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Opportunities for bioenergy in the Baltic Sea Region

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Abstract

Security of energy supply, promotion of the bio-economy, nutrient recycling, and innovation are prioritized policy areas in the EU Strategy for the Baltic Sea Region (EUBSR). The Baltic Sea Region (BSR) has a great bioenergy potential worth exploring in this context. This paper explores the state-of-art of bioenergy systems and synergies with eco-systems services in the BSR region in the context of developing the region's bio-economy. In this brief assessment, we consider 8 countries (i.e. Sweden, Finland, Estonia, Latvia, Lithuania, Poland, Denmark, and Belarus) in the region. While the production and use of modern bioenergy can help reduce greenhouse gas (GHG) emissions, promote energy security, diversify energy resources, and contribute to a successful circular economy and rural development, it is important to find a balance between the exploration of resources and the management of eco-systems services. In addition, both climate change vulnerability and bioenergy production may affect the environment and the capacity of the BSR to deliver ecosystem services (ESS). We recommend integrated strategies for optimal use of bioresources in the region. Bioeconomy can be realized by innovative approaches, establishing cross-cutting institutional and policy linkages for increased prosperity and green growth in the Baltic Sea Region.

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1. Introduction

Security of energy supply, promotion of the bio-economy, nutrient recycling, and innovation are prioritized policy areas in the EU Strategy for the Baltic Sea Region (EUBSR) [1]. The EUBSR aims at conserving the sea, connecting the region, and increasing the economic prosperity of its inhabitants. Bioenergy is an abundant renewable resource in the BSR which can be deployed to explore multiple environmental and socio-economic benefits, thus supporting the stated priorities. Biomass feedstocks are available in the form of energy crops, agro-forest residues, by-products from industries, and biogenic municipal waste. This biomass can be used for multiple purposes (e.g. food, fibre, fodder, biofuel, and bio-materials) in bio-refineries [2].

Recently, the concept of a bio-based economy, so-called 'bioeconomy', is guiding the search for alternatives to substitute the 'fossil-based economy'. Bioeconomy primarily includes: (a) sustainable production of renewable bioresources with the aim to reduce both anthropogenic climate impacts and the dependency on fossil-based products, and (b) increased added value of biomass materials considering a reduced consumption of natural resources. In this context, it is important to evaluate the bioresources potential, conversion into multiple products (biofuels, food, bio-materials, etc.), nutrient recycling, and synergies for climate mitigation and adaptation strategies. Within this background it is crucial to assess sustainable bioeconomy development scenarios based on holistic and multidisciplinary approach.

Bioenergy can play an important role in providing energy security and diversifying energy sources, as well as mitigating climate change. Bioenergy pathways can help develop a bioeconomy in the BSR, promoting sustainable development and prosperity. The bioeconomy concept implies efficient utilization of renewable bioresources from land and sea as inputs for food, feed, and non-food products. However, the concept of biotechonomy is the utilization of bioresources for creation of products with high added value that are competitive to replace existing products in the market [3]. The use of bio-waste and bio-based processes, for example, can provide starting points for an innovative approach to substitute fossil-based products. The Baltic Sea is being polluted by industrial effluents, sewage discharge, and other municipal/industry waste [4]. Without proper treatment, this creates serious environmental and ecological problems such as algae blooming and loss of biodiversity. Many effluents could be used for the production of biogas and organic fertilizer. Waste-to-biogas technologies can provide multiple benefits such as waste management, renewable energy production for fossil energy substitution, and nutrient recycling.

