# THE DEVELOPMENT OF BIOECONOMY OF THE BALTIC REGION IN THE CONTEXT OF REGIONAL AND GLOBAL CLIMATE CHANGE

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*Climate change is projected to have a profound effect on natural ecosystems, biodiversity, and societies both in the Baltic region and globally, particularly so through agriculture and food systems. The Baltic region has a vast potential for the development of bioeconomy due to the existing opportunities for biomass production and advances in microbiology leading to process- and product innovations in biomass production and utilization. The development of sustainable bioeconomy in the Baltic region, however, requires a flexible and timely adaptation to climate change. Based on an overview of the relevant state-of-the-art literature, the article explores the implications of the development of bioeconomy for the adaptation to and the mitigation of climate change in the Baltic region. The paper elaborates on actions that may facilitate the sustainability of bioeconomy in the region. It concludes that scientific collaboration across borders in the Baltic region can accelerate innovations to successfully adapt bioeconomy to climate change. Sustainable development of bioeconomy can provide considerable opportunities for mitigating climate change.*

***Keywords:***
climate change, adaptation, mitigation, bioeconomy, geography, Baltic region, sustainable development

## 1. Introduction

The impact of climate change is becoming more dramatic in many parts of the world, including the Baltic region. Compared to the pre-industrial period (1850—1900), the global mean temperature (over land and oceans) has currently increased by 0.87°C. The mean temperature over land alone has grown almost twice as fast and is now 1.53°C higher than during the pre-industrial period [1].

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These seemingly small changes in temperature have a profound effect on the functioning of natural ecosystems, on biodiversity and societies, agriculture and food systems [1].

Climate change is projected to have considerable effects on the Baltic Sea region, including a rise in land and sea temperatures, increased frequency and intensity of adverse climate events (such as storms, extreme precipitation, heat waves, floods), a drop in crop and fish yields, forest fires, and a rise in the number of infectious diseases [1—3]. The available literature shows that the temperatures in the Baltic Sea have been rising two to four times faster than the global average. Only between 1982—2006, the recorded increase was 1.35°C [4—6]. The rising seawater temperatures are leading to an increase in Vibrio infections resulting in foodborne disease outbreaks [7]. Simultaneously, the water salinity in the Baltic Sea decreased between 1975 and 2000 [4; 8; 9], which had important implications for marine ecosystems. Fish production in the region is being negatively affected by decreasing numbers of phytoplankton [10; 11].

The Baltic region has a substantial potential for the development of bioeconomy due to good conditions for biomass production, as well as rapid advances in microbiology leading to process and product innovations in biomass utilization. However, the sustainable development of bioeconomy in the region can be constrained by climate change impacts. The objective of this paper is to review the latest literature to explore the implications of the development of bioeconomy for climate change adaptation and mitigation in the Baltic region. Based on this assessment, the paper intends to elaborate on actions that may facilitate the sustainability of bioeconomy in the region.

## 2. Bioeconomy Concept

Changes in land use and unsustainable land management practices have led to soil and land degradation affecting from 3 % to 43 % of the land area in different parts of the Baltic region, leading to significant economic losses in terms of land ecosystem services [12]. Climate change and land degradation combined can pose significant challenges to the sustainable development of agriculture, fisheries and food systems in the Baltic Sea region. Borders in the Baltic region, of course, do matter for economic geography, as it is highlighted by Fedorov [13]. And yet, using bioeconomy and addressing climate change can benefit only from trans-border cooperation, research and actions.

The principles of the emerging bioeconomy are being rapidly introduced in agriculture and food systems both globally and regionally. Bioeconomy is "the production and utilization of biological resources (including knowledge) to provide products, processes and services in all sectors of trade and industry within the framework of a sustainable economy"[1]. Thus, bioeconomy aims for sustainable production and use of biological resources, processes and principles. Bioeconomy belongs to a family of new terminologies, but is not synonymous with circular economy and green economy, and these three notions should not be used interchangeably [14;15]. As defined above, bioeconomy is basically circular if it is based on sustainable use of natural resources and processes, and thus it can significantly contribute to a circular economy, which also includes the re-use of any materials. Both bioeconomy and circular economy must keep environmental externalities (often simplified as environmental footprints) of processes and products (over lifecycles) in mind. Bioeconomy and circular economy are to facilitate intelligent, sustainable and inclusive growth that allows transition toward green economy, the latter being a broader and fuzzier concept than bioeconomy and circular economy. Bioeconomy is not solely about a more optimal use of resources. Rather it seeks societal transformations and a "biologization" of industrial and agricultural processes and of the economy as a whole to achieve sustainable development.

