RĪGAS TEHNISKĀ UNIVERSITĀTE

Krista Laktuka

KLIMATA POLITIKA ILGTSPĒJĪGAI ATTĪSTĪBAI

Promocijas darbs

RTU Izdevniecība
Rīga 2026

RĪGAS TEHNISKĀ UNIVERSITĀTE
Dabaszinātņu un tehnoloģiju fakultāte
Vides aizsardzības un siltuma sistēmu institūts

Krista Laktuka
Doktora studiju programmas “Vides inženierija” doktorante

KLIMATA POLITIKA ILGTSPĒJĪGAI ATTĪSTĪBAI

Promocijas darbs

Zinātniskās vadītājas:
profesore *Dr. habil. sc. ing.*
DAGNIJA BLUMBERGA

tenūrprofesore *Dr. sc. ing.*
ANDRA BLUMBERGA

Rīga 2026

Promocijas darbs izstrādāts Latvijas Zinātnes padomes fundamentālo un lietišķo pētījumu projektā Nr. lzp-2024/1-0417 "Politikas plānošanas ceļa karte oglekļsaistīgas lauksaimniecības sertifikācijas shēmām" un ar Eiropas Sociālā fonda projekta Nr. 8.2.2.0/20/I/008 "Rīgas Tehniskās universitātes un Banku augstskolas doktorantu un akadēmiskā personāla stiprināšana stratēģiskās specializācijas jomās" atbalstu.

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ANOTĀCIJA

Eiropas zaļais kurss un mērķis sasniegt klimatneitralitāti līdz 2050. gadam pieprasa būtiskas pārmaiņas bioekonomikas un enerģētikas nozarēs. Pārmaiņu īstenošanai nepietiek tikai ar tehnoloģiskiem risinājumiem, nepieciešama arī politikas transformācija, kas balstās jaunākajos zinātnes atklājumos un nodrošina saskaņotu rīcību dažādos pārvaldības līmeņos. Efektīva un koordinēta politika ir priekšnoteikums resursu ilgtspējīgai pārvaldībai, emisiju samazināšanai un inovāciju ieviešanai praksē. Lai arī Eiropas Savienības līmenī noteiktie mērķi ir skaidri definēti un šķietami pietiek tikai ar to īstenošanu, praksē progress dalībvalstīs ir nevienmērīgs. Vairāki mērķi – atjaunojamo energoresursu izmantošanas palielināšana, energoefektivitātes uzlabošana, blakusproduktu pārstrāde un emisiju samazināšana – netiek pilnībā īstenoti. Tas notiek neskatoties uz to, ka tehnoloģijas ir kļuvušas ekonomiski pieejamākas, un jau pierādīts, ka ieviešot pat vienkāršus pasākumus, piemēram, enerģijas taupības praksi vai blakusproduktus izmantojot augstākas pievienotās vērtības produktos, iespējams panākt būtiskus uzlabojumus. Tādēļ būtiski identificēt aspektus, kas kavē pāreju uz ilgtspējīgāku saimniekošanas modeli. Šajā promocijas darbā tiek analizētas iespējamās barjeras un kavēkļi klimata politikas plānošanā un ieviešanā, kas var būt saistīti gan ar administratīviem šķēršļiem un politikas fragmentāciju, gan ar vilcināšanos dalībvalstu līmenī ieviest nepieciešamās pārmaiņas praksē.

Promocijas darba mērķis ir izstrādāt analītisku ietvaru klimata politikas novērtēšanai, balstoties uz politikas saskaņotības analīzi, šķēršļu un nepilnību identificēšanu un politikas ieviešanas dimensiju izvērtējumu, lai formulētu secinājumus un ieteikumus ilgtspējīgākai resursu pārvaldībai. Darbs ir starpdisciplinārs pētījums, kurā apvienotas vides inženierzinātņu un politikas zinātņu metodes, pielietojot kvalitatīvu satura analīzi, daudzkritēriju lēmumu pieņemšanas metodes (*TOPSIS*, AHP), stratēģiskās plānošanas un izvērtējuma metodes (SVID, *TOWS*), kā arī empīriskās datu vākšanas metodes un aptaujas.

Promocijas darbs ir veidots kā publikāciju kopa, kas balstās deviņās tematiski vienotās zinātniskajās publikācijās, kas izstrādās doktorantūras studiju ietvaros. Darba 1. nodaļā sniegts literatūras pārskats par starptautiskā un ES līmenī noteiktajiem klimata mērķiem, analizēta klimata politikas nozīme to sasniegšanā. 2. nodaļā aprakstītas galvenās promocijas darbā izmantotās metodes un to lietojums pētījumu kontekstā. 3. nodaļa ietver rezultātus un diskusiju, kas strukturēti trīs pētījuma segmentos: (1) politikas saskaņotības novērtējums, kas ļauj noteikt oglekļsaistīgas lauksaimniecības, bioekonomikas un energoefektivitātes politiku horizontālo un vertikālo koherenci; (2) šķēršļu un nepilnību identificēšana politikas optimizācijai, izmantojot gadījuma izpētes atjaunojamo energoresursu un meža bioekonomikas sektorā; (3) politikas ieviešanas dimensiju analīzi, ietverot rekomendāciju izstrādi ilgtspējīgiem risinājumiem profesionālās izglītības un akvakultūras nozarēs, kā arī sabiedrības informētības un komunikācijas aspektus. Darbs tiek noslēgts ar galveno pētījuma secinājumu apkopošanu.

Promocijas darbs ir izstrādāts latviešu valodā, tas sastāv no 302 lapaspusēm, iekļaujot 9 pielikumus, ietver 31 attēlu, 19 tabulas, 16 vienādojumus un 377 atsauces.

ANNOTATION

The European Green Deal and the goal of achieving climate neutrality by 2050 necessitate substantial modifications to the bioeconomy and energy sectors. Technological solutions alone cannot bring about this change; policy transformation based on the latest scientific findings, ensuring coordinated action at various levels of governance, is also necessary. Effective and coordinated policy is essential for sustainable resource management, reducing emissions, and implementing innovation. Although the European Union's targets are clearly defined, progress in the Member States has been uneven. Several targets, such as increasing the use of renewable energy sources, improving energy efficiency, recycling by-products, and reducing emissions, are not being fully implemented. This is despite technologies becoming more affordable and simple measures, such as energy-saving practices or using by-products in higher-value products, being proven to lead to significant improvements. Therefore, it is important to identify the factors hindering the transition to more sustainable management practices. This doctoral thesis analyses possible barriers and obstacles in policy planning and implementation, which may be related to administrative barriers, policy fragmentation and hesitation among Member States to implement the necessary changes.

The doctoral thesis aims to develop an analytical framework for assessing climate policies. This framework is based on policy coherence analysis, the identification of barriers and gaps, and the assessment of policy implementation dimensions. The aim is to formulate conclusions and recommendations for more sustainable resource management. This interdisciplinary study combines methods from environmental engineering and political science. Qualitative content analysis, multiple-criteria decision analysis methods (TOPSIS and AHP), strategic planning methods (SWOT and TOWS) and empirical data collection methods are employed, as well as surveys.

The doctoral thesis is structured as a collection of nine thematically unified scientific publications developed during the course of the doctoral studies. Chapter 1 provides a literature review of climate targets set at international and EU levels, analysing the importance of the climate policy in achieving these targets. Chapter 2 describes the main methods employed in the thesis and how they were applied in the context of the research. Chapter 3 contains the results and discussion, structured into three research segments: (1) an assessment of policy coherence to determine the horizontal and vertical coherence of carbon farming, bioeconomy and energy efficiency policies; (2) an identification of barriers and gaps for policy optimisation, using case studies in the renewable energy and forest bioeconomy sectors; (3) an analysis of policy implementation dimensions, including the development of recommendations for sustainable solutions in vocational education and aquaculture, as well as public awareness and communication aspects. Thesis concludes with a summary of the main research findings.

This doctoral thesis is written in Latvian, consists of 302 pages including 9 appendices and contains 31 figure, 19 tables and 16 equations, as well as 377 references.

PATEICĪBA

Vispirms vēlos pateikties savām promocijas darba vadītājām *Dr. habil. sc. ing.* Dagnijai Blumbergai un *Dr. sc. ing.* Andrai Blumbergai. Studiju laikā tiku nemitīgi izaicināta – ar jaunām pētniecības idejām, tēmām un uzdevumiem, kas sākumā šķita mazliet par lielu. Tas lika mācīties ātrāk, domāt plašāk un arī mazāk pieticīgi skatīties uz savām zināšanām un prasmēm. Esmu pateicīga arī par iespēju visus studiju gadus lasīt studiju kursu “Ievads biotehonomikā”. Lekcijas nebija tikai mācīšanas process, tā drīzāk bija iespēja dalīties ar iegūtajām zināšanām, kopā domāt, diskutēt un smieties. Tādējādi auditorija kļuva par vietu, kur nebaidīties uzdot jautājumus, domāt skaļi un meklēt atbildes, pat ja ļoti negribas.

Milzīgs paldies maniem kolēģiem par profesionālo vidi, sadarbību un neskaitāmajām sarunām darba gaitā! Starp nopietnām diskusijām par pētniecību nereti tika meklēti arī labākie sinonīmi, precīzākie formulējumi vai vienkārši tas viens teikums, kas skan vislabāk. Paldies par radīto piederības sajūtu un iedvesmu!

Liels paldies maniem draugiem un ģimenei par to, ka ar aizrautību sekojāt līdzi šim ceļojumam un manai izaugsmei, un par ticību maniem spēkiem brīžos, kad pašai pārliecība par tiem bija mazliet mazāka. Īpašs paldies Frodo, kurš konsekventi atgādināja, ka arī doktorantūras laikā ir jāiet ārā pastaigās!

SATURA RĀDĪTĀJS

LIETOTIE SAĪSINĀJUMI

AER – Atjaunojamie energoresursi
AHP – Analītiskais hierarhijas process
ANO – Apvienoto Nāciju Organizācija
CO_2 – Oglekļa dioksīds
CRCF regula – Eiropas Parlamenta un Padomes Regula (ES) 2024/3012 (2024. gada 27. novembris), ar ko izveido Savienības sertifikācijas satvaru pastāvīgai oglekļa piesaistei, oglekļsaistīgai saimniekošanai un oglekļa uzkrāšanai produktos
EAA – Ekosistēmu pieeja akvakultūrai
ES – Eiropas Savienība
IAM – 17 ilgtspējīgas attīstības mērķi
IMTA – Integrētā daudzlīmeņu akvakultūra
IoT – Lietu internets
IPCC pamatnostādnes – 2006. gada Klimata pārmaiņu starpvaldību padomes pamatnostādnes par valstu siltumnīcefekta gāzu inventarizāciju
IPRS – Dīķu ūdensceļu sistēmas
IVN – Ietekmes uz vidi novērtējums
KLP – Eiropas Savienības Kopējā lauksaimniecības politika
LPP – Labākas pārvaldības prakses
MCDA – Daudzkritēriju lēmumu pieņemšanas metodes
MI – Mākslīgais intelekts
MVA – Megavoltampēri
NEKP2030 – Latvijas Nacionālais enerģētikas un klimata plāns 2021-2030
PAS – Sadalītās akvakultūras sistēmas
PIKC - Profesionālās izglītības kompetences centrs
PV – Fotoelementu paneļi
RAS – Recirkulācijas akvakultūras sistēmas
SAW – Svērto summu metode
SEG – Siltumnīcefekta gāzes
SES – Saules elektrostacijas
SLP – Sistemātisks literatūras pārskats
SVID – Stiprās un vājās puses, iespējas un draudi
UNFCCC – Apvienoto Nāciju Organizācijas Vispārējā konvencijas par klimata pārmaiņām
VES – Vēja elektrostacijas
TOPSIS – Alternatīvu prioritizēšana pēc līdzības ar ideālo risinājumu
TOWS – Draudi, iespējas, vājās un stiprās puses (*Threats, Opportunities, Weaknesses, Sthrenghts*)
ZIZIMM – Zemes izmantošanas, zemes izmantošanas maiņa un mežsaimniecība

Piezīme par tulkošanu. Darba sagatavošanā izmantots MI balstīts tulkošanas rīks DeepL (maksas versija) publikāciju tulkošanai latviešu valodā. Autore ir pārskatījusi un rediģējusi tulkojumu un uzņemas pilnu atbildību par satura precizitāti.

IEVADS

Eiropas Savienības (ES) dalībvalstis ir ieguldījušas ievērojamus resursus, lai nostiprinātu ES kā ietekmīga reģionāla un globāla dalībnieka nozīmi. Vienlaikus katra dalībvalsts individuāli ir veicinājusi kopējo Eiropas projektu, uzņemoties saistības un integrējot ES politikas prioritātes savās nacionālajās stratēģijās. ES nevar skatīt kā ārēju, no dalībvalstīm atdalītu struktūru, jo tā pastāv, tikai pateicoties dalībvalstu iesaistei un atbalstam. Tādēļ mērķiem, kas noteikti ES līmenī, piemēram, klimatneitralitātes sasniegšanai, ir jābūt savstarpēji saskaņotiem ar dalībvalstu individuālajiem mērķiem. Pretējā gadījumā to īstenošana praksē kļūst fragmentēta un mazāk efektīva. Ideālā gadījumā politikas virsmērķi tiek formulēti ES līmenī, pēc tam strukturēti nacionālā līmenī un īstenoti vietējā pārvaldībā, ņemot vērā reģionālās īpatnības un konkrētās politikas prioritātes. Šāda daudzlīmeņu koordinācija ir būtiska, lai nodrošinātu, ka politikas dokumentos definētie uzdevumi ir savstarpēji papildinoši, nevis pretrunīgi. Pirmais solis šajā procesā ir normatīvo un plānošanas dokumentu novērtējums, identificējot to atbilstību definētajiem mērķiem [1], [2].

Politikas saskaņotība ir īpaši nozīmīga klimata politikas kontekstā, jo klimata pārmaiņu mazināšanai nepieciešama gan horizontāla gan vertikāla integrācija dažādu līmeņu un nozaru normatīvajos un politikas dokumentos. Valdībām, izstrādājot plānošanas dokumentus īsā, vidējā vai ilgtermiņā, jānodrošina skaidrs nākotnes redzējums un konsekventa mērķu sasaiste starp dažādiem pārvaldības līmeņiem. Lēmumu pieņēmējiem ir jāspēj pielāgot politikas virzienus mainīgajiem apstākļiem un vienlaikus sistemātiski iekļaut ilgtspējas un vides dimensiju visos politikas plānošanas posmos. Tāpēc saskaņotība ir svarīga ne tikai klimata mērķu sasniegšanai, bet arī pašas ES stabilitātei, jo ilgstoša disonanse starp dalībvalstīm varētu pastiprināt fragmentācijas riskus vai pat veicināt "vairāku ātrumu Eiropas" scenāriju [3], [4], kas mazām valstīm, tostarp Latvijai, varētu radīt ekonomiskās atpalicības risku un ārējā apdraudējuma iespējamību.

Pētījuma aktualitāte

Politikas saskaņotība dažādos pārvaldības līmeņos ir būtisks virzītājspēks ceļā uz klimatneitralitāti, resursu efektivitāti, siltumnīcefekta gāzu (SEG) emisiju samazināšanu un bioloģiskās daudzveidības saglabāšanu. Tā ir nozīmīgs priekšnosacījums dalībvalstu ekonomiskās stabilitātes nodrošināšanai un konkurētspējas stiprināšanai. Nesaskaņota vai pretrunīga politika rada neprognozējamu vidi uzņēmējdarbībai un investīcijām. Neskaidrības par kādas dalībvalsts politisko virzību ne vien kavē jaunu investīciju piesaisti, bet arī rada risku, ka esošie uzņēmumi savu darbību pārcels uz valstīm, kur politiskie signāli ir skaidrāki. Savukārt saskaņota un mērķtiecīga politikas plānošana un īstenošana uzņēmumiem ļauj drošāk plānot ilgtermiņa investīcijas attīstībā un jaunu produktu virzīšanā tirgū.

Politikas saskaņotība būtiski ietekmē arī valsts budžeta efektivitāti. Skaidri definēti mērķi palīdz novērst publisko līdzekļu tērēšanu dublējošiem vai savstarpēji pretrunīgiem pasākumiem, vienlaikus radot iespēju ar mazākiem finanšu resursiem sasniegt labākus rezultātus, tos precīzi virzot noteiktajiem attīstības mērķiem. Promocijas darba kontekstā būtiski izcelt politikas saskaņotības ietekmi uz zināšanās balstītas bioekonomikas attīstību un enerģētisko drošību, kuras nodrošināšanā būtiska nozīme ir atjaunojamo energoresursu (AER) īpatsvara palielināšana kopējā enerģijas bilancē. Daudzlīmeņu saskaņotība veicina enerģētisko drošību, īpaši, ja valsts politika ir vērsta uz energoresursu diversifikāciju. Bioekonomikas attīstīšana sekmē produktu ar augstāku pievienoto vērtību radīšanu ar mazāku resursu patēriņu, kā arī stiprina lauku teritorijas un nozaru izturētspēju. Saskaņota un mērķtiecīga rīcībpolitika nodrošina to, ka inovācijas, jauni produkti un tehnoloģijas netiek bremzēti nesaskaņotu politikas signālu dēļ, bet gan atbalstīti un virzīti tirgū.

Ne mazāk būtiska ir dalībvalstu starptautiskā reputācija un ietekme. To var nostiprināt, konsekventi pārņemot un īstenojot ES līmenī noteiktos mērķus nacionālā līmenī. Dalībvalstīm ir dažādi mehānismu, kā ietekmēt lēmumu pieņemšanu ES līmenī, taču pēc kopēja lēmuma pieņemšanas ir nozīmīgi tos atbilstoši implementēt, tā apliecinot uzticamību un spēju darboties kā komandas spēlētājiem.

Rezumējot, klimata pārmaiņu, saspīlētas ģeopolitiskās situācijas un globālās ekonomiskās nestabilitātes apstākļos politikas saskaņotība kļūst par būtisku nepieciešamību visām dalībvalstīm. Ne tikai kā apliecinājums demokrātiskām vērtībām, bet arī atbildība par Parīzes nolīgumā, Eiropas zaļajā kursā un citos saistītajos politikas dokumentos pausto apņemšanos izpildi klimata politikas jomās.

Darba mērķis un uzdevumi

Darba mērķis ir izstrādāt analītisku ietvaru klimata politikas novērtēšanai, kas balstīts politikas saskaņotības analīzē, šķēršļu un nepilnību identificēšanā un politikas ieviešanas dimensiju izvērtējumā (ilgtspējīgi risinājumi, inovācijas, resursu efektivitāte un komunikācija), lai formulētu secinājumus un ieteikumus ilgtspējīgai resursu pārvaldībai. Lai sasniegtu pētījuma mērķi, ir noteikti trīs savstarpēji saistīti uzdevumi ar apakšuzdevumiem:

1. Politikas saskaņotības novērtējums:
    - 1.1. analizēt starptautiskos, ES un nacionālos normatīvos un politikas plānošanas dokumentus bioekonomikas, enerģētikas un siltumapgādes un dzesēšanas nozarēs;
    - 1.2. novērtēt mērķu, instrumentu un pasākumu koherenci dažādos politikas līmeņos;
2. Šķēršļu un nepilnību identificēšana politikas optimizācijai:
    - 2.1. noteikt administratīvos, normatīvos un institucionālos šķēršļus saražotās enerģijas no AER palielināšanai un produktu ar augstāku pievienoto vērtību ražošanai;
    - 2.2. veikt gadījuma izpētes sektoros, lai noteiktu potenciālās optimizācijas iespējas.
3. Politikas ieviešanas dimensijas ilgtspējīgi risinājumi, resursu efektivitāte un komunikācija:
    - 3.1. novērtēt izglītības un izglītības iestāžu lomu resursu efektivitātes uzlabošanā un ilgtspējīgas pārejas nodrošināšanā;
    - 3.2. izpētīt ilgtspējīgu akvakultūras sistēmu attīstības potenciālu, īpašu uzmanību pievēršot tehnoloģiskajiem aspektiem un inovācijām;
    - 3.3. komunikācijas ar sabiedrību loma ilgtspējīgai resursu pārvaldībai.

Darba hipotēze

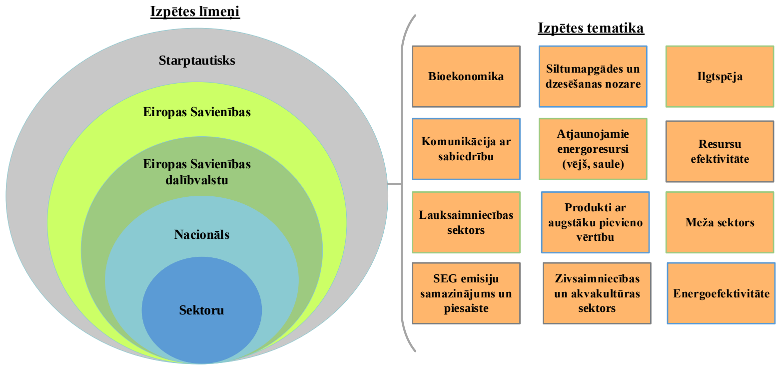
Sistemātisks politikas dokumentu izvērtējums, nepilnību un šķēršļu identificēšana, kā arī pierādījumos balstītu rekomendāciju izstrāde var būtiski uzlabot politikas saskaņotību un ieviešanas efektivitāti, tādējādi paātrinot Eiropas zaļā kursa mērķu sasniegšanu.

Zinātniskā novitāte

Promocijas darbs ir starpdisciplinārs pētījums, kurā apvienotas vides inženierzinātnēs un politikas zinātnēs izmantotās pētniecības metodes. Atšķirībā no politikas zinātņu tradicionālās pieejas, kur vides problēmas tiek aplūkotas, izmantojot noteiktas teorijas, piemēram, daudzlīmeņu pārvaldības, politikas saskaņotības vai ekoloģiskās modernizācijas prizmu, šajā darbā politikas saskaņotība un lietotie politikas instrumenti tiek skatīti kā praktiski mehānismi, kuru efektivitāti iespējams sistemātiski vērtēt, strukturēt un optimizēt. Politikas saskaņotības un ieviešanas efektivitātes izvērtējums promocijas darbā nav balstīts vienotā kvantitatīvu indikatoru kopumā, bet gan politikas procesu analīzē, kas ļauj novērtēt saskaņotības, caurredzamības un ieviešanas kvalitātes uzlabojumus.

Darba novitāte izpaužas tajā, ka satura analīzes un politikas pētniecībā ierastās pieejas sistemātiska literatūras analīze, atslēgvārdu meklēšana, ekspertu aptaujas u.c. – tiek papildinātas ar inženierzinātnēm raksturīgām metodēm, piemēram, daudzkritēriju lēmumu pieņemšanas (*MCDA*), empīriskās datu vākšanas un novērtējuma metodēm. Šī metodoloģiskā integrācija ļauj politikas saskaņotības un efektivitātes vērtēšanu padarīt kvantitatīvāku un salīdzināmāku, tādējādi radot jaunu skatījumu uz politiku un normatīvo dokumentu analīzi.

Būtiski, ka pētījumā analizētie problēmjautājumi, piemēram, zināšanās balstītas bioekonomikas attīstība, ilgtspēja, AER ieviešana un SEG emisiju samazinājums un piesaiste, ir vides inženierzinātnēs pētītā problemātika. Promocijas darbā politikas un politikas instrumenti tiek interpretēti kā praktiski rīki, kas nodrošina resursu ilgtspējīgu pārvaldību, inovāciju izveidi un ieviešanu. Tiek piedāvāts koncepts, kura ietvaros politikas mehānismi tiek analizēti līdzīgi kā inženiertehniska sistēma ar: (1) ievades punktu (definētie mērķi, aktuālie normatīvie dokumenti, izmantotie resursi); (2) procesiem (politikas instrumentu kombinācijas, šķēršļu identificēšana); (3) izvadi (sasniedzami rezultāti – SEG emisiju samazinājums, resursu patēriņa optimizācija, AER tehnoloģiju ieviešana). Promocijas darbā aptvertie izpētes līmeņi un tematika redzami 1. attēlā.



1. att. Promocijas darba izpētes līmeņi un aptvertās tēmas.

Praktiskā nozīme

Darbs sniedz pierādījumos balstītu pamatojumu, kā politikas dokumentus un normatīvo regulējumu padarīt efektīvāku un savstarpēji saskaņotāku. Izveidotais analītiskais ietvars ne tikai ļauj identificēt trūkumus un pretrunas starp ES iezīmēto nākotnes attīstības trajektoriju un dalībvalstu īstenoto, bet arī izstrādāt priekšlikumus to novēršanai. Pētījuma pieeja sniedz praktisku ieguldījumu politikas plānošanas un veidošanas procesa uzlabošanā, jo ļauj politikas mehānismus analizēt kā sistemātisku procesu, identificējot saskaņotības trūkumus un administratīvās barjeras, kā arī piedāvājot stratēģijas to optimizācijai nākotnes mērķu sasniegšanai. Nozaru uzņēmumiem pētījuma rezultāti sniedz izvērtējumu par politikas vertikālo un horizontālo saskaņotību, ilgtermiņa politikas virzieniem, kas ļauj plānot investīcijas un noteikt tehnoloģiskās attīstības virzienus. Zinātnes jomā darbs piedāvā metodoloģisku ietvaru politikas saskaņotības un efektivitātes novērtēšanai, ko iespējams piemērot arī citu nozaru vai valstu situācijas izpētei. Politikas un normatīvo dokumentu izvērtējums kalpo arī kā būtisks instruments nākotnes aktualitāšu prognozēšanai pētniecības nozarēs un pētāmajās tēmās, jo ES un dalībvalstu pētniecības projektu konkursi ir cieši saistīti ar politiski noteiktajiem mērķiem. Sabiedrības ieguvums ir tieši pakārtots minētajiem ieguvumiem, jo tādējādi tiek sekmēta resursu izmantošanas efektivitāte, kas ietekmē enerģijas, pārtikas un produktu nodrošinājumu, vienlaikus sekmējot SEG emisiju samazinājumu. Promocijas darbs ir nepieciešams, lai pāreja uz ilgtspējīgu, zināšanās balstītu bioekonomiku, klimatneitralitāti un resursu efektivitāti notiktu ne tikai stratēģiju un politikas dokumentu līmenī, bet arī praksē, savienojot ES noteiktos stratēģiskos mērķus ar reālām darbībām dalībvalstīs.

Papildus tam darba praktisko nozīmi apliecina fakts, ka promocijas darbā izstrādātais AER projektu administratīvo procesu kartējums [5] ticis izmantots Latvijas Investīciju un attīstības aģentūrā kā atbalsta materiāls sarunās ar potenciālajiem investoriem, tādējādi veicinot informētību par normatīvo regulējumu pētījumā iekļautajās valstīs.

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Promocijas darba struktūra

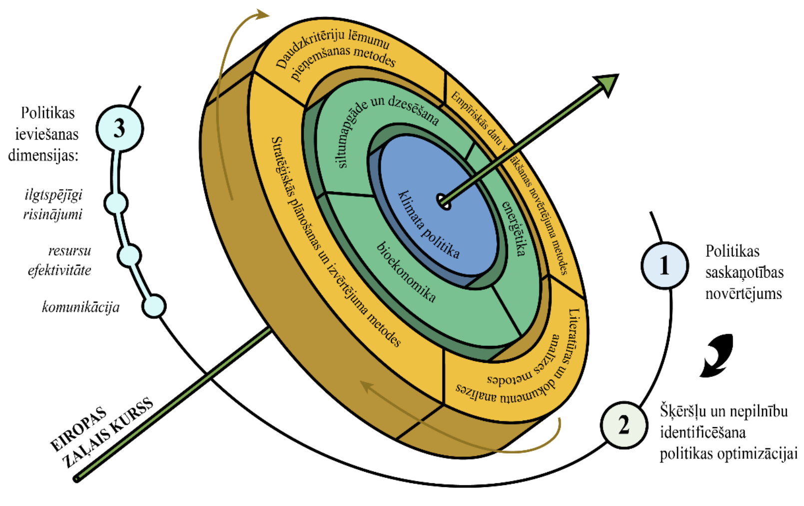
Promocijas darbs balstīts trīs tematiski vienotos pētījuma segmentos, kuru mērķis ir risinājumu identificēšana klimata politikā ilgtspējīgai attīstībai. Segmenti aprobēti, publicējot pētījumus starptautiski atzītos zinātniskajos žurnālos un prezentējot rezultātus starptautiskās zinātniskās konferencēs. 1. tabulā apkopoti darbā izmantotie zinātniskie raksti, grupēti pa trim segmentiem, saglabājot to hronoloģisko publicēšanas secību.

1. tabula

Promocijas darbā izmantotās zinātniskās publikācijas

Sadaļa	Nr.	Publikācijas nosaukums
Politikas saskaņotības novērtējums	1.	*Combining policy measures to reach long term energy targets*
	2.	*Assessing Bioeconomy Development Opportunities in the Latvian Policy Planning Framework*
	3.	*A Comparative Analysis Of Bioeconomy Development In European Union Countries*
	9.	*Policy Coherence of the EU Carbon Removal Certification Framework: Integration of Carbon Farming in Climate and Agricultural Policy*
Šķēršļu un nepilnību identificēšana politikas optimizācijai	4.	*Renewable energy project implementation: Will the Baltic States catch up with the Nordic countries?*
	8.	*Strategic Pathways for a Bioeconomy With High Value-added Products: Lessons Learnt from the Latvian Forest Sector*
Politikas ieviešanas dimensijas ilgtspējīgi risinājumi, resursu efektivitāte un komunikācija	5.	*Driving Sustainable Practices in Vocational Education Infrastructure: A Case Study from Latvia*
	6.	*Towards Sustainable Intensification of Aquaculture: Exploring Possible Ways Forward*
	7.	*The Role of Environmental Communication in Advancing Sustainability in Fisheries and Aquaculture: A Case Study of Latvia*

Promocijas darba struktūra redzama 2. attēlā, kur parādīta trīs pētījuma segmentu savstarpējā mijiedarbība un to papildinošā loma analītiskajā ietvarā. Darba centrā atrodas klimata politika kā pamatvirziens, ko nosaka Eiropas zaļā kursa stratēģiskais ietvars. Eiropas zaļais kurss promocijas darbā tiek interpretēts nevis tikai kā Eiropas Komisijas paziņojums, bet kā simbols ES kopējai virzībai uz klimatneitralitāti un politiku integrāciju šī mērķa sasniegšanai. Ap klimata politikas kodolu izvietoti trīs pētītie sektori – bioekonomika, enerģētika un siltumapgāde un dzesēšana, kuros analizēta politikas saskaņotība, administratīvie šķēršļi un praktiskās ieviešanas dimensijas.



2. att. Promocijas darba struktūra.

Ārējais gredzens attēlo darbā izmantotās metodes: literatūras un dokumentu analīzes metodes; daudzkritēriju lēmumu pieņemšanas metodes; stratēģiskās plānošanas un izvērtējuma metodes; empīriskās datu vākšanas un novērtējuma metodes. 2. attēlā shematiski atspoguļota arī secīgā pieeja, sākot ar politikas saskaņotības novērtējumu, kas ir darba pirmais segments, kam seko šķēršļu un nepilnību identificēšana politikas optimizācijai, noslēdzot ar trešo segmentu, kurā tiek skatītas politikas ieviešanas dimensijas. Šāda struktūra atspoguļo promocijas darbā izmantoto integrēto analītisko ietvaru un pētījuma loģisko secību.

Promocijas darbs ietver ievadu un četras galvenās nodaļas: (1) literatūras analīze; (2) pētījuma metodika; (3) rezultāti un diskusija; (4) secinājumi. Ievadā izklāstītas pētījuma aktualitātes galvenās iezīmes, promocijas darba novitāte un praktiskā nozīme. Promocijas darba mērķis un hipotēze, kā arī aprakstīta publicēto pētījuma rezultātu aprobācija.

Darba 1. nodaļā sniegts literatūras pārskats par starptautiskā un ES līmenī noteiktajiem klimata mērķiem, analizēta klimata politikas nozīme to sasniegšanā, kā arī iezīmēti potenciālie risinājumi ilgtspējīgas attīstības nodrošināšanai. 2. nodaļā aprakstītas galvenās promocijas darbā izmantotās metodes un to lietojums pētījumu kontekstā. 3. nodaļa ietver rezultātus un diskusiju, kas strukturēti trīs pētījuma segmentos. Noslēgumā, 4. nodaļā, apkopoti secinājumi.

1. LITERATŪRAS ANALĪZE

Ilgtspējīgas pārejas uz klimatneitralitāti aktualitāte

Apvienoto Nāciju Organizācijas (ANO) Vispārējās konvencijas par klimata pārmaiņām (*UNFCCC*) pieņemšana 1992. gadā un tai sekojošais Kioto protokols 1997. gadā iezīmēja pirmos starptautiskos soļus cīņā pret klimata pārmaiņām [6], [7], [8]. Parīzes nolīgumā, kas stājās spēkā 2016. gada novembrī un ar kuru tika aizstāts Kioto protokols, tika izvirzīts mērķis nepieļaut globālās temperatūras paaugstināšanos virs 2°C, cenšoties panākt samazinājumu līdz 1,5°C salīdzinot ar pirmsindustriālo līmeni [9], [10]. Šos starptautiskos centienus papildina 17 ilgtspējīgas attīstības mērķi (IAM), kas apstiprināti 2015. gadā, pieņemot ANO "Ilgtspējīgas attīstības programmu 2030" [11].

ES Parīzes nolīguma kontekstā ir apņēmusies līdz 2030. gadam samazināt SEG emisijas par 55 %, salīdzinot ar 1990. gada līmeni [12], [13]. ES iekšējās saistības ir izklāstītas Eiropas zaļajā kursā un Eiropas Klimata likumā, kurā ir noteikts juridiski saistošs mērķis līdz 2050. gadam panākt klimatneitralitāti. Šie mērķi tiek īstenoti, izmantojot tiesību aktu paketi "Gatavi mērķrādītājiem 55 %" (*Fit for 55 %*) [13], [14], [15]. Minētais samazinājums attiecas arī uz zemes izmantošanas, zemes izmantošanas maiņas un mežsaimniecības (ZIZIMM) nozari [6].

ANO 1987.gada Bruntlandes ziņojumā ir iekļauta viena no zināmākajām ilgtspējas definīcijām [16], definējot ilgtspējīgu attīstību kā "pašreizējo vajadzību apmierināšana, neapdraudot nākamo paaudžu spēju apmierināt savas vajadzības" [17]. Ilgtspēja biežāk tiek saprasta arī kā "cilvēka darbību ilgtermiņa noturība, vienlaikus saglabājot vidi veselīgā stāvoklī" [16]. Ilgtspējas jēdziens mūsdienās tiek interpretēts dažādi, tāpēc būtiski uzsvērt trīs tās pīlārus: ekonomisko, sociālo un vides ilgtspēju. Ekonomiskā ilgtspēja nozīmē cilvēku spēju turpināt pelnīt iztiku no konkrētas darbības; sociālā ilgtspēja balstās uz sabiedrības piekrišanu un atbalstu; savukārt vides ilgtspēja - uz spēju īstenot darbības, nenodarot kaitējumu videi un neapdraudot resursu pieejamību nākotnē [16]. Visi trīs ilgtspējas pīlāri ir savstarpēji saistīti un nedalāmi [16], [18], tomēr pieaugošais globālais pieprasījums pēc bioloģiskajiem resursiem rada izaicinājumu līdzsvara panākšanai starp tiem [16], [19].

Vides ilgtspēja un politika, kas vērsta uz piesārņojuma mazināšanu vai vides uzlabošanu, ES darba kārtībā ir kopš pagājušā gadsimta 70. gadiem [20], savukārt nacionālu valstu valdības tikai nesen ir atzinušas vides problēmu un ilgtspējas nozīmi [21], [22]. Ilgtspējīgas ražošanas sistēmas ir būtiskas, lai saglabātu ekosistēmu produktivitāti un daudzveidību, vienlaikus nodrošinot pārtikas pieejamību [23], [24]. Ražošanas sistēmu un piegādes ķēžu tiešā un netiešā ietekme uz vidi, tostarp ar enerģijas pieprasījumu saistītā ietekme, potenciāli rada apdraudējumu vides ilgtspējai [23], [25]. Ekonomikas teorijā ilgtspējīga ekonomiska attīstība tiek skaidrota kā ekonomikas sistēma, kurā ražošanas bāze vai kopējais kapitāls laika gaitā paliek nemainīgs [16]. Šajā gadījumā kapitāls attiecas uz visaptverošu sistēmas bagātību, ieskaitot tās cilvēkresursus, vides un ekonomikas komponentes [16]. Planētas ierobežotie resursi limitē neierobežotas izaugsmes iespējas, bet tajā pašā laikā nav iespējams skaidri noteikt sistēmas robežas un kvantitatīvi novērtēt sekas [16]. Sociālo ilgtspēju var definēt kā kopienas locekļu labklājības uzlabošanu vai saglabāšanu [16]. Sociālā ilgtspēja ir vērsta uz godīgas darba prakses nodrošināšanu un centieniem mazināt sociālo nevienlīdzību, uzlabot dzīves kvalitāti, aizsargāt cilvēktiesības un novērst riskus, veicinot taisnīgas un vienlīdzīgas sociālās, ekonomiskās un vides politikas pielāgošanu [16], [26]. Ražošanas sistēmu zema finansiālā rentabilitāte un nepietiekama izturētspēja apdraud sociālo un ekonomisko ilgtspēju [23].

Bioekonomikas loma Eiropas zaļā kursa mērķu sasniegšanā

Eiropas Komisija ir atzinusi, ka bioekonomika ir "sistēmisko pārmaiņu katalizators" Eiropas zaļā kursa mērķu sasniegšanai [27], veicinot ilgtspējīgas prakses piemērošanu tādās bioresursu ieguves nozarēs kā lauksaimniecība, meža nozare, zivsaimniecība un akvakultūra, palielinot iegūto resursu izmantošanas efektivitāti pārtikas un izejvielu ražošanā un samazinot atkarību no neatjaunojamiem enerģijas avotiem [27], [28], [29]. Lai sekmīgi integrētu bioekonomiku dažādās nozarēs, nepieciešams uzlabot sabiedrības informētību, īpaši politikas veidotāju un uzņēmumu vidū, vienlaikus ieviešot jaunas pārvaldības prakses. Tas veicinātu ilgtspējīgi domājošas sabiedrības veidošanos [30].

2025. gadā aprit 13 gadi kopš pirmās Eiropas bioekonomikas stratēģijas "Inovācijas ilgtspējīgai izaugsmei - bioekonomika Eiropai" pieņemšanas [31], [32], tās uzdevums bija paplašināt bioresursu izmantošanu un ar tiem aizstāt fosilo resursu lietojumu virknē produktu. Veicināt pāreju no "vecās" uz "jauno" bioekonomiku - zināšanās balstītu un inovatīvu [32], [33]. Uzlabot pašreizējo zemes izmantošanas un resursu pārvaldības praksi, samazināt SEG emisijas resursu ieguves un pārstrādes procesos, radīto atkritumu daudzumu, attīstot blakusproduktu izmantošanu jaunu produktu ražošanā ar augstāku pievienoto vērtību [32], [33]. Iedzīvināt praksē aprites ekonomikas principus, līdz minimumam samazināt neatjaunojamu, neilgtspējīgu resursu izmantošanu, palielināt resursu izmantošanas efektivitāti - no mazāk saražojot vairāk [32], [33].

Kopš bioekonomikas stratēģijas pieņemšanas, bioekonomika nav zaudējusi savu aktualitāti. Gluži pretēji, globālās klimata pārmaiņas, sarežģītā ģeopolitiskā situācija, bioresursu un enerģijas cenu pieaugums liek arvien vairāk uzsvērt nepieciešamību ilgtspējīgi izmantot bioresursus un pēc iespējas samazināt fosilo resursu izmantošanu [34], [35]. Arī Eiropas Komisijas 2022. gadā publicētajā bioekonomikas progresa ziņojumā [36] tika pārapstiprināta nepieciešamība turpināt darbu pie 2012. gada stratēģijā un rīcības plānā, gan tās atjauninātāja 2018. gada versijā nospraustо mērķu izpildes. Vienlaikus uzsverot, nacionālo bioekonomikas stratēģiju izstrādes būtiskumu [15].

Bioresursu plašais lietojums pārtikas, enerģētikas, rūpniecības un transporta nozarēs, padara bioekonomikas stratēģiju par daļu no plašāka politikas ietvara, kura uzdevums ir nodrošināt saskaņotību starp plānošanas dokumentiem un izmantotajiem instrumentiem bioresursu pārvaldībā ES un dalībvalstu līmenī. Bioekonomikas attīstības potenciāla izvērtējums ļauj identificēt politikas dokumentu savstarpējo koherenci gan starp nozarēm, gan katras nozares ietvaros, pārbaudot, cik konsekventi formulēti mērķi un instrumenti [37]. Ar starptautiskiem mērķiem saskaņoti nacionālie rīcības plāni var mazināt pārtikas un energoapgādes riskus, veicināt efektīvāku bioresursu izmantošanu un novērst strauju cenu pieaugumu [35]. Tāpēc viena no promocijas darba pētījuma jomām ir bioekonomikas mērķu integrācijas analīze politikas plānošanas dokumentos, izmantojot lejupvērstu (*top-down*) pieeju, kā arī saskaņotības novērtējums dažādos politikas līmeņos [34], [37], [38], [39], [40].

Lauksaimniecības un meža nozares ir Latvijas bioekonomikas veicinātājas [41], [42]. Meža nozare un no tās iegūtie resursi ir ļoti būtiski Latvijas bioekonomikai, neskatoties uz to, ka gan koksnes, gan nekoksnes resursu potenciāls pašlaik netiek pilnībā izmantots [41], [43]. Latvijas Bioekonomikas stratēģija 2030 uzsver Latvijas kokrūpniecības un mēbeļu ražošanas nozares nozīmi, jo dažādas kvalitātes izejvielas, kas pašlaik tiek eksportētas, varētu aizstāt ar Latvijā ražotiem produktiem ar augstu pievienoto vērtību, piemēram, kokšķiedras plātnēm, mēbelēm vai koka moduļu ēkām [42], [44]. Iespējams attīstīt arī celulozes rūpniecību [42].

Lauksaimniecības sektora ceļš uz klimatneitralitāti: oglekļsaistīga lauksaimniecība

Lai gan sākotnēji tika uzskatīts, ka ES klimata mērķus varētu sasniegt ar pakāpeniskiem klimata pārmaiņu mazināšanas pasākumiem, tagad ir skaidrs, ka ar to nepietiks un būs nepieciešama liela mēroga oglekļa dioksīda (CO_2) aizvākšanas pasākumi [14]. Viens no iespējamiem risinājumiem ir plašāka oglekļsaistīgas lauksaimniecības prakšu izmantošana. Jau 2004. gadā veiktajā pētījumā *Lal* [45] norādīja uz ZIZIMM sektora būtisko lomu oglekļa sekvestrācijā dabiskajās ekosistēmās norādot, ka to pārveidošana par agro-ekosistēmām var izraisīt augsnes organiskā oglekļa krājumu samazināšanos līdz pat 60-75 %. Tanī pat laikā identificējot risinājumu - zemes apsaimniekošanas prakses, kas neizraisa augsnes organiskā oglekļa samazināšanos, bet gan palielina oglekļa piesaisti [45].

Neraugoties uz zinātniski pamatoto oglekļsaistīgas lauksaimniecības prakšu potenciālu [46], [47], [48], ES līdz šim trūka saskaņotas sistēmas, lai kvantitatīvi novērtētu un atalgotu šādu prakšu ieviešanu. Tas tika mainīts ar Eiropas Parlamenta un Padomes 2024. gada 27. novembrī pieņemto Regulu (ES) 2024/3012, ar ko izveido Savienības sertifikācijas satvaru pastāvīgai oglekļa piesaistei, oglekļsaistīgai saimniekošanai un oglekļa uzkrāšanai produktos (*CRCF* regula) [49]. *CRCF* regula paplašinās papildu ienākumu iespējas kā zaļais uzņēmējdarbības modelis lauksaimniekiem un zemes apsaimniekotājiem, kā arī būs mehānisms, kas varētu atbalstīt ES dalībvalstu emisiju samazināšanas un piesaistes mērķu sasniegšanu saskaņā ar pārskatīto Eiropas Parlamenta un Padomes Regulu (ES) 2018/841 par zemes izmantošanā, zemes izmantošanas maiņā un mežsaimniecībā radušos SEG emisiju un piesaistes iekļaušanu klimata un enerģētikas politikas satvarā laikposmam līdz 2030. gadam [50].

ZIZIMM un *CRCF* regulas nosaka, ka oglekļa piesaistei jābūt kvantitatīvi noteiktai, un piesaistes aprēķina metodoloģijām jābūt saskaņotām ar 2006. gada Klimata pārmaiņu starpvaldību padomes pamatnostādnēm par valstu SEG emisiju inventarizāciju (*IPCC* pamatnostādnes), lai nodrošinātu savietojamību ar valstu nacionālajām SEG emisiju inventarizācijas sistēmām [51], [52], [53]. Tādējādi nākotnē pastāv iespēja, ka SEG emisiju samazinājuma un piesaistes rezultāti, kas panākti ZIZIMM un *CRCF* kontekstā, būs salāgojami ar dalībvalstu ziņošanas pienākumiem *UNFCCC* un Parīzes nolīguma kontekstā, kā arī saskaņā ar Regulu (ES) 2018/1999 par Enerģētikas savienības pārvaldību [53], [54].

Ilgtspējīgas akvakultūras: pārtikas nodrošinājuma un uzturvielu avots

Eiropas bioekonomikas stratēģijā definētā bioekonomika ir inovatīva, uz zināšanām balstīta un apritīga, kas konceptuāli atšķiras no tradicionālās un resursu ziņā neefektīvās konvencionālās bioekonomikas principiem [29]. Turpretī iekšzemes akvakultūras sistēmās vēsturiski izmantotās tradicionālās audzēšanas metodes var uzskatīt par ilgtspējīgākām nekā mūsdienu intensificētās akvakultūras sistēmas [55]. Tas tādēļ, ka tradicionālās akvakultūras sistēmas bija cieši integrētas saimniecības darbībā, kur blakusproduktus un atliekas izmantoja audzēto ūdens organismu barošanai [55]. Akvakultūras sistēmām ideālā gadījumā būtu jāspēj atdarināt dabiskos apstākļus, kādus zivis un citi ūdens organismi varētu atrast savvaļā, taču šāda pieeja ne vienmēr ir saderīga ar intensifikāciju un ražošanas apjoma paaugstināšanu [16]. Līdz ar to ilgtspējīgas akvakultūras praksei jātiek galā ar izaicinājumu nodrošinot nepārtrauktu barības vielu piegādi ūdens organismiem, nenodarot kaitējumu esošajām ekosistēmām un nepārsniedzot planētas dabiskās robežas [16], [23]. Pieaugošais pieprasījums pēc ilgtspējīgi ražotām olbaltumvielām ir veicinājis strauju akvakultūras sistēmu izaugsmi, apsteidzot liellopu audzēšanas apjomus, un sekmējis tās intensifikāciju [16], [23], [56]. Tomēr intensifikācija ne vienmēr ir saderīga ar ilgtspējības koncepciju [16].

Tropiskajās jaunattīstības valstīs zivis un gliemjus var audzēt ar zemākām izmaksām, savukārt produktu transportēšana uz ekonomiski attīstītajām patērētājvalstīm līdz šim nav bijis būtisks izmaksu faktors [16]. Tādējādi attīstītās mērenā klimata valstis ir neizdevīgākā situācijā, jo audzēšanas, ražošanas un darbaspēka izmaksas ir augstākas, un ir grūti konkurēt ar saldētiem produktiem no tropiskajām valstīm [16]. Tanī pat laikā mērenā klimata valstu tuvums tirgiem, kuros ir augsts pieprasījums pēc svaigiem zivju produktiem, jāuzskata par priekšrocību, kas nākotnē būtu jāizmanto [16]. Līdz ar to jāatrod veids, kā samazināt audzēšanas izmaksas un intensificēt akvakultūru mērenā klimata valstīs, vienlaikus saglabājot ilgtspēju.

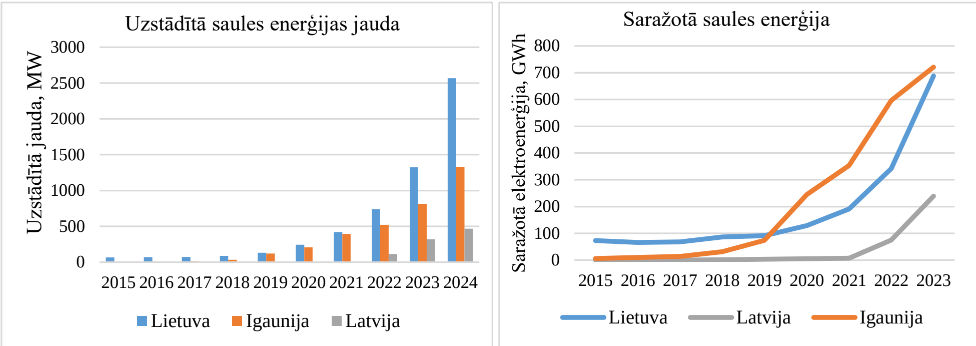
Enerģijas no atjaunojamiem energoresursiem īpatsvara palielināšana

AER izmantošana paplašina rūpniecības attīstības iespējas, var veicināt ekonomikas izaugsmi un radīt jaunas darbavietas. Gan pasaule gan ES šobrīd atrodas globālās enerģētikas pārveides sākumposmā. Enerģijas ražošanas īpatsvara palielināšana no AER ir viens no priekšnoteikumiem ceļā uz klimatneitrālām enerģētikas sistēmām [15]. Nozīmīgi, lai pāreja uz AER notiktu sociāli taisnīgi, saglabājot par prioritāti arī sociāli neaizsargāto iedzīvotāju grupu intereses ES dalībvalstīs, vienlaikus nepakļaujot tos enerģētiskās nabadzības riskam [15].

