Environmental and Climate Technologies
2025, vol. 29, no. 1, pp. 623–640
https://doi.org/10.2478/rtuect-2025-0043
https://content.sciendo.com

RIGA TECHNICAL UNIVERSITY

Climate Neutrality Strategies for Peatland Management: Case Study about Peat Extraction Field Repurposing Scenarios in Latvia

Dita KAZMERE[1], Maksims FEOFILOVS[2*], Francesco ROMAGNOLI[3]

[1–3]*Institute of Energy Systems and Environment, Riga Technical University, 12/1 Azenes iela, Riga LV-1048, Latvia*

Received 29.04.2025; accepted 11.09.2025

***Abstract* – To mitigate land degradation caused by peat mining, the European Commission, through the Nature Restoration Law (Regulation (EU) 2024/1991), has established a goal to restore habitats. This includes repurposing peat mining fields into areas designated for various restoration measures. When defining a repurposing strategy for a specific peat extraction field, an important aspect is to assess the environmental impact of the different scenarios. This study is made in cooperation with a Latvian peat extraction company, with the goal to achieve climate neutrality by the year 2050. The company is a significant producer of peat substrate with a capacity of 115 thousand tonnes per year. Ten recultivation scenarios were identified for the company's peat extraction field: afforestation, blueberry cultivation, cranberry cultivation, paludiculture, waterbodies, croplands, grasslands, rewetting, solar parks and wind parks. These scenarios were compared with the baseline scenario, i.e. the situation if peat extraction were to continue in this field. The required data for the recultivation scenarios were collected and normalized to the functional unit of 1 ha. In the environmental life cycle analysis, the avoided impact from electricity production was considered. The avoided impact shows how much emission is reduced when the grid's electricity is replaced with green energy. Three main emission reference points were identified for the 50-year greenhouse gas emissions assessment: short-term (2030), medium-term (2050) and long-term - emissions after 50 years (2075). The results show that the highest emissions per 1 ha over a 50-year period are from the installation and reconstruction of solar panels. And the largest avoided impact is from wind turbines. It was determined that each scenario individually results in lower emissions compared to the baseline. However, when the emissions from all scenarios are added together, the sum is greater than the baseline. Therefore, it is necessary to investigate the recultivation scenarios further and optimise the land areas to optimise the recultivation scenario's area and impact from them.**

***Keywords* – Environmental LCA; GHG emissions; peatlands; recultivation; sustainable development goals.**

1. INTRODUCTION

Peatlands have a crucial role in the environment, impacting the carbon cycle, biodiversity, and socio-economical aspects. Current information indicates that approximately 570 million hectares are covered by wetlands, which is about 6 % of the Earth's total land area, where 30 % of these territories are covered by bogs and 26 % are covered by fen [1]. Bog and fen

*Corresponding author.
E-mail address: maksims.feofilovs@rtu.lv

are peatlands respectively, both wetlands form and accumulate peat, but the main difference between bog and fen is the water circulation and the way how water supplies the plants with nutrients. Furthermore, plant species differ between both wetlands [2].

Peatlands are defined as wetlands where a peat layer has formed naturally, close to the water surface. Peat is defined as partially decomposed plant remains that still have a vegetative structure after being in anaerobic conditions for hundredths of years [3]. Peatlands can be found globally for now, they are dated in approximately 180 countries [4], the total peatland terrestrial territory is 4.23 km^2, which is approximately 3 % [5].

The largest area of peatlands is in Asia with a territory of about 160 million ha, while North America has a territory of about 158 million ha, South America has a territory of about 63 million ha, and Europe has a territory of about 59 million ha. The smallest territories are in Africa with about 40 million ha and Australia and Antarctica with a combined territory of 7.07 million ha. The total emissions from drained and degraded peatlands are 1940 Mt CO_2 eq/y, which sums up to 4 % of the total anthropogenic global emissions [6]. Europe's peatlands account only for 12 % of the world's total terrestrial area, while degraded peatlands account for 46.6 %, and 10 % of these territories are completely lost. European peatlands have a total carbon stock of 42.620 Mt C, and annual emissions from peatlands are 582 Mt CO_2 eq, which is 30 % of the global peatland emissions that are emitted from drained peatlands [3], [6].

Peatlands are important not only for emissions and the carbon cycle but also for the United Nations Sustainable Development Goals (SDG). Peatlands affect 8 of the 17 SDGs, peatlands have effect on water circulation that improve food production in different territories (SDG 2 – Zero hunger), it improves water purity by working as a natural filtration system, a lot of terrestrial water passes through wetlands and peatlands (SDG 6 – Clean water), peatlands can be used for growing biomass for renewable green energy (SDG 7 – Clean energy), peatlands act as natural water reservoirs and thus reduce flood risk and help with thermoregulation (SDG 11 – Sustainable cities and communities), sustainable peatland management and the integration of paludiculture could ensure economic and ecological sustainability (SDG 12 – Responsible consumption), intact peatlands sequester large amounts of carbon (SDG 13 – Climate action), healthy coastal peatlands affect the "health" of sea and oceans (SDG 14 – Life below water), a large variety of species live and breed in wetlands and peatlands and their degradation impacts the breeding of the species and threatens the existence of these species (SDG 15 – Life on land) [7], [8].

Peatlands are mostly drained to create agricultural land, forest land, or peat extraction fields. For peatland drainage, it is necessary to prepare the peatlands, for example, by clearing the area from vegetation and draining it by digging ditches [9]–[11]. The impact from ditches has not been fully assessed, but there is a correlation between long-term peatland degradation and active ditches even after peat extraction has ended. It is also important to note that the location of peatlands impacts the degradation level's extent. Respectively, if peatlands are located on a slope, peat volume will decrease more rapidly than on flat terrain [12].

Emissions from peatlands and ditches are inventoried to measure emissions. These inventories are based on globally accepted methods, which are based on the Intergovernmental Panel on Climate Change for the development of the greenhouse gas (GHG) Emission Inventory report, also known as the GHG Protocol. The GHG Protocol is the global standard used for GHG emissions accounting and reporting. It was developed by the World Resources Institute for the World Business Council for Sustainable Development. The GHG Protocol helps organisations to better understand, quantify, manage and report on emissions from these organisations [13]. The method is intended to provide a standardised and scientifically based approach to calculating and reporting emissions. It is used at the national and international levels to track emissions trends and develop climate policies. A common GHG emissions reporting methodology provides a global set of standards and tools that contribute to a unified and coordinated approach in the combat against climate change. This method of measuring GHG emissions helps decision-makers to understand the climate change challenge and develop appropriate policies and strategies. It takes into account direct and indirect emissions from the organisation's activities, production processes and services. The emission accounting approach sets out how companies should measure and report their emissions, including Scope 1, 2 and 3 emissions [13]–[15].

Since peatlands accumulate large amounts of carbon, and sequester emissions, peatland restorations are particularly important to achieve climate neutrality objectives given the likely emissions from degraded peatlands [16]. Climate neutrality is about balancing emissions and removals, and to achieve this it is necessary to achieve the balance of emissions in every sector, but currently more emissions are emitted than removed. The key objective is to achieve a 55 % reduction in emissions by the year 2030 compared to the year 1990; this is the so-called "Fit 55" package [17], [18]. It has been established that progress towards climate neutrality is not on track, and it is for a variety of reasons, such as the COVID-19 pandemic or the Russian invasion of Ukraine. Also, it is determined that emission reductions from peatlands are not happening fast enough, with implications for achieving climate neutrality. It is indicated that croplands, grasslands and wetlands emit the majority of the emissions from the Land Use, Land Use Change and Forestry sector [19].

