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Abstract

Climate change is projected to have profound impacts on the functioning of natural ecosystems, on biodiversity, and on societies in the Baltic Sea Region, particularly through affecting the bioeconomy sectors. This policy brief explores opportunities and implications from bioeconomy development for climate action in the region. It also elaborates on actions that may facilitate the sustainability of bioeconomy. The policy brief concludes that scientific collaborations across borders in the Baltic Sea Region could help generate accelerated innovations in order to successfully leverage bioeconomy development for climate action. Sustainable bioeconomy development, in its turn, can provide with considerable opportunities for green growth and economic competiveness.

Key words: climate change, adaptation and mitigation, bioeconomy, geography, Baltic Sea region, sustainable development

1. Introduction

The Baltic Sea Region (BSR) has a substantial potential for bioeconomy development due to high biomass availability and because of rapid ongoing advances in microbiology leading to process- and product innovations in biomass utilization (Vanhamäki, Schneider and Manskinen, 2019; von Braun and Mirzabaev, 2019). Sustainable bioeconomy development in the region will be strongly affected by climate change impacts on biomass production. On the other hand, bioeconomy development can also play a significant role in climate change mitigation and adaptation. In this regard, purposefully leveraging the advances in bioeconomy for climate change action can provide with multiple-win outcomes.

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.

Biomass is a broad term defining all types of biological resources used for or processed into energy, food, feed, or any other bio-based products.

Sources: Andersen (2007), Pearce et al., (2013), BioÖkonomieRat (2009).

Agriculture and food systems both globally and in the BSR are rapidly becoming embraced by the emerging bioeconomy. Bioeconomy aims for sustainable production and use of biomass. The term 'bioeconomy' belongs to a family of new terminologies, but is not synonymous with 'circular economy' and 'green economy', and these three should not be used interchangeably (Andersen, 2007; BioÖkonomieRat, 2009; Pearce, Markandya and Barbier, 2013). Bioeconomy is circular if based on sustainable use of natural resources and processes, and thus significantly contributes to a 'circular economy', which also includes re-use of any materials. Both bioeconomy and circular economy must seek to minimize environmental footprints of processes and products (over lifecycles). Bioeconomy and circular economy seek to facilitate intelligent, sustainable and inclusive growth that allows transition toward a 'green economy', the latter being a broader and fuzzier concept than bioeconomy and circular economy. Bioeconomy is not solely about more optimal resource use but seeks societal transformation and a 'biologization' of industrial and agricultural processes and of the economy as a whole in order to achieve sustainable development.

Bioeconomy is key for coping with climate change and it is also emerging as a key component of economic systems' transformation toward sustainability in general (IPBES, 2019; IPCC, 2019), which implies increased use of renewable resources, with sustainably produced and processed biomass playing a key role. A knowledge-based and sustainable bioeconomy contrasts with exploitative use of biomass and other natural resources and related adverse effects on the environment.

The 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 specialization and state of development (German Bioeconomy Council, 2015). National and regional bioeconomy strategies often seek not only to make use of the potential of biological resources to promote environmental sustainability (FAO, 2016), but also achieve climate-friendly economic growth and job creation. Such dedicated bioeconomy strategies have been developed by several BSR countries such as Finland, Germany, Latvia, Lithuania, while other BSR countries are currently working on developing such strategies or incorporating bioeconomy-related elements in their other policy strategies. The European Union, as a supranational organization, released a bioeconomy strategy in 2012 (European Commission, 2012). In this regard, the BSR as a whole could explore a joint trans-border bioeconomy strategy. This would be in line with suggestions for more integration rather than divergence in the region (Fedorov and Mikhaylov, 2018).

The objective of this policy brief is to explore the implications of bioeconomy development for climate change adaptation and mitigation and elaborate on actions that may facilitate the sustainability of bioeconomy under the changing climate in the BSR.

2. Observed and projected impacts of climate change in BSR

The observed impacts of climate change are becoming more pronounced across the world, including in the BSR. Compared to the pre-industrial times (1850-1900), the global mean temperature (over both land and oceans) has currently increased by 0.87°C. The mean temperature over land alone has grown almost twice faster, now standing 1.53°C higher than during the pre-industrial period (IPCC, 2019). In the BSR, annual mean temperature increases equaled about 1.4°C between 1878-2020 (Meier *et al.*, 2021).