Bioeconomy is key for coping with climate change and it is also becoming an essential component of the transformation of economic systems, which is aimed at sustainability in general [1;16;17]. On the other hand, the negative impact of climate change and land degradation on the development of bioeconomy is clearly visible in the reduced availability of biomass and increased competition for it in the region. There is a broad agreement — also articulated in the Sustainable Development Goals [18] — that renewable resources should preferably be used and sustainably produced and processed materials should play a more important role. The Paris Agreement on climate change adds impetus to investing in a sustainable bioeconomy. A knowledge-based sustainable bioeconomy contrasts with the excessive use of biological and other natural resources and adverse environmental effects caused by it. This paper aims to explore the opportunities for the development of bioeconomy for economic transformation and climate change adaptation and mitigation in the Baltic Sea region. The paper also elaborates on actions that may facilitate the sustainability of bioeconomy in the region.

[1] What is Bioeconomy? URL: http://biooekonomierat.de/en/bioeconomy/ (access date: 13.07.2019).

# 3. Mitigating and Adapting to Climate Change through Bioeconomy

## *3.1. Synergies and Trade-offs of the Development of Bioeconomy*

Sustainable bioeconomy development facilitates response to climate change by reducing greenhouse gas emissions and increasing climate change adaptive capacities. For example, limiting a rise in temperature between 1.5°C- 2°C requires land-based mitigation and land-use change, including reforestation, afforestation, reduced deforestation, and bioenergy [3]. Afforestation and reforestation help sequester carbon, increase the availability of biomass for the development of bioeconomy and can provide with a wide range of ecosystem services. However, getting these benefits takes time [1]. From this perspective, the Baltic region has experienced an impressive growth in the forested area over the past few decades. Between 2001 and 2009, the extent of forests in the Baltic region increased by 5.7 million hectares (representing an 18 % growth), while during the same time, the area of grassland, woodland and shrubland decreased by about 60—75 % [12].

On the other hand, the wide-scale application of land-based climate change mitigation options through afforestation, reforestation, and expanded biofuel production can jeopardize food and fodder supplies. Sustainable forest management, improved management of cropland and grazing lands allow for reducing land conversion for food production [1]. Sustainable forest management is particularly important for the Baltic region, where several countries — Sweden, Latvia and Estonia — are among the top global wood pellet producers and exporters [19]. It is well-known that bioenergy provides an important share of the total primary energy supply in these countries and Finland [19]. The need for expanding agricultural land could be reduced by a higher crop and livestock productivity, shifting to more plant-based diets, and reducing food waste and losses. Besides, using organic waste for bioenergy production could lessen the tradeoffs associated with bioenergy development [1]. Bioeconomy helps adapt to limitations in fossil resources by providing substitutes, including modern bioenergy, and creating markets for carbon and ecosystems services [20; 21].

As with any strategy for climate change mitigation and adaptation, the consequences of bioeconomy development for economic development need to be carefully considered. There are certainly tradeoffs among the goals of food security, environmental sustainability, and energy security that need to be considered. Large-scale utilization of biomass for bioenergy generation could help with climate change mitigation but may reduce food production and negatively affect biodiversity. Many newly planted managed forests are often made up of only a few tree species and can harbour much less biodiversity than natural forests. On the other hand, bioeconomy development can boost agricultural growth, strengthen energy security and provide new jobs both in rural and urban areas, thus considerably aiding climate change adaptation.

Agricultural production and energy systems are intricately linked. Fossil fuels are used both as a direct input in agricultural activities (e.g. for operating agricultural machinery) and indirectly when they are used for producing chemical fertilizers for crop production [22]. Agricultural biomass is also used for bioenergy production, with biofuels often competing with food production for land, water and other resources [23; 24]. Rapid biofuel expansion has been found to shift price volatility from energy markets to agricultural markets [25; 26]. Technological and institutional innovations in bioeconomy that increase agricultural productivity and reduce food waste and losses could help mitigate these tradeoffs between food and energy uses of biomass, while also reducing CO2 emissions.

Reducing food loss and waste also requires shifts in consumption and diets, i.e. changes in socioeconomic behaviour. Policies that influence consumption choices through providing access to information, education, setting price incentives need to be coordinated with broader bioeconomy policies. The ultimate purpose of bioeconomy policies is to provide long-run incentives for sustainable farming, sound bio-resource management and industrial development. Facilitating collective action at the regional and international level is a priority, especially in terms of sharing new bioeconomy-related knowledge and best practices between the Baltic region and other European regions and countries.