Considering the emissions from peatlands and the increasing degradation of peatlands, recultivation of these areas is necessary to reduce the impact from degradation [20], [21]. Restoration of peatlands would fall under the climate neutrality objectives of reducing emissions and mitigating impacts on organic soils, but the high economic impact of peat extraction needs to be emphasised, and therefore the economic impact of peatland closure needs to be considered [22]. The peat extraction business provides extra job opportunities in rural areas, as well as greater economic stability. Peat products are also an important material for various agricultural and forestry processes. Consequently, peat extraction has a wide impact on supply chains and their economic contribution to the national economy. Peat is an important import and export product in Europe. However, rapid environmental degradation is forcing legislators to introduce measures to protect peatlands, which has an impact on the broad market for peat products, so there is a need to find alternatives that reduce environmental impacts and even improve them while ensuring economic stability for businesses [23].

After peat extraction has ended, there are possibilities to achieve economic, social and environmental benefits. Recultivation of peatlands provides economical support to the community through locally sourced products and different materials that are grown on the peatland. Also, there is a benefit from ecosystem services and recreational opportunities in these areas. Restoring peatlands improves water quality and natural water circulation, restores biodiversity and provides carbon sequestration. It also provides a social contribution to the community, for example, as a cultural, historical or religious site and the opportunity to involve the community in biodiversity restoration work [24].

Given the current state of peatlands, there is a need to start restoring peatlands both locally and globally. In Latvia, peatlands cover approximately 10–15 % which is from 6782 km^2 till 9700 km^2 of the total land area, of which 501.79 km^2 are considered degraded peatlands [25]. To understand more about the situation in Latvian peatlands, in cooperation with the LIFE programme, the Life REstore project was developed. In this project it was determined that Latvia's degraded peatlands can be recultivated with different land-use options. This project is one of the several projects that indicate Latvia's readiness to improve degraded organic soil areas. It is also established that peat extraction and peat use for energy purposes should end by 2030 and that the recultivation of historical peatlands should be promoted by selecting the most appropriate form of recultivation [26], [27].

Considering the state of peatlands and the move towards climate neutrality, it is necessary to develop recultivation strategies in both private and public peat companies. This paper presents a case study of a Latvian peat extraction company that has decided to develop different recultivation scenarios. The main objective of the study is to determine the environmental impacts of different recultivation scenarios. Additionally, the study aims to identify potential emission compensation and emission storage options within the recultivated peatlands.

2. METHODOLOGY

In this case study, a specific peat extraction field was investigated, and identified scenarios for the repurpose of the peat extraction field in collaboration with the owners of the peat extraction field. The aim of this study is to determine the possible positive and negative environmental impacts from the proposed scenarios. The analysis methodology used in this paper is described in detail in the following chapters.

2.1. Case Study Definition

The case study was developed in cooperation with the peat extraction company SIA "Laflora", located in Jelgava municipality, Līvbērzes parish. The peat extraction takes place in three different bog areas with a total area of 2059 ha. The name of the study area is "Kaigu peat bog", with a total area of 740.26 ha and a total of 24 peat extraction polygons in this territory. Peat extraction started in 1995, and the extracted peat is used to produce substrate for agriculture, forestry and horticulture needs, for example, to produce vegetables, tree seedlings and ornamental plants. The annual peat production is approximately 115 000 m^3. The products of peat are exported to around 40 different countries. The company claims that they provide a complete peatland management cycle, i.e., peat extraction, processing and different product development, as well as peatland repurposing [28]–[30].

The company has set a target of recultivating Kaigu peat bog to meet set climate neutrality goals by 2050. One of the current objectives is to create a green industrial area on the peat extraction field. It is expected that the development of green industrial area will offset the GHG emissions emitted during the peat extraction and processing. To make this development possible, the installation of wind turbines has been identified as one of the area development scenarios for the site. It is expected that the portion of the wind energy generated will be used for further development of the peatland, thereby reducing emissions from the existing fossil fuel generated electricity. The wind park is planned to be completed in 2026 [31].

During development of the company's climate neutrality strategy, it was determined that it was necessary to assess the environmental impact of implementing the strategy. This was done using the environmental life cycle assessment approach (E-LCA). E-LCA was used because in this way it is possible to describe the emissions as accurately as possible from the chosen strategy and it is possible to determine whether climate neutrality will be achieved once the scenarios are implemented. Life cycle perspective is the basis for calculating the carbon footprint of products and processes. It provides a systematic assessment of GHG emissions at all stages of the life cycle. This type of approach helps to identify the stages and the different aspects that generate the highest emissions, such as soil use, raw material extraction, fuel consumption, water use, etc. By identifying the biggest impacts during the life cycle, companies and policy makers can develop and implement strategies to reduce emissions, e.g. green energy production, promotion of the circular economy, and restructuring of material chains. By developing E-LCAs it is possible to identify the most effective way to achieve environmental neutrality.

The E-LCA was developed based on the ISO 14044:2006 standard [32], [33]. Therefore, four main steps were followed during the development of the E-LCA model: 1. The goal and scope definition; 2. The inventory analysis; 3. The impact assessment; 4. The result interpretation.

The main objective of this case study is to develop E-LCAs for ten different recultivating scenarios and to determine their environmental impact and their role in achieving climate neutrality. Although this study is carried out in collaboration with a specific company, the results can serve as a guide for other companies or policy makers. The E-LCA emissions modelling was carried out by identifying Scope 1, 2 and 3 emissions.

When developing the E-LCA it was determined that for an accurate representation of the data the emissions from upstream activities, that count as direct emissions from company will be accounted but the downstream emissions were not accounted, because they are outside the system boundaries. It was determined that a Cradle-to-Gate approach would be applied. This was done because it is now important to assess the emissions that occur during the set-up and maintenance of the scenarios. In this case study, the Cradle-to-Gate approach includes emissions from soil preparation, fuel consumption, emissions from the equipment to be installed, emissions from different agricultural processes (e.g. different types of fertilisers) and emissions from the harvesting of agricultural products.

The functional unit (FU) represents the peatland usage parameters and emission accounting from land use. For this study a FU was set "1 ha over a year of emissions from peatland that is used for peat extraction and recultivation". This FU was chosen because a lot of the data that was collected was already calculated per 1 ha, and it is easier to assess and compare the environmental impacts of the chosen scenarios in this way.

It has already been mentioned above that this case study looks at the environmental impacts of ten different remediation scenarios. These scenarios were largely based on the company's stated strategy and were complemented by scenarios described in the literature. Below is a brief description of each scenario, which summarises the essence of the scenario, and a baseline scenario (the scenario against which the other scenarios are compared). The baseline scenario was chosen as a 1 ha peat field with active peat extraction, i.e. a no-change area. The scenarios selected are as follows:

- Rewetting – a form of bog recultivation that restores the natural bog environment. Rewetting aims to restore the ecosystem functions and hydrological regime of the bog. To restore the peat bog ecosystem, the water level in the peat extraction site must be raised by closing drainage ditches, either by filling them in or by creating dams or other hydraulic structures;
- Water bodies – an artificial body of water used for agriculture, fisheries, recreation or mixed use. The creation of water reservoirs is possible in areas where historically a marsh has formed because of the overgrowth of a lake or pond;
- Afforestation – the peat bog area is forested, the area may contain a thin layer of residual peat or be fully established, depending on the tree species, e.g., a thin peat layer is suitable for conifers or fast-growing trees;
- Paludicultures – plants that can be grown on peat soils and bogs that are usually periodically flooded or wet. They contribute to peat preservation and even accumulation and can be grown in different types of peat bogs. The variety of species of these crops ensures that it is possible to find and grow a suitable paludiculture for

each peat type. In Latvian conditions, it is possible to grow several paludicultures - reeds, sedges, alders, sphagnum mosses and others;