The available evidence shows that the temperatures in the Baltic Sea are rising two to four times faster than the global average. Only between 1982-2006, the recorded increase was by 1.35°C (Aleksandrov, Zhigalova and Zezera, 2009; Belkin, 2009). These seemingly small average temperature changes have, in fact, profound impacts on the functioning of natural ecosystems, on biodiversity, and on societies, particularly through agriculture and food systems (IPCC, 2019). The changes in precipitation across the BSR did not show definitive patterns, but extreme precipitation intensity was indicated to have increased since 1960 (Meier *et al.*, 2021).

Key observed impacts of climate change on terrestrial ecosystems in the region include advancement of the growing season (Jin *et al.*, 2019), upslope shifts in mountain treeline, increases in land surface greenness due to carbon fertilization effect (Smith *et al.*, 2008; Meier *et al.*, 2021), and losses in permafrost (Obu *et al.*, 2021). Moreover, climate change is indicated to have led to a stronger forest growth (Niemelä *et al.*, 2015), especially in the northern and western parts of the region (Krug *et al.*, 2015). Land use changes and unsustainable land management practices have led to soil and land degradation from 3% to 43% of the land area in different countries of the BSR, with significant economic losses in terms of land ecosystem services (von Braun and Mirzabaev, 2016).

Combined climate change and land use effects increased the eutrophication in the Baltic Sea expanding the areas with oxygen deficiency (Carstensen, Andersen, *et al.*, 2014; Carstensen, Conley, *et al.*, 2014; Lennartz *et al.*, 2014; Jokinen *et al.*, 2018), led to changes in the structure of fish populations, and altered the marine food webs (Meier *et al.*, 2021). The rising sea water temperatures are leading to increases in *Vibrio* infections resulting in foodborne disease outbreaks (Baker-Austin *et al.*, 2013). Simultaneously, the water salinity in the Baltic Sea decreased between 1975 and 2000 (Möllmann *et al.*, 2003; Aleksandrov, Zhigalova and Zezera, 2009), which has important implications for marine ecosystems.

Climate change and land degradation will pose significant challenges to the sustainable development and functioning of food systems in the region. Future climate change will be manifested though higher land and sea temperatures, altered frequency and intensity of extreme weather events (such as storms, extreme precipitation, heat waves, floods), lower crop yields and potential declines in fisheries, forest fires, and higher health burden due to infectious diseases (IPCC, 2019; Meier *et al.*, 2021). Carbon fertilization effect is projected to stimulate vegetation growth, while leading to shifts in the composition and distribution of vegetation (Meier *et al.*, 2021). The ongoing loss of permafrost is expected to accelerate (Meier *et al.*, 2021).

Taken together, these changes will present both challenges and opportunities for bioeconomy development in the BSR. The direct impact of climate change and land degradation on bioeconomy development in the region can occur through affecting the availability of biomass and increasing the competition among the different uses of biomass.

3. Mitigating and adapting to climate change through bioeconomy

3.1. Opportunities and constraints from bioeconomy development

As the IPCC Special Report on Climate Change and Land demonstrated, achieving climate change mitigation targets is extremely challenging without comprehensively including food systems into mitigation strategies (IPCC, 2019). Currently, about a third of all global greenhouse gas emissions are coming from the food systems (IPCC, 2019). This is also true for the BSR. The demand for food, feed, fiber and energy is growing due to population and income growth. Meeting this demand growth by relying on fossil fuels is no longer environmentally feasible, requiring shifts to cleaner sources of energy. The use of renewable and sustainable biomass has an important role to play in such energy transitions away from fossil fuels. In 2011, about 14% of the total biomass globally were used for food, 58% for feed, 10% for bio-based chemicals and materials, 17% for fuel and the rest for other uses (Piotrowski, Carus and Essel, 2015).

Sustainable bioeconomy development can help reduce greenhouse gas emissions by replacing fossil fuels with biomass across a wide range of end uses and applications, by storing carbon in bio-based products, and by sequestering atmospheric carbon in biomass (European Commission, 2012; Hoff *et al.*, 2018). For example, limiting warming to 1.5°C or well below 2°C requires land-based mitigation and land-use change, including reforestation, afforestation, reduced deforestation, and bioenergy (de Coninck *et al.*, 2018). Afforestation and reforestation helps sequester carbon, increase the availability of biomass for bioeconomy development, and can provide with a wide range of ecosystem services, but usually take time in delivering these benefits (Mirzabaev *et al.*, 2019; Smith *et al.*, 2019; Arneth *et al.*, 2021). From this perspective, the BSR has experienced an impressive growth in forested area over the past few decades. Between 2001 and 2009, the extent of forests in the region increased by 5.7 million hectares (representing an 18% growth), while during the same time, grasslands, woodlands and shrublands declined in the region by about 60-75% (von Braun and Mirzabaev, 2019). Sustainable use and management of these forests and forest products, restoration of degraded ecosystems, and continued efforts for conservation of biodiversity could provide both carbon sequestration and biomass production benefits.