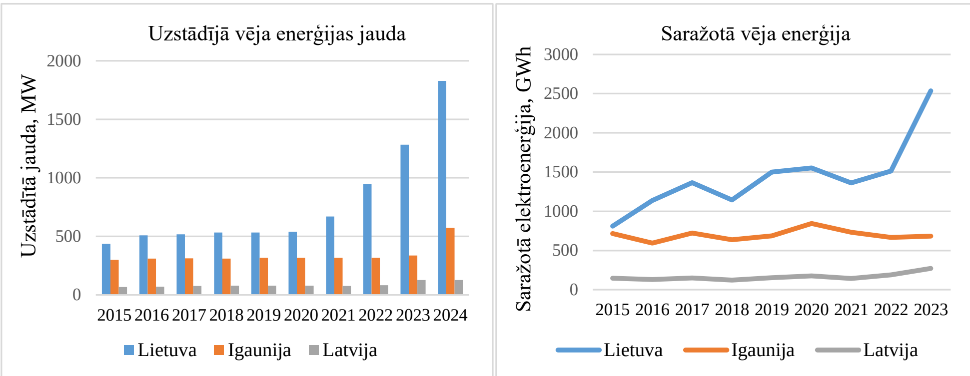
AER projektu īstenošanas process var tikt sekmēts vai arī kavēts atkarībā no projektu ieviešanas posmiem un procedūru pārredzamības [57], [58]. Galvenokārt tāpēc, ka administratīvie šķēršļi vai nesaprotamas procedūras, lai pieslēgtos tīklam, var aizkavēt AER projektu īstenošanu pat par vairākiem gadiem [57]. Neskaidras un sarežģītas administratīvās procedūras [59], neizprotams un nestabils normatīvais regulējums vai negatīva sabiedrības attieksme var ietekmēt investoru vēlmi attīstīt AER projektus konkrētā valstī [60], kas ilgtermiņā var kaitēt ES klimata mērķu sasniegšanai pārejā no fosilā kurināmā uz AER [61]. Tāpēc Eiropas Parlamenta un Eiropadomes 2018. gada 11. decembra Direktīvā (ES) 2018/2001 par AER izmantošanas veicināšanu ir noteikti pasākumi, kas būtu veicami administratīvo procedūru atvieglošanai un AER projektu īstenošanas termiņu saīsināšanai [62].

Saules un vēja enerģijas integrācija Baltijas valstu enerģijas tirgos pēdējā desmitgadē ir turpinājusi pieaugt. 1.1. un 1.2. attēlā parādītas vēja un saules enerģijas sistēmu uzstādītās jaudas un saražotā saules un vēja enerģija Lietuvā, Latvijā un Igaunijā laika posmā no 2015.

gada līdz 2023. gadam (saražotajai elektroenerģijai, GWh) un līdz 2024. gadam (uzstādītajai jaudai, MW) [63]. Lietuvā uzstādītās saules un vēja enerģijas jaudas no 2015. gada līdz 2024. gadam pieaugušas ārkārtīgi strauji, salīdzinājumā ar 2021. gadu saules enerģijai pat seškārtīgi [63]. Ievērojamu izaugsmi piedzīvojušas uzstādītās saules enerģijas jaudas Igaunijā, kamēr vēja enerģija būtiskāku lēcienu piedzīvojusi vien 2024. gadā [63]. Tomēr Latvijā vēja un saules enerģijas sistēmu integrācija noris lēnāk – saules enerģijai piedzīvojot manāmāku izaugsmi sākot no 2021. gada, kamēr uzstādītajai vēja enerģijas jaudai no 2015. gada saglabājoties gandrīz nemainīgai [63].



1.1. att. Uzstādītā saules enerģijas jauda (MW) un saražotais elektroenerģijas daudzums (GWh) [63].



1.2. attēls Uzstādītā vēja enerģijas jauda (MW) un saražotais elektroenerģijas daudzums (GWh) [63].

Atšķirības uzstādītajā saules un vēja enerģijas jaudā Baltijas valstīs var skaidrot gan ar atšķirīgu atbalsta politiku katrā valstī, gan ar dažādiem šķēršļiem, kas rodas īstenošanas procesā. Tādēļ viens no promocijas darba pētījuma posmiem bija procesa soļu saules un vēja elektrostaciju uzstādīšanai Latvijā, Lietuvā un Igaunijā izvērtējums un salīdzinājums ar labās prakses piemēriem Somijā, Norvēģijā un Zviedrijā, lai identificētu būtiskākos šķēršļus AER projektu īstenošanā.

Izglītības iestāžu loma klimata mērķu sasniegšanā

ANO IAM [64] tieši ietekmē gan ilgtspējīgas izglītības attīstību, gan ēku enerģijas patēriņu. SEG emisiju samazināšana ir nozīmīga šo mērķu, kā arī Parīzes nolīgumā definēto saistību izpildei, jo 2021. gadā ēku sektors radīja 27 % no kopējām enerģētikas nozares emisijām [65], [66]. Ilgtspējīga izglītība sniedz skolēniem zināšanas, vērtības un prasmes, kas nepieciešamas apzinātu lēmumu pieņemšanai un dzīves kvalitātes uzlabošanai, vienlaikus nodrošinot nākamo paaudžu vajadzības [67], un tādējādi var būtiski ietekmēt virzību uz klimatneitralitāti [68], [69]. Tomēr tikai pēdējos gados ir uzsvērta izglītības loma klimata mērķu sasniegšanas kontekstā [70]. Lai uzlabotu ilgtspējību, ir nepieciešamas būtiskas pārmaiņas organizācijās, piegādes ķēdēs un kopienās, un to var panākt tikai ar nepārtrauktu mācīšanos un inovācijām [71]. Tāpēc spēcīga profesionālās izglītības sistēma var sniegt daudz priekšrocību, piemēram, veicinot zaļo izaugsmi un palielinot darba ražīgumu [72]. Padziļināta izpratne par klimata pārmaiņām var iedvesmot skolēnus aktīvi iesaistīties klimatneitralitātes sasniegšanā un radīt atbildības sajūtu vides jomā [73], [74], [75]. Skolotāji var izmantot šo informāciju, lai uzlabotu skolēnu izpratni par klimata pārmaiņu ietekmi un iedvesmotu viņus pievērsties enerģijas taupībai, īstenojot izglītības iniciatīvas, kas palielina vides apziņu [74].

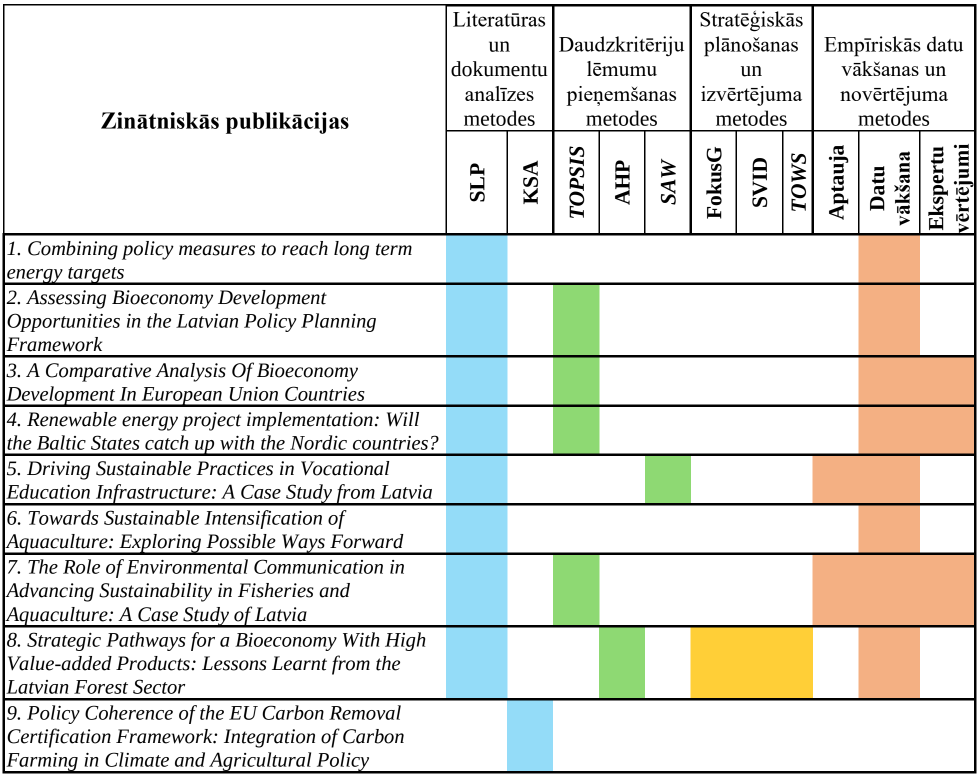
Papildus ilgtspējīgas izglītības veicināšanai arī izglītības iestāžu ēkām ir būtiska nozīme primārās enerģijas patēriņa samazināšanā un motivējošas mācību vides nodrošināšanā [76]. Tām ir potenciāls būtiski ietekmēt SEG emisiju samazināšanu, izmantojot energoefektivitātes pasākumus un AER ražošanu [77], [78]. Dažādos pētījumos ir analizēts potenciālais enerģijas ietaupījums, ko iespējams panākt izglītības iestāžu ēkās, piemēram, Spānijā par 66 % tika samazināts neatjaunojamās primārās enerģijas patēriņš un par 71 % CO_2 emisijas [79]. Dažādu scenāriju optimizācija, kas ietver centralizēto siltumapgādi un zemes siltumsūkņus kombinācijā ar fotoelementu paneļiem, sniedz vairākus izmaksu ziņā optimālus risinājumus, vienlaikus nodrošinot primārās enerģijas patēriņu, kas vienāds vai mazāks par 170 kWh/m^2 gadā [79]. Tomēr ieguldījumu izmaksas un enerģijas tarifi būtiski ietekmē energoefektivitātes un enerģijas ražošanas pasākumu Pareto optimalitāti [80]. Ēku enerģijas patēriņa pakāpes uzlabošanu no G līdz B līmenim var panākt, kombinējot energoefektivitātes pasākumus, piemēram, ēku ārējo norobežojošo konstrukciju siltināšanu un jaunu logu un durvju uzstādīšanu, ar tādiem AER ražošanas pasākumiem kā fotoelementu paneļiem, biomasas apkures sistēmām, kombinētās saules enerģijas sistēmām un apgaismes ierīču nomaiņu [81]. Kazahstānas - Vācijas universitātes Almati, Kazahstānā, gadījuma izpētē tika konstatēts, ka modernizācijas pasākumi samazina CO_2 emisijas par 48-82 % [82]. Kopumā izglītības iestāžu ēkām ir liels potenciāls SEG emisiju samazināšanā, izmantojot energoefektivitātes pasākumus un AER izmantošanu.

Promocijas darbs izstrādāts kā starpdisciplinārs pētījums, kurā politikas un normatīvo dokumentu analīze tiek skatīta no vides inženierzinātņu perspektīvas, nevis tradicionāli politikas vai tiesību zinātnēs dominējošās pieejas. Līdzšinējā pētniecībā politikas saskaņotības un iesviešanas aspekti pārsvarā analizēti ar kvalitatīvām metodēm, kas sniedz būtisku kontekstu, taču ierobežo iespējas savstarpēji salīdzināt politikas instrumentus un to īstenošanas rezultātus. Šajā darbā minētie aspekti tiek kvantificēti, integrējot *MCDA* metodes (*TOPSIS,* AHP) un empīriskās datu vākšanas un novērtējuma pieejas politikas dokumentu analīzē, tādējādi izgaismojot politikas saskaņotības un regulējuma ieviešanas dimensijas, kas ar kvalitatīvām metodēm bieži ir grūtāk identificēt un strukturēt.

Zināšanu plaisa izriet no tā, ka zinātniskajā literatūrā dominē pētījumi par Eiropas zaļā kursa tehnoloģiskajiem un inovāciju ieviešanas aspektiem, savukārt mazāk analizēta politikas ieviešanas kvalitāte dalībvalstu līmenī – administratīvā kapacitāte, procesu sarežģītība, politikas dokumentu un normatīvā regulējuma interpretācija un ar to saistītie sociālie faktori, tostarp zināšanu un informētības trūkums, kā arī praktiskās ieviešanas šķēršļi. Līdz ar to šis pētījums risina vides inženierzinātņu problemātiku, kurā ilgtspējīgi risinājumi un tehnoloģijas iestrēgst ieviešanas posmā tieši politikas un administratīvo procesu fragmentācijas, kapacitātes un zināšanu trūkuma dēļ.

2. METODIKA

Promocijas darba metodika balstās četrās galvenajās pieejās. Pirmkārt, izmantotas literatūras un dokumentu analīzes metodes, lai izvērtētu energoefektivitātes pasākumus, oglekļsaistīgas lauksaimniecības ES politiskā un normatīvā ietvara politisko saskaņotību, kā arī identificētu administratīvos šķēršļus AER projektu īstenošanā. Otrkārt, *MCDA* metodes lietotas bioekonomikas stratēģiju implementācijas novērtēšanai, profesionālās izglītības kompetences centru (PIKC) energoefektivitātes novērtēšanai, administratīvo šķēršļu izvērtēšanai un prioritāšu noteikšanai meža nozares bioekonomikas attīstībā. Treškārt, stratēģiskās plānošanas un izvērtējuma metodes izmantotas, lai identificētu stiprās un vājās puses, kā arī attīstības scenārijus. Visbeidzot, ceturtā pieeja ir empīriskās datu vākšanas un novērtējuma metodes - aptaujas, objektu apsekojumi un datu vākšana, kā arī ekspertu vērtējumi, kas sniedza ieskatu izglītības iestāžu īstenotajos energoefektivitātes un ilgtspējas pasākumos, atklāja projektu īstenotāju pieredzi par administratīvajiem šķēršļiem AER projektu realizācijā un palīdzēja identificēt atbilstošākos komunikācijas kanālus ilgtspējas jautājumu skaidrošanai. Promocijas darba mērķu sasniegšanai tika lietota jauktu metožu pieeja, apvienojot dokumentu un literatūras analīzes metodes ar *MCDA*, stratēģiskās plānošanas un izvērtējuma vai empīriskās datu vākšanas un novērtējuma metodēm (2.1. att.).



2.1. att. Zinātniskās publikācijas un tajās izmantotās pētniecības metodes.

Pētījumā izmantotās metodes tika izvēlētas, balstoties uz konkrētajiem izpētes jautājumiem un nepieciešamību sistemātiski novērtēt politikas un normatīvo dokumentu saturu, to saskaņotību un īstenošanas potenciālu. Politikas un normatīvo dokumentu satura analīze tika izmantota gadījumos, kad nepieciešams identificēt mērķus, pasākumus un instrumentus, savukārt *MCDA* pieejas tika piemērotas, ja bija iespējams kvantificēt stratēģiju vai rīcībpolitiku savstarpējo salīdzināmību. Analīzes detalizācijas pakāpi noteica arī dokumentu struktūra, ja politikas dokumentam bija izstrādāts rīcības plāns, bija iespējams veikt padziļinātu un kvantitatīvu novērtējumu, savukārt dokumentiem tikai ar stratēģisko daļu novērtējums aprobežojās ar mērķu un instrumentu formālu saskaņotību. Attiecīgi metožu piemērošana nav saistīta ar analīzes līmeni (ES, nacionāls vai lokāls), bet gan ar to, cik lielā mērā konkrētais dokuments ļauj analizēt rīcībpolitikas saturu, piemērojamos instrumentus un sagaidāmo ietekmi. Detalizēta metožu piemērošana, datu avoti un analītiskie soļi atspoguļoti promocijas darbā iekļautajās publikācijās (1.-9. publikācija), kas veido šī pētījuma empīrisko un analītisko pamatu.

Promocijas darba ietvaros horizontālā politikas saskaņotība tiek definēta kā noteikto mērķu un rīcību atbilstība starp vienāda pārvaldības līmeņa dokumentiem, savukārt vertikāla saskaņotība kā lejupvērsta (*top-down*) saskaņotība starp augstāka un zemāka līmeņa politikas vai normatīvajos dokumentos noteiktajiem mērķiem un rīcībām. Horizontālo un vertikālo politikas saskaņotības novērtējumu var pielīdzināt ceļa kartes izstrādei turpmākajiem soļiem, neatkarīgi no tā, vai tie nepieciešami rīcībpolitikas ieviešanai, zinātniskiem pētījumiem vai investīciju plānošanai. Horizontālā saskaņotība ļauj izprast atsevišķas politikas jomas stratēģisko virzību un nospraustos mērķus, savukārt vertikālā saskaņotība dod iespēju novērtēt, vai nacionālais politikas plānošanas satvars atbilst augstāka līmeņa dokumentos noteiktajām prioritātēm vai arī nepieciešami uzlabojumi, lai nodrošinātu vienotu virzību.

2.1. Literatūras un dokumentu analīzes metodes

Promocijas darbā sektoru izvēle balstīta Eiropas Komisijas uzsvērtajā bioekonomikas lomā Eiropas zaļā kursa mērķu īstenošanā [27], kur lauksaimniecība, meža sektors, zivsaimniecības un akvakultūras sektors, kā arī attiecīgie apstrādes un pārstrādes sektori definēti kā stratēģiski virzieni ar būtisku ieguldījumu resursu efektivitātē, emisiju samazināšanā un atkarības no fosilajiem resursiem mazināšanā. Vienlaikus darbā iekļautas arī enerģētikas un siltumapgādes un dzesēšanas nozares, jo to pārveide ir priekšnosacījums klimata, tai skaitā bioekonomikas, politikas mērķu sasniegšanai – īpaši attiecībā uz AER integrāciju, energoefektivitāti un politikas instrumentu praktisku īstenošanu dalībvalstīs. Analizētie sektori identificēti kā ar lielāko potenciālu sniegt tiešu ieguldījumu klimatneitralitātes sasniegšanā. Tādēļ to iekļaušana pētījumā nav balstīta tikai datu pieejamībā, bet gan politikas nozīmīgumā, rīcībpolitikas instrumentu sarežģītībā un pārvaldības kvalitātes ietekmē uz Eiropas zaļā kursa mērķu īstenošanu dalībvalstīs.

2.1.1. Sistemātisks literatūras pārskats

Sistemātiska literatūras pārskata (SLP) metode ir sakņota pierādījumos balstītā politikā un praksē. SLP aizsākumi rodami medicīnas un pierādījumos balstītas politikas novērtēšanā. Plaši tiek lietota vides jautājumu risināšanai un politikas vai politikas instrumentu novērtēšanai [83], [84]. SLP tiek lietota, lai meklētu atbildes uz konkrētu jautājumu vai hipotēzi [83]. SLP var kļūt ļoti laikietilpīga, ja jāanalizē liels dokumentu apjoms, tādēļ nereti to papildina ar atslēgvārdu piešķiršanas metodi [85], [86]. Atslēgvārdu piešķiršanas metode ir mazāk darbietilpīga, ļauj precīzāk pārskatīt dokumentus un efektīvāk atbildēt uz pētniecības jautājumiem, vienlaikus saglabājot konsekvenci [85], [86].

Bioekonomikas politikas saskaņotības novērtējums

Lai novērtētu bioekonomikas politikas vertikālo saskaņotību starp starptautisko un nacionālo līmeni, pētījumā (2. publikācija) tika analizēti starptautiski nozīmīgi dokumenti: (1) OECD ziņojums "Bioekonomika līdz 2030. gadam. Politikas darba kārtības izstrāde" [87]; (2) Eiropas bioekonomikas stratēģijas (2012., 2018. gads) [88], [89]; ANO "Pārveidojot mūsu pasauli: 2030. gada ilgtspējīgas attīstības programma" [11], [90]. No tiem identificētie mērķi kalpoja kā atslēgvārdi Latvijas politikas dokumentu izvērtējumam.

Nākamajā posmā, izmantojot SLP un "sniega pikas" izlasi, padziļinātai analīzei tika atlasīti 10 nacionāla līmeņa stratēģiskie dokumenti, sākot ar Latvijas Bioekonomikas stratēģiju 2030. Atslēgvārdu piešķiršanas metode [85], [86], [91] tika izmantota, lai noteiktu, kādā mērā nacionālie dokumenti atspoguļo starptautiskos mērķus un kāda prioritāte tiem piešķirta. Sākotnējie rezultāti tika apkopoti ilustratīvā skrīninga matricā, vērtēšanai izmantojot Likerta tipa skalu [92]. Mērķa prioritāte tika noteikta pēc tā pieminēšanas reižu skaita.

Energoefektivitātes paaugstināšana siltumapgādes un dzesēšanai nozarē

SLP tika izmantota, lai identificētu noteiktos mērķus un pasākumus energoefektivitātes paaugstināšanai Latvijas siltumapgādes un dzesēšanai nozarē, kā arī izmantotos politikas instrumentus to izpildei (1. publikācija). Pirmkārt tika apzināti ES līmenī noteiktie mērķi un izvērtēts, vai tie implementēti Latvijas ilgtermiņa un vidēja termiņa politikas dokumentos, tādējādi nosakot vertikālo politikas saskaņotību. Otrkārt padziļināti analizēti nozarei specifiski dokumenti, kuros detalizēti izklāstīti politikas pasākumi un sagaidāmie rezultāti. Identificētie pasākumi tika klasificēti četrās politikas instrumentu kategorijās, kas atbilst ES līmeņa literatūrā lietotajai politikas instrumentu tipoloģijai. Instrumentu kategorijas un to piemēri apkopoti 2.1. tabulā, kas metodoloģiski kalpo kā atsauce vienotai politikas instrumentu klasifikācijai, ko pētījumā piemēro identifikācijas un saskaņotības analīzei. Šāda pieeja ļāva ne tikai sistematizēt politikas pasākumus politikas instrumentu kategorijās un novērtēt to potenciālo efektivitāti, bet arī izvērtēt politikas saskaņotību starp ES un nacionālo līmeni, identificējot gan pārklāšanās riskus, gan nepilnības instrumentu piemērošanā.

2.1. tabula

Politikas instrumentu kategorijas un politikas instrumentu piemēri [2], [93], [94]

Politikas instrumentu kategorijas	Politikas instrumentu piemēri
Normatīvais regulējums	Saistoši tiesību akti
	Vides, emisiju un projektēšanas standarti
	Būvnormatīvi
	Obligātie energoauditi un enerģijas patēriņa monitorings
	Obligāts ieguldījumu pienākums energoefektivitātes uzlabšanā
	Izglītības programmas
Brīvprātīgie instrumenti	Patērētāju izvēles
	Vides aizsardzības vienošanās
	Uzņēmējdarbības vai nozaru pašregulācijas iniciatīvas
Publiskie izdevumi	Subsīdijas un stimuli
	Ieguldījumi brīvprātīgas rīcības veicināšanai
	Izglītība, pētniecība un zinātne
	Aizdevumi
	Subsīdijas energoefektivitātes veicināšanai
Ekonomiskie (tirgus) instrumenti	Maksa par izmešiem, resursu izmantošanu un noteiktām produktu grupām
	Tirgojamas atļaujas
	Depozīta sistēma
	Naudas sodi, nodevas, sankcijas
	Enerģijas patēriņa samazinājuma sertifikāti
	Nodokļi

Ilgtspējīgas akvakultūras sistēmu intensifikācijas iespējas

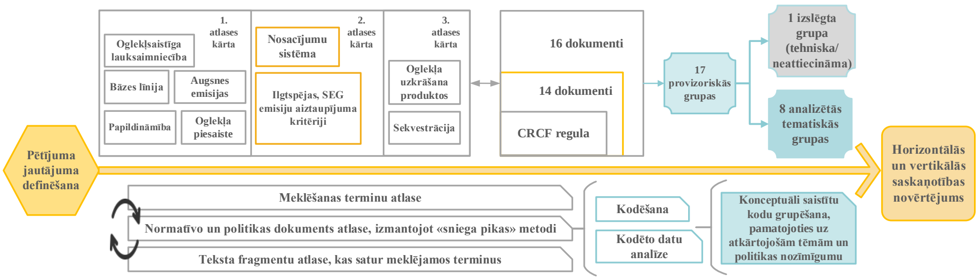
Šī pētījuma posma mērķis bija izvērtēt akvakultūru ilgtspējīgas intensifikācijas iespējas, fokusējoties uz tehnoloģiskajiem risinājumiem un sistēmām, kas var nodrošināt lielāku produktivitāti, vienlaikus mazinot negatīvo ietekmi uz vidi (6. publikācija). Literatūras pārskatā uzmanība tika koncentrēta uz audzēšanas sistēmām un to tehnoloģiskajiem elementiem, kā arī labākās pārvaldības praksēm. Analīze tika vērsta uz vairākiem izpētes jautājumiem: (1) kādas akvakultūras sistēmas ir piemērotākās ilgtspējīgai attīstībai; (2) kādi tehnoloģiskie risinājumi šobrīd tiek izmantoti; (3) kādas ir nākotnes perspektīvas; (4) kā labākās pārvaldības prakses var sekmēt nozares attīstību. Kopumā tika analizēti vairāk nekā 120 zinātniskie un politikas avoti, nodrošinot plašu pārskatu par nozares attīstības virzieniem un iespējām.

Pārskats aptver informāciju par intensīvi barotām monokultūrām un polikultūrām, integrēto daudzlīmeņu akvakultūru, akvaponiku un bioflokas sistēmām, kā arī dīķu un tvertņu sistēmām produktivitātes un ilgtspējas uzlabošanai (tradicionālās dīķu sistēmas, sadalošās akvakultūras sistēmas, recirkulācijas akvakultūras sistēmas un marikultūras). Īpaša uzmanība tika pievērsta tehnoloģiskajiem risinājumiem, piemēram, aerācijai, AER integrācijai, augsto tehnoloģiju lietojumam, kā arī labākās pārvaldības praksēm, izsekojamībai un pārredzamībai, un ekosistēmu pieejas integrēšanai akvakultūrās. Šāda pieeja ļāva identificēt galvenos attīstības virzienus un potenciālos šķēršļus, kā arī izcelt risinājumus, kas varētu būt piemēroti Eiropas kontekstā.

2.1.2. Kvalitatīva satura analīze

ES normatīvo un politikas dokumentu analīzei papildus SLP, tika izmantota arī kvalitatīva satura analīze, jo tā ļauj sistemātiski identificēt tēmas, nozīmes un struktūras dažādos tekstos, saglabājot caurredzamību [95], [96]. Šī metode tika uzskatīta par piemērotu, jo tā atvieglo normatīvo un politikas dokumentu strukturētu analīzi un ir īpaši noderīga politikas veidošanas un saskaņotības izpētei politikas izstrādes un īstenošanas kontekstā [95], [96]. Kā definējis *Mayring* [97], kvalitatīvā satura analīze ir sistemātiska, noteikumos balstīta metode tekstuāla materiāla interpretēšanai. Tā ļauj veikt empīrisku, teorētiski pamatotu analīzi bez priekšlaicīgas kvantificēšanas. Kvalitatīvā satura analīze ir piemērota pelēkās literatūras analīzei un tās interpretācijai atbilstoši kontekstam [98], [99]. Metode ļauj izstrādāt analītiskas kategorijas, pamatojoties uz pētījuma jautājumu, un tās var pielāgot, izpētes gaitā [99]. Kategorijas jeb tematiskās grupas netiek iepriekš noteiktas, bet izveidojas kodēšanas procesa laikā, atlasot teksta fragmentus ar meklēšanas terminu palīdzību un grupējot tos atbilstoši aptvertajām tēmām [98]. Pētījuma jautājums ir par pamatu kodēšanas struktūras izstrādei un turpmākajai tematiskajai analīzei, nodrošinot analītiskā procesa un pētījuma mērķu saskaņotību [98]. Horizontālās politiskās saskaņotības noteikšanai ES līmenī tika izmantota hibrīda kategorizācijas pieeja, apvienojot deduktīvu un induktīvu stratēģiju [98]. Deduktīvā pieeja balstās uz esošo teorētisko pamatu un iepriekšējām zināšanām, kas tiek izmantotas, lai izstrādātu sākotnējos kodus [98]. Attiecīgā pētījuma kontekstā tie bija ES normatīvie un politikas dokumenti, kas saistīti ar *CRCF* regulu un tās darbības elementiem. Savukārt induktīvā (uz datiem balstītā) pieeja tika izmantota, lai identificētu papildu tēmas vai jēdzienus, kas parādījās analīzes procesā [98].

Pētījuma (9. publikācija) pirmais solis bija pētījuma jautājuma definēšana, kas attiecīgā pētījuma posma kontekstā bija: (1) kā *CRCF* regula ir horizontāli integrēta ar citiem ES klimata un lauksaimniecības politikas dokumentiem, jo īpaši saistībā ar oglekļsaistīgu lauksaimniecību un (2) kādi ir galvenie izaicinājumi un iespējas, lai panāktu vertikālu politikas saskaņotību, īstenojot *CRCF* regulu dalībvalstu līmenī. Pētījuma jautājuma definēšanai sekoja piecu sākotnējo meklēšanas terminu atlase, izmantojot deduktīvo pieeju. Analīze tika iesākta ar *CRCF* regulu, savukārt turpmākie dokumenti tika atlasīti ar “sniega pikas” izlases palīdzību [100], [101], iekļaujot analīzē politikas un normatīvos dokumentus, uz kuriem tika atrastas atsauces atlasītajos teksta fragmentos. Tādējādi nākamajam analīzes posmam tika atlasīti vēl 14 dokumenti, kā arī divi papildu meklēšanas termini. Trešajā iterācijā tika identificēti vēl 16, kopā sasniedzot 31 dokumentu. Kopumā tika atlasīti un visu dokumentu analīzē izmantoti deviņi meklēšanas termini. 2.2. attēlā apkopoti kvalitatīvās satura analīzes procesa un metodoloģijas soļi. Attēla augšējā daļā parādīti meklēšanas terminu un dokumentu atlases soļi, kam seko atlasīto teksta fragmentu kvalitatīva analīze un manuāla grupēšana 17 provizoriskās kategorijās, kas vēlāk strukturēti deviņās tematiskās grupās, pamatojoties uz atkārtojošām tēmām, kontekstuālām saiknēm un nozīmīgumu, kas novērots visā datu kopā. Atbilstošie analīzes soļi norādīti apakšā.



2.2. att. Kvalitatīvās satura analīzes metodika *(virs bultas: meklēšanas termini un to atlases posmi, dokumentu atlases posmi un deviņas identificētās tematiskās grupas; zem bultas: atbilstošie metodiskie posmi)*.

Rezultātu sadaļā (3.1.1. apakšnod.) sniegts pārskats par analizētajiem dokumentiem, meklēšanas terminu pieminēšanas biežumu un teksta fragmentu sadalījumu pa tematiskajām grupām.

2.2. Daudzkritēriju lēmumu pieņemšanas metodes

2.2.1. Alternatīvu prioritizēšana pēc līdzības ar ideālo risinājumu

MCDA alternatīvu prioritizēšana pēc līdzības ar ideālo risinājumu (*TOPSIS*) metode bieži tiek lietota vides stratēģiju un ilgtspējīgas attīstības novērtēšanā. Metodes galvenā priekšrocība ir iespēja salīdzināt vairākas alternatīvas, nosakot to tuvumu ideāliem pozitīviem un negatīviem risinājumiem [102], [103], [104]. Ideālie pozitīvie un negatīvie rezultāti tiek noteikti aprēķinu procesā [102], [103]. *TOPSIS* stiprā puse ir tās vienkāršība un salīdzinoši nelielais datu apjoms, kas nepieciešams tās piemērošanai [104], [105]. Viena no metodes būtiskām sastāvdaļām ir svērto kritēriju vērtību izmantošana, atkārtojot aprēķinu ar vienādiem kritēriju svariem, tādējādi nosakot svaru ietekmi uz rezultātiem [105]. Metodes lietojums tika veikts sekojot zemāk uzskaitītajiem soļiem un aprēķina formulām [106], [107], [108]:

$$D = \begin{array}{c} A_1 \\ \vdots \\ A_m \end{array} \overset{\begin{array}{ccc} C_1 & \dots & C_n \end{array}}{\begin{pmatrix} x_{11} & \cdots & x_{1n} \\ \vdots & \ddots & \vdots \\ x_{m1} & \cdots & x_{mn} \end{pmatrix}} \qquad (2.1.)$$

kur $A1 \dots A_m$ – salīdzināmās alternatīvas;

$C1 \dots C_n$ - kritēriji, saskaņā ar kuriem tiek veikts salīdzinājums;

x_{ij} - alternatīvas i (kur i ir alternatīva no 1 līdz m) sniegums/vērtība saskaņā ar kritēriju j (kur j no 1 līdz n).

Secīgi tiek izstrādāta lēmumu pieņemšanas matrica. Vērtības tiek normalizētas un izstrādāta normalizēta lēmumu matrica. Normalizētais vērtējums tiek aprēķināts, izmantojot 2.2. formulu:

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}} \qquad (2.2.)$$

kur i — alternatīva;

j — kritērijs;

x_{ij} —sākotnējais rādītājs (alternatīvas *i* vērtība pēc kritērija *j*)

r_{ij} —normalizētā vērtība (alternatīvas *i* vērtība pēc kritērija *j*, pēc normalizācijas);

Kad iegūts normalizētais visu alternatīvu vērtējums, tiek noteikts katra kritērija individuālais svars w_j. Svars tiek noteikts, izpildot nosacījumu – kritēriju svara summa ir vienāda ar 1. Nākamajā solī kritēriju svara koeficienti w_j tiek reizināti ar normalizētajām vērtībām r_{ij}, lai iegūtu normalizēto svērto vērtību w_{ij}, kā parādīts 2.3. vienādojumā:

$$w_{ij} = w_j \times r_{ij} \tag{2.3.}$$

Kad normalizētā svērto lēmumu matrica izveidota, tiek aprēķināts ideālais pozitīvais risinājums (d_i^+) un ideālais negatīvais risinājums (d_i^-). Vispirms tiek noteikts attālums līdz ideālajam risinājumam (MAX) un attālums līdz ideālajam negatīvajam risinājumam (MIN). Attālumi tiek noteikti izmantojot šādas formulas:

$$= MAX\ (w_{1j} \div w_{mj}) \tag{2.4.}$$

$$= MIN\ (w_{1j} \div w_{mj}) \tag{2.5.}$$

Pēc attāluma līdz ideālajam pozitīvajam un ideālajam negatīvajam risinājumam noteikšanas, nākamais solis ir ideālā pozitīvā (d_i^+) un ideālā negatīvā risinājuma (d_i^-) noteikšana saskaņā ar formulām 2.6. un 2.7.:

$$d_i^+ = \sqrt{\sum_{j=1}^{n}\left(w_{ij} - w_j^+\right)^2} \tag{2.6.}$$

$$d_i^- = \sqrt{\sum_{j=1}^{n}\left(w_{ij} - w_j^-\right)^2} \tag{2.7.}$$

Alternatīvas relatīvais tuvums ideālajam risinājumam tiek aprēķināts, kā parādīts 2.8. formulā:

$$C_i = \frac{d_i^-}{d_i^+ + d_i^-} \tag{2.8.}$$

Rezultāts ir vienāds ar vērtībām, kas parāda alternatīvas ar lielāku *Ci* vērtību tuvumu ideālajam pozitīvajam risinājumam un attālumu no ideālā negatīvā risinājuma.

Jutīguma analīze tika veikta, lai novērtētu, kā *TOPSIS* rezultāti mainās, variējot kritēriju svaru. Katram kritērijam tika pakāpeniski mainīts svars ar soli 0,1 intervālā no 0,1 līdz 0,9, vienlaikus nodrošinot, ka visu kritēriju svaru summa ir vienāda ar 1. Mainot konkrētā kritērija svaru w_{j^*}, atlikušais svars tika vienmērīgi sadalīts starp pārējiem kritērijiem saskaņā ar 2.9. formulu:

$$w_j = \frac{1 - w_{j^*}}{n-1}, \quad j \neq j^* \tag{2.9.}$$

kur *n* – kopējais kritēriju skaits,

w_{j^*} — svērtā kritērija vērtība, kuru variē jutīguma analīzē;

wj – pārējo kritēriju svars, kas sadalās vienmērīgi.

Iegūtie relatīvā tuvuma koeficienti C_i tika attēloti diagrammās, kas parādīja alternatīvu rangu izmaiņas. Ilgtspējīgākā alternatīva tika noteikta kā tā, kuras rezultāti saglabājās visstabilāk, t.i., ar pārsvarā augšupejošām līknēm kritēriju svaru variācijas gadījumā.

Eiropas un nacionālo bioekonomikas stratēģiju saskaņotības novērtējums

2012. gada Eiropas Bioekonomikas stratēģijas [88] un tās atjauninātās versijas 2018. gadā [89] vertikālā saskaņotības ar deviņu ES dalībvalstu bioekonomikas stratēģijām (2.2. tab.) novērtēšanai tika izmantota *TOPSIS* metode. Pētījuma (3. publikācija) ietvaros tika identificēti mērķi un rīcības virzieni nacionālajās bioekonomikas stratēģijās un tematiski grupēti atbilstoši Eiropas bioekonomikas stratēģijā noteiktajiem mērķiem un rīcības virzieniem.

2.2. tabula

Analīzē iekļautās dalībvalstu bioekonomikas stratēģijas

Valsts	Gads	Valsts bioekonomikas stratēģija
Austrija	2019	Austrijas bioekonomika Stratēģija Austrijai [109]
Somija	2014	Somija Somijas bioekonomikas stratēģija [110]
Francija	2015	Francijas bioekonomikas stratēģija. Mērķi, problēmas un nākotnes redzējums [111]
	2017	Francijas bioekonomikas stratēģija. 2018.–2020. gada rīcības plāns [112]
Vācija	2020	Valsts bioekonomikas stratēģija [113]
Īrija	2018	Valsts politikas paziņojums par bioekonomiku [114]
Itālija	2019	Bioekonomika Itālijā (BIT II) [115]
	2017	Bioekonomika Itālijā (BIT) [116]
Latvija	2017	Latvijas Bioekonomikas stratēģija 2030 [42]
Nīderlande	2018	Bioekonomikas nozīme Nīderlandē [117]
Spānija	2016	Spānijas bioekonomikas stratēģija – 2030. gads [118]

Tika pārskatīti nacionālo bioekonomikas stratēģiju pilnie teksti. Katru reizi, kad tika atrasta saikne, tā tika reģistrēta, piešķirot tai vērtību 1, vēlāk skaitļi tika summēti. Valstu bioekonomikas stratēģijās minētie mērķi un pasākumi, kurus nevarēja tieši sasaistīt ar Eiropas līmenī noteiktajiem, tika uzskaitīti sadaļā "Citi pasākumi". Rezultāti tika apkopoti un analizēti, izmantojot *TOPSIS* metodi. Kritēriju svara noteikšanai tika izmantota ekspertu aptaujas metode, un iegūto novērtējumu vidējās vērtības (2.3. tab.) tika izmantots kā *TOPSIS* kritēriju svars ar kopējo summu 100 %. Ekspertu atlases principi un svaru noteikšanas kārtībā aprakstīta 2.4.3. apakšnodaļā un 3. publikācijā, kas arī veido šīs pieejas metodoloģisko pamatojumu. Lai noteiktu ekspertu novērtējumā noteikto svaru ietekmi uz kritēriju novērtējumu, tiek veikta atkārtota novērtēšana, visiem kritērijiem piešķirot vienādus svarus. Šī pieeja kalpo kā jutīguma analīze, kas ļauj pārbaudīt rezultātu stabilitāti attiecībā pret svaru izmaiņām.

Pētījuma nepārtrauktības un rezultātu salīdzināmības nodrošināšanai, politiskās saskaņotības novērtējumam starp Eiropas bioekonomikas stratēģiju un 10 dažāda līmeņa Latvijas politikas plānošanas dokumentiem (2. publikācija) tika izmantoti tie paši kritēriju svari, kas norādīti 2.3. tabulā. Šie svērumi tika ievadīti *TOPSIS* matricā un izmantoti aprēķinos.

2.3. tabula

Kritēriju svari mērķiem un rīcības virzieniem, kas noteikti Eiropas bioekonomikas stratēģijā

Nr.	**Rīcības virzieni**	**Kritēriju svars, w_j**
1	Pārtikas un uztura nodrošinājums	0,11
2	Dabas resursu ilgtspējīga apsaimniekošana	0,18
3	Mazāka atkarība no neatjaunojamiem, neilgtspējīgiem resursiem	0,19
4	Klimata pārmaiņu mazināšana un pielāgošanās tām	0,12
5	Eiropas konkurētspējas stiprināšana un darbavietu radīšana	0,10
6	Stiprināt un paplašināt bioloģiskās nozares, atraisīt investīcijas un tirgu	0,13
7	Ātra vietējo bioekonomiku ieviešana visā ES	0,08
8	Izpratne par bioekonomikas ekoloģiskajām robežām	0,09
KOPĀ		**1,00 (100 %)**

Zivsaimniecības un akvakultūras produktu ilgtspējas novērtējums

Tika salīdzināti seši dažādi zivsaimniecības un akvakultūras produkti (7. publikācija): (1) biogāze; (2) spirulīna (uztura bagātinātājs); (3) augu mēslojums no aļģēm; (4) zivju milti un eļļa; (5) biodīzeļdegviela; (6) zivju konservi. Lai salīdzinātu alternatīvas, pētīto alternatīvu izejvielu daudzums tika noteikts 1 tonna aļģu un 1 tonna zivju vai to blakusproduktu. Produktu ilgtspējas novērtēšanai kritēriji tika sadalīti četrās kategorijās - ekonomiskie, vides, tehniskie un sociālie kritēriji. Sešas no astoņām kritēriju vērtībām, tika noteiktas, aprēķinot vidējo aritmētisko no ekspertu sniegtā vērtējuma. Tika izvērtēti arī divi kvantitatīvie kritēriji, proti, izvēlēto produktu cena un enerģijas patēriņš. Pārdošanas cena tika noteikta, aprēķinot produkta vidējo cenu, pēc datu apkopošanas no tiešsaistes tirdzniecības vietnēm.

Ilgtspējīgākā zivsaimniecības un akvakultūras produkta noteikšanai, tika lietota *TOPSIS* metode. Pamatojoties uz iepriekš minētajiem kritērijiem, tika izveidota vērtību matrica un kritēriji tematiski sagrupēti pa kategorijām (2.4. tab.). Alternatīvas sakārtotas pēc attiecīgā produkta veida, vispirms norādot alternatīvas no aļģēm, pēc tam no zivju produktiem.

2.4. tabula

TOPSIS analīzei izmantotās vērtības

	Biogāze	**Spirulīna**	**Mēslojums**	**Zivju eļļa un milti**	**Biodīzeļdegviela**	**Pārtika (konservēta)**
Ekonomiskie rādītāji	3,30	3,82	2,75	3,64	3,38	3,36
Pārdošanas cena (EUR/t)	67,00	30,00	10,00	2350,00	57,21	4750,00
Vides un klimata rādītāji	3,39	3,39	3,11	3,20	3,54	3,04
Ietekme uz bioloģisko daudzveidību	2,90	3,29	3,04	3,43	3,32	3,29
Tehnoloģiju attīstības līmenis	3,54	3,32	3,43	3,57	2,90	4,00
Enerģijas patēriņš (kWh/t)	220,00	218,00	350,00	32,00	187,70	170,00
Potenciālais darbavietu skaits	2,90	3,54	2,70	3,54	3,18	4,07
Ētiskie aspekti	3,60	4,30	3,60	2,67	2,08	2,85

Visiem kritērijiem tika piešķirts vienāds svars 0,125. Pēc svērtās normalizētās matricas izveides tika noteikts to tuvums ideālajiem pozitīvajiem un negatīvajiem risinājumiem. Visos gadījumos, izņemot enerģijas patēriņa un ietekmes uz bioloģisko daudzveidību kritēriju aprēķinu, par ideālo pozitīvo vērtību tika ņemta maksimālā skaitliskā vērtība, bet par ideālo negatīvo vērtību – minimālā skaitliskā vērtība. Noteiktās ideālās pozitīvās un negatīvās vērtības tika izmantotas, lai aprēķinātu relatīvo tuvuma koeficientu.

Lai noteiktu katra kritērija vērtības ietekmi uz kopējo izvērtējumu, pēc *TOPSIS* metodes lietošanai, tika veikta jutīguma analīze. Šim nolūkam katram kritērijam tika izveidota matrica, kurā parādītas katras alternatīvas relatīvā tuvuma koeficienta vērtības, mainot kritērija svērumu.

2.2.2. Analītiskais hierarhijas process

Analītiskais hierarhijas process (AHP) tiek izmantots, lai noteiktu kritēriju relatīvo nozīmīgumu, balstoties uz pāru salīdzinājuma matricu, kas atspoguļo lēmuma pieņēmēju vērtējumu par kritēriju savstarpējo nozīmi. AHP ir viena no visplašāk lietotajām *MCDA* metodēm, ko izmanto arī sociālo un politisko jautājumu izvērtēšanai [119], [120].

Pāru salīdzinājuma un alternatīvo risinājumu vērtēšanas matricas tika veidotas, balstoties *Samal un Kansal* (2015) aprakstītajā metodikā [121]. Salīdzinot divus risinājumus, to krustpunktā ievada attiecīgo vērtējumu. Vērtējumi tika noteikti, izmantojot *Saaty* relatīvās nozīmības skalu (1–9), kas ļauj ņemt vērā vairākus viedokļus vai ekspertu perspektīvas [119], [122]. AHP matricas izveidei un faktoru vērtību noteikšanai tika izmantoti zemāk norādītie vienādojumi [104], [123]. Normalizētas matricas aprēķins veikts ar vienādojumu 2.10.:

$$X_{ij} = \frac{C_{ij}}{\sum C_{ij}} \quad (2.10.)$$

kur *Cij* – kritērija vērtība;

$\sum$*Cij* - kolonnas summa.

Prioritātes vektora aprēķināšana tiek veikta pēc vienādojuma 2.11.:

$$W_{ij} = \frac{\sum X_{ij}}{\mathrm{n}} \quad (2.11.)$$

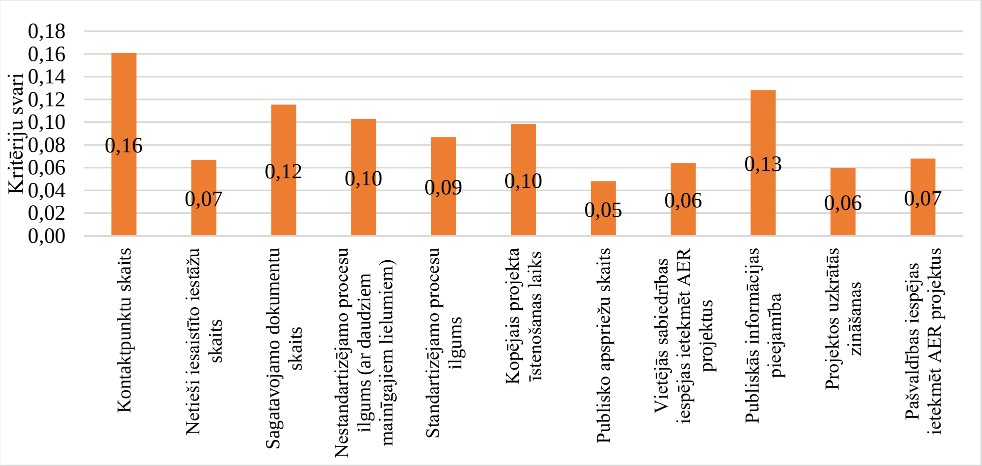
kur $\sum$*Xij* – normalizēta matricas kolonnu summa;

n – kritēriju skaits.

AER projektu īstenošanas administratīvo satvaru salīdzinājums

AER elektroenerģijas ražošanas infrastruktūras projektu īstenošanas administratīvo satvaru salīdzinājums (4. publikācija) balstījās piecos galvenajos kritērijos: (1) īstenošanas procesa grafiks; (2) sarežģītība; (3) informācijas pieejamība; (4) sabiedrības viedokļa ietekme; (5) pašvaldības ietekme. Tika ņemti vērā tādi faktori kā izpildes termiņi, procesa sarežģītība, informācijas pieejamība, sabiedrības viedokļa ietekme un vietējo pašvaldību loma. Kritēriju vērtējumi tika analizēti, izmantojot *MCDA* metodes *TOPSIS* un AHP, kas ļauj vienlaikus salīdzināt kvalitatīvus un kvantitatīvus rādītājus. AHP metode tika lietota, lai noteiktu kritēriju relatīvo nozīmīgumu, atspoguļojot lēmumu pieņēmēju skatījumu. Pieci neatkarīgi eksperti izstrādāja svaru matricas, un gala aprēķinos tika izmantoti vidējie svērumi. Kritērijiem piešķirtie svari redzami 2.3. attēlā. Tā kā svari noteikti no projektu īstenotāju perspektīvas, augstākie vērtējumi piešķirti kontaktpunktu skaitam, pieejamās publiskās informācijas apjomam un nepieciešamo dokumentu daudzumam.

TOPSIS rezultātu jutīguma analīze netika veikta, jo kritēriju svari tika noteikti, izmantojot piecu neatkarīgu ekspertu vērtējumus, un gala aprēķinos izmantotas šo vērtējumu vidējās vērtības. Tā kā ekspertu atlase un piešķirtie svari atspoguļo AER projektu attīstītāju faktisko perspektīvu, vienādu svaru scenārija piemērošana vai alternatīvu normalizācijas metožu izmantošana būtu metodoloģiski neatbilstoša šī pētījuma mērķim.



2.3. att. Noteiktie kritēriju svari.

TOPSIS metode tika lietota, lai atsevišķi novērtētu dažādus enerģijas ražošanas tehnoloģiskos risinājumus: mikroģeneratori, liela un vidēja mēroga saules elektrostaciju (SES) un liela un vidēja mēroga vēja elektrostaciju (VES) projektus. VES un SES tiek uzskatītas par vidēja lieluma iekārtām ar jaudu līdz 10 MW un liela mēroga elektrostacijām ar jaudu virs 10 MW; šis iedalījums balstās uz jaudu, kas pieslēdzama elektroenerģijas pārvades sistēmai, kas vairumā pētījumā iekļauto valstu sākas no 10 MW.

Nišas produktu attīstības ietekmējošo faktoru izvērtējums

AHP metode tika izmantota, lai noteiktu stipro un vājo pušu, iespēju un draudu analīzes (SVID) relatīvo nozīmīgu identificētajiem faktoriem (8. publikācija). Pēc tam, kad eksperti bija noteikuši trīs perspektīvus meža sektora nišas produktus un izvērtējuši to stiprās un vājās puses, iespējas un draudus, katrā kategorijā tika atlasīti pieci nozīmīgākie faktori. Šie faktori tika pakļauti papildu pāru salīdzināšanai, kas ļāva integrēt dažādus ekspertu skatījumus. Rezultātā tika izveidotas AHP matricas un noteikti faktoru svari, kas turpmāk tika izmantoti *TOWS* matricā, lai izstrādātu stratēģiskos attīstības virzienus produktiem un meža nozarei kopumā.