- Cranberries – a shrub that provides a seasonal crop of berries. The most suitable species for peat bog recultivation is the large-leaved cranberries (*Vaccinium macrocarpon*). Cranberry cultivation requires well-decomposed and friable turf. In the cranberry field, it is important to ensure that the water level in the field does not rise above the surface layer, so it is important to maintain drainage and irrigation systems in the area;
- Blueberries – a shrub that provides a seasonal crop of berries. The most suitable for peat bog recultivation are broad-leaved blueberries (*Vaccinium corymbosum*) or narrow-leaved blueberries (*Vaccinium angustifolium*);
- Meadow – it is possible to introduce pastures, meadows or mowing grasslands, each one of these types is specific. Pasture is used for livestock farming by free-range grazing of livestock. Meadows are undisturbed areas with plants typical of the area (meadows can be artificially created). Grassland is agricultural land, intended for feeding livestock, regularly mown and otherwise reseeded. In this case, a meadow was chosen which is artificially created but not mown;
- Croplands - involves converting a peat extraction field into agricultural land for growing various crops. Before the cropland can be developed, the surface layer must be tilled, smoothed and watered, hard debris from trees and other plants must be removed and the land fertilised (depending on the type and composition of the peat), and effective drainage systems must be provided to prevent the crop field from flooding;
- Wind parks – a wind farm is installed on-site to generate green energy;
- Solar parks – solar panels are installed on-site to generate green energy.

The assessment of the recultivation scenarios did assume that the electricity generated by wind and solar power would be fed back into the grid, so it was determined that this type of electricity would offset emissions from fossil fuels. Emission offsetting is the process of using a product or process that replaces the original and its use reduces emissions dramatically. In this case, green electricity replaces electricity from fossil fuels.

Afforestation provides an additional bonus to the emissions matrix, i.e. emissions that are deposited in wood or soil are sequestered through forests. This process helps to reduce emissions and ensure progress towards climate neutrality. This study examines the emissions from the establishment and maintenance of a forest stand and then calculates the emissions removals that occur annually per 1 ha of forest land.

2.2. Data Collection and Inventory Analysis

Before entering the data into the modelling software, the data was extracted, and a data inventory was developed. The data for the model was obtained from information available in the literature, from a library of data in a computer program and from information provided by the company. The data from the company was used for the base case model, based on the information provided by the company, the following steps were developed: peat field preparation, peat extraction, transport to factory, peat refinement, peat packaging.

Data for the agricultural (winter wheat, summer wheat and rapeseed), blueberry, cranberry, meadow and waterbodies models were obtained from the Latvian Rural Advisory and Education Centre website. This website provides extensive information on gross margins for crop and livestock production. It gives an overview of the amount and cost of materials, services and machinery required for each activity. Gross margin is an indicator that provides information on the difference between the revenue and variable costs per unit of production (in crop production per 1ha and in livestock production per animal). The data provided are the responsibility of the experts in the field and the calculations for the result are carried out using parameters appropriate to the technology to give the most optimum result [34].

Data on forests and paludicultures were extracted from information collected by the LIFE REstore project. In addition, information from the Latvian Rural Advisory and Education Centre (Latvijas lauku konsultācijas un izglītības centrs (LLKC)) website was used [35]–[37]. For the parameters of the installation of the rewetting, general information and data from the Peat4Res project were collected in collaboration with the project's scientific team and for the emission factors, information was taken from the scientific literature [38].

Data on solar and wind farms were extracted from information provided by the company and supplemented by information provided in the scientific literature [39]–[42]. During the development of the model, it was determined that the information in the modelling software on solar panels and wind turbines was incorrect and did not reflect the latest technology, hence the decision to develop new models for solar panels and wind turbines. This smart approach ensured the most accurate possible data representation.

The Ecoinvent library (described in more detail in subsection 2.3) was used to develop all models. Input parameters were based on this library and are searched according to the input parameters defined in the data. The parameters in the Ecoinvet library were adapted and modified according to the inventory data. The data inventories were carried out according to ISO standard Determination of incoming and outgoing material and energy flows (the date-based data inventory is presented in Annexes Table 1 to Table 13). The data inventory was carried out for all the models developed, and during the data input, the data were adjusted to the defined FU, the units of measurement were recalculated to fit the input parameters in the model, and the following assumptions were made during the data processing:

- Blueberries – Assumptions only made in relation to the use of peat for fertiliser purposes, the data shows the volume reported in the field as "m^3". Calculations were made to determine the mass of peat (tonnes), the calculations assumed that dry peat is applied to the field – the density of dry peat is 400 kg/m^3. A further assumption was made regarding the use of machinery on the soil to be tilled, according to the information provided by the LLKC all available data is calculated per 1 ha, so when it was stated that the machinery is used once per year it was assumed that the particular piece of machinery works on 1 ha of soil;
- Cranberries – it is stated that the machinery is used once per year, it was assumed that the piece of machinery works on 1 ha of soil;
- Meadow – it was stated that the machinery was used once a year, it was assumed that the machinery unit in question works on 1 ha of soil;
- Croplands – three main groups of cereals were identified - winter wheat, spring wheat and oilseed rape – these cereals were selected on the basis of the amount of crop produced each season, it was assumed that the machinery was used once during the year, it was assumed that a given piece of machinery works on 1 ha of soil;
- Waterbodies – the data were assumed to be the same as if a pond had been set up for fish farming, but no account was taken of impacts directly related to the fish farming process. It was assumed that the pond would be cleaned annually;
- Afforestation – maintenance was assumed to take place over 10 years;
- Paludicultures – it was assumed that the area was planted with reeds and that the fields were not mown afterwards;
- Rewetting – in this case, two assumptions can be made, one assumption is that emissions from soil are no longer counted after rewetting is complete, because

rewetted soil is considered a habitat and emissions from it are not counted. The second assumption is to count emissions from the soil until the rewetting area has restored the natural biotope. The following calculations considered the second version of the assumptions. The assumption for the rewetting was made based on the natural cycles in the peatlands that accrue when the peat bog regaining it natural structure;
- Wind Park – a specific type of wind turbine was identified that is closest to the type of turbine chosen by the company. It should be noted that the paper considered wind turbines that were two times shorter in size than those chosen by the company, so it was assumed that all the data was multiplied by 2 when entered the computer program;
- Solar Park – system losses were assumed to be around 14 %.

Also, for both solar park and wind park models, data was only used and upgraded for the European market. The reference document for the GHG emissions of grid-connected electricity was the report "EU Reference Scenario 2016 Energy, transport and GHG emissions Trends to 2050" issued by the European Commission in 2016. [43], which describes information on energy, transport and GHG emission trends from 2025 up to 2050 every five years.

2.3. Impact Assessment and Life Cycle Modelling

The models were developed in SimaPro© version 9.6.0.1 using the Ecoinvent version 3.10 library. SimaPro© was developed by PRé, a company specialised in the development of computer software for life cycle analysis of various products and materials [44]. SimaPro© is a professional tool that provides an analysis of the environmental aspects of a product or service. This is done in a systematic and consistent way, so that optimal solutions can be found. LCA software can be used to analyse environmental impacts, for example GHG emissions throughout the life cycle of a product or process. To input data into SimaPro, a new project must be set up, during which it is determined which data library will be used to analyse a specific material or product. SimaPro offers several libraries/databases containing specific information on, for example, processes in agriculture (processes from arable, crop, livestock, etc. are included). The Ecoinvent database consists of several thousand datasets containing information on energy types, agricultural products, transport modes, packaging materials and many other specific datasets [45].

