

Krista Laktuka

**CLIMATE POLICY FOR
SUSTAINABLE DEVELOPMENT**

Summary of the Doctoral Thesis



RIGA TECHNICAL UNIVERSITY

Faculty of Natural Sciences and Technology
Institute of Energy Systems and Environment

Krista Laktuka

Doctoral Student of the Study Programme “Environmental Engineering”

**CLIMATE POLICY FOR SUSTAINABLE
DEVELOPMENT**

Summary of the Doctoral Thesis

Scientific supervisors

Professor Dr. habil. sc. ing.
DAGNIJA BLUMBERGA

Tenured Professor Dr. sc. ing.
ANDRA BLUMBERGA

RTU Press
Riga 2026

Laktuka, K. Climate Policy for Sustainable Development. Summary of the Doctoral Thesis. Riga: RTU Press, 2026. 52 p.

Published in accordance with the decision of the Promotion Council “RTU P-19” of 12 December 2025, Minutes No. 235.

This Thesis research has been supported by the Latvian Council of Science’s Fundamental and Applied Research Project No. lzp-2024/1-0417 “Policy Planning Roadmap for Carbon Farming Certification Schemes” and by the European Social Fund within the Project No. 8.2.2.0/20/I/008 “Strengthening of PhD students and academic personnel of Riga Technical University and BA School of Business and Finance in the strategic fields of specialisation”.



Cover image from www.shutterstock.com.

<https://doi.org/10.7250/9789934372735>
ISBN 978-9934-37-273-5 (pdf)

**DOCTORAL THESIS PROPOSED TO RIGA TECHNICAL UNIVERSITY FOR
PROMOTION TO THE SCIENTIFIC DEGREE OF DOCTOR OF SCIENCE**

To be granted the scientific degree of Doctor of Engineering Sciences, the present Doctoral Thesis has been submitted for defence at the open meeting of RTU Promotion Council on April 9, 2026 at the Faculty of Natural Sciences and Technology of Riga Technical University, 12/1 Āzenes Street, Room 607.

OFFICIAL REVIEWERS

Tenured Professor *Dr.sc.ing.* Francesco Romagnoli
Riga Technical University

Professor *Dr.sc.* Peter Lund
Aalto University, Finland

Associate Professor *Ph.D.* Morten Risstad
Norwegian University of Science and Technology, Norway

DECLARATION OF ACADEMIC INTEGRITY

I hereby declare that the Doctoral Thesis submitted for review to Riga Technical University for promotion to the scientific degree of Doctor of Engineering Sciences is my own. I confirm that this Doctoral Thesis has not been submitted to any other university for promotion to a scientific degree.

Krista Laktuka (signature)

Date:

The Doctoral Thesis has been written in Latvian. It consists of an Introduction, 3 chapters, Conclusions, 31 figures, 19 tables, and 9 appendices; the total number of pages is 302, including appendices. The Bibliography contains 377 titles.

TABLE OF CONTENTS

TABLE OF CONTENTS	4
INTRODUCTION	6
Research topicality.....	6
Aim and objectives	7
Hypothesis	8
Scientific novelty	8
Practical relevance	9
Approbation of the research results	10
Other scientific publications.....	10
Approval of the work at scientific conferences	11
Structure of the Thesis	11
1. LITERATURE REVIEW	13
2. METHODOLOGY	16
2.1. Literature and document analysis methods.....	17
2.1.1. Systematic literature review.....	17
2.1.2. Qualitative content analysis	18
2.2. Multiple-criteria decision analysis methods	18
2.2.1. Technique of Order Preference Similarity to the Ideal Solution	18
2.2.2. Analytical Hierarchy Process.....	19
2.2.3. Simple Additive Weighting	20
2.3. Strategic planning and evaluation methods	21
2.3.1. Focus group discussion.....	21
2.3.2. SWOT analysis	21
2.3.3. TOWS matrix.....	21
2.4. Empirical data collection and evaluation methods.....	22
2.4.1. Surveys	22
2.4.2. Data collection	22
2.4.3. Expert evaluations	23
3. RESULTS	24
3.1. Policy coherence assessment	24
3.1.1. Assessment of policy coherence: Carbon farming.....	24

3.1.2. Assessment of bioeconomy policy coherence in EU Member States	26
3.1.3. Assessment of bioeconomy policy coherence: The case study of Latvia	28
3.1.4. Policy coherence assessment: Heating and cooling sector.....	30
3.2. Identification of obstacles and shortcomings in policy implementation	32
3.2.1. Removal of administrative barriers to the implementation of RES projects ...	32
3.2.2. Identification of enablers and constraints to the strategic development of the Latvian forest sector.....	35
3.3. Dimensions of policy implementation: Sustainable solutions, resource efficiency and communication.....	39
3.3.1. Reflection of policy objectives in infrastructure and institutions	39
3.3.2. Resource efficiency in practice – sustainable production models	41
3.3.3. The importance of communication and participation.....	45
CONCLUSIONS	47
REFERENCES.....	50

INTRODUCTION

The Member States of the European Union (EU) have invested considerable resources in strengthening the EU's role as a major regional and global player. At the same time, each Member State has individually contributed to the common European project by making commitments and integrating EU policy priorities into their national strategies. The EU cannot be seen as an external structure separate from its Member States, as it exists only through their participation and support. Therefore, the objectives set at the EU level, such as achieving climate neutrality, must be consistent with the individual objectives of the Member States. Otherwise, their implementation in practice becomes fragmented and less effective. Ideally, policy objectives are formulated at the EU level, then structured at the national level and implemented in local government, taking into account regional characteristics and specific policy priorities. Such multi-level coordination is essential to ensure that the tasks defined in policy documents are complementary rather than contradictory. The first step in this process is to assess regulatory and policy planning documents to identify their compliance with the objectives set.

Policy coherence is particularly important in the context of climate policy, as climate change mitigation requires both horizontal and vertical integration across different levels and sectors in regulatory and policy documents. When developing short-, medium- or long-term planning documents, governments must ensure a clear vision for the future and consistent linking of objectives between different levels of government. Decision-makers must be able to adapt policies to changing circumstances while systematically incorporating sustainability and environmental dimensions into all stages of policy planning. Coherence is, therefore, important not only for achieving climate goals but also for the stability of the EU itself, as prolonged dissonance between Member States could increase the risks of fragmentation or even contribute to a “multi-speed Europe” scenario, which could pose a risk of economic backwardness and external threats for small countries, including Latvia.

Research topicality

Policy coherence at different levels of governance is an essential driver towards climate neutrality, resource efficiency, greenhouse gas (GHG) emission reduction and biodiversity conservation. It is an important prerequisite for ensuring the economic stability and strengthening the competitiveness of Member States. Inconsistent or contradictory policies create an unpredictable environment for business and investment. Uncertainty about a Member State's political direction not only hinders the attraction of new investment but also creates the risk that existing companies will relocate their operations to countries where the political signals are clearer. On the other hand, coordinated and targeted policy planning and implementation allow companies to plan their long-term investments in development and the launch of new products on the market with greater certainty.

Policy coherence also has a significant impact on the efficiency of the state budget. Clearly defined objectives help to prevent the duplication or contradiction of public spending, while enabling better results to be achieved with fewer financial resources by targeting them precisely

at specific development objectives. In the context of this Thesis, it is important to highlight the impact of policy coherence on the development of a knowledge-based bioeconomy and energy security in the EU, where increasing the share of renewable energy sources (RES) in the overall energy balance plays a significant role. Multi-level coherence promotes energy security, especially when national policy is geared towards energy diversification. The development of the bioeconomy contributes to the creation of higher value-added products with lower resource consumption and strengthens the resilience of rural areas and sectors. A coherent and targeted policy ensures that innovation, new products and technologies are not hampered by inconsistent policy signals, but are supported and promoted in the market.

The international reputation and influence of Member States are no less important. This can be strengthened by consistently adopting and implementing EU-level objectives at the national level. Member States have various mechanisms at their disposal to influence decision-making at the EU level, but once a joint decision has been taken, it is important to implement it appropriately, thus demonstrating their reliability and ability to act as “team players”.

In summary, in the context of climate change, tense geopolitical situations and global economic instability, policy coordination is becoming an essential requirement for all Member States. This is not only a matter of upholding democratic values, but also of fulfilling the commitments made in the Paris Agreement, the European Green Deal and other related policy documents in the field of climate policy.

Aim and objectives

The Thesis aims to develop an analytical framework for assessing climate policy based on an analysis of policy coherence, identification of obstacles and shortcomings, and an assessment of the policy implementation dimension (sustainable solutions, innovation, resource efficiency and communication) in order to formulate conclusions and recommendations for sustainable resource management. To achieve the objective of the study, three interrelated tasks with sub-tasks have been set.

1. Assessment of policy coherence:

- 1.1. Analyse international, EU and national regulatory and policy planning documents in the bioeconomy, energy, heating and cooling sectors.
- 1.2. Assess the coherence of objectives, instruments and measures at different policy levels.

2. Identification of obstacles and shortcomings for policy optimisation:

- 2.1. Identify administrative, regulatory and institutional barriers to increasing energy production from RES and manufacturing higher value-added products.
- 2.2. Conduct case studies in sectors to identify potential optimisation opportunities.

3. Policy implementation dimensions – sustainable solutions, resource efficiency and communication:

- 3.1. Assess the role of education and educational institutions in improving resource efficiency and ensuring a sustainable transition.
- 3.2. Explore the potential for developing sustainable aquaculture systems, with a particular focus on technological aspects and innovation.

3.3. The role of communication with the public in sustainable resource management.

Hypothesis

A systematic assessment of policy documents, the identification of obstacles and shortcomings, and the development of evidence-based recommendations can substantially enhance policy coherence and implementation effectiveness, thereby accelerating progress towards the objectives of the European Green Deal.

Scientific novelty

This Thesis is an interdisciplinary study that combines research methods from environmental engineering and political science. Unlike the traditional approach in political science, where environmental issues are examined through specific theories, such as multi-level governance, policy coherence or ecological modernisation, this study views policy coherence and the policy instruments used as practical mechanisms whose effectiveness can be systematically assessed, structured and optimised. The assessment of policy coherence and implementation effectiveness in the Thesis is not based on a single set of quantitative indicators, but rather on an analysis of policy processes that allows for the evaluation of improvements in coherence, transparency and implementation quality.

The novelty of the Thesis lies in complementing established approaches in content analysis and policy research – such as systematic literature reviews, keyword searches, and expert surveys – with methods characteristic of engineering sciences, including multi-criteria decision analysis methods (MCDA) and empirical data collection and assessment techniques. This methodological integration enables a more quantitative and comparable evaluation of policy coherence and effectiveness, thereby offering a new perspective on policy and regulatory analysis.

It is important to note that the issues analysed in the study, such as the development of a knowledge-based bioeconomy, sustainability, the introduction of RES and the reduction and sequestration of GHG emissions, are topics that have been studied in environmental engineering. In the Thesis, policies and policy instruments are interpreted as practical tools that ensure sustainable resource management and the creation and implementation of innovations. A concept is proposed in which policy mechanisms are analysed in a similar way to an engineering system with (1) input points (defined objectives, current regulatory documents, resources used), (2) processes (combination of policy instruments, identification of obstacles), and (3) outputs (achievable results – reduction of GHG emissions, optimisation of resource consumption, implementation of RES technologies). The research levels and topics covered in the Thesis are shown in Fig. 1.

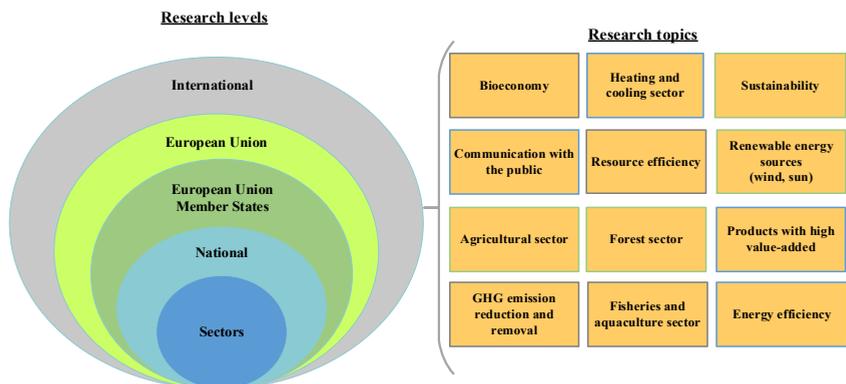


Fig. 1. Research levels and topics covered in the Thesis.

Practical relevance

The Thesis provides evidence-based justification for making policy documents and regulatory frameworks more effective and mutually consistent. The analytical framework developed not only allows for the identification of shortcomings and obstacles between the future development trajectory outlined by the EU and that implemented by Member States but also for the development of proposals to address them. The research approach provides a practical contribution to improving the policy planning and development process, as it allows policy mechanisms to be analysed as a systematic process – identifying inconsistencies and administrative barriers, as well as offering strategies for their optimisation in order to achieve future goals. For companies in the sector, the research results provide an assessment of the vertical and horizontal coherence of policies and long-term policy directions, which allows them to plan investments and determine directions for technological development. In the field of science, the Thesis offers a methodological framework for assessing policy coherence and effectiveness, which can also be applied to the study of situations in other sectors or countries. The evaluation of policies and regulatory documents also serves as an important instrument for anticipating future research priorities, as the EU and Member State research funding calls are closely aligned with politically defined objectives. The societal benefits are directly linked to these gains, as improved resource efficiency enhances the availability of energy, food and products while simultaneously contributing to reductions in GHG emissions. The Thesis is necessary to ensure that the transition to a sustainable, knowledge-based bioeconomy, climate neutrality and resource efficiency takes place not only at the level of strategies and policy documents but also in practice, by linking the strategic objectives set by the EU with real actions in the Member States.

Moreover, the practical relevance of the Thesis is demonstrated by the fact that the administrative process mapping for RES projects developed within this research [1] has been used by the Latvian Investment and Development Agency as a support tool in negotiations with potential investors, thereby enhancing awareness of the regulatory frameworks in the countries analysed.

Approbation of the research results

1. Laktuka, K., Pakere, I., Lauka, D., Combining policy measures to reach long-term energy targets. *2021 IEEE 62nd International Scientific Conference on Power and Electrical Engineering of Riga Technical University (RTUCON)*, 2021, pp. 1–6, doi:10.1109/RTUCON53541.2021.9711713.
2. Laktuka, K., Blumberga, D., Rozakis, S., Assessing Bioeconomy Development Opportunities in the Latvian Policy Planning Framework. *Sustainability*, 2023, 15, 1634, <https://doi.org/10.3390/su15021634>.
3. Dolge, K., Balode, L., Laktuka, K., Kirsanovs, V., Barisa, A., Kubule, A., A Comparative Analysis of Bioeconomy Development in European Union Countries, *Environmental Management*, 2022, <https://doi.org/10.1007/s00267-022-01751-3>.
4. Laktuka, K., Pakere, I., Kalnbalkite, A., Zlaugotne B., Blumberga, D., Renewable energy project implementation: Will the Baltic States catch up with the Nordic countries? *Utilities Policy*, Vol. 82, 2023, 101577, ISSN 0957-1787, <https://doi.org/10.1016/j.jup.2023.101577>.
5. Bohvalovs, G., Kalnbalkite, A., Pakere, I., Vanaga, R., Kirsanovs, V., Lauka, D., Prodanuks, T., Laktuka, K., Dolge, K., Zundans, Z., Bremane, I., Blumberga, D., Blumberga, A., Driving Sustainable Practices in Vocational Education Infrastructure: A Case Study from Latvia. *Sustainability*, 15(14), 2023, 10998, DOI: 10.3390/su151410998.
6. Laktuka, K., Kalnbalkite, A., Sniega, L., Logins, K., Lauka, D., Towards Sustainable Intensification of Aquaculture: Exploring Possible Ways Forward. *Sustainability*, 15(24), 16952, <https://doi.org/10.3390/su152416952>.
7. Kalnbalkite, A., Poca, P., Laktuka, K., Lauka, D., Blumberga, D., The Role of Environmental Communication in Advancing Sustainability in Fisheries and Aquaculture: A Case Study of Latvia. *Sustainability*, 15(23), 16418, <https://doi.org/10.3390/su152316418>.
8. Laktuka, K., Kubule, A., Vamza, I., Rozakis, S., Blumberga, D., Strategic Pathways for a Bioeconomy with High Value-added Products: Lessons Learnt from the Latvian Forest Sector. *Biomass and Bioenergy*, Vol. 190, 107400, <https://doi.org/10.1016/j.biombioe.2024.107400>.
9. Laktuka, K., Luksta I., Blumberga, D., Policy Coherence of the EU Carbon Removal Certification Framework: Integration of Carbon Farming in Climate and Agricultural Policy. *Environmental and Climate Technologies*, Vol. 29, No. 1, Riga Technical University, 2025, pp. 658–684. <https://doi.org/10.2478/rtuect-2025-0045>.