2.2.3. Svērto summu metode

Svērto summu metode (*SAW*) ir *MCDA* metode, kas balstās normalizēto vērtību svērtajā summā katrai alternatīvai visiem kritērijiem [124]. Mērķis ir atrast augstāko punktu skaitu un tādējādi labāko alternatīvu. Šī metode normalizē lēmumu pieņemšanas matricu salīdzināmai skalai. Šo metodi galvenokārt izmanto, lai risinātu daudzkritēriju lēmumu pieņemšanas problēmas.

Lēmumu matrica ir ($m \times n$) matrica, kurā katrs elements x_{ij} atspoguļo alternatīvas A_i vērtību, pamatojoties uz lēmuma kritēriju C_j. Alternatīvas apzīmē ar $i = 1, 2, 3, ..., m$, kritērijus apzīmē ar $j = 1, 2, 3, ..., n$. Katram elementam tiek piešķirts skaitliskais svars w_j [124], [125]. Pirmais solis ir normalizēt lēmumu matricu, izmantojot 2.12. vienādojumu ieguvuma atribūtam un 2.13. vienādojumu izmaksu atribūtam [124].

$$r_{ij} = \frac{x_{ij}}{Max\,(x_{ij})} \tag{2.12.}$$

$$r_{ij} = \frac{Min\,(x_{ij})}{x_{ij}} \tag{2.13.}$$

kur r_{ij} ir i alternatīvas normalizētā vērtība j kritērijam.

Katras alternatīvas kopējo punktu skaitu aprēķina, reizinot normalizētos datus katram kritērijam ar tā svarīgumu. Svarīgumam ir piemērojami ierobežojumi 2.14. un 2.15. vienādojumā. Kopējo punktu skaita rezultāts ir parādīts 2.16. vienādojumā [124].

$$\sum_{j=1}^{n} w_j = 1 \tag{2.14.}$$

$$0 \leq w_j \leq 1 \tag{2.15.}$$

$$S_i = \sum_{j=1}^{n} w_j\, r_{ij} \tag{2.16.}$$

kur S_i ir i alternatīvas kopējais vērtējums.

Alternatīvas tiek sarindotas atbilstoši to kopējiem rezultātiem, un alternatīva ar augstāko kopējo rezultātu ir labākā [124].

Ranga noteikšana profesionālās izglītības kompetences centriem

23 PIKC rangs tika noteikts (5. publikācija), izmantojot vienkāršo salikto rādītāju un *SAW* metodi, kurā tika ņemti vērā trīs kritiski faktori. Faktors tika uzskatīts par "ieguvuma atribūtu", ja tā vērtības palielinājums bija vēlams, un par "izmaksu atribūtu", ja noticis pretējais [126]. Šie faktori bija šādi:

- Objekta apsekojuma laikā uz vietas iegūto aptaujas punktu skaits, kas ir ieguvuma atribūts un kam piešķirts svars 0,1;
- Primārās enerģijas patēriņa samazinājums uz vienu ieguldīto eiro; tas ir ieguvuma atribūts, kam piešķirts svars 0,45;
- Nepieciešamās investīcijas eiro, lai samazinātu CO_2 emisijas par vienu kilogramu; tas ir izmaksu atribūts, kam arī piešķirts svars 0,45.

Ņemot vērā šos trīs kritērijus un to svērumu, tika noteikts kompetenču centru rangs, nodrošinot objektīvu vērtējumu. *SAW* metodika tika izmantota tādēļ, ka visi trīs kritēriji ir skaidri izmērāmi un savstarpēji tieši salīdzināmi, tāpēc papildu jutīguma analīze šajā gadījumā nebūtu sniegusi būtisku pievienoto vērtību.

2.3. Stratēģiskās plānošanas un izvērtējuma metodes

2.3.1. Fokusgrupas diskusija

Fokusgrupas ir plaši izmantota metode sociālajās un uzvedības zinātnēs, lai izprastu indivīdu uzskatus, motivāciju un attieksmi, kas ietekmē to rīcību, reaģējot uz konkrētām sociālām parādībām [127], [128]. Fokusgrupas diskusiju var uzskatīt par vairāku indivīdu viedokļu apmaiņu un dalīšanos ar informāciju, lai izpētītu dažādus temata vai zināšanu jautājuma aspektus [127], [128]. Būtiski atzīmēt, ka diskusiju mērķis nav panākt vienprātību par tēmu, bet gan aptvert tās dažādās šķautnes un izvērtēt perspektīvas [127], [128]. Fokusgrupu diskusijās parasti piedalās cilvēki, kuri nepazīst cits citu, bet ir zinoši par tēmu, un šīs diskusijas bieži vien notiek kā diskusiju cikls [129].

2.3.2. SVID analīze

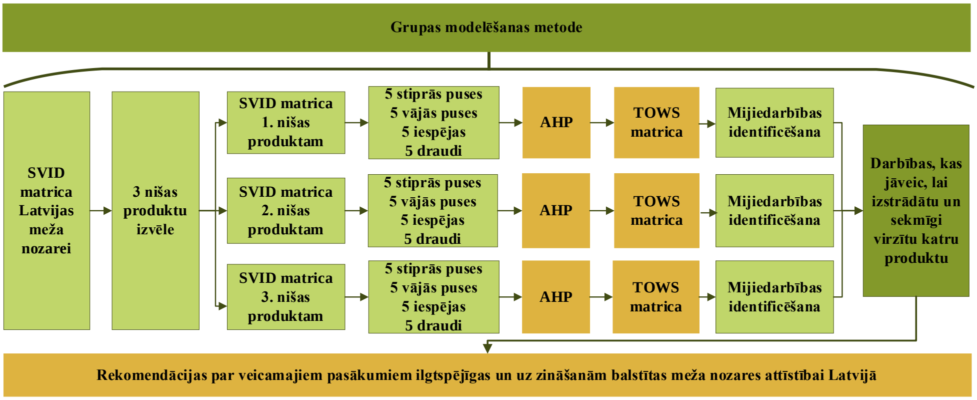
SVID matrica ir plaši izmantota metode iekšējo un ārējo ietekmju novērtēšanai un lēmumu pieņemšanai [130], [131]. Tā tiek uzskatīta par stratēģiskās plānošanas instrumentu, kas bieži izmantots uzņēmējdarbībā un dažādu projektu novērtēšanā, tā arvien plašāk tiek lietota arī politikas plānošanas un publiskās pārvaldības kontekstā, jo ļauj savlaicīgi identificēt turpmākās attīstības iespējas un riskus [130], [132]. Vienlaikus SVID matricas trūkums ir tas, ka tā vispārina matricā uzskaitītos faktorus, neizvērtējot katru faktoru detalizēti [130], [131]. Tādēļ šī metode nereti tiek kombinēta ar citām metodēm, piemēram, AHP vai *TOWS*, kas nodrošina dziļāku analīzi un stratēģisko izvēļu pamatojumu. Līdzīgu pieeju izmantojuši *Kurttila et al.* [130], kur šādu metožu kombinācija tika izmantota kā daļa no meža sertifikācijas procesa stratēģiskās plānošanas. Pētījumā tika secināts, ka šo metožu kombinācija uzlabo stratēģiskajai plānošanai pieejamo informāciju un stiprina lēmumu pieņemšanas procesu [130].

2.3.3. TOWS matrica

TOWS matricu 1982. gadā izstrādāja *Weihrich* kā situācijas analīzes rīku, kas piemērots stratēģiskai plānošanai un piemērojams dažāda veida organizācijās [133]. Akronīms *TOWS* (angļu val. - *Threats, Opportunities, Weaknesses, Sthrenghts*) sastāv no tiem pašiem elementiem kā SVID matrica, taču pieeja ir atšķirīga – tā ļauj sasaistīt ārējos draudus un iespējas ar organizācijas iekšējām stiprajām un vājajām pusēm [133], [134], [135]. TOWS balstās uz četrām stratēģiju kombinācijas: (*SO*) *maxi-maxi* - iespēju maksimāla izmantošana, balstoties uz konkrētiem stiprajiem aspektiem; (*WO*) *mini-maxi* – vājās puses tiek mazinātas, izmantojot iespējas; (*ST*) *maxi-mini* – draudu mazināšana, izmantojot noteiktus spēcīgos aspektus; (*WT*) *mini-mini* – vājās puses tiek mazinātas un draudi novērsti.

Meža bioekonomikas transformācijas iespēju identificēšana

Barjeru pārvarēšanai un meža nozares spēcīgo pušu stiprināšanai, tika izmantota hibrīda pieeja, apvienojot grupu modelēšanas metodi (piemērota saskaņā ar fokusgrupu metodoloģijas principiem) ar SVID, AHP un *TOWS* metodēm (8. publikācija). Grupas modelēšanas sesijās piedalījās nozares eksperti, kuru uzdevums bija identificēt perspektīvus nišas produktus ar augstāku pievienoto vērtību un izstrādāt nozares pārveides virzienus (2.4. att.).



2.4. att. Metodika nišas produktu attīstības stratēģiju izveidei.

Lai SVID matricā iekļautos faktoru novērtējumu padarītu analītiskāku, tie tika sarindoti pēc to nozīmīguma un ietekmes, izmantojot AHP metodi. Katras matricas ietvaros tika noteikti pieci būtiskākie stipro un vājo pušu, iespēju un draudu faktori, kas tālāk tika pakļauti pāru salīdzināšanai ar *Saaty* relatīvās nozīmības skalu (1–9), nodrošinot lielāku konsekvenci un salīdzināmību. Papildus tika izmantota *TOWS* matrica, lai sintezētu ar SVID un AHP iegūtos rezultātus un noteiktu faktoru savstarpējo mijiedarbību. Šī pieeja ļāva izstrādāt četras stratēģiskās kombinācijas (*SO, WO, ST, WT*), palielinot stratēģisko pasākumu pievienoto vērtību un nodrošinot iespēju izstrādāt attīstības stratēģijas meža bioekonomikai.

2.4. Empīriskās datu vākšanas un novērtējuma metodes

2.4.1. Aptaujas

Komunikācijas stratēģijas izstrāde par ilgtspējas jautājumiem

Efektīvas komunikācijas un sabiedrības izpratnes veicināšanai sākotnēji tika veikts sešu zivsaimniecības un akvakultūras produktu ilgtspējas novērtējums kā gadījuma izpēte (7. publikācija). Nākamais solis bija sabiedrības izpratnes par klimata pārmaiņām un ilgtspējīgu produktu izvēli noskaidrošana un piemērotāko komunikācijas veidu identificēšana. Par galveno datu vākšanas rīku tika izvēlēta aptauja, kas veidota un izplatīta elektroniski, lai nodrošinātu pēc iespējas plašāku respondentu skaitu. Jautājumi bija izstrādāti tā, lai noteiktu piemērotākos komunikācijas kanālus, izvērtētu sabiedrības attieksmi pret izglītojošu saturu un noskaidrotu viedokļus par komunikācijas vides un klimata pārmaiņu jautājumos.

Aptaujas rezultāti sniedza būtisku ieguldījumu, palīdzot identificēt piemērotāko formātu, izplatīšanas veidus un informācijas sniedzējus, lai sabiedrībai sniegtu uz zināšanām balstītu informāciju. Tas savukārt veicina patērētāju spēju pieņemt informētus lēmumus un izvēlēties ilgtspējīgus produktus un materiālus. Aptauja tika izstrādāta *Google Forms* vidē un izplatīta sociālajā tīklā *Facebook*. Kopumā to aizpildīja 140 respondenti dažādās vecuma grupās, no kurām lielākā daļa bija vecumā no 18 līdz 55 gadiem. Ņemot vērā to, ka izlase veidojās ar pašatlasi, rezultāti nav reprezentatīvi visai Latvijas sabiedrībai, taču tie sniedz uzticamu ieskatu izvēlētās respondentu grupas komunikācijas paradumos.

Izglītības iestāžu apsekojumi un aptaujas

PIKC novērtēšana (5. publikācija) tika veikta, tās apmeklējot klātienē un izsniedzot vienotu aptauju katras iestādes pārstāvim. Aptauja tika sagatavota, balstoties *Groves et al.* [136] metodikā, un ietvēra četras jautājumu kategorijas: (1) enerģijas patēriņš un uzvedība; (2) vides politika un izglītība; (3) galvenie elektroenerģijas patērētāji; (4) līdz šim īstenotie energoefektivitātes un taupības pasākumi.

Aptaujas mērķis bija iegūt gan tehnisko informāciju par primārās enerģijas patēriņu un izglītības iestāžu ēku ekspluatācijas apstākļiem, gan plašāku ieskatu par organizētajām vides aktivitātēm, izglītības programmās iekļautajām vides tēmām, atkritumu apsaimniekošanu un mācībspēku iesaistīšanos ilgtspējīgas attīstības iniciatīvās. Atbildes tika kvantificētas, izmantojot bināro punktu sistēmu (pozitīva atbilde 1 punkts, negatīva atbilde 0 punkti) [137]. Šī pieeja ļāva sistemātiski novērtēt esošo enerģētikas un vides pārvaldības praksi un identificēt iespējamos primārās enerģijas patēriņa samazināšanas pasākumus.

2.4.2 Datu vākšana

AER projektu īstenošanas administratīvo satvaru salīdzinājums

AER elektroenerģijas ražošanas infrastruktūras projektu īstenošanas administratīvo sistēmu salīdzinājums (4. publikācija) balstās noteiktos un saskaņotos kritērijos. Procedūru salīdzināšanai tika noteikti pieci galvenie aspekti (2.5. tab.), ņemot vērā izpildes termiņus, sarežģītību, informācijas pieejamību, sabiedrības viedokļa ietekmi un vietējo pašvaldību lomu. Katrs no kritērijiem ietvēra vienu vai vairākus apakškritērijus, kuru izvērtēšanai tika apkopots apjomīgs datu kopums, nodrošinot daudzpusīgu administratīvo sistēmu novērtējumu. Analīze balstījās pētījumā iekļauto valstu spēkā esošajos normatīvajos dokumentos, nepieciešamības gadījumā izmantojot publiski pieejamu informāciju par procesa soļiem no valsts pārvaldes iestāžu tīmekļa vietnēm.

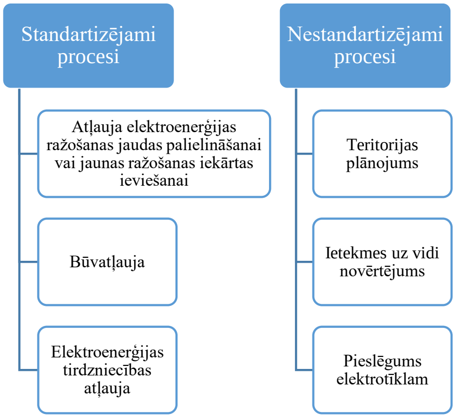
Dažas projektu īstenošanas atļauju izsniegšanas procedūras ir specifiskas katram projektam un atkarīgas no vietējās situācijas un projektu izstrādātājiem [138], [139]. Tāpēc termiņi tiek analizēti atsevišķi procesiem ar standartizējamiem un skaidri definējamiem noteikumiem, un atsevišķi nestandartizējamiem atļauju izsniegšanas vai apstiprināšanas procesiem, kuros ņemti vērā dažādi projekta specifiski elementi, kā arī izstrādātāja spēja savlaicīgi izpildīt iestāžu prasības.

2.5. tabula

Kritēriju pārskats, lai salīdzinātu AER enerģijas ražošanas infrastruktūras projektu īstenošanas procedūras dažādās valstīs

Dimensija	Kritēriji	Novērtējuma veids	Mērvienība	Datu avots
Īstenošanas procesa grafiks	Standartizējamo procesu posmu ilgums	Kvantitatīvs	Dienu skaits	Normatīvie dokumenti un publiski pieejamā informācija valsts iestāžu timekļa vietnēs
	Laiks nestandartizējamiem procesa posmiem	Kvantitatīvs	Dienu skaits	Normatīvie dokumenti un publiski pieejamā informācija valsts iestāžu timekļa vietnēs, projektu apraksti
	Kopējais projekta īstenošanas laiks	Kvantitatīvs	Dienu skaits	Informācija par īstenotajiem projektiem
Sarežģītība	Kontaktpunktu skaits (kontaktinstitūcijas)	Kvantitatīvs	Kontaktinstitūcijų skaits	Normatīvie dokumenti un publiski pieejamā informācija valsts iestāžu timekļa vietnēs
	Vairākas netieši iesaistītas iestādes	Kvantitatīvs	Iesaistīto iestāžu skaits	Normatīvie dokumenti un publiski pieejamā informācija valsts iestāžu timekļa vietnēs
	Nepieciešamo dokumentu skaits	Kvantitatīvs	Dažādu veidu dokumentu skaits	Normatīvie dokumenti un publiski pieejamā informācija valsts iestāžu timekļa vietnēs
Informācijas pieejamība	Publiskās informācijas pieejamība	Kvalitatīvs	3 punktu skala	Ekspertu novērtējums par informācijas pieejamību
	Uzkrātās zināšanas par projekta īstenošanu	Kvantitatīvs	Rādītājs (kW/tūkstoš iedzīvotāju)	Statistikas dati
Sabiedrības viedokļa ietekme	Sabiedrisko apspriežu skaits, kas jāorganizē projekta īstenošanas procesā	Kvantitatīvs	Sabiedrisko apspriežu skaits	Normatīvie dokumenti un publiski pieejamā informācija valsts iestāžu timekļa vietnēs
	Vietējās sabiedrības iespējas ietekmēt AER projektu īstenošanu	Kvalitatīvs	3 punktu skala	Ekspertu novērtējums, pamatojoties uz pieejamo informāciju
Pašvaldības ietekme	Pašvaldības iespēja ietekmēt AER projektu īstenošanu	Kvalitatīvs	3 punktu skala	Ekspertu novērtējums, pamatojoties uz pieejamo informāciju

2.5. attēlā redzami standartizējami procesi ar paredzamiem mainīgajiem lielumiem un fiksētu īstenošanas termiņu — atļaujas elektroenerģijas ražošanas jaudas palielināšanai vai jaunas ražošanas iekārtas ieviešanai, būvatļaujas un elektroenerģijas tirdzniecības atļaujas. Pieteikumu izskatīšanas un attiecīgo atļauju izsniegšanas termiņi ir noteikti, analizējot normatīvos dokumentus un iestāžu tīmekļa vietnēs publiski pieejamo informāciju. Tādi procesi kā ietekmes uz vidi novērtējums (IVN), izmaiņas teritoriālajā plānojumā un pieslēgums elektrotīklam ir atkarīgi no konkrētā projekta un prasa papildu ekspertu iesaistīšanu, kā arī saskaņojumu no tuvumā esošo zemju īpašniekiem. Tāpēc šie procesi tika definēti kā "nestandartizējami", dēļ atšķirīgajiem izpildes termiņiem [140], [141]. Kopējais projektu īstenošanas laiks tika noteikts, balstoties uz gadījumu izpētēm, intervijām ar VES un SES parku attīstītājiem, kā arī realizēto projektu analīzi attiecīgajās valstīs.



2.5. att. Laika grafika analīze atkarībā no īstenošanas procesa.

Viens no projektu ieviešanas analīzes aspektiem bija koordinācijas procesa sarežģītība, tieši iestāžu skaits, kurās projekta attīstītājam jāiesniedz saņemtās atļaujas vai apstiprinājumi projekta attīstības ietvaros veicamajām darbībām [142], [143]. Direktīva (ES) 2018/2001 nosaka, ka, lai AER projektu īstenošana noritētu vienmērīgāk, dalībvalstīm būtu jāizveido vienots kontaktpunkts, kurā var saņemt visus nepieciešamos apstiprinājumus vai atļaujas, lai atvieglotu projektu īstenošanu [58], [62]. Tādējādi pirmais kritērijs "sarežģītības" dimensijā ir kontaktpunktu skaits. Otrs kritērijs ir netieši iesaistīto iestāžu skaits, piemēram, VES gadījumā tās varētu būt militārās institūcijas, bet SES gadījumā lidostas tuvums un nepieciešamie saskaņojumi no tām. Trešais kritērijs ir aptuvenais dokumentu skaits, kas nepieciešams projekta apstiprināšanai, kas varētu norādīt uz papildus administratīvo slogu.

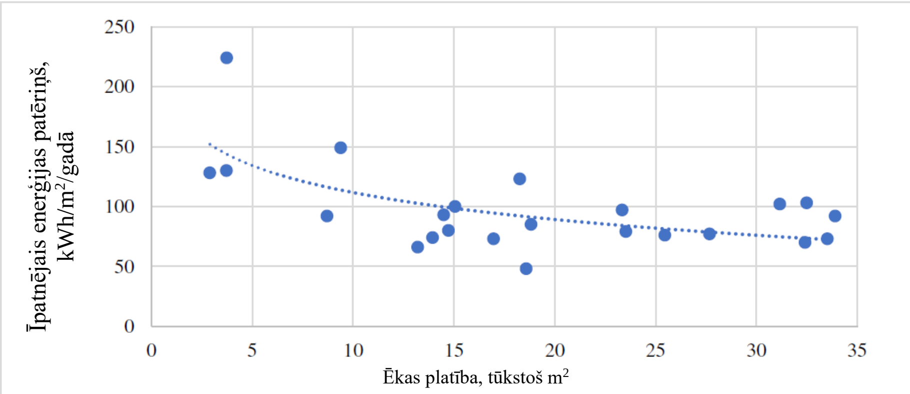
Būtisks aspekts, kas nodrošina AER projektu sekmīgu īstenošanu, ir pieejamā informācija par administratīvajām procedūrām un nepieciešamajām atļaujām [144]. Pētījumā tika novērtēta informācijas pieejamību, izmantojot 3 punktu skalu, kur 3 punkti tika piešķirti, ja informācija ir viegli pieejama, par visu procesu un termiņiem atrodama vienā avotā, bet 0 punkti, ja informācija nav atrodama, nav publiski pieejama. Kā kritērijs tika iekļautas uzkrātās zināšanas par AER projektu īstenošanas procesu, kas šā pētījuma kontekstā tika mērītas proporcionāli uzstādītajai jaudai.

Vietējās kopienas var būtiski ietekmēt AER projektu īstenošanu [145], [146]. Tādēļ tika vērtēta sabiedrības ietekme uz AER projektu atļauju izsniegšanas procesu un projektu īstenošanu. Pirmais identificētais kritērijs ir maksimālais publisko apspriežu skaits par AER projekta īstenošanas apstiprināšanu, otrs kritērijs ir vietējās sabiedrības iespēja ietekmēt AER projektu īstenošanu [143].

AER projekta īstenošanas panākumi un ātrums ir lielā mērā atkarīgi no vietējās pašvaldības pieredzes šāda veida projektu koordinēšanā un no tās attieksmes pret tehnoloģiju [147], [148], [149], [150]. Kvalitatīvs kritērija novērtējums tika veikts, balstoties uz normatīvo dokumentu analīzi un gadījumu izpēti, piešķirot punktus pēc 3 punktu skalas, kā tas tika darīts vietējo kopienu ietekmes novērtēšanai.

Izglītības iestāžu ilgtspējas novērtējums

Tika vākti detalizēti dati, lai novērtētu enerģijas patēriņa modeļus izglītības iestādēs (5. publikācija). Analīzē iekļautās iestādes atbilst visiem 23 PIKC Latvijā, tādējādi nodrošinot pilnu šīs institucionālās grupas aptvērumu, nevis izlasi. Datu kopa ietvēra informāciju par 167 ēkām visos 23 pētījumā iekļautajos un apsekotajos PIKC un ietvēra ēku platību, siltumenerģijas un elektroenerģijas patēriņu no 2017. gada līdz 2022. gadam mēneša griezumā, kā arī katras ēkas siltuma un elektroenerģijas avotus. Iegūtie enerģijas patēriņa dati analizētajām izglītības ēkām apkopoti 2.6. attēlā. Lielākajā daļā ēku īpatnējais enerģijas patēriņš bija robežās no 48 līdz 93 kWh/m^2/gadā, kas liecina par salīdzinoši augstu energoefektivitāti. Tikai 30 % ēku īpatnējais enerģijas patēriņš pārsniedza 100 kWh/m^2. Provizoriskā datu analīze liecināja, ka lielākajā daļā ēku jau ir tikuši veikti kompleksi renovācijas pasākumi, un, lai turpinātu uzlabot ēku kopējo efektivitāti, ir jāidentificē citi potenciāli enerģijas taupības pasākumi.



2.6. att. Regresijas analīze par ēku enerģijas patēriņu attiecībā pret kopējo ēkas platību.

Ilgtspējas pasākumu noteikšana bija daļa no vienkāršota saliktā rādītāja izveides, un pasākumu izvēle tika balstīta visaptverošā literatūras analīzē, enerģijas patēriņa datos, ēku energoefektivitātes pārbaudēs, apmeklējumos uz vietas un aptaujās. Noteiktos ilgtspējas pasākumus var iedalīt divās grupās: (1) pasākumi, kas ir līdzīgi vairumā izglītības iestāžu (obligātie pasākumi); (2) individuāli pasākumi (papildu pasākumi). Ņemot vērā pieejamo finansējumu uzlabojumu veikšanai, pirmā pasākumu grupa tika noteikta kā prioritāra finansējuma saņemšanai, bet otrajai pasākumu grupai piešķirtie līdzekļi ir starpība starp kopējo finansējuma apjomu un pirmajai pasākumu grupai nepieciešamo finansējumu. Papildu pasākumu prioritāte tiek noteikta, izmantojot optimizācijas metodi. Šī pieeja ļāva izvēlēties rentablus pasākumus, maksimāli palielinot to ietekmi uz enerģijas patēriņa un SEG emisiju samazināšanu.

Tika veikta izmaksu un ieguvumu analīze, lai noteiktu pasākumus, kvantificējot potenciālo enerģijas ietaupījumu un nepieciešamās investīciju izmaksas. 2.6. tabulā apkopotas izmaksu prognozes galvenajiem identificētajiem enerģētikas pasākumiem.

2.6. tabula

Identificēto pasākumu izmaksu pieņēmumu pārskats

Energoefektivitātes pasākums	Attiecīgās izmaksas	Avots
Enerģētikas pārvaldības darbinieka iecelšana un apmācība	1173 EUR/gadā	[151]
Ēkas pārvaldības sistēmas ieviešana	7,6 EUR/m^2	[151]
Vides politikas īstenošana	1000 EUR par ēku	Aptaujas rezultāti
Iekštelpu temperatūras kontrole	0	Ēku energoefektivitātes auditi
Informatīvie materiāli	0,01 EUR/m^2	[152]
Mehāniskā ventilācija ar rekuperāciju	30 EUR/m^2	[151]
Apgaismojuma modernizācija	8,9 EUR/m^2	[153]
Sienu siltināšana (no iekšpuses)	no 9 līdz 60 EUR/m^2	Ēku energoefektivitātes auditi
Jumta siltināšana	no 0,3 līdz 2,7 EUR/m^2	Ēku energoefektivitātes auditi
Cokola siltināšana	4,3 EUR/m^2	Ēku energoefektivitātes auditi
Logu nomaiņa	no 28,9 līdz 88,8 EUR/m^2	Ēku energoefektivitātes auditi
Sildelementu nomaiņa ar termoregulatoriem	7,4 EUR/m^2	Ēku energoefektivitātes auditi
Siltummaina nomaiņa	0,03 EUR/m^2	Ēku energoefektivitātes auditi
Siltumapgādes apakšstacijas renovācija	0,8 EUR/m^2	Ēku energoefektivitātes auditi
Jaunu apkures katlu uzstādīšana	3,6 EUR/m^2	[154]
Saules kolektori	1169,8 EUR/m^2	[154]
Saules paneļu uzstādīšana	308,2 EUR/m^2	[154]
Pieslēgums centralizētajai siltumapgādei	24,5 EUR/m^2	[154]

Papildus pasākumu optimizācija tika veikta, izmantojot *Microsoft Excel* izklājlapu programmatūru un datu risināšanas rīku [155]. Mērķis bija atrast optimālo problēmas risinājumu. Papildus pasākumi tika attēloti kā binārie mainīgie, kur vērtība 1 norāda, ka pasākums ir piemērots, bet vērtība 0 norāda, ka pasākums nav piemērots. Optimizācijas mērķis ir maksimāli samazināt primārās enerģijas patēriņu. Pieejamais budžets bija 19,14 miljoni eiro, kas tika sadalīts trīs daļās: 203 tūkstoši eiro demonstrācijas projektiem; 10,4 miljoni eiro obligātajiem pasākumiem un 8,54 miljoni eiro papildus pasākumu optimizācijai. Optimizācijas mērķis bija noteikt efektīvāko pasākumu kombināciju, kas samazinātu enerģijas patēriņu, nepārsniedzot 8,54 miljonu eiro budžeta robežu.

2.4.3. Ekspertu vērtējumi

Promocijas darba ietvaros tika izmantoti arī ekspertu vērtējumi, lai atspoguļotu nozares profesionāļu skatījumu. Pētījumos, kuros tika skatīta Eiropas bioekonomikas stratēģijas politikas saskaņotība ar ES dalībvalstu nacionālajām stratēģijām (3. publikācija), kā arī secīgajā pētījumā, kurā tika skatīta Eiropas bioekonomikas stratēģijas saskaņotība ar Latvijas politikas plānošanas dokumentiem (2. publikācija), tika veikta tiešsaistes aptauja. Aptaujā ekspertiem bija jānovērtē, kuri no pieciem mērķiem un trim rīcības jomām, kas noteikti Eiropas bioekonomikas stratēģijā [89], ir būtiskākie, lai panāktu strauju zināšanās balstītas bioekonomikas attīstību. Aptaujas anketa tika izsūtīta 35 ekspertiem, izmantojot personīgos kontaktus. Priekšnoteikums bija eksperta darbība kādā no bioekonomikas primāro resursu ieguves nozarēm (lauksaimniecība, meža sektors vai zivsaimniecība un akvakultūra) vai zinātniskā pētniecība bioekonomikas, klimata un vides ilgtspējas jomā. Aizpildītas aptaujas anketas tika saņemtas no 27 ekspertiem.

Zivsaimniecības un akvakultūras produktu ilgtspējas novērtējumam (7. publikācija) elektroniski tika aptaujāti 28 eksperti, kuri katra kritērija ietekmi uz alternatīvu novērtēja piecu punktu skalā. Vienīgais izņēmums bija kritērijs "ietekme uz bioloģisko daudzveidību". Šim kritērijam vērtējuma skala bija apgriezta: jo augstāka skaitliskā vērtība, jo negatīvāks vērtējums. To var pamatot ar to, ka ilgtspējīgai alternatīvai ir iespējami mazākā ietekme uz bioloģiskās daudzveidības samazināšanos. Ekspertu vērtējumi kritērijiem bija līdzīgi, lai gan eksperti ir specializējušies dažādās jomās.

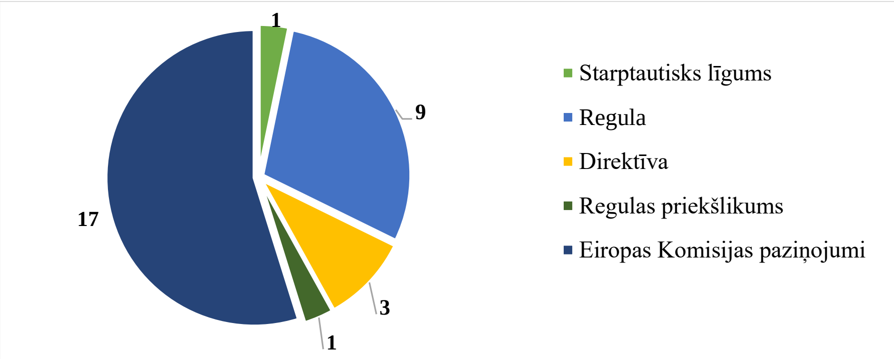
3. REZULTĀTI

3.1. Politikas saskaņotības novērtējums

Politikas saskaņotības novērtējums balstījās literatūras un dokumentu analīzes metodēs (SLP, kvalitatīva satura analīze), ko papildināja datu vākšana un *MCDA* metodes. Pirmkārt, tika vērtēta horizontālā politikas saskaņotība, analizējot, kā *CRCF* regula iekļaujas plašākā ES klimata, lauksaimniecības un ZIZIMM politikas un normatīvajā ietvarā un kādās tematiskajās jomās tās savstarpēji mijiedarbojas. Vienlaikus tika identificētas iespējamās barjeras vertikālās saskaņotības nodrošināšanai, ieviešot *CRCF* regulas sertifikācijas satvaru dalībvalstīs. Otrkārt, vertikālās saskaņotības analīze tika veikta, izvērtējot, vai Eiropas bioekonomikas stratēģijā definētie mērķi implementēti dalībvalstu bioekonomikas stratēģijās. Trešajā posmā uzmanība pievērsta Latvijas gadījumam, novērtējot vertikālo saskaņotību starp Eiropas bioekonomikas stratēģijas mērķiem un Latvijas ilgtermiņa un vidēja termiņa politikas dokumentiem. Visbeidzot, vertikālās saskaņotības novērtējums starp ES un Latvijas dokumentiem tika papildināts ar rīcībpolitikā iekļauto politikas instrumentu analīzi.

3.1.1. Politikas saskaņotības novērtējums. Oglekļsaistīga lauksaimniecība

Šajā pētījumā (9. publikācija) kvalitatīva satura analīze tika izmantota, lai analizētu 31 normatīvo un politikas dokumentu, tostarp vienu starptautisku līgumu (Parīzes nolīgumu) un vienu regulas priekšlikumu. Dokumenti, kas ir cieši saistīti ar *CRCF* regulu, ietvēra trīs direktīvas un deviņas regulas, savukārt lielākais dokumentu skaits (17) bija Eiropas Komisijas paziņojumi. Analizēto dokumentu struktūra pēc dokumentu veida ir redzama 3.1. attēlā.

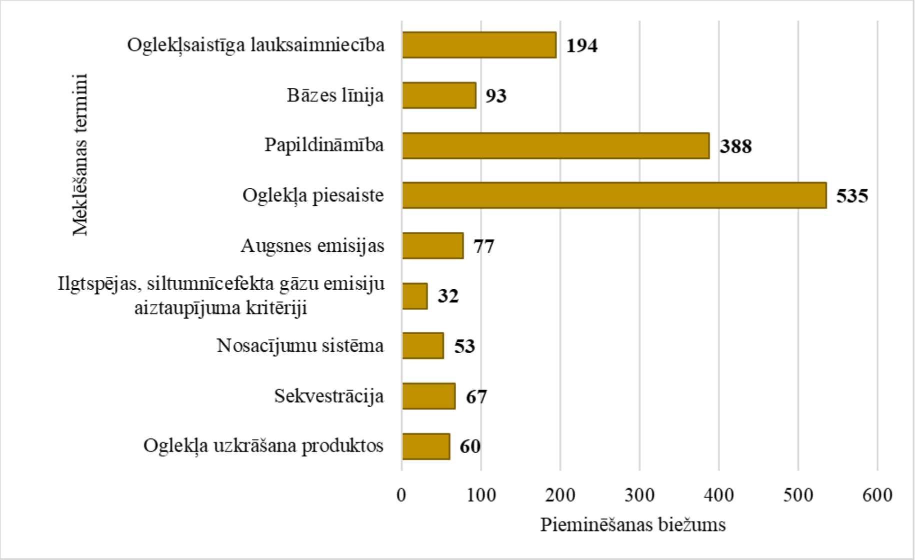


3.1. att. Analizētie dokumenti pēc dokumentu veida, skaits.

Vissenāk pieņemtais dokuments ir 2003. gadā pieņemtā "Eiropas parlamenta un padomes direktīva 2003/87/EK, ar kuru nosaka sistēmu siltumnīcas efektu izraisošo gāzu emisijas kvotu tirdzniecībai Kopienā" [39], bet jaunākais ir pieņemts 2024. gadā. Salīdzinot atlasīto dokumentu skaitu pa gadiem, no 2003. līdz 2017. gadam atlasīti tikai pieci dokumenti, bet laika posmā no 2018. līdz 2024. gadam atlasīti 26 dokumenti, kas liecina par strauju normatīvo un politikas dokumentu attīstību pētījuma jautājuma kontekstā.

Meklēšanas terminu biežuma un sadalījuma analīze

Pētījuma jautājums atspoguļojas ne tikai analizēto dokumentu skaitā, bet arī atslēgas vārdu pieminējumu biežumā. Salīdzinot divus dokumentu pieņemšanas periodus, no 2003. gada līdz 2017. gadam un no 2018. gada līdz 2024. gadam, redzams, ka pieminējumu skaits ir ievērojami pieaudzis. Pirmajā periodā (2003.–2017.) analizētajos dokumentos meklēšanas termini pieminēti tikai 26 reizes, bet no 2018. līdz 2024. gadam minējumu skaits palielinās līdz 1473. Jāuzsver, ka šie dati atspoguļo meklēšanas terminu pieminēšanas biežumu visos dokumentos, pirms saturiskas tekstu fragmentu analīzes, kuras laikā tika izslēgti tehniskie un tematiski neatbilstošie fragmenti. Meklēšanas terminu pieminējumu straujais pieaugums no 2018. gada sakrīt ar izmaiņām ES klimata politikā pēc Parīzes nolīguma noslēgšanas 2015. gada beigās. Pārejas periods pēc Parīzes nolīguma pieņemšanas atspoguļo tipisku normatīvo pārskatīšanas un politikas pielāgošanas ciklu, kurā ES sāka izstrādāt jaunas politikas un politikas instrumentus, lai mazinātu klimata pārmaiņas un veicinātu oglekļa piesaisti un sekvestrāciju. Sīkāks pieminējumu sadalījums pa meklēšanas terminiem ir redzams 3.2. attēlā.



3.2. att. Meklēšanas terminu minēšanas biežums analizēto dokumentu kopumā, skaits.

Atlasītie teksta fragmenti tika kvalitatīvi analizēti, kā rezultātā tie tika iedalīti deviņās tematiskās grupās (3.1. tab.). Šīs grupas atspoguļo galvenās mijiedarbības un saskaņotības jomas starp *CRCF* regulu un citiem ES normatīvajiem un politikas dokumentiem, jo īpaši saistībā ar klimata un lauksaimniecības politiku. Tematiskās grupas tika veidotas, pamatojoties uz to atbilstību pētījuma jautājumam, un kā ar *CRCF* regulu izveidotais sertifikācijas satvars ir strukturēts un horizontāli integrēts ES politikas instrumentos. *CRCF* regulas praktiskās īstenošanu jeb vertikālās integrācijas izaicinājumiem. Astoņas no deviņām tematiskajām grupām tika aprakstītas sīkāk, bet devītā grupa netika detalizētāk analizēta, jo ietvēra tehnisku vai ar pētījuma jautājumu nesaistītu informāciju.

3.1.tabula

Dokumentos identificētās teksta fragmentu grupas

Nr. p.k.	Tematiskā grupa	Teksta fragmentu skaits	Dokumenti, no kuriem tika atlasīti teksta fragmenti*
1.	Vispārīga informācija par ES SEG emisiju samazināšanas mērķiem	117	[15], [49], [62], [65], [88], [89], [156], [157], [158], [159], [160], [161], [162], [163], [164], [165], [166], [167], [168], [169], [170], [171], [172]
2.	*CRCF* regulas sertifikācijas sistēma kā instruments ES klimata mērķu īstenošanai	42	[49], [89], [156], [161], [164], [166], [167], [168], [173]
3.	Sertifikācijas sistēma, uzraudzība, atbalsta instrumenti	84	[49], [89], [156], [165], [167], [168]
4.	Kvantificēšana, bāzes līnija, iepriekšējās piesaistes reversija	53	[49], [156], [159], [161], [169]
5.	Saiknes un mijiedarbība starp *CRCF* un KLP	42	[156], [157], [163], [164], [165], [166], [167], [171], [174], [175], [176]
6.	Oglekļsaistīga lauksaimniecība kā uzņēmējdarbības modelis	34	[89], [156], [161], [163], [164], [165], [167], [168], [169], [171]
7.	Oglekļsaistīga lauksaimniecība un oglekļa uzglabāšana ekosistēmās un produktos	29	[49], [89], [156], [159], [160], [163], [164], [166], [173], [174], [177]
8.	Ilgtspēja, papildināmība un darbības ar papildu ieguvumiem	14	[15], [49], [62]
9.	Teksta fragmenti, kas izslēgti no turpmākas analīzes **	485	-

** Atsauces attiecas uz dokumentiem, kas uzskaitīti literatūras sarakstā*
*** Detalizēts 9 tematiskās grupas apraksts nav sniegts, jo tajā ir teksta fragmenti, kas tika izslēgti no turpmākas analīzes*

Šajā pētījumā tika izvirzīti divi pētījuma jautājumi: (1) Kā *CRCF* regula ir horizontāli integrēta ar citiem ES klimata un lauksaimniecības politikas dokumentiem, jo īpaši saistībā ar oglekļsaistīgu lauksaimniecību; (2) Kādas ir galvenās barjeras un iespējas, lai panāktu vertikālu politikas saskaņotību, īstenojot *CRCF* regulu dalībvalstu līmenī. Atbildes uz šiem jautājumiem tika meklētas, veicot kvalitatīvu satura analīzi 31 politikas un normatīvajam dokumentam. Termini “oglekļsaistīga lauksaimniecība” un “oglekļa uzglabāšana” pirmo reizi tika ieviesti 2018. gada Eiropas bioekonomikas stratēģijā “Ilgtspējīga bioekonomika Eiropai” [89], kur šie termini tika traktēti kā inovatīvas pieejas ar lielu potenciālu klimata pārmaiņu mazināšanā. Tādējādi iezīmējot šo terminu ienākšanu ES politikas satvarā, kā ekonomiski dzīvotspējīgiem, uz rezultātiem balstītiem sabiedriskā labuma nodrošināšanas modeļiem lauksaimniekiem un mežsaimniekiem, un saistīti ar plašākām politikas jomām, piemēram, bioekonomiku, aprites ekonomiku un klimatneitralitāti [89]. Līdzīgi termins “augsnes emisijas” pirmo reizi parādās 2018. gada paziņojumā “Tīra planēta visiem” [160], bet specifiskāk definēts *CRCF* regulā, kurā tas ir iekļauts kā atsevišķa oglekļa piesaistes kategorija [49]. Agrākos ES politikas dokumentos termins “oglekļa sekvestrējums” (*carbon sequestration*), tika plaši lietots, lai aprakstītu oglekļa piesaistes un uzglabāšanas procesu augsnē vai biomasā, bieži saistībā ar zemes apsaimniekošanas praksi [156], [160], [173]. Tomēr CRCF regulā ir redzama koncepcijas maiņa: "oglekļa piesaiste" (*carbon removal*) un "augsnes emisiju samazināšana" ir ieviestas kā atsevišķas, uz procesu balstītas sertifikācijas kategorijas, savukārt "oglekļa sekvestrējums" nu jau attiecināts nevis uz procesu, bet uz kvantificējamu rezultātu (piesaistes vienību), kas ir verificēts oglekļsaistīgas lauksaimniecības prakses piesaistes rezultāts [49]. Šī terminoloģijas attīstība ilustrē virzību uz lielāku precizitāti, metodoloģisko diferenciāciju un tirgus piemērojamību ES oglekļa pārvaldības sistēmās.

Horizontālās politikas saskaņotības novērtējums, pamatojoties uz pirmajām četrām tematiskajām grupām (3.1. tab.), sniedz izpratni par *CRCF* regulas lomu plašākā ES klimata, lauksaimniecības, ZIZIMM un enerģētikas politikas kontekstā. Šīs grupas uzsver saikni starp *CRCF* regulu un plašākiem stratēģiskajiem mērķiem, tostarp oglekļa piesaistes palielināšanu, bioekonomikas attīstību un klimatneitralitātes sasniegšanu. Tiek ilustrēta *CRCF* regulas metodoloģiskā pieeja, tostarp sertifikācijas sistēma, uzraudzība, kā arī inovāciju un digitalizācijas nepieciešamība, kas ir daļa no vispārējās ES vīzijas politikas un normatīvo dokumentu attīstībā. Zemes apsaimniekotāju zināšanu un kapacitātes stiprināšana, to iesaistīšana un uzticības veidošana tiek atzīta kā nozīmīga jaunu iniciatīvu iedzīvināšanai praksē. *CRCF* regula balstās iepriekš izklāstītajā politiskajā vīzijā, jo īpaši paziņojumā *"Ilgtspējīgi oglekļa aprites cikli",* un papildina esošos instrumentus, nodrošinot koordinētu pieeju oglekļsaistīgas lauksaimniecības prakses īstenošanai.

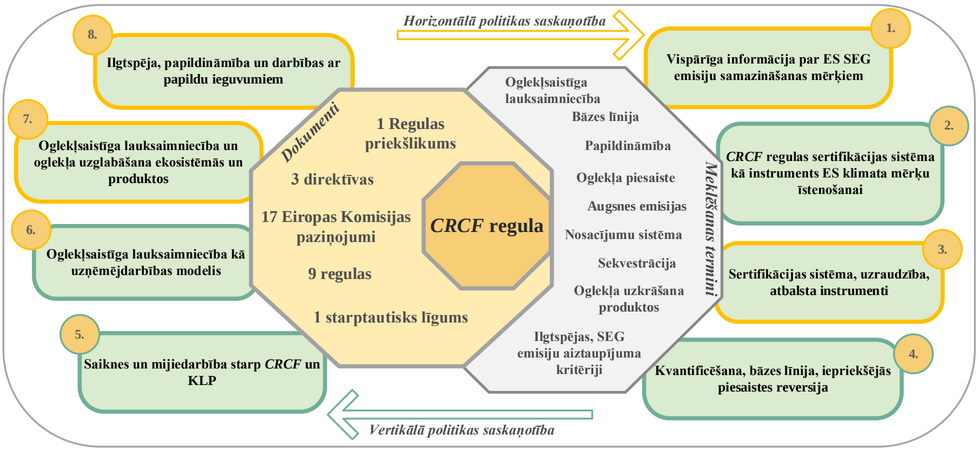
Piektajā un sestajā tematiskajā grupā uzmanība pievērsta *CRCF* regulas un Kopējās lauksaimniecības politikas (KLP) savstarpējai saiknei, kā arī oglekļsaistīgas lauksaimniecības kā zaļās uzņēmējdarbības modeļa attīstības potenciālam. Horizontālā politikas saskaņotība starp KLP un *CRCF* regulu tika identificēta saistībā ar ilgtspējīgu zemes apsaimniekošanu, klimata mērķu sasniegšanu un uzlabotu vides sniegumu. *CRCF* regula ir pozicionēta kā brīvprātīgs un papildinošs mehānisms, kas īstenojams uz rezultātiem balstītā finansējuma piešķīrumā, savukārt KLP turpina darboties kā darbībās balstīta atbalsta sistēma. Sestā tematiskā grupa parāda saskaņotību ar citām ES stratēģijām, tostarp industriālo oglekļa pārvaldību, mežu noturības veicināšanu, pārtikas ķēžu dekarbonizāciju un bioekonomikas attīstību. Tajā pašā laikā tā atklāj esošās sistēmas trūkumus: ES Emisiju tirdzniecības sistēma tika izstrādāta, lai veicinātu emisiju samazināšanu lielajiem emisiju radītājiem, kur emisiju samazināšanas rezultātus ir salīdzinoši vieglāk kvantificēt un pārbaudīt. Tomēr ES Emisiju tirdzniecības sistēma pašlaik neatzīst negatīvās emisijas, piemēram, CO_2 piesaisti no atmosfēras, kas būtu izmantojamas atbilstības nodrošināšanai. Līdz ar to bija nepieciešams tirgus mehānisms, kas veicinātu vai finansiāli atalgotu ieguldījumus zemes vai tehnoloģiskajā oglekļa piesaistē. Ar *CRCF* regulu tiek izveidots papildinošs satvars, kas sniedzas tālāk par emisiju samazināšanu un paplašina ES klimata politikas instrumentus, ieviešot brīvprātīgu, zinātniski pamatotu un pārredzamu sertifikācijas satvaru. Tādējādi attīstot brīvprātīgu oglekļa tirgu un stimulējot ieguldījumus ne tikai emisiju samazināšanā, bet arī CO_2 piesaistē un ilgtermiņa uzglabāšanā ekosistēmās un biomasā, paverot iespējas jauniem uzņēmējdarbības modeļiem un ilgtermiņa klimata risinājumiem.

Septītā tematiskā grupa parāda horizontālo saskaņotību ar ES politiku bioloģiskās daudzveidības saglabāšanas, ilgtspējīgas zemes apsaimniekošanas un oglekļa piesaistīšanas produktos jomā. Tā ilustrē dažādus oglekļa piesaistes un sekvestrācijas risinājumus no zemes apsaimniekošanas līdz koksnes izmantošanai ilgmūžīgos produktos, kā arī šo risinājumu pakāpenisku integrāciju plašākā ES vides, klimata un produktu politikā. Tajā pašā laikā ir konstatēti arī trūkumi - jūras un piekrastes oglekļa piesaiste jeb "zilā oglekļa" integrācijā plašākā politikas sistēmā. Politikas dokumentos tam piešķirta nevienāda nozīme, liecinot par nevienmērīgu līdzsvaru starp nozarēm. Tam par pamatu varētu būt zinātniski pamatotu zināšanu trūkums par jūras un piekrastes ekosistēmu oglekļa piesaistes potenciālu, monitoringa metodēm un praktiskām īstenošanas iespējām, kas varētu kavēt to iekļaušanu plašākos klimata politikas rīcības plānos.