The IPCC2021 GWP100 method (including CO_2 uptake) was used to estimate GHG emissions. This method is best able to reproduce the impact of emissions on global warming and is defined as "the International Panel on Climate Change (IPCC) Global Warming Potential (GWP) climate change method with factors for a 100-year time horizon where carbon dioxide uptake and biogenic carbon dioxide emissions are explicitly included." The method offers an improved framework for assessing the potential climate change impacts of different emissions over a 100-year time horizon. The 100-year indicator is a widely accepted measure for comparing the potential climate change impacts of GHGs on a common scale. The choice of the IPCC2021 GWP100 method is consistent with the objective of assessing the long-term environmental impacts of land-use scenarios, as it provides a time-integrated measure of the amount of emissions that GHGs retain in the atmosphere up to 100 years after they are emitted [46].

GWP100 assessment involves calculating the cumulative radiative forcing effect of a given unit mass of GHGs compared to a unit mass of CO_2 over a 100-year period. Each GHG is assigned a GWP100 factor that quantifies its warming effect. The reference gas with a GWP value of 1 is CO_2, while other gases such as methane (CH_4) 28 and nitrous oxide (N_2O) 265 have a higher GWP value because of their stronger effect on radiation trapping per unit mass. The GWP100 method does not consider the atmospheric lifetimes of different GHGs; it integrates warming effects over a given time horizon, regardless of the actual persistence of the gases in the atmosphere. Furthermore, it does not account for other indirect GHG effects [47].

The method includes CO_2 uptake and biogenic CO_2 emissions, offering a more nuanced representation of the carbon cycle. The method includes carbon cycle reactions on methane (both biogenic and fossil) and specific chemical compounds such as CFC-11. Indirect emissions from substances such as nitrogen oxides and volatile organic compounds are not included [47].

Comparisons were made between these data on a per hectare basis (details in Chapter 3). These data were then calculated for the areas identified in the strategy. According to the information provided by the company, a corresponding tertiary unit is applicable for each scenario. Emissions from the identified strategy were calculated by multiplying the emissions per ha by the area in ha for each scenario. After the calculation it was possible to determine the environmental impact of the overall strategy, and its magnitude compared to the baseline.

The model was developed considering the possibility of uncertainties, and during the development of this work the model was developed with as recent data as possible, however there is a possibility that there is error in the data that could not be traced. During the development of the model, parameters from the Ecoinvent database were adjusted to match the latest technology, however it must be assumed that not all input parameters in the Ecoinvent library have been updated to the latest technology (a prominent example is wind turbines and solar panels which were recycled). Also, throughout the development of the work, there is a human factor, i.e., the possibility of errors in calculations, data interpretations, input of parameters into the SimaPro software and interpretation and calculation of the results obtained.

3. Comparative Analysis of GHG Data Reporting Practices

This chapter will describe the results obtained from the E-LCA. It will describe the comparison between the data obtained and determine the environmental impacts of the peat scenario individually and of the identified strategy. Initially the emissions data for the identified FU and then the data from the strategy will be looked at. The emission data are presented as t CO_2 eq/ha.

3.1. Emission Profiles for Different Land Use Scenarios per 1 ha

For each of the recultivation scenarios, GHG emissions were determined according to the life cycle analysis described in Chapter 2. The data for the recultivation scenarios have been aggregated and GHGs have been calculated on a per ha basis to reflect the emissions to air from a specific type of recultivation to subsequently calculate the emissions from the total area planned to be dedicated to a specific recultivation scenario. All scenario emissions are attributed to land use over 50 years, Fig. 1 shows the comparison between the baseline and the recultivation scenarios.

The GHG emissions from recultivation scenarios that involve intensive land cultivation but no development of the site is depicted in Fig. 2 – the highest impact from land cultivation is directly during the establishment of agricultural land, i.e., during the cultivation of fallow crops (oilseed rape, spring and winter wheat). However, it should be noted that these GHG emissions may change with changes in land cultivation practices.

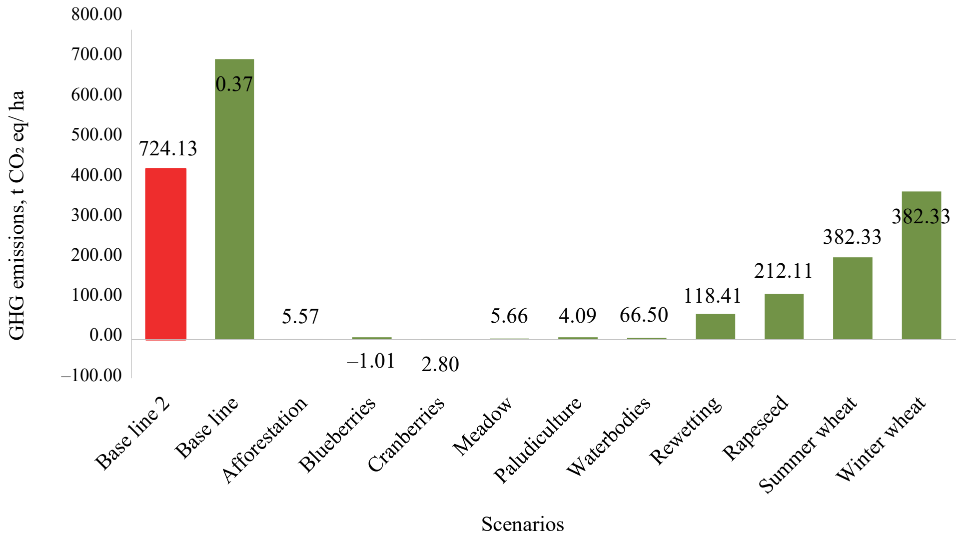


Fig. 1. Total GHG emissions over 50 years per 1 ha.

The emissions inventory starts with 2025 as the starting year for the implementation of the scenarios. Three main emission reference points were identified for the assessment of GHG emissions over a 50-year period: short-term 2030 (when peat extraction for energy must cease), medium-term 2050 when climate neutrality must be achieved and long-term – emissions after 50 years (2075) when the vegetative life cycle of plants ends.