Other scientific publications

1. Bezrucko, T., Lauka, D., Laktuka, K., Sniega, L., Vamza, I., Dzalbs, A., Terjanika, V., Blumberga, D., Bioeconomy Towards Green Deal. Case Study of Citric Acid Production through Fuzzy Cognitive Maps. *Environmental and Climate Technologies*, 26(1), 684–696, <https://doi.org/10.2478/rtuect-2022-0052>.

2. Teirumnieka, E., Patel, N., Laktuka, K., Dolge, K., Veidenbergs, I., Blumberga, D., Sustainability dilemma of hemp utilisation for energy production. *Energy Nexus*, Vol. 11, 2023, 100213, ISSN 2772-4271, <https://doi.org/10.1016/j.nexus.2023.100213>.
3. Liberova, V., Bremane, I., Lauka, D., Laktuka, K., Bezrucko, T., Zvirbule, K., Bezrucko, E., Blumberga, D., Unleashing Energy Potential: Insights of Energy Audit Practices. *Energies*, 18(3), 522, <https://doi.org/10.3390/en18030522>.
4. Terjanika, V., Laktuka, K., Vistarte, L., Pubule, J., Blumberga, D., Co-creating low-carbon futures: An Open Innovation Roadmap for Regional CO₂. *Journal of Open Innovation: Technology, Market, and Complexity*, Vol. 11, No. 3, 2025, <https://doi.org/10.1016/j.joitmc.2025.100596>.

Approval of the work at scientific conferences

1. Laktuka, K., Pakere, I., Lauka, D., Combining policy measures to reach long-term energy targets. *2021 IEEE 62nd International Scientific Conference on Power and Electrical Engineering of Riga Technical University (RTUCON)*, Riga, Latvia, 15–17 November 2021.
2. Laktuka, K., Blumberga, D., Rozakis, S., Assessing Bioeconomy Development Opportunities in the Latvian Policy Planning Framework. *International Scientific Conference of Environmental and Climate Technologies (CONNECT2022)*, Riga, Latvia, 11–13 May 2022.
3. Laktuka, K., Poca, P., Blumberga, D., Promoting sustainability in fisheries and aquaculture through biodiplomacy. *1st International Conference on Sustainable Chemical and Environmental Engineering*, Rethymno, Crete, Greece, 31 August – 4 September 2022.
4. Laktuka, K., Vanza, I., Kubule, A., Blumberga, D., Rozakis, S., Opportunities for Bioeconomy Development: A Study of the Latvian Forest Sector and Identification of High-Value Niche Products. *International Scientific Conference of Environmental and Climate Technologies (CONNECT2023)*, Riga, Latvia, 10–12 May 2023.
5. Laktuka, K., Lauka, D., Impact of EU Funding on Latvian Aquaculture: Productivity, Competitiveness and Perspectives. *International Scientific Conference of Environmental and Climate Technologies CONNECT2024*, Riga, Latvia, 15–17 May 2024.
6. Laktuka, K., Luksta I., Blumberga, D., Carbon Farming in the EU: A Policy Tool or a Business Opportunity? *International Scientific Conference of Environmental and Climate Technologies CONNECT2025*, Riga, Latvia, 14–16 May 2025.

Structure of the Thesis

The Thesis is based on three main thematically unified segments, the aim of which is to identify solutions in climate policy for sustainable development. The segments have been approved by publishing research in internationally recognised scientific journals and presenting the results at international scientific conferences.

The structure of the Thesis is presented in Fig. 2, which illustrates the interaction between the three research segments and their complementary role in the analytical framework. At the centre of the Thesis lies climate policy, understood as the guiding axis defined by the strategic

direction of the European Green Deal. In this Thesis, the European Green Deal is interpreted not merely as a communication from the European Commission but as a symbol of the EU’s overarching trajectory towards climate neutrality and policy integration in pursuit of this goal. Surrounding this climate policy core are the three sectors analysed – bioeconomy, energy, and heating and cooling – within which policy coherence, administrative barriers and practical implementation dimensions are examined.

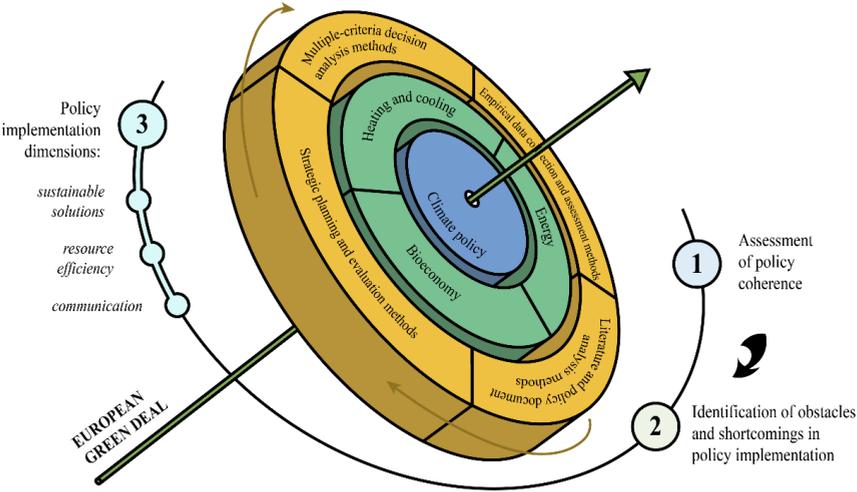


Fig. 2. Structure of the Thesis.

The outer ring depicts the methods used in the Thesis: literature and document analysis methods, multiple-criteria decision analysis methods, strategic planning and evaluation methods, and empirical data collection and assessment methods. Fig. 2 also schematically reflects the sequential approach, starting with the assessment of policy coherence, which is the first segment of the Thesis, followed by the identification of obstacles and shortcomings for policy optimisation, and concluding with the third segment, which examines the dimensions of policy implementation. This structure reflects the integrated analytical framework used in the Thesis and the logical sequence of the study.

The Thesis consists of an introduction and four main sections: (1) literature review; (2) research methodology; (3) results and discussion; and (4) conclusions. The introduction outlines the main features of the research, the novelty of the Thesis and its practical significance. It sets out the aim and hypothesis of the Thesis and describes the validation of the published research results.

Chapter 1 provides a literature review of the climate targets set at international and EU levels, analyses the importance of climate policy in achieving them, and outlines potential solutions for ensuring sustainable development. Chapter 2 describes the main methods used in the Thesis and their application in the context of the research. Chapter 3 contains the results and discussion, structured in three research segments. Finally, Chapter 4 summarises the conclusions.

1. LITERATURE REVIEW

The relevance of a sustainable transition to climate neutrality

The adoption of the United Nations Framework Convention on Climate Change (UNFCCC) in 1992 and the subsequent Kyoto Protocol in 1997 marked the first international steps in the fight against climate change [2]–[4]. The Paris Agreement, which entered into force in November 2016 and replaced the Kyoto Protocol, set the goal of limiting global temperature rise to below 2 °C, with efforts to limit it to 1.5 °C above pre-industrial levels [5], [6]. These international efforts are complemented by the 17 Sustainable Development Goals (SDGs) adopted in 2015 as part of the UN 2030 Agenda for Sustainable Development [7].

In the context of the Paris Agreement, the EU has committed to reducing GHG emissions by 55 % by 2030 compared to 1990 levels [8], [9]. The EU’s internal commitments are set out in the European Green Deal and the European Climate Law, which sets a legally binding target of achieving climate neutrality by 2050. These targets are being implemented through the “*Fit for 55*” legislative package [9]–[11].

Environmental sustainability and policies aimed at reducing pollution or improving the environment have been on the EU agenda since the 1970s, while national governments have only recently recognised the importance of environmental issues and sustainability [12], [13]. Sustainable production systems are essential for maintaining the productivity and diversity of ecosystems while ensuring food availability. The direct and indirect environmental impacts of production systems and supply chains, including those related to energy demand, potentially pose a threat to environmental sustainability.

The role of the bioeconomy in achieving the European Green Deal objectives

The European Commission has recognised that the bioeconomy is a “catalyst for systemic change” in achieving the objectives of the European Green Deal [14] by promoting the adoption of sustainable practices in bio-based industries such as agriculture, forest sector, fisheries and aquaculture, increasing the efficiency of resource use in food and raw material production, and reducing dependence on non-renewable energy sources. In order to successfully integrate the bioeconomy into various sectors, it is necessary to improve public awareness, especially among policymakers and businesses, while introducing new management practices. This would contribute to the development of a sustainability-minded society.

The wide use of bio-resources in the food, energy, industry and transport sectors makes the bioeconomy strategy part of a broader policy framework aimed at ensuring consistency between planning documents and the instruments used in the management of bio-resources at the EU and Member State level. Assessing the development potential of the bioeconomy makes it possible to identify the coherence of policy documents both between sectors and within each sector by examining how consistently the objectives and instruments are formulated. National action plans aligned with international objectives can reduce food and energy supply risks, promote more efficient use of bio-resources and prevent sharp price increases. Therefore, one of the areas of research in this Thesis is the analysis of the integration of bioeconomy objectives

into policy planning documents using a top-down approach, as well as an assessment of consistency at different policy levels.

The agricultural sector's path to climate neutrality: carbon farming

Although it was initially thought that the EU's climate targets could be achieved through gradual climate change mitigation measures, it is now clear that this will not be enough and that large-scale carbon dioxide (CO₂) removal measures will be necessary [10]. One possible solution is the wider use of carbon farming practices. In order to quantify and reward the implementation of such practices, Regulation (EU) 2024/3012 establishing a Union certification framework for permanent carbon removals, carbon farming and carbon storage in products (CRCF Regulation) [15]. The CRCF Regulation will expand additional income opportunities as a green business model for farmers and land managers, and will also be a mechanism that could support EU Member States in achieving their GHG emission reduction and removal targets in accordance with the revised Regulation (EU) 2018/841 on the inclusion of GHG emissions and removals from land use, land use change and forestry in the 2030 climate and energy framework [16].

Sustainable aquaculture: a source of food security and nutrition

Ideally, aquaculture systems should be able to replicate the natural conditions that fish and other aquatic organisms would find in the wild, but this approach is not always compatible with intensification and increased production. Sustainable aquaculture practices, therefore, face the challenge of ensuring a continuous supply of nutrients to aquatic organisms without harming existing ecosystems or exceeding the planet's natural limits. The growing demand for sustainably produced protein has led to rapid growth in aquaculture systems, overtaking cattle farming in terms of volume and contributing to its intensification [17]–[19]. However, intensification is not always compatible with the concept of sustainability.

Increasing the share of energy from renewable energy sources

The implementation process of RES projects can be facilitated or hindered depending on the stages of project implementation and the transparency of procedures. This is mainly because administrative barriers or unclear procedures for connecting to the grid can delay the implementation of RES projects. Unclear and complex administrative procedures, unclear and unstable regulatory frameworks or negative public attitudes can affect investors' willingness to develop RES projects in a particular country, which in the long term can undermine the EU's climate goals of transitioning from fossil fuels to RES [20]. Therefore, Directive (EU) 2018/2001 on the promotion of the use of energy from renewable sources sets out measures to be taken to simplify administrative procedures and shorten the implementation period for RES projects [21].

The integration of solar and wind energy into the Baltic energy markets has increased significantly over the last decade, as evidenced by the increase in installed wind and solar capacity and electricity generated [22]. The differences in installed solar and wind energy capacities in the Baltic States can be explained by both the different support policies in each

country and the various obstacles that arise during the implementation process. Therefore, one of the stages of the Thesis research was to evaluate the process of installing solar and wind power plants in Latvia, Lithuania and Estonia, and compare them with examples of good practice in Finland, Norway and Sweden in order to identify the most significant obstacles to the implementation of RES projects.

The role of educational institutions in achieving climate goals

The UN SDGs [23] directly influence both the development of sustainable education and the energy consumption of buildings. Reducing GHG emissions is important for achieving these goals, as well as the commitments set out in the Paris Agreement, as in 2021, the building sector accounted for 27 % of total energy sector emissions [24], [25]. Sustainable education provides students with the knowledge, values and skills they need to make informed decisions and improve their quality of life, while ensuring the needs of future generations are met, and can thus have a significant impact on progress towards climate neutrality. However, it is only in recent years that the role of education in achieving climate goals has been emphasised. Improving sustainability requires fundamental changes in organisations, supply chains and communities, which can only be achieved through continuous learning and innovation. A strong vocational education system can therefore offer many benefits, such as promoting green growth and increasing labour productivity. A deeper understanding of climate change can inspire students to actively engage in achieving climate neutrality and create a sense of environmental responsibility. Teachers can use this information to improve students' understanding of the impact of climate change and inspire them to focus on energy conservation by implementing educational initiatives that raise environmental awareness.

The Thesis is an interdisciplinary study in which the analysis of policy and regulatory documents is viewed from the perspective of environmental engineering rather than the traditional approach dominant in political science or law. In previous research, aspects of policy coherence and implementation have been analysed mainly using qualitative methods, which provide important context but limit the possibilities for comparing policy instruments and their implementation results. In this study, these aspects are quantified by integrating MCDA methods (TOPSIS, AHP) and empirical data collection and evaluation approaches into the analysis of policy documents, thus highlighting dimensions of policy coherence and regulatory implementation that are often more difficult to identify and structure using qualitative methods.

The knowledge gap stems from the fact that scientific literature is dominated by studies on the technological and innovation implementation aspects of the European Green Deal, while less attention has been paid to the quality of policy implementation at Member State level – administrative capacity, process complexity, interpretation of policy documents and regulatory frameworks, and related social factors, including lack of knowledge and awareness, as well as practical implementation barriers. This study, therefore, addresses issues in environmental engineering where sustainable solutions and technologies are stuck in the implementation phase due to fragmentation of policy and administrative processes and a lack of capacity and knowledge.

2. METHODOLOGY

The methodology of the Thesis is based on four main approaches. Firstly, literature and document analysis methods were used to evaluate energy efficiency measures, the political coherence of the EU's political and regulatory framework for carbon farming, and to identify administrative barriers to the implementation of RES projects. Secondly, MCDA methods were used to assess the implementation of bioeconomy strategies, the energy efficiency of vocational education competence centres (VECC), administrative barriers and priorities for the development of the forest sector bioeconomy. Thirdly, strategic planning and assessment methods have been used to identify strengths and weaknesses, as well as development scenarios. Finally, the fourth approach consists of empirical data collection and assessment methods – surveys, site visits and data collection, as well as expert surveys, which provided insight into the energy efficiency and sustainability measures implemented by educational institutions, revealed the experience of project implementers regarding administrative barriers to the implementation of RES projects and helped to identify the most appropriate communication channels for explaining sustainability issues. A mixed-method approach was used to achieve the objectives of the Thesis, combining document and literature analysis methods with MCDA, strategic planning and evaluation, or empirical data collection and assessment methods (Fig. 2.1).