In addition, more research and development need to be directed towards higher carbon efficiencies across the production, transportation, distribution and waste disposal processes across the bioeconomy sectors (Cudlínová, Lapka and Vávra, 2017). Achieving synergies among bioeconomy development, climate action and food security in the BSR requires increased efficiency and innovativeness across the entire value webs rather than its individual components alone, such as crop production or livestock production separately (Wesseler and von Braun, 2017). Some examples of such efficiency gains include bio-based innovations in fibers with novel industrial applications (e.g. artificial spider fibers and milk-protein based fibers), developments in modern industrial biotechnology (use of vegetable oils in industry by integrating fatty acid profiles, the use of succinic acid plants in the chemical industry), innovations related to dedicated lignocellulosic crops converted into ethanol in bio-refinery, 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 for different products, i.e., cascades, whereby the most valuable substances are used first, then intermediate products, and only in the end, for instance biomass leftovers are used for biofuels. Examples from modern wood processing and wood building construction apply here.

On the other hand, wide-scale application of bioeconomy-based climate change mitigation options through afforestation, reforestation, and expanded biofuel production could reduce food and feed supplies. In this regard, sustainable forest management, improved management of cropland and grazing lands allow for reducing land conversion for food production and mitigating food-energy competition for biomass use (IPCC, 2019). Sustainable forest management is particularly important for BSR, where several countries, such as Sweden, Latvia and Estonia, are among the top global wood pellet producers and exporters (Silveira *et al.*, 2017), while bioenergy provides an important share of the total primary energy supply in the same countries as well as in Finland (Silveira *et al.*, 2017). On the other hand, the demand for new agricultural expansions could be also reduced by bioeconomy innovations and social changes such as higher crop and livestock productivity, shifting to more plant-based diets, and reducing food waste and losses. In addition, using organic waste for bioenergy generation could lessen the tradeoffs associated with bioenergy development (Smith *et al.*, 2019). Bioeconomy helps adapt to limitations in fossil resources by providing substitutes, including modern bioenergy, and creating markets for carbon and ecosystems services (von Braun, 2015; Börner *et al.*, 2017).

Animal production is among the major source of greenhouse gas emissions from agriculture. Moreover, there is a growing consumption of animal products, which are biomass intensive, such as meat. Therefore, animal production needs to be included into efficient value webs as part of bioeconomy development in order to reduce CO_2 emissions from the food systems.

Like 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. Large-scale sustainable utilization of biomass for bioenergy 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 harbor 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.

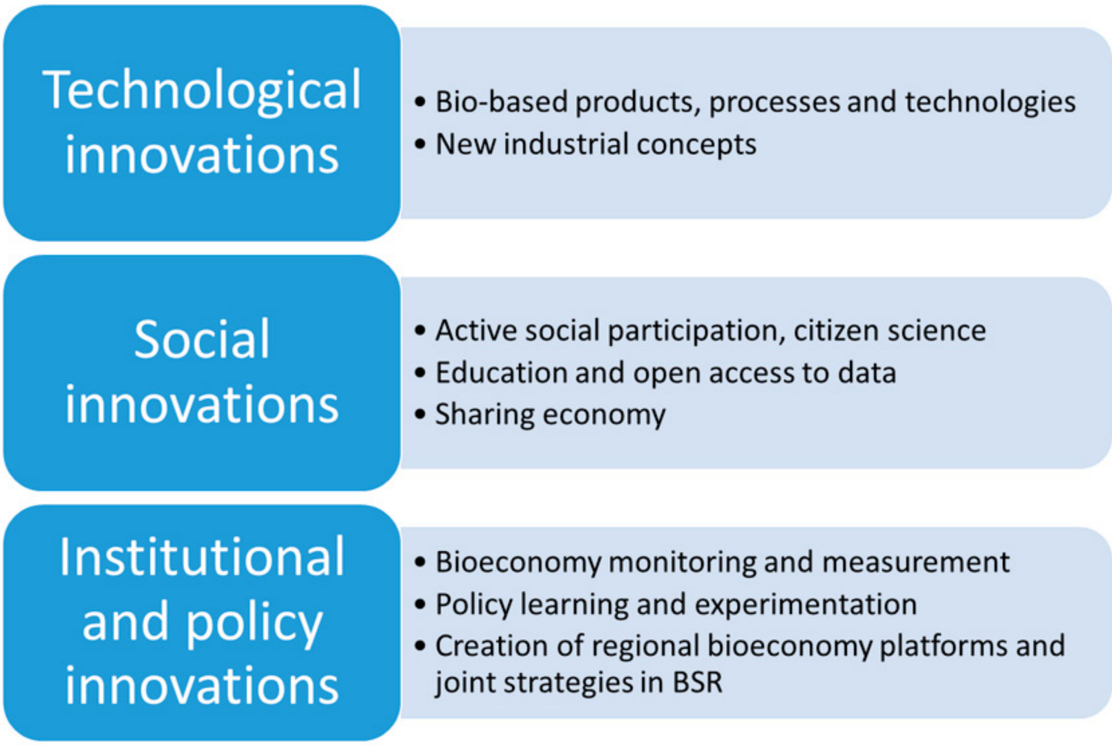
Biomass produced in agriculture is also used for bioenergy production, with biofuels often competing with food production for land, water and other resources. Rapid biofuel expansion was found to transmit price volatility from energy markets to agricultural markets (Hertel and Beckman, 2011; Haile *et al.*, 2017). Technological and institutional innovations in the bioeconomy that increase agricultural productivity and reduce food waste and losses could help mitigate these tradeoffs between food and energy uses of biomass, while often also reducing CO_2 emissions.