Degraded land can be used for energy crop cultivation and this can help improve soil and water conservation which, in turn, can contribute to expansion of eco-system services and capacity to adapt to climate change. Yet, despite recent expansion in the use of bioenergy and international trade in the region, only a small portion of the existing potential has been harnessed for energy generation. Worldwide, negative effects have been observed as a result of increased bioenergy/biofuels production, including deforestation, biodiversity loss, water scarcity, competition between food and fuel, direct and indirect land use emissions, and destruction of natural ecosystems services [5–7]. These negative impacts explain to a great extent why debates are still ongoing on the merits of bioenergy, creating insecurity about the sustainability of bioenergy development over time. At the same time, the absence of strategies to develop bioenergy are not any guarantee for preservation of natural environments and related eco-systems services, but rather could pose a threat to their long term protection.

The establishment of a bio-based economy faces several challenges related to sustainability of natural resources management, food security, mitigation and adaptation to climate change, and maintenance of competitiveness [8]. The use of agricultural crops for biofuel may limit food and feed production. Therefore, a coherent and integrated approach for the utilization of bioresources is required when dealing with the challenges of climate change, resource efficiency, economic prosperity and food security. Innovative planning methods, policies and economic instruments are required for exploring the opportunities at hand so as to capture the potential multiple benefits of a bioeconomy in which also bioenergy has a role to play. The need for climate change mitigation (reduction of GHG emissions), improved security of energy supply (promotion of renewable bioenergy systems), and maintenance of eco-services can serve as motivation for exploring new strategies and pathways.

How can we harness the full potential of bioenergy while maintaining ecosystem services? What are the potential synergies for bioenergy development in the bioeconomy? What are the challenges for meeting low-carbon development in the BSR region? This paper explores present conditions, bioenergy initiatives, and synergetic impacts of bioenergy deployment as a way to define a starting point for a sustainable bioeconomy in the region. We consider 8 countries in this initial evaluation (i.e. Sweden, Finland, Estonia, Latvia, Lithuania, Poland, Denmark, and Belarus), looking into cross-cutting issues/policies, relevant stakeholders and actions to promote low-emission and climate resilient development, as well as secure energy supply and efficient use of resources in the BSR.

2. Baltic Sea initiatives for bioenergy and bioeconomy

The European Union has adopted a strategy for the Baltic Sea Region (BSR) to make the region prosperous, safe and secure. The strategy aims at bringing together initiatives for economic growth and sustainable development, as well as promoting cooperation between stakeholders in the BSR. Prioritized policy areas include: security of energy supply, promotion of the bio-economy, and improved nutrient recycling (EUBSR) [1]. The EUBSR – the first macro-regional strategy in Europe – also promotes flagship-projects aimed at a macro-regional impact in the BSR. The EU Baltic Sea Region covers eight countries, namely Sweden, Denmark, Estonia, Finland, Germany, Latvia, Lithuania, and Poland. These countries share common features and challenges, and comprise 17 % of the EU population (85 million inhabitants).

The EU climate strategy aims at supporting the transition of the region to a low emission and climate resilient economy. The interlinkages and synergies between mitigation and adaptation strategies, together with the energy transition and ecosystem services management are of great importance when building a resilient system. The BSR comprises a rich diversity of ecosystems services (ESS) [9]. At the same time, it has a great bioenergy potential. Deployment of bioenergy can help reduce GHG emissions but may also result in impacts on ESS. However, the BSR is highly vulnerable to climate change. For that reason, climate is one of the four Horizontal Actions (HA) in the EUBSR. HA for climate covers climate adaptation and low emission development in the region. Thus careful attention is required not to jeopardize the delivery of ESS, which also includes climate resilience.

Bioeconomy is one of the key policy areas of the EUBSR action plan, and it is strongly linked with the overall prosperity and green growth of the BSR region. But the bioenergy-water-land-climate nexus is complex. If not properly managed, the use of land for energy crops may affect food supply and forest cover, thereby reducing the natural adaptive capacity to climate change impacts. Moreover, the indirect land use (iLUC) impacts of extended bioenergy production and trade may influence GHG emissions [10]. Therefore, the supply chain of different bioenergy systems should be examined considering the spatial dimensions and material (including waste and nutrient streams) flows created at the various stages of production and use. Within this context, it is surprising that the interplay between ESS and the deployment of bioenergy is not more properly documented in the BSR.