Otrais pētījuma jautājums bija vērsts uz vertikālās saskaņotības novērtējumu, kura mērķis bija identificēt galvenos izaicinājumus un iespējas *CRCF* regulas īstenošanā dalībvalstu līmenī. Šis aspekts īpaši atspoguļojās otrajā, ceturtajā, piektajā un sestajā tematiskajā grupā (3.1. tab.). Otrajā un ceturtajā tematiskajā grupā tika analizēta vertikālā saskaņotība starp *CRCF* regulas sertifikācijas satvaru, starptautisko un ES līmeņa ziņošanas pienākumu piemērošanu dalībvalstu līmenī. Šie pienākumi izriet no Parīzes nolīguma, ZIZIMM regulas (ES) 2018/841 un Regulas (ES) 2018/1999 par Enerģētikas savienības un rīcības klimata jomā pārvaldību. *CRCF* regula ir saskaņota ar šīm sistēmām, piemērojot *IPCC* vadlīnijas, kas ir pamats SEG emisiju uzskaites metodēm, ko izmanto gan ES, gan starptautiskajā klimata ziņošanā saskaņā ar Parīzes nolīgumu. Tomēr *CRCF* regula ievieš arī zināmu metodoloģisko nenoteiktību. Tā paredz izmantot iepriekš noteiktu bāzes līniju ($CR_{\text{bāzes līnija}}$) oglekļa piesaistes ieguvuma aprēķināšanai saskaņā ar Regulas (ES) 2018/841 noteikumiem. Lai gan šī regula nosaka kopējos oglekļa piesaistes mērķus ZIZIMM nozarei ES un dalībvalstu līmenī, tajā nav definēti konkrēti bāzes līmeņi atkarībā no zemes izmantošanas veida vai piesaistes [159]. Tāpēc joprojām nav skaidrs, vai rādītāji, kas izmantoti ZIZIMM mērķu noteikšanai, tiks izmantoti arī bāzes līnijas noteikšanai saskaņā ar *CRCF* regulu. Tajā pašā laikā *CRCF* regulā ir noteikts, ka oglekļa piesaistes un augsnes emisiju samazināšanas ieguvumi jāaprēķina saskaņā ar *IPCC* vadlīnijām un ZIZIMM sistēmu, kas liecina, ka $CR_{(\text{bāzes līnija})}$ un $LSE_{(\text{bāzes līnija})}$ bāzes līnijas, visticamāk, tiks saskaņotas ar esošajām datu struktūrām. Tajā pašā laikā saglabājas neskaidrības par to, kā tiks panākta metodoloģiskā saskaņotība starp sertifikācijas sistēmu un dalībvalstu ziņošanas mehānismiem.

Piektā tematiskā grupa ilustrē gan horizontālo, gan vertikālo politikas saskaņotību starp KLP un *CRCF* sistēmu. Tomēr tajā atrodamas norādes, kas liecina par politikas nepilnībām, kas rada jautājumu, kā tiks risināta iespējamā finansējuma pārklāšanās starp KLP un *CRCF* sistēmu? Vai zemes apsaimniekotājiem būs jāizvēlas starp garantētiem, uz rīcību balstītiem KLP maksājumiem un neparedzamāku, uz rezultātiem balstītu *CRCF* sertifikācijas sistēmu, kas prasa pierādīt neto oglekļa piesaistes ieguvumu piecu gadu periodā un nodrošināt uzglabātā oglekļa pastāvību? Vai arī pašreizējā KLP (2023–2027) vienkārši ir pārejas mehānisms, kas izstrādāts, lai veicinātu oglekļsaistīgas lauksaimniecības prakses ieviešanu? Šīs neskaidrības vēl vairāk pastiprina ar tirgu saistīti faktori, jo īpaši jautājums par to, vai oglekļa kredītu cenas būs pietiekami augstas, lai kompensētu zemes apsaimniekotāju risku. Lai gan pētījums nesniedza skaidras atbildes uz šiem jautājumiem, sertifikācijas metodoloģijas, kas pētījuma veikšanas laikā vēl bija izstrādes stadijā, visticamāk ietvers detalizētus noteikumus, šo neskaidrību novēršanai.

Sestā tematiskā grupa apskata oglekļsaistīgu lauksaimniecību kā zaļo uzņēmējdarbības modeli, kas zemes apsaimniekotājiem varētu nodrošināt papildu ienākumu avotu, vienlaikus iezīmējot pāreju no tradicionālās oglekļa kompensācijas prakses (*offsetting*) uz oglekļa iekļaušanu (*insetting*) [178], kur oglekļa kredītus pērk uzņēmumi tajā pašā vērtības ķēdē. Šī pieeja veicina klimatam draudzīgas lauksaimniecības un mežsaimniecības prakses ieviešanu un atspoguļo pieaugošo uzņēmumu atbildību par 3. tvēruma emisijām tālāk piegādes ķēdē [178]. Tādējādi ilustrējot vertikālo politikas saskaņotību, jo sasaista ES līmeņa normatīvos pasākumus saskaņā ar *CRCF* regulu un to īstenošanu dalībvalstu līmenī, vienlaikus izmantojot ekonomiskos (tirgus) politikas instrumentus - iesaistot privāto sektoru un izmantojot emisiju samazināšanas stratēģijas vērtības ķēdes. 3.3. attēlā apkopotas tematiskās grupas, kas identificētas saskaņotības novērtējuma laikā, kā arī analizēto politikas un normatīvo dokumentu sadalījums un meklēšanas termini, kas izmantoti, lai strukturētu kvalitatīvo satura analīzi.



3.3. att. Analizēto dokumentu, meklēšanas terminu un tematisko grupu pārskats *(tematiskās grupas, kas norāda uz horizontālo saskaņotību, ir iezīmētas ar dzeltenu rāmi; tās, kas norāda arī uz vertikālo saskaņotību, ir iezīmētas ar zaļu).*

CRCF regulā noteiktais sertifikācijas sistēmas satvars netiek piemērots kā sods vai obligāts pienākums. Tā vietā tas ievēro brīvprātības principu, darbojoties kā stimuls, kas mudina lauksaimniekus un citus zemes apsaimniekotājus ieviest oglekļsaistīgas lauksaimniecības prakses, vienlaikus nodrošinot papildu ieguvumus, piemēram, bioloģiskās daudzveidības saglabāšanu un uzlabotus ekosistēmu pakalpojumus. Lai gan šī pieeja *CRCF* regulu pozicionē kā konstruktīvu un elastīgu politikas instrumentu, tā arī raisa jautājumu par tās pietiekamību: vai šāda mehānisma iekļaušana KLP obligātajā struktūrā nebūtu efektīvāka, lai sasniegtu ES ilgtermiņa klimata mērķus? *CRCF* regula ir būtisks solis, lai pozicionētu ES kā globālu līderi oglekļa piesaistes sertificēšanā, aptverot gan zemes, gan industriālo piesaisti.

Kā jauns instruments ES klimata politikas satvarā *CRCF* regula paver ievērojamas iespējas. Tomēr tās efektivitāte būs atkarīga no tā, kā šie sertifikācijas mehānismi tiks implementēti dalībvalstīs. Galvenie uzdevumi ir precizēt sertificējamas oglekļa lauksaimniecības darbības, definēt uzticamas un konsekventas bāzes līnijas, nodrošināt sertifikācijas metodoloģiju vides integritāti un izveidot pārredzamus nosacījumus oglekļa kredītu izmantošanai. Tikpat nozīmīga būs *CRCF* regulas savietojamība ar esošajiem obligātajiem politikas instrumentiem, piemēram, KLP, ZIZIMM regulu ES 2018/841 un Regulu (ES) 2018/1999 par Enerģētikas savienības un rīcības klimata jomā pārvaldību, lai nodrošinātu saskaņotību un izvairītos no dublēšanās. Dalībvalstu politikas veidotājiem būs izšķiroša nozīme, nosakot, cik konsekventi un mērķtiecīgi oglekļa lauksaimniecības prakses tiks atbalstītas un iekļautas valstu atbalsta sistēmās, konsultāciju pakalpojumos un tirgus mehānismos.

CRCF regulas gadījuma izpētē tika analizēta saskaņotība ES politikas un normatīvajā ietvarā, taču, tā kā *CRCF* regulas sertifikācijas satvars joprojām atrodas izstrādes stadijā, detalizētu vertikālās saskaņotības novērtējumu nebija iespējams veikt. Tāpēc turpmākajās divās nodaļās uzmanība pievērsta Eiropas bioekonomikas stratēģijā noteikto mērķu vertikālajai saskaņotībai, vispirms ES dalībvalstu stratēģiju līmenī, pēc tam Latvijas politikas plānošanas dokumentu kontekstā.

3.1.2. Bioekonomikas politikas saskaņotības novērtējums ES dalībvalstīs

Nacionālo bioekonomikas stratēģiju analīzē (3. publikācija) tika skatīti stratēģijās izvirzītie mērķi un rīcības virzieni. Tika analizētas deviņas stratēģijas, kas bija pieejamas angļu valodā. Mērķi un rīcības virzieni tika grupēti pamatojoties uz Eiropas bioekonomikas stratēģijas un rīcības plāna pieciem mērķiem un trim prioritārajām jomām [88], [89]. Rezultāti apkopoti 3.2. tabulā.

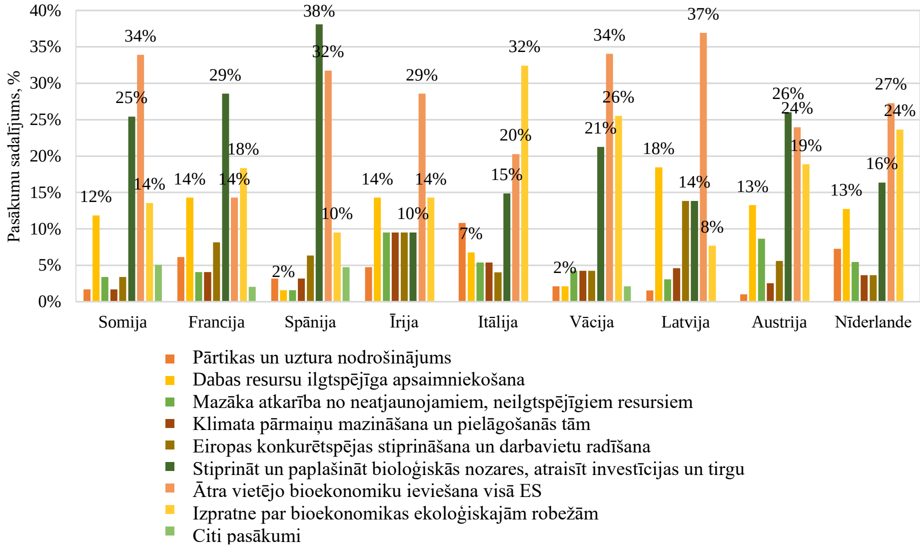
3.2. tabula

Nacionālajās bioekonomikas stratēģijās izvirzītie mērķi un rīcības virzieni

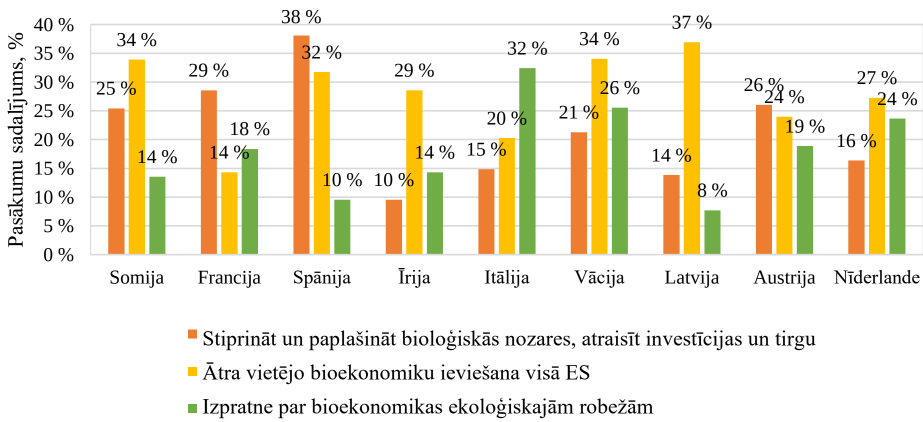
Mērķis un rīcības virzieni	**Saistīto mērķu skaits**	**%**
Pārtikas un uztura nodrošinājums	23	4 %
Dabas resursu ilgtspējīga apsaimniekošana	69	11 %
Mazāka atkarība no neatjaunojamiem, neilgtspējīgiem resursiem	35	6 %
Klimata pārmaiņu mazināšana un pielāgošanās tām	23	4 %
Eiropas konkurētspējas stiprināšana un darbavietu radīšana	39	6 %
Stiprināt un paplašināt bioloģiskās nozares, atraisīt investīcijas un tirgu	145	23 %
Ātra vietējo bioekonomiku ieviešana visā ES	170	27 %
Izpratne par bioekonomikas ekoloģiskajām robežām	117	19 %
Citi pasākumi	8	1 %
KOPĀ	**629**	**100 %**

Praktiski visās izvērtētajās nacionālajās bioekonomikas stratēģijās ir implementēti ES līmenī noteiktie mērķi un rīcības virzieni, jo tikai 1 % no stratēģijās minētajiem mērķiem un rīcības virzieniem nebija tieši sasaistāms ar ES līmenī noteiktajiem. Nacionālās stratēģijas galvenokārt ir vērstas uz ātru vietējo bioekonomiku ieviešanu visā ES (27 %) un bioloģisko nozaru stiprināšanu un paplašināšanu, atraisot investīcijas un tirgu (23 %). Būtisks mērķu skaits stratēģijās saistīts ar bioekonomikas ekoloģisko robežu izpratšanu, kas ieņem trešo vietu (19 %). Stratēģijās mazāk akcentētas jomas, kas saistītas ar pārtikas un uztura nodrošinājumu (4 %) un klimata pārmaiņu mazināšana un pielāgošanos tām (4 %).

3.4. attēlā redzams visu deviņu valstu salīdzinājums, pamatojoties uz to mērķiem. Rezultāti liecina, ka nacionālās stratēģijas galvenokārt vērstas uz trim jaunajām rīcības jomām, kas definētas atjauninātajā 2018. gada Eiropas bioekonomikas stratēģijā. Retāk uzsvērti pieci mērķi no 2012. gada stratēģijas, no kuriem nacionālā līmenī visplašāk implementēti mērķi, kas vērsti uz dabas resursu ilgtspējīgu apsaimniekošanu. Šis mērķis biežāk minēts Latvijas (18 %), Francijas (14 %) un Īrijas (14 %) stratēģijās.



3.4. att. Nacionālo bioekonomikas stratēģiju mērķu un pasākumu grupēšana atbilstoši Eiropas bioekonomikas stratēģijā noteiktajiem.



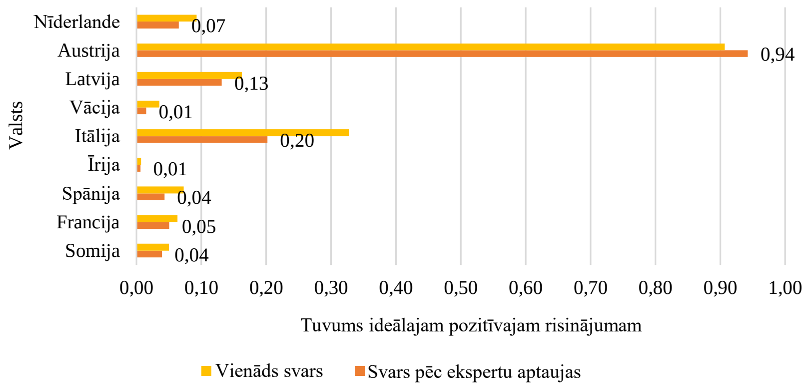
3.5. att. Nacionālo bioekonomikas stratēģiju mērķu un pasākumu grupēšana atbilstoši Eiropas bioekonomikas stratēģijā noteiktajām rīcības jomām.

3.5. attēlā redzams, ar kuru no trim rīcības jomām visbiežāk saistīti nacionālajās stratēģijās iekļautie pasākumi. Augstāki rezultāti ir rīcībai “ātra vietējo bioekonomiku ieviešana visā ES”

(27 %). Valstis, kuras šai rīcībai piešķir augstāku prioritāti, ir Latvija (37 %), Vācija (34 %), Somija (34 %) un Spānija (32 %). No trim rīcības jomām retāk minēti pasākumi saistībā ar “izpratne par bioekonomikas ekoloģiskajām robežām”. Itālija (32 %), Vācija (26 %) un Nīderlande (24 %) ir valstis, kas savās stratēģijās šai rīcībai jomai piešķir būtisku nozīmi.

Stratēģiju analīzē iegūtie rezultāti tika ievadīti *TOPSIS* lēmumu pieņemšanas matricā, normalizēti un svērti atbilstoši ekspertu novērtējuma rezultātiem (2.3. tab.). Saskaņā ar *TOPSIS* rezultātiem (3.6. att.), piemērojot ekspertu kritēriju svarus, visaugstāko punktu skaitu ieguva Austrija (0,94), otrajā vietā ierindojās Itālija (0,20), lai arī ievērojami atpaliekot no līdera. Trešais rezultāts, kas visvairāk tuvinājās ideālajam pozitīvajam risinājumam, ir Latvija (0,13). Nīderlande (0,07), Francija (0,05), Spānija (0,04), Vācija (0,01) un Īrija (0,01) novērtējumā ieguva zemākos vērtējumus. Aprēķins pēc tam atkārtots, visiem astoņiem kritērijiem nosakot vienādus svarus (0,125). Minētais atkārtotais aprēķins kalpo kā jutīguma analīze, ļaujot pārbaudīt rezultātu stabilitāti attiecībā pret kritēriju svaru maiņu un novērtēt ekspertu vērtējuma ietekmi uz alternatīvu relatīvo novietojumu.

Augstākos rezultātus sasniegušās valstis nacionālajās stratēģijās bija implementējušas visvairāk mērķu un pasākumu, kas saistāmi ar Eiropas bioekonomikas stratēģijā noteikto – Austrija 196, Itālija 74 un Latvija 65 pasākumi. Austrijas augstie rādītāji ir saistāmi arī ar to, ka tā savā nacionālajā bioekonomikas stratēģijā ir noteikusi skaitliski daudz vairāk mērķu un rīcības pasākumu nekā citas pētījumā iekļautās valstis. Šī sakarība gan nav novērojama stratēģijās ar zemāko sniegumu, kur pasākumu sadalījums pa mērķiem attiecībā uz kritēriju svērumu ir bijis nozīmīgāks nekā ierosināto pasākumu skaitliskais daudzums. 3.6. attēlā redzams, ka ekspertu novērtējums ietekmē iegūtos rezultātus, bet ne tik ļoti, lai mainītu kopējos rezultātus.



3.6. att. *TOPSIS* novērtējuma rezultāti.

Nacionālo bioekonomikas stratēģiju mērķu un pasākumu analīze parāda, ka pastiprināta uzmanība pievērsta 2018. gada atjauninātās Eiropas bioekonomikas stratēģijas prioritātēm. Stratēģijās, kas pieņemtas pirms 2018. gada (Somija 2014, Francija 2017 un Spānija 2016), dominēja 2012. gada stratēģijas pieci mērķi, savukārt jaunākajās stratēģijās, kas pieņemtas pēc 2018. gada, skaidri uzsvērta virzība saskaņā ar atjaunoto Eiropas Bioekonomikas stratēģijas ietvaru. ES līmeņa prioritātes lielākoties ir pārņemtas nacionālajās stratēģijās, jo tikai astoņas darbības jeb 1 % no visām darbībām nebija tieši sasaistāmas ar ES bioekonomikas mērķiem. Tas apliecina dalībvalstu spēju nodrošināt vertikālo saskaņotību ar ES politikas ietvaru, tādējādi stiprinot kopējo politikas saskaņotību.

Rezultāti atklāja galvenos bioekonomikas virzītājspēkus un stūrakmeņus katrā valstī, sniedzot orientierus politikas veidotājiem bioekonomikas turpmākai attīstībai. Stratēģiju novērtējums, izmantojot jauktu metožu pieeju, kas apvienoja SLP un *TOPSIS* analīzi, apliecināja šīs pieejas piemērotību, lai identificētu ne tikai vertikālo saskaņotību starp dažādiem politikas plānošanas līmeņiem, bet arī horizontālo saskaņotību dalībvalstu līmenī. Analīze parādīja, ka valstis ar detalizētāk izstrādātām nacionālajām stratēģijām *TOPSIS* vērtējumā ieguva augstāku punktu skaitu, tomēr skaitliski vairāk rīcības virzienu un pasākumu, ne vienmēr nozīmē ātrāku to īstenošanu. Precīzākam priekšstatam par stratēģiju īstenošanas iespējām, būtu nepieciešams analizēt stratēģijas pavadošos rīcības plānus, lai gan šajā gadījumā ne visām stratēģijām tādi bija izstrādāti. Rīcības plānos parasti ir noteikti konkrēti pasākumi, atbildīgās iestādes, sagaidāmie rezultāti un termiņi, līdz ar to noteikto pasākumu un politikas instrumentus analīze sniegtu sīkāku ieskatu par to, cik reāli sasniedzami ir stratēģijās izvirzītie mērķi.

Pētījuma dizainā identificēti vairāki ierobežojumi. Saskaņotības noteikšana starp dažāda līmeņa dokumentiem var būt salīdzinoši vienkārša, taču tieši pretrunas var būt izšķirošas noteikto mērķu īstenošanā. Tādēļ turpmākajos pētījumos nepieciešama padziļināta izpēte, kas ļautu identificēt gan iespējamās barjeras, gan politikas nepilnības. Lai novērtētu politikas saskaņotības faktisko efektivitāti, būtu jāsašaurina tvērums un jāanalizē, kā konkrētu rīcības virzienu pasākumi tiek īstenoti praksē.

3.1.3. Bioekonomikas politikas saskaņotības novērtējums. Latvijas gadījuma izpēte

Vertikālās politikas saskaņotības izvērtējums starp Eiropas Bioekonomikas stratēģiju un nacionālajām stratēģijām parādīja, ka precīzākam priekšstatam par reālo saskaņotību un īstenošanas iespējām nepieciešama detalizētāka rīcības plānu analīze. Tā kā Latvijas Bioekonomikas stratēģijai 2030 nav izstrādāts atsevišķs rīcības plāns, tika pieņemts lēmums analizēt ES mērķu implementāciju dažāda līmeņa nacionālos politikas dokumentus, tostarp nozaru stratēģijas, kas sasaistītas ar bioekonomiku. Šāda pieeja ļāva novērtēt ne tikai vertikālo saskaņotību starp ES un Latviju, bet arī horizontālo politikas saskaņotību nacionālā līmenī, paplašinot analīzes tvērumu no šaura sektorāla skatījuma uz bioekonomikas attīstības prioritātēm kopumā.

Latvijas politikas plānošanas dokumentu analīzē (2. publikācija) kā atslēgvārdi tika izmantoti Eiropas bioekonomikas stratēģijā un tās rīcības plānā (2012, 2018) [88], [89] noteiktie mērķi un rīcības virzieni (2.3. tab.). Šāda pieeja ļāva koncentrēt meklēšanu un nodrošināt atbilstību ES līmeņa ietvaram. OECD ziņojumā [87] un ANO ilgtspējīgas attīstības programmā [11] noteiktajos mērķos noteiktās prioritātes netika analizētas atsevišķi, jo tās konceptuāli jau ir integrētas Eiropas bioekonomikas stratēģijā un rīcības plānā [88], [89]. Meklējums tika papildināts ar četriem atslēgvārdiem – lauksaimniecības sektors, meža sektors, zivsaimniecības un akvakultūras sektors, kā norāde uz bioresursu primārās ieguves sektoriem. Lai noteiktu, vai šie sektori politikas dokumentos tiek uzskatītas par stratēģiski nozīmīgiem vai, tieši pretēji, tām pievērsta nepietiekama uzmanība. Tas ļauj turpmākos pētījuma posmos precīzāk izvērtēt, kurām nozarēm nepieciešams papildu stratēģiskais atbalsts.

Latvijas Bioekonomikas stratēģija 2030 [42], kas pieņemta 2017. gadā, nosaka bioekonomikas lomu valsts attīstībā un izvirza mērķus nodarbinātības, produktu pievienotās vērtības un eksporta apjoma palielināšanai [42]. Stratēģija tika iekļauta analīzē kā sākumpunkts, paplašinot atlasi uz Latvijas ilgtspējīgas attīstības stratēģiju līdz 2030. gadam [179], kā arī dokumentiem, kas saistīti ar klimatneitralitātes sasniegšanu [180], pāreju uz aprites ekonomiku [181], atkritumu apsaimniekošanu [182] un citiem ar bioekonomikas nozari saistītiem politikas plānošanas dokumentiem (3.3. tab.). Katra politikas dokumenta analīzei vidēji tika izmantoti 15–20 atslēgvārdi vai atslēgfrāzes latviešu valodā, teksta fragmentu atlasei.

3.3. tabula

Analīzē iekļautie Latvijas politikas plānošanas dokumenti

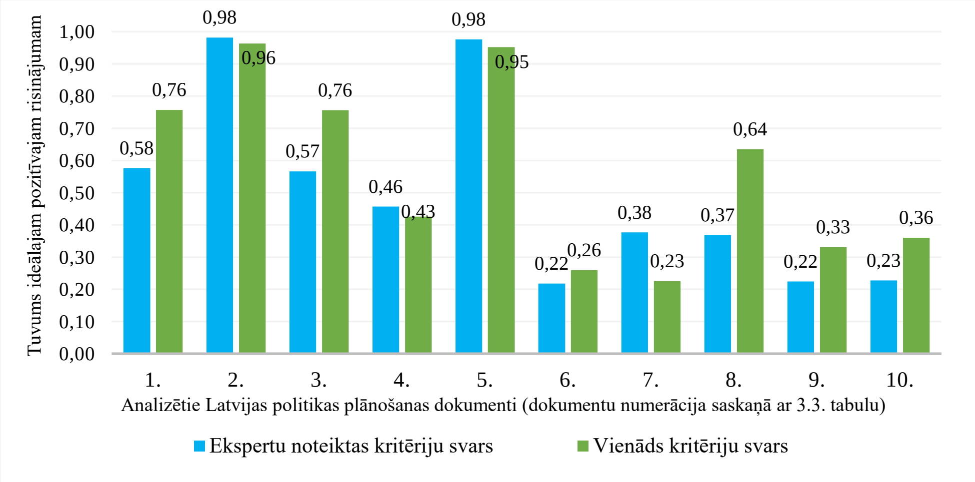
	Pieņemšanas gads	Rīcības virzieni mērķu sasniegšanai	Rezultatīvie rādītāji	Starpposma izvērtējums	Norādītais finansējums	Finanšu resursu avots
1. Latvijas ilgtspējīgas attīstības stratēģija līdz 2030. gadam [179]	2010	Konkrēti	Kvalitatīvi un kvantitatīvi	Jā (ik pēc 2 gadiem)	Nav norādīts	Saskaņā ar pieejamo valsts budžetu, ES fondi, privātais
2. Latvijas stratēģija klimatneitralitātes sasniegšanai līdz 2050. gadam [180]	2019	Vispārīgi	Kvalitatīvi un kvantitatīvi	Jā (ik pēc 10 gadiem)	Jā	Saskaņā ar pieejamo valsts budžetu, ES fondi, privātais
3. Latvijas Nacionālais attīstības plāns 2021.-2027. gadam [183]	2020	Konkrēti	Kvalitatīvi un kvantitatīvi	Jā (ik pēc 2 gadiem)	Jā	Saskaņā ar pieejamo valsts budžetu, ES fondi, privātais
4. Latvijas nacionālais enerģētikas un klimata plāns 2021. – 2030. gadam [184]	2020	Konkrēti	Kvalitatīvi un kvantitatīvi	Jā	Jā	Saskaņā ar pieejamo valsts budžetu, ES fondi, privātais
5. Latvijas Bioekonomikas stratēģija 2030 [42]	2017	Vispārīgi	Vispārīgi	Nē	Nav norādīts	Nav norādīts
6. Latvijas pielāgošanās klimata pārmaiņām plāns laika posmam līdz 2030. gadam [185]	2019	Konkrēti	Kvalitatīvi un kvantitatīvi	Jā (vidusposma)	Nav norādīts	Saskaņā ar pieejamo valsts budžetu, ES fondi, privātais
7. Atkritumu apsaimniekošanas valsts plāns 2021. – 2028. gadam [182]	2021	Konkrēti	Kvalitatīvi un kvantitatīvi	Jā (vidusposma)	Jā	Saskaņā ar pieejamo valsts budžetu, ES fondi, privātais
8. Nacionālās industriālās politikas pamatnostādnes 2021-2027 [186]	2021	Konkrēti	Kvalitatīvi un kvantitatīvi	Jā (vidusposma)	Jā	Saskaņā ar pieejamo valsts budžetu, ES fondi, privātais
9. Rīcības plāns pārejai uz aprites ekonomiku 2020.-2027. gadam [181]	2020	Konkrēti	Kvalitatīvi un kvantitatīvi	Nē	Nav norādīts	Saskaņā ar pieejamo valsts budžetu, ES fondi, privātais
10. Vides politikas pamatnostādnes 2021.-2027. gadam [187]	2021	Konkrēti	Kvalitatīvi un kvantitatīvi	Nē	Nav norādīts	Saskaņā ar pieejamo valsts budžetu, ES fondi, privātais

Sarindojot dokumentus pēc to pieņemšanas gada vissenākais dokuments ir 2010. gadā pieņemtā Latvijas ilgtspējīgas attīstības stratēģija 2030. gadam [179], kam seko 2017. gadā pieņemtā Latvijas Bioekonomikas stratēģija 2030 [42]. Pārējie politikas dokumenti pieņemti 2019. gadā vai vēlāk. Lielākajā daļā pētījumā iekļautajos politikas dokumentos ir noteikti ne tikai sasniedzamie mērķi, bet arī konkrētas rīcības jomas un rezultatīvie rādītāji. Latvijas stratēģija klimatneitralitātes sasniegšanai līdz 2050. gadam [180] un Latvijas Bioekonomikas stratēģija 2030 [42] ir dokumenti, kuros mērķi formulēti vispārīgi, neparedzot konkrētas rīcības. Tas skaidrojams ar to, ka abi dokumenti ir klasificējami kā "informatīvie ziņojumi" – dokumenta veids, kura uzdevums ir sniegt valdībai pārskatu vai informāciju par tās kompetencē esošo jautājumu risināšanas gaitu [188], un tie neietver kvalitatīvus vai kvantitatīvus rādītājus mērķu īstenošanai, kā arī rīcības plānu [42]. Lai gan tehniski "informatīvie ziņojumi" nav klasificējami kā politikas plānošanas dokumenti, tie tika iekļauti analīzē kā politikas dokumenti, lai nodrošinātu salīdzināmību un pilnīgu pārskatu par bioekonomikas politikas mērķiem. Būtisks elements politikas plānošanas dokumentos izvirzīto mērķu sasniegšanā ir starpposma novērtējums, lai uzraudzītu īstenošanas gaitu. Septiņos no desmit analizētajiem dokumentiem ir iekļauts periodisks vai starpposma novērtējums, kas vērtējams kā pozitīvs rādītājs. Pusei jeb pieciem pārskatītajiem politikas plānošanas dokumentiem nav norādīts nepieciešamais finansējums mērķu īstenošanai. Attiecībā uz finansējuma avotiem daži politikas dokumenti ietver informāciju, ka nospraustie mērķi un rīcības virzieni tiks īstenoti esošā valsts budžeta ietvaros, tanī pat laikā primāri uzsverot iespēju piesaistīt finansējumu no ES struktūrfondiem, kā arī citiem finansējuma avotiem, tostarp privāto finansējumu.

Starptautisko mērķu implementācija Latvijas politikas dokumentos

Starptautiski noteikto bioekonomikas attīstības mērķu prioritizācijas novērtējumam Latvijas politikas plānošanas dokumentos tika izmantots SLP un atslēgvārdu piešķiršanas metode, un sākotnējie rezultāti apkopoti ilustratīvā skrīninga matricā. Matricā netika analizēta mijiedarbības būtība, bet tika izvērtēta attiecīgo Eiropas Bioekonomikas stratēģijas mērķu prioritāte, pieņemot, ka biežāka to pieminēšana norāda uz augstāku prioritāti un lielāku īstenošanas varbūtību. Secīgi, iegūtās vērtības tika ievadītas *TOPSIS* matricā un normalizētas. *TOPSIS* kritēriju svari tika noteikti atbilstoši ekspertu vērtējumam [189], izmantojot tos pašus kritērijus un ekspertu vērtējums, kas parādīti 2.3. tabulā.

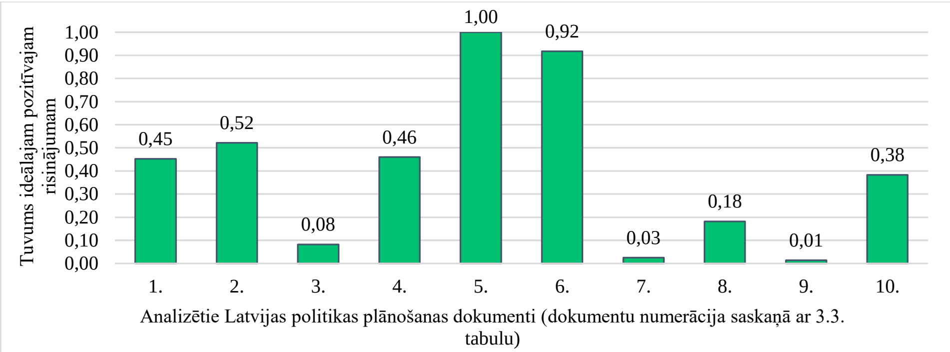
Novērtējumā vistuvāk ideālajam pozitīvajam risinājumam atradās Latvijas Bioekonomikas stratēģija 2030 (0,98) un Latvijas stratēģija klimatneitralitātes sasniegšanai līdz 2050. gadam (0,98) (3.7. att., zilā krāsā). Latvijas ilgtspējīgas attīstības stratēģija līdz 2030. gadam ar 0,58 punktiem un Latvijas Nacionālais attīstības plāns 2021.-2027.gadam ar 0,57 punktiem ieguva ievērojami zemākus rezultātus. Nedaudz augstāku vērtējumu sasniedza Latvijas nacionālais enerģētikas un klimata plāns 2021. – 2030. gadam (NEKP2030) ar 0,46 punktiem. Pārējie dokumenti novērtēti būtiski zemāk: Atkritumu apsaimniekošanas valsts plāns 2021. – 2028. gadam (0,38 punkti); Nacionālās industriālās politikas pamatnostādnes 2021-2027 (0,37 punkti); Vides politikas pamatnostādnes 2021.- 2027. gadam (0,23 punkti); Latvijas pielāgošanās klimata pārmaiņām plāns laika posmam līdz 2030. gadam un Rīcības plāns pārejai uz aprites ekonomiku 2020.-2027. gadam abi ieguva 0,22 punktus.



3.7. att. *TOPSIS* rezultāti Latvijas politikas dokumentu prioritātēm bioekonomikā.

Rezultāti, kas iegūti, piemērojot vienādus kritēriju svarus, uzrāda atšķirīgu analizēto dokumentu relatīvo novietojumu, taču saglabā līdzīgu dokumentu grupējumu ar skaidri izteiktu augstāko, vidējo un zemāko rezultātu intervālu (3.7. att., zaļā krāsā). Arī šajā gadījumā augstākais rezultāts ir Latvijas stratēģijai klimatneitralitātes sasniegšanai līdz 2050. gadam (0,96), Latvijas Bioekonomikas stratēģijai 2030 (0,95). Latvijas ilgtspējīgas attīstības stratēģija līdz 2030. gadam ar 0,76 punktiem un Latvijas Nacionālais attīstības plāns 2021.-2027.gadam ar 0,76 punktiem uzrādīja būtiski augstāku rezultātu nekā ar ekspertu noteiktiem kritēriju svariem, lai gan saglabā trešo un ceturto vietu. Nozīmīgu ranga pieaugumu uzrādīja arī Nacionālās industriālās politikas pamatnostādnes 2021-2027, kas ar vienādiem svariem sasniedza par 0,26 punktiem augstāku vērtējumu (0,64 punkti). Savukārt NEKP2030 ar 0,43 punktiem saglabā gandrīz identisku rezultātu abos novērtējumos. Zemāki vērtējumi piešķirti Vides politikas pamatnostādnēm 2021.- 2027. gadam (0,36 punkti), Rīcības plāns pārejai uz aprites ekonomiku 2020.-2027. gadam 0,33 punkti, Latvijas pielāgošanās klimata pārmaiņām plāns laika posmam līdz 2030. gadam 0,26 punkti un Atkritumu apsaimniekošanas valsts plāns 2021. – 2028. gadam 0,23 punkti. Atšķirības starp abiem svaru scenārijiem kalpo kā jutīguma analīze un parāda *TOPSIS* modeļa reakciju uz kritēriju svēruma maiņu. Lietojot vienādus svarus, mainās relatīvais novietojums, taču saglabājas līdzīgas rezultātu grupas, un izmaiņas nemaina pētījuma secinājumus par Eiropas Bioekonomikas stratēģijas mērķu ieviešanas līmeni Latvijas politikas dokumentos.

TOPSIS analīzes rezultāti lauksaimniecības, meža sektora, zivsaimniecības un akvakultūras sektora prioritātes noteikšanai Latvijas politikas plānošanas dokumentos redzami 3.8. attēlā. Novērtējums tika veikts izmantojot vienādu kritēriju svaru, pieņemot, ka visi sektori ir vienlīdz nozīmīgi. Rezultāti parāda, ka Latvijas Bioekonomikas stratēģija 2030 ieguvusi maksimālo punktu skaitu (1,00) un uzskatāma par ideālo pozitīvo risinājumu. Tuvākais rezultāts bija Latvijas pielāgošanās klimata pārmaiņām plānam laika posmam līdz 2030. gadam [185] ar 0,92 punktiem. Pārējie dokumenti uzrādīja būtiski zemākus vērtējumus: Latvijas stratēģija klimatneitralitātes sasniegšanai līdz 2050. gadam ieguva 0,52 punktus; Latvijas Nacionālais attīstības plāns 2021.-2027.gadam 0,46 punktus; Latvijas ilgtspējīgas attīstības stratēģija līdz 2030. gadam 0,45 punktus; Vides politikas pamatnostādnes 2021.- 2027. gadam 0,38 punktus; Nacionālās industriālās politikas pamatnostādnes 2021-2027 0,18 punktus. Vistālāk no ideālā pozitīvā risinājuma atradās Latvijas Nacionālais attīstības plāns 2021.-2027.gadam ar 0,08 punktiem; Atkritumu apsaimniekošanas valsts plāns 2021. – 2028. gadam ar 0,03 punktiem un Rīcības plāns pārejai uz aprites ekonomiku 2020-2027 ar 0,01 punktu.



3.8. att. *TOPSIS* rezultāti lauksaimniecības, mežsaimniecības, zivsaimniecības un akvakultūras sektoriem.

Latvijas politikas plānošanas dokumentu novērtējums liecina, ka lielākajā daļā no tiem ir definēti konkrēti pasākumi, kā arī izstrādāti indikatori un starpposma novērtējumi, lai sekotu līdzi īstenošanas progresam (3.3. tab.). Tomēr kritisks elements, kas raksturīgs visiem dokumentiem, ir neskaidri noteikts finansēšanas mehānisms. Bieži vien paredzēts, ka pasākumu īstenošanai resursi tiek nodrošināti no ikgadējā valsts budžeta, kas piesaistīti no ES struktūrfondiem vai privātā sektora, taču konkrēts sadalījums un finansējuma nodrošinājums nav skaidri noteikts. Šāda pieeja rada risku, ka noteiktie mērķi un rīcības virzieni var palikt deklaratīvi, ja tiem netiek piešķirts skaidrs finansējuma nodrošinājums.

Latvijas ilgtermiņa un vidēja termiņa dokumentu analīze, izmantojot *TOPSIS* metodi, parāda pozitīvu tendenci, jo visi 10 dokumenti sasaistāmi ar starptautiski noteiktiem bioekonomikas mērķiem. Dokumenti, kas atrodas politikas plānošanas hierarhijas augšgalā, piemēram, Latvijas ilgtspējīgas attīstības stratēģija līdz 2030. gadam, Latvijas stratēģija klimatneitralitātes sasniegšanai līdz 2050. gadam un Latvijas Nacionālais attīstības plāns 2021.-2027.gadam, ieguva augstākus vērtējumus nekā zemāka līmeņa nozaru plāni, kas apliecina vertikālās politikas saskaņotību. Tajā pašā laikā ir likumsakarīgi, ka nozaru vai tematiskajiem plāniem ir zemāki rezultāti, jo tie koncentrējas uz sektoram specifiskiem pasākumiem. Savukārt Latvijas Bioekonomikas stratēģija 2030 ir vienīgais dokuments, kas tieši veltīts bioekonomikai, sasniedza augstākos rezultātus.

Atsevišķi bioekonomikas mērķi politikas dokumentos tomēr ir mazāk akcentēti. Piemēram, "Pārtikas un uztura nodrošinājums" visticamāk netiek uzskatīts par aktuālu izaicinājumu, jo valsts lauksaimniecības nozare spēj nodrošināt apjoma ziņā pietiekamu un ES kvalitātes standartiem atbilstošu pārtiku [190]. Lai gan dokumentos ir atzīta fosilā kurināmā negatīvā ietekme uz vidi [179], [180], [182], mērķim "Mazāka atkarība no neatjaunojamiem, neilgtspējīgiem resursiem" [88] piešķirta zema prioritāte. Trūkst konkrētu pasākumu fosilā kurināmā pakāpeniskai aizstāšanai, kas varētu liecināt par politikas veidotāju piesardzību vai pat pretestību, ņemot vērā esošo infrastruktūru un ilgstoši zemo dabasgāzes un naftas cenu ietekmi. Pēc Krievijas pilna mēroga iebrukuma Ukrainā un sankciju ieviešanas pret Krieviju situācija būtiski mainījās, un šobrīd līdzīga dokumentu analīze, iespējams uzrādītu atšķirīgus rezultātus.

Pasākumi lauksaimniecības un meža nozarēs tiek minēti salīdzinoši bieži, savukārt zivsaimniecības un akvakultūras sektoru attīstībai, izņemot Latvijas Bioekonomikas stratēģiju 2030, piešķirta ievērojami mazāka uzmanība. Viena no iespējamajām skaidrojošām versijām ir zivsaimniecības un akvakultūras nozares vēsturiskā attīstība, kas lielā mērā balstījās uz zveju jūrā [191], [192], taču pēc Padomju Savienības sabrukuma un vēlākā ES zvejas kvotu ieviešanas, kas saistītas ar nozīmīgu zivju sugu izsīkumu, nozare piedzīvoja stagnāciju [193], [194]. Tomēr inovatīvas tehnoloģijas un pāreja uz ūdens organismu audzēšanu akvakultūras sistēmās var radīt jaunas iespējas [195], [196]. Īpaši iekšzemes ūdeņu un tajos sastopamo zivju, gliemju un aļģu efektīva apsaimniekošana un izmantošana inovatīvu produktu ražošanā varētu būt nozīmīgs pagrieziena punkts [195], [196]. Tas atklāj horizontālās politikas saskaņotības nepilnības, jo atsevišķas bioekonomikas nozares plānošanas dokumentos ir mazāk pārstāvētas.

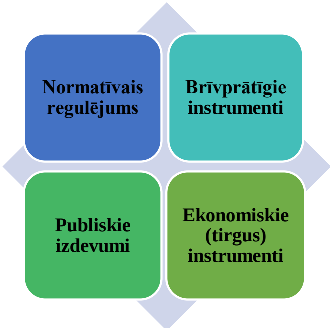
Šajā promocijas darba posmā izstrādātā metodika ļauj salīdzinoši ātri identificēt politikas dokumentos izvirzītos mērķus un pasākumus, kā arī novērtēt tiem piešķirto prioritāti. Līdzīgi kā apakšnodaļā 3.1.2. aprakstītā metodika, tā ir izmantojama kā pirmais solis plašākā politikas dokumentu analīzē, lai noteiktu bioekonomikas attīstības prioritāšu līmeni un izvērtētu, kuriem dokumentiem nepieciešama padziļināta izpēte. Galvenais ierobežojums ir nespēja atklāt tiešas pretrunas starp dokumentiem vai starp mērķiem un to īstenošanas mehānismiem, tāpēc turpmākajos pētījumos šī pieeja būtu jāpapildina ar detalizētāku kvalitatīvo analīzi.

Bioekonomikas politikas saskaņotības novērtējumā *TOPSIS* metode sniedza relatīvu salīdzinājumu Latvijas politikas dokumentu ietvarā, parādot, ka Latvijas Bioekonomikas stratēģija 2030 uzrāda augstāko rezultātu nacionālā kontekstā. Savukārt, analizējot ES dalībvalstu bioekonomikas stratēģijas atsevišķā *TOPSIS* matricā (3.1.2. apakšnod.), Latvijas bioekonomikas stratēģija ieguva zemāku novērtējumu, kas liecina par *TOPSIS* relatīvo salīdzināšanas raksturu. Raugoties izolēti tikai uz Latvijas gadījuma izpēti, kā būtiskākā nepilnība identificēta Latvijas Bioekonomikas stratēģijas 2030 pārejas posma neesamība no "informatīva ziņojuma" uz rīcības plānu ar konkrētiem pasākumiem un finansēšanas mehānismiem. Šādas pārejas iztrūkums ierobežo iespēju sistemātiski plānot un kvantitatīvi novērtēt bioekonomikas attīstības tempus Latvijā, ne tikai vērtēt tās formālo atbilstību ES mērķiem. Papildus tam, politikas plānošanas ietvarā nepietiekami akcentēta zivsaimniecības un akvakultūras sektora attīstība, lai gan tā potenciāls ilgtspējīgākas olbaltumvielu ieguves nodrošināšanā varētu būt nozīmīgs.

3.1.4. Politiskās saskaņotības novērtējums. Siltumapgādes un dzesēšanas nozare

Precīzi izvēlētu politikas instrumentu kopums ir būtisks, lai sasniegtu mērķus jebkurā politikas jomā. Efektīvākais veids, kā izmantot politikas instrumentus, ir tos kombinēt, nevis paļauties tikai uz vienu instrumentu [197]. Turklāt politikas instrumenti vislabāk darbojas, ja tie ir pielāgoti valsts un reģionālajām īpatnībām, jo īpaši ņemot vērā esošos tirgus apstākļus [93], [94], [197].

Politikas instrumentus var iedalīt pēc dažādiem principiem. Instrumenti var būt vērsti uz konkrētiem procesiem vai normām, piemēram, piemērot papildu nodokļus, lai veicinātu SEG emisiju samazināšanu, izstrādāt tehnoloģiju standartus, veidot sadarbības līgumus, kompensāciju sistēmas. Tā kā šo instrumentu daudzveidība ir plaša, politikas instrumentu klasifikācijai un analīzei tika izvēlētas četras politikas instrumentu kategorijas, kas piemērotas ilgtspējas un vides jautājumu akcentēšanai: normatīvais regulējums, brīvprātīgie instrumenti, publiskie izdevumi un ekonomiskie (tirgus) instrumenti (3.9. att.) [93].



3.9. att. Politikas instrumentu kategorijas [93].

Normatīvais regulējums ir viens no visplašāk izmantotajiem politikas instrumentiem, jo valdībām to ir salīdzinoši viegli piemērot [93]. Šajā kategorijā ietilpst ES līmenī pieņemtās regulas un direktīvas, kā arī nacionālo valstu likumi un saistošie noteikumi, kas nosaka, piemēram, pieļaujamā piesārņojuma (gaisa, ūdens, augsnes u. c.) līmeni [2], [93], [198]. Normatīvo aktu juridiski saistošais raksturs ir būtisks, ja nepieciešams mainīt uzvedību, kuru ar citiem instrumentiem nav iespējams ietekmēt [2], [199]. Stiprās puses ir stingrāka problēmu regulācija un sankciju iespējamība, savukārt vājās puses var būt papildus administratīvais slogs, augstas prasības un uzraugošo iestāžu nespēja izsekot noteikumu ievērošanai [93], [199].

Brīvprātīgie instrumenti ietver sabiedrības, uzņēmumu vai citu ieinteresēto pušu iniciatīvas, kas nav juridiski saistošas un nav tieši stimulētas ar labumiem, bet kuru mērķis ir veicināt ilgtspēju un vides aizsardzību [93], [200]. Tie var izpausties kā brīvprātīgas vienošanās, tehniskie standarti vai saziņa starp valsti, sabiedrību un uzņēmumiem [2], [93]. Šīs kategorijas efektivitāte ir neviennozīmīga, jo pārmaiņu ieviešanai industrijā nepieciešama brīvprātīga motivācija, kas bieži vien iztrūkst [2]. Kā piemēru var minēt uzņēmumu ilgtspējas ziņojumus, kuros tie apkopo datus par SEG emisijām, atkritumiem, enerģijas patēriņu un citiem vides, sociālajiem un pārvaldības rādītājiem [201]. Šādu brīvprātīgo rīcību bieži virza vēlme stiprināt reputāciju investoru un patērētāju acīs [202], [203], [204]. Vēl viens piemērs ir Vides vadības un audita sistēma, kas gan dažkārt tiek kritizēta par nepietiekami augstiem standartiem [205]. Tādēļ brīvprātīgos instrumentus nevar uzskatīt par efektīvāko un ekonomiski ietekmīgāko politikas instrumentu kategoriju, taču tie demonstrē uzņēmumu un sabiedrības gatavību mazināt savu ietekmi uz vidi [200], [205], [206].