### *3.2. Enabling Bioeconomy for Climate Action*

The key elements for enabling bioeconomy to contribute to climate change mitigation and adaptation in the Baltic region are, firstly, through appropriate policies, institutions and governance systems of all scales and mutually supportive climate and land policies. Secondly, it can be done through policies that operate across the food and energy systems, and thirdly, by strengthened multilevel and cross-sectoral governance with flexible policies. The ultimate goal of these policy and governance approaches is to stimulate climate-smart technological, social and organisational innovations within bioeconomy (Fig. 1).

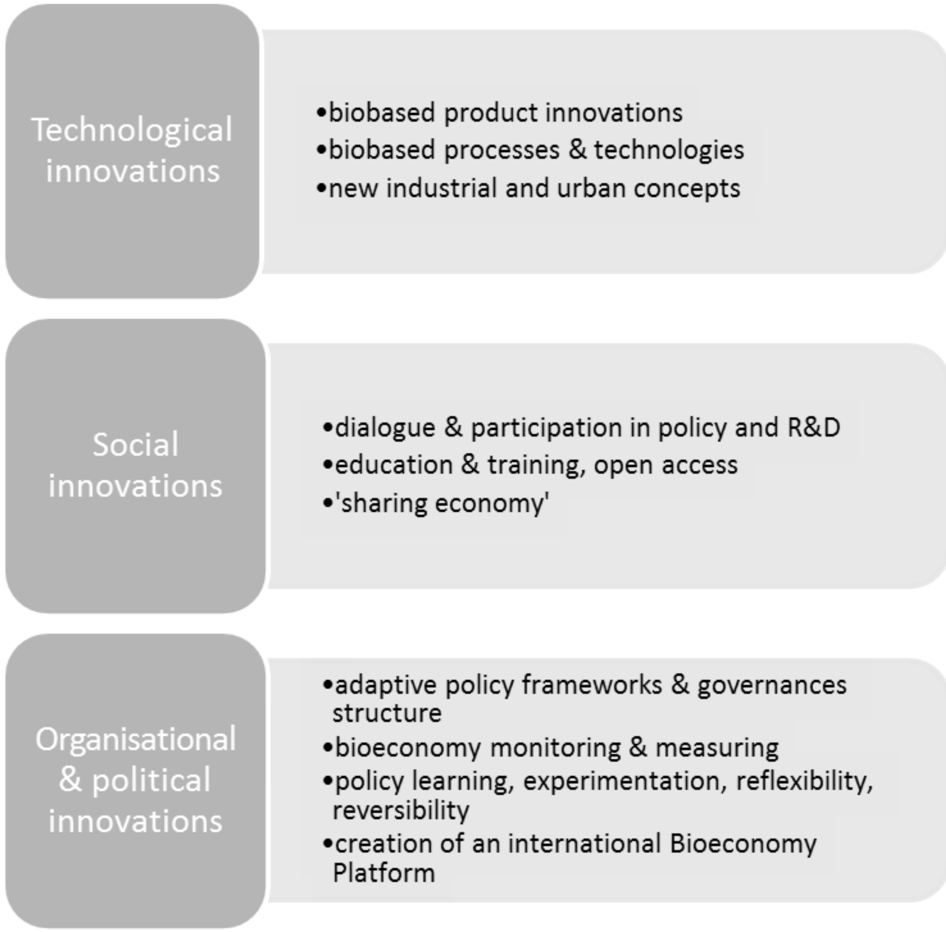


Fig. 1. Innovations for sustainable Bioeconomy development

The development of bioeconomy is warranted by the need to ensure a more sustainable use of resources and tackle climate change. Moreover, technological and scientific innovations, changing consumer preferences and social innovations (e.g. sharing economy), as well as organisational innovations (e.g. improved monitoring and assessment of bioeconomy) are currently facilitating the rapid development of bioeconomy in many regions of the world, including in the Baltic region. It is expected that bioeconomy development will help societies to address such major environmental challenges such as decreasing biodiversity, land degradation, and air pollution. Specific characteristics of bioeconomy development depend on local conditions and vary from one region to another, depending on their comparative advantages such as resource endowment, economic specialisation and the state of development [27].