Scientific publications	Literature and document analysis methods		Multiple-criteria decision analysis methods			Strategic planning and evaluation methods			Empirical data collection and evaluation methods		
	SLR	QCA	TOPSIS	AHP	SAW	FocusG	SWOT	TOWS	Survey	Data collection	Expert surveys
<i>1. Combining policy measures to reach long-term energy targets</i>	■									■	
<i>2. Assessing Bioeconomy Development Opportunities in the Latvian Policy Planning Framework</i>	■		■							■	
<i>3. A Comparative Analysis of Bioeconomy Development in European Union Countries</i>	■		■							■	
<i>4. Renewable Energy Project Implementation: Will the Baltic States Catch up with the Nordic Countries?</i>	■		■							■	
<i>5. Driving Sustainable Practices in Vocational Education Infrastructure: A Case Study from Latvia</i>	■				■				■	■	
<i>6. Towards Sustainable Intensification of Aquaculture: Exploring Possible Ways Forward</i>	■									■	
<i>7. The Role of Environmental Communication in Advancing Sustainability in Fisheries and Aquaculture: A Case Study of Latvia</i>	■		■							■	
<i>8. Strategic Pathways for a Bioeconomy with High Value-added Products: Lessons Learnt from the Latvian Forest Sector</i>	■			■		■	■	■		■	
<i>9. Policy Coherence of the EU Carbon Removal Certification Framework: Integration of Carbon Farming in Climate and Agricultural Policy</i>		■									

Fig. 2.1. Scientific publications and research methods that were used.

Detailed application of methods, data sources and analytical steps are reflected in the publications included in the Thesis (see Publications 1–9), which form the empirical and analytical basis of this study.

2.1. Literature and document analysis methods

The selection of sectors in the Thesis is based on the role of the bioeconomy emphasised by the European Commission in the implementation of the European Green Deal objectives [14], where agriculture, forest sectors, fisheries and aquaculture, as well as the relevant processing and manufacturing sectors, are defined as strategic areas with a significant contribution to resource efficiency, emission reduction and reducing dependence on fossil resources. At the same time, the research also covers the energy, heating and cooling sectors, as their transformation is a prerequisite for achieving climate and bioeconomy policy objectives, particularly with regard to the integration of RES, energy efficiency and the practical implementation of policy instruments in Member States.

2.1.1. Systematic literature review

The systematic literature review (SLR) method is rooted in evidence-based policy and practice. SLRs originated in medicine and evidence-based policy evaluation. This method is widely used to address environmental issues and evaluate policies or policy instruments. SLR is used to find answers to specific questions or hypotheses. SLR can be very time-consuming if a large volume of documents needs to be analysed, so it is often supplemented with the keyword assignment method. The keyword assignment method is less labour-intensive, allows for more accurate document review and more effective responses to research questions, while maintaining consistency.

Assessment of bioeconomy policy coherence

In order to assess the vertical coherence of bioeconomy policy between the international and national levels, internationally significant documents were analysed in the study (Publication 2). The objectives identified in these documents served as keywords for the evaluation of Latvian policy documents, in which ten national-level policy documents were selected for in-depth analysis using SLR and snowball sampling, starting with the Latvian Bioeconomy Strategy 2030. The keyword assignment method was used to determine the extent to which national documents reflect international objectives and the priority assigned to them.

Improving energy efficiency in the heating and cooling sector

The SLR was used to identify the objectives and measures set for improving energy efficiency in Latvia's heating and cooling sector, as well as the policy instruments used to implement them (Publication 1). Sector-specific documents detailing policy measures and expected results were analysed in depth. The identified measures were classified into four categories of policy instruments, which correspond to the typology of policy instruments used

in EU-level literature. This approach made it possible not only to systematise policy measures according to the categories of policy instruments and assess their potential effectiveness but also to evaluate policy coherence between the EU and national levels, identifying both risks of overlap and gaps in the application of instruments.

Opportunities for the intensification of sustainable aquaculture systems

This phase of the study aimed to assess the possibilities for sustainable intensification of aquaculture, focusing on technological solutions and systems that can ensure greater productivity while reducing negative impacts on the environment (Publication 6). The literature review focused on farming systems and their technological elements, as well as best management practices.

2.1.2. Qualitative content analysis

In addition to SLR, qualitative content analysis was also used to analyse EU regulatory and policy documents, as it allows for the systematic identification of themes, meanings and structures in different texts while maintaining transparency. This method was considered appropriate because it facilitates the structured analysis of regulatory and policy documents and is particularly useful for researching policy-making and coherence in the context of policy development and implementation. As defined by Mayring [26], qualitative content analysis is a systematic, rule-based method for interpreting textual material. It allows for empirical, theoretically grounded analysis without premature quantification. Qualitative content analysis is a suitable method for analysing and interpreting grey literature in context.

Carbon farming in EU policy and regulatory documents

The first step in the study (Publication 9) was to define the research question, which in the context of the relevant research phase was: (1) *How is the CRCF Regulation horizontally integrated with other EU climate and agricultural policy documents, particularly in relation to carbon farming?* and (2) *What are the main challenges and opportunities for achieving vertical policy coherence in the implementation of the CRCF Regulation at the Member State level?* The analysis began with the CRCF Regulation, while subsequent documents were selected using a “snowball” sampling method, including policy and regulatory documents referenced in the selected text fragments.

2.2. Multiple-criteria decision analysis methods

2.2.1. Technique of Order Preference Similarity to the Ideal Solution

The MCDA method, Technique of Order Preference Similarity to the Ideal Solution (TOPSIS), is often used in the assessment of environmental strategies and sustainable development. The main advantage of the method is the ability to compare several alternatives by determining their proximity to ideal positive and negative solutions. The ideal positive and

negative solutions are determined during the calculation process. The strength of TOPSIS lies in its simplicity and the relatively small amount of data required for its application. One of the essential components of the method is the use of weighted criterion values, repeating the calculation with equal criterion weights, thus determining the impact of weight on the results.

Assessment of the coherence of European and national bioeconomy strategies

The TOPSIS method was used to assess the vertical coherence of the 2012 European Bioeconomy Strategy and its updated version in 2018 with the bioeconomy strategies of nine EU Member States. The study (Publication 3) identified the objectives and action lines in national bioeconomy strategies and grouped them thematically according to the objectives and action lines set out in the European bioeconomy strategy. The results were summarised and analysed using the TOPSIS method. The expert survey method was used to determine the weight of the criteria, and the average values of the obtained assessments were used as the weight of the TOPSIS criteria with a total sum of 100 %.

To ensure continuity and comparability across the research, the assessment of policy coherence between the European Bioeconomy Strategy and ten Latvian policy planning documents (Publication 2) employed the same criterion weights as those used in Publication 3. These weights were entered into the TOPSIS matrix and applied in the calculations.

Assessment of the sustainability of fishery and aquaculture products

Six different fishery and aquaculture products were compared (Publication 7): (1) biogas; (2) spirulina (nutritional supplement); (3) plant fertiliser from algae; (4) fish meal and oil; (5) biodiesel; (6) canned fish. Eight criteria for assessing product sustainability were divided into four categories: economic, environmental, technical and social criteria. The TOPSIS method was used to determine the most sustainable fishery and aquaculture product.

2.2.2. Analytical Hierarchy Process

The Analytical Hierarchy Process (AHP) is used to determine the relative importance of criteria based on a pairwise comparison matrix that reflects the decision-maker's assessment of the relative importance of the criteria. AHP is one of the most widely used MCDA methods, which is also used to evaluate social and political issues. Pairwise comparison and alternative solution evaluation matrices were constructed based on the methodology described by Samal and Kansal (2015) [27]. When comparing two solutions, the corresponding rating is entered at their intersection. The ratings were determined using Saaty's relative importance scale (1–9), which allows for the consideration of multiple opinions or expert perspectives [28], [29].

Comparison of the administrative frameworks for implementing RES projects

The comparison of the administrative frameworks for implementing RES electricity generation infrastructure projects (Publication 4) was based on five main criteria: (1) implementation schedule; (2) complexity; (3) availability of information; (4) influence of public opinion; (5) influence of local authorities. Factors such as deadlines, complexity of the

process, availability of information, influence of public opinion and the role of local authorities were taken into account. The criteria assessments were analysed using the MCDA methods TOPSIS and AHP, which allow for the simultaneous comparison of qualitative and quantitative indicators. The AHP method was used to determine the relative importance of the criteria, reflecting the views of decision-makers. Five independent experts developed weight matrices, and average weights were used in the final calculations. Various energy production technologies were evaluated separately: microgenerators, large and medium-scale solar power plants (SES) and large and medium-scale wind power plants (WPP).

Assessment of factors influencing the development of niche products

The AHP method was used to determine the relative significance of the identified factors in the analysis of strengths, weaknesses, opportunities and threats (SWOT) (Publication 8). After the experts had identified three promising niche products from the forest sector and assessed their strengths, weaknesses, opportunities and threats, the five most significant factors in each category were selected. These factors were subjected to additional pair comparisons, which allowed for the integration of different expert views. As a result, AHP matrices were created and factor weights were determined, which were then used in the TOWS matrix to develop strategic development directions for products and the forest sector as a whole.

2.2.3. Simple Additive Weighting

The Simple Additive Weighting (SAW) method is an MCDA method based on the weighted sum of normalised values for each alternative for all criteria. The aim is to find the highest score and thus the best alternative. This method normalises the decision-making matrix to a comparable scale. This method is mainly used to solve multi-criteria decision-making problems. The decision matrix is an $(m \times n)$ matrix in which each element x_{ij} reflects the value of alternative A_i based on decision criterion C_j . Alternatives are denoted by $i = 1, 2, 3, \dots, m$, while criteria are denoted by $j = 1, 2, 3, \dots, n$. Each element is assigned a numerical weight w_j [30], [31]. Alternatives are ranked according to their total scores, and the alternative with the highest total score is the best.

Ranking of vocational education competence centres

The ranking of 23 VECC was determined (Publication 5) using a simple composite indicator and the SAW method, which took into account three critical factors. A factor was considered a “benefit attribute” if an increase in its value was desirable, and a “cost attribute” if the opposite was true. These factors were as follows: (1) the number of survey points obtained on site during the inspection of the objects, which is a benefit attribute and is assigned a weight of 0.1; (2) the reduction in primary energy consumption per euro invested, which is a benefit attribute and was assigned a weight of 0.45; (3) the investment required in euros to reduce CO₂ emissions by one kilogram is a cost attribute and was also assigned a weight of 0.45. Taking into account these three criteria and their weighting, a ranking of competence centres was established, ensuring an objective assessment.

2.3. Strategic planning and evaluation methods

2.3.1. Focus group discussion

Focus groups are a widely used method in social and behavioural sciences to understand the views, motivations and attitudes of individuals that influence their behaviour in response to specific social phenomena. A focus group discussion can be seen as an exchange of views and sharing of information among several individuals to explore different aspects of a topic or knowledge issue. It is important to note that the aim of the discussion is not to reach consensus on the topic, but rather to cover its various aspects and evaluate different perspectives. Focus group discussions usually involve people who do not know each other but are knowledgeable about the topic, and these discussions often take place as a series of discussions.

2.3.2. SWOT analysis

The SWOT analysis is a widely used method for assessing internal and external influences and making decisions. It is considered a strategic planning tool that is often used in business and in the evaluation of various projects, but is also increasingly used in the context of policy planning and public administration, as it allows for the timely identification of future development opportunities and risks. At the same time, the disadvantage of the SWOT method is that it generalises the factors listed in the matrix without evaluating each factor in detail. Therefore, this method is often combined with other methods, such as AHP or TOWS, which provide a more in-depth analysis and justification for strategic choices. A similar approach was used by Kurttila et al. in [32], where a combination of such methods was used as part of the strategic planning of the forest certification process.

2.3.3. TOWS matrix

The TOWS matrix was developed in 1982 by Wehrich [33] as a situation analysis tool suitable for strategic planning and applicable to various types of organisations. The acronym TOWS (Threats, Opportunities, Weaknesses, Strengths) consists of the same elements as the SWOT matrix, but the approach is different – it allows external threats and opportunities to be linked to the internal strengths and weaknesses of the organisation. TOWS is based on four strategy combinations: (SO) maxi-maxi – maximum use of opportunities based on specific strengths; (WO) mini-maxi – weaknesses are mitigated by exploiting opportunities; (ST) maxi-mini – threats are mitigated by exploiting specific strengths; (WT) mini-mini – weaknesses are mitigated and threats are eliminated.

Identifying opportunities for forest bioeconomy transformation

To overcome the identified barriers and strengthen the forest sector's key advantages, a hybrid approach was used, combining group model building (applied in accordance with the principles of focus group methodology) with SWOT, AHP and TOWS methods (Publication 8).

Industry experts participated in group model building sessions, whose task was to identify promising high value-added niche products and to develop directions for the transformation of the industry. In order to make the assessment of the factors included in the SWOT matrix more analytical, they were ranked according to their importance and impact using the AHP method. Within each matrix, the five most significant strengths, weaknesses, opportunities and threats were identified and then subjected to pairwise comparison using Saaty's relative importance scale (1–9), ensuring greater consistency and comparability. In addition, a TOWS matrix was used to synthesise the results obtained with SWOT and AHP and to determine the interaction between factors. This approach allowed the development of four strategic combinations (SO, WO, ST, WT), increasing the added value of strategic measures and providing an opportunity to develop development strategies for the forest bioeconomy.

2.4. Empirical data collection and evaluation methods

2.4.1. Surveys

Development of a communication strategy on sustainability issues

In order to promote effective communication and public awareness of sustainable products, an initial assessment of the sustainability of six fishery and aquaculture products was carried out as a case study (Publication 7). The next step was to conduct an online survey, which was developed in *Google Forms* and distributed on *Facebook*. A total of 140 respondents in different age groups completed the survey, most of whom were between 18 and 55 years old. As the sample was self-selected, the results are not representative of Latvian society as a whole, but they do provide a reliable insight into the communication habits of the selected group of respondents.

Surveys and questionnaires in educational institutions

The VECC assessment (Publication 5) was carried out by visiting the institutions in person and distributing a standardised questionnaire to representatives of each institution. The questionnaire was prepared based on the methodology of Groves et al. [34] and consisted of four categories of questions: (1) energy consumption and behaviour; (2) environmental policy and education; (3) main electricity consumers; (4) energy efficiency and conservation measures implemented to date.

2.4.2. Data collection

Comparison of administrative frameworks for the implementation of RES projects

The comparison of administrative systems for implementing RES electricity generation infrastructure projects (Publication 4) is based on specific and harmonised criteria. Each criterion included one or more sub-criteria, for the assessment of which a large data set was compiled, ensuring a comprehensive evaluation of the administrative systems. The analysis was based on the regulatory documents in force in the countries included in the study, using publicly

available information on the steps of the process from the websites of public administration institutions where necessary.

Assessment of the sustainability of educational institutions

Detailed data was collected to assess energy consumption patterns in educational institutions (Publication 5). The data set included information from 167 buildings in all 23 VECCs included and surveyed in the study, including building area, heat and electricity consumption. The identification of sustainability measures was part of the creation of a simplified composite indicator, and the selection of measures was based on a comprehensive literature review, energy consumption data, building energy efficiency audits, site visits and surveys. The proposed sustainability measures can be divided into two groups: (1) measures that are common to most educational institutions (mandatory measures), and (2) individual measures (optional measures).

2.4.3. Expert evaluations

In studies examining the policy coherence of the European Bioeconomy Strategy with the national strategies of EU Member States (Publication 3), as well as in a follow-up study examining the coherence of the European Bioeconomy Strategy with Latvian policy planning documents (Publication 2), an online survey of experts was conducted. In the survey, experts were asked to assess which of the five objectives and three areas of action set out in the European Bioeconomy Strategy are most important for achieving rapid development of a knowledge-based bioeconomy. Completed questionnaires were received from 27 experts.