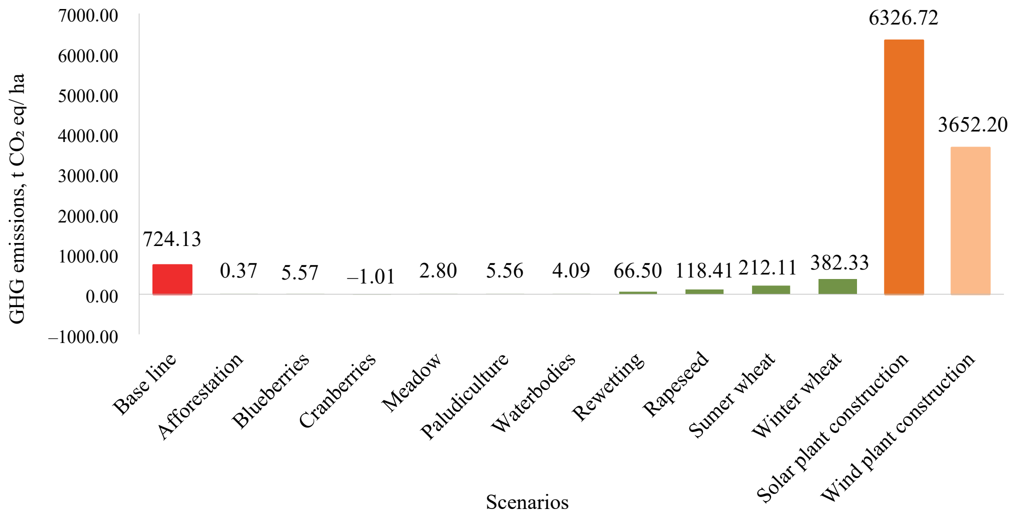
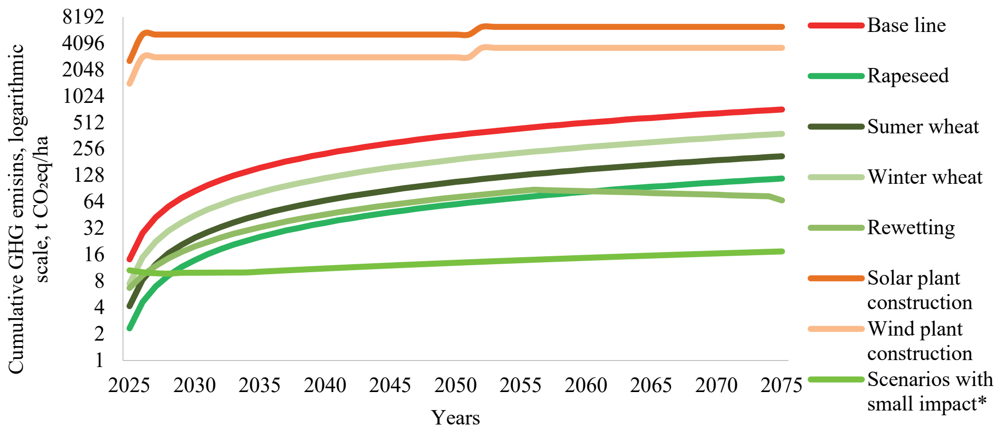


Fig. 2. GHG emissions to the atmosphere over 50 years from the recultivation of a 1 ha field, including solar and wind power scenarios.

The cumulative emissions for each recultivation scenario per hectare of land are displayed in Fig. 2. The red shading indicates a range of emissions from scenarios that emit more than the baseline. Laflora has identified the area of the peat bog to be developed as a site for solar and wind power plants, which will contribute to reducing emissions in order to meet climate neutrality targets and promote the production and use of renewable energy. The construction, maintenance and renovation of the solar and wind power plant generate GHG emissions.

Fig. 2 also shows that the highest emissions per ha over a 50-year period are from the construction and reconstruction of a solar power plant. Both the construction of a solar power plant and a wind power plant have the highest environmental impact. This is because of the large number of emission-intensive materials consumed, such as aluminium, silicon, iron, etc. However, as technology advances, there is a noticeable trend towards a reduction in the volume of materials used and also a change in the volume of materials used. It is therefore reasonable to say that the emissions from solar and wind power plants may decrease significantly in the near future. A comparison of cumulative emissions between the different scenarios including emissions from the construction and reconstruction of the solar and wind farm, which is anticipated to take place in 25 years is depicted in Fig. 3.



*Scenarios with small impact include afforestation, blueberries, cranberries, meadow, paludicultures and waterbodies scenarios

Fig. 3. Emissions from the recultivation scenarios that are plotted on a logarithmic scale with base 2.

Diagrams in Fig. 3 show that the largest amount of fossil emissions comes from the construction and reconstruction of solar and wind farms. The data is presented using a lognormal scale with base 2. A random variable with a normally distributed logarithm has a lognormal distribution. When X is a lognormally distributed random variable, its natural logarithm, $\ln(X)$, follows a normal distribution. This was done to more clearly show the emissions from the recultivation scenarios. Given the thin data slide between the very low and high emission scenarios, the logarithmic scale allows for a more accurate comparison between the scenarios. Emissions from agriculture are significantly elevated, but below the baseline. Also, initial emissions from rewetted peatland are elevated but emissions start to level off around 2060. This is due to the fact that after the peat bog has been rewetted, it becomes more and more emissions-intensive each year and the emissions from the peat soil start to reduce when sequestration amount increases.

3.2. Carbon Sequestration Potential vs Avoided Emissions from Fossil fuels

Restoring peat bogs through both afforestation and rewetting measures can trap emissions through plant structure and soil. Based on the information in the literature, during the rewetting process, as soon as the peat bog has been restored, carbon sequestration starts, i.e., 0.69 t CO_2 eq/ha/y is sequestered. The higher emission removals occur when the peat bog is close to its natural state and when it is fully restored. When the peat bog is close to its natural state, the emission removal is 5.06 t CO_2 eq/ha/y [38].

Emissions removal through forests are much higher based on literature available information, it is possible to offset 1 t of GHG emissions from 1.5 ha of forest land [48]. Given that the area of the forest plantation was determined to be 54.24 ha during the case study, this means that 36.16 t of GHG emissions will be avoided in one year. Thus, making the achievement of climate neutrality targets feasible.

The model takes into account offset emissions from electricity generation. This is the allocation of the electricity grid for the coming years, and the modelling indicated that this grid electricity would be replaced by green electricity that is produced in the solar park and wind park, respectively avoiding emissions from the fossil fuels (avoided impact). Avoided impact is an emission that are avoided by reducing anthropogenic emissions in air, soil or water. This could be done by reducing the emissions directly from the source or increasing technologies that are used to produce green energy and capture emissions as well as being carbon neutral [49]. It should be emphasized that Fig. 4 depicts the current theoretically ideal scenario, even if the amount of green electricity in the system will grow over time.

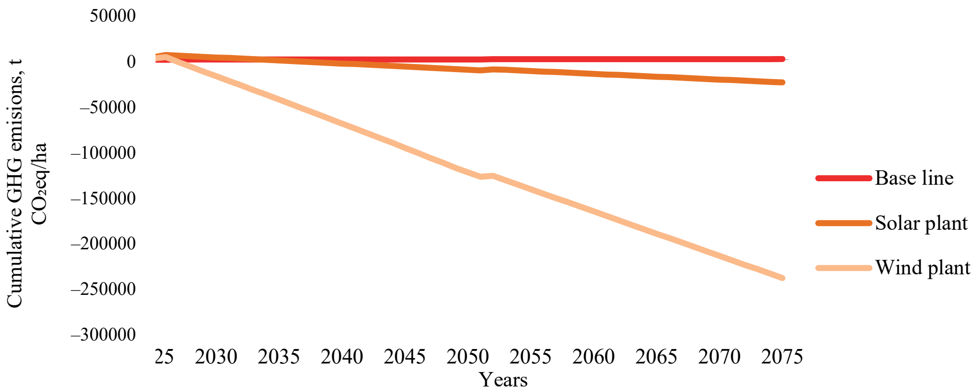


Fig. 4. Avoided emissions from solar and wind farm electricity compared to baseline.

Given that the total installed capacity of solar panels is lower than that of wind turbines and the emissions from their construction and reconstruction are higher, their emissions offset is slower and much lower. Wind power has a significantly higher positive impact on the emissions balance. Already in 2030, the wind power plant will achieve a net-negative emissions balance. Emissions from a solar power plant achieve negative balance only around 2035. The results show that the electricity generated by the power plants is sufficient to offset the emissions from the other scenarios under emissions scope 2.