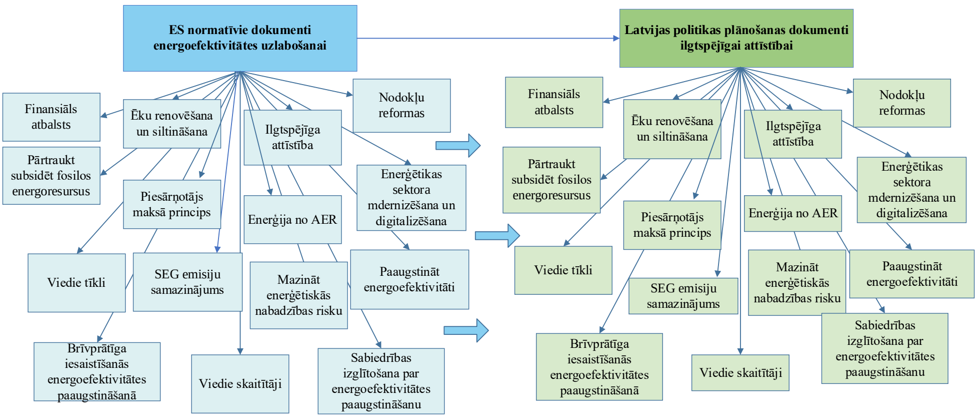
Publiskie izdevumiem ir valdību finansiālais atbalsts un ieguldījumi, kas veicina vides mērķu sasniegšanu un ilgtspējīgu attīstību. Lai gan literatūrā tie nereti tiek iekļauti tirgus vai ekonomisko instrumentu kategorijā [2], to nozīmīguma dēļ lietderīgi tos izdalīt kā atsevišķu kategoriju. Klasiski piemēri ir subsīdijas un dotācijas ar nelielu līdzmaksājumu, kā arī investīcijas infrastruktūrā – AER uzstādīšanai vai ražošanas jaudu palielināšanai, elektroauto uzlādes staciju izveidē vai atkritumu šķirošanas sistēmu pilnveidē [93], [207]. Publiskie izdevumi var pozitīvi ietekmēt sabiedrības un uzņēmumu uzvedību, radīt pārmaiņas tirgus darbībā un uzlabot mazāk efektīvu nozaru rādītājus [208]. Tomēr to efektivitāte ir atkarīga no valdības spējām nodrošināt finansējuma mērķtiecīgu un jēgpilnu izmantošanu [208]. Papildu izaicinājums ir iespējamais spiediens uz valsts budžetu, īpaši mazāk attīstītajās valstīs, kur prioritāri jārisina drošības un sociālie jautājumi [207]. Tipisks piemērs ir emisiju tirdzniecība, kur tiek noteikti griesti kopējām SEG emisiju daudzumam un uzņēmumi tirgo emisiju kvotas vai ietaupījumus.

Ekonomiskie un tirgus instrumenti tiek klasificēti kā netiešās pārvaldības instrumenti, un ietver tādas pieejas kā "ierobežo un tirgo" *(cap and trade),* "mērķē un tirgo" *(target and trade)* vai finanšu iniciatīvas [209]. Tie balstās uz tirgus mehānismiem, piemēram, nodokļiem par piesārņojošām darbībām vai produktiem, "piesārņotājs maksā" principu un subsīdiju atcelšanu fosilajiem resursiem [2], [209], [210]. Viena no būtiskākajām to priekšrocībām ir papildu budžeta ieņēmumi, ko var novirzīt vides un energoefektivitātes projektiem [93], [210]. Tipisks piemērs ir emisiju tirdzniecība, kur tiek noteikti griesti kopējam SEG emisiju daudzumam un uzņēmumi tirgo emisiju kvotas vai ietaupījumus [210]. Šajā instrumentu kategorijā ietilpst arī depozīta sistēmas, kas stimulē iepakojuma pārstrādi [93]. Tomēr atšķirībā no normatīvā regulējuma šie instrumenti balstās uz teorētiskiem aprēķiniem un sabiedrības gatavību iesaistīties, tāpēc nodokļi bieži tiek noteikti zemāki par nepieciešamo, lai izvairītos no pārāk zemas līdzdalības [93], [210].

Katrai politikas instrumentu kategorijai ir stiprās un vājās puses atkarībā no sasniedzamā rezultāta, un bieži instrumentu kombinācijas politikas plānošanas procesā tiek veidotas atbilstoši situācijai [2]. Līdz ar to būtiski noteikt, vai ir tikusi piemērota efektīvākā politikas instrumentu kombinācija, lai panāktu neieciešamo ietekmi [211]. Normatīvā regulējuma instrumentiem ir nozīmīga loma nākotnes attīstības pamatprincipu definēšanā, tomēr šie instrumenti jāpapildina ar tirgus instrumentiem un atbilstošiem publiskajiem izdevumiem [209], [211]. Turklāt publiskos izdevumus iespējams apvienot ar citiem instrumentiem, piemēram, papildus nodokļiem par radītajām SEG emisijām vai, gluži pretēji, nodokļu atvieglojumiem energoefektivitātes uzlabošanai apvienojumā ar stingrāku tiesisko regulējumu [199], [208]. Eiropas Komisijas "Labāka regulējuma instrumentu kopumā" norādīts, ka ne visas politikas instrumentu kombinācijas ir veiksmīgas un dod gaidītos rezultātus, tāpēc, kombinējot politikas instrumentus jānodrošina to samērīgums un savstarpēja papildināmība [2].

Ilgtermiņa plānošanas dokumentu analīze

Politikas dokumentu vertikālās koherences novērtējuma rezultāti (1. publikācija) redzami 3.10. attēlā un norāda uz augstu saskaņotības līmeni. Tajā pašā laikā, Latvijas ilgtermiņa plānošanas dokumentos ir minēts princips “energoefektivitāte pirmajā vietā”, bet nav atrodamas norādes par nepieciešamību “dot priekšroku zaļiem un ilgtspējīgiem risinājumiem”, kas minēti ES normatīvajos un politikas dokumentos. Turklāt Latvijas ilgtermiņa plānošanas dokumentos nav atrodamas atsauces uz energoefektivitātes marķējuma izvietošanas nepieciešamību vai “vispirms domā par mazajiem” principa piemērošanu, kas mudina politisku lēmumu pieņemšanas procesā izvērtēt mazo un vidējo uzņēmumu kapacitāti un spēju pielāgoties normatīvo aktu izmaiņām [212]. Joprojām tiek piemēroti nodokļu atvieglojumi fosilajiem energoresursiem un nav izveidoti atbalsta mehānismi AER izmantošanai vai energoefektivitātes paaugstināšanai [184]. Pētījuma veikšanas laikā akcīzes nodoklis nebija sasaistīts ar fosilā kurināmā radīto ietekmi uz vidi, un arī princips “energoefektivitāte pirmajā vietā” praksē netika īstenots, jo piešķirot publisko finansējumu attīstības projektiem, šis aspekts netiek ņemts vērā [184], [213]. Attīstības virzieni un atbilstošas rīcībpolitikas valsts līmenī ir noteiktas, taču nepieciešama detalizētāka ieviešanas plānošana, lai nodrošinātu noteikto mērķu sasniegšanu [184].



3.10. att. ES mērķu implementācija Latvijas ilgtermiņa plānošanas dokumentos.

Politikas un to īstenošanas pasākumi

Pēc ES un Latvijas līmenī noteikto mērķu vertikālās saskaņotības noteikšanas, nākamais solis bija NEKP2030 4. pielikumā “Plānotās rīcībpolitikas un to īstenošanas pasākumi” uzskaitīto politikas pasākumu, kas plānoti energoefektivitātes uzlabošanai siltumapgādē un dzesēšanā, iedalīšana politikas instrumentu kategorijās [184]. Tika identificēti 34 rīcības virzieni ar 110 plānotiem pasākumiem, kas tieši vai netieši var veicināt siltumapgādes un dzesēšanas nozares efektivitāti, un tie tika tematiski klasificēti četrās politikas instrumentu kategorijās (3.4. tab.). NEKP2030 ietvaros paredzēti energoefektivitātes uzlabošanas pasākumi, “energoefektivitāte pirmajā vietā” principa īstenošana, siltumapgādes nozares efektivitātes paaugstināšana, kā arī siltumtrašu renovācija un paplašināšana, lai veicinātu jaunu pieslēgumu izveidi [184]. Turklāt uzsvērta nepieciešamību veicināt AER izmantošanu un veikt izmaiņas nodokļu regulējumā [184].

Kā redzams 3.4. tabulā, lielākais plānoto politikas pasākumu skaits ir politikas instrumentu kategorijā "Normatīvais regulējums" (69 % jeb 76 pasākumi), otrajā vietā ir "Publiskie izdevumi" (20 % jeb 22 pasākumi), kam seko "Ekonomiskie (tirgus) instrumenti" (7 % jeb astoņi pasākumi) un vismazāk pasākumu atbilst kategorijai "Brīvprātīgie instrumenti" (4 % jeb četri pasākumi). Rezultāti parāda, ka plānotie politikas pasākumi nav vienmērīgi izvietoti starp instrumentu kategorijām. "Ekonomiskie (tirgus) instrumenti" un "Brīvprātīgie instrumenti" ir visretāk izmantotie, un tie galvenokārt kombinēti ar normatīvā regulējuma instrumentiem.

3.4. tabula

NEKP2030 plānoto rīcībpolitiku un to īstenošanas pasākumu sadalījums pa politikas instrumentu kategorijām

Politikas instrumentu kategorija	**Normatīvais regulējums**	**Brīvprātīgie instrumenti**	**Publiskie izdevumi**	**Ekonomiskie (tirgus) instrumenti**
Pasākumi	76	4	22	8

Visbiežāk minētie "Normatīvā regulējuma" instrumenti ir jaunu normatīvo aktu izstrāde - Ministru kabineta noteikumi, procedūras vai vadlīnijas (37 pasākumi) un dažādu pētījumu un izvērtējumu veikšana (19 pasākumi). Retāk minēti tādi pasākumi kā vienotu kontaktpunktu izveide, informācijas kampaņas un mācību materiālu izstrāde. Kā "Brīvprātīgie instrumenti" minētas brīvprātīgas vienošanās, sabiedrības līdzdalības veicināšana ESCO un PESCO tirgus darbībā, energoefektivitātes uzlabošana. "Publiskie izdevumi" bieži minēti saistībā ar normatīvo aktu grozījumiem, lai nodrošinātu Eiropas struktūrfondu un investīciju fondu pieejamību pēc 2021. gada (saistībā ar septiņiem pasākumiem). Minēts arī finansiāls atbalsts renovācijai, siltināšanai, energoefektivitātei; atbalsts brīvprātīgiem nolīgumiem; fonda izveide AER un energoefektivitātes veicināšanai. Attiecībā uz "ekonomiskajiem instrumentiem" NEKP2030 neparedz to tiešu ieviešanu, bet gan novērtējuma veikšanu par to piemērošanas iespējamību, piemēram, energoefektivitātes uzlabošanā radušos ietaupījumu pārdošana, nodokļu atvieglojumi par energoefektivitātes uzlabošanu vai AER izmantošanu, kā arī nodokļu sloga palielināšana fosilajiem kurināmajiem, potenciāli iekļaujot tos kā grozījumus normatīvajos aktos.

Vairākiem pasākumiem ir piemērots politikas instrumentu kopums, piemēram, kombinējot "Normatīvo regulējumu" ar "Brīvprātīgiem instrumentiem" un "Publiskiem izdevumiem"; "Normatīvo regulējumu" kombinējot ar "Tirgus instrumentiem". Retākos gadījumos "Normatīvais regulējums" ir kombinēts ar "Publiskiem izdevumiem" un "Tirgus instrumentiem".

Novērojama vertikālā saskaņotība starp ES noteiktajiem mērķiem un Latvijas ilgtermiņa un vidēja termiņa politikas plānošanas dokumentiem. Tomēr, analīze atklāja atsevišķus sadrumstalotus elementus un nepilnības. Piemēram, lai arī dokumentos ir uzsvērta nepieciešamība veicināt AER izmantošanu, atbalsta mehānismi to ieviešanai praksē ir nepietiekami attīstīti. Līdzīgi, politikas dokumentos noteikta apņemšanās pakāpeniski pārtraukt atbalstu fosilajiem energoresursiem, taču nav izstrādāts skaidrs īstenošanas plāns. Šo izaicinājumu ilustrē arī fakts, ka jau 2013. gadā "Latvijas ilgtermiņa enerģētikas stratēģijā 2030" nostiprināta nepieciešamību pāriet no fosilā kurināmā uz AER, bet gandrīz 10 gadus vēlāk NEKP2030 atkal aktualizē šo jautājumu, nepiedāvājot pietiekami konkrētus risinājumus [184], [214].

Latvijas ilgtermiņa plānošanas dokumentos uzmanība pievērsta energoefektivitātes uzlabošanai gan siltumenerģijas ražošanā, gan pārvadē, vienlaikus samazinot siltuma zudumus. Analizētajos dokumentos ir ierobežota informācija par iespēju pārvadīt ražošanas uzņēmumu siltumenerģiju un dzesēšanas pārpalikumus uz centralizētās siltumapgādes tīkliem. ES dokumentos uzsvērta nepieciešamība izveidot patērētājiem pārredzamu un taisnīgu energoapgādes sistēmu — galapatērētājiem jāsaņem skaidri un detalizēti rēķini par patērēto siltumu un karsto ūdeni, kā arī jābūt iespējai uzstādīt individuālos skaitītājus, lai spētu ietekmēt enerģijas patēriņu. Latvijas plānošanas dokumentos nav minēta informācija par iespējamiem grozījumiem apkures un karstā ūdens uzskaites un norēķinu kārtībā.

Kopumā Latvijas plānošanas dokumenti norāda uz vertikālu saskaņotību ar ES noteiktajiem mērķiem, taču analīzes laikā identificētie politikas instrumenti energoefektivitātes uzlabošanai siltumapgādes un dzesēšanas nozarē vērtējami kā ierobežoti. NEKP2030 pārsvarā izmantoti kategorijas "Normatīvais regulējums" instrumentus, kas var nozīmēt papildu administratīvo slogu, lai gan Latvijas plānošanas dokumentu analīzē jau konstatētas norādes uz sarežģītiem birokrātiskajiem procesiem un ierobežotu institucionālo kapacitāti [183], [184], [213]. Kategorijā "Publiskie izdevumi" minētie pasākumi atspoguļo valdības iniciatīvu atbalstīt energoefektivitātes uzlabošanu, tomēr padziļināta analīze rāda, ka tie galvenokārt saistīti ar normatīvo dokumentu grozījumiem ES fondu piesaistei, nevis papildu valsts finansējumu. NEKP2030 retāk lietoti kategoriju "Ekonomiskie (tirgus) instrumenti" un "Brīvprātīgie instrumenti" pasākumi, turklāt paredzētie pasākumi šķiet mazāk ambiciozi, piemēram, brīvprātīgo nolīgumu skaita pieaugums no diviem līdz 10 vai atsauce uz iespējamām nodokļu izmaiņām nākotnē, kas formulēts kā "novērtēt iespējamo normatīvo izmaiņu apjomu", nevis "veikt izmaiņas" [184]. Lai sasniegtu ilgtermiņa mērķus enerģētikas sektora dekarbonizācijā un efektivitātes paaugstināšanā, politikas pasākumu kopumam būtu jāpārorientējas uz tirgus instrumentus izmantošanu un mērķtiecīgāku pāreju no novērtēšanas fāzes uz rīcības fāzi.

Apakšnodaļās 3.1.1.-3.1.4. analizēti četri piemēri politiskās saskaņotības novērtēšanai. Apakšnodaļā 3.1.1. veikts *CRCF* regulas horizontālās saskaņotības novērtējums plašākā ES klimata, lauksaimniecības un ZIZIMM politiku ietvarā, kā arī aplūkoti iespējamie šķēršļi vertikālās saskaņotības nodrošināšanai, ieviešot *CRCF* regulas sertifikācijas satvaru dalībvalstīs. Tā kā pētījuma veikšanas laikā sertifikācijas satvars un metodikas vēl bija izstrādes stadijā, padziļināts vertikālās saskaņotības izvērtējums nebija iespējams. Apakšnodaļās 3.1.2. un 3.1.3. vērtēta bioekonomikas politikas vertikālā saskaņotība, analizējot Eiropas Bioekonomikas stratēģijas mērķu implementāciju dalībvalstu un Latvijas politikas dokumentos. Rezultāti parādīja, ka dalībvalstis, tostarp Latvija, ES mērķus ir integrējušas savās bioekonomikas stratēģijās. Izvērtējums ļāva noteikt pasākumu formālu saskaņotību, ierobežojot iespēju veikt turpmāku novērtējumu par noteikto mērķu praktiskās izpildes efektivitāti. To ilustrē arī kvantitatīvie rezultāti: 1 % jeb astoņi pasākumi nacionālajās bioekonomikas stratēģijās nav sasaistāmi ar Eiropas Bioekonomikas stratēģijas mērķiem (3. publikācija), tomēr valstu stratēģiju mērķu un pasākumu precizitāte un strukturētība būtiski atšķiras. To atspoguļo arī *TOPSIS* rezultātu plašā amplitūda (0,01-0,94), kas norāda uz ievērojamām atšķirībām politikas īstenošanas gatavībā, nevis pašas politikas kvalitātē. Latvijas Bioekonomikas stratēģija 2030 Latvijas politikas dokumentu izvērtējumā (2. publikācija) ieguva 0,98, izmantojot ekspertu svarus, un, 0,95 izmantojot vienādus svarus, kas *TOPSIS* metodē norāda tuvumu ideālajam pozitīvajam risinājumam, taču tās relatīvi zemākā pozīcija ES dalībvalstu bioekonomikas stratēģijas salīdzinājumā parāda, ka formālā saskaņotība ne vienmēr nozīmē augstu praktiskās ieviešanas sagatavotību.

Lai izvērtētu, kā formālā saskaņotība atspoguļojas praktiskajā īstenošanā, tika veikta gadījuma izpēte, kur papildus vertikālajai saskaņotībai analizēts arī NEKP2030 rīcības plāns mērķu īstenošanai (1. publikācija). Rezultāti parādīja izteiktu politikas instrumentu disproporciju: 69 % jeb 76 pasākumi ietilpst "Normatīvā regulējuma" kategorijā, savukārt "Ekonomiskie (tirgus) instrumenti" veido tikai 7% (astoņi pasākumi). Šāda struktūra norāda uz ierobežotu instrumentu dažādību un salīdzinoši vāju ekonomisko (tirgus) mehānismu izmantošanu. Lai gan mērķi un virzienu siltumapgādes un dzesēšanas nozares attīstībai atbilst ES līmenī noteiktajiem, pasākumu uzbūve balstīta uz normatīvajiem risinājumiem, nevis līdzsvarotu politikas instrumentu kopumu, kas ierobežo pasākumu efektivitāti un kavē mērķu sasniegšanu.

Iegūtie rezultāti stiprina promocijas darba hipotēzi, ka politikas saskaņotības novērtējums atklāj tikai formālu mērķu implementāciju, savukārt to īstenošanā nozīmīga ir atbilstošu pasākumu izstrāde un politikas instrumentu piemērošana. Tādēļ nepietiek ar dokumentu saskaņotības izvērtējumu, nepieciešama padziļināta analīze, kas ļauj identificēt procesu optimizācijas iespējas un novērst barjeras, lai stiprinātu bioekonomikas un klimata politikas efektivitāti.

Šie secinājumi kalpoja kā pamats nākamajam promocijas darba segmentam - šķēršļu un nepilnību identificēšana politikas optimizācijai. Šajā posmā tika veiktas divas gadījuma izpētes. Pirmajā analizēts AER projektu īstenošanas process, lai identificētu vai tajā nepastāv barjeras, jo iepriekšējā posmā (3.1.4. apakšnod.) izgaismojās būtisks aspekts – lēna AER attīstība Latvijā, kam par iemeslu varētu būt birokrātiskais slogs un administratīvās prasības. Otrajā gadījuma izpētē turpināta bioekonomikas attīstības iespēju analīze, koncentrējoties uz meža sektoru. Tā tika veikta, izmantojot *Maciejczak* [215] izstrādāto un *Wreford et al.* [33] papildināto pieeju bioekonomiku ietekmējošo faktoru izvērtēšanai. Pamatojoties uz šo analīzi tika identificēti trīs ilgtspējīgi nišas produkti un izstrādātas to attīstības stratēģijas.

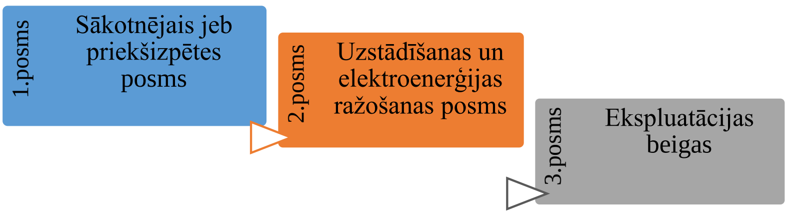
3.2. Šķēršļu un nepilnību identificēšana politikas optimizācijai

Šķēršļu un nepilnību identificēšana politikas optimizācijai balstījās uz literatūras un dokumentu analīzes metodēm, ko papildināja datu vākšana, daudzkritēriju lēmumu pieņemšanas analīze, kā arī stratēģiskās plānošanas un izvērtējuma pieejas. Pirmajā gadījuma izpētē analizēti Baltijas un Ziemeļvalstu AER projektu īstenošanas un apstiprināšanas procesi, no projekta idejas koordinēšanas līdz stacijas būvniecībai un nodošanai ekspluatācijā.

Administratīvo procesu efektivitāte tika vērtēta pēc kvalitatīviem un kvantitatīviem kritērijiem, un sniegtas rekomendācijas to optimizācijai. Otrajā gadījuma izpētē uzmanība pievērsta Latvijas meža sektoram, kur ar nišas produktu attīstības scenāriju analīzes palīdzību identificēti sektora transformāciju kavējošie šķēršļi un barjeras, kā arī izvērtētas iespējas to pārvarēšanai, veicinot ilgtspējīgu nozares attīstību.

3.2.1. Administratīvo šķēršļu novēršana AER projektu ieviešanā

Pētījuma (4. publikācija) kontekstā administratīvais process ir procesu kopums, kas vēja elektrostaciju (VES) vai saules elektrostacijas (SES) projektu izstrādātājam jāveic, lai īstenotu projektu no projekta koncepcijas līdz elektroenerģijas ražošanai. Pētījumā administratīvie procesi ietver pieslēgšanas procesa ilgumu, procesa pārredzamību, ierobežošanu un tīkla paplašināšanu, taisnīgu un neatkarīgu enerģētikas nozares regulējumu, administratīvā procesa sarežģītību, zemes izmantošanas un vides plānošanu, procesu ilgumu, sabiedrības uztveri, saziņu starp attiecīgajām ieinteresētajām personām [59], [60], [216], [217]. Daži šķēršļi atšķirīgi ietekmē sauszemes un atkrastes VES, kā arī SES projektu īstenošanu [60], piemēram, administratīvie procesi un AER iekļaušana teritoriālajā plānojumā ir sarežģītāka VES nekā SES [218]. SES un VES tehnoloģiju uzstādīšanas procesu var iedalīt trīs procesa posmos: sākotnējais jeb priekšizpētes posms, uzstādīšanas un elektroenerģijas ražošanas posms un ekspluatācijas beigu jeb izbeigšanas posms (3.11. att.).

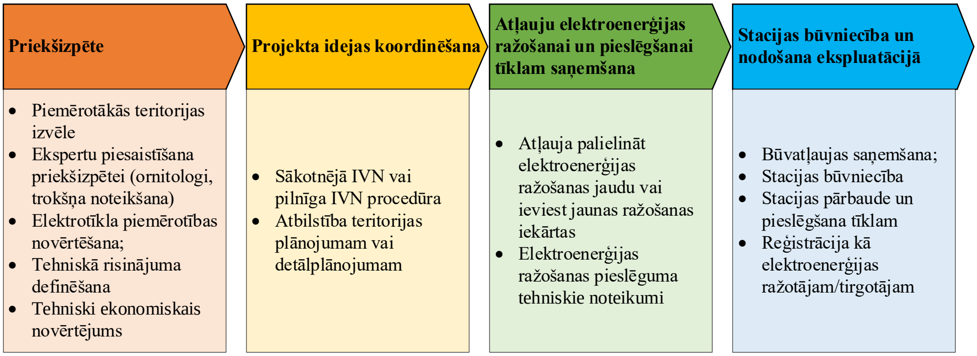


3.11. att. Elektroenerģijas ražošanai paredzēto AER tehnoloģiju ieviešanas posmi.

AER projektu ieviešanas process analizētajās valstīs

Pētījumā konstatēts, ka normatīvais regulējums un administratīvās procedūras VES un SES uzstādīšanai pētītajās valstīs ir praktiski vienādas projektu īstenošanas posmu un nepieciešamo atļauju ziņā, ar dažām nelielām atšķirībām. Tipiski literatūrā administratīvais process VES un SES novērtēts atsevišķi, lai gan abām tehnoloģijām procesa posmi ir gandrīz identiski, ar galveno atšķirību, ka SES galvenokārt nav pakļautas telpiskā plānojuma ierobežojumiem un nav nepieciešama IVN. AER projektu īstenošanas procesi ir šādi: priekšizpēte; projekta idejas koordinācija; atļauju elektroenerģijas ražošanai un pieslēgšanai tīklam saņemšana; stacijas būvniecība un nodošana ekspluatācijā (3.12. att.), tādējādi aptverot gandrīz divus no trim 3.11. attēlā minētajiem projekta īstenošanas posmiem līdz elektroenerģijas ražošanas uzsākšanai.

Projekta priekšizpētes fāze netika detalizēti izvērtēta, lai gan intervijās nozares pārstāvji minēja šādus elementus: vēja ātrums vai noēnojums izvēlētajā teritorijā; teritorijas plānojuma ierobežojumi; IVN sākotnējais novērtējums; trokšņa mērījumi; pieslēgums tīklam un tā izmaksas; tehnoloģiju transportēšanas infrastruktūra; projekta ekonomiskā dzīvotspēja, kā arī attālums no militārām iekārtām un radariem.



3.12. att. Vispārīgie pasākumi AER projektu īstenošanas un apstiprināšanas procesā.

Zviedrijā atļaujas izsniegšanas process VES attīstīšanai var tikt uzsākts tikai tad, ja pašvaldība ir izsniegusi atļauju [219], [220]. Pretējā gadījumā pirmais solis AER projekta īstenošanā ir vai nu teritorijas plānojuma grozīšana, vai, ja nepieciešams, IVN procedūras veikšana [219], [220]. Parasti tiek noteiktas vispārīgās prasības telpiskās attīstības plānošanai — teritorijas izmantošanai un būvniecības ierobežojumiem. Pašvaldības savos telpiskajos plānos vai detālplānos var noteikt atsevišķas teritorijas, kurās atļauta vai aizliegta VES būvniecība. Atsevišķos gadījumos pašvaldības iekļauj arī ierobežojumus attiecībā uz SES uzstādīšanu. Baltijas valstīs, ja pašvaldība saskaņā ar telpisko plānu vai detālplānu neparedz VES uzstādīšanu izvēlētajā teritorijā, projekta attīstītājam jāiesniedz pašvaldībai pieteikums par grozījumu veikšanu detālplānojumā [221], [222]. Turklāt, ja kāda plānotā teritorijas daļa nav projekta attīstītāja īpašumā, jānoslēdz zemes nomas līgumi, kā arī jāvienojas ar blakus esošo zemes īpašniekiem. Administratīvā procedūra pašvaldības telpiskā plānojuma grozīšanai var ietvert sabiedrisko apspriešanu [221], [222]. Norvēģijā pašvaldības ir atbildīgas par teritorijas plānojumu visās nozarēs, izņemot enerģētiku, kur projektu izstrādātāji vēršas pie Norvēģijas Ūdens resursu un enerģētikas direktorāta [150], [223]. Saskaņā ar Lietuvas Republikas Likumu par atjaunojamajiem energoresursiem (XI-1375) mazām sistēmām, kuru jauda nepārsniedz 500 kW un kuras izmanto AER nav nepieciešami detalizēti telpiskie plāni vai primārās zemes izmantošanas maiņa, ja tas nav pretrunā ar noteikumiem par vietējās pārvaldes zemes izmantošanu [224].

Nākamais solis vidēja un liela mēroga VES parasti ir sākotnējais IVN vai obligātais IVN, atkarībā no uzstādāmās elektrostacijas jaudas [150]. IVN procedūra var tikt veikta arī pirms izmaiņu veikšanas pašvaldības telpiskajā plānā, vai abas procedūras var tikt veiktas paralēli. SES parasti nav pakļautas IVN procedūrai, tomēr Igaunijā pastāv iespējamība, ka SES būvniecībai var būt nepieciešams sākotnējais IVN kā daļa no būvatļaujas saņemšanas procedūras, ja attiecīgā pašvaldība nolemj, ka tās darbība var negatīvi ietekmēt vidi. Zviedrijas pašvaldībām ir tiesības izteikties, tostarp pārsūdzēt lēmumus, jautājumos, kas saistīti ar VES un SES atļaujām saskaņā ar Vides kodeksu, lai aizsargātu vides un sabiedrības intereses pašvaldības teritorijā [225], [226]. Somijas pašvaldības var veicināt VES attīstību, pieņemot lokālu ģenerālplānu vēja enerģijas izmantošanai, kurā jau ir iekļauti nepieciešamie vides novērtējumi [227]. Vairumā gadījumu sākotnējā IVN un IVN procedūras laikā tiek veiktas aptuveni trīs sabiedriskās apspriešanas [228], [229], savukārt Lietuvas IVN procedūrā var identificēt piecas sabiedriskās apspriešanas, kā arī iespēju atbildīgajai iestādei vairākas reizes nosūtīt ziņojumu atpakaļ labošanai [230].

Pēc IVN ziņojuma apstiprināšanas un atbilstības ar telpisko plānojumu saskaņošanas, Latvijā un Lietuvā ir jāsaņem atļauja jaunu elektroenerģijas ražošanas iekārtu uzstādīšanai [231], [232], [233]. Somijā elektrostacijām, kuru elektriskā jauda ir vismaz 1 MVA, ir jāpaziņo Somijas Enerģētikas aģentūrai par elektrostacijas būvniecības plānu vai lēmumu palielināt tās jaudu [234].

Nākamais solis VES un SES uzstādīšanai ir būvatļaujas saņemšana un būvdarbu uzsākšana [235], [236], [237]. Mikroģeneratoru uzstādīšanai bieži nav noteikts pienākums saņemt būvatļauju [238]. Piemēram, Lietuvā SES un VES ar uzstādīto jaudu līdz 30 kW, kas nepārsniedz trokšņa līmeni, var uzstādīt uz ēkām vai integrēt ēkās bez būvatļaujas [224]. Igaunijā, ja iespējams, IVN procedūra tiek apvienota ar Būvniecības kodeksa procedūrām; šādā gadījumā ir jāievēro abu procedūru prasības [237], [239]. Somijas Zemes izmantošanas un būvniecības likumā ir noteikts, ka būvatļauja VES var tikt izsniegta, ja juridiski saistošā teritorijas plānojumā ir noteikts, ka plāns vai tā daļa ir būvatļaujas pamats [240]. Zviedrijā, ja ir plānots būvēt objektu, kam nepieciešama būvatļauja, attīstītājs var iesniegt iepriekšēju pieteikumu, lai savlaicīgi noskaidrotu, vai konkrētajā vietā ir iespējams realizēt projektu [241], [242], [243]. Pozitīvs iepriekšējs lēmums dod attīstītājam tiesības veikt attiecīgos pasākumus konkrētajā vietā, ja attīstītājs divu gadu laikā iesniedz būvatļaujas pieteikumu [241]. Pirms būvdarbu uzsākšanas attīstītājam jāiesniedz būvatļaujas un plānošanas atļaujas pieteikums un jāgaida lēmums [241]. Somijā ir izveidots vienots digitālais pakalpojumu portāls *Lupapiste*, kas paredzēts būvatļauju un citu ar licencēm saistītu pakalpojumu pārvaldībai, lai pašvaldības varētu rīkoties saskaņā ar Zemes izmantošanas un būvniecības likumu; šis pakalpojums ir pielāgots pašvaldību, attīstītāju un citu atļauju izsniegšanas procedūrā iesaistīto pušu individuālajām vajadzībām [244], [245].

Lietuvā un Igaunijā ir jāiegūst atļauja elektroenerģijas ražošanai [246], [247], [248]. Pirms darbības uzsākšanas elektroenerģijas ražotājiem vai tirgotājiem ir jāreģistrējas attiecīgajā elektroenerģijas ražotāju vai tirgotāju reģistrā [246], [249], [250]. Elektroenerģijas tirdzniecībai Somijā nav nepieciešama atsevišķa licence elektroenerģijas tirdzniecībai, bet Norvēģijā ir nepieciešama tirdzniecības licence [251], [252], [253].

Vairumā pētījumā iekļauto valstu mazas un vidējās jaudas elektrostaciju ar jaudu līdz 10 MW pieslēgšanai tīklam jāvēršas pie sadales sistēmas operatora, bet lielo elektrostaciju ar jaudu virs 10 MW pieslēgšanai tīklam jāvēršas pie pārvades sistēmas operatora. Lietuvā projektu attīstītājiem ir jāsaņem nodoma vēstule, par plānu pievienot elektrostaciju elektroenerģijas tīklam [224], [232]. Sadales sistēmu operatoru skaits pētījumā iekļautajās valstīs ir ļoti atšķirīgs – Latvijā 11, Lietuvā 6, Igaunijā 34, Somijā 77, Norvēģijā vairāk nekā 120, Zviedrijā 170 [254], [255], [256].

Norvēģija ir vienīgā pētījumā iekļautā valsts, kurā ir vienots kontaktpunkts, kas koordinē SES un VES attīstību un izsniedz darbības uzsākšanai nepieciešamās atļaujas – Norvēģijas

Ūdens resursu un enerģētikas direktorāts [150]. Zviedrijas Enerģētikas aģentūra pētījuma veikšanas brīdī vēl strādāja pie digitāla kontaktpunkta izveides, kas aptvertu atļaujas, izņēmuma gadījumus un paziņošanas procedūras AER iekārtām un to pieslēgšanu tīklam [257].

Projektu īstenošanas termiņi

3.5. tabulā ir parādīts standartizējamo procesu ilgums dažādiem AER projektiem. Norvēģijā un Igaunijā mikroģeneratoru uzstādīšana ir vislaikietilpīgākā, jo ir ilgs būvatļaujas saņemšanas process. Ilgākais termiņš lielām un vidējām SES ir Lietuvā un Igaunijā, bet VES — Lietuvā un Zviedrijā.

Nestandartizējamo procesu aptuvenais ilgums ir aprēķināts, pamatojoties uz normatīvajiem aktiem un vairākiem pieņēmumiem, jo tādiem procesiem kā IVN vai izmaiņām telpiskajā plānojumā ilgums ir atkarīgs no konkrētā projekta un vienā un tajā pašā valstī var atšķirties ne tikai par dienām, bet pat par mēnešiem. Tomēr, ņemot vērā iepriekš minēto, ir aprēķināts SES un VES projektu īstenošanas ilgums, nosakot maksimālo termiņu.

3.5. tabula

Dažādu veidu AER projektu īstenošanas vidējais ilgums (dienās) (2021. gads)

	Standartizējamie procesi (dienas)			**Nestandartizējamie procesi (dienas)**			**Aplēstais reālais projekta ilgums, dienas**	
Valsts	Mikroģeneratori	SES	VES	Mikroģeneratori	SES	VES	SES	VES
Latvija	30	91	91	30	343	1676	300	3285
Lietuva	0	89	89	48	519	1878	365	2920
Igaunija	60	165	165	30	720	1817	273	3650
Somija	14	58	180	30	720	1268	365	2920
Norvēģija	0	103	154	90	638	822	365	1460
Zviedrija	70	70	100	90	430	1247	365	2920

AER tehnoloģiju projektu izstrādei nepieciešamais laiks ir atkarīgs no dažādiem aspektiem, tādēļ īstenošanas laiks katram projektam ir atšķirīgs. Veiktā 14 dažādu SES un VES projektu gadījumu izpēte dažādās valstīs liecina, ka vidēji sauszemes VES projektu īstenošana ilgst piecus gadus. SES attīstības projekti galvenokārt tiek pabeigti 1–2 gadu laikā.

Sarežģītība

3.6. tabulā norādīts kontaktpunktu skaits (pašvaldības, valsts iestādes, aģentūras), kas iesaistītas projekta īstenošanas procesā un visu nepieciešamo atļauju saņemšanā. Kā redzams, kontaktpunktu skaits mikroģeneratoru uzstādīšanai nepārsniedz vienu vai divas iestādes. Pirmā iestāde parasti ir vietējā pašvaldība vai pašvaldības būvvalde. Visos gadījumos, izņemot Zviedriju, otrais kontaktpunkts ir sadales sistēmas operators, kas koordinē pieslēgšanu elektrotīklam. Visbeidzot, Zviedrijas gadījumā, lai izveidotu pieslēgumu, jāsazinās ar sertificētu elektromontieri kādā elektromontāžas uzņēmumā.

SES un VES projektu īstenošanas procesā kontaktpunktu skaits visās novērtētajās valstīs ir līdzīgs. Visvairāk kontaktpunktu ir Baltijas valstīs, jo īpaši Latvijā. Norvēģija ir vienīgā pētījumā iekļautā valsts, kas koordinācijas procesu ir konceptuāli īstenojusi, izmantojot vienotu kontaktpunktu [150]. Norvēģijas Ūdens resursu un enerģētikas direktorāts ir centrālais kontaktpunkts, bet dažos gadījumos, lai uzstādītu mazākas elektrostacijas, ir jāsazinās ar vietējo pašvaldību.

3.6. tabula

AER projektu īstenošanā tieši vai netieši iesaistīto kontaktpunktu skaits un nepieciešamie dokumenti (2021.gads)

	Kontaktpunktu skaits			Netieši iesaistīto iestāžu skaits			Nepieciešamo dokumentu skaits	
Valsts	Mikroģeneratori	SES	VES	Mikroģeneratori	SES	VES	SES	VES
Latvija	2	6	8	0	2	4	2	15
Lietuva	1	4	5	0	2	2	1	18
Igaunija	2	4	5	1	2	2	2	17
Somija	2	4	4	1	1	2	1	3
Norvēģija	1	1	1	2	3	3	1	4
Zviedrija	2	3	3	0	3	3	1	2

Pētījuma laikā nebija iespējams noteikt precīzu netieši iesaistīto iestāžu skaitu, jo tās ne vienmēr ir norādītas normatīvajos dokumentos vai citā oficiāli pieejamā informācijā. Iespējams, ka, lemjot par atļaujas piešķiršanu, iestādes, kas ir tieši iesaistītas apstiprināšanas procesā (kontaktpunkti), sazinās ar netieši iesaistītajām iestādēm, kuras pēc tam sniedz atzinumu par vides un tehniskajiem aspektiem. Netieši iesaistīto iestāžu skaits arī ir līdzīgs visās pētījumā iekļautajās valstīs.

AER tehnoloģiju ieviešanai nepieciešamo dokumentu skaits tika iegūts, analizējot normatīvos dokumentus vai tos atrodot iestāžu oficiālajās tīmekļa vietnēs. Dati ir apkopoti 3.7. tabulā, un tie liecina, ka Baltijas valstīs attīstītājiem ir jāiesniedz vairāk dokumentu nekā Ziemeļvalstīs. Šī atšķirība varētu būt saistīta ar to, ka Baltijas valstīs normatīvajos aktos ir noteikti konkrēti dokumenti, kas jāizstrādā un jāiesniedz, lai saņemtu atļaujas. Ziemeļvalstīs īstenotā sistēma to neparedz, taču informāciju par nepieciešamajiem dokumentiem var iegūt, sazinoties ar attiecīgajām iestādēm. Visbiežāk minētie dokumenti ir pieteikumi nepieciešamo atļauju saņemšanai – būvatļaujas, atļaujas enerģijas ražošanai, atļaujas elektroenerģijas pārdošanai, pieteikumi un tehniskā dokumentācija par pieslēgšanos tīklam, kā arī pieteikums IVN. Mikroģeneratoru uzstādīšanai nepieciešami tikai daži dokumenti, kas atšķiras atkarībā no uzstādāmās tehnoloģijas, jaudas un atrašanās vietas. Vidēja un liela mēroga SES, VES gadījumā nepieciešamo dokumentu skaits ir līdzīgs, galvenokārt atkarībā no izvēlētās vietas ierobežojumiem, jo ir teritorijas, kur nepieciešamas papildu atļaujas. Ņemot vērā administratīvo datu pieejamības atšķirības starp valstīm, interpretācijas risks tika mazināts, salīdzinot informāciju vairākos avotos un pārbaudot tās konsekvenci starp normatīvajiem dokumentiem, iestāžu tīmekļa vietnēm un ekspertu sniegtajām atziņām (sk. Publikāciju Nr. 4). Šāda pieeja ļāva nodrošināt informācijas konsekvenci un samazināja interpretācijas kļūdu iespējamību.

Informācijas pieejamība

Informācijas pieejamība par AER projektu īstenošanas procesu tika iegūta, analizējot katras valsts oficiālajās tīmekļa vietnēs pieejamo informāciju un, ja nepieciešams, pārskatot normatīvos aktus. Analīzes mērķis bija vienuviet atrast vispusīgu, skaidrojošu un oficiālu informāciju par administratīvā procesa posmiem un iestādēm, pie kurām jāvēršas, lai uzstādītu AER tehnoloģijas.

Rezultāti ir apkopoti 3.7. tabulā, kā redzams no veiktā novērtējuma, visaptverošākā informācija par nepieciešamajām atļaujām un projektu īstenošanas procesiem ir pieejama Norvēģijā, jo SES un VES projektu izstrādes procesu koordinē vienots kontaktpunkts – Norvēģijas Ūdens resursu un enerģētikas direktorāts. Lai gan Zviedrijā pētījuma veikšanas brīdī nebija izveidotos vienots kontaktpunkts un atļauju izsniegšanas process AER elektrostaciju attīstības projektiem koordinēja pašvaldības, vispusīga informācija par SES un VES projektu īstenošanu ir pieejama Zviedrijas Enerģētikas aģentūras tīmekļa vietnē. Zviedrija ir izstrādājusi arī ērti lietojamu rīku Plānošanas un būvniecības likuma izmantošanai — *PBL Knowledge Bank* (*Boverket*) [258], [259], kur sīki izskaidrota Plānošanas un būvniecības likuma piemērošana un interpretācija atkarībā no veicamajām darbībām teritorijas plānošanas un būvniecības jomā.

3.7. tabula

Kvalitatīvā novērtējuma kopsavilkums par informācijas pieejamību (2021.gads)

	Informācijas pieejamības novērtējums			**Uzkrātās zināšanas, kW/tūkstoš iedzīvotāju**	
Valsts	Mikroģeneratori	SES	VES	SES	VES
Latvija	2	2	1	2	5
Lietuva	3	2	2	12	35
Igaunija	1	1	1	51	12
Somija	1	2	1	37	232
Norvēģija	1	3	3	20	384
Zviedrija	2	3	3	60	280

Rādītājs par uzkrātajām zināšanām balstās uz īstenoto AER projektu jaudu no 2015. gada līdz 2019. gadam un valsts iedzīvotāju skaitu. Ja tiks īstenoti vairāk AER projektu, tiks iegūtas plašākas zināšanas un pieredze, kas būs noderīga turpmāko projektu izstrādē. Norvēģija un Zviedrija ir valstis ar visplašākajām zināšanām un pieredzi. Igaunija pēdējos gados ir sasniegusi lielāko uzstādītās jaudas pieaugumu starp Baltijas valstīm, taču salīdzinājumā ar Ziemeļvalstīm tas joprojām ir zems.

Sabiedrības viedokļa un pašvaldību ietekme

Sabiedrības viedokļa ietekme ir novērtēta, izmantojot divus kritērijus – sabiedrisko apspriežu skaitu par AER projektu īstenošanu un sabiedrības iespējas ietekmēt to. Tā kā pētītajās valstīs nav sabiedrisko apspriežu par mikroģeneratoru iekārtu uzstādīšanu, tie tika izslēgti no turpmākas analīzes.

Iegūto kritēriju vērtību kopsavilkums ir redzams 3.8. tabulā. Vismazākā sabiedrības ietekme uz SES projektu īstenošanu ir identificēta Latvijā, kur nav nepieciešams organizēt sabiedriskās apspriedes par SES uzstādīšanu. Augstākie sabiedrības ietekmes rādītāji saistībā ar VES uzstādīšanu novērojami Somijā, Norvēģijā un Zviedrijā, kur vietējie iedzīvotāji ir labi informēti un kopumā atbalsta AER tehnoloģijas, kas veicinājis lielākas uzstādītās jaudas šajās valstīs.

Neskatoties uz to, ka gan Zviedrijā pašvaldībām ir piešķirtas veto tiesības [219], bet Norvēģijā gan pašvaldībām, gan iedzīvotājiem ir neformālas iespējas ietekmēt lēmumus par VES izvietošanu [223].

3.8. tabula

Sabiedrības un pašvaldību ietekmes novērtējuma pārskats (2021. gads)

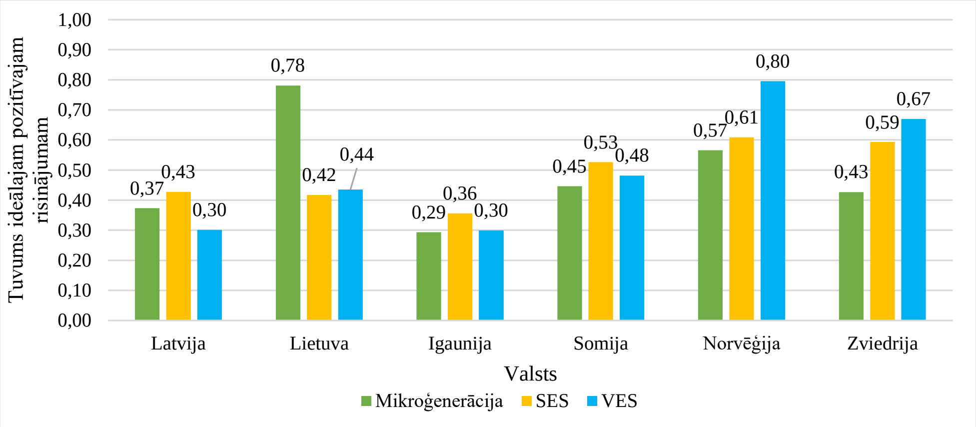
	Pašvaldības ietekmes novērtējums		**Sabiedrības ietekmes novērtējums**		**Sabiedrisko apspriežu skaits**	
Valsts	SES	VES	SES	VES	SES	VES
Latvija	3	1	0	2	0	3
Lietuva	3	1	3	2	1	5
Igaunija	1	1	2	2	2	2
Somija	3	2	2	3	2	2
Norvēģija	3	3	2	3	2	2
Zviedrija	1	1	2	3	1	2

Attiecībā uz pašvaldību ietekmi augstākais novērtējums piešķirts SES ieviešanai Latvijā, Lietuvā, Somijā un Norvēģijā, kur vietējām pašvaldībām ir plašas iespējas uzklausīt projekta īstenotājus un ietekmēt projekta gaitu (3.8. tab.).

MCDA rezultāti

Tika salīdzinātas dažādas jaudas SES un VES projektu īstenošanas procesi Baltijas valstīs un Ziemeļvalstīs, ņemot vērā 11 kritērijus un piemērojot *TOPSIS* metodi. Salīdzinājums veikts, ņemot vērā projekta īstenošanas grafiku, sarežģītību, informācijas pieejamību un ietekmi uz vietējo sabiedrību un pašvaldībām. Turklāt kā ietekmīgākie novērtēšanas kritēriji noteikti kontaktpunktu skaits, pieejamā publiskā informācija un projekta apstiprināšanai nepieciešamo dokumentu skaits (2.4. att). *TOPSIS* rezultāti redzami 3.13. attēlā. Jutīguma analīze šajā gadījumā netika veikta, jo kritēriju svari tika definēti, izmantojot piecu neatkarīgu ekspertu vērtējumus, un gala aprēķinos tika izmantota šo vērtējumu vidējās vērtības, kas atspoguļo projektu attīstītāju faktisko prioritāšu secību. Svaru noteikšanas kārtība aprakstīta 2.2.2. apakšnodaļā un detalizēti 4. publikācijā. Attiecībā uz mikroģeneratoriem Lietuva ieguva augstāko vērtējumu, jo Lietuvas Republikas Likums par atjaunojamajiem energoresursiem (XI-1375) skaidri definē mikroģeneratoru uzstādīšanas normatīvo sistēmu — jaudas ierobežojumus, paredz vienkāršotu uzstādīšanas procesu saistībā ar teritoriju un būvatļaujām. Šāds vienots dokuments, kas apkopo AER tehnoloģiju regulējumu, var tikt uzskatīts par AER tehnoloģiju ieviešanas veicinošu faktoru, kā arī palīdz nodrošināt procesu pārredzamību. Otrais augstākais rādītājs ir Norvēģijai, bet Somija ierindojas trešajā vietā. Saskaņā ar rezultātiem Igaunija ierindojas pēdējā vietā mikroģeneratoru ražošanas projektu īstenošanā.

Ziemeļvalstis – Norvēģija un Zviedrija - ir ieguvušas augstāko novērtējumu liela un vidēja izmēra SES projektu īstenošanā un augstāko punktu skaitu, kam seko Somija. Šāds rezultāts sasniegts pateicoties mazākam kontaktpunktu skaitam nepieciešamo atļauju saņemšanai un procesu skaidrojošas informācijas pieejamībai. Baltijas valstis ir ieguvušas zemākus rezultātus, Latvija ierindojas ceturtajā vietā uzreiz aiz Somijas, savukārt Lietuva un Igaunija attiecīgi ieņem piekto un sesto vietu. Igaunija ierindota pēdējā vietā, jo SES projektu īstenošanai salīdzinot ar citām valstīm var tikt piemērota IVN, kā arī var būt nepieciešamas izmaiņas telpiskajā plānojumā. Arī attiecībā uz VES Ziemeļvalstis ir ieguvušas augstākus rezultātus, arī tas skaidrojams ar mazāku iesaistīto iestāžu skaitu un īsāku projektu īstenošanas periodu. Turklāt pētījumā secināts, ka VES projektu īstenošana Norvēģijā norit visraitāk, pateicoties optimizētiem atļauju izsniegšanas procesiem un vienotam kontaktpunktam.



3.13. att. Dažādu AER projektu *TOPSIS* rezultāti.

Normatīvais regulējums un administratīvās procedūras jāpielāgo potenciālajai mērķauditorijai, lai izvairītos no nevajadzīgiem administratīviem šķēršļiem, attiecīgi - elektroenerģijas ražošana privātai lietošanai (tostarp - mazās elektrostacijas) ar mikroģeneratoriem; mazas un vidējas jaudas elektroenerģijas ražošanas iekārtām, kas nodrošina elektroenerģiju uzņēmumiem vai kopienai; lielas jaudas elektrostacijām, kas paredzētas ienākumu gūšanai no elektroenerģijas pārdošanas. Šāda pieeja varētu veicināt no AER saražotās elektroenerģijas daļas palielinājumu dažādos sektoros.