For the sustainability assessment of fisheries and aquaculture products (Publication 7), 28 experts were surveyed electronically and assessed the impact of each criterion on the alternatives on a 5-point scale.

3. RESULTS

3.1. Policy coherence assessment

The policy coherence assessment was based on literature and document analysis methods (SLR, qualitative content analysis), supplemented by data collection and MCDA methods. First, horizontal policy coherence was assessed by analysing how the CRCF Regulation fits into the broader EU climate, agriculture and LULUCF policy and regulatory framework and in which thematic areas they interact. At the same time, potential barriers to ensuring vertical coherence were identified when implementing the CRCF Regulation certification framework in Member States. Secondly, an analysis of vertical coherence was carried out by assessing whether the objectives defined in the European Bioeconomy Strategy have been implemented in the bioeconomy strategies of Member States. The third stage focused on the case of Latvia, assessing the vertical coherence between the objectives of the European Bioeconomy Strategy and Latvia's long-term and medium-term policy documents. Finally, the assessment of vertical coherence between EU and Latvian documents was supplemented by an analysis of the policy instruments included in the action plan.

3.1.1. Assessment of policy coherence: Carbon farming

In this study (Publication 9), qualitative content analysis was used to answer two research questions. The set of documents analysed included 31 regulatory and policy documents closely related to the CRCF Regulation and its implementation, including one international agreement (the Paris Agreement), one proposal for a regulation, three directives and nine regulations, while the largest number of documents (17) were European Commission communications. Nine keywords related to carbon sequestration, additionality and carbon farming were searched for in the documents. The selected text fragments were qualitatively analysed and divided into nine thematic groups (Table 3.1). These groups reflect the main areas of interaction and coherence between the CRCF Regulation and other EU regulatory and policy documents, particularly in relation to climate and agricultural policy.

Table 3.1

Thematic Groups of Text Fragments Identified in the Documents

No.	Thematic group	Number of text fragments
1	General information on EU GHG emission reduction targets	117
2	The CRCF Regulations certification framework as an instrument for implementing EU climate objectives	42
3	Certification framework, monitoring, support tools	84
4	Quantification, baseline, reversal of previous removal	53
5	Links and interactions between CRCF and CAP	42
6	Carbon farming as a business model	34
7	Carbon farming and carbon storage in ecosystems and products	29
8	Sustainability, additionality and activities with co-benefits	14
9	Text fragments excluded from further analysis	485

The assessment of horizontal policy coherence based on the first four thematic groups (Table 3.1) provides an understanding of the role of the CRCF Regulation in the broader context of EU climate, agriculture, LULUCF and energy policies. These groups highlight the link between the CRCF Regulation and broader strategic objectives, including increasing carbon sequestration, developing the bioeconomy and achieving climate neutrality. The methodological approach of the CRCF Regulation is illustrated, including the certification framework, monitoring, and the need for innovation and digitalisation, which are part of the overall EU vision for policy and regulatory development. Strengthening the knowledge and capacity of land managers, involving them and building trust is recognised as important for putting new initiatives into practice. The CRCF Regulation builds on the political vision set out above, in particular in the Communication on Sustainable Carbon Cycles, and complements existing instruments by providing a coordinated approach to the implementation of carbon farming practices.

The fifth and sixth thematic groups focus on the interconnection between the CRCF Regulation and the Common Agricultural Policy (CAP), as well as the development potential of carbon farming as a green business model. The CRCF Regulation is positioned as a voluntary and complementary mechanism to be implemented on a results-based approach, while the CAP continues to operate within an activity-based support system. The sixth thematic group demonstrates coherence with other EU strategies. The CRCF Regulation introduces a complementary framework that expands the EU's climate policy instruments beyond emission reduction, by establishing a voluntary, scientifically grounded and transparent certification system. This enables the development of a voluntary carbon market and stimulates investments not only in emission reductions but also in CO₂ removals and long-term storage in ecosystems and biomass, opening up opportunities for new business models and long-term climate solutions.

The seventh thematic group demonstrates horizontal coherence with EU policies on biodiversity conservation, sustainable land management and carbon sequestration in products. It illustrates the gradual integration of various carbon removal and sequestration solutions, ranging from land management to the use of wood in durable products, into the EU's broader environmental, climate, and product policies. However, a gap has been identified in the integration of marine and coastal carbon sequestration, or "blue carbon", into the broader policy framework. Policy documents assign an uneven level of importance to it, indicating an imbalance between sectors.

The second research question focused on the assessment of vertical coherence, aiming to identify the main challenges and opportunities for implementing the CRCF Regulation at the national level. This dimension was especially reflected in thematic groups 2, 4, 5 and 6 (Table 3.1). Thematic groups 2 and 4 explore vertical coherence between the CRCF Regulation's certification framework and the application of international and EU-level reporting obligations at Member State level. The CRCF Regulation aligns with these frameworks by applying IPCC guidelines, which underpin GHG accounting methodologies used both in EU and international climate reporting under the Paris Agreement. At the same

time, there remains uncertainty around how methodological consistency will be achieved between the certification framework and Member State reporting mechanisms.

Thematic group 5 illustrates both horizontal and vertical policy coherence between CAP and the CRCF framework. However, it also identifies information and policy gaps, raising the question: How will potential overlaps in funding be managed between the CAP and the CRCF framework? Or is the current CAP (2023–2027) simply a transitional mechanism designed to facilitate the uptake of carbon farming practices? These uncertainties are further exacerbated by market-related factors, particularly the question of whether carbon credit prices will be high enough to offset the risks faced by land managers.

Thematic group 6 presents carbon farming as a green business model, which could provide land managers with an additional source of income, while signalling a shift away from traditional carbon offsetting towards carbon insetting [72], where carbon credits are purchased by companies within the same value chain. This illustrates vertical policy coherence by linking EU-level regulatory measures under the CRCF Regulation and their implementation at Member State level, while using economic (market) policy instruments – involving the private sector and using value chain emission reduction strategies.

As a new instrument within the EU climate policy architecture, the CRCF Regulation holds substantial potential. However, its effectiveness will ultimately depend on how it is implemented across Member States. Key challenges include clarifying certifiable carbon farming activities, defining robust and consistent baselines, ensuring environmental integrity of certification methodologies, and establishing transparent conditions for the use of carbon credits. Equally important will be the CRCF Regulations integration with existing mandatory policy instruments, such as the CAP, LULUCF Regulation EU 2018/841 and the Regulation (EU) 2018/1999 on the Governance of the Energy Union and Climate Action, to ensure alignment and avoid duplication. National policymakers will play a decisive role in shaping how consistently and purposefully carbon farming practices are supported and embedded within national support systems, advisory services and market mechanisms.

3.1.2. Assessment of bioeconomy policy coherence in EU Member States

The analysis of national bioeconomy strategies (Publication 3) examined the objectives and measures set out in the strategies. The objectives and measures were grouped based on the five objectives and three priority areas of the European Bioeconomy Strategy and action plan [35], [36]. Practically all of the national bioeconomy strategies evaluated have implemented the objectives and action lines set at the EU level, as only 1 % of the objectives and action lines mentioned in the strategies were not directly linked to those set at the EU level.

Figure 3.1 shows a comparison of all nine countries included in the study based on their stated objectives. The results show that national strategies mainly focus on the three new areas of action defined in the updated 2018 European Bioeconomy Strategy. The five objectives from the 2012 strategy are less frequently emphasised, with the objectives aimed at the sustainable management of natural resources being the most widely implemented at the national level. This

objective is most frequently mentioned in the strategies of Latvia (18 %), France (14 %) and Ireland (14 %).

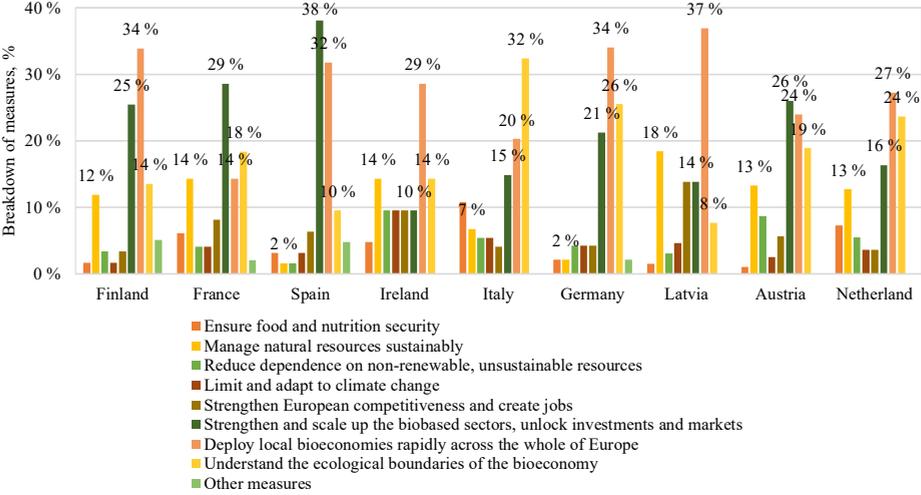


Fig. 3.1. Grouping of national bioeconomy strategy objectives and measures in line with those set out in the European bioeconomy strategy.

The results obtained in the strategy analysis were entered into the TOPSIS matrix, normalised and weighted according to the results of the expert assessment. According to the TOPSIS results (see Fig. 3.2), applying the expert criteria weights, Austria received the highest score (0.94), followed by Italy (0.20), although significantly behind the leader. The third result, which came closest to the ideal positive solution, was Latvia (0.13). The Netherlands (0.07), France (0.05), Spain (0.04), Germany (0.01) and Ireland (0.01) received the lowest scores in the assessment. The calculation was then repeated, assigning equal weights (0.125) to all eight criteria.

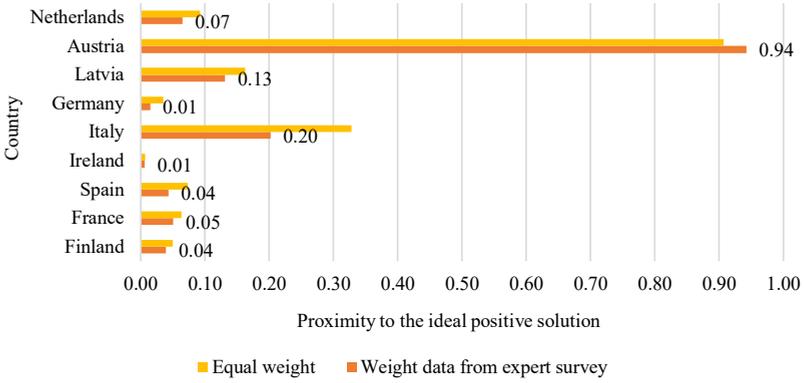


Fig. 3.2. TOPSIS assessment results.

The countries with the highest results had implemented the most objectives and measures in their national strategies that are related to the European Bioeconomy Strategy – Austria 196, Italy 74 and Latvia 65 measures. Austria’s high scores are also linked to the fact that it has set significantly more targets and action measures in its national bioeconomy strategy than other countries included in the study. However, this correlation is not observed in the strategies with the lowest performance, where the distribution of measures by target in terms of criterion weighting has been more significant than the number of measures proposed. Figure 3.2 shows that the expert assessment influences the results obtained, but not to such an extent as to change the overall results.

An analysis of the objectives and measures of national bioeconomy strategies shows that the main focus is generally on the priorities of the 2018 updated European Bioeconomy Strategy. EU-level priorities have largely been incorporated into national strategies, with only eight actions, or 1 % of all actions, not directly linked to EU bioeconomy objectives. This confirms the Member States’ ability to ensure vertical alignment with EU policy, thereby strengthening overall policy coherence.

The evaluation of the strategies using a mixed-method approach combining SLR and TOPSIS analysis confirmed the suitability of this approach for identifying not only vertical coherence between different levels of policy planning, but also horizontal coherence at the Member State level. The analysis showed that countries with more detailed national strategies scored higher in the TOPSIS assessment, but a greater number of action lines and measures does not necessarily mean faster implementation. For a more accurate picture of the possibilities for implementing the strategies, it would be necessary to analyse the accompanying action plans, although in this case, not all strategies had such plans.

3.1.3. Assessment of bioeconomy policy coherence: The case study of Latvia

This stage of the study analysed the implementation of EU objectives in various Latvian policy documents, including sectoral strategies related to the bioeconomy (Publication 2). This approach made it possible to assess not only vertical coordination between the EU and Latvia, but also horizontal policy coordination between various national-level documents. The analysis was supplemented with four keywords – the agricultural sector, the forest sector, the fisheries and aquaculture sector – as an indication of the primary extraction sectors of biological resources.

Implementation of international goals in Latvian policy documents

The SLR and keyword assignment method was used to assess the prioritisation of internationally set bioeconomy development goals in Latvian policy planning documents. The weights of the TOPSIS criteria were determined according to expert evaluation, using the same criteria and expert assessment as in Publication 3.

In the assessment, the Latvian Bioeconomy Strategy 2030 (0.98, see Fig. 3.3, Document 5) and Latvia’s Strategy for Achieving Climate Neutrality by 2050 (0.98, see Fig. 3.3, Document 2), while Latvia’s Sustainable Development Strategy until 2030 scored 0.58 (see

Fig. 3.3, Document 1) and Latvia’s National Development Plan for 2021–2027 with 0.57 (see Fig. 3.3, Document 3) achieved significantly lower results (Fig. 3.3, blue bars).

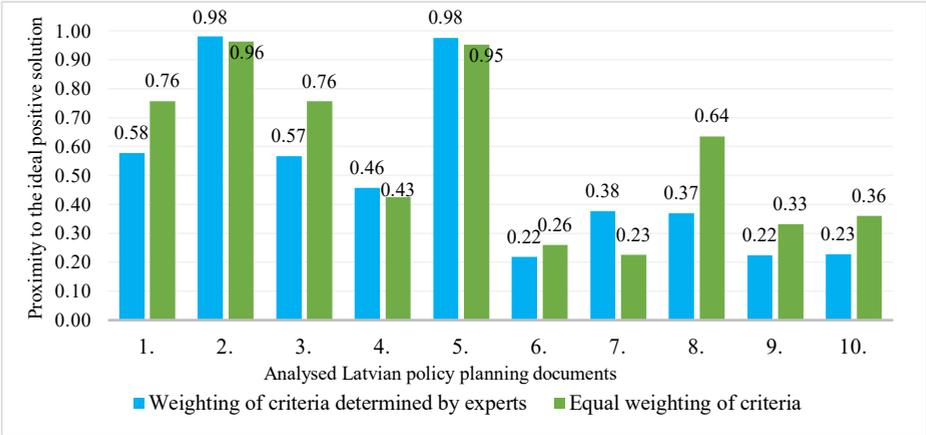


Fig. 3.3. TOPSIS results for Latvian policy document priorities in the bioeconomy.

The results obtained by applying equal weightings to the criteria show a different relative ranking of the analysed documents, but maintain a similar grouping of documents with clearly defined highest, average and lowest result intervals (Fig. 3.3, green bars). In this case, too, the highest score is for Latvia’s Strategy for Achieving Climate Neutrality by 2050 (0.96, see Fig. 3.3, Document 2), followed by Latvia’s Bioeconomy Strategy 2030 (0.95, see Fig. 3.3, Document 5).

The results of the TOPSIS analysis for determining the priorities for the agriculture, forest sector, fisheries and aquaculture sectors in Latvia’s policy planning documents are shown in Fig. 3.4. The assessment was carried out using equal weighting of criteria, assuming that all sectors are equally important. The results show that Latvia’s Bioeconomy Strategy 2030 received the maximum number of points (1.00, see Fig. 3.4, Document 5) and can be considered an ideal positive solution. The closest result was Latvia’s Climate Change Adaptation Plan for the period up to 2030 with 0.92 points (see Fig. 3.4, Document 6). The other documents received significantly lower scores.