The existing scenario for the construction of power plants and offsetting GHG emissions takes into account only one defined scenario for the development of the Latvian electricity network. Changes in the electricity market are difficult to predict, and there is a possibility that the reduction of emissions may occur more slowly. Therefore, it should be emphasized that the data obtained are only theoretical. Fig. 5 shows a comparison of emissions between the scenarios with the highest impact and the largest amount of offset emission.

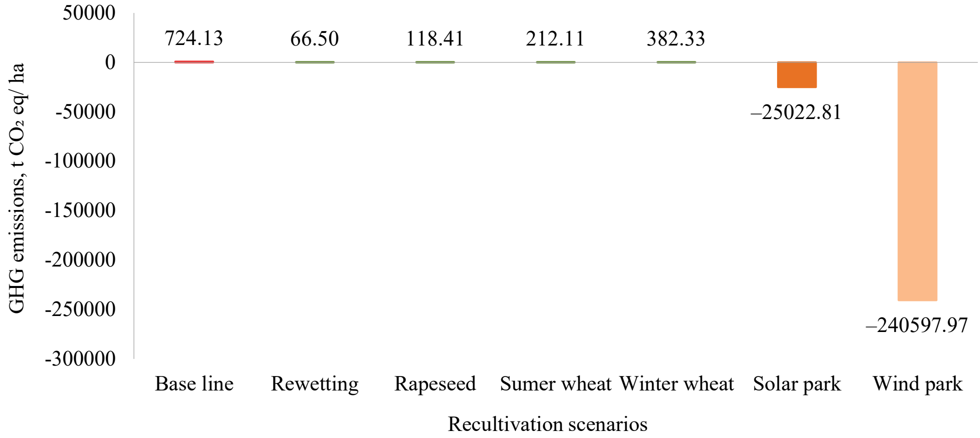
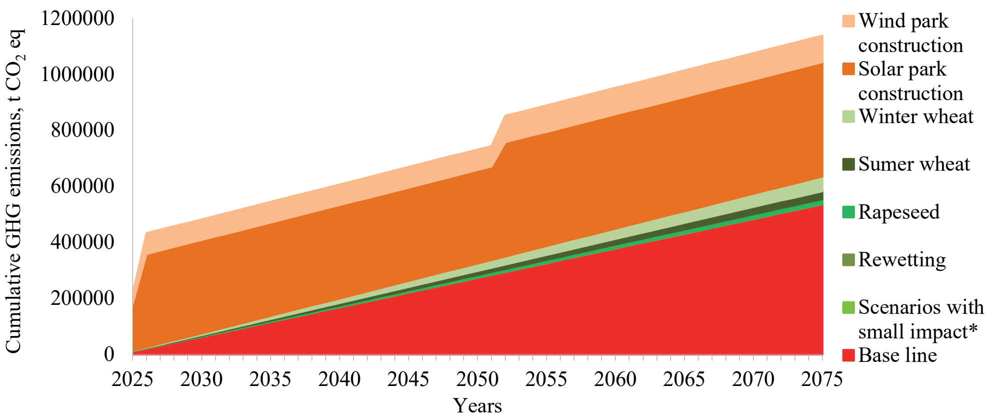


Fig. 5. Comparison between agricultural and electricity production scenarios per 1 ha over a 50-year period.

It is clear that the emission compensation is much greater than the agricultural emissions generated. The largest emission compensation is observed from wind farms, which can be explained by the fact that wind farms produce much more electricity than solar farms.

3.3. Results of Peat Extraction Field Repurposing

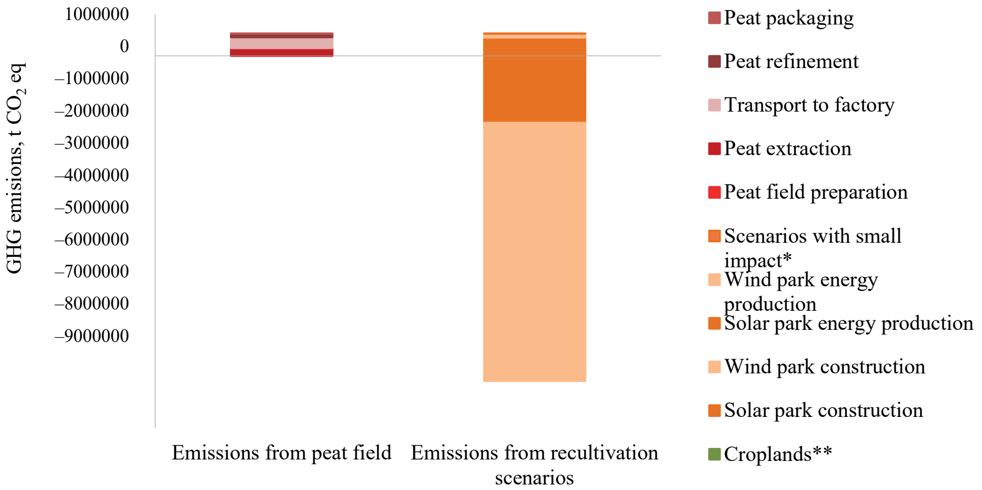
As mentioned above, the site for each remediation scenario was identified in cooperation with the company. The emissions per 1 ha were multiplied by the determined land area to obtain the emissions per land area. It was determined that the emission dynamics followed a similar trend as the emissions per 1 ha. The total cumulative emissions for an annual increase in emissions are displayed in Fig. 6.



* Scenarios with small impact include afforestation, blueberries, cranberries, meadow, paludicultures and waterbodies scenarios

Fig. 6. Cumulative emission comparison based on repurpose strategy defined by the company.

Fig. 6 also shows that GHG emissions from base line will increase in the absence of improvements. In the baseline scenario, GHG emissions can reach 63 064.19 t CO_2 eq in 2030, 273 278.17 t CO_2 eq in 2050 and 536 045.64 t CO_2 eq in 2075. Emissions from the solar park and wind farm construction and reconstruction are below the baseline but not in all reference years. Emissions from the solar park reach 333 502.25 t CO_2 eq in 2030, and in 2050 emissions could theoretically remain at about the same level as in 2030 and in 2075 emissions from the solar park could reach 408 200.15 t CO_2 eq. Emissions from wind farm construction and refurbishment could remain at the same level as in 2030 at 73 976.11 t CO_2 eq. and in 2050 emissions could theoretically remain at about the same level as in 2030 and in 2075 emissions from the wind park could reach 94 811.11 t CO_2 eq. Emissions from the other scenarios are much lower compared to the baseline; however, spring wheat, winter wheat and rapeseed have visibly elevated emission levels. Following the comparative comparison of the data, a comparison of the data for the 50-year period between the baseline and the recultivation scenarios is made (Fig. 7).



* Scenarios with small impact includes afforestation, blueberries, cranberries, meadow, paludicultures, waterbodies and rewetting

** Croplands include average value from winter wheat, summer wheat and rapeseed

Fig. 7. Emission comparison and distribution for peatland recultivation scenarios for the repurposing strategy defined by the company.

Wind power plants have the largest offset emissions over a 50-year period, as seen in Fig. 7, offsetting 6 245 923.29 t CO_2 eq. It can be seen that the emission savings are much lower than the total emissions from the strategy. Also, the offsetting of emissions from energy production is higher than the emissions from peat recultivation. These results indicate the importance of green energy, but it should be stressed that this is modelled as the best theoretical variance and there is a possibility that the offset emissions could be lower.

It is important to ensure an ecological and economic balance when managing peatlands during and after peat extraction. This is to ensure that peat bogs will provide the resources people need in the long term, while continuing to sequester and store carbon. To ensure this balance, it is necessary to promote the cessation of peat extraction by encouraging the development of areas that will contribute economically while minimizing environmental impacts. Such development could include the creation of wet woodland or paludiculture. In general, the protection of natural areas that also contribute economically is a goal to strive for, so that human livelihoods are not affected, and the fragile ecosystem is preserved and protected.