Mikroģeneratori

Administratīvajās procedūrās, kas saistītas ar mikroģeneratoru uzstādīšanu, starp valstīm konstatētas tikai nelielas atšķirības. Kopumā uzstādīšanas process ilgst no viena līdz trim mēnešiem, kas liecina par salīdzinoši vienkāršotu uzstādīšanas un pieslēgšanas tīklam kārtību. Salīdzinošā analīze rāda, ka Lietuvā ir vislabvēlīgākie administratīvie nosacījumi - gan lielākā atļautā mikroģeneratoru jauda Baltijas valstīs, gan arī tas, ka nav telpiskās plānošanas ierobežojumu un nav nepieciešama būvatļauja. Savukārt citās valstīs atsevišķos gadījumos var būt nepieciešama būvatļauja vai apstiprinājums no par būvniecību atbildīgās iestādes. Baltijas valstīs kā mikroģeneratori tiek klasificētas iekārtas ar mazāku jaudu nekā Ziemeļvalstīs. Ņemot vērā pieaugošās elektroenerģijas cenas [260], šādi jaudas ierobežojumi mājsaimniecību mikroģeneratoriem var būt nepietiekami, lai segtu patēriņu. Tādēļ tiek rekomendēts pārskatīt Baltijas valstu normatīvo regulējumu un noteikt lielāku jaudas slieksni mikroģeneratoriem.

Sadales tīklu operatoru publicētā informācija par prasībām mikroģeneratoru pieslēgšanai elektrotīklam un procesu apraksti tika novērtēti kā izsmeļoši un lietderīgi. Tomēr pētījumā tika konstatēts, ka gandrīz visās pētījumā iekļautajās valstīs vispārīga informācija par VES un SES mikroģeneratoru uzstādīšanu ir nepilnīga. Vadlīnijas mikroģeneratoru vai maza mēroga VES un SES uzstādīšanai (katrai tehnoloģijai atsevišķi) ar paskaidrojošu informāciju par procesa soļiem un obligātajām prasībām uzlabotu pārredzamību un, iespējams paātrinātu procesu.

Vidēja un liela mēroga sauszemes VES un SES

Direktīvā (ES) 2018/2001 par no AER iegūtas enerģijas izmantošanas veicināšanu [62] 16. panta 1. punktā ierosināts, ka dalībvalstis izveido vienu vai vairākus kontaktpunktus, kur AER projektu īstenotāji var vienuviet saņemt nepieciešamās konsultācijas un atļaujas, nevēršoties citās iestādēs. Vienota kontaktpunkta izveide atbilst arī Latvijas un Lietuvas Nacionālajos enerģētikas un klimata plānos noteiktajam mērķiem [184], [261]. Kā labās prakses piemērs tika identificētas Zviedrijā un Norvēģijā izveidotās enerģētikas aģentūras, kas uztur detalizētu informāciju par AER tehnoloģijām, uzstādīšanas administratīvo procesu un normatīvo regulējumu [226]. Gan veiktā literatūras analīze, gan pētījums sniedza apstiprinājumu, ka vienota kontaktpunkta esamība paātrina AER projektu ieviešanu [57], [58], [145], līdz ar to būtu lietderīgi šādu pieeju īstenot arī Baltijas valstīs, izveidojot kontaktpunktus valstu enerģētikas aģentūrās vai pašvaldībās. Baltijas valstīs tika konstatēta liela sabiedrības pretestība pret AER tehnoloģiju uzstādīšanu, kas iespējams, saistāma ar zināšanu trūkumu un stereotipiem par SES un VES. Enerģētikas aģentūras līdz ar to varētu būt Baltijas valstu organizācijas, kas ar pārredzamas un uzticamas informācijas sniegšanu veicina uzticību saules un vēja enerģijai [145].

Pašvaldības ir atbildīgas par to, lai VES vai SES projekti atbilstu telpiskajam plānojumam, izsniegtu būvatļaujas un piedalītos IVN procesā, kas veido nozīmīgu daļu no projektu īstenošanas soļiem. Tomēr Baltijas valstīs pašvaldību un citu pārvaldes iestāžu tīmekļa vietnēs bieži trūkst skaidrojošas informācijas par šim procedūrām. Tāpēc būtu lietderīgi sekot Zviedrijas un Norvēģijas piemēram, publicējot izsmeļošāku un saprotamāku informāciju par administratīvajām prasībām AER tehnoloģiju uzstādīšanai.

Informācijas apkopošana par būvatļauju izsniegšanas nosacījumiem un to pieprasīšanas nepieciešamības bija viena no sarežģītākajām administratīvā procesa daļām visās pētītajās valstīs, izņemot Zviedriju. Lai atvieglotu ar būvniecības procesu saistītās procedūras, būtu lietderīgi normatīvajos aktos skaidri izcelt prasības, kas piemērojamas AER tehnoloģiju uzstādīšanai [145] (šajā gadījumā SES un VES), padarot regulējumu saprotamāku un vienmērīgāk piemērojamu [226], [262]. Alternatīvi iespējams publicēt skaidrojošu informāciju, kas palīdzētu korekti interpretēt normatīvo regulējumu [144], [263]. Līdzīgu pieeju ieviesusi Zviedrijas Valsts mājokļu, būvniecības un plānošanas padome (*Boverket),* izdodot rokasgrāmatu, kurā skaidrota, piemēram, Plānošanas un būvniecības likuma piemērošana [259].

Pētījumā netika konstatēta skaidra praktiska nepieciešamība, kādēļ Latvijā un Lietuvā ir jāsaņem atļauja jaunas elektroenerģijas ražošanas iekārtas ieviešanai vai elektroenerģijas ražošanas jaudas palielināšanai, kā arī kādi kritēriji tiek ņemti vērā, izsniedzot šādas atļaujas [233]. Teorētiski šī procedūra varētu tikt vienkāršota, apvienojot to ar pieteikumu pieslēgumam elektrotīklam vai iekļaujot to būvatļaujā. Alternatīvi, izveidojot vienotu kontaktpunktu, atļaujas prasība varētu tikt integrēta SES vai VES projektu īstenošanas kopējā koordinācijas procesā.

Pētījuma veikšanai tika analizēts liels skaits dokumentu vairākās valodās (latviešu, lietuviešu, igauņu, somu, zviedru un norvēģu valodā). Process bija īpaši sarežģīts Baltijas valstīm, kur gandrīz visas procedūru shēmas bija jāizstrādā no nulles, balstoties galvenokārt normatīvajos dokumentos. Tas radīja interpretācijas precizitātes risku, īpaši būvatļauju saņemšanas procedūrās SES un VES uzstādīšanai. Pētījumu ierobežoja arī atšķirīgie telpiskās plānošanas noteikumi pašvaldību līmenī, tāpēc rezultāti tika vispārināti valsts, nevis pašvaldību līmenī. Vēl viens ierobežojums ir pētījuma laika posms – tas tika veikts 2021. gadā, pirms Krievijas pilna mēroga iebrukuma Ukrainā 2022. gada februārī. Pēc šī notikuma strauji pieauga fosilā kurināmā cenas, kas pētījumā iekļautajās valstīs aktualizēja izmaiņu nepieciešamību normatīvajā regulējumā, lai vienkāršotu prasības SES un VES uzstādīšanai. Literatūras apskats rāda, ka gan saules, gan vēja enerģijas uzstādītās jaudas Baltijas valstīs pēc 2022. gada turpina pieaugt, īpaši Lietuvā un Igaunijā, kur daļa jaudu pieauguma varētu būt saistāma ar administratīvo procedūru atvieglojumiem un augsto enerģijas cenu periodu (1.1. un 1.2. att.). Tomēr šo izmaiņu precīza ietekme uz identificētajām administratīvajām barjerām būtu jāvērtē atsevišķā pētījumā, jo pieaugums uzstādītajās jaudās var atspoguļot gan regulējuma izmaiņas, gan tirgus dinamiku, tehnoloģiju izmaksu kritumu un investoru aktivitāti.

Šajā pētījuma posmā veikta detalizēta AER projektu īstenošanas administratīvo procesu analīze, kas parādīja, ka būtisks kavējošais faktors ir sarežģītās procedūras un ar tām saistītais administratīvais slogs. Lai gan būtu iespējami turpmāki pētījumi, kuros padziļināti tiktu izvērtēti atsevišķi procesa posmi, pieteikumu noraidījumu iemesli un veiktas padziļinātās intervijas ar atbildīgo iestāžu darbiniekiem, promocijas darbā netika analizēti šie aspekti.

Pētījuma laikā izstrādātā metodoloģija, lai gan laikietilpīga, sniedza būtisku pienesumu, jo ļāva strukturēti izprast AER projektu administratīvo virzību un identificēt konkrētus posmus, kuros projektu attīstība palēninās. Kvantitatīvie rezultāti papildināja kvalitatīvo analīzi, jo *TOPSIS* metode ļāva skaitliski salīdzināt administratīvo prasību ietekmi uz AER projektu īstenošanu. Novērtējums tika veikts, izmantojot 11 kritērijus, kas ietvēra tiešus kvantitatīvus rādītājus, piemēram, nepieciešamo dokumentu skaitu, iesaistīto institūciju un kontaktpunktu skaitu un procesa ilgumu dienās. Kā arī rādītājus, kas sākotnēji bija kvalitatīvi, bet pārveidoti vienotā skalā, piemēram publiski pieejamās informācijas apjomu vai iespēju ietekmēt projektu virzību. Zinātniskajā kontekstā tas papildina līdz šim maz pētītus AER projektu ieviešanas aspektus, savukārt praktiskajā līmenī nodrošina pārskatāmu informāciju par administratīvajiem soļiem, nepieciešamajām atļaujām un normatīvo regulējumu pētījumā iekļautajās valstīs. Pētījuma rezultāti tiek izmantoti arī praksē, piemēram, Latvijas Investīciju un attīstības aģentūras darbā ar potenciālajiem investoriem un SES un VES parku attīstītājiem. Kā arī sniegtas rekomendācijas politikas veidotājiem par administratīvā procesa optimizācijas iespējām, atsaucoties uz identificētajiem labās prakses piemēriem Baltijas un Ziemeļvalstīs. Iegūtie rezultāti stiprina promocijas darba hipotēzi, apliecinot, ka tikai politikas saskaņotības izvērtējums nav pietiekams – nepieciešama arī padziļināta šķēršļu un nepilnību analīze, lai nodrošinātu efektīvāku AER ieviešanu.

3.2.2. Latvijas meža sektora stratēģiskās attīstības veicinošo un kavējošo faktoru identificēšana

Iepriekšējās nodaļas (3.2.1. apakšnod.) pētījums bija vērsts uz šķēršļu un nepilnību, kā arī labās prakses piemēru identificēšanai AER projektu īstenošanā, balstoties uz normatīvā regulējuma, valsts pārvaldes iestāžu un to institūciju, kā arī īstenoto projektu analīzi administratīvo procesu optimizācijai. Savukārt nākamajā posmā (8. publikācija) uzmanība tika pievērsta kavējošo un veicinošo faktoru identificēšanu ar mērķi izstrādāt pierādījumos balstītus nākotnes attīstības scenārijus, tādējādi stiprinot politikas veidošanu un lēmumu pieņemšanu.

Meža nozare un no tās iegūtie resursi ir būtiski Latvijas bioekonomikas un tautsaimniecības izaugsmei, lai gan koksnes, gan nekoksnes resursu potenciāls pašlaik netiek pilnībā izmantots [41], [43]. Latvijas Bioekonomikas stratēģija 2030 uzsver kokrūpniecības un mēbeļu ražošanas nozares nozīmi, norādot, ka dažādas kvalitātes izejvielas, kas pašlaik tiek eksportētas, var aizstāt ar Latvijā ražotiem produktiem ar augstu pievienoto vērtību, piemēram, kokšķiedras plātnes, mēbelēm vai koka moduļu ēkas [42], [44]. Attīstības potenciāls pastāv arī celulozes rūpniecībā [42].

Tā kā Latvijas Bioekonomikas stratēģija 2030 tehniski klasificējama kā "informatīvais ziņojums", nevis politikas plānošanas dokuments, šī pētījuma posms bija īpaši būtisks, lai sniegtu rekomendācijas rīcībpolitikas izstrādei meža nozares attīstības veicināšanai tā maksimālā potenciālā sasniegšanai. Izstrādātās metodoloģijas pirmais solis bija sešu zināšanās balstītas bioekonomikas attīstībai nozīmīgu sistēmas elementu analīze (atjaunojamie resursi, zināšanas, inovācijas, tehnoloģijas, procesi, produkti un pakalpojumi, pētniecība un attīstība, finanses un pārvaldība, privātās un publiskās ekspektācijas), kam sekoja veicinošo un kavējošo faktoru izvērtējums katrā no tiem (apkopojums 3.9. tab.).

3.9. tabula

Latvijas meža nozares sistēmas elementi

Sistēmas elements	Veicinātāji	Ierobežojošie faktori
Atjaunojamie resursi	Plašs mežu pārklājums; Vērtīgi nekoksnes resursi – medījami dzīvnieki, sēnes, ogas, sūnas	Mežos esošos nekoksnes resursus nevar ne kvantificēt, ne ekonomiski novērtēt; Pārmērīga mežu izstrāde var negatīvi ietekmēt bioloģisko daudzveidību
Zināšanas, inovācijas, tehnoloģijas	Gadiem uzkrātas zināšanas un prasmes; Profesionālā un augstākā izglītība mežsaimniecībā un kokapstrādē	Industrija darbojas saskaņā ar "vecās" bioekonomikas principiem; Zemā atalgojuma dēļ ir grūti atrast konkurētspēju un inovāciju izstrādi veicinošus pedagogus
Procesi, produkti un pakalpojumi	Kokapstrādes uzņēmumi visā Latvijā; Ekonomiski nozīmīga primārā resursu ieguves nozare	Ražošana ir orientēta uz koksnes produktiem ar zemu pievienoto vērtību; 90 % no koksnes tiek eksportēta, radot iekšzemes konkurenci par izejvielām
Pētniecība un attīstība	Daudzas augsta līmeņa pētniecības iestādes specializējas vai veic pētījumus meža un saistītās nozarēs	Pētniecība gandrīz pilnībā atkarīga no valsts finansējuma; Zemi rādītāji pētniecības un attīstības ieguldījumos un inovatīvo MVU īpatsvarā

Finanses un pārvaldība	Nozaru attīstība iekļauta RIS3 un citos politikas plānošanas dokumentos; Puse no mežu platības pieder valstij un tās apsaimnieko viens uzņēmums	Nozaru politikas [Grab your reader's attention with a great quote from the document or use this space to emphasize a key point. To place this text box anywhere on the page, just drag it.] plānošanas dokumenti ir novecojuši; Spēcīgs lobijs intensīvākai mežizstrādei; Zems finansiālais atbalsts inovācijām
Privātās un publiskās ekspektācijas	Mežiem ir būtiska loma nekoksnes resursu ieguvē pašpatēriņam; Mežu saglabāšana ir būtiska sabiedrībai	Ekonomisko interešu pārsvars pār sabiedrības interesēm (intensīva mežizstrāde); Sabiedrības viedokļa atšķirības par piekoptu mežizstrādes praksi, bažas par bioloģiskās daudzveidības samazināšanos

Latvijas Bioekonomikas stratēģijā norādīts uz kokapstrādes un mēbeļu ražošanas nozares attīstības potenciālu. Šāda vīzija atbilst arī nepieciešamībai efektīvāk izmantot koksni, lai ražotu produktus ar augstāku pievienoto vērtību [264]. Sabiedrības pretestība pret straujo mežizstrādes intensitātes pieaugumu un bažas par resursu izmantošanas efektivitāti un pieejamību nākotnē norāda uz nepieciešamību plašāk izmantot koksnes blakusproduktus un zemas kvalitātes koksni, lai ražotu un eksportētu preces ar augstāku pievienoto vērtību.

Latvijas meža un kokrūpniecības nozare ir spēcīga, pateicoties vietējiem resursiem, gadu gaitā uzkrātajām zināšanām un prasmēm, kā arī spēcīgiem uzņēmumiem, kas spēj konkurēt tirgū ar cenām (gan resursu pieejamības, gan zemās darbaspēka izmaksas dēļ) un vēsturiski izveidoto infrastruktūru. Tanī pat laikā 3.10. tabulā atrodama norāde uz nozares attīstību kavējošo faktoru, proti, pašreizējās politiskās stratēģiskās virzības nepietiekamību meža bioekonomikā (kā arī bioekonomikas kopumā) Latvijā, lai veicinātu produkcijas ar augstāku pievienoto vērtību ražošanu.

2020. gadā meža nozare veidoja 1,9 % un kokrūpniecības nozare – 3,1 % no visas Latvijas ekonomikas pievienotās vērtības [265]. Turklāt kokapstrādes nozare veido gandrīz ceturto daļu (24,8 % 2020. gadā) no visām Latvijas ražošanas nozarēm [265]. Tomēr, kā teikts Nacionālās industriālās politikas pamatnostādnēs 2021-2027 [265], pievienotā vērtība uz vienu nodarbināto bioekonomikas ražošanā Latvijā joprojām nesasniedz ES vidējo rādītāju [265]. Minētajās politikas pamatnostādnēs aicināts arī plašāk izmantot inovācijas kā iespējamo risinājumu, lai uzlabotu ražīgumu un resursu efektivitāti bioekonomikā [265].

Kopumā galvenie kavējošie faktori inovatīvas meža bioekonomikas attīstībai Latvijā, ir finanšu resursu trūkums – infrastruktūrai, inovāciju finansēšanai, zinātnes un izglītības kapacitātei, kā arī komunikācijai un informētības veicināšanai. Bioekonomikas nozarei raksturīgas problēmas: nav visaptveroša nozares robežu definīcija (daži nozares lomu piedēvē tikai tradicionālajām bioekonomikas nozarēm; zināšanās balstītai bioekonomikai vēl nav pietiekama lobija) tādējādi trūkst efektīvas visas nozares pārvaldības. Nepietiekami attīstītas bioekonomikas inovācijas, kas balstītos uz konstruktīvo koksni (*engineered wood*), koksnes biorafinēšanu un uzlabotu resursu kaskādveida izmantošanas konceptu, zemas kvalitātes koksnes biomasas izmantošanu augstākas pievienotās vērtības produktu ražošanā, kavē meža nozares attīstību.

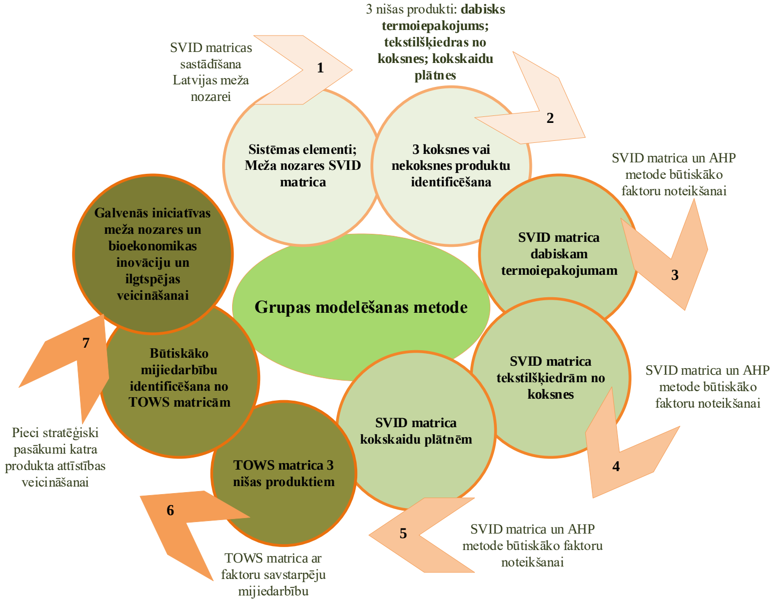
Tanī pat laikā ir pozitīvi vērtējami Latvijas sasniegumi daudzās pētniecības un inovāciju jomās, īpaši ņemot vērā nelielo zinātnes bāzes finansējumu. Latvijā un starptautiskos augsta līmeņa zinātniskajos projektos gūtā pieredze ļauj virzīt zinātnisko pētniecību bioekonomikā. Lai turpinātu veicināt zināšanu nodošanu, ir jānostiprina sadarbība starp pētniecības iestādēm un inovatīviem kokapstrādes uzņēmumiem.

Metodoloģiskais ietvars meža bioekonomikas attīstības iespēju izvērtēšanai

Tika izveidota piecu ekspertu grupa no Latvijas meža nozares, kokapstrādes un ilgtspējīgas produktu attīstības jomām, lai identificētu un prioritizētu inovatīvus bioloģiskas izcelsmes produktus ar augstu pievienoto vērtību. Tika veikta tādu produktu atlase, kas varētu veicināt valsts ekonomisko izaugsmi un resursu ilgtspējīgu izmantošanu, lai veicinātu atteikšanos no ierastās prakses, kad daļa koksnes tiek eksportēta ar nelielu pievienoto vērtību. Grupas modelēšanas sesijas vadīja pētnieks, kas katras sesijas sākumā paskaidroja veicamo uzdevumu un vadīja diskusiju. Grupas modelēšanas metode tika izvēlēta kā optimāla pieeja nišas produktu attīstības scenāriju izstrādei un analīzei. Turklāt, lai optimizētu pētījuma efektivitāti un paaugstinātu objektivitāti, papildus tika veiktas konsultācijas ar ekspertiem no saistītajām jomām, tostarp enerģētikas, bioekonomikas, resursu efektivitātes, atkritumu apsaimniekošanas un politikas jomās.

Grupas modelēšanas sesijas tika organizētas klātienē. Sesiju laikā eksperti tika aicināti apspriest un izteikt viedokli par noteiktām tēmām, katra sanāksme ilga 1–2 stundas. Pirmajā sesijā eksperti tika iepazīstināti ar pētījuma jautājumu un līdz šim paveikto, tostarp Latvijas meža nozares sistēmas elementiem. Eksperti sagatavoja SVID matricu Latvijas meža nozarei. Turpmākajās modelēšanas sesijās eksperti identificēja trīs potenciālos koksnes vai nekoksnes nišas produktus un izstrādāja tiem SVID matricas. Tika identificēti pieci faktori no katras SVID matricas daļas, kas varētu būtiskāk ietekmēt produktu attīstību un virzību. Pēc tam šie pieci faktori tika sarindoti, izmantojot AHP metodi. Iegūtie rezultāti tika ievadīti katram produktam sastādītā *TOWS* matricā un identificētas iespējamās mijiedarbības, nepieciešamās darbības katra nišas produkta attīstīšanai un jaunu tirgus iespēju atvēršanai, kā arī iezīmēti ilgtermiņa risinājumi meža nozares un bioekonomikas attīstībai kopumā. Attēls 3.14. ilustrē ekspertu grupas darba strukturēšanas metodoloģiju un kalpo kā vizuāls pārskats par analītisko procesa secību, kurā balstās turpmāk rezultatīvajā sadaļā apspriestie secinājumi.

Grupas modelēšanas sesiju laikā notikušās debates un izveidotā SVID matrica parādīja gan Latvijas meža nozares iespējas, gan stiprās puses. Stiprās puses ir meža resursu (koksnes) pieejamība un labi attīstīta piekļuves infrastruktūra, kas ietver pieejamu eksporta infrastruktūru pa sauszemes un jūras ceļiem. Meža resursi (koksne) ir atzīti par būtiskiem resursiem reģionālās un valsts politikas plānošanas dokumentos. Vienlaikus eksperti kā stipro pusi min pieredzējušos pētniecības institūtus, to uzkrātās zināšanas un pieredzi meža nozarē. Meži vēsturiski raksturo Latvijas kultūras vērtības, un latvieši novērtē mežu nemateriālās vērtības un resursus. Šis pieejamo resursu bagātums un pieaugošais pieprasījums pēc ilgtspējīgas koksnes biomasas kopā ar tehnoloģiju attīstību varētu nodrošināt Latvijai lieliskas ekonomiskās izaugsmes iespējas. Eksperti uzsver nepieciešamību izmantot esošo mežu potenciālu, lai veicinātu augstas pievienotās vērtības produktu ražošanu no zemas kvalitātes koksnes, izmantojot tehnoloģiskos sasniegumus, piemēram, konstruktīvās koksnes produktus vai inovatīvus produktus no nekoksnes resursiem. Tostarp Latvijai būtu jāuzsver arī mežu nemateriālā vērtība, izmantojot meža sniegtos ekosistēmu pakalpojumus. Lai to panāktu, jānovērš esošie trūkumi normatīvajā regulējumā un jāatjaunina tajos noteiktās saistības un politikas virzieni atbilstoši Eiropas zaļajam kursam un no tā izrietošajiem dokumentiem. Kā vēl viens trūkums tiek minēts, ka puse no Latvijas mežu zemes pieder valstij, kas kavē lēmumu pieņemšanu un var izraisīt lēmumu politizāciju. Būtu jāveicina inovāciju plašāka izmantošana meža resursu izmantošanā. Jāsamazina pētniecības atkarība no piešķirtā valsts finansējuma un jāpalielina skolotāju atalgojums, lai stiprinātu profesionālo izglītību un tādējādi veicinātu kvalificēta darbaspēka apmācību, kura pašlaik ir nepietiekamā līmenī. Kā drauds tiek uzskatīta koksnes izmantošana produktos ar zemu pievienoto vērtību, piemēram, enerģijas ražošanai un eksportam, kas palielina konkurenci par izejmateriāliem priekš produktu ar augstāku pievienoto vērtību ražošanai. Turklāt mežizstrādes intensifikācijas radītās ekonomiskās izaugsmes iespējas rada būtisku apdraudējumu esošajām meža ekosistēmām un bioloģiskajai daudzveidībai. Bioloģiskās daudzveidības samazināšanās ietekmē visu meža ekosistēmu un ne vienmēr tikai vietējā līmenī, tāpēc ir jāmeklē līdzsvars starp ekonomiskajiem un ekoloģiskajiem ieguvumiem.



3.14. att. Ekspertu grupas darba soļi (metodoloģiskais pārskats).

Pēc meža nozares SVID matricas izstrādes nākamajā posmā ekspertiem bija jāidentificē daudzsološi nišas produkti, kas atbilstu inovatīvas, uz zināšanām balstītas un ilgtspējīgas bioekonomikas principiem. Ekspertiem tika lūgts identificēt produktus, kurus varētu ražot no koksnes vai nekoksnes resursiem, pamatojoties uz četriem bioekonomikas pārveides virzieniem, balstoties uz *Dietz et al.* [266] izstrādāto klasifikācijas sistēmu. Šie pārveides virzieni ir: (1) fosilā kurināmā aizstāšana ar bioresursiem; (2) ražīguma palielināšana bioresursu ieguves primārajās nozarēs; (3) biomasas izmantošanas efektivitātes palielināšana; (4) vērtības radīšana un pievienošana, piemērojot bioloģiskos principus un procesus, kas nav saistīti ar liela mēroga biomasas ražošanu [266], kas ir cieši saistīti ar ANO definētajiem IAM [11]. Katra attīstības virziena izvēle ietver ne tikai priekšrocības, bet arī potenciālus riskus [266]. Tādēļ pēc ilgām diskusijām eksperti turpmākai analīzei izvēlējās trīs koksnes produktus ar augstāku pievienoto vērtību, kas atbilst dažādiem pārveides ceļiem (3.10. tab.).

3.10. tabula

Ekspertu izvēlētie trīs nišas produkti (pārņemts no [266])

Pārveides virziens	Apraksts	Identificētais produkts
(1) (3)	Ierosināts naftas cenu pieauguma dēļ. Palielinājies pieprasījums pēc bioenerģijas, kas tieši un netieši ietekmē zemes izmantošanu atkarībā no zemes pieejamības, vides un ekonomikas pārvaldības sistēmu efektivitātes. Inovācijas pakārtotajās nozarēs, lai palielinātu biomasas izmantošanas efektivitāti un atkritumu plūsmu pārstrādi. Nākotnē varētu aizstāt plaši izmantotus neilgtspējīgus vai fosilos resursus.	**Tekstilšķiedra no koksnes**
(2)	Tehnoloģiskas inovācijas, lai palielinātu ražīgumu mežu nozarē, iedarbinot pārveides procesus un jaunas ražošanas metodes. Produkts, kas jau ir pieejams tirgū, pieprasīts un ar plašu lietojuma spektru, tā vides sniegumu var uzlabot saskaņā ar ilgtspējības un aprites bioekonomikas principiem.	**Kokskaidu plātnes**
(3)	Inovācijas pakārtotajās nozarēs, lai palielinātu biomasas izmantošanas efektivitāti un atkritumu plūsmu pārstrādi. Inovatīvs produkts, kas varētu nonākt tirgū tuvākajos gados.	**Dabisks termoiepakojums**

Lai gan Latvijas mežos esošo nekoksnes resursu potenciāls vēl nav pilnībā izmantots, eksperti tomēr atbalstīja trīs produktu virzīšanu no koksnes, tostarp zemas kvalitātes koksnes vai koksnes blakusproduktiem. Šāds lēmums varētu būt saistīts ar zināmākiem tehnoloģiskajiem procesiem un jau izveidotu piegādes un pārstrādes infrastruktūru. Augstākas pievienotās vērtības produktu attīstībā no nekoksnes resursiem ir daudz nezināmo un mainīgo, tostarp ieguves apjomi un to sezonalitāte.

Tekstilšķiedra no koksnes

SVID matricas sastādīšana tekstilšķiedrai no koksnes noris ātri un bez plašām diskusijām. To iespējams skaidrot ar to, ka Latvijā nav šāda tipa ražotnes un ir sarežģīti pilnībā izprast potenciālās iespējas, draudus un trūkumus, kas saistīti ar tehnoloģiskās zinātības pārņemšanu un ieviešanu no valstīm, kurās šādas ražotnes jau ir izveidotas. Pēc SVID matricas izstrādes tekstilšķiedrai no koksnes eksperti noteica piecus faktorus no katras kategorijas (stiprās un vājās puses, iespējas un draudi), kas varētu būt ar lielāko ietekmi uz ražošanas procesu un ienākšanu tirgū. Katras kategorijas pieciem faktoriem tika izveidota AHP matrica, lai kvantitatīvi raksturotu faktoru ietekmi. Pēc faktoru rangu noteikšanas un AHP matricas izveides, rezultāti tika ievadīti *TOWS* matricā. Aizpildot *TOWS* matricu ekspertiem bija jāidentificē mijiedarbība starp uzskaitītajiem faktoriem (stiprās puses – iespējas; stiprās puses – draudi; vājās puses – iespēja; vājās puses – draudi stratēģijas), piemēram, attiecībā uz stiprajām pusēm un draudiem – kā stiprās puses var izmantot, lai mazinātu identificētos draudus [133]. Pēc *TOWS* matricas aizpildīšanas ekspertiem tika dots laiks apspriesties, kuras no identificētajām mijiedarbībām varētu būt izšķirošas nozīmes produkta ražošanas uzlabošanā.

Tekstilšķiedras no koksnes ražotnes izveidei un tehnoloģijas ieviešanai, tostarp pētniecībai, nepieciešams finansiāls atbalsts un valsts garantijas, lai vismaz pilotprojekta izveidei mazinātu administratīvo slogu. Valsts apņemšanās sasniegt Eiropas zaļajā kursā noteiktos mērķus, kā arī apņemšanās pakāpeniski aizstāt neilgtspējīgus tekstilizstrādājumus un šķiedru no fosilajiem resursiem, ievērojami veicinātu investīciju piesaisti. Lai veicinātu inovācijas un tekstilšķiedras no koksnes licencēšanu, būtu jānostiprina sadarbības mehānismi starp pētniecības iestādēm, uzņēmumiem un investoriem. To varētu panākt, veicinot arī zināšanu pārnesi no citām valstīm, kurām ir pieredze ražošanas tehnoloģijās, uz Latviju. Eksperti norādīja uz sabiedrības informētības trūkumu par plaši izmantotu tekstilšķiedru ietekmi uz vidi un to dzīves ciklu, ko varētu mainīt tikai ilgtermiņā, papildinot izglītības saturu un veicot papildu izglītojošo darbu dažādos izglītības līmeņos.

Kokskaidu plātnes

Pēc SVID matricas izstrādes kokskaidu plātnēm, eksperti identificēja piecus būtiskākos faktorus no katras kategorijas un izveidoja AHP matricu, lai tos saranžētu pēc ietekmes. Rezultāti tika ievadīti *TOWS* matricā un identificētas mijiedarbības. Pēc *TOWS* matricas izveides ekspertiem bija laiks apspriesties, kurām no identificētajām mijiedarbībām varētu būt izšķiroša nozīme, lai ražotu kokskaidu plātnes ar labāku vides sniegumu un uzlabotiem vai pat bioloģiski noārdāmiem līmvielu savienojumiem.

Eksperti secināja, ka kokskaidu plātnes ir tirgū esošs un labi pazīstams produkts, kura ilgtspējības un vides snieguma uzlabošanai būtu nepieciešami papildu pētījumi un ieguldījumi ražošanas tehnoloģijās [267]. Ilgtspējīgāku produktu ražošanas sekmēšanai nozīmīgi uzlabot patērētāju informētību, kas panākams ar informācijas kampaņu palīdzību. Lai gan patērētāju pieprasījums pēc kokskaidu plātnēm ar uzlabotām vides īpašībām tiek uzskatīts par izšķirošo faktoru, būtiska ietekme būtu arī subsīdiju piešķiršanai vai atbalsta mehānismiem ražotājiem, kuri veicina bioresursu izmantošanu produktos ar augstāku pievienoto vērtību saskaņā ar bioresursu vērtības piramīdu.

Dabisks termoiepakojums

Pēc SVID matricas izstrādes dabiskam termoiepakojumam tika piemērota iepriekš aprakstītā darba plūsma. Tai skaitā ekspertiem tika lūgts identificēt prioritizēto un klasificēto faktoru mijiedarbību, izstrādājot *TOWS* matricu.

Prioritārās darbības ietver infrastruktūras izveidi sekundāro un terciāro koksnes resursu savākšanai lauku apvidos. Zemas vērtības koksnes atlieku savākšanas veicināšana nodrošinātu resursu pilnvērtīgāku izmantošanu un vienlaikus veicinātu to izmantošanu jaunu produktu ražošanā. Būtiska nozīme būtu arī skaidrai valdības apņēmībai sasniegt Eiropas zaļajā kursā noteiktos mērķus, tādējādi daļēji vai pilnībā aizstājot fosilos resursus ar bioresursiem un to blakusproduktiem, papildinot šo procesu ar mērķtiecīgu finansiālu atbalstu uzņēmumiem bioloģiskas izcelsmes produktu attīstībai un komercializācijai. Dabiskā termoiepakojuma popularizēšanā svarīga nozīme būtu arī sabiedrības, uzņēmumu un to pārstāvju apvienību informēšanai par kaskādes principa ievērošanu resursu ieguves un pārstrādes procesā.

Identificētās stratēģiskās darbības

Latvijas bioekonomika saskaras ar vairākiem izaicinājumiem, tostarp stimulu trūkumu augstākas pievienotās vērtības produktu un inovāciju radīšanai, birokrātisko sarežģītību un nepietiekamu finansējumu. Viens no ekspertu piedāvātajiem risinājumiem ir valsts pamatnostādņu izstrāde uzņēmumiem, lai veicinātu zemas kvalitātes koksnes izmantošanu augstākas pievienotās vērtības produktiem. Šīs pamatnostādnes iespējams izstrādāt, balstoties Eiropas Komisijas izstrādātajā Atsauces dokumentā par labākajām pieejamajām metodēm (*BREF*). Lai šādām pamatnostādnēm būtu praktiska nozīme, būtiski tās pielāgot vietējiem apstākļiem, ņemot vērā starptautisko pieredzi šajā jomā.

Lai veicinātu pētniecības un inovācijas iniciatīvas augstas pievienotās vērtības produktu izstrādē, būtu jāievieš šim mērķim paredzēti finanšu atbalsta mehānismi, piemēram, valsts dotācijas, subsīdijas un pētniecības projekti. Šādi instrumenti palīdzētu pārvarēt būtiskāko finansiālos šķēršļus, tostarp, nepietiekamu pētniecības, attīstības un inovāciju finansējumu. Vienlaikus ir svarīgi sniegt skaidrus signālus par ilgtermiņa plānošanu un apņemšanos ievērot Eiropas zaļā kursa un Eiropas bioekonomikas stratēģijas mērķus, tādējādi praksē veicinot aprites bioekonomiku un ilgtspējīgus risinājumu ieviešanu.

Zināšanu intensīvas bioekonomikas attīstībai nepieciešams spēcīgs izglītības un zinātnes pamats, taču Latvijas zinātnes un izglītības finansējums joprojām raksturojams kā ierobežots un nepietiekami prognozējams [41]. Lai nodrošinātu pētniecības nepārtrauktību un stiprinātu pētniecības un attīstības kapacitāti, būtiski mazināt finansējuma ciklisko raksturu un nodrošināt stabilu, prognozējamu un pietiekamu resursu pieejamību [41]. Daļai Latvijas bioekonomikas uzņēmumu vājā vieta ir tehnoloģiju energoietilpība, kā arī zema enerģijas un resursu izmantošanas efektivitāte. Vides un enerģijas pārvaldības sistēmu ieviešana var sniegt nozīmīgu ieguldījumu uzņēmumu konkurētspējas paaugstināšanā, kā arī sekmēt efektivitāti un inovāciju kultūras nostiprināšanos.

Būtisks faktors ir sabiedrības informētības veicināšanai un informācijas plūsmai par bioekonomiku un ilgtspējīgu produktu izvēli. Tas ietver pasākumus pret "zaļmaldināšanu" un nepieciešamību mudināt uzņēmumus sertificēt savus inovatīvos un ilgtspējīgos produktus. Jāorganizē semināri un apmācības nozares uzņēmumiem par koksnes un koksnes atlieku izmantošanas iespējām produktos ar augstāku pievienoto vērtību būvniecībā un saskaņā ar aprites bioekonomiku [268]. Bioekonomikas popularizēšanas koncepcija jāpapildina ar sabiedrībai saprotamu skaidrojumu par bioresursu efektīvu izmantošanu un taupību, klimatneitralitātes nozīmi un tās sasniegšanas iespējām, AER izmantošanu.

3.1.3. apakšnodaļā aprakstītais pētījums parādīja, ka Latvijas politikas plānošanas dokumentos ES bioekonomikas mērķi kopumā ir implementēti augstā līmenī. Tomēr, atsevišķi aplūkojot meža nozari, atklājās vairākas nepilnības. Pētījuma veikšanas brīdī (2022. gadā) nebija pieejami atjaunināti mežu nozares stratēģiskie dokumenti – nebija izstrādātas Mežu un saistīto nozaru attīstības pamatnostādnes laika posmam pēc 2020. gada, valsts Mežu politika pēdējo reizi atjaunināta 1998. gadā. Līdz ar to dokumentos trūka ilgtermiņa mērķu, kas radīja neskaidrības par nozares attīstības virzienu un saskaņotību ar Eiropas zaļo kursu un jauno ES Mežu stratēģiju līdz 2030. gadam. Papildus tam, ieteicams pārorientēt subsīdijas no mazāk efektīvas biomasas izmantošanas uz tās izmantošanu produktiem ar augstāku pievienoto vērtību. Eksperti norāda, ka industrijai nepieciešami skaidri signāli no valdības par tās ilgtermiņa plāniem un saistībām, lai radītu prognozējamu investīciju vidi, jo īpaši nozarēs ar augstāku risku.

Metodikā tika apvienotas plaši atzītas pieejas (SVID, *TOWS* un AHP) ar *Maciejczak* [215] izstrādāto un *Wreford et al.* [33] paplašināto bioekonomikas analīzes pieeju. Pētījuma pirmajā posmā tika analizēti seši meža nozares sistēmas elementi, lai iegūtu visaptverošu priekšstatu par nozari un tās attīstību ietekmējošiem faktoriem. Otrajā posmā izvērtētas meža nozares attīstības iespējas no šaurākas, produktu attīstības perspektīvas. Grupas modelēšanas rezultāti lielā mērā sakrita ar pirmajā posmā identificētajiem nozari kavējošiem un veicinošiem faktoriem, liecinot par būtisku savstarpējo mijiedarbību. Tādējādi izstrādātā pieeja ļāva gan formulēt produktu attīstības stratēģijas, gan atkārtoti norādīja nozares pamatproblēmas, kas ietekmē meža nozares transformācijas iespējas. Piemēram, apsverot bioekonomikas attīstības virzienus, kritiskais faktors nav tikai konkrētas produktu grupas attīstības iespējas, bet gan izejvielu pieejamības nodrošinājums, stabils normatīvais regulējums, kā arī finansējuma pieejamība inovāciju attīstībai un komercializācijai.

Izstrādātā metodika ir salīdzinoši vienkārši piemērojama un noderīga politikas veidotājiem, priekšizpētes strukturēšanai un ieinteresēto pušu iesaistei stratēģiju izstrādē. Priekšizpētes strukturēšana sešos sistēmas elementos sniedz visaptverošāku skatījumu uz nozares attīstību ietekmējošiem faktoriem. Šie rezultāti ne tikai palīdz identificēt trūkumus politikas plānošanā, bet arī stiprina secinājumus, kas definēti pēc politikas saskaņotības novērtējuma, ka nepieciešama padziļināta analīze, lai atklātu attīstību kavējošās barjeras un nepilnības. Tajā pašā laikā šķēršļu identificēšana nav vērtējama kā kritika politiskajai sistēmai, bet gan kā optimizācijas iespēju apzināšana sekmīgai nākotnes attīstībai.

Turpmākajos pētījuma posmos uzmanība vērsta uz politikas ieviešanas dimensijām, izceļot trīs aspektus. Pirmkārt, resursu efektivitāti, kur detalizēti analizēti 23 Latvijas PIKC, novērtējot to energoefektivitātes paaugstināšanas iespējas, AER izmantošanas potenciālu un ilgtspējības pasākumus. Otrkārt, ilgtspējīgi risinājumi, īpaši akvakultūras sistēmu attīstības potenciāls, kas aktualizēts jau iepriekš, konstatējot, ka zivsaimniecības un akvakultūras nozare Latvijas politikas plānošanas satvarā līdz šim atstāta novārtā. Treškārt, komunikācijas dimensija, kuras nozīme iezīmējās arī šajā nodaļā, tiek meklēti risinājumi efektīvas komunikācijas stratēģijas izstrādei, lai veicinātu sabiedrības izpratni par bioekonomiku un ilgtspējīgiem produktiem.

3.3. Politikas ieviešanas dimensijas. Ilgtspējīgi risinājumi, resursu efektivitāte un komunikācija

Padziļināta analīze tika veikta trīs politikas ieviešanas dimensijās, lai identificētu ilgtspējīgus risinājumus un veicinātu resursu efektīvāku izmantošanu sektoru griezumā, kā arī novērtētu komunikācijas nozīmi Eiropas zaļā kursa mērķu sasniegšanā. Analīze balstījās literatūras un dokumentu analīzē, *MCDA* un empīriskās datu vākšanas un novērtējuma pieejās.

3.3.1. Politikas mērķu atspoguļojums infrastruktūrā un institūcijās

Enerģijas patēriņa analīze (5. publikācija) atklāja esošo energoefektivitātes līmeni izglītības iestādēs un norādīja jomas, kurās ir attīstības potenciāls. Apmeklējot PIKC un veicot aptaujas, tika apkopota informācija par izglītības iestāžu energoefektivitātes praksi, AER avotiem un īstenoto vides politiku. Visas izglītības iestādes veidoja vairāku ēku kompleksi, piemēram, mācību ēkas ar klasēm, virtuvēm, darbnīcām, kopmītnēm, sporta zālēm un administratīvajām ēkām. Katrai ēkai bija unikāls būvprojekts ar atšķirīgu platību, atrašanās vietu, norobežojošajām konstrukcijām un inženierkomunikāciju sistēmām. Lielākā daļa ēku bija renovētas, bet četras bija jaunceltnes. Ēku platība svārstījās no mazāk nekā 200 m^2 līdz 12 555 m^2 plašām ēkām. Tāpēc bija nepieciešams veikt individuālu energoefektivitātes novērtējumu, lai identificētu potenciālos ilgtspējas pasākumus.

Pēc objektu apmeklējuma, aptaujas rezultātiem un enerģijas patēriņa, un emisiju datiem tika noteikti iespējamie pasākumi. Ieteiktie pasākumi tika sadalīti divās grupās: obligātie un papildus pasākumi. Turklāt skolām, kurās ir specifiskas izglītības programmas (piemēram, celtniecības tehniķi, siltumapgādes un apkures sistēmu tehniķi, automobiļu mehāniķi), tika ierosināti inovatīvi demonstrējumu projekti, lai parādītu novatoriskus risinājumus ēku energoefektivitātes uzlabošanai, AER sistēmu uzstādīšanai, elektroauto ieviešanai, kā arī citas nākotnes tehnoloģijas.

Turklāt, ņemot vērā izglītības iestāžu ierobežoto budžetu, tika optimizēti energoefektivitātes un ilgtspējības pasākumi, lai izvēlētos labākos pieejamos pasākumus. Aprēķināts kopējais primārās enerģijas patēriņa (gan atjaunojamās, gan neatjaunojamās) un gada SEG emisiju samazinājums, kas varētu tikt panākts, īstenojot noteiktos pasākumus. Šos rādītājus apvienojot ar aptaujas rezultātiem, tika izveidots vienkāršots saliktais rādītājs, lai noteiktu PIKC, kuros pasākumi jāīsteno ar augstāku prioritāti. Pamatojoties uz aptaujas rezultātiem un izstrādātajiem demonstrējumu projektiem, tika izstrādātas rekomendācijas.

Objektu apsekojumi un aptauju rezultāti parādīja, ka lielākā daļa izglītības iestāžu saskaras ar līdzīgām problēmām. Apsekojumu laikā tika identificētas iespējas veikt renovāciju un uzlabojumus, un, ņemot vērā katras iestādes vajadzības un specifiku, tika izvēlēti atbilstoši pasākumi. Tipiskākie no tiem aprakstīti turpmākajās nodaļās.

Energopārvaldnieku iecelšana un enerģijas pārvaldības sistēmas ieviešana

Katrā izglītības iestādē ir darbinieks, kas atbild par enerģētikas sistēmām un inženiertehniskajām komunikācijām. Apmeklējumu laikā tika novērots, ka šo darbinieku zināšanu līmenis par enerģijas taupību, dažādu sistēmu darbību un regulēšanu ir atšķirīgs. Arī motivācija taupīt enerģiju šiem darbiniekiem ir atšķirīga. Atsevišķās izglītības iestādēs motivācijas trūkums bija saistīts ar zināšanu trūkumu.

Kompetenta energopārvaldnieku iecelšana ļauj sasniegt ievērojamu enerģijas ietaupījumu, vienlaikus nosakot atbildīgos par enerģētikas sistēmu uzturēšanu un enerģijas taupības pasākumu īstenošanu. Tajā pašā laikā energopārvaldnieka funkciju definēšana un īstenošana prasa attieksmes un pārvaldības procesu maiņu iestādes iekšienē. Patlaban izglītības iestāžu tehniskie darbinieki galvenokārt atbild par iekārtu netraucētu darbību, nevis energoefektivitātes uzlabošanu. Ja iespējams, būtu jāievieš motivācijas sistēma, kas balstītos panāktā enerģijas ietaupījuma sasaistīšanu ar atalgojumu. Alternatīvi varētu ieviest enerģētikas vadītāja amatu atbildīgajā ministrijā, kurš uzraudzītu visu iestāžu īstenoto enerģētikas pārvaldību. Enerģijas pārvaldības sistēmas izveide un ieviešana nodrošinātu 15–30 % enerģijas patēriņa samazinājumu izglītības iestādēs, kurās nav ieviests enerģijas pārvaldnieks vai ēku vadības sistēmas funkcijas. Citās iestādēs enerģijas ietaupījumi varētu sasniegt 5–10 %.

Ēku vadības sistēmas ieviešana

Tikai dažos no apsekotajiem PIKC ir uzstādītas ēku vadības sistēmas, kas ļauj iegūt enerģijas patēriņa datus, tos analizēt un veikt pasākumus enerģijas patēriņa samazināšanai. Lielākajā daļā izglītības iestāžu radiatori ir tikai daļēji aprīkoti ar termoregulatoriem. Tas ir vai nu tāpēc, ka tie nav uzstādīti sistēmas nesaderības un sistēmas rekonstrukcijas nepieciešamības dēļ, vai arī tāpēc, ka tie ir bijuši uzstādīti, bet izglītības iestāžu audzēkņi tos noņem. Dažās izglītības iestādēs ir nepieciešams aizstāt vecās siltumapgādes apakšstacijas ar jaunām, lai nodrošinātu automātisku siltumapgādes regulēšanu.

Saskaņā ar Eiropas standartu [269] ēku vadības sistēmas tiek iedalītas četrās kategorijās: A — augsta energoefektivitātes kontrole; B — daļēji optimizēta kontrole; C — standarta kontrole; D — bez automatizācijas. A klases ēku vadības sistēmas var nodrošināt enerģijas patēriņa samazinājumu izglītības iestādēs par 30 %, salīdzinājumā ar iestādēm, kurās nav enerģijas pārvaldnieka vai nav ieviestas ēku vadības sistēmas (salīdzinājumā ar D klasi), bet citās iestādēs tas nodrošinātu 20 % ietaupījumu (salīdzinājumā ar C klasi). Ēku vadības sistēmas ieviešana jāveic kopā ar enerģijas pārvaldības sistēmas izveidi. Tas tādēļ, ka ēku vadības sistēma ir instruments, kas atvieglo enerģijas pārvaldnieka ikdienu, jo daudzas funkcijas tiek veiktas automātiski un manuālam darbam nepieciešamo darba stundu skaits tādējādi tiek ievērojami samazināts.

Apgaismes spuldžu nomaiņa pret LED spuldzēm

Lielākajā daļā PIKC ir veikta tikai daļēja pāreja no tradicionālajām spuldzēm uz *LED* apgaismojumu. Dažas iestādes tās pakāpeniski nomaina, izmantojot uzkrātos līdzekļus. Visos PIKC, kurās tas nav veikts, ir nepieciešams nomainīt neefektīvās spuldzes pret *LED* spuldzēm un veikt gaismas sensoru uzstādīšanu vietās, kur tas ir nepieciešams. Ja izglītības iestādē ir jānomaina 50 % spuldžu, spuldžu nomaiņa samazinās kopējo elektroenerģijas patēriņu par 10%.