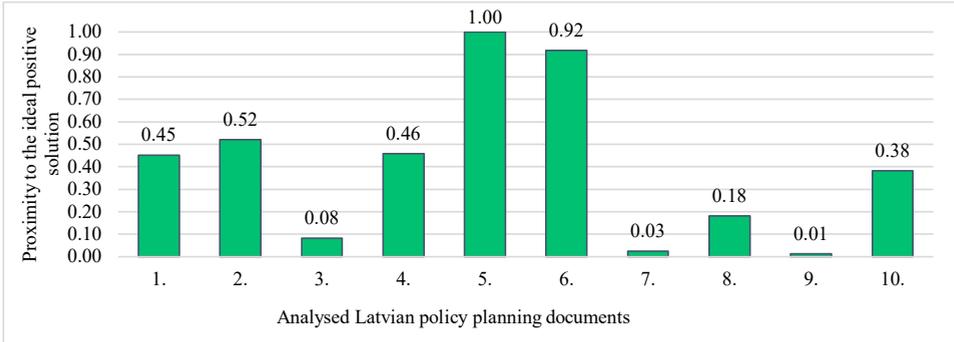


Fig. 3.4. TOPSIS results for the agriculture, forest, fisheries and aquaculture sectors.

An analysis of Latvia's long-term and medium-term documents using the TOPSIS method shows a positive trend, as all ten documents are linked to internationally defined bioeconomy goals. Documents at the top of the policy planning hierarchy received higher ratings than lower-level sectoral plans, confirming the vertical coherence of policies. At the same time, it is logical that sectoral or thematic plans have lower scores, as they focus on sector-specific measures. In turn, Latvia's Bioeconomy Strategy 2030, as the only document directly dedicated to the bioeconomy, achieved the highest scores. Measures in the agricultural and forest sectors are mentioned relatively often, while the development of the fisheries and aquaculture sector, with the exception of Latvia's Bioeconomy Strategy 2030, has received significantly less attention. This reveals gaps in horizontal policy coherence, as certain bioeconomy sectors are less represented in planning documents.

In assessing the consistency of bioeconomy policies, the TOPSIS method provided a relative comparison within the framework of Latvian policy documents, showing that Latvia's Bioeconomy Strategy 2030 has the highest score in the national context. However, when analysing the bioeconomy strategies of EU Member States in a separate TOPSIS matrix (see Subsection 3.1.2), Latvia's Bioeconomy Strategy received a lower rating, which indicates the relative nature of the TOPSIS comparison. Looking solely at the case study of Latvia, the most significant shortcoming identified is the absence of a transition phase in Latvia's Bioeconomy Strategy 2030 from an "informative report" to an action plan with specific measures and financing mechanisms. The absence of such a transition limits the possibility of systematically planning and quantitatively assessing the pace of bioeconomy development in Latvia, rather than merely assessing its formal compliance with EU objectives.

3.1.4. Policy coherence assessment: Heating and cooling sector

A carefully selected set of policy instruments is essential to achieve objectives in any policy area. The most effective way to use policy instruments is to combine them rather than rely on a single instrument. Policy instruments can target specific processes or norms, such as applying additional taxes to promote GHG emission reductions, developing technology standards, establishing cooperation agreements, and compensation systems, etc. For the classification and analysis of policy instruments in the Thesis, four categories of policy instruments were selected that are suitable for emphasising sustainability and environmental issues: regulatory instruments, voluntary instruments, government expenditure and market-based instruments. Each category of policy instruments has its strengths and weaknesses depending on the desired outcome, and combinations of instruments are often tailored to the situation in the policy planning process. Not all combinations of policy instruments are successful and produce the expected results, so when combining policy instruments, proportionality and complementarity must be ensured.

Categorisation of policy instruments

After determining the vertical consistency of the targets set at EU and Latvian level, which showed a high level of coherence, the next step was to divide the NECP2030 policy measures

planned to improve energy efficiency in heating and cooling into policy instrument categories (Publication 1). A total of 34 action areas with 110 planned measures were identified and classified thematically into four categories of policy instruments (see Table 3.2). The largest number of planned policy measures is in the policy instrument category “regulation” (69 % or 76 measures), followed by “government expenditure” (20 % or 22 measures), then “market-based instruments” (7 % or 8 measures), with the fewest measures falling under the category of “voluntary action” (4 % or 4 measures). The results show that the planned policy measures are not evenly distributed across the instrument categories. Market-based instruments and “voluntary actions” are the least frequently used and are mainly combined with regulatory instruments.

Table 3.2

Breakdown of Planned NECP2030 Policies and their Implementation Measures by Policy Instrument Category

Policy instrument category	Regulation	Voluntary actions	Government expenditure	Market-based instruments
Measures	76	4	22	8

Overall, Latvia’s planning documents indicate vertical coherence with the EU’s objectives, but the policy instruments identified during the analysis for improving energy efficiency in the heating and cooling sector are considered to be limited. NECP2030 mainly uses regulatory instruments, which may entail an additional administrative burden, although the analysis of Latvian planning documents has already identified indications of complex bureaucratic processes and limited institutional capacity. The measures mentioned in the “government expenditure” category reflect the government’s initiative to support energy efficiency improvements, but a more in-depth analysis shows that they are mainly related to amendments to regulatory documents for attracting EU funds, rather than additional state funding. NECP2030 makes less use of “market-based instruments” and “voluntary instruments”, and the measures envisaged appear to be less ambitious. In order to achieve the long-term goals of decarbonisation and efficiency improvement in the energy sector, the policy package should be reoriented towards the use of market-based instruments and a more targeted transition from the “assessment phase” to the “action phase”.

The results obtained reinforce the hypothesis of the Thesis that the assessment of policy coherence reveals only the formal implementation of objectives, while the development of appropriate measures and the application of policy instruments are important for their implementation. Therefore, it is not enough to assess the coherence of documents; an in-depth analysis is needed to identify opportunities for process optimisation and remove barriers in order to strengthen the effectiveness of bioeconomy and climate policy.

3.2. Identification of obstacles and shortcomings in policy implementation

The identification of obstacles and shortcomings for policy optimisation was based on literature and document analysis methods, supplemented by data collection, MCDA methods, and strategic planning and evaluation approaches.

3.2.1. Removal of administrative barriers to the implementation of RES projects

In the context of the study (Publication 4), the administrative process is a set of processes that a wind power plant (WPP) or solar power plant (SPP) project developer must carry out in order to implement the project from the project concept to electricity generation. In the study, administrative processes include the duration of the connection process, the transparency of the process, restrictions and network expansion, fair and independent regulation of the energy sector, the complexity of the administrative process, land use and environmental planning, the duration of the process, public perception, and communication between relevant stakeholders. The process of installing SPP and WPP technologies can be divided into three stages: the initial or preliminary research stage, the implementation and electricity generation stage, and the end of operation or decommissioning stage.

The process of implementing RES projects in the countries analysed

The study found that the regulatory framework and administrative procedures for the installation of WPP and SPP in the countries studied are practically identical in terms of project implementation stages and the necessary permits, with a few minor differences. The RES project implementation processes are as follows: feasibility study; coordination of the project idea; power generation and grid permits; construction and commissioning (Fig. 3.5).

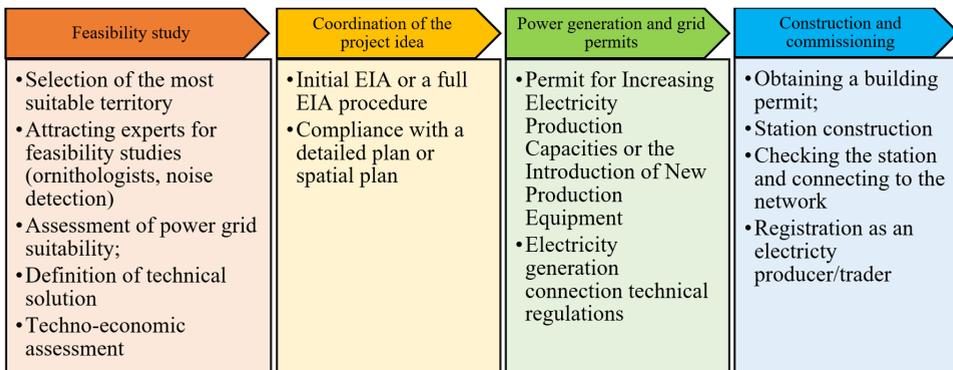


Fig. 3.5. General steps for RES project implementation and approval process.

In most of the countries included in the study, small and medium-sized power plants with a capacity of up to 10 MW are connected to the distribution system operator, while large power plants with a capacity above 10 MW are connected to the transmission system operator.

Norway is the only country included in the study that has a single point of contact that coordinates the development of SPP and WPP and issues the necessary permits for commencement of operations – the Norwegian Water Resources and Energy Directorate. At the time of the study, the Swedish Energy Agency was still working on establishing a digital contact point covering permits, exemptions and notification procedures for RES installations and their connection to the grid.

MCDA results

The TOPSIS results are shown in Fig. 3.6. The weighting procedure is described in Subsection 2.2.2 and in detail in Publication 4. Lithuania received the highest score for microgenerators, as the Law of the Republic of Lithuania on Energy from Renewable Sources (XI-1375) clearly defines the regulatory framework for the installation of microgenerators – capacity limits, and provides for a simplified installation process in relation to territory and building permits. Such a single document, which summarises the regulation of RES technologies, can be considered a factor promoting the introduction of RES technologies and also helps to ensure the transparency of the process. Norway ranks second, while Finland ranks third. According to the results, Estonia ranks last in terms of microgenerator installation.

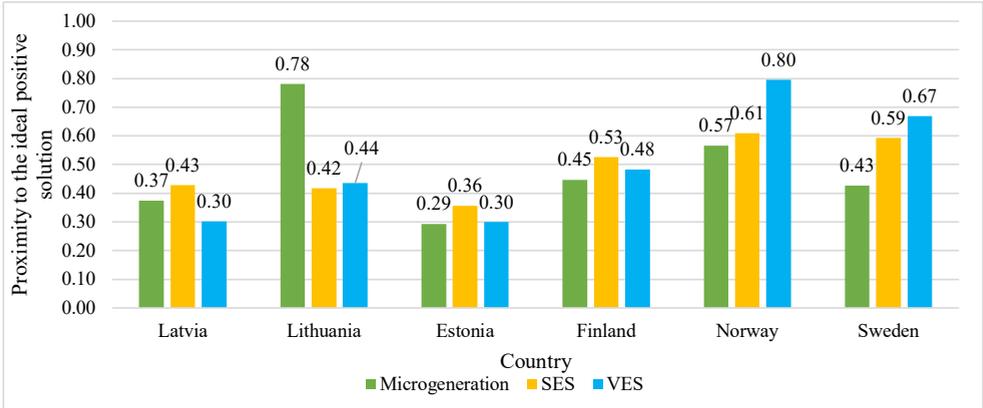


Fig. 3.6. TOPSIS results for various AER projects.

The Nordic countries have received the highest ratings for the implementation of large and medium-sized SPP projects – Norway and Sweden have received the highest scores, followed by Finland. This result has been achieved thanks to the smaller number of contact points required to obtain the necessary permits and the availability of information explaining the process. The Baltic States have achieved lower results, with Latvia ranking fourth, just behind Finland, while Lithuania and Estonia rank fifth and sixth, respectively. Estonia ranks last because, compared to other countries, SPP projects may be subject to an EIA and may require changes to spatial planning. The Nordic countries also scored higher in terms of RES, again due to the smaller number of institutions involved and the shorter project implementation period. Furthermore, the study concludes that RES project implementation in Norway is the most efficient thanks to optimised permit issuance processes and a single point of contact.

Regulatory frameworks and administrative procedures should be tailored to the potential target audience in order to avoid unnecessary administrative barriers, namely, electricity generation for private use (including small power plants) with microgenerators; small and medium-capacity electricity generation facilities that supply electricity to businesses or communities; large-capacity power plants designed to generate income from the sale of electricity. This approach could contribute to increasing the share of electricity produced from RES in various sectors.

Microgenerators

There are only minor differences between countries in the administrative procedures related to the installation of microgenerators. Overall, the installation process takes between one and three months, which indicates a relatively simplified installation and grid connection procedure. A comparative analysis shows that Lithuania has the most favourable administrative conditions, both in terms of the highest permitted microgenerator capacity in the Baltic States and the fact that there are no spatial planning restrictions and no building permit is required. In the Baltic States, microgenerators are classified as equipment with a lower capacity than in the Nordic countries. Given the rising prices of electricity, such capacity limits for household microgenerators may be insufficient to cover consumption. It is therefore recommended that the legislation in the Baltic States defining microgeneration and its capacity should be revised, and a higher capacity should be established.

The information published by distribution network operators on the requirements for connecting microgenerators to the electricity grid and the descriptions of the processes were assessed as comprehensive and useful. However, it was found that in almost all countries included in the study, general information on the installation of WPP and SPP microgenerators is incomplete. Guidelines for the installation of microgenerators or small-scale WPP and SPP (separately for each technology), with explanatory information on the steps involved and the mandatory requirements, would improve transparency and possibly speed up the process.

Medium and large-scale onshore WPP and SPP

Directive (EU) 2018/2001 on the promotion of the use of energy from renewable sources [21] Article 16 (1) proposes that Member States establish one or more contact points where RES project developers can obtain the necessary advice and permits in one place. The energy agencies established in Sweden and Norway, which maintain detailed information on RES technologies, the administrative process for installation and the regulatory framework, were identified as examples of good practice. Both the literature review and the study confirmed that the existence of a single point of contact accelerates the implementation of RES projects, so it would be useful to implement this approach in the Baltic States as well, by establishing contact points in national energy agencies or local governments. In the Baltic States, there was significant public resistance to the installation of RES technologies, which is likely due to a lack of knowledge and stereotypes about WPP and SPP. Energy agencies could, therefore, be the organisations in the Baltic States that promote trust in solar and wind energy by providing transparent and reliable information.

Local authorities are responsible for ensuring that WPP or SPP projects comply with spatial planning, issuing building permits and participating in the EIA process, which is an important part of the project implementation steps. However, the websites of local authorities and other administrative bodies in the Baltic States often lack explanatory information about these procedures. It would therefore be useful to follow the example of Sweden and Norway by publishing more comprehensive and understandable information on the administrative requirements for installing RES technologies.

Gathering information on the conditions for issuing building permits and the need to apply for them was one of the most complex parts of the administrative process in all the countries studied, with the exception of Sweden. In order to facilitate the procedures related to the construction process, it would be useful to clearly specify in the regulatory documents the requirements applicable to the installation of RES technologies (in this case, SPP and WPP), making the regulations more understandable and easier to apply.

A large number of documents in six languages (Latvian, Lithuanian, Estonian, Finnish, Swedish and Norwegian) were analysed for the study. The process was particularly complex for the Baltic States, where almost all procedural schemes had to be developed from scratch, based on regulatory documents as the primary source. This created a risk regarding the accuracy of interpretation, especially in the procedures for obtaining building permits for the installation of SPP and WPP. The study was also limited by differing spatial planning regulations at the municipal level, so the results were generalised at the national level rather than the municipal level. Another limitation is the time period of the study – it was conducted in 2021, before Russia's full-scale invasion of Ukraine in February 2022. After this event, fossil fuel prices rose sharply, which highlighted the need for changes in the regulatory framework in the countries included in the study in order to simplify the requirements for the installation of SPP and WPP.