Reducing food loss and waste also requires shifts in consumption and diets, i.e. changes in socioeconomic behavior. 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 regional and international level is a priority, especially in terms of sharing new bioeconomy-related knowledge and best practices between the BSR and the rest of Europe, and other regions.

3.2. Enabling bioeconomy for climate action

The key element for enabling bioeconomy to contribute to climate change mitigation and adaptation in the BSR is an appropriate design of policies, institutions and governance systems that are mutually supportive of bioeconomy, climate and land policies, by working across bioeconomy sectors and by strengthening multilevel and cross-sectoral governance. The ultimate goal of these policy and governance approaches is to stimulate climate-smart technological, social and organization innovations within the bioeconomy (Figure 1).

Figure 1. Innovations for sustainable bioeconomy development



Source: based von Braun and Mirzabaev (2019).

Such policies for bioeconomy development need to provide a stable and conducive framework for long-term development of bioeconomy not only through rules, regulations and financial aid, but also through public procurement of bioeconomy sector products (European Commission, 2018). In this regard, carbon pricing and carbon trading would provide a strong incentive for bioeconomy development. Recent agreements during the Glasgow conference of the United Nations Framework Convention on Climate Change on the implementation mechanisms for carbon trading as part of the article 6 of the Paris Agreement offer new possibilities for bioeconomy development, including in the BSR countries.

In addition to policy frameworks, technological and scientific innovations, changing consumer preferences and social innovations (e.g. sharing economy) facilitate bioeconomy's rapid development. 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.

Policy measures to support bioeconomy development need to be guided by appropriate measurement and monitoring of bioeconomy. In fact, without an appropriate measurement of bioeconomy, assessing the contributions of bioeconomy to climate change mitigation and adaptation will be difficult. The measurement of bioeconomy relates to measurement of sustainability and climate consequences of actions by economic agents, such as investors, policy makers, and consumers. Several approaches may be used for measuring bioeconomy, but each needs to be scrutinized regarding measurement of what and how (Wesseler and von Braun, 2017). One widely used approach is based on using the system of national accounts to provide an overview about the contribution to the regional or national economy, and employment and consumption shares. This might not provide a comprehensive picture about future opportunities. Other approaches look at bioeconomy clusters, or the emergence of key technologies and innovations, and applications and private and public sector investments. Furthermore, bioeconomy's contributions to environmental sustainability and people's well-being would need to factor in health and ecological effects as bioeconomy outcome measurement, and to capture spatial dimensions, an economic geography approach for measurement of bioeconomy is needed.

Globally and for the BSR in particular, outcome based measures rather than sectoral measurement or measurement of products' bio-contents is more promising. 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.

4. Conclusions

Bioeconomy development provides new opportunities to respond to the challenges posed by climate change in the BSR. Bioeconomy will, however, not unfold its full transformational potential if pursued in isolation by individual countries. In order to successfully adapt the bioeconomy to climate change, science policy in the BSR need to 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 and adaptation, but also equally importantly, help maintain and enhance BSR's industrial base and economic competitiveness. The BSR as a whole could explore a joint trans-border bioeconomy strategy, as have other world regions. Scientific collaborations across borders in the BSR could help generate accelerated innovations in order to successfully leverage bioeconomy development for climate action.

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