Saules paneļu uzstādīšana

Saules enerģijas tehnoloģijas ir uzstādītas vairākos PIKC, bet tikai viena iestāde tās izmanto enerģijas ražošanai. Tāpēc visās izglītības iestādēs, kur to ļauj ēku jumta konstrukcijas, būtu jāuzstāda saules paneļi, lai segtu daļu no ēkas elektroenerģijas patēriņa. Saules paneļu uzstādīšana samazinās primārās enerģijas patēriņa koeficientu no 2,5 līdz 1 un CO_2 emisijas koeficientu no 109 gCO_2/kWh līdz 0 gCO_2/kWh [270].

Vides politikas izstrāde

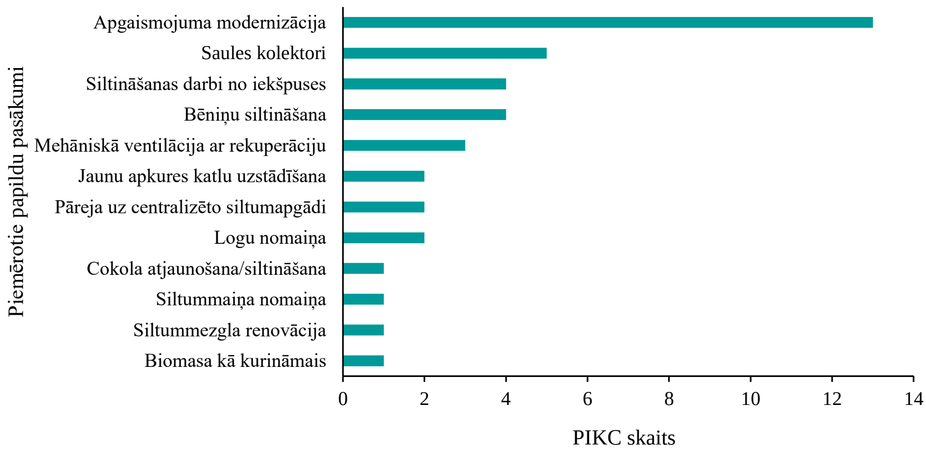
Dažos PIKC ir daļēji ieviesta vides politika vai tās elementi, bet vairumā izglītības iestāžu tā nav ieviesta. Dažos PIKC vides jautājumi ir iekļauti dažādos mācību priekšmetos.

Nepieciešams izstrādāt vides politiku un tās īstenošanas plānu, kas nosaka, kā izglītības iestādē tiek īstenoti dažādi pasākumi, kas saistīti ar vides aspektiem, samazinot to kopējo ietekmi uz vidi. Vides politikas esamība izglītojamajiem, darbiniekiem un sabiedrībai apliecina, ka tā ir videi draudzīga iestāde, kas saprot un demonstrē savu atbildību par ietekmes uz vidi samazināšanu. Vides politika ietver trīs aspektus: (1) vai izglītības iestādes audzēkņiem ir veselīga un ilgtspējīga dzīves kvalitāte (piemēram, iekštelpu mikroklimats un gaisa kvalitāte, pārtikas kvalitāte, āra kvalitāte); (2) cik labi izglītības iestāde sagatavo audzēkņus darbam 21. gadsimta ekonomikā, kas virzās uz klimatneitralitāti, un nodrošina audzēkņu pilsoniskās apziņas attīstību, lai dzīvotu pasaulē, kurā ar vides problēmām saistītie izaicinājumi un iespējas kļūst arvien nozīmīgāki; (3) cik videi draudzīga ir izglītības iestādes politika (piemēram, attiecībā uz enerģijas patēriņu, atkritumu apsaimniekošanu, ūdens apriti, bioloģiskās daudzveidības saglabāšanu, videi draudzīgiem ieradumiem, ietekmes uz klimatu samazināšanu, pielāgošanos klimata pārmaiņām).

Funkcionālas vides politikas ieviešana samazinātu enerģijas patēriņu, kas ir atkarīgs no indivīdu uzvedības, piemēram, ūdens patēriņa, velosipēda vai sabiedriskā transporta izmantošanas, un telpu temperatūras regulēšanas, kā arī samazinātu vides piesārņojumu, samazinot atkritumu daudzumu, ietekmi uz bioloģisko daudzveidību, gaisa piesārņojumu utt.

Noteiktie obligātie pasākumi katram no 23 PIKC ietvēra vairākus elementus, kuru mērķis bija palielināt energoefektivitāti un samazināt iestāžu ietekmi uz vidi. Šie pasākumi ietvēra enerģijas pārvaldības sistēmas ieviešanu un energopārvaldnieka iecelšanu, ēkas pārvaldības sistēmas uzstādīšanu, saules paneļu uzstādīšanu, informācijas materiālu izvietošanu izglītības iestādēs, uzsverot enerģijas taupības pasākumus, un vides politikas pieņemšanu. Šo obligāto pasākumu mērķis ir radīt ilgtspējīgākas un videi draudzīgākas izglītības iestādes, vienlaikus samazinot to izmaksas par enerģijas.

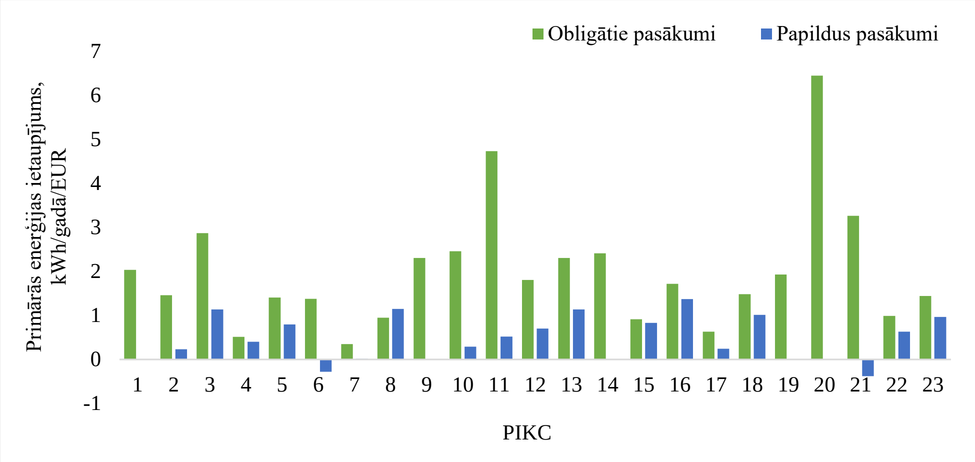
Papildus pasākumi tika pielāgoti katra PIKC individuālajām vajadzībām, un to mērķis bija vēl vairāk palielināt energoefektivitāti un samazināt enerģijas patēriņu. Daži no pasākumiem ietvēra apgaismojuma sistēmas un katlumājas modernizāciju, bēniņu un iekšējo sienu siltināšanu, pāreju no individuālās apkures uz efektīvāku centralizēto apkuri, ventilācijas sistēmas uzstādīšanu, pāreju no dabasgāzes uz atjaunojamo biomasu katlumājās un apkures iekārtas renovāciju. Šie pasākumi sniedza iestādēm papildu iespējas samazināt to ietekmi uz vidi un saglabāt resursus nākamajām paaudzēm. Piemērotie papildu pasākumi ir redzami 3.15. attēlā.



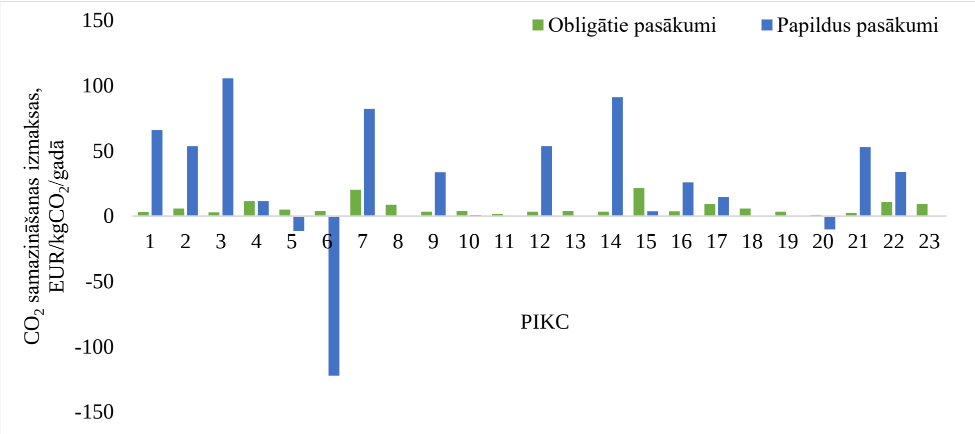
3.15. att. PIKC skaits ar piemērotajiem papildus pasākumiem.

3.16. attēlā redzams aprēķinātais primārās enerģijas ietaupījums uz nepieciešamajām investīcijām dažādiem PIKC. Obligātie energoefektivitātes pasākumi nodrošināja lielāku enerģijas ietaupījumu uz kapitālieguldījumu, pateicoties uzlabotai enerģijas pārvaldībai, kas neprasa lielu finansiālu atbalstu. Vidējais enerģijas ietaupījums no šīm darbībām būtu 1,99 kWh/gadā/ieguldītie EUR. Tomēr tā pati vērtība papildus pasākumiem ir 0,6 kWh/gadā/ieguldītie EUR, kas liecina, ka papildus pasākumiem būtu nepieciešams lielāks ieguldījums, lai sasniegtu tādu pašu enerģijas ietaupījumu kā obligātajiem pasākumiem. Dažās ēkās enerģijas ietaupījums pat ir negatīvs dēļ nepieciešamības uzstādīt mehānisko ventilācijas sistēmu, jo tā prasa papildu enerģijas patēriņu, taču vienlaikus uzlabo gaisa kvalitāti telpās.

CO_2 samazināšanas izmaksu rezultāti ir redzami 3.17. attēlā. Emisiju samazinājumu var panākt, samazinot enerģijas patēriņu un uzstādot AER tehnoloģijas. Obligāto pasākumu vidējās samazināšanas izmaksas ir 5,87 EUR/kgCO_2/gadā, bet papildus pasākumu vidējā vērtība ir 33,80 EUR/kgCO_2/gadā. Atsevišķos gadījumos (PIKC Nr. 5, Nr. 6 un Nr. 20) aprēķinātās CO_2 samazināšanas izmaksas ir negatīvas, kas nozīmē, ka konkrētie pasākumi neuzrāda emisiju samazinājumu attiecībā pret ieguldījumiem vai pat palielina CO_2 intensitāti uz investīciju vienību.



3.16. att. Primārās enerģijas ietaupījumu salīdzinājums, izmantojot obligātos pasākumus un papildus pasākumus.



3.17. attēls. CO_2 samazināšanas izmaksu salīdzinājums obligātajiem pasākumiem un papildus pasākumiem.

Demonstrācijas projekti

Deviņi no 23 PIKC apmāca speciālistus AER, mehatronikas, ēku inženierijas sistēmu un vides tehnoloģiju jomā. Šīs iestādes īsteno demonstrējumu projektus, kuru mērķis ir uzlabot izglītības programmas, iepazīstinot ar tehnoloģijām, kas nepieciešamas pārejai uz klimatneitralitāti [271], un iekļaujot tās izglītības procesā. Šāda pieeja sniedz studentiem praktisku pieredzi tādās jomās kā enerģija no AER, mehatronika un vides aizsardzība, sagatavojot viņus karjerai šajās jomās, kā ar nodrošinot atbilstību ar IAM [272].

Demonstrācijas projektu sistēma ietver mazapjoma AER avotus, enerģijas uzglabāšanas tehnoloģijas, enerģijas patērētājus un tehnoloģijas energoefektivitātes uzlabošanai apkures, dzesēšanas un elektroenerģijas patēriņa jomā. Demonstrācijas projekti jāveido nelieli un tajos jāiekļauj šādi elementi:

- AER tehnoloģijas (piemēram, saules paneļi 2,4 kW, saules paneļu koks 1,8 kW, saules kolektori 1 kW, vēja ģenerators 1 kW, biogāzes tvertne 100 l un gāzes sadedzināšanas iekārta 1 kW, biomasas katls 10 kW);
- enerģijas uzglabāšanas tehnoloģijas (piemēram, hidrolīzes iekārta, ūdeņraža uzglabāšanas tvertne, degvielas elements: 10 kW; karstā ūdens uzglabāšanas tvertne 100 l; litija jonu baterijas 1 kW);
- enerģijas patērētāji (elektriskie transportlīdzekļi - motorolleri, automašīnas, velosipēdi; saules enerģijas gaisa dzesēšanas iekārta; siltumsūknis);
- tehnoloģijas energoefektivitātes uzlabošanai gala patēriņā: tehnoloģijas siltumenerģijas un dzesēšanas patēriņa samazināšanai - ēkas makets (2 m^3), viedie ūdens sadalītāji, notekūdeņu siltuma atgūšana ar 200 W siltummaini, energoefektīvas sadzīves elektroiekārtas, ventilācijas iekārta ar efektīvu siltumatguvi un dzinējiem, kas aprīkoti ar frekvenču pārveidotājiem;
- viedā vadības sistēma ar A klases ēkas vadības sistēmu un atjaunojamās enerģijas pārvaldību, datu nolasīšanas un uzraudzības sistēmu, lietu internetu (IoT).

Primārā enerģijas patēriņa un emisiju samazināšana

Obligātu un situācijai atbilstošu pasākumu ieviešana varētu ievērojami samazināt enerģijas patēriņu, primārās enerģijas patēriņu un gada kopējās emisijas. Tika aprēķināts, ka enerģijas patēriņš PIKC pēc pasākumu ieviešanas samazinātos par 9,7 GWh/gadā, kas ir 25 % no kopējā enerģijas patēriņa; primārās enerģijas patēriņš samazinātos par 21,5 GWh/gadā, kas ir 39 % no sākotnējā primārās enerģijas patēriņa, un ievērojami samazinātos arī gada kopējās emisijas - par 2,5 ktCO_2/gadā, kas ir 34 % no kopējām gada emisijām pirms pasākumu īstenošanas. SEG emisiju samazinājums PIKC gadā būtu 11-66 %, bet primārās enerģijas patēriņa samazinājums būtu 20-55 % robežās. Samazinājums pirms un pēc pasākumu īstenošanas ir parādīts 3.11. tabulā.

3.11. tabula

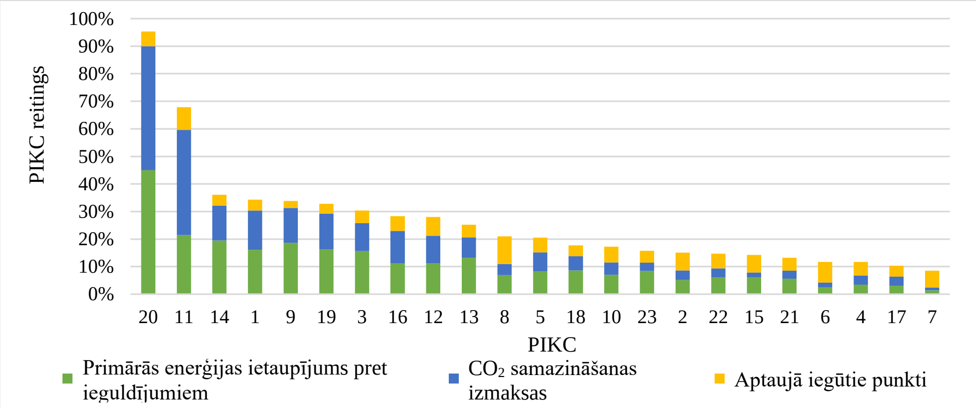
Enerģijas patēriņa un emisiju dati pirms un pēc ilgtspējas pasākumu īstenošanas

	Enerģijas patēriņš, GWh/gadā	**Primārās enerģijas patēriņš, GWh/gadā**	**Gada emisijas, ktCO_2/gadā**
Pirms	38,4	55,2	7,41
Pēc	28,7	33,7	4,91
Absolūtais samazinājums	9,7	21,5	2,5
Samazinājums procentos, %	25 %	39 %	34 %

Izglītības iestāžu reitings

Salikto rādītāju rezultāti ir redzami 3.18. attēlā, tie norādīti procentos. PIKC Nr. 20 ieguva augstāko rezultātu – 95 %. Savukārt, PIKC Nr. 7 ieguva zemāko rezultātu – 8 %. PIKC ir uzskaitīti dilstošā secībā atbilstoši to salikto rādītāju rezultātiem. Izglītības iestādes ar augstāko punktu skaitu, ne tikai ieguva labus rezultātus aptaujā, bet jau pirms pētījuma bija ieviesušas dažādus energoefektivitātes pasākumus un izmantoja AER, būtiskākie ieguvumi tiktu panākti, īstenojot obligātos pasākumus. PIKC ar vidējo un zemāko punktu skaitu jāīsteno individuāli piemērotie papildus pasākumi. Papildu pasākumu īstenošana saistāma ar zemāku novērtējumu, jo to ieguldījums primārās enerģijas patēriņa un emisiju samazinājumā ir mazāks nekā obligāto pasākumu gadījumā. PIKC ar zemāko novērtējumu nav uzstādījušas vai uzlabojušas savas mehāniskās ventilācijas sistēmas, un tā rezultātā primārās enerģijas patēriņš un emisiju samazinājums ir mazāks nekā samazinājums, kas panākts ar citiem pasākumiem.

Pastāv dilemma starp energoefektivitātes paaugstināšanu un atbilstošām ventilācijas sistēmām izglītības iestādēs. No vienas puses, mērķis ir samazināt enerģijas patēriņu, izmantojot energoefektīvas ēku sistēmas un AER avotus. No otras puses, ir svarīgi uzturēt atbilstošu gaisa kvalitāti telpās, lai nodrošinātu skolēnu un darbinieku veselību un drošību, kas bieži vien prasa enerģiju patērējošas ventilācijas sistēmas un iekārtas [273], [274], [275]. Tādējādi PIKC, kuriem ir obligāta prasība uzstādīt ventilācijas sistēmas, rezultātos ieņem zemākas vietas.



3.18. att. PIKC reitings, pamatojoties uz ilgtspējas kritērijiem.

PIKC pārstāvji aizpildīja aptaujas anketas, kam sekoja ēku un energosistēmu klātienes apsekojumi. Šo apsekojumu laikā tika konstatēts, ka intervijās sniegtā informācija neatbilst aktuālajai situācijai. Iespējams, pārstāvji sniedza apstiprinošas atbildes, lai parādītu savu iestādi labvēlīgā gaismā un izvairītos no negatīvām atsauksmēm. Tomēr pastāv iespēja, ka viņi patiesi uzskatīja, ka sniegtā informācija ir patiesa [276], [277], [278]. Neatkarīgi no tā, analizējot intervēto personu atbildes, svarīgi paturēt prātā iespēju, ka tās var neatspoguļot aktuālo situāciju. Daži PIKC pārstāvji demonstrēja padziļinātas zināšanas par enerģijas pārvaldības sistēmām un izmantotajiem enerģijas avotiem, savukārt citiem šādas kompetences trūka. Nepietiekamas zināšanas var radīt risku pieņemt nepareizus lēmumus par enerģijas izmantošanu un pārvaldību, nelietderīgiem energoefektivitātes pasākumiem un saglabāt atkarību no neefektīviem enerģijas avotiem [279], [280], [281]. Tāpēc svarīgi nodrošināt, ka atbildīgie darbinieki ir informēti par ilgtspējīgām praksēm [282].

Ilgtspējas pasākumu izmaksas būtiski ietekmēja pētījuma rezultātus. Analīzē tika iekļauti tikai tie risinājumi, kuru diskontētais atmaksāšanās laiks to ekonomiskās dzīves laikā bija pozitīvs. Enerģijas tarifu izmaiņas var stimulēt izglītības iestādes ieviest vai pārskatīt energoefektivitātes pasākumus, vienlaikus ietekmējot enerģijas taupīšanu. Arī energoefektivitātes pasākumu cenu svārstības ietekmē to pieejamību, investīciju atdevi un īstenošanas tempu, augstu izmaksu apstākļos pasākumi var tikt atlikti līdz brīdim, kad tie atkal kļūst izdevīgi [283], [284], [285]. Tādēļ pasākumi izglītības iestādēm jāizvēlas, balstoties gan uz to finansiālo pieejamību, gan konkrētām vajadzībām.

Vienīgais pasākums, ko daži PIKC veikuši saistībā ar pielāgošanos klimata pārmaiņām, ir koku stādīšana, lai radītu noēnojumu. Lai gan koki nodrošina arī oglekļa piesaisti un bioloģisko daudzveidību, PIKC pārstāvji šādus iemeslus nav minējuši. Kopumā pārstāvjiem pielāgošanās klimata pārmaiņām, nelikās aktuāla tēma. Tomēr, ja izglītības iestāžu ēkas netiks atbilstoši pielāgotas, studenti un darbinieki var saskarties ar veselības riskiem, ko rada karsts iekštelpu klimats un gaisa piesārņojums [286]. Izturētspējas pret klimata pārmaiņām paaugstināšanai, izglītības iestādēs jāvairo izpratne, sadarbība un tālredzība [287], to var paveikt uzlabojot informētību par klimata izturētspējas aspektiem [288], [289], [290].

Šī pētījuma posma mērķis bija izpētīt stratēģijas, kā palielināt Latvijas profesionālās izglītības sistēmas ilgtspēju, veicot visaptverošu potenciālo energoefektivitātes un ilgtspējas pasākumu novērtējumu. Pasākumu efektivitāte tika kvantificēta, izmantojot vienkāršotu salikto rādītāju. Pētījuma rezultāti rāda, ka pēc pasākumu ieviešanas vidējais primārās enerģijas patēriņš samazinātos par 39 %, bet emisijas samazinātos par 34 %. Primārās enerģijas patēriņa samazinājums PIKC bija robežās no 20 % līdz 55 % un SEG emisiju samazinājums no 11 % līdz 66 %.

Saliktais rādītājs ir vērtīgs instruments izglītības iestāžu energoefektivitātes un vides pasākumu novērtēšanai un salīdzināšanai. Rezultāti liecina, ka finansiālie stimuli obligāto un izvēles pasākumu īstenošanai būtu mērķtiecīgi jāpiešķir PIKC ar augstākiem rezultātiem, tādējādi nodrošinot resursu efektīvu izlietojumu. Obligātie pasākumi, piemēram, automatizētas enerģijas pārvaldības sistēmas un SES uzstādīšana, nodrošina būtisku primārās enerģijas patēriņa samazinājumu un tika iekļauti obligātajos pasākumos. Savukārt papildu pasākumi var kalpot kā papildinājums, taču to finansiālā efektivitāte ir zemāka salīdzinot ar obligātajiem pasākumiem. Demonstrējuma projekti pielāgoti konkrēto PIKC vajadzībām un var atšķirties no projektiem, kas īstenoti citos PIKC, atkarībā no klimata, pieejamajiem resursiem un mācību vides.

Iegūtie rezultāti apstiprina, ka politikas saskaņotības un šķēršļu identificēšana politikas plānošanas optimizācijai jāpapildina ar politikas ieceru īstenošanas novērtējumu institucionālā un sektoru līmenī. Tas ļauj atklāt kavēkļus augstākā līmenī noteikto mērķu ieviešanai praksē un definēt nepieciešamos pasākumus to novēršanai. Šajā pētījuma posmā kā galvenais izaicinājums energoefektivitātes paaugstināšanā identificēts daļas PIKC darbinieku kompetences un motivācijas trūkums. Ieteikto pasākumu, un līdz ar to arī optimizācijas iespēju, īstenošana cieši saistīta ar finansējuma pieejamību, lai gan tas nav izšķirošais faktors. Primārās enerģijas patēriņu un SEG emisijas iespējams samazināt arī bez papildu finansiāliem ieguldījumiem, piemēram, ieviešot un konsekventi īstenojot enerģijas taupības pasākumus. Pētījuma kontekstā saliktais rādītājs var kalpot kā instruments, kas palīdz identificēt optimizācijas iespējas un padarīt politikas pasākumus efektīvākus, veicinot nosprausto mērķu sasniegšanu.

3.3.2. Resursu efektivitāte praksē – ilgtspējīgi ražošanas modeļi

Aizvien nozīmīgāka kļūst ne tikai audzēto ūdens organismu, bet arī barības sastāvdaļu ražošanas ilgtspēja un drošība, ietekme uz vidi, potenciālā atkarība no importa un pārtikas nodrošinājums [16]. Tradicionālās akvakultūras pamatā ir integrētas lauksaimniecības un akvakultūras sistēmas, kurās izmanto lauksaimnieciskās darbības blakusproduktus, mēslus un augu materiālus (kompostu) [55]. Barības vielām bagātināti dīķi, jo īpaši dīķi, kas baroti ar citās darbībās radušajiem atkritumiem, ir pievilcīgi, jo tie ir maz atkarīgi no ārējiem resursiem pārtikas, enerģijas un atkritumu apstrādei [16]. Tomēr lielāka barības daudzuma ievadīšana dīķos nepalielina zivju produkciju, jo lielākā daļa uzņemtās barības netiek pārvērsta ražā, bet tiek izvadīta ūdenī kā atkritumi, kas var negatīvi ietekmēt vidi, kurā tiek audzētas zivis [16]. Barības vielu nonākšana no dīķiem ārējā vidē ir apgriezti proporcionāla ūdens apmaiņas ātrumam, jo ievērojama daļa piesārņojuma tiek apstrādāta uz vietas stāvoša ūdens dīķos [55]. Zemas intensitātes dīķos notiek minimāla notekūdeņu novadīšana, kas gandrīz vai nemaz neietekmē apkārtējo vidi, jo dīķa ekosistēma kultivēšanas cikla laikā pārstrādā ievērojamu atkritumu daudzumu [55].

Šajā pētījuma posmā (6. publikācija) uzmanība tika pievērsta tām akvakultūras sistēmām un tehnoloģiskajiem risinājumiem, kas zinātniskajā literatūrā visbiežāk minēti kā savietojami ar ilgtspējīgu intensifikāciju un norāda potenciālos attīstības virzienus, ko būtu iespējams pielāgot reģionāliem vai lokāliem apstākļiem. Ņemot vērā to, ka ES akvakultūras nozare attīstās lēnāk nekā citur pasaulē, politikas dokumentos bieži uzsvērta inovāciju nepieciešamība, taču nenorādot konkrētas tehnoloģijas vai sistēmas. Tika veikta zinātniskās literatūras analīze, lai identificētu praksē jau ieviestus risinājumus, ko ES un Latvija varētu adaptēt, un tā balstās tikai uz literatūras analīzi, neveicot jaunu modelējumu. Aprakstītās sistēmas atspoguļo galvenos literatūrā identificētos ūdens organismu audzēšanas tehnoloģiskos virzienus un risinājumus, kas veicina resursu efektivitāti un pēc iespējas samazina vai ierobežo akvakultūru negatīvo ietekmi uz vidi.

Intensīvi barotas monokultūras un polikultūras

Monokultūra jeb vienas ūdens sugas audzēšana dažādos blīvumos, ir plaši izplatīta visā pasaulē – Eiropā, Ziemeļamerikā, Ķīnā, Austrālijā [16], [291], [292]. Monokultūras ir raksturīgas intensīvām recirkulācijas akvakultūras sistēmām, kurās augstā blīvumā audzē augstvērtīgas zivis un vēžveidīgos [291]. Monokultūrās izmanto kvalitatīvu komerciālo barību, kas parasti veido 50–80 % no ražošanas izmaksām [16]. Monokultūru akvakultūra balstās lineārās ekonomikas konceptā [16] un ir mazāk izturīga pret patogēniem un vīrusiem [291].

Polikultūra ir divu vai vairāku sugu audzēšana vienā fiksētā platībā, savstarpēji kombinējot augus un dzīvniekus, zivis vai augus, pat ūdens un sauszemes sugas [291], [293]. Mūsdienās polikultūras koncepcija ir ievērojami attīstījusies, bet tās pamatprincips paliek nemainīgs: audzējamajiem ūdens organismiem jāieņem atšķirīgas ekoloģiskās nišas un tie nedrīkst konkurēt savā starpā par barības vielām [293]. Vairāku ūdens organismu audzēšana sniedz tādas priekšrocības kā papildu resursu efektivitāte un ekonomiskie ieguvumi vienlaikus no visām audzētajām un pārdotajām sugām, kā arī tiek uzlabota ūdens kvalitāte [293].

Integrētā daudzlīmeņu akvakultūra

Integrētā daudzlīmeņu akvakultūra (*IMTA*) ir sena un vienlaikus jauna koncepcija, kas balstās principā, ka vienā akvakultūras sistēmā (dīķī, tvertnē vai sprostā) audzē vairāk nekā vienu sugu [55], [292]. *IMTA* var uzskatīt par polikultūras uzlabotu versiju, kur zivju vai garneļu audzēšanu papildina aļģes, kas noārda neorganiskās barības vielas, un nogulumu ēdāji, piemēram, gliemji un/vai jūras gurķi noārda organiskās barības vielas [292], [293], [294]. *IMTA* uzdevums ir izveidot līdzsvarotu ūdens organismu sistēmu, tādēļ ir nepieciešamas zināšanas par katras sugas trofisko līmeni, barošanās ieradumiem, skābekļa vajadzībām un citām specifiskām prasībām, kas atšķirīgas katrai sugai [294], [295].

Veiktie pētījumi [292], [296], [297] liecina par *IMTA* pozitīvo ietekmi visās trīs ilgtspējas dimensijās — vides, ekonomikas un sociālajā jomā. Turklāt *IMTA* sistēmas darbojas saskaņā ar aprites ekonomikas principiem, uzlabojot ne tikai resursu efektivitāti, bet arī energoefektivitāti un samazinot piesārņojuma risku [298], [299]. *IMTA* sistēmas resursu efektivitāti pierāda tās spēja no pievadītā barības daudzuma ražot vairāk olbaltumvielu nekā citas tradicionālās ražošanas sistēmas [16].

Tā kā *IMTA* sistēmas tiek uzskatītas par nepietiekami izpētītām, tostarp Eiropā [296], ir vairāki trūkumi, kas būtu jānovērš nākotnē [295]. Viens no trūkumiem ir augstās sākotnējās un turpmākās ekspluatācijas izmaksas [295], [300]. Papildu atbalsts no valstu valdībām un nozares, kā arī pierādījumi par finansiālajiem ieguvumiem no sistēmas varētu veicināt *IMTA* plašāku ieviešanu [295], [296], [300].

Akvaponika

Akvaponiku var definēt kā dārzeņu audzēšanu bezaugsnes barības šķīdumā, mēslojot augus ar barības vielām no akvakultūras tvertņu notekūdeņiem [55], [294], [301]. Akvaponiku var uzskatīt par *IMTA* atvasinājumu, kas papildināts ar elementiem no recirkulācijas akvakultūras sistēmas un hidroponikas [55], [294], [301], [302]. Akvaponikas sistēmu priekšrocības ietver barības vielu uzsūkšanu augos un uzlabotu ūdens kvalitāti, kas tiek atgriezts zivju tvertnēs [294], [301]. Akvaponikas sistēmas galvenokārt nodrošina dārzeņu, nevis zivju audzēšanu, tādēļ augstas kvalitātes zivju barība, ko izmanto augu "mēslošanai", nav rentabla [55]. Turklāt akvaponikas sistēmām ir lielākas kapitāla un ekspluatācijas izmaksas, enerģijas patēriņš un SEG emisijas uz vienu ražošanas vienību nekā dīķu un būru kultūrām [55], [301]. Tomēr akvaponikai var būt potenciāls valstīs ar ierobežotiem saldūdens resursiem vai lai tirgotu šādās sistēmās ražotas zivis un dārzeņus kā nišas produktus [55].

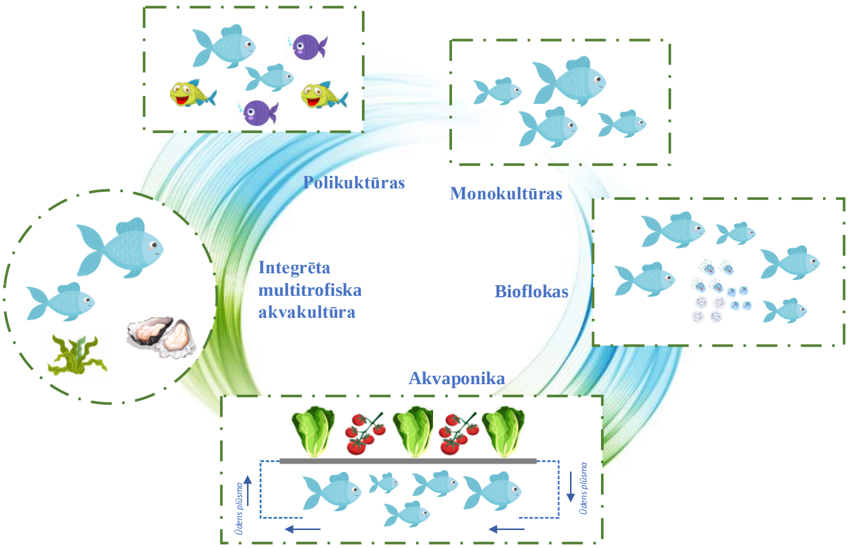
Bioflokas

Bioflokas akvakultūra jeb bioflokas tehnoloģija ir kontrolēta vides sistēma, kas apvieno suspendētu fitoplanktonu, heterotrofās baktērijas, aļģes, vienšūņus, izkārnījumus un neapēsto barību, lai ražotu organisku zivju barību [16], [294], [301], [303]. Bioflokas koncepcija tika izstrādāta 1970. gados, un tās mērķis ir risināt divas galvenās akvakultūras vides problēmas: notekūdeņu attīrīšanu un proteīnu ekstrakciju [293], [301]. Pieņēmumam, ka bioflokas kļūs par vienu no akvakultūras ceļiem uz ilgtspējīgu nākotni, ir vairāki iemesli [303], [304], [305],

[306]: (a) minimāla vai nekāda ārējā ūdens apmaiņa; (b) nepieciešams mazāk barības, kas samazina izmaksas par 30 %; (c) daudzi mikroorganismi uzlabo ūdens attīrīšanu; (d) uzlabota kultivēto ūdens organismu augšana, produktivitāte un imunitāte; (e) dažas baktēriju sugas ir noderīgas atmosfēras CO_2 sekvestrācijā.

Bioflokas tehnoloģiju būvniecība un ekspluatācija ir ļoti dārga un energoietilpīga, tādēļ nepieciešama augsta tehniskā kompetence [16], [304]. Patērētāju vēlmi iegādāties bioflokās audzētās zivis var mazināt ūdenī esošie metabolīti (geosmīna un 2-metilizoborneola), kas piešķir produktiem zemes vai dūņu garšu [304], [307], [308]. *Ogello et al.* [303] norāda uz nepieciešamību uzlabot akvakultūras politiku, lai veicinātu inovatīvas akvakultūras metodes ilgtspējīgai ražošanai un akvakultūras uzņēmumu dzīvotspējai.

Ūdens organismu audzēšanas tehnoloģiju pārskats redzams 3.19. attēlā.

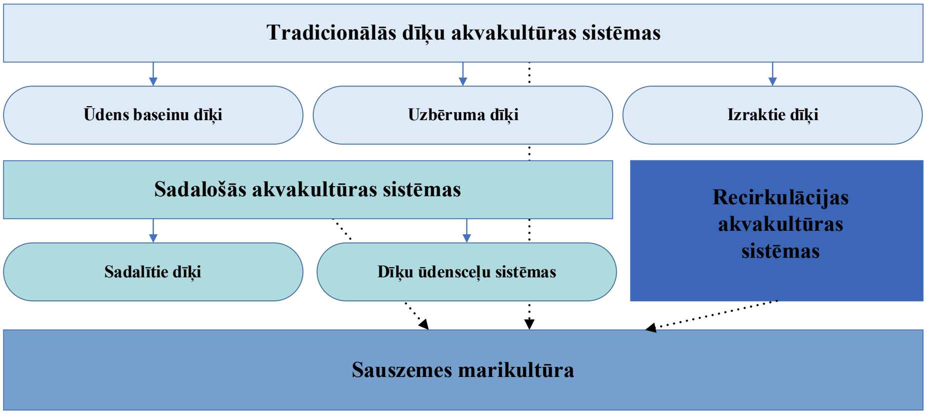


3.19. att. Vienkāršots ūdens organismu audzēšanas tehnoloģiju attēlojums.

Dīķu un tvertņu sistēmas produktivitātei un ilgtspējai

Dīķu ekosistēmu reģenerācijas spēja nav neierobežota, un šī pašreģenerācijas robeža sakrīt ar aerēto akvakultūras dīķu intensifikācijas augšējo robežu [16]. Lai pārsniegtu pašreģenerācijas robežu, ir jāatrod veids, kā mehāniski attīrīt ūdeni vai palielināt dīķu pašattīrīšanās spēju [16]. Dīķa iekšējo atkritumu izvadīšanas spēju var palielināt, izmantojot bioflokas, pārprojektējot dīķi un izmantojot dažādas tehnoloģijas, lai iegūtu lielāku kontroli pār iekšējiem bioloģiskajiem procesiem [16]. Dīķu ar ūdens apmaiņu ietekme uz vidi atšķiras no dīķu bez ūdens apmaiņas vai ar ierobežotu ūdens apmaiņu ietekmes [16]. Dažādu veidu dīķos apmainītā ūdens daudzums var svārstīties no nulles līdz vairākiem dīķa tilpumiem dienā [16]. Ūdens apmaiņa palielina ūdens patēriņu, noteces un infekcijas slimību izplatību risku, kā arī pārnes atkritumu apstrādes ekoloģisko un ekonomisko slogu no dīķa uz citiem ūdens objektiem, kam ir ētiskas sekas un kas var būt pakļauts tiesiskam regulējumam [16].

Apkopojums par biežāk sastopamajām tradicionālajām un inženiertehniski sarežģītākām sauszemes akvakultūras sistēmām sniegts 3.20. attēlā un turpmāk aprakstīts tekstā.



3.20. att. Sauszemes akvakultūras sistēmas (saldūdens un sālsūdens).

Tradicionālās dīķu sistēmas

Boyd et al. [309], [310] apraksta trīs tradicionālās dīķu sistēmas – ūdens baseinu dīķi, uzbēruma dīķi un izraktie dīķi. Ūdens baseina dīķus, kas pazīstami arī kā lietus ūdens dīķi vai terases dīķi, veido, uzbūvējot uzbērumu, lai savāktu notekūdeņus [43], [44]. Šāda veida dīķi parasti ir pilni ar ūdeni visa gada garumā, jo ūdens nepārtraukti ieplūst no tuvumā esošajiem avotiem vai strautiem vai tiek mehāniski pievadīts no citiem ārējiem avotiem [309], [310]. Uzbēruma dīķi tiek veidoti uz līdzenas zemes, noņemot pietiekamu augsnes slāni, lai izveidotu uzbērumu, kas norobežo teritoriju, kurā atrodas ūdens [43]. Šādu dīķu priekšrocība ir vieglāk kontrolējams ūdens līmenis, kā arī iespējams ievākt ražu, iztukšojot dīķi [309]. Izraktais dīķis veidojas, izveidojot zemē baseinu [309], [310]. Ja gruntsūdens līmenis ir pietiekami augsts, izraktais dīķis piepildās līdz esošajam gruntsūdens līmenim un to papildina lietus ūdens [309]. Lielākais trūkums tradicionālajām dīķu akvakultūras sistēmām ir tas, ka jāpievērš lielāka uzmanība tās darbības ietekmei uz vidi, lai neapdraudētu tuvumā esošās ekosistēmas, jo barības vielām bagāts dīķa ūdens un organiskās vielas var izraisīt eitrofikāciju [310].

Sadalošās akvakultūras sistēmas

Sadalītie dīķi, saukti arī par sadalītām akvakultūras sistēmām (*PAS*), vienkāršojot, ir nodalījums vai fiziska zivju audzēšanas un ūdens attīrīšanas atdalīšana [311]. *PAS* tika izstrādātas 1990. gados, lai ļautu ūdenim cirkulēt starp intensīvās zivsaimniecības kanāliem un notekūdeņu attīrīšanas kanāliem, lai attīrītu notekūdeņus, tos neizvadot [16], [302], [312]. *PAS* izmanto fitoplanktona augsto ražīgumu, lai ekstrahētu neorganiskās barības vielas no zivju audzēšanas procesa, stimulētu aļģu augšanu, noārdītu atkritumus un ražotu skābekli, vienlaikus funkcionējot kā ūdens filtram [311], [312]. *PAS* sistēmas nodrošina augstāku dīķa kapacitāti, ļaujot sasniegt lielāku zivju ražību uz vienu platības vienību [313]. Tilapija ir visbiežāk audzētā suga *PAS* sistēmās, jo tai ir augstas pielāgošanās spējas un zemākas prasības pret barības kvalitāti [311].

Saskaņā ar *Tucker et al.* [314], sadalītie dīķi, kas balstīti uz *PAS,* tika izveidoti ASV 2000. gados ar mērķi padarīt sistēmu vieglāk pārvaldāmu samu audzētājiem. Sadalītie dīķi būtībā ir finansiāli izdevīgāks *PAS* variants, kas sastāv no diviem dīķiem ar atšķirīgām funkcijām, bet savstarpēji mijiedarbojas [16], [311], [314], [315]. Mazākais dīķis, kas veido apmēram 15–20 % no abu dīķu kopējās platības, tiek izmantots ūdens organismu audzēšanai [313], [315], [316]. Otrs dīķis ir aptuveni četras reizes lielāks par pirmo, tajā nav zivju vai citu kultivētu organismu, bet tajā ir augsts aļģu blīvums, un tas tiek izmantots ūdens attīrīšanai [16], [311], [315]. Slāpekļa, fosfora un citu augu barības vielu slodze sadalītajos dīķos ir lielāka nekā tradicionālajos samu dīķos, jo zivju krājumi un barošanas intensitāte ir lielāka [314], [315]. Sadalīto dīķu augstās sākotnējās izmaksas kompensē to augstais ražīgums un īsais atmaksāšanās periods [313], [314], [317].

Dīķu ūdensceļu sistēmas (*IPRS*) radušās ASV, kur tās tika izveidotas kanāla samu akvakultūrai [302]. Veiksmīgais dizains un iespēja integrēt *IPRS* esošajā infrastruktūrā ir veicinājusi to plašu un veiksmīgu izmantošanu karpu, tilapiju un citu visēdāju zivju audzēšanā [302], [318]. *IPRS* piedāvā līdzīgas priekšrocības kā *PAS*, tostarp barošanas vienkāršošanu, zivju savākšanu, aizsardzības pret plēsējiem uzlabošanu, turklāt to izveide ir rentablāka [16], [319]. Viena no lielākajām *IPRS* priekšrocībām ir tā, ka tās var izmantot gandrīz jebkurā ūdenstilpē [319]. Sistēma nodrošina augstāku ražību nekā tradicionālie dīķi un to ekspluatācijā nepieciešams mazāk darbaspēka [319], [320]. Atšķirībā no audzēšanas būros, *IPRS* sistēmas ļauj savākt audzēto ūdens organismu radītos atkritumus, tādējādi mazinot negatīvo ietekmi uz vidi [319], [320], [321].

IPRS trūkums ir nepieciešamība pēc pastāvīgas ūdens cirkulācijas, savukārt ūdens cirkulācijas iekārtas parasti darbojas ar elektrību [322]. Tāpēc ir svarīgi uzstādīt avārijas enerģijas sistēmas, lai audzētajiem ūdens organismiem nekaitētu strāvas padeves pārtraukumi [320], [322]. Tāpat kā citām iepriekš minētajām *PAS* sistēmām, *IPRS* ir augstas sākotnējās un ekspluatācijas izmaksas (izmaksas ir atšķirīgas atkarībā no *IPRS* konteineru tehnoloģiskā risinājuma un ūdens cirkulācijas sūkņu enerģijas avota) [322], [323]. *IPRS*, tāpat kā citām *PAS,* potenciālā ietekme uz vides parametru, piemēram, gaismas, temperatūras un ūdens kvalitātes, regulēšanu ir ierobežota [318].

Recirkulācijas akvakultūras sistēmas

Recirkulācijas akvakultūras sistēmas (RAS) var raksturot kā intensīvu akvakultūru ar slēgtu sistēmu [301], [324]. RAS galvenā priekšrocība ir salīdzinoši maza ietekme uz vidi, jo efektīvākās sistēmās 90–99 % ūdens var atkārtoti izmantot, un tās aizņem mazāku zemes platību nekā caurplūdes sistēmas [55], [301], [325], [326]. RAS parasti sastāv no tādiem elementiem kā audzēšanas tvertnes, cieto atkritumu aizvākšanas, notekūdeņu attīrīšanas, filtrēšanas sistēmas, enerģijas ģeneratoriem, skābekļa piegādes sistēmas, ūdens sūkņiem utt. [301], [302], [324].

RAS trūkums ir salīdzinoši augstās sākotnējās un ekspluatācijas izmaksas, kā arī sistēmas sarežģītība, kas attur uzņēmumus izvēlēties šādas akvakultūras sistēmas [55], [294], [302], [326], [327]. Materiālu plūsmas procesi un nepārtraukta skābekļa piegāde RAS padara ļoti energoietilpīgu un nepieciešama vairāku mehānisko vienību strukturāla un funkcionāla koordinācija [301], [326]. Elektroenerģijas padeves pārtraukuma gadījumā sistēmas darbība var apstāties, kas var izraisīt nopietnas sekas – audzējamo organism bojāeju [301].

Sakarā ar nelielo papildu ūdens daudzumu, kas jāpievada, un augsto notekūdeņu attīrīšanas līmeni, RAS tiek uzskatīta par videi draudzīgu un ilgtspējīgu sistēmu [326], [328]. Tanī pat laikā no aprites bioekonomikas viedokļa RAS nav optimāla sistēma, jo ūdenī esošās barības vielas (slāpeklis, fosfors, ogleklis) pēc attīrīšanas netiek atgriezti ražošanas ciklā [301]. Tomēr, domājot par aprites bioekonomikas veicināšanu, akvakultūrā radušos bīstamos slāpekļa atkritumus varētu savākt un pārvērst augstas pievienotās vērtības, olbaltumvielām bagātos produktos [301], [327].

Marikultūra

Marikultūra ir sālsūdens akvakultūra, ko var veikt jūrā, okeānā vai pat uz sauszemes [329]. Marikultūras sistēmu izveide uz sauszemes dažus kilometrus no krasta ar jūras ūdens iesūknēšanas iespējām speciāli izveidotos dīķos vai tvertnēs varētu būt viena no iespējām akvakultūras attīstībai piekrastes reģionos. Sauszemes marikultūras sistēmas tiek uzskatītas par videi draudzīgu un ilgtspējīgu risinājumu, jo notekūdeņu apsaimniekošanas un barošanas efektivitātes uzlabošana uz sauszemes ir vienkāršāka un lētāka nekā atklātā ūdenī [330]. Tiek novērsta patogēnu un gēnu pārnese starp kultivētajām un savvaļas sugām, nav jāuztraucas par laikapstākļu radītiem postījumiem un netiek ierobežota sabiedrības piekļuve jūrai [330]. Sauszemes marikultūras sistēmas var veidot saskaņā ar *IMTA* principiem, piemēram, vienā sistēmā apvienojot jūras zivis un gliemjus ar fitoplanktonu kā biofiltru un barību gliemjiem, padarot to vēl ilgtspējīgāku [329], [330]. Marikultūras izveide iekšzemē ir ar mazāku vides ietekmi un prognozējamām ūdens sūknēšanas izmaksām [16]. Tomēr jāņem vērā vietējie apstākļi un tehniskās prasības lielu sālsūdens apjomu filtrēšanai un sūknēšanai, jo pastāv saldūdens piesārņojuma risks [16].

Tehnoloģiskie risinājumi – aerācija

Lai uzturētu zivīm piemērotus apstākļus, izšķīdušā skābekļa koncentrācijai ūdenī siltūdens zivīm, kā arī ūdensceļu sistēmās un apļveida baseinos jābūt vismaz 5 mg/l, aukstūdens zivīm vismaz 6 mg/l [331], [332], [333]. Ilgstoša skābekļa koncentrācija zem 3 mg/l ir apdraud ūdens organismu izdzīvošanas iespējas, bet skābekļa koncentrācija 0,5 mg/l lielākajai daļai ūdens organismu tiek uzskatīta par letālu [331], [334], [335], [336]. Aerātori ir ierīces, kas mehāniski cirkulējot ievada ūdenī skābekli [294], uzlabojot ūdens kvalitāti, barības vielu pieejamību [55], [331] un zivju veselību, kas ir būtiski faktori ekonomiskās ilgtspējas sasniegšanā [16]. Aerācija arī palielina zemes un ūdens izmantošanas efektivitāti salīdzinājumā ar neaerētiem dīķiem, tādējādi atbalstot ilgtspējīgas ražošanas praksi [16].

Aerātora izvēle ir atkarīga no audzētajām sugām, dīķa ģeometrijas, ūdens attīrīšanas un ekonomiskiem apsvērumiem, piemēram, uzstādīšanas, uzturēšanas un enerģijas izmaksām [331]. Energoefektīvāka aerātoru izmantošana samazina izmaksas, ietaupa enerģiju un samazina emisijas [331]. Saskaņā ar *Boyd et al.*[337] and *Roy et al.*[336] akvakultūrā papildus dabiskajai aerācijai ir trīs galvenie aerātoru veidi: (1) šļakatu aerātori; (2) aerātori, kas izlaiž gaisa burbuļus ūdenī, vai burbuļojošā aerācija; (3) gravitācijas aerātori. Tehnoloģijas nepārtraukti attīstās, uzlabojot esošās sistēmas un ieviešot inovācijas, piemēram, saules enerģijas darbinātus aerātorus. Piemēram, *Solar Updraft Aeration* (*SUpA*) sistēma pasīvi veicina destratifikāciju, izmantojot saules siltumu, samazinot skābekļa zudumus un palielinot izšķīdušā skābekļa saturu [338]. Tiek attīstīti arī aerātori, kas nav pieslēgti elektrotīklam un izmanto AER avotus, jo īpaši saules enerģiju [339], [340], [341].