The methodology developed during the study, although time-consuming, provided significant added value, as it allowed for a structured understanding of the administrative progress of RES projects and identified specific stages at which project development slows down. The quantitative results complemented the qualitative analysis, as the TOPSIS method allowed for a numerical comparison of the impact of administrative requirements on the implementation of RES projects. In a scientific context, this complements the little-researched aspects of RES project implementation, while at a practical level, it provides transparent information on the administrative steps, necessary permits and regulatory framework in the countries included in the study. These results reinforce the hypothesis of the Thesis, confirming that assessing policy coherence alone is insufficient; a thorough analysis of obstacles and shortcomings is also necessary for the effective implementation of RES.

3.2.2. Identification of enablers and constraints to the strategic development of the Latvian forest sector

In the next stage (Publication 8), attention was directed towards identifying the constraints and enablers with the aim of developing evidence-based future development scenarios, thereby strengthening policy design and decision-making. The first step of the developed methodology

involved analysing six system elements essential for knowledge-based bioeconomy development, followed by an assessment of the drivers and barriers within each of them. To evaluate development opportunities for the forest bioeconomy, a group of five experts was convened to identify and prioritise innovative, high-value-added bio-based products.

During the first modelling session, the experts were introduced to the identified Latvian forest sector system elements and prepared a SWOT matrix for it. In subsequent modelling sessions, the experts identified three niche wood products and developed SWOT matrices for them. Five factors from each component of the SWOT matrix were identified as the most likely to influence product development and market uptake. These five factors were then ranked using the AHP method. The results were incorporated into a TOWS matrix developed for each product, allowing the identification of possible interactions, the actions required to advance each niche product, and opportunities for opening new markets, as well as outlining long-term solutions for the development of the forest sector and the bioeconomy as a whole. Figure 3.7 illustrates the methodology used to structure the work of the expert group and serves as a visual overview of the analytical process on which the conclusions discussed in the following section are based.

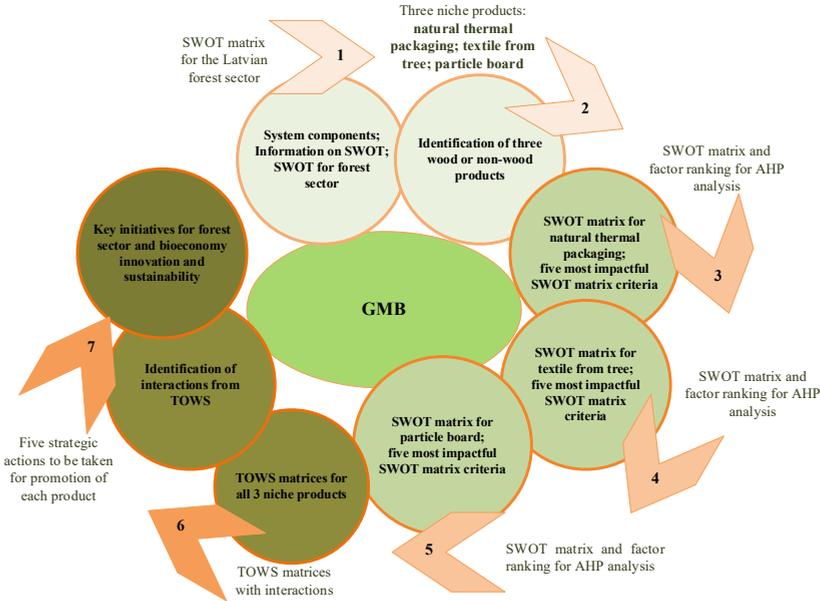


Fig. 3.7. Steps in the study of the expert group (methodological overview).

The creation of a textile fibre from wood production plants and the introduction of technology, including research, need financial support and state guarantees to reduce the administrative burden, at least for the establishment of a pilot project. The state’s commitment to achieving the goals set out in the European Green Deal, as well as its commitment to gradually replacing unsustainable textiles and fibres from fossil resources, would significantly contribute to attracting investment. In order to promote innovation and the licensing of wood-

based textile fibres, cooperation mechanisms between research institutions, companies and investors should be strengthened. This could also be achieved by promoting the transfer of knowledge from other countries with experience in manufacturing technologies to Latvia. Experts pointed to a lack of public awareness about the environmental impact and life cycle of widely used textiles, which could only be changed in the long term by supplementing educational content and carrying out additional educational work at various levels of education.

The experts concluded that particleboard is an existing and well-known product on the market for which additional research and investment in production technology would be required to improve sustainability and environmental performance. In order to stimulate both production and consumer preference for such a product, information campaigns should be conducted to stimulate demand for particleboard with improved properties. Although consumer demand for particleboard with improved environmental properties is seen as the decisive factor, government subsidies or support mechanisms for producers aimed at promoting the use of bioresources for products with higher added value, according to the bioresource value pyramid, could also have a decisive impact.

In order to develop natural thermal packaging, infrastructure for the collection of secondary and tertiary wood resources in rural areas should be created. Encouraging the collection of low-value wood residues, not only to ensure the full utilisation of the resource, but also to encourage the use of these residues in the manufacture of new products. Government commitment to Green Deal targets would also play an important role in encouraging greater use of bioresources in products previously made fully or partly from fossil resources by providing targeted financial support to companies to develop and market such bio-based products. An important role for the promotion of natural thermal packaging would also be to communicate the importance of cascading and the circular economy to the public, companies and their representative associations.

Identified strategic actions

The bioeconomy in Latvia faces several challenges, including a lack of incentives for higher value products and innovations, bureaucratic complexity and insufficient funding. To address these issues, the author suggests developing national guidelines for companies to promote the use of lower-quality wood for higher value-added products. These guidelines could be inspired by the Best Available Technology (BREF) reference documents provided by the European Commission. These guidelines should be adapted to local conditions while taking into account the international state of the art in this field.

Financial support mechanisms such as public grants, subsidies and research projects should be introduced to direct research and innovation initiatives towards higher value-added products. This would help overcome financial bottlenecks, such as a lack of funds for research, development and innovation. In addition, the government needs to give clear signals on long-term planning and adherence to the objectives of the European Green Deal and the European Bioeconomy Strategy in order to promote the circular bioeconomy and sustainable solutions in practice.

A knowledge-intensive bioeconomy requires a strong educational and scientific background, but funding for science and education in Latvia is insufficient and unpredictable. To ensure continuity of research and strengthen R&D, it is necessary to break the cyclical nature of funding and ensure predictable and sufficient science funding. The weaknesses of Latvian bioeconomy companies are partly due to the energy-intensive nature of their technology and their insufficient energy and resource efficiency. Introducing environmental and energy management systems can help companies become more competitive, efficient and innovative.

Promoting public awareness and the flow of information is also crucial. This includes measures to counteract “greenwashing” and encourage companies to certify their bioeconomy products. Workshops and training for industry on the wide use of wood and wood residues in higher-value-added products, construction and in line with the circular bioeconomy should be provided. The concept of promoting the bioeconomy should be supplemented with explanations that are understandable to the public about the efficient use and conservation of biological resources, the importance of climate neutrality and ways to achieve it, and the use of renewable energy sources.

The study described in Subsection 3.1.3 showed that the EU bioeconomy objectives have generally been implemented at a high level in Latvian policy planning documents. The main concern, however, is the policy planning documents dealing specifically with the forest sector. At the time of this research (year 2022), the forest sector-specific policy planning documents were not up to date – there were no officially available Guidelines for the Development of Forests and Related Sectors beyond 2020, and the national Forest Policy was last updated in 1998. Long-term development goals are missing from the forest sector’s policy planning documents, leading to uncertainties about its development towards the European Green Deal and the EU Forest Strategy for 2030.

The results of the group modelling sessions largely coincided with the enablers and constraints identified in the forest sector, indicating significant mutual interaction. Thus, the developed approach allowed both to formulate product development strategies and to re-emphasise the fundamental problems of the sector that affect the transformation opportunities of the Latvian forest sector. For example, when considering the directions of bioeconomy development, the critical factor is not only the development opportunities of specific product groups, but also the availability of raw materials, a stable regulatory framework, and the availability of funding for innovation development and commercialisation.

The methodology developed is applicable and useful for policy makers, for structuring preliminary research and for involving stakeholders in strategy development. Structuring preliminary research into six system elements provides a more comprehensive overview of the factors that influence the development of the sector. These results not only help to identify weaknesses in policy planning but also reinforce the conclusions drawn from the policy coherence assessment that in-depth analysis is needed to identify obstacles and shortcomings that hinder development. At the same time, the identification of obstacles should not be seen as a criticism of the political system, but rather as an opportunity to optimise future development.

3.3. Dimensions of policy implementation: Sustainable solutions, resource efficiency and communication

An in-depth analysis was conducted in three policy implementation dimensions to identify sustainable solutions and promote more efficient use of resources across sectors, as well as to assess the importance of communication in achieving the European Green Deal objectives. The analysis was based on literature and document analysis, MCDA and empirical data collection and evaluation approaches.

3.3.1. Reflection of policy objectives in infrastructure and institutions

The energy consumption analysis (Publication 5) revealed the current level of energy efficiency in VECC and identified areas with potential for improvement. The energy efficiency assessment was carried out by combining surveys, questionnaires and consumption data analysis. In addition, given the limited budget of educational institutions, energy efficiency and sustainability measures were optimised to select the most effective ones. The total reduction in primary energy consumption (both renewable and non-renewable energy) and annual GHG emissions that could be achieved by implementing the identified measures was calculated. By combining these indicators with the survey results, a simplified composite indicator was created to identify VECCs where measures should be implemented with higher priority.

On-site visits and survey results showed that most educational institutions face similar problems. During the surveys, opportunities for renovation and improvement were identified, and appropriate measures were selected, taking into account the needs and specific characteristics of each institution.

Each educational institution has an employee responsible for energy systems and engineering communications. During the visits, it was observed that the level of knowledge of these employees about energy saving, the operation and regulation of various systems varies. The motivation to save energy also varies among these employees. The appointment of competent energy managers allows for significant energy savings to be achieved, while at the same time identifying those responsible for the maintenance of energy systems and the implementation of energy-saving measures. At the same time, defining and implementing the role of energy manager requires a change in attitudes and management processes within the institution. Currently, technical staff in educational institutions are mainly responsible for the smooth operation of equipment, rather than improving energy efficiency. If possible, a motivation system should be introduced that links energy savings achieved to remuneration.

Only a few of the surveyed VECCs have building management systems installed that allow energy consumption data to be collected, analysed, and measures to be taken to reduce energy consumption. In most educational institutions, radiators are only partially equipped with thermostats. In some educational institutions, it is necessary to replace old heat supply substations with new ones to ensure automatic heat supply regulation. Building management systems can provide significant energy consumption reduction and control over consumption. At the same time, it is a tool that facilitates the daily work of the energy manager, as many

functions are performed automatically, thus significantly reducing the number of working hours required for manual work. Most VECCs have only partially switched from traditional light bulbs to LED lighting. It is therefore necessary to replace inefficient light bulbs and install light sensors, which is one of the simplest and most effective measures that can be taken. Solar energy technologies have been installed in several VECCs, but only one institution uses them for energy production. Therefore, solar panels should be installed in all educational institutions where the roof structure of the building allows it, in order to cover part of the building's electricity consumption.

Some VECCs have partially implemented environmental policies or elements thereof, but most educational institutions have not. It is necessary to develop an environmental policy and an implementation plan that specifies how various measures related to environmental aspects are implemented in the educational institution, reducing their overall impact on the environment. The existence of an environmental policy for students, staff and the public confirms that it is an environmentally friendly institution that understands and demonstrates its responsibility to reduce its impact on the environment, while the implementation of a functional environmental policy would reduce energy consumption.

Primary energy savings were calculated for the necessary investments in various VECCs. Mandatory energy efficiency measures ensured greater energy savings per capital investment thanks to improved energy management, which does not require significant financial support. Optional measures would require greater financial investment to achieve the same energy savings as mandatory measures. In some buildings, energy savings are even negative due to the need to install a mechanical ventilation system, as this requires additional energy consumption, but at the same time improves indoor air quality. Emissions reductions can be achieved by reducing energy consumption and installing RES technologies. In some cases, the calculated CO₂ reduction costs are negative, which means that the specific measures do not result in emission reductions in relation to the investment or even increase CO₂ intensity per investment unit.

The implementation of mandatory and optional measures could significantly reduce energy consumption, primary energy consumption and total annual emissions. It has been calculated that energy consumption at VECCs would be reduced by 9.7 GWh/year after the implementation of the measures, which is 25 % of total energy consumption; primary energy consumption would be reduced by 21.5 GWh/year, which is 39 % of the initial primary energy consumption, and total annual emissions would also be significantly reduced – by 2.5 ktCO₂/year, which is 34 % of total annual emissions before the implementation of the measures. The reduction in GHG emissions at VECCs would be 11–66 % per year, while the reduction in primary energy consumption would be in the range of 20–55 %.

Educational institution ranking

The results of the composite indicators are shown in Fig. 3.8. The results are given as percentages. VECC 20 achieved the highest result – 95 %. VECC 7 achieved the lowest result – 8 %. The educational institutions with the highest scores not only achieved good results in the survey but had already implemented various energy efficiency measures and used RES before

the study, with the most significant benefits being achieved through the implementation of mandatory measures. VECCs with average and lowest scores should implement individually tailored additional measures. The implementation of optional measures is associated with a lower ranking, as their contribution to reducing primary energy consumption and emissions is smaller than in the case of mandatory measures. VECCs with the lowest rankings have not installed or improved their mechanical ventilation systems, resulting in lower reductions in primary energy consumption and emissions than those achieved by other measures.

This phase of the study aims to explore solutions for increasing the sustainability of Latvia’s vocational education system by conducting a comprehensive assessment of potential energy efficiency and sustainability measures. The effectiveness of the measures was quantified using a simplified composite indicator, which is a valuable tool for assessing and comparing the energy efficiency and environmental measures of educational institutions. The results show that financial incentives for the implementation of mandatory and optional measures should be targeted at VECC with higher results, thus ensuring the efficient use of resources. Mandatory measures ensure a significant reduction in primary energy consumption, while optional measures can serve as a supplement, but their financial efficiency is lower compared to mandatory measures. Demonstration projects are tailored to the specific needs of the VECCs and may differ from projects implemented in other VECCs, depending on the climate, available resources and learning environment.

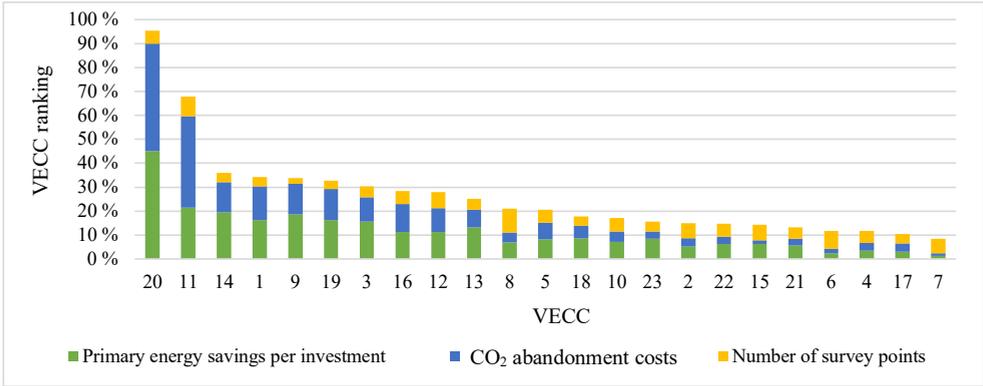


Fig. 3.8. VECC ranking based on sustainability criteria.

The results confirm that identifying policy coherence and barriers to optimising policy planning must be complemented by assessing policy implementation at institutional and sectoral levels. This makes it possible to identify obstacles to the implementation of higher-level objectives in practice and to define the measures necessary to overcome them.