The Baltic Marine Environment Protection Commission, also known as HELCOM, is an intergovernmental platform of the nine Baltic Sea coastal countries and the European Union working to protect the marine environment of the Baltic Sea from all sources of pollution. The Council of the Baltic Sea States (CBSS) is an overall political forum for empowering regional inter-governmental cooperation in the region. The members of CBSS are 11 states in the BSR and EU, including Denmark, Estonia, Finland, Germany, Iceland, Latvia, Lithuania, Norway, Poland, Russia, Sweden and a representative from the EU. HELCOM action areas include agriculture and industrial/municipal releases, among others. Reduction of nutrient release to the sea and nutrient recycling in agriculture and wastewater treatment plants are planned. Diverting solid and liquid waste away from the sea, and using it for biogas and organic fertilizer production can promote significant change in this context. Optimal cooperation between the HELCOM action plan and EUBSR should be explored, aiming at synergies and complementarity for efficient resource utilization and achievement of mutual goals.

As per the EU-Renewable Energy Directive, all member countries should introduce at least 10 % of renewable fuels in transport (mainly biofuels) by 2020 [11]. Biofuels should meet the EU stringent sustainability criteria, a measure to ensure that the biofuels are produced in a sustainable and environmentally friendly manner. Debates on biofuel versus food security, and emissions related to iLUC are driving the sustainability agenda of biofuel production. The EU has recently amended the Renewable Energy Directive to reduce the risk of indirect land use change, also called the "iLUC directive" in 2015 [12]. The amendment limits the share of biofuels from agricultural "food" crops in the 2020 renewable energy targets to 7 %, as opposed to the original 10 % targets. In other words, the contribution of biofuels produced from food crops is capped at 7 %. The remaining 3 % biofuels will come from advanced and novel biofuels derived from waste, seaweeds, and microalgae. Also this development has implications for the implementation of the EUBSR.

Thus the development of a bioeconomy in the BSR needs to be considered in its potential to promote the EUBSR, goals set by the HELCOM Baltic Sea Action Plan, and implementation of the Renewables Directive and the Paris Agreement to the climate convention. In this context, strategies are needed for balancing bioenergy and ecosystems services (ESS) in the BSR with the help of economic and spatial support systems, which are also aligned with climate change strategies. In the next section, we look more closely at the conditions for bioenergy development in the BSR countries.

3. Energy systems in the Baltic Sea Region: Why bioenergy is important?

Fossil fuels dominate the primary energy consumption in the Baltic Sea Region (BSR). Fig. 1(a) shows the total primary energy supply in the BSR. Among the 8 countries analyzed here, Poland consumes the largest share of energy, followed by Sweden, Finland and Belarus. Sweden and Finland have nuclear power plants for electricity generation but the share of bioenergy in the primary energy supply of these two countries is also quite significant. Sweden, Latvia, Estonia, and Finland do not have fossil reserves, while Estonia has a vast reserve of oil shale that is used for primary electricity generation and shale oil production. Denmark is the highest crude oil producer in the region but one can see a sharp decline in the production of fossil oil due to limited reserves [13].

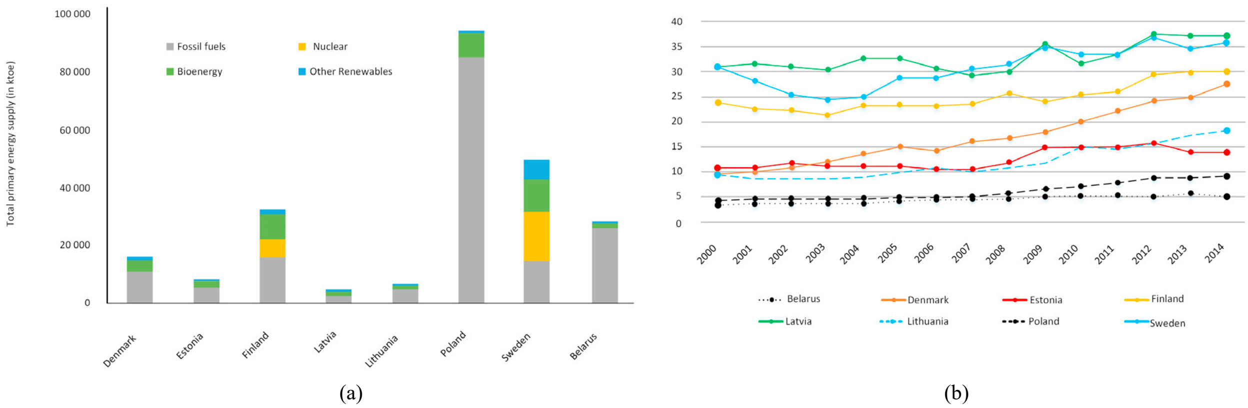


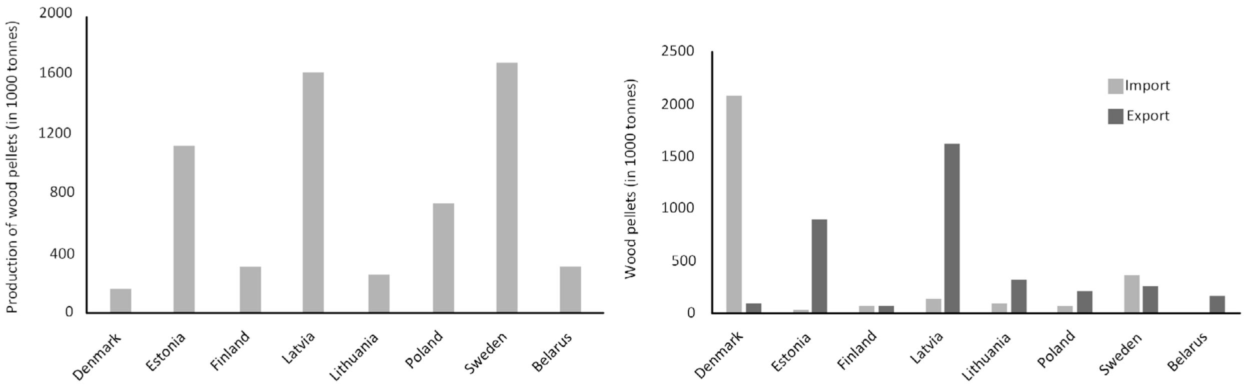
Fig. 1. (a) Primary energy supply in the BSR region [14]; (b) percentage of renewable energy share of primary energy supply, 2000–2014 [13].

The share of renewables in the primary energy supply is shown in Fig. 1(b). In 2014, Latvia and Sweden had the highest shares of renewable energy, that is, 37 % and 36 %, respectively. Denmark has drastically increased its renewable share from 10 % to 28 % between 2000 and 2014. Finland and Lithuania are also progressing well in terms of energy supply from renewable sources. Meanwhile, Poland and Belarus have less than 10 % renewables in their primary energy supply in spite of their huge bioenergy potential.

Bioenergy is a versatile energy source with varying feedstock, conversion technologies and end uses. The supply of biomass can be classified into three broad sectors – forestry, agriculture and waste. The BSR has abundant biomass resources which are largely untapped. Bioenergy is one of the leading energy carriers in Sweden and Finland. These two countries have the highest share of forest cover in the region, with more than 65 % of the land area being forests. Estonia and Latvia had 52 % and 46 % of their land covered by forests in 2013, respectively [15]. Bioenergy can play a key role in achieving Estonia's goal to reach 80 % of heat and 50 % of electricity from renewables by 2030. Denmark has 14 % forest land but residues from agriculture can be quite significant.

In Lithuania, the share of biomass in district heating (DH) has increased from 2 % to 65 % between 2000 and 2016 [16]. Forests cover approximately 33.2 % of Lithuania, and heating with biomass is up to 3 times cheaper than heating with natural gas. In 2015, DH demand amounted to 500 ktoe in Lithuania. If that energy demand had been covered by solid-biomass only, it would have resulted in 57 million Euro for circulation in the domestic economy [16]. In contrast, the share of bioenergy in the total primary energy supply of Belarus only reached 5.1 % in 2016, in spite of 40 % forest coverage and the country's significant opportunity to develop bioenergy [17].

One of the key areas of biomass utilization in the BSR is the production and trade of wood pellets. Sweden, Latvia and Estonia are among the top 10 pellet producers in the world (see Fig. 2). Lithuania is relatively small in comparison but exports most of its wood pellets production. The same goes for Latvia, a major producer and exporter of pellets. Denmark is the 2nd largest importer of wood pellets while Latvia is the 3rd largest exporter of wood pellets globally.



(a) (b)

Fig. 2. (a) Wood pellets production in 2015; (b) import/export of pellets in 2015 [18].

4. Balancing bioenergy and ecosystem services (ESS) in the bioeconomy

Despite the expanding bioenergy production and international trade within the BSR, and increasing ecosystem services (ESS) demand, decision support systems lack comprehensive analysis on the implications of integrated use of bioenergy and ESS in the region. We propose an integrated and holistic approach for harnessing bioenergy potential, also facilitating interactive cross-sectoral collaboration among stakeholders, favoring synergies and the alignment of policies, and actions to promote low-emission and climate resilient development, secure energy supply and efficient use of resources in the BSR. An integrated system approach is proposed to deal with multi-sectoral and functional perspectives on the supply chain of bioresources and material flows, including land and water, waste streams and nutrients, and develop synergetic and multidisciplinary linkages between bioenergy, ESS and climate strategies. This can be achieved in the following steps: (a) synthesis of resource base, (b) mapping bioenergy systems, (c) analyzing synergies and inter-linkages, and (d) implementation plans including stakeholders' engagement.

The integrated approach serves to derive and simulate diversified and optimal bioenergy options under different scenarios, thus helping identify sustainable energy solutions while maintaining ESS [19]. It is also important to assess the bioenergy systems on a full GHG emissions lifecycle, resource utilization, land use performance and practices, mitigation and adaptation costs, aiming at creating simultaneous adaptation and mitigation benefits for livelihoods and ESS. A full understanding of the different potentials provides the basis to assess the feasibility of projects in the BSR, starting from a theoretical potential determined by the biophysical limits only, and moving down to techno-economic feasibility that contemplates the sustainable implementation potential [20].

4.1. Synthesis of resource base

The synthesis of the resource base can be summarized in terms of:

- Data and local knowledge base (land use, bioresources/feedstocks, ESS);
- Analysis of local priorities (policies/government priorities, present conditions, state-of-the art knowledge and technologies).

An initial assessment is thus needed to develop a picture of the overall conditions in the BSR when it comes to bio-resources. From there, the identification of potential for multiple functions within the BSR bioeconomy will be possible.

4.2. Mapping bioenergy systems and ESS in the bioeconomy

To identify the most suitable final energy products for the BSR, a complete study of the different bioenergy supply chains should be assessed. Starting from the type, location and availability of the feedstock (e.g., short rotation woody biomass, forest biomass, municipal solid waste), combined with different transport modes in an economically, timely and environmentally efficient manner, to reach the location of the conversion process site (e.g., gasification, esterification, pyrolysis) that will convert the feedstock into an end-use product (e.g., methanol, ethanol, heat and power). See Fig. 3 for an overview of the different possible pathways for bioenergy in the BSR. The model framework will identify the optimal mix of technologies, as well as biomass resources and end-use products that the BSR would optimally need under different socio-political scenarios to meet the climate and renewable energy targets in a cost minimization approach.

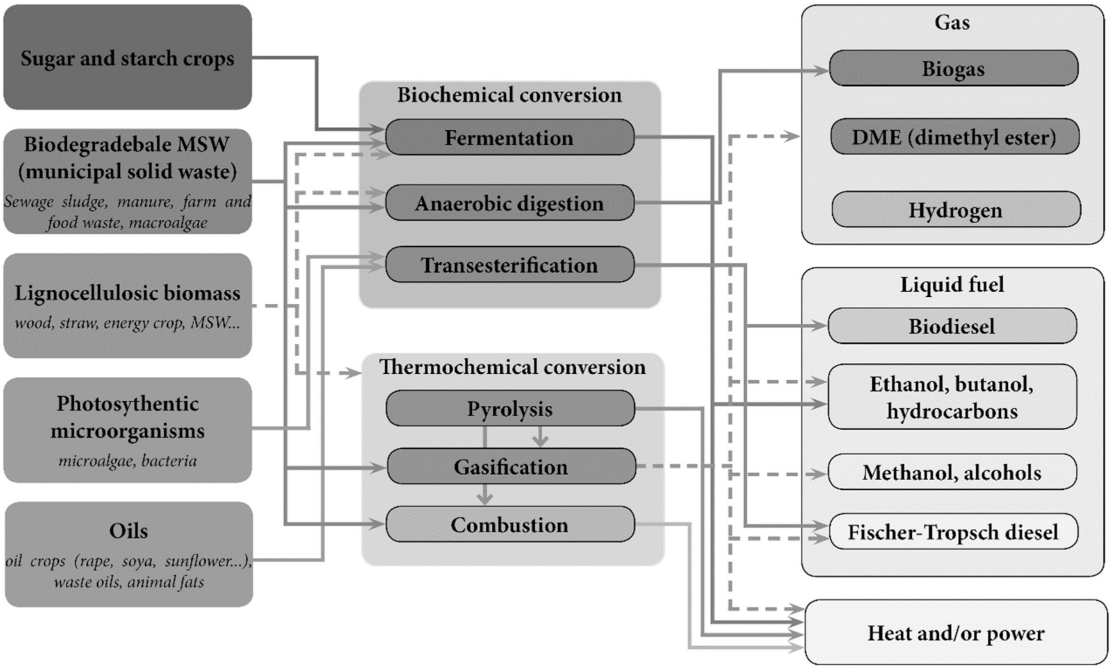


Fig. 3. Bioenergy routes that can potentially be studied, adapted from [21].

Process integration in the existing production plants is also a key development for bioenergy. It does not provide new infrastructure, and the capital cost would be reduced considerably. As an example, black liquor gasification in pulp and paper mills to increase the production of electricity or biofuel, or even co-firing would also be an alternative technology to decrease the consumption of coal in the BSR (presented as combustion in Fig. 3). The optimal resources mix and thus technologies, will be affected by the access, availability and policies that are implemented on the ecosystems services. The increase of constraints related to prevailing physical conditions and ESS in the BSR will have impact on the final optimal technology mix. It is, therefore, of interest and importance to simulate different ESS accessibility in order to measure the impact on (1) the final optimal biomass use, (2) the technology mix, (3) the final cost of production, and (4) emission mitigation benefit, compared to a business as usual scenario.

4.3. Analysis of synergies and inter-linkages

Analysis of synergies is crucial in the effort to develop strategies for balancing bioenergy and ecosystems services (ESS) in the BSR. It is important to highlight that the integrated bioenergy and ESS planning reduces the risk of economic and environmental losses, keeps the region attractive for living & working, strengthens competitiveness and stimulates future investments. For that, a transnational and societal transparent dialogue is envisaged that addresses multiple environment objectives, interdependencies and trade-offs between ESS and other economic activities. Supportive planning instruments for integrated assessments and policy design need to be developed for that purpose. A geographically explicit engineering model for bioenergy systems optimization, combined with GIS tools such as GIS-based ecological assessment models are required. All these land-based effects lead to e.g. less sewage and waste discharge, less GHG emissions responsible for acidification and eutrophication, and, finally, an improved ecological footprint for the region along with a fostered bioeconomy.

4.1. Implementation actions – stakeholder's engagement

The implementation actions need to be planned through: (a) developing case studies at the local/municipal level to implement local bioenergy plan, (b) analysing the bioenergy market and policy instrument (also government support), (c) transferring and testing the applicability of strategic results in pilot areas, (d) applying a multi-scale approach to evaluate how local and regional aspects/impacts contribute at the national or in the BSR region.

5. Implementing a bio-based economy: a way forward

An integrated use of bioresources and ESS in the BSR should not only bridge knowledge gaps but also facilitate interactive cross-sectoral discussions among both private and public stakeholders, favoring synergies and the alignment of policies and actions to promote low-emission and climate resilient development, secure energy supply and efficient use of bioresources. This deals with multi-sectoral and functional perspectives on the supply chain of bioresources and material flows, including land and water, waste streams and nutrients, and develop synergetic linkages between bioenergy, ESS and climate strategies. The bioeconomy offers a unique opportunity to address inter-connected societal challenges such as food security, natural resource depletion, and climate change impact, while simultaneously achieving sustainable economic development [22]. Moreover, the demand for bioresources and various ESS is not restricted by national borders and, therefore, the BSR should be understood in its wholeness.

ESS are intertwined around the ecological systems of the BSR. To implement innovative approach and strategies, support from multiple stakeholders in different sectors is required, especially private companies and governments. Meanwhile, climate and spatial planning are important components of actions. Bioenergy is already part of the local economies but great potential still exists which can be explored as part of the EUBSR strategy. This shall contribute to a sustainable deployment of multiple environmental and socio-economic opportunities and benefits in the BSR region. Poor energy planning, or lack of strategies for bioenergy deployment can have undesired consequences for the ecosystem services and the local economy.

The sustainable use of the BSR potential for renewable energy production requires both strategic planning at transboundary scale and detailed local assessments. Implementing these recommendations will be challenging given the lack of detailed data (e.g. with respect to ecosystem services) and the large complexity of trans-boundary protection legislation and regional acceptance to renewable energy projects. With participatory approaches, the appropriate location of renewable energy projects can be determined and environmental impacts can be minimized at the same time that the stakeholders' interests are taken into account and compliance with conservation legislation is more effectively achieved. For this purpose, the development and use of interactive online decision support tools (e.g., [23] is suggested). Such tools can facilitate understanding of bioenergy and bioeconomy developments in the BSR and enhance the involvement of stakeholders and local communities in transparent decision-making process. Last but not least, the interconnectivity within the region but also beyond – i.e. with the rest of Europe – need to be considered in decision making and planning. For example, can specific and innovative methodologies that are to be developed for the BSR be used in other countries or vice-versa?

6. Concluding remarks

The Baltic Sea Region (BSR) has abundant biomass resources, but this exists within the context of a rich diversity of ecosystems services (ESS). Bioenergy pathways have been evolving differently in the region but need to be explored in a more comprehensive way to help develop a sustainable bioeconomy in the BSR. An integrated and synergic approach is needed to deal with multi-sectoral and functional perspectives on the supply chain of bioresources, land and water, waste streams and nutrients in the BSR. Such an integrated approach will serve to derive optional bioenergy pathways while simultaneously addressing climate strategies and maintaining ecosystems services (ESS. The integrated planning reduces the risk of economic and environmental losses, strengthens competitiveness, and creates business opportunities. Innovative decision support systems together with policies and economic instruments are required for exploring the opportunities at hand so as to capture the potential multiple benefits of a bioeconomy. A decentralized energy planning with stakeholder involvement can provide shared solutions to make energy systems compatible with regional sustainable development

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