Ir izstrādātas automātiskās aerātoru vadības sistēmas, kas aktivizē un deaktivizē aerātorus, reaģējot uz signāliem no izšķīdušā skābekļa monitoringa zondes, kas novietota izvēlētā vietā dīķī [16]. Pāreja uz aerātoru automātisku darbību ļauj ietaupīt enerģiju [309] un tādējādi uzlabot akvakultūras ilgtspējību. Tomēr esošās monitoringa programmas vēl nav sasniegušas pietiekamu tehnoloģisko briedumu, lai nodrošinātu aerācijas kontroles sistēmu precīzu un uzticamu darbību [16], [342]. Pētījumos dominē Āzijas valstīs veiktie pētījumi un testi, bet ES tehnoloģiskā attīstība akvakultūrā, šajā gadījumā aerācijā, var uzskatīt par neattīstītu un maz pētītu. Lai nodrošinātu esošās akvakultūras ilgtspējīgu intensifikāciju ES, būtu jāpievērš papildu uzmanība pētniecībai un uz zināšanām balstītu akvakultūras sistēmu attīstība.

Enerģija no AER un augstās tehnoloģijas

Akvakultūra saskaras ar šķēršļiem pārejā uz ilgtspējīgiem ražošanas modeļiem, jo nespēj atteikties no fosilā kurināmā kā primārā enerģijas avota [16]. Ideāli būtu, ja akvakultūras sistēmas visos ražošanas posmos samazinātu fosilās enerģijas izmantošanu un to aizstātu ar AER [16], jo tiem ir zemas ekspluatācijas izmaksas, ilgs dzīves cikls, tās savas darbības laikā nerada SEG emisijas un vides piesārņojumu [341]. Saules enerģijas izmantošana akvakultūrā turpina attīstīties un tā nodrošina enerģijas ražošanu, aerātoru, barotavu, sūkņu un ūdens sildīšanas sistēmu darbināšanu [341]. Vēl viens iemesls AER un akvakultūras sistēmu integrācijai ir ūdens virsmas izmantošanas palielināšana, kas ļauj zemi izmantot citiem mērķiem, piemēram, lauksaimniecībai [341], [343]. Akvakultūras sistēmas, kas apvienotas ar saules fotoelementu paneļiem (PV) tiek dēvētas par *floatovoltaics* [341], [343], kas pazīstamas arī kā *aquavoltaics* vai *AquaPV* [344]. Uz ūdens virsmas uzstādītās PV sistēmas sniedz tiešu praktisku labumu, samazinot ūdens zudumu, kas radies iztvaikošanas rezultātā, par 70–85 % [343], [344] un var samazināt aļģu augšanas ātrumu [344], [345].

Paredzams, ka nākotnē arvien plašāk tiks izmantots IoT un mākslīgais intelekts (MI), kas pavērs ceļu uz ilgtspējīgām akvakultūras sistēmām [301], [346], [347]. Modernās tehnoloģijas var izmantot datu vākšanai un analīzei, saziņai ar sistēmas apkalpojošo personālu un pat lēmumu pieņemšanai [301], [346]. MI sistēmas ir gana attīstītas, lai varētu prognozēt precīzu barības daudzumu un barošanas laiku, pamatojoties uz zivju kustībām, augšanas tempu un citiem tehniskajiem datiem [301]. Sensoru sistēmas, kas balstās uz MI, var prognozēt iespējamo ūdens kvalitātes pasliktināšanos un slimību uzliesmojumus [301]. Augsto tehnoloģiju izmantošana akvakultūrā tiek attīstīta šādās galvenajās jomās: ūdens kvalitātes mērījumi, barošana, ūdens recirkulācija, transports un izsekojamība, kā arī labturība [348]. Dažādu procesu automatizācija un informācijas tehnoloģijas akvakultūrās tiek ieviestas lēni, jo lielākā daļa uzņēmumu, nevēlas investēt lielas naudas summas jaunās tehnoloģijās, baidoties, ka tās neatmaksāsies [301], [347], [349]. Nepārprotami ir nepieciešami turpmāki pētījumi, lai uzlabotu sensoru kvalitāti un samazinātu to izmaksas, padarot tos pieejamākus mazākiem akvakultūras uzņēmumiem [348], [350].

Dažas komerciālās akvakultūras izmanto bezpilota lidaparātus, lai uzraudzītu zivju veselību un augšanu, palīdzot noteikt optimālo barošanas taktiku un samazināt barības atkritumus [301]. Bezpilota lidaparāti atvieglo regulāru ūdens kvalitātes uzraudzību un reāllaika datu iegūšanu [301].

Labākas pārvaldības prakses

Mūsdienu akvakultūras nozari var raksturot kā "bioloģisko ražošanu" [351], [352]. Pāreja uz ilgtspējīgiem ražošanas modeļiem veicina inovatīvu labāku pārvaldības prakšu (LPP) ieviešanu vides, ekonomikas un sabiedrības labā [301]. LPP akvakultūrā nozīmē, ka ūdens organismi tiek audzēti saskaņā ar dažādu valdības un nevalstisko organizāciju noteiktiem standartiem, ar mērķi samazināt ietekmi uz vidi, mazināt kaitējumu vietējām kopienām, kā arī kontrolēt un uzlabot dzīvnieku labturību [294]. Eiropas Komisijas pieņemtās Stratēģiskās pamatnostādnes ilgtspējīgākai un konkurētspējīgākai ES akvakultūrai laikposmam no 2021. līdz 2030. gadam ir vīzija nākotnei un mudinājums izmantot LPP ilgtspējīgai attīstībai dalībvalstu līmenī [353]. Jāvienkāršo licencēšanas procedūras, jāpievērš uzmanība dzīvnieku labturībai, klimata pārmaiņu ietekmes mazināšanai un pielāgošanās tām, kā arī plašākam sabiedrības atbalstam, integrējot akvakultūras uzņēmumus vietējās kopienās [353]. *Afewerki et al.* [351] apraksta Norvēģijas gadījumu, kur tika ieviestas īpašas licences kā inovācijas politikas instruments, lai veicinātu akvakultūras nozares ilgtspējīgu attīstību, tostarp piesārņojuma kontroli un samazināšanu.

Ilgtspējīgas akvakultūras sertifikācijas shēmas (arī ekosertifikācijas shēmas) prasa, lai akvakultūras uzņēmumi ievēro noteiktu rādītāju kopumu, kurus pēc tam mēra un uzrauga, tādējādi veicinot LPP ieviešanu [23], [354], [355]. Akvakultūras uzņēmumi būtu jāiedrošina sertificēt savu darbību un virzīties uz ilgtspējību un patērētājiem drošu ražošanu [355]. Sertifikācija būtu jāapvieno ar ekosistēmu pieejas principiem akvakultūrā, lai uzlabotu sociālo un vides ilgtspēju dažādos līmeņos [355].

Izsekojamība un pārredzamība

Aizvien pieaug bažas par ētikas jautājumiem, kas saistīti ar ūdens organismu izmantošanu pārtikas ražošanā un izplatīšanā iesaistīto personu labklājību, ražošanas sistēmu vides ilgtspēju, ģenētiski modificētu barības vai zivju izmantošanu un dzīvnieku labturību [23]. Droša pārtika un pārtikas piegāde nodrošina uzturvērtību, vienlaikus samazinot risku patērētāju veselībai [23], [354]. Tāpēc produktu izsekojamība piegādes ķēdēs ir ļoti svarīga, lai nodrošinātu to, ka piesārņoti produkti vai produkti ar augstu piesārņojuma risku, tostarp neatbilstīgi produkti, netiek uzdoti par produktiem bez šāda riska [23], [356]. Tāpēc ir ļoti svarīgi zināt, "kur" (izsekojamība) un "kā" (pārredzamība) pārtika ir ražota, un varēt uzticēties ražotāja sniegtajai informācijai [16], [356]. Izsekojamība un pārredzamība ir būtiska, lai pierādītu atbildību un tiekšanos uz IAM sasniegšanu [16], [354]. Tādējādi viens no nākotnes uzdevumiem ilgtspējīgai akvakultūrai ir pārredzamības un izsekojamības ieviešana, kā arī uzņēmumu sociālā atbildība [16], [357].

ES tiek importēts ievērojams daudzums zivju un citu ūdens organismu [358], tomēr atsevišķos gadījumos piegādes ķēdēs tiek konstatēts pārredzamības un izsekojamības trūkums [356]. Pat salīdzinoši labi regulētās piegādes ķēdēs pārtikas izcelsmes krāpniecība akvakultūrā ir izplatīta parādība [23], [356]. Tuvākajā nākotnē pārtikas izcelsmes krāpniecību varētu novērst, vienlaikus uzlabojot izsekojamību un pārredzamību, izmantojot blokķēdes (*blockchains*), jo šī tehnoloģija ļauj reģistrēt darījumus vai digitālos notikumus, bez iespējas tos dzēst [359]. Nākotnē svarīgi nodrošināt, ka akvakultūras nozare virza ilgtspējas ideju, nevis gaida, ka patērētāji to regulēs ar savu pieprasījumu [356]. Ar valsts pārvaldes un normatīvo sistēmu palīdzību ir iespējams dot nozarei papildu impulsu virzībā uz ilgtspējīgākām audzēšanas un pārstrādes metodēm [356].

Ekosistēmu pieeja akvakultūrai

Ekosistēmu pieeja akvakultūrai (*EAA*) ir "stratēģija, kas paredz integrēt šo darbību plašākā ekosistēmā, veicinot gan pašreizējo, gan nākamo paaudžu ilgtspējīgu attīstību, savstarpēji saistītu sociāli ekoloģisko sistēmu taisnīgumu un noturību" [360], [361]. Šis koncepts ietver ciešu saikni starp zinātni, politiku un pārvaldību, kā arī tā integrāciju valstu attīstības politikā, stratēģijās un plānos *EAA* īstenošanai [361], [362]. *EAA* pamatnostādņu [361] galvenais mērķis ir atbalstīt valstis, iestādes un politikas veidotājus ilgtspējīgas attīstības izstrādē un īstenošanā akvakultūras nozarē, akvakultūras integrācijā citās nozarēs un tās ieguldījumā sociālajā un ekonomiskajā attīstībā [363].

EAA paredz, ka kopienas attīstības plānošanā tiktu iesaistītas fiziskas, ekoloģiskas, sociālas un ekonomiskas sistēmas, kā arī citas ieinteresētās personas, tādējādi aptverot visas trīs akvakultūras ilgtspējības dimensijas [24]. Akvakultūras sistēmas galvenokārt tiek vērtētas, ņemot vērā to finansiālo devumu saimniecībām un uzņēmumiem, bet ne to sociālekonomisko devumu, kas varētu pilnībā mainīties, ieviešot *EAA* [55]. Pāreju uz ilgtspējīgākām akvakultūras sistēmām varētu panākt, ja tiktu īstenota politika, kas pienācīgi piemēro principu "piesārņotājs maksā" [55]. Piemērojot *EAA* un īstenojot piesardzības pieeju un adaptīvu pārvaldību, iespējams pārvarēt virkni šķēršļu, kas saistīti ar akvakultūru ilgtspēju [24], [364].

Saskaņā ar *Brugere et al.* [365] pētījumu par *EAA* tematikas aktualitāti zinātniskajā literatūrā, secināts, ka šis koncepts visbūtiskāk ietekmējis akvakultūras telpisko plānošanu, tostarp vietu izvēli un ekosistēmu ietilpību gan upju baseinu, gan saimniecību līmenī. Lai gan *EAA* ir veicinājis arī ievērojamus uzlabojumus zemes izmantošanas un telpiskā plānojuma izstrādē [362], lēmumu pieņēmēji un plānotāji to nav izmantojuši, lai izprastu un atrisinātu sarežģītākus institucionālus jautājumus, kas ietekmē akvakultūras attīstību kopumā [365].

Ilgtspējīgu akvakultūru intensifikāciju iespējams panākt uzlabojot dažādus tehnoloģiskos risinājumus, ieviešot LPP, pārdomāti plānojot akvakultūras saimniecību izvietojumu, lai tās nepārsniegtu ekosistēmu nestspēju. *Henares et al.* [294] norāda, ka akvakultūras sistēmu ilgtspēju varētu uzlabot, izvēloties ūdens organismus, audzēšanas vietu, kā arī ražošanas un pārvaldības praksi pirms ražošanas uzsākšanas. Nākotnes attīstība jābalsta uz *EAA*, veicinot ekoloģiski un sociāli atbildīgu akvakultūras sistēmu attīstību un darbību [55]. Lai tā notiktu jālīdzsvaro dažādie akvakultūru ietekmes līmeņi (saimniecība, upju baseins, globālais līmenis), lai samazinātu ietekmi uz katru no tiem. Risinājums varētu būt ekosertifikācijas shēmu ieviešana, kuras ietvaros tiktu novērtēta akvakultūras ietekme uz ekosistēmām saimniecības vai organizācijas līmenī.

Integrēto lauksaimniecības un akvakultūras modeļu priekšrocība ir resursu efektīva izmantošana aprites ciklā, kas palielina gan vides, gan ekonomisko ilgtspēju. Literatūrā uzsvērts, ka akvakultūras, kas darbojas saskaņā ar aprites ekonomiku var vienlaikus uzlabot ražīgumu, nodrošināt iztiku, samazināt negatīvo ietekmi uz vidi un padarīt nozari rentablāku [301], [302]. Šādi risinājumi ir īpaši nozīmīgi klimata pārmaiņu un resursu ierobežojumu apstākļos.

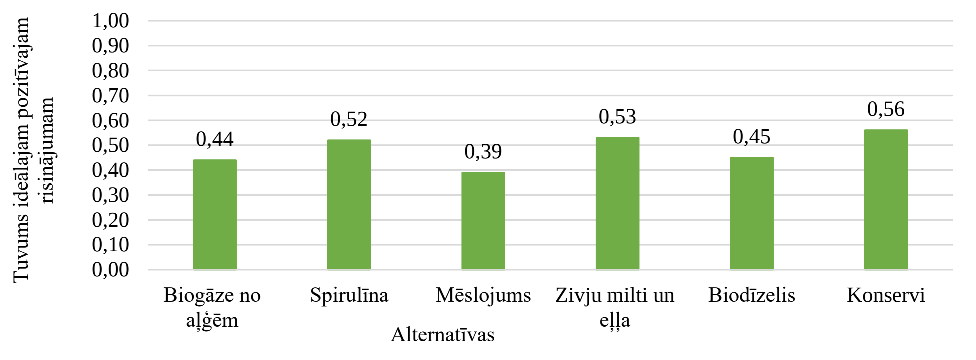
Roy et al. [336] norāda, ka aerācijas sistēmas akvakultūrā nereti tiek izmantotas empīriski, nepievēršot pietiekamu uzmanību to piemērotībai, efektivitātei un apsaimniekošanas izmaksām, kas var samazināt sistēmas veiktspēju. Īpaši RAS būtiski ieviest energoefektivitātes pasākumus, lai optimizētu elektroenerģijas un siltuma patēriņu. Pieredze citās energoietilpīgās nozarēs liecina, ka šādi pasākumi spēj būtiski uzlabot enerģijas izmantošanas efektivitāti un patēriņa paradumus [366], [367], [368]. Lai akvakultūra kļūtu ilgtspējīgāka, būtiska ir ciešāka sadarbība starp universitātēm, pētniecības institūtiem un uzņēmumiem, kas veicinātu jaunu tehnoloģiju pārnesi un risinājumu ieviešanu. Daudzi nozīmīgi pētījumi veikti pirms vairākām desmitgadēm, bet tehnoloģiju attīstība (IoT risinājumi, sensori, MI) paver jaunas iespējas sistēmu efektivitātes paaugstināšanai [320], [369], [370], [371], [372]. Vienlaikus nepieciešams stiprināt arī cilvēkkapitālu – specializētas apmācības akvakultūras un akvakultūras inženierijas jomā joprojām pieejamas tikai dažās ES valstīs, tādēļ to paplašināšana būtu svarīgs priekšnoteikums ilgtspējīgai akvakultūras sistēmu intensifikācijai.

Potenciāls šķērslis akvakultūras attīstībai ES ir nozarei piešķirtā salīdzinoši mazā nozīme, salīdzinot ar citiem bioekonomikas sektoriem. Papildu izaicinājumu rada mainīgie gadalaiki un aukstās ziemas, kas ierobežo ūdens organismus audzēšanu atklātās sistēmās un dīķos visa gada garumā, pretēji Āzijas valstīm. Alternatīva ir iekštelpu sistēmas, piemēram, RAS, bet tās ir tehniski sarežģītas, kapitālietilpīgas un ar augstu enerģijas patēriņu. Nozares attīstības veicināšanai, nepieciešamas gadījuma izpētes par sauszemes akvakultūras uzņēmumiem ES, un to izmantotajām tehnoloģijām, lai novērtētu pieejamos tehniskos risinājumus, zināšanu līmeni un uzņēmēju gatavību veikt uzlabojumus. ES konkurētspēju globālā mērogā varētu stiprināt ar energoefektivitātes, resursu efektivitātes un AER izmantošanas uzlabošanu akvakultūrā.

Akvakultūrā audzētas zivis un vēžveidīgie ir būtisks olbaltumvielu avots ar salīdzinoši mazāku oglekļa pēdu nekā tradicionālā lopkopība [373]. Lai šīs priekšrocības saglabātos, nozarei jādarbojas saskaņā ar ilgtspējas principiem, īpaši pievēršot uzmanību energoefektivitātes uzlabošanai. Līdz šim akvakultūras nozarei (3.1.3. apakšnod.) Latvijas politikas plānošanas ietvarā, piešķirta ierobežota uzmanība, un datu pieejamība par nozares izaicinājumiem ir nepietiekama. Tomēr šajā pētījuma posmā apskatītie tehnoloģiskie risinājumi parāda iespējamos nozares attīstības virzienus, kuri ar atbilstošu stratēģiju un pasākumu ieviešanu varētu veicināt nozares produktivitāti un konkurētspēju, vienlaikus sekmējot IAM sasniegšanu.

3.3.3. Komunikācijas un līdzdalības nozīme

TOPSIS novērtējuma rezultāti (7. publikācija) par sešiem zivsaimniecības un akvakultūras produktiem, kas analizēti pēc noteiktiem ilgtspējības kritērijiem, redzami 3.21. attēlā. Analīzē izmantotie kritēriju svari tika noteikti, aptaujājot 28 nozares ekspertus, kuri novērtēja katra kritērija relatīvo nozīmīgumu piecu punktu skalā (ar apgriezto skalu kritērijam "Ietekme uz bioloģisko daudzveidību"), tādējādi atspoguļojot nozarei būtiskas prioritātes.



3.21. att. *TOPSIS* analīzes rezultāti.

Redzams, ka konservētas zivis ir vistuvāk ideālajam pozitīvajam risinājumam, sasniedzot 0,56, kas nozīmē, ka saskaņā ar kritērijiem konservētas zivis var uzskatīt par ilgtspējīgāko produktu starp dotajām alternatīvām. Tomēr jāatzīmē, ka relatīvās tuvības koeficientu vērtības visām alternatīvām ir līdzīgas. Zivju miltu un eļļas vērtība atšķiras no konservētajām zivīm tikai par 0,03, savukārt spirulīna ieņem trešo vietu, atšķiroties no konservētām zivīm par 0,04.

Rezultāti liecina, ka tie produkti, kuru vērtības ir vistuvāk ideālajam risinājumam, ir plaši pazīstami un izmantoti. Tas nozīmē, ka tiem ir augsts tehnoloģiskās attīstības līmenis, tirgus pieprasījums un pierādīta stabilitāte. Tomēr var redzēt, ka biodīzeļdegvielas un aļģu biogāzes vērtības ir salīdzinoši tuvas zivju miltu, konservētu zivju un spirulīnas vērtībām, kas nozīmē, ka alternatīvu ilgtspējas novērtējuma rangs laika gaitā var mainīties, attīstoties biodīzeļdegvielas un biogāzes ražošanas tehnoloģijām.

Jutīguma analīzes rezultāti

Jutīguma analīze tika veikta, atsevišķi mainot astoņu kritēriju svarus sešiem analizējamajiem produktiem jeb alternatīvām, lai novērtētu *TOPSIS* metodes rezultātu stabilitāti. Analīze parādīja, ka izvēlēto kritēriju svārstības būtiski ietekmē alternatīvu relatīvo novērtējumu, īpaši gadījumos, kad kāda alternatīva ir izteikti labāka par citām. Biogāzes stabilitāti skaidro fakts, ka tā saglabā salīdzinoši labus rādītājus visos analizētajos kritērijos bez izteikti vājiem parametriem, kas padara to mazāk jutīgu pret kritēriju svaru izmaiņām. Rezultāti apliecina, ka visstabilāk augstu novērtējumu saglabāja biogāze, kam sekoja zivju konservi, spirulīna un zivju milti un eļļa. Savukārt biodīzeļa un mēslojuma gadījumā rezultāti bija jutīgāki pret kritēriju izmaiņām, kas norāda uz lielāku nenoteiktību šo alternatīvu novērtējumā (3.12.

tab.). Kopumā jutīguma analīze apstiprināja galvenos secinājumus par alternatīvu pievilcīgumu, taču uzsvēra nepieciešamību izvērtēt kritēriju svaru ietekmi, īpaši ekonomisko un sociālo aspektu gadījumā.

3.12. tabula

Jutīguma analīzes rezultāti

	Biogāze	Uztura bagātinātājs (spirulīna)	Mēslojums	Zivju milti un eļļa	Biodīzelis no zivīm	Konservi
Augšupejošu līkņu skaits	6	4	2	4	3	4
Lejupejošu līkņu skaits	2	4	6	4	5	4
Starpība	4	0	-4	0	-2	0

Veiktā jutīguma analīze apstiprināja, ka pievilcīgākās alternatīvas ir biogāze, zivju konservi, spirulīna, un zivju milti un eļļa.

Aptaujas rezultātu analīze

Pēc aptaujas rezultātu apkopošanas, pirmais solis bija izvērtēt, kurus informācijas avotus respondenti ikdienā izmanto visbiežāk. Sakarā ar to, ka lielākā daļa cilvēku ikdienā izmanto vairākus informācijas avotus dažādiem mērķiem, bija iespējams atzīmēt vairākus atbilžu variantus. No respondentu atbildēm var secināt, ka trīs populārākie informācijas avoti, kas tiek izmantoti ikdienā, ir sociālie tīkli, ziņu portāli un televīzija. Tam seko radio, avīzes un citi avoti. Tomēr jāņem vērā, ka aptauja tika izplatīta platformā *Facebook,* līdz ar to iespējama saistība ar to, ka visbiežāk saņemtā atbilde bija informācijas ieguve sociālajos tīklos.

Lai saprastu, kurš komunikācijas kanāls vai platforma veido uzticību un palīdz cilvēkiem vieglāk apgūt jaunu informāciju, pētījuma ietvaros tika skaidrots, kā cilvēki sazinās savā starpā un kādus komunikācijas kanālus izmanto ikdienā. Šis jautājums varētu būt vēl aktuālāks komunikācijā ar nozari vai uzņēmumiem, lai izstrādātu personalizētu pieeju un pēc iespējas efektīvāk pārliecinātu tos pārskatīt savas nozares vai uzņēmuma ilgtspēju. Saziņas līdzekļi var atšķirties atkarībā no tā, ar ko notiek saziņa, piemēram, profesionālajā vidē informācijas apmaiņa ar kolēģiem noris citādāk nekā ar draugiem vai ģimenes locekļiem. Tādēļ respondentiem arī šajā jautājuma bija iespēja izvēlēties vairākas atbildes vienlaikus. No saņemtajām atbildēm redzams, ka vairākums dod priekšroku saziņas rīkam *WhatsApp, Facebook Messenger*, kā arī tikties klātienē personiskai saziņai.

Sakarā ar to, ka lielākā daļa respondentu informācijas iegūšanai izmanto dažādas interneta platformas, ir svarīgi saprast, vai tajās piedāvātais izglītojošais saturs tos apmierina un kādā formātā liekas saistošāks. Gandrīz 93 % respondentu atbildēja, ka patērē izglītojošu saturu, dodot priekšroku galvenokārt vizuālam un audiovizuālam materiālam. Tas būtu skaidrojams ar to, ka šādā formātā pasniegtā informācija ir vieglāk uztverama un parasti ir īsa un kodolīga, salīdzinājumā ar izglītojoša satura informācijas iegūšanas no blogiem vai zinātniskajām publikācijām. Tomēr jāņem vērā, ka minētās atbildes varētu ietekmēt dažādi ārējie faktori.

No respondentu atbildēm secināms, ka efektīvākais veids, kā informēt sabiedrību par tādām tēmām kā vide, ilgtspējīga attīstība un klimata pārmaiņu mazināšana, ir vizuālie un audiovizuālie materiāli (34 %). Otra izplatītākā atbilde bija vides akcijas (20 %), piemēram, “Lielā talka”, “Neapēd zemeslodi” utt. Mazāks respondentu skaits izvēlējās šādus komunikācijas formātus: 17 % vizuālie materiāli/ infografikas; 14 % sabiedrībā pazīstamu personu motivējošas runas; 8 % informatīvi raksti; 4 % izglītojoši semināri un lekcijas; 3 % citi.

Sabiedrībā zināmas personas un digitālā satura veidotāji, neskatoties uz to, ka viņiem var trūkt tehniskās vai zinātniskās kompetences, spēj efektīvi sniegt informāciju un ir atvērtāki alternatīviem viedokļiem. Vides apziņas un ilgtspējīgas attīstības veicināšana sabiedrībā zināmu personu un digitālā satura veidotāju vidū var palielināt informācijas izplatīšanas efektivitāti. Tāpēc aptaujā tika iekļauts jautājums par to, kuri informācijas sniedzēji visdrīzāk varētu veicināt sabiedrības informētību. Tika piedāvāti vairāki atbilžu varianti, tostarp valsts iestādes, vides organizācijas, pētniecības iestādes, digitālā satura veidotāji utt. Lielākā daļa respondentu (46 %) izvēlējās atbilžu variantu - vietējās un starptautiskās vides organizācijas. Otrajā vietā ar 29 % ierindojās sabiedrībā zināmas personas un digitālā satura veidotāji, bet trešajā vietā ar 19 % - valsts iestādes (ministrijas, ES institūcijas). Interesanti, ka zinātnieki un pētniecības iestādes ieguva zemāko rezultātu, tikai 3 % respondentu uzskatīja, ka zinātnieki būtu labi informācijas sniedzēji, kas veicinātu sabiedrības informētību. Citi atbilžu variantos neiekļautie mediji ieguva 3% no respondentu atbilžu. Tomēr jāņem vērā arī mērķauditorija un sniedzamā informācija, piemēram, cilvēki no akadēmiskās vides ir vairāk tendēti uzticēties zinātniskajā sabiedrībā atzītai informācijai un ekspertiem. Iespējams sabiedrības informētības un vides apziņas veidošanā labākus rezultātus varētu panākt, ja vairākas informācijas sniedzēju grupas savstarpēji sadarbojoties izstrādātu saskaņotu un faktos balstītu komunikācijas stratēģiju. Pielāgojot informāciju formātu un komunikācijas kanālus attiecīgai mērķauditorijai, vienlaikus nemainot sniegtā vēstījuma saturu, informācijas sniedzēji varētu vieglāk iegūt dažādu sociālo grupu uzticību.

Klimata pārmaiņu mazināšanas, vides problēmu un ilgtspējīgas attīstības attēlojums dažādos informācijas avotos ir atšķirīgs, galvenokārt balstoties uz priekšrocību un iespējamo trūkumu novērtējumu. Minētie avoti uzsver potenciālos ieguvumus vai zaudējumus, kas var rasties, ja šie aspekti netiek efektīvi risināti. Ir avoti, kas uzsver klimata pārmaiņu negatīvos aspektus, izplatot dažādas fotogrāfijas vai filmas, kas izraisa spēcīgas negatīvas emocijas, tostarp bailes. Attēli bieži vien ataino dabas katastrofas un ledāju kušanu, kā arī citus fenomenus. Taču ir arī avoti, kas mudina cilvēkus mainīt savus ikdienas paradumus un izmantot AER, vizualizē ideju par skaistu, nepiesārņotu nākotni. Tāpēc aptaujā tika iekļauts jautājums par respondentu skatījumā optimālo stratēģiju, lai veicinātu sabiedrības pārdomas par klimata pārmaiņu nozīmi, vides problēmām un ilgtspējīgu dzīvesveidu. Rezultāti liecina, ka lielākā daļa respondentu (aptuveni 43 %) deva priekšroku klimata pārmaiņu negatīvās ietekmes pasvītrošanai, bet gandrīz 36 % respondentu norādīja, ka nepieciešams koncentrēties uz ieguvumiem. Gandrīz 19 % respondentu uzskata, ka piemērotākā stratēģija izpratnes veicināšanai būtu zinātniski pierādīti fakti, kas liecina par cilvēka darbības ietekmi uz vidi. Tā kā rezultāti ir salīdzinoši līdzīgi, vienotas komunikācijas stratēģijas veidošanā vēlams iekļaut gan klimata pārmaiņu negatīvās puses, gan ilgtspējīga dzīvesveida priekšrocības.

Anketā bija iekļauts jautājums par biodiplomātiju kā savstarpēja dialoga konceptu starp sabiedrību, industriju un zinātni, lai saprastu vai šāda pieeja varētu veicināt sabiedrības un industrijas informētību. Aptaujas rezultāti liecina, ka lielākā daļa respondentu (95 %) pozitīvi vērtē biodiplomātijas ideju un tās nozīmi ilgtspējīgas attīstības kontekstā. Tas nozīmē, ka biodiplomātijas konceptam kopumā ir potenciāls, un rezultāti liecina, ka sabiedrība ir gatava apgūt jaunas zināšanas. Tomēr ir svarīgi nodrošināt, ka izplatītā informācija ir viegli uztverama un saprotama, lai saglabātu sabiedrības atbalstu un interesi.

Šajā pētījuma posmā tika novērtēta zivsaimniecības un akvakultūras produktu ilgtspēja un analizēti piemērotākie komunikācijas kanāli sabiedrības informēšanai par ilgtspējīgiem risinājumiem. *TOPSIS* analīzē augstākos rezultātus ieguva zivju konservi, eļļa un milti, kā arī spirulīna kā ilgtspējīgākie produkti, saskaņā ar definētajiem kritērijiem. Kvantitatīvais novērtējums balstījās uz astoņiem kritērijiem, tostarp produktu cenu, enerģijas patēriņu, ietekmi uz bioloģisko daudzveidību un sociālekonomiskajiem aspektiem, kā arī ekspertu noteiktajiem kritēriju svariem. Jutīguma analīze apstiprināja rezultātu stabilitāti – biogāze, zivju konservi un spirulīna saglabāja augstāko relatīvo novērtējumu arī svaru variācijas gadījumā.

Ilgtspējas mērķu sasniegšanai nepietiek ar produktu ilgtspējas pamatošanu, būtiska ir arī sabiedrības informēšana. Aptaujas rezultāti parādīja, ka lielākā daļa sabiedrības informāciju iegūst no sociālajiem tīkliem un dod priekšroku audiovizuāliem materiāliem. Uz jautājumu par uzticamākajiem informācijas sniedzējiem tikai 3 % respondentu minēja zinātniekus, kas liek pārdomāt līdzšinējo komunikācijas praksi un pētniecības iestāžu tēlu kā zināšanu un informācijas nesējiem. Vienots vēstījums dažādos medijos, kas vizualizētu un skaidrotu ilgtspējīga dzīvesveida priekšrocības un arī draudus, varētu būt efektīvākais veids, kā veicināt sabiedrības uzticību un iesaisti.

Komunikācija ar ieinteresētajam pusēm ir nozīmīga politikas ieviešanas dimensija, kas jāņem vērā, izstrādājot politikas un to īstenošanas pasākumus. Pētījuma posmā par AER administratīvo šķēršļu novēršanu, sabiedrības un pašvaldību informētība tika atzīta par nozīmīgu ietekmējošo faktoru (3.2.1. apakšnod.). Tika secināts arī tas, ka savlaicīgas pārrunas starp AER projektu īstenotājiem un vietējām kopienām var veicināt pozitīvu iznākumu vēlākajās oficiālajās sabiedriskajās apspriedēs [149], [374]. Līdzīga atziņa izskanēja arī grupas modelēšanas sesijās, kur sabiedrības informētības ietekme tika uzsvērta kā nozīmīgs faktors nišas produktu virzīšanai tirgū un ilgtspējīgu izvēļu veicināšanai (3.2.2. apakšnod.).

SECINĀJUMI

Promocijas darba mērķis tika sasniegts, izstrādājot analītisku ietvaru klimata politikas novērtēšanai un tās efektivitātes paaugstināšanai. Promocijas darba ietvars balstīts trīs secīgos segmentos - politikas saskaņotības analīzē, šķēršļu un nepilnību identificēšanā, kā arī politikas ieviešanas dimensiju izvērtējumā. Šāds ietvars ļāva ne tikai kvalitatīvi analizēt politikas procesus, bet arī balstīt secinājumus kvantitatīvos rādītājos, piemēram, daudzkritēriju novērtējumos, kas izgaismoja būtiskas atšķirības politikas plānošanas dokumentos, mērķu detalizācijas pakāpē, piemēroto instrumentu līdzsvarā un administratīvo prasību sarežģītībā, kā arī politikas ieviešanas praktiskajā gatavībā, tādējādi nodrošinot strukturētu pieeju, ar kuras palīdzību iespējams formulēt secinājumus un rekomendācijas ilgtspējīgai resursu pārvaldībai un politikas pilnveidei.

Horizontālās politikas saskaņotības novērtējums ļāva labāk izprast analizēto politikas jomu stratēģisko virzību un identificēt to mērķus, savukārt vertikālās saskaņotības izvērtējums deva iespēju noteikt, vai dalībvalstu virzība atbilst šiem mērķiem. Gadījuma izpētē par *CRCF* regulas horizontālo saskaņotību tika identificēti astoņi tematiskie bloki, kas ir savstarpēji papildinoši un saskanīgi, savukārt potenciālo vertikālās saskaņotības analīzi ierobežoja zemā brieduma pakāpe, kurā pētījuma laikā atradās sertifikācijas satvars. Vienlaikus analīze atklāja arī iespējamos izaicinājumus *CRCF* regulas implementācijas fāzē, ja netiks skaidri nodalīti KLP un *CRCF* satvara finansējuma mehānismi oglekļsaistīgas lauksaimniecības praksēm. Dalībvalstu motivāciju šo prakšu atbalstam var vājināt neskaidrības par to, vai ar tām panāktais oglekļa piesaistes apjoms tiks ieskaitīts saistību izpildē saskaņā ar ZIZIMM regulu (ES) 2018/841.

Eiropas bioekonomikas stratēģijā noteikto mērķu vertikālās saskaņotības analīze, vispirms ES dalībvalstu stratēģiju līmenī un pēc tam Latvijas politikas plānošanas dokumentu kontekstā, parādīja, ka izstrādātā metodika ļauj salīdzinoši ātri identificēt politikas dokumentos definētos mērķus un pasākumus, kā arī novērtēt to prioritāti. *TOPSIS* metode ir ērti izmantojama alternatīvu salīdzināšanai, taču tā sniedz tikai relatīvu salīdzinājumu vienas datu kopas ietvaros. To parādīja bioekonomikas politiskās saskaņotības novērtējums, kur Latvijas Bioekonomikas stratēģija 2030 uzrādīja augstāko rezultātu nacionālā līmenī, bet zemāku līmeni salīdzinot ar citām ES dalībvalstīm. Kopumā rezultāti apliecināja vertikālo politisko saskaņotību, tomēr tikai formālā līmenī, jo ne visām stratēģijām bija izstrādāti rīcības plāni, pēc kuriem varētu vērtēt praktiskās izpildes efektivitāti. Lai padziļināti analizētu mērķu īstenošanu, tika veikta gadījuma izpēte, kurā analizēts NEKP2030 rīcības plāns. Pasākumi tika grupēti atbilstoši politikas instrumentu kategorijām, lai novērtētu to iespējamo efektivitāti siltumapgādes un dzesēšanas sektorā. Analīze parādīja, ka stratēģijas un mērķi formulēti skaidri un saskan ar ES līmenī noteiktajiem, taču izstrādātie pasākumi pārsvarā koncentrējas normatīvā regulējuma instrumentu kategorijā, savukārt ekonomiskie un tirgus instrumenti izmantoti ierobežotā skaitā, liecinot par instrumentu līdzsvara trūkumu, kas var kavēt mērķu praktisku īstenošanu.

Politikas saskaņotības novērtējumā izmantotie pētījumu dizaini nodrošina izpratni par pētāmo tēmu neatkarīgi no tā, vai tā ir saistīta ar bioekonomiku, enerģētiku vai aprites ekonomiku. Šāds novērtējums ļauj identificēt iespējamos kavēkļus un pretrunas, kas var būt izšķirošas mērķu īstenošanā, taču tas pārsvarā atklāj tikai formālu mērķu uzskaitījumu, nevis to īstenošanai nepieciešamos pasākumus un politikas instrumentus. Tādēļ, kā secīgs solis ir nepieciešama padziļināta analīze, kas ļauj identificēt procesu optimizācijas iespējas un novērst barjeras, stiprinot bioekonomikas un klimata politikas efektivitāti.

Administratīvo, institucionālo un normatīvo procesu kartēšana, apkopojot administratīvo procesu soļus, nepieciešamās atļaujas un identificējot piemērojamo normatīvo regulējumu, ļāva kvalitatīvi un kvantitatīvi salīdzināt AER projektu ieviešanas posmus dažādās valstīs, vienlaikus ļaujot identificēt optimizācijas iespējas, kā arī pārņemt labās prakses piemērus. AER projektu īstenošanas administratīvo procesu analīze parādīja, ka būtisks kavējošais faktors ir sarežģītās procedūras un ar tām saistītais administratīvais slogs. Šis rezultāts korelē ar promocijas darba pirmajā segmentā definēto atziņu un norādēm analizētajos dokumentos uz birokrātisko procesu sarežģītību, administratīvo slogu un ierobežotu institucionālo kapacitāti [183], [184], [213]. Turklāt analīze apliecināja, ka politikas instrumenti lielākoties koncentrējas normatīvā regulējuma kategorijā, kas praksē nozīmē papildu atļauju, saskaņojumu un procedūru prasības. Tas veicina birokrātisko procesu sarežģītību un palielina administratīvo slogu, tādējādi ierobežojot politikas mērķu īstenošanas efektivitāti [375], [376].

Izstrādātā pieeja veicinošo un kavējošo faktoru identificēšanai meža nozarei ļāva gan formulēt produktu attīstības stratēģijas, gan atklāja nozares pamatproblēmas, kas ietekmē meža nozares transformācijas iespējas. Apsverot bioekonomikas attīstības virzienus, kritiskais faktors nav tikai konkrētu produktu grupu attīstības potenciāls, bet arī izejvielu pieejamības nodrošinājums, stabils un prognozējams normatīvais regulējums, kā arī finansējuma pieejamība pētniecībai, inovācijām un komercializācijai. Nozares transformāciju ierobežo novecojuši politikas plānošanas dokumenti, kas rada nenoteiktību par meža nozares ilgtermiņa attīstības virzienu un tā saskaņotību ar ES klimata un bioekonomikas mērķiem. Identificētā situācija atbilst promocijas darbā hipotēzei, norādot, ka, ja politikas dokumentu pamatā nav aktuāls, stratēģiski orientēts un ar ES mērķiem saskaņots plānošanas satvars, tas var radīt iespaidu par "vilcināšanas politiku" [377] un vājināt vertikālo saskaņotību. Šāda situācija, savukārt palielina fragmentācijas risku starp dalībvalstīm un apgrūtina kopīgo klimatneitralitātes mērķu sasniegšanu.

Izstrādāta metodoloģija šķēršļu un nepilnību identificēšanai, lai gan laikietilpīga, ļāva sasniegt promocijas darba mērķi. Rezultāti palīdzēja ne tikai noteikt barjeras, bet arī apstiprināja secinājumus, kas definēti pēc politikas saskaņotības novērtējuma, proti, ka nepieciešama padziļināta analīze, lai atklātu nozares attīstību kavējošos faktorus. Šķēršļu identificēšanas pieejas pamatā ir optimizācija, kas paredz ne vien norādīt nepilnības, bet arī piedāvāt risinājumus, kā tas veikts abās gadījuma izpētēs. Izstrādātā metodika un izmantotās metodes (dokumentu analīze, *TOPSIS*, AHP, SVID) ir salīdzinoši vienkārši piemērojamas arī politikas veidotājiem stratēģiju izstrādē.

Trešajā promocijas darba segmentā uzmanība pievērsta politikas ieviešanas dimensijām, lai pietuvinātu politikas ieceru īstenošanas novērtējumu institucionālā un sektoru līmenī. Tas ļauj atklāt kavēkļus augstākā līmenī noteikto mērķu ieviešanai praksē un definēt nepieciešamos pasākumus to novēršanai. PIKC energoefektivitātes paaugstināšana atkarīga no atbildīgo darbinieku kompetences un motivācijas. Lai gan pasākumu īstenošana saistīta ar finansējuma pieejamību, būtisku ietaupījumu iespējams panākt arī bez papildu ieguldījumiem, konsekventi īstenojot enerģijas taupības pasākumus. Saliktais rādītājs var kalpot kā instruments, kas palīdz identificēt optimizācijas iespējas un padarīt politikas pasākumus efektīvākus, veicinot noteikto mērķu sasniegšanu.

Akvakultūras attīstību ES un Latvijā kavē tās salīdzinoši zemā prioritāte bioekonomikas politikas ietvaros. Nozares potenciāla izmantošanai nepieciešamas padziļinātas gadījuma izpētes par sauszemes akvakultūras tehnoloģijām, uzņēmumu praksi un zināšanu līmeni. ES akvakultūru konkurētspēju globālā mērogā varētu stiprināt ar energoefektivitātes, resursu efektivitātes un AER risinājumu ieviešanu, tādējādi nodrošinot patērētājiem būtisku olbaltumvielu avotu ar mazu oglekļa pēdu. Atbilstošas stratēģijas un pasākumi spētu palielināt nozares produktivitāti un konkurētspēju, vienlaikus sekmējot ilgtspējīgas attīstības mērķu sasniegšanu.

Komunikācija ar ieinteresētajam pusēm ir nozīmīga politikas ieviešanas dimensija, kas jāņem vērā, izstrādājot politikas un to īstenošanas pasākumus. Pētījuma posmā par AER administratīvo šķēršļu novēršanu sabiedrības un pašvaldību informētība tika atzīta par nozīmīgu ietekmējošo faktoru. Tāpat tika secināts, ka savlaicīgas pārrunas starp AER projektu īstenotājiem un vietējām kopienām var veicināt pozitīvu iznākumu vēlākās oficiālajās sabiedrības apspriedēs. Līdzīga atziņa izskanēja arī grupas modelēšanas sesijās, kur sabiedrības informētības ietekme tika uzsvērta kā nozīmīgs faktors nišas produktu virzīšanai tirgū un ilgtspējīgu izvēļu veicināšanai. Ilgtspējas mērķu sasniegšanai nepietiek tikai ar politiku izstrādi un ilgtspējīgu produktu veicināšanu, būtiska ir arī sabiedrības informēšana un izpratnes veidošana. Sabiedrība nav nošķirta no politikas veidotājiem, uzņēmumu vadītājiem vai energopārvaldniekiem – šo grupu profesionālā rīcība sakņojas sabiedrībā valdošajos priekšstatos. Ja ilgtspējīgas izvēles tiek nostiprinātas kā sociālā norma, tās atspoguļojas arī lēmumu pieņemšanā un profesionālajā praksē.

Promocijas darba izstrādi ietekmēja vairāki ierobežojumi, kas nosaka tā rezultātu interpretācijas robežas. Pirmkārt, daļai analizēto politikas plānošanas dokumentu nav izstrādāti rīcības plāni, kas ierobežoja iespēju novērtēt to praktisko īstenošanu un nozīmēja, ka saskaņotība vairākos gadījumos bija nosakāma tikai formālā līmenī. Otrkārt, administratīvo procesu kvantitatīvajos novērtējumos izmantotā informācija balstījās normatīvo dokumentu analīzē un publiski pieejamos datos, kas dažādās valstīs ir atšķirīgi detalizēti un nereti interpretējami atšķirīgi. Treškārt, vairākās pētījuma daļās izmantoti ekspertu vērtējumi, kas atspoguļo ekspertu profesionālo skatījumu, nevis vispārinošu populācijas viedokli, un līdz ar to nodrošina kvalitatīvu, nevis statistiski reprezentatīvu vērtējumu. Turklāt jāņem vērā arī tas, ka atsevišķi analizētie politikas un normatīvie dokumenti ir tikuši atjaunināti pēc pētījumu veikšanas, kas var ietekmēt to, cik aktuāli ir konkrētie secinājumi. Ceturtkārt, promocijas darbs balstās statiskā laika griezumā, tādēļ iegūtie rezultāti neļauj veikt nākotnes attīstības scenāriju modelēšanu, kā tas būtu iespējams izmantojot dinamiskas modelēšanas pieejas, piemēram, sistēmdinamiku vai enerģētikas optimizācijas modeļus. Taču arī šādu modeļu izmantošana būtu sarežģīta analizēto dokumentu kontekstā, jo rīcības plānu neesamība un zems pasākumu konkretizācijas līmenis ierobežo ticamu pieņēmumu formulēšanu. Šie ierobežojumi neietekmē promocijas darba hipotēzi, taču nosaka robežas tam, cik plaši kvantitatīvi var novērtēt politikas sniegumu visos pētījumā iekļautajos segmentos.

Promocijas darba rezultāti apstiprina definēto hipotēzi, ka sistemātisks politikas dokumentu izvērtējums, nepilnību un šķēršļu identificēšana, kā arī pierādījumos balstītu rekomendāciju izstrāde ir lietderīga pieeja, kas sniedz pamatu politikas saskaņotības un ieviešanas efektivitātes stiprināšanai. Lai gan promocijas darbs neapliecina reālas izmaiņas politikas praksē, tas nodrošina metodoloģisku un analītisku ietvaru, ar kura palīdzību iespējams veidot efektīvākas un zināšanās balstītas stratēģijas, tādējādi paātrinot virzību uz Eiropas zaļā kursa mērķu sasniegšanu.

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Combining policy measures to reach long term energy targets

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***Abstract*— Choosing the optimal mix of policy instruments can make a significant contribution to energy efficiency. Well-organized and improvement-oriented legislation and regulations, as well as the right policy incentives, can open up new opportunities to improve energy efficiency and foster new technological innovations. The EU has created a favourable environment for the necessary changes, so it is crucial to identify whether the measures defined at the EU have been implemented at the national level. Systematic literature analysis has been used to identify EU targets for energy efficiency improvements and their implementation into national long-term planning documents of Latvia. The Latvian National Energy and Climate Plan for 2021-2030 has been analysed. The identified policy instruments have been categorized to evaluate the potential strength of long-term planning documents. The foreseeable impact of the planned policies and their implementation mechanisms on future energy efficiency improvement measures is assessed.**

***Keywords*—energy policy, national energy and climate plan, long term planning documents, policy instruments**

I. Introduction

National governments must play an active role in developing national planning documents, creating a clear vision for the future and a sustainable political environment. To stop climate change, governments need to adapt their thinking to the complex circumstances and integrate the environmental dimension into policy decisions wherever possible.

The effectiveness of policy instruments could be enhanced if they were applied more individually at each level of governance. Primary policy goals and directions should be developed at the global or at least EU level and then further structured at the national level and met at the local level, considering regional specificities and the policy objectives pursued. The first step towards identifying the optimal policy mix is to assess and classify the existing regulatory approaches and development strategies according to the objectives to be achieved [1], [2]. Next, assess whether they can deliver the objectives set.[2].

A. Policy Instruments

A set of well-chosen policy instruments is essential for achieving objectives in any policy area. The most effective way to use policy instruments is to combine them rather than rely on just one instrument [3]. Furthermore, policy instruments work best when adapted to national and regional specificities, especially in the light of existing market conditions [4], [5], [3].

Policy instruments can be categorised according to different principles. Instruments can target specific processes or norms - additional taxes to reduce GHG emissions; technology standards; cooperation agreements; compensation systems; energy consumption, etc. can be applied. The European Commission's "Better regulation Toolbox" on best practice for better governance lists four categories of policy instruments: "hard" legally binding rules; "soft" regulation; education and information; economic instruments [1]. In some cases division into three major groups – "taxes, standards, tradable permits" is used [6]. For this paper a toolset that includes the previously mentioned instruments and covers a broad range of areas, but at the same time is not too detailed, is chosen as the most suitable.

Fig. 1. Categories of policy instruments [4]

For further research and classification of policy instruments, four categories of policy instruments were selected for solving environmental issues: "regulation, voluntary action, government expenditure, and market-based instruments" [4] (Figure 1.).

B. Regulation as a Policy Instrument

One of the most widely used policy instruments is regulation [4]. Regulations are laws and normative documents issued by governments and binding on the parties involved. Legally binding rules are essential when behaviour needs to be changed, but cannot be expected to change through other instruments [1], [7]. At the EU level they can be in the form of

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regulations, directives, or decisions, at the level of national governments - laws or other legally binding rules that set norms for permissible pollution (air, water, soil, etc.) or any other activity that could cause environmental pollution [1], [4], [8].

Regulation is considered to be the most widely used environmental policy instrument because it is relatively easy for governments to apply [4]. The most challenging part of the regulatory instruments is not the legal framework of the prohibition or restriction but the monitoring of implementation and compliance, which requires administrative capacity, human resources, and sectoral knowledge [1], [4], [7]. A more robust regulatory framework to tackle issues and the possible sanctions that could be expected in case of non-compliance, are strengths of regulatory policy instruments [7]. On the other hand, institutional weaknesses, high requirements, and the inability to track compliance with existing regulations could be the most significant shortcomings of regulatory instruments [4], [7].

C. Voluntary Action as a Policy Instrument

Policy instrument "voluntary action" includes voluntary activities of the society, companies, or any other actor; they are not imposed by legislation or other regulatory documents; are not promoted by any other benefits, and aim to protect the environment [9], [4]. Voluntary action can be in the form of communication between the state, society, and companies as well as voluntary agreement or technical standards [4], [1]. By engaging in voluntary actions, individuals and society can reduce the direct impact on the environment and set foundations for sustainable development [4].

For voluntary agreements to work, industry and individuals need to have the same preferences on a given issue because, without external pressure, the industry is not sufficiently motivated to impose restrictions of any kind [1]. The effectiveness and economic contribution of voluntary action is therefore often considered to be ambiguous. It is believed that the tasks achieved in environmental protection through voluntary action would often have been achieved through other types of instruments or would happen by themselves [9].

One example of a voluntary agreement is The Eco-Management and Audit Scheme (EMAS) [10]. EMAS sometimes is criticised for not setting