Although industrial land use makes great economic and social sense, there is a need to promote peatland restoration. This paper has looked at the environmental benefits of peatland rehabilitation and the development of a rehabilitation strategy that includes both environmental and economic aspects. The economic benefits of yields and electricity savings were not highlighted in the article – this was not considered because it was outside the framework.

Developing natural areas and restoring habitats contributes to the emission sinks in these areas, thus contributing to climate neutrality objectives. One of the aspects highlighted in this article is the possibility of installing solar and wind farms to promote green energy production, which is also in line with climate neutrality objectives. It should be stressed that peatland restoration will make a major contribution to climate neutrality and carbon sequestration. The main obstacles to peatland restoration are the financial burden, loss of income and high costs of restoration, as well as the reduced income from the restored tertiary crops (berries, paludiculture, forests). There are also political obstacles, such as the absence of common legislation to determine the management of these lands and the absence of political instruments to support the operator during the recultivation process.

4. CONCLUSION

The main objective of this article was to determine the environmental impacts of different recultivation scenarios. In the case study, 10 recultivation scenarios were identified based on the results of other projects and communication with the company. The environmental impacts were determined to be the highest from the construction and reconstruction of a solar park and a wind park as well as from croplands. However, it was found that the green energy produced would be able to offset the emissions.

In order to develop strategically sustainable climate targets, it is necessary to base them on verifiable data generated from case studies. It is necessary to create databases and to promote monitoring activities so that it is possible to promote a more rapid reduction of emissions by identifying emission dens sectors and areas. This is particularly important in order to promote habitat protection and restoration.

In the development of this paper, it was determined that there is a need for more in-depth research into the life cycle emissions of peatland recultivation and renaturalisation scenarios. Such studies would provide a more in-depth understanding of emission cycles and would provide a strong basis for policy maker decisions. These types of studies could also be a first step in a broader study that could be part of a national climate plan. There is currently a lack of a concrete strategy for the recultivation and renaturalisation of historic and active peatlands, so further research of this type is needed to give businesses and policy makers a better understanding of peatlands and emissions from them.

ANNEX

Zenodo link: https://zenodo.org/records/17255460

ACKNOWLEDGEMENT

The work has been developed as part of the Fundamental and Applied Research Project "Sustainable Strategies for the Restoration of Peat Mining Sites (Peat4Res)", project no. lzp-2022/1-0405, within the framework financed by the Latvian Science Council.

During the writing of this article, DeepL and Google translate was used to translate the text from Latvian to English. QuillBot was used to improve the language.

REFERENCES

[1] Ramsar. Ramsar Information Paper no. 1. [Online]. [Accessed 06.11.2024]. Available: https://www.ramsar.org/sites/default/files/documents/library/info2007-01-e.pdf
[2] Tanneberger F. *et al.* Mires in Europe – Regional Diversity, Condition and Protection. *Diversity* 2021:13(8). https://doi.org/10.3390/d13080381
[3] United Nations Environment Programme. Global Peatlands Assessment: The State of the World's Peatlands – Evidence for Action toward the Conservation, Restoration, and Sustainable Management of Peatlands. United Nations Environment Programme, 2022. https://doi.org/10.59117/20.500.11822/41222
[4] Parish F., Sirin A., Charman D., Joosten H., Minayeva T. Assessment on peatlands, biodiversity and climate change.
[5] Apori S. O., Mcmillan D., Giltrap M., Tian F. Mapping the restoration of degraded peatland as a research area: A scientometric review. *Frontiers in Environmental Science* 2022:10. https://doi.org/10.3389/fenvs.2022.942788
[6] U. N. Environment. Global Peatland Hotspot Atlas 2024. UNEP – UN Environment Programme. [Online]. [Accessed 25.02.2025]. Available: https://www.unep.org/resources/report/global-peatland-hotspot-atlas-2024
[7] Heinrich-Böll-Stiftung & others. Peatland Atlas 2023, Brussels, Sep. 1, 2023. [Online]. [Accessed 19.02.2025]. Available: https://eu.boell.org/sites/default/files/2023-09/peatlandatlas2023_web_20230914.pdf
[8] United Nations. The Sustainable Development Goals Report 2024. 2024. [Online]. [Accessed 10.03.2025]. Available: https://unstats.un.org/sdgs/report/2024/The-Sustainable-Development-Goals-Report-2024.pdf
[9] Chapter 4: Land Degradation – Special Report on Climate Change and Land. [Online]. [Accessed 28.02.2025]. Available: https://www.ipcc.ch/srccl/chapter/chapter-4/
[10] Dommain R., Frolking S., Jeltsch-Thömmes A., Joos F., Couwenberg J., Glaser P. H. A radiative forcing analysis of tropical peatlands before and after their conversion to agricultural plantations. *Global Change Biology* 2018:24(11):5518–5533. https://doi.org/10.1111/gcb.14400
[11] O'Driscoll C. *et al.* National scale assessment of total trihalomethanes in Irish drinking water. *Journal of Environmental Management* 2018:212:131–141. https://doi.org/10.1016/j.jenvman.2018.01.070
[12] Young D. M., Baird A. J., Morris P. J., Holden J. Simulating the long-term impacts of drainage and restoration on the ecohydrology of peatlands. *Water Resources Research* 2017:53(8):6510–6522. https://doi.org/10.1002/2016WR019898
[13] Bhatia P., Cummis C., Brown A., Rich D., Draucker L., Lahd H. Corporate Value Chain (Scope 3) Accounting and Reporting Standard. World Resources Institute and World Business Council for Sustainable Development. [Online]. [Accessed 10.03.2025]. Available: https://ghgprotocol.org/sites/default/files/standards/Corporate-Value-Chain-Accounting-Reporing-Standard-EReader_041613_0.pdf
[14] Anshari G. Z. *et al.* Chapter 1 – Introduction. Intergovernmental Panel on Climate Change, 2013. [Online]. [Accessed 10.03.2025]. Available: https://www.ipcc-nggip.iges.or.jp/public/wetlands/pdf/Wetlands_separate_files/WS_Chp1_Introduction.pdf
[15] Rypdal K. *et al.* Introduction to the 2006 guidelines. Intergovernmental Panel on Climate Change, 2006. [Online]. [Accessed 10.03.2025]. Available: https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/1_Volume1/V1_1_Ch1_Introduction.pdf
[16] Qiu C. *et al.* A strong mitigation scenario maintains climate neutrality of northern peatlands. *One Earth* 2022:5(1):86–97. https://doi.org/10.1016/j.oneear.2021.12.008
[17] European Parliament. What is carbon neutrality and how can it be achieved by 2050? Dec. 04, 2023. [Online]. [Accessed 10.03.2025]. Available: https://www.europarl.europa.eu/topics/en/article/20190926STO62270/what-is-carbon-neutrality-and-how-can-it-be-achieved-by-2050