Currently, more than 40 countries worldwide pursue the development of bioeconomy in their policy strategies. These bioeconomy strategies seek to make use of available biological resources to promote environmental sustainability [28], climate-friendly economic growth and creation of new jobs. Some Baltic countries such as Finland, Latvia, Lithuania have already developed their bioeconomy strategies, while Russia has bioeconomy-related elements in some of its strategies. The European Union as a supranational organisation released a bioeconomy strategy in 2012 [29]. The Baltic region can connect, in this regard, to the neighbouring Nordic countries and Germany. Russia would benefit from a comprehensive dedicated bioeconomy strategy of its own. Similarly to other regions of the world, the Baltic region as a whole could elaborate a joint trans-border bioeconomy. This would be in line with suggestions for more integration rather than divergence in the region [30].

### *3.3. Bioeconomy — Agriculture Linkages*

As the IPCC Special Report on Climate Change and Land demonstrated, achieving climate change mitigation targets is extremely challenging without comprehensively including agriculture and food systems into mitigation strategies [1]. This is also true for the Baltic region. The demand for food, fodder, fibre and energy is growing due to population and income growth. Meeting this demand by relying on fossil fuels is no longer environmentally feasible, and it requires a shift to cleaner sources of energy. The use of renewable and sustainable biomass has an important role to play in the energy transition away from fossil fuels. In 2011, about 14 % of the total biomass produced globally were used for food, 58 % for fodder, 10 % for bio-based chemicals and materials, 17 % for fuel and the rest for other purposes [31].

Animal production is among the major source of greenhouse gas emissions from agriculture. Moreover, there is a growing consumption of animal products (for instances, meat) which are biomass intensive. Therefore, animal production needs to be included in efficient value networks as part of bioeconomy development to reduce CO2 emissions from the food systems.

Achieving synergies among bioeconomy development, climate action and food security in the Baltic region requires increased efficiency and innovativeness across the entire value network rather than its individual components alone, such as crop production or livestock production separately [32]. Some examples of such efficiency gains include new bio-based industrial fibres (e.g. artificial spider fibres and milk-protein based fibres) [33], developments in modern industrial biotechnology (the use of vegetable oils in industry by integrating fatty acid profiles, the use of succinic acid plants[2] in the chemical industry), innovations

[2] Succinic acid is a diprotic, dicarboxylic acid with chemical formula $C_4H_6O_4$. More recently, succinic acid is being produced through the fermentation of glucose from renewable feedstock. As chemical industries transform from petro-based to environmentally sustainable materials, succinic acid is emerging as one of the competitive new bio-based chemicals.

related to dedicated lignocellulosic crops converted into ethanol in bio-refinery [34], new bioplastics, bio-based synthetic meat, etc.

Cutting across these innovations is a process innovation, called a cascade approach. This means that resources are used in steps (cascade) for manufacturing different products: the most valuable resources are used first, followed by intermediate products, and finally, the least valuable products, for instance, biomass leftovers, are used for biofuels. This approach to production and consumption states that energy recovery should be the last option, and only after all higher-value products and services have been exhausted. There are numerous examples of cascading from modern wood processing and wood building construction apply here.

To sum up, a food security-sensitive and climate-friendly bioeconomy requires new biomass types with low resource requirements, cascading re-use systems, as well as end-product innovations, even unrelated to existing biomass production, such as indoor farming using hydroponics.

## 4. Bioeconomy and Structural Transformations

Bioeconomy is no longer driven by rising price expectations for fossil fuels. The main drivers are climate and resource conservation and the potential for bio-based innovations [35]. In the following section, a set of approaches is discussed to frame, model and analyse bioeconomy, its role in climate action and related challenges from global perspectives, which are also highly relevant for the Baltic Sea region.

### *4.1. Sector perspective*

Bioeconomy is not a sector, but actually is a part of and cuts across various sectors of the economy. The traditional approach of studying economic transformation takes a sectoral perspective of changing (GDP) shares of agriculture, industries and services in the economy. Nowadays, agriculture represents only about 4 % of GDP and provides 20 % of employment globally, where employment may include significant shares of part-time jobs in the sector. This concept of structural transformation based on sectoral change has outlived its relevance to depict economic change almost everywhere except the least developed countries. This is not only due to the limitations of GDP accounting, but also to the very concept of 'sectors', whose diversity changes mainly within rather than between sectors.

