat business.

Factors that influence the peat business:

A. The First World War, Latvia's independence from Russia, Soviet rule, its second independence (in 1991), and foreign investors all contributed to the decline of peat production in Latvia.

B. Sociological reasons include the development of worker competence and technological advancements as well as European Union membership.

As in other nations, peat extraction in Latvia has predominantly been for horticultural purposes (95 percent) for the past 18 years. It has already been renovated to satisfy the climate needs of the peat extraction sector in Latvia, which is a substantial improvement over that of other countries.

Peat resources have been politicized because of the EU's heavy use of peat as a source of energy. Despite the fact that it is a slowly replenishing resource, it is included in the category of fossil resources in the energy industry. Peat, according to the Combined Nomenclature's foreign trade data, is also an energy product. For horticultural peat and for energy peat, there should be different methodologies and regulatory frameworks.

The peat market's structure has evolved through time. Peat was utilized for domestic purposes in Latvia until the late 20th century, but it has primarily been exported since the turn of the 21st century. Currently, 93% of Latvia's peat harvest is destined for export. Peat products account up 1.44 percent of Latvia's total export volume (in 2018) and are a key portion of the country's exports [47].

Peat extraction is influenced primarily by climatic and environmental concerns at this time. In 2025, countries will be forced to disclose emissions from economically utilised wetlands, which will have a substantial impact on GHG emissions from extraction activities. Peat extraction is therefore constrained, and the sector is forced to consider strategies for reducing emissions while also compensating for those lost. Compensation solutions for GHG emissions must be devised for the peat extraction business if it is going to preserve its long-term viability. More scientific investigation is required to develop higher-value peat products, which will boost the national economy by emitting fewer tons of greenhouse gases every ton of peat extracted. Only processed peat should be exported from Latvia, and favorable conditions should be created for local consumption. In order to manage peat resources in the most efficient and emission-friendly manner possible, it is imperative that GHG emissions measurements and research be continued at the national level.

When there is a growing need for food and an increasing population on Earth, limiting GHG emissions by cutting back on peat mining is counterproductive. For the foreseeable future, peat extraction areas and available peat quantities in Latvia are required to be maintained at their current levels by following the country's Peat Guidelines, a document used to guide policy decisions. Predictability in peat extraction, as well as the desire to invest in production facilities, would result in the creation of additional value to peat, and more efficient resource management, as a result of this. For 10 years, peat resources in the country have grown faster than the amount of peat that can be extracted at present extraction rates. In total, 9.9% of the territory of Latvia is covered by peatlands, where 11.3 billion m^3 or 1.7 billion tonnes of peat have accumulated [1,2]. Peat is widely used as a fuel and for agricultural purposes and was an essential part of the national economics during the 20th century [3]. So far only 4% of all peatland areas in Latvia have been used for peat extraction, but the purposes of peat use changed significantly in the period between 1920 and 2020 as a result of social, economic and political processes [48-70].

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