[18] Gancone A., Viznere R., Kaleja D., Pubule J., Blumberga D. Towards Climate Neutrality via Sustainable Agriculture in Soil Management. *Environmental and Climate Technologies* 2022:26(1):535–547. https://doi.org/10.2478/rtuect-2022-0041
[19] Velten E. K. *et al.* State of EU progress to climate neutrality. Flagship Report, 2024. [Online]. [Accessed 10.03.2025]. Available: https://climateobservatory.eu/sites/default/files/2024-07/ECNO_Flagship_Report_2024_online.pdf
[20] Loisel J., Gallego-Sala A. Ecological resilience of restored peatlands to climate change. *Communications Earth & Environment* 2022:3(1):1–8. https://doi.org/10.1038/s43247-022-00547-x
[21] Sabūnas A. Lithuania's, Latvia's and Japan's Climate Policies. Are we Far from the Ideals of the Paris Agreement? *Environmental and Climate Technologies* 2024:28(1):760–775. https://doi.org/10.2478/rtuect-2024-0059
[22] Von Sonntag H. Peatlands and the Path to Climate Neutrality. Eurosite. [Online]. [Accessed 10.03.2025]. Available: https://www.eurosite.org/peatlands-and-the-path-to-climate-neutrality/
[23] Hirschler O., Osterburg B. Peat extraction, trade and use in Europe: a material flow analysis. *Mires Peat* 2022:28(24):1–27.
[24] Barbier E. B., Burgess J. C. Economics of Peatlands Conservation, Restoration and Sustainable Management. *SSRN Electron. J.* 2024. https://doi.org/10.2139/ssrn.4695533
[25] Par Kūdras ilgtspējīgas izmantošanas pamatnostādnēm 2020.–2030. gadam. (On the Guidelines for the Sustainable Use of Peat for 2020–2030). [Online]. [Accessed 11.03.2025]. Available: https://likumi.lv/doc.php?id=319013 (In Latvian).
[26] Eiropas Savienības kohēzijas politikas programmas 2021.–2027. gadam 6.1.1. specifiskā atbalsta mērķa 'Pārejas uz klimatneitralitāti radīto ekonomisko, sociālo un vides seku mazināšana visvairāk skartajos reģionos' 6.1.1.1. pasākuma 'Atteikšanās no kūdras izmantošanas enerģētikā' pirmās projektu iesniegumu atlases kārtas īstenošanas noteikumi (Implementation rules for the first round of project application selection for measure 6.1.1.1. 'Abandonment of peat use in energy' under specific objective 6.1.1. 'Mitigate the economic, social and environmental consequences of the transition to climate neutrality in the regions most affected' of the European Union Cohesion Policy Programme 2021–2027). [Online]. [Accessed 11.03.2025]. Available: https://likumi.lv/doc.php?id=353524 (In Latvian).
[27] Par taisnīgas pārkārtošanās teritoriālo plānu (On the territorial just transition plan). [Online]. [Accessed 11.03.2025]. Available: https://likumi.lv/doc.php?id=334018 (In Latvian).
[28] Laflora. Peat for demanding gardeners. [Online]. [Accessed 26.02.2025]. Accessed: Feb. 26, 2025. [Online]. Available: https://laflora.lv/mes/laflora
[29] Laflora. Facts – Peat for demanding gardeners. [Online]. [Accessed 26.02.2025]. Available: https://laflora.lv/mes/fakti
[30] Laflora. History – Peat for demanding gardeners. [Online]. [Accessed 26.02.2025]. Available: https://laflora.lv/en/we/history
[31] Laflora. Wind Parks. Peat for demanding gardeners. [Online]. [Accessed 26.02.2025]. Available: https://laflora.lv/projekti/laflora-veja-parks
[32] Environmental Management – Life Cycle Assessment – Requirements and Guidelines, Geneva, Switzerland., 2006. https://www.ditan.com/static/upload/file/20240419/1713505312117144.pdf
[33] Environmental Management – Life Cycle Assessment – Principles and Framework, Geneva, Switzerland., 2006. [Online]. [Accessed 14.03.2025]. Available: https://www.iso.org/standard/37456.html
[34] Latvijas Lauku konsultāciju un izglītības centrs (Latvian Rural Consulting and Education Center). [Online]. [Accessed 14.03.2025]. Available: https://new.llkc.lv/ (In Latvian).
[35] Krīgere I., Kalniņa L. Types of recultivation suitable for Latvian conditions. In Priede A., Gancone A. (eds.) Sustainable and Responsible after-use of peat extraction areas. Rīga: Baltijas krasti, 2019.
[36] Laiks apsekot un kopt jaunaudzes. Latvijas Lauku konsultāciju un izglītības centrs (Time to inspect and care for young stands. Latvian Rural Consulting and Education Center). [Online]. [Accessed 17.03.2025]. Available: https://new.llkc.lv/lv/nozares/mezsaimnieciba/laiks-apsekot-un-kopt-jaunaudzes (In Latvian).
[37] Peat4Res. Project: Sustainable strategies for the restoration of peat extraction sites. Riga Technical University, Institute of Energy Systems and Environment. [Online]. [Accessed 17.03.2025]. Available: https://videszinatne.rtu.lv/zinatne/projekti-un-petijumi/peat4res/ (In Latvian).
[38] Ross K. Potential for Greenhouse Gas Emission Savings from Paludiculture. Department for Environment, Food and Rural Affairs, Dec. 2024. [Online]. Available: https://www.paludiculture.org.uk/post/what-are-the-greenhouse-gas-emissions-savings-associated-with-paludiculture
[39] Schreiber A., Marx J., Zapp P. Comparative life cycle assessment of electricity generation by different wind turbine types. *Journal of Cleaner Production* 2019:233:561–572. https://doi.org/10.1016/j.jclepro.2019.06.058
[40] European Commission. Photovoltaic Geographical Information System (PVGIS). [Online]. [Accessed 17.03.2025]. Available: https://re.jrc.ec.europa.eu/pvg_tools/en/tools.html
[41] Ferrara C., Marmiroli B., Carvalho M. L., Girardi P. Life Cycle Assessment of Photovoltaic electricity production in Italy: Current scenario and future developments. *Science of the Total Environment* 2024:948:174846. https://doi.org/10.1016/j.scitotenv.2024.174846

[42] Life Cycle Inventories and Life Cycle Assessments of Photovoltaic Systems. Aug. 2020. [Online]. [Accessed 17.03.2025]. Available: https://iea-pvps.org/key-topics/life-cycle-inventories-and-life-cycle-assessments-of-photovoltaic-systems/
[43] De Vita A. *et al.*, Eds., EU reference scenario 2016. Energy, transport and GHG emissions: trends to 2050. Luxembourg: Publications Office of the EU, 2016. https://doi.org/10.2833/9127.
[44] About PRé. PRé Sustainability. [Online]. [Accessed 02.05.2023]. Available: https://pre-sustainability.com/about/about-pre/
[45] SimaPro-Tutorial.pdf. [Online]. [Accessed 02.05.2023]. Available: https://simapro.com/wp-content/uploads/2023/04/SimaPro-Tutorial.pdf
[46] Bruijn H. *et al.* Handbook on Life Cycle Assessment: Operational Guide to the ISO Standards. In *Eco-Efficiency in Industry and Science*, no. 7. Dordrecht: Kluwer Academic Publishers, 2004. https://doi.org/10.1007/0-306-48055-7
[47] Intergovernmental Panel on Climate Change (IPCC), Climate Change 2021 – The Physical Science Basis: Working Group I Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, 1st ed. Cambridge University Press, 2023. https://doi.org/10.1017/9781009157896
[48] Interreg Baltic Sea Region. Transitional guideline for the certification of GreenIndustrialAreas. Interreg Baltic Sea Region, Germany, Mar. 2024.
[49] Archibald A. T., Folberth G., Wade D. C., Scott D. A world avoided: impacts of changes in anthropogenic emissions on the burden and effects of air pollutants in Europe and North America. *Faraday Discuss* 2017:200:475–500. https://doi.org/10.1039/C7FD00004A