3.3.2. Resource efficiency in practice – sustainable production models

This phase of the study (Publication 6) focused on those aquaculture systems and technological solutions that are most frequently mentioned in the scientific literature as being compatible with sustainable intensification and point to potential directions for development

that could be adapted to regional or local conditions. As the EU aquaculture sector is developing more slowly than elsewhere in the world, policy documents often emphasise the need for innovation, but without specifying specific technologies or systems, an analysis of scientific literature was carried out to identify solutions already implemented in practice that could be adapted by the EU and Latvia. The systems described reflect the main technological trends and solutions identified in the literature for the cultivation of aquatic organisms, which promote resource efficiency and minimise or limit the negative impact of aquaculture on the environment.

The spectrum of sustainable production models in aquaculture

Monocultures are characteristic of intensive recirculating aquaculture systems, where high-value fish and crustaceans are farmed at high densities. Monoculture aquaculture is based on the concept of a linear economy and is less resistant to pathogens and viruses. Polyculture is the farming of two or more species in a single fixed area, combining plants and animals, fish or plants, even aquatic and terrestrial species. The simultaneous farming of several aquatic organisms offers advantages such as additional resource efficiency and economic benefits from all species farmed and sold, as well as improved water quality.

Integrated multi-trophic aquaculture (IMTA) is an old yet new concept based on the principle of farming more than one species in a single aquaculture system (pond, tank or cage). IMTA aims to create a balanced aquatic ecosystem. Studies show that IMTA has a positive impact on all three dimensions of sustainability: environmental, economic and social. In addition, IMTA systems operate in accordance with the principles of the circular economy, improving not only resource efficiency but also energy efficiency and reducing the risk of pollution. One of the drawbacks is the high initial and operating costs.

Aquaponics can be defined as growing vegetables in a nutrient solution without soil, fertilising the plants with nutrients from the wastewater of aquaculture tanks. The advantages of aquaponics systems include nutrient uptake by plants and improved water quality returned to fish tanks. Aquaponics systems have higher capital and operating costs, energy consumption and GHG emissions than pond and cage cultures. However, aquaponics may have potential in countries with limited freshwater resources or as a niche product.

Biofloc aquaculture, or biofloc technology, is a controlled environmental system that combines suspended phytoplankton, heterotrophic bacteria, algae, protozoa, faeces and uneaten feed to produce organic fish feed. Biofloc has the potential to become one of the pathways to a sustainable future for aquaculture due to (a) minimal or no external water exchange, (b) reduced feed requirements, which lowers costs by 30 %, (c) microorganisms improving water purification, (d) improved growth, productivity and immunity, and (e) some bacterial species that are useful for atmospheric CO₂ sequestration. The downside is the high construction and operating costs.

Productivity and sustainability of pond and tank systems

The regenerative capacity of pond ecosystems is not unlimited, and this self-regeneration limit coincides with the upper limit of intensification of aerated aquaculture ponds. The internal

waste removal capacity of a pond can be increased by using bioflocs, redesigning the pond and using technology. Water exchange increases water consumption, the risk of runoff and the spread of infectious diseases, and transfers the ecological burden of waste treatment from the pond to other water bodies. A summary of the most common traditional and more technically complex land-based aquaculture systems is provided in Fig. 3.9 and described in detail in Publication 6.

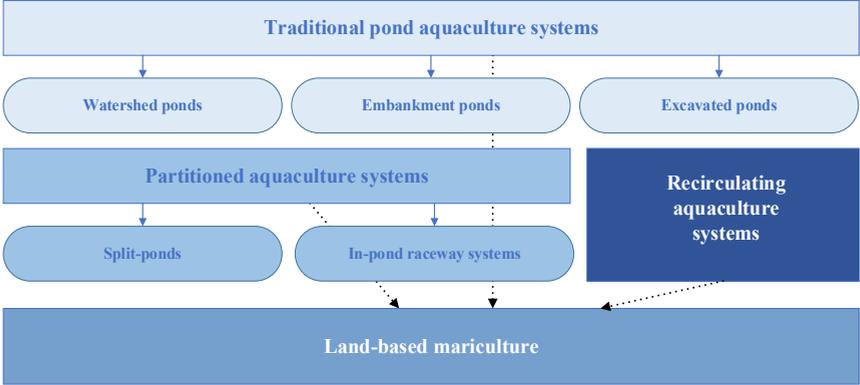


Fig. 3.9. Land-based aquaculture systems (freshwater and saltwater).

Technological solutions – aeration

To maintain conditions suitable for fish, the concentration of dissolved oxygen in the water must be at least 5 mg/l for warm-water fish and at least 6 mg/l for cold-water fish [37]–[39]. Aerators are devices that mechanically circulate oxygen into the water, improving water quality, nutrient availability and fish health. The choice of aerator depends on the species being farmed, the geometry of the pond, water treatment and economic considerations such as installation, maintenance and energy costs. The use of more energy-efficient aerators reduces costs, saves energy and reduces emissions. In aquaculture, in addition to natural aeration, there are three main types of aerators: (1) splash aerators, (2) aerators that release air bubbles into the water, or bubbling aeration, and (3) gravity aerators. Automatic aerator control systems have been developed that activate and deactivate aerators in response to signals from a dissolved oxygen monitoring probe placed at a selected location in the pond.

Energy from RES and high-technologies

Aquaculture faces sustainability challenges because it is unable to move away from fossil fuels as its primary energy source. Ideally, aquaculture systems should reduce their use of fossil fuels at all stages of production and replace them with RES, as these have low operating costs, a long life cycle and do not generate GHG emissions or environmental pollution during their operation. The use of solar energy in aquaculture continues to develop and provides energy for power generation, aerators, feeders, pumps and water heating systems. Another reason for integrating RES and aquaculture systems is to increase the use of water surfaces, allowing land to be used for other purposes, such as agriculture. Aquaculture systems combined with solar photovoltaic panels (PV) are called floatovoltaics, also known as aquavoltaics or AquaPV. PV

systems installed on water surfaces provide a direct practical benefit by reducing water loss through evaporation by 70–85 % [40], [41] and can reduce the rate of algae growth.

Better management practices

Sustainability is an increasingly important issue, driving the adoption of innovative better management practices (BMPs) for the benefit of the environment, the economy and society. BMP in aquaculture means that aquatic organisms are farmed in accordance with standards set by various governmental and non-governmental organisations, with the aim of reducing environmental impact, minimising harm to local communities, and controlling and improving animal welfare. The European Commission’s Strategic Guidelines for a more sustainable and competitive EU aquaculture for the period 2021–2030 provide a vision for the future and encourage the use of BMPs for sustainable development at the Member State level. Licensing procedures need to be simplified, attention needs to be paid to animal welfare, climate change mitigation and adaptation, and broader public support by integrating aquaculture into local communities. Sustainable aquaculture certification schemes (including eco-certification schemes) aim to ensure that aquaculture businesses comply with a set of specific indicators. Certification should be combined with ecosystem approach principles in aquaculture to improve social and environmental sustainability at various levels.

Traceability and transparency

There are growing concerns about ethical issues related to the welfare of aquatic organisms used in food production and distribution, the environmental sustainability of production systems, the use of genetically modified feed or fish, and animal welfare. Product traceability in supply chains is crucial to ensure that contaminated products or products with a high risk of contamination, including non-compliant products, are not misrepresented as products without such risks. It is therefore very important to know “where” (traceability) and “how” (transparency) food is produced and to be able to trust the information provided by the producer. Demonstrating accountability and commitment to achieving the SDGs requires traceability and transparency. In the future, it will be important to ensure that the aquaculture industry drives the idea of sustainability, rather than waiting for consumers to regulate it through their demand. With the help of public administration and regulatory systems, it is possible to give the sector an additional impetus towards more sustainable farming and processing methods.

Ecosystem approach to aquaculture

The ecosystem approach to aquaculture (EAA) emphasises the integration of aquaculture into a broader ecological and social context, ensuring that production intensification does not exceed the carrying capacity of ecosystems. The EAA is based on close links between science, policy and management, which enable the development of sustainable aquaculture practices and ensure their compatibility with national development strategies. An essential tool in this process is the consistent application of the polluter pays principle, which promotes resource efficiency and limits environmental pressure. More sustainable aquaculture systems can be achieved through careful selection of farming sites, BMPs and technological solutions that

reduce energy consumption and pollution so that they do not exceed the carrying capacity of ecosystems. Within the framework of the EAA, a promising solution could be the introduction of eco-certification schemes, assessing the impact of farms on ecosystems and promoting market demand for sustainably produced products.

Energy efficiency measures need to be introduced in aquaculture systems, especially in energy-intensive recirculating aquaculture systems. Aeration systems should be improved based on accurate efficiency indicators rather than empirical practice. Further progress can be ensured through cooperation between research institutions and businesses, promoting the transfer of innovative technologies (IoT, sensors, AI solutions). Strengthening human capital is also required for the development of sustainable aquaculture, as specialised training in aquaculture and aquaculture engineering is currently only available in a few EU countries.

3.3.3. The importance of communication and participation

The results of the TOPSIS assessment (Publication 7) of six fishery and aquaculture products analysed according to specific sustainability criteria are shown in Fig. 3.10. The weights of the criteria used in the analysis were determined by surveying 28 industry experts, who assessed the relative importance of each criterion on a five-point scale (with a reverse scale for the criterion “impact on biodiversity”), thus reflecting the priorities that are important to the sector.

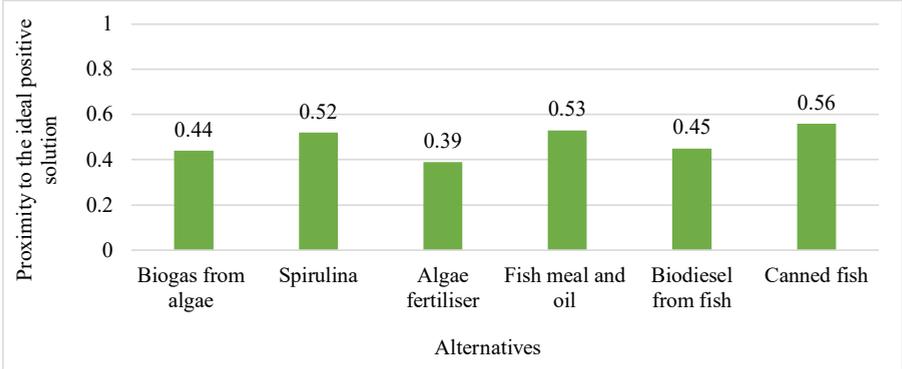


Fig. 3.10. Results of the TOPSIS analysis.

It can be seen that canned fish is closest to the ideal positive solution, reaching 0.56, which means that canned fish can be considered the most sustainable product among the given alternatives according to the criteria. However, it should be noted that the relative closeness coefficient values are similar across all alternatives. The value of fish meal and oil differs from canned fish by only 0.03, while spirulina ranks third, differing from canned fish by 0.04.

Analysis of survey results

In order to achieve SDGs, it is not enough to justify the sustainability of products; effective public information is also essential. The survey results showed that the majority of respondents

obtain information from social networks and prefer audiovisual content. At the same time, only 3 % of respondents cited scientists as one of the most reliable sources of information. This suggests that the current communication approach needs to be reviewed and that the image of research institutions as reliable sources of knowledge needs to be strengthened. This information gap is a significant factor in the implementation of sustainability policies, as public support and trust influence both the effectiveness of policies and the response to new regulations. A clear and consistent message across different media, especially in a visual format, can be an important tool for promoting public trust and engagement in sustainability issues.

Communication with stakeholders is an important dimension of policy implementation that must be taken into account when developing policies and measures for their implementation. During the study phase on removing administrative barriers to RES, public and local government awareness was identified as a significant influencing factor (see Subsection 3.2.1). It was also concluded that timely discussions between RES project developers and local communities can contribute to a positive outcome in subsequent formal public consultations. A similar finding emerged from the group model-building sessions, where the impact of public awareness was highlighted as an important factor in promoting niche products in the market and encouraging sustainable choices (see Subsection 3.2.2).

CONCLUSIONS

The objective of the Thesis was achieved by developing an analytical framework for assessing climate policy and increasing its effectiveness. The framework of the Thesis is based on three consecutive segments: policy coherence analysis, identification of obstacles and shortcomings, and assessment of the policy implementation dimensions. This framework not only allowed for a qualitative analysis of policy processes but also enabled conclusions to be based on quantitative indicators, such as multi-criteria assessments, which highlighted significant differences in policy planning documents, the level of detail of objectives, the balance of instruments used and the complexity of administrative requirements, as well as the practical readiness of policy implementation. This ensured a structured approach that made it possible to formulate conclusions and recommendations for sustainable resource management and policy improvement.

The assessment of horizontal policy coherence provided a better understanding of the strategic direction of the policy areas analysed and identified their objectives, while the assessment of vertical coherence made it possible to determine whether the Member States' progress was in line with these objectives. The case study on the horizontal coherence of the CRCF Regulation identified eight thematic blocks that are complementary and consistent with each other, but the analysis of potential vertical coherence was limited by the low level of maturity of the certification framework at the time of the study. At the same time, the analysis also revealed potential challenges in the implementation phase of the CRCF Regulation if the CAP and CRCF funding mechanisms for carbon farming practices are not clearly separated. Member States' motivation to support these practices may be weakened by uncertainty as to whether the carbon removal achieved through them will count towards their commitments under the LULUCF Regulation (EU) 2018/841.

An analysis of the vertical coherence of the objectives set out in the European Bioeconomy Strategy, first at the level of EU Member States' strategies and then in the context of Latvian policy planning documents, showed that the developed methodology allows for relatively quick identification of the objectives and measures set out in policy documents, as well as assessment of their priority. The TOPSIS method is convenient for comparing alternatives, but it only provides a relative comparison within a single data set. This was demonstrated by the assessment of bioeconomy policy coherence, where Latvia's Bioeconomy Strategy 2030 scored highest at the national level but lower in comparison with other EU Member States. Overall, the results confirmed vertical policy coherence, but only at a formal level, as not all strategies had action plans in place to assess the effectiveness of practical implementation. In order to analyse the implementation of the objectives in more depth, a case study was carried out to analyse the NECP2030 action plan. The measures were grouped according to policy instrument categories in order to assess their potential effectiveness in the heating and cooling sector. The analysis showed that the strategies and targets are clearly formulated and consistent with those set at the EU level, but the measures developed mainly focus on the category of regulatory instruments, while market-based instruments are used to a limited extent. This points to an imbalance in the instruments, which may hinder the practical implementation of the objectives.

Mapping administrative, institutional and regulatory processes, summarising administrative steps, necessary permits and identifying applicable regulatory frameworks allowed for a qualitative and quantitative comparison of the stages of RES project implementation in different countries. At the same time, it allowed for the identification of opportunities for optimisation and the adoption of examples of good practice. The analysis of the administrative processes involved in the implementation of RES projects showed that a significant hindering factor is the complexity of the procedures and the associated administrative burden. This result correlates with the findings and observations made in the first section of the Thesis regarding the complexity of bureaucratic processes, administrative burden and limited institutional capacity in the analysed documents.

The approach developed for identifying factors enabling and constraining the forest sector allowed both the formulation of product development strategies and the identification of key problems affecting the sector's transformation potential. When considering the directions of bioeconomy development, the critical factor is not only the development potential of specific product groups but also the availability of raw materials, a stable and predictable regulatory framework, as well as the availability of funding for research, innovation and commercialisation. The transformation of the sector is hampered by outdated policy planning documents, which create uncertainty about the long-term development direction of the forest sector and its alignment with EU climate and bioeconomy goals. The identified situation is consistent with the hypothesis put forward in the Thesis, indicating that a lack of a relevant, strategically oriented planning framework consistent with EU objectives in policy documents may create the impression of a "policy of delay" [42] and weaken vertical coherence. This situation, in turn, increases the risk of fragmentation among Member States and hinders the achievement of common climate neutrality goals.