Agriculture is a case in point, combining industrial and service features to a growing extent, both at farm level and in value chains originating from primary production. Remote sensing and digital-based precision agriculture is an example, as are complex service contracts and cooperation arrangements for produce marketing. It would be tempting to overcome the problem of inadequacy of sectoral approaches by simply disaggregating sectors as far as possible and proceeding with bioeconomic analyses under a sector concept. Its characteristic of cutting across sectors, however, would get partly lost [36], and depicting process innovations, recycling efficiencies, and technical changes in production functions would require approximation [32]. As a result, a sector perspective will give a rather fragmented view of bioeconomy's contributions to climate change mitigation and adaptation.

### *4.2. Firms' perspective*

Firms can be a useful unit of the analysis of bioeconomy, as this would integrate the role of the demand side, issues of the optimal size of firms and locational advantages. According to Coase [37], people organise their production in firms when the transaction costs of coordinating production through the market exchange, given imperfect information, are greater than within the firm. This basic theory also applies to bioeconomy, and it depends upon the nature of products, processes — such as the abovementioned cascade use — and input supply chains and locations of output demand and input supplies that define firms' size and locations. The demand for bioeconomy originates in markets for sustainably provided bio-based products. These markets may be shaped not only by household demand, but also by the demand of government sectors for product acquisitions. The latter may be the outcome of political markets of environmental transformative policies, such as tax reductions for bio-products purchased by the public sector or carbon pricing, and can be distorted by rent-seeking of political actors and industries.

Given the considerable involvement of government initiatives and new interlinkages among industries, "industrial organization" approaches may be helpful to guide a business strategy and a public policy [38]. Joint innovation efforts across firms to reduce environmental pollution pursued recently in the pulp and paper industry are an example of a coordinated industrial organisation [39]. To evaluate bioeconomic change for an industry's performance, a usual set of criteria is applied, i.e., allocation efficiency, production efficiency, equity, and technological advancement [32]. Bioeconomy can be part of a new industrial strategy in which sustainability and climate action are considered. Industries' competitiveness in a bioeconomy context will depend on innovations around bio-based products and processing technologies. They will be in demand only if they are competitive in the market and perceived as better than non-bio-based products by consumers.

### *4.3. A systems perspective*

At the core of the economics of bioeconomy are systems thinking with a comprehensive attention to externalities and transaction costs. Figure 1 presents a systems perspective of the bioeconomy with clusters and interlinked value chains. Key elements are primary production, health and other services, and transforming bio-based industry clusters, all clusters being integral with and impacted by bioscience and other innovations, at the centre of the systems graph.

In a systems analysis approach, drivers of the bioeconomy are related to changes in system components, and impacts on growth, distribution, and ecology are derived in the context of policy interventions. Competition among goals and complementarities of instruments should be explicitly modelled. Such an approach would best include lifecycle analyses of inputs and outputs. However, the usual limitations of systems modelling apply—for instance, selective capture of causal relations, difficulties of systems boundary definition, and dynamics of technological change. The above-discussed industry clustering perspective can be usefully combined in the narrative of bioeconomy systems modelling and may even be integrated.

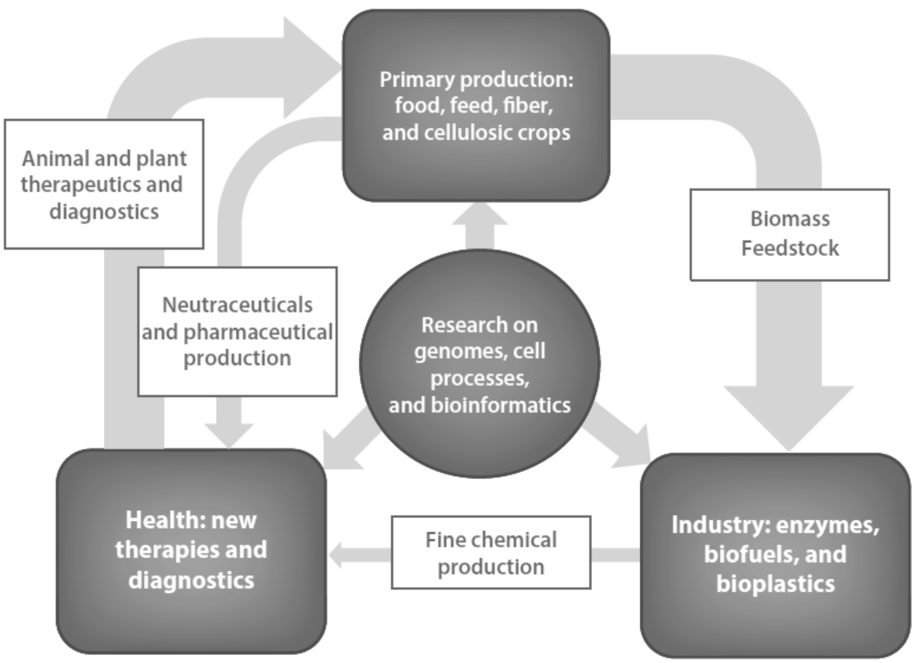


Fig. 2. The emerging bioeconomy: clusters with interlinkages

Source: adapted from the German Bioeconomy Council, 2018.

### *4.4. An innovation economics perspective*

The basic theoretical underpinnings of bioeconomy can be explored through the lens of the economics of induced innovation [41], where innovations result from factor scarcities and related expected price changes (i.e., prices of land, water, carbon dioxide (CO2), and energy). As in Hayami and Ruttan [41], a conceptual framework for the development of bioeconomy must take into account the key role of knowledge components and their endogenous nature. New thinking about innovation systems is relevant here. Hekkert et. al [42] point out that it is necessary to provide more insight into the dynamics of innovation systems. They propose a framework that focuses on a number of processes important for well-functioning innovation systems. These processes are labelled by Hekkert et. al [42] as 'functions of innovation systems'. The authors propose a method for systematically mapping the processes taking place in innovation systems, thus resulting in technological change. This analysis of processes and event history analysis are also appropriate and relevant for the innovation systems of bioeconomy.

Combining the four approaches mentioned above — sector, firms, systems, and innovation perspective — with innovation storylines may provide insights into the opportunities and constraints of bioeconomy. This combination may identify conflicting goals, for example, those related to climate action, may offer a broader resource use, facilitate development, and enhance food security. Bioeconomy and its relation to climate action presents new challenges, requiring economists to go beyond the limitations of an isolated value chain, sectoral and commodity analyses. It brings economists to the need to learn more about a much broader set of relevant technologies, intermediate and final demands related to bio-based processes and products. There is also a need for close collaboration with other disciplines (nutrition, ecology, biotechnologies, biochemistry, etc.), if they want to serve as "bioeconomists".

### *4.5. Measuring Size, Value and Outcomes of Bioeconomy in the Baltic Region*

It will be difficult to assess the contribution of bioeconomy to the climate change agenda without an appropriate measurement of bioeconomy. It is related to the measurement of sustainability and climate consequences of actions by economic agents, such as investors, policymakers, and consumers. Several approaches may be used for measuring bioeconomy, but each needs to be scrutinized from the perspective of what should be measured and how it can be done [32]. One widely used approach is based on using the system of national accounts to provide an overview of the contribution to the regional or national economy, and employment and consumption shares. This might not provide a comprehensive picture of future opportunities. Other approaches are related to bioeconomy clusters, or the emergence of key technologies and innovations, their application as well as private and public sector investments. Furthermore, the contribution of bioeconomy to environmental sustainability and people's well-being would need to factor in health and ecological effects as bioeconomy outcome measurement. To capture spatial dimensions, the economic geography approach for measurement of bioeconomy is called for. We also need to improve empirical methods for causal inference (including the opportunities of using big spatially referenced ecology data) to actually learn about causal links between size, type, and outcomes of bioeconomy policies and programmes.

In general and for the Baltic region in particular, outcome-based measures rather than sectoral measurement or measurement of products' bio-contents is desirable. Outcomes would include reduced carbon emissions, sustainability of water, soil and biodiversity improvements, measured in both technical and economic ways, including non-price measurement approaches, but also in well-being outcomes such as health improvements (e.g., reduced air pollution, people's actual health related to environmental factors) and improved amenities, such as greener cities.

## 5. Conclusions

The development of bioeconomy provides new opportunities for responding to the challenges posed by climate change in the Baltic Sea region. The generation of bioenergy and other renewable energy sources can significantly reduce greenhouse gases emissions. Bioeconomy will, however, not unlock its transformational potential if pursued in isolation by regions. The Baltic region as a whole could elaborate and implement a joint trans-border bioeconomy strategy, as other regions of the world did. Sharing new bioeconomy knowledge from science systems and support for adaptation to local circumstances is a necessary collective action, particularly for promoting action on climate. To successfully adapt the bioeconomy to climate change, science policy in the Baltic region must generate accelerated innovations, and resource protection policies need to enhance sustainable utilization of land, water and biodiversity. Sustainable bioeconomy development, in its turn, can provide with considerable opportunities for climate change mitigation.

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