The methodology developed for identifying obstacles and shortcomings, although time-consuming, enabled the objectives set out in the Thesis to be achieved. The results not only helped to identify barriers, but also confirmed the conclusions drawn from the policy coherence assessment, namely that an in-depth analysis is needed to identify the factors hindering the development of the sector. The approach to identifying barriers is based on optimisation, which involves not only pointing out shortcomings, but also offering solutions, as was done in both case studies in the second segment of the Thesis. The developed methodology and the applied methods (document analysis, TOPSIS, AHP and SWOT) are relatively straightforward for policymakers to use in strategy development.

The third segment of the Thesis focuses on the dimensions of policy implementation to bring the assessment of policy implementation closer to the institutional and sectoral levels. This allows the identification of obstacles to the implementation of higher-level objectives in practice and the definition of the necessary measures to overcome them. Improving energy efficiency in VECCs depends on the competence and motivation of the responsible employees. Although the implementation of measures is linked to the availability of funding, significant savings can also be achieved without additional investment by consistently implementing energy-saving measures. The composite indicator can serve as a tool to help identify

opportunities for optimisation and make policy measures more effective, thereby contributing to the achievement of the set objectives.

The development of aquaculture in the EU and Latvia is hampered by its relatively low priority within bioeconomy policy. In order to exploit the potential of the sector, in-depth case studies on land-based aquaculture technologies, business practices and knowledge levels are needed. The EU's global competitiveness could be strengthened by introducing energy efficiency, resource efficiency and RES solutions, thus providing consumers with an important source of protein with a low carbon footprint. Appropriate strategies and measures could increase the sector's productivity and competitiveness, while contributing to the achievement of sustainable development goals.

Communication with stakeholders is an important dimension of policy implementation that must be taken into account when developing policies and measures for their implementation. During the research phase into removing administrative barriers to the implementation of RES projects, it was identified that public and local government awareness was a significant influencing factor. A similar conclusion was reached during the group model-building sessions, where the impact of public awareness was highlighted as an important factor in promoting niche products on the market and encouraging sustainable choices. In order to achieve SDGs, it is not enough to develop policies and promote sustainable products; it is also essential to inform the public and raise awareness.

The development of the Thesis was influenced by several limitations, which set the boundaries for the interpretation of its results. Firstly, some of the policy planning documents analysed did not have action plans, which limited the possibility of assessing their practical implementation and meant that in several cases, coherence could only be determined at a formal level. Secondly, the quantitative assessments of administrative processes relied on regulatory documents and publicly available data, which vary from country to country. Thirdly, expert assessments reflect the professional views of experts rather than the general opinion of the population. Some of the analysed policy and regulatory documents have been updated since the study was conducted, which may affect the relevance of specific conclusions. Fourthly, the Thesis is based on a static time frame, so the results obtained do not allow for the modelling of future development scenarios, as would be possible using dynamic modelling approaches such as system dynamics or energy optimisation models. However, the use of such models would also be complicated in the context of the analysed documents, as the lack of action plans and the low level of specificity of the measures limit the formulation of reliable assumptions. These limitations do not affect the hypothesis of the Thesis, but they do set limits on the extent to which policy performance can be quantitatively assessed in all segments included in the study.

The results of the Thesis confirm the hypothesis that systematic evaluation of policy documents, identification of obstacles and shortcomings, and development of evidence-based recommendations is a useful approach that provides a basis for strengthening policy coherence and implementation effectiveness. Although the Thesis does not confirm actual changes in policy practice, it provides a methodological and analytical framework that can be used to develop more effective and knowledge-based strategies, thereby accelerating progress towards the European Green Deal objectives.

REFERENCES

- [1] A. Blumberga, D. Blumberga, I. Pakere, A. Vidžups, K. Laktuka, and Z. Feodorova, “Optimization of Implementation Procedures For RES Electricity Generation Infrastructure Projects In The Baltic States.” Accessed: Sep. 29, 2025. [Online]. Available: <https://www.em.gov.lv/en/energy-studies>
- [2] Klimata un enerģētikas ministrija and A. Gancone, “Par siltumnīcefekta gāzu emisiju samazināšanas un oglekļa dioksīda piesaistes saistību izpildi (2023),” Jul. 2023. [Online]. Available: https://tapportals.mk.gov.lv/legal_acts/3e4d5998-941b-4426-a476-ab2080be8b6c
- [3] European Commission, “Kyoto Protocol,” European Commission – European Commission. Accessed: Nov. 19, 2024. [Online]. Available: https://ec.europa.eu/commission/presscorner/detail/lv/memo_04_43
- [4] UNFCCC, “What is the Kyoto Protocol?” Accessed: Nov. 19, 2024. [Online]. Available: https://unfccc.int/kyoto_protocol
- [5] United Nations, “Marking the Kyoto Protocol’s 25th anniversary,” United Nations. Accessed: Nov. 20, 2024. [Online]. Available: <https://www.un.org/en/climatechange/marking-kyoto-protocol%E2%80%99s-25th-anniversary>
- [6] N. Doan, H. Doan, C. P. Nguyen, and B. Q. Nguyen, “From Kyoto to Paris and beyond: A deep dive into the green shift,” *Renew. Energy*, vol. 228, p. 120675, Jul. 2024, doi: 10.1016/j.renene.2024.120675.
- [7] United Nations, “THE 17 GOALS | Sustainable Development.” Accessed: Feb. 06, 2024. [Online]. Available: <https://sdgs.un.org/goals>
- [8] M. H. Thorsøe, “Carbon Farming: The foundation for carbon farming schemes – lessons learned from 160 European schemes”, doi: <http://dx.doi.org/10.2139/ssrn.4725455>.
- [9] European Council and Council of the European Union, “Fit for 55,” Consilium. Accessed: Nov. 21, 2024. [Online]. Available: <https://www.consilium.europa.eu/lv/policies/fit-for-55/>
- [10] A. Brad and E. Schneider, “Carbon dioxide removal and mitigation deterrence in EU climate policy: Towards a research approach,” *Environ. Sci. Policy*, vol. 150, p. 103591, Dec. 2023, doi: 10.1016/j.envsci.2023.103591.
- [11] “Communication from the commission to the European Parliament, the European Council, the Council, the European Economic and Social Committee and the Committee of the Regions. The European Green Deal.” Brussels, Nov. 12, 2019. Accessed: Aug. 29, 2023. [Online]. Available: <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM%3A2019%3A640%3AFIN>
- [12] S. Albrizio, T. Kozluk, and V. Zipperer, “Environmental policies and productivity growth: Evidence across industries and firms,” *J. Environ. Econ. Manag.*, vol. 81, pp. 209–226, Jan. 2017, doi: 10.1016/j.jeem.2016.06.002.
- [13] S. M. S. U. Eskander and S. Fankhauser, “Reduction in greenhouse gas emissions from national climate legislation,” *Nat. Clim. Change*, vol. 10, no. 8, pp. 750–756, Aug. 2020, doi: 10.1038/s41558-020-0831-z.
- [14] Directorate-General for Research and Innovation (European Commission), *How the bioeconomy contributes to the European Green Deal*. LU: Publications Office of the European Union, 2020. Accessed: Jan. 04, 2023. [Online]. Available: <https://data.europa.eu/doi/10.2777/67636>
- [15] European Parliament, *Regulation (EU) 2024/3012 of the European Parliament and of the Council of 27 November 2024 establishing a Union certification framework for permanent carbon removals, carbon farming and carbon storage in products*. 2024.

- Accessed: Dec. 22, 2024. [Online]. Available: <http://data.europa.eu/eli/reg/2024/3012/oj/eng>
- [16] F. Fallasch *et al.*, “The EU Carbon Removal Certification Framework: Options for using certified removal units and funding mitigation activities,” Ecologic Institute, Berlin, Interim ISSN 1862-4359, 2024. [Online]. Available: <https://www.ecologic.eu/sites/default/files/publication/2024/50122-the-eu-carbon-removal-certification-framework.pdf>
- [17] C. E. Boyd *et al.*, “Achieving sustainable aquaculture: Historical and current perspectives and future needs and challenges,” *J. World Aquac. Soc.*, vol. 51, no. 3, pp. 578–633, 2020, doi: 10.1111/jwas.12714.
- [18] S. Jennings *et al.*, “Aquatic food security: insights into challenges and solutions from an analysis of interactions between fisheries, aquaculture, food safety, human health, fish and human welfare, economy and environment,” *Fish Fish.*, vol. 17, no. 4, pp. 893–938, 2016, doi: 10.1111/faf.12152.
- [19] A. R. Jones, H. K. Alleway, D. McAfee, P. Reis-Santos, S. J. Theuerkauf, and R. C. Jones, “Climate-Friendly Seafood: The Potential for Emissions Reduction and Carbon Capture in Marine Aquaculture,” *BioScience*, vol. 72, no. 2, pp. 123–143, Feb. 2022, doi: 10.1093/biosci/biab126.
- [20] Seetharaman, K. Moorthy, N. Patwa, Saravanan, and Y. Gupta, “Breaking barriers in deployment of renewable energy,” *Heliyon*, vol. 5, no. 1, p. e01166, Jan. 2019, doi: 10.1016/j.heliyon.2019.e01166.
- [21] European Commission, *Directive (EU) 2018/2001 of the European Parliament and of the Council of 11 December 2018 on the promotion of the use of energy from renewable sources (recast) (Text with EEA relevance.)*, vol. 328. 2018. Accessed: Dec. 30, 2024. [Online]. Available: <http://data.europa.eu/eli/dir/2018/2001/oj/eng>
- [22] International Renewable Energy Agency, “Renewable Energy Statistics 2025,” 2025. [Online]. Available: <https://www.irena.org/Publications/2025/Jul/Renewable-energy-statistics-2025>
- [23] United Nations, “Transforming our world: the 2030 Agenda for Sustainable Development | Department of Economic and Social Affairs.” Accessed: Jun. 26, 2025. [Online]. Available: <https://sdgs.un.org/2030agenda>
- [24] United Nations, *The Paris Agreement*. United Nations, 2015. Accessed: Dec. 30, 2024. [Online]. Available: <https://www.un.org/en/climatechange/paris-agreement>
- [25] The International Energy Agency, “Buildings – Energy System,” IEA. Accessed: Jun. 26, 2025. [Online]. Available: <https://www.iea.org/energy-system/buildings>
- [26] P. Mayring, “Qualitative Content Analysis,” *Forum Qual. Sozialforschung Forum Qual. Soc. Res. -Line J. Httpqualitative-Res.-E2-00inhalt-Ehtm*, vol. 1, Jun. 2000.
- [27] R. K. Samal and M. L. Kansal, “Sustainable development contribution assessment of renewable energy projects using AHP and compromise programming techniques,” in *2015 International Conference on Energy, Power and Environment: Towards Sustainable Growth (ICEPE)*, Shillong, India: IEEE, Jun. 2015, pp. 1–6. doi: 10.1109/epetsg.2015.7510096.
- [28] T. L. Saaty, “What is the Analytic Hierarchy Process?” in *Mathematical Models for Decision Support*, G. Mitra, H. J. Greenberg, F. A. Lootsma, M. J. Rijkaert, and H. J. Zimmermann, Eds., in NATO ASI Series. Berlin, Heidelberg: Springer, 1988, pp. 109–121. doi: 10.1007/978-3-642-83555-1_5.
- [29] J. Ananda and G. Herath, “The use of Analytic Hierarchy Process to incorporate stakeholder preferences into regional forest planning,” *For. Policy Econ.*, vol. 5, no. 1, pp. 13–26, Jan. 2003, doi: 10.1016/S1389-9341(02)00043-6.

- [30] I. Kaliszewski and D. Podkopaev, "Simple additive weighting – A metamodel for multiple criteria decision analysis methods," *Expert Syst. Appl.*, vol. 54, pp. 155–161, Jul. 2016, doi: 10.1016/j.eswa.2016.01.042.
- [31] A. Mardani, A. Jusoh, K. MD Nor, Z. Khalifah, N. Zakwan, and A. Valipour, "Multiple criteria decision-making techniques and their applications – a review of the literature from 2000 to 2014," *Econ. Res.-Ekonom. Istraživanja*, vol. 28, no. 1, pp. 516–571, Jan. 2015, doi: 10.1080/1331677X.2015.1075139.
- [32] M. Kurttila, M. Pesonen, J. Kangas, and M. Kajanus, "Utilizing the analytic hierarchy process (AHP) in SWOT analysis – a hybrid method and its application to a forest-certification case," *For. Policy Econ.*, vol. 1, no. 1, pp. 41–52, May 2000, doi: 10.1016/S1389-9341(99)00004-0.
- [33] H. Weihrich, "The TOWS matrix – A tool for situational analysis," *Long Range Plann.*, vol. 15, no. 2, pp. 54–66, Apr. 1982, doi: 10.1016/0024-6301(82)90120-0.
- [34] R. M. Groves, F. J. Fowler, M. Couper, J. M. Lepkowski, E. Singer, and R. Tourangeau, *Survey methodology*, 2nd ed. in Wiley series in survey methodology. Hoboken, N.J.: Wiley, 2009. Accessed: Jul. 23, 2025. [Online]. Available: http://www.123library.org/book_details/?id=30696
- [35] European Commission, *Communication From The Commission To The European Parliament, The Council, The European Economic And Social Committee And The Committee Of The Regions Innovating for Sustainable Growth: A Bioeconomy for Europe*. 2012. Accessed: Jan. 07, 2025. [Online]. Available: <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52012DC0060&qid=1736248700119>
- [36] "Communication from the commission to the European parliament, the council, the European economic and social committee and the committee of the regions A Sustainable Bioeconomy for Europe: Strengthening the Connection between Economy, Society and the Environment." Brussels, Nov. 10, 2018. Accessed: Aug. 29, 2023. [Online]. Available: <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52018DC0673>
- [37] Ridwan, R. Irawan, and M. A. Mubarak, "Number of holes and blades to control the performance of aquaculture aerator," *Aquac. Fish*, vol. 8, no. 6, pp. 672–680, Nov. 2023, doi: 10.1016/j.aaf.2023.02.007.
- [38] R. C. Summerfelt, "Water Quality Considerations for Aquaculture," *Dep. Anim. Ecol.*, pp. 2–7, 2000.
- [39] J. Huan, W. Cao, and Y. Qin, "Prediction of dissolved oxygen in aquaculture based on EEMD and LSSVM optimized by the Bayesian evidence framework," *Comput. Electron. Agric.*, vol. 150, pp. 257–265, Jul. 2018, doi: 10.1016/j.compag.2018.04.022.
- [40] A. M. Pringle, R. M. Handler, and J. M. Pearce, "Aquavoltaics: Synergies for dual use of water area for solar photovoltaic electricity generation and aquaculture," *Renew. Sustain. Energy Rev.*, vol. 80, pp. 572–584, Dec. 2017, doi: 10.1016/j.rser.2017.05.191.
- [41] D. Matulić *et al.*, "Agrivoltaics and Aquavoltaics: Potential of Solar Energy Use in Agriculture and Freshwater Aquaculture in Croatia," *Agriculture*, vol. 13, no. 7, Art. no. 7, Jul. 2023, doi: 10.3390/agriculture13071447.
- [42] N. Pietarinen, M. Pecurul-Botines, and M. Brockhaus, "Politics of delay hinder the implementation of EU Forest Strategy in Finland," *Ambio*, pp. 1–16, Jul. 2025, doi: 10.1007/s13280-025-02207-8.



Krista Laktuka was born in 1989 in Talsi, Latvia. She obtained a Bachelor's degree in Social Sciences in Political Science from the Baltic International Academy in 2019. She was awarded a double Master's degree from Riga Technical University (RTU) and Vilnius Gediminas Technical University in Environmental Science (2021) and Environmental Engineering (2021). She has been working at RTU since 2015 and has been a researcher at the RTU Institute of Energy Systems and Environment since 2021. Her research interests include climate policy and regulatory analysis, sustainability and circular bioeconomy (forest and aquaculture sectors, carbon farming practices), as well as greenhouse gas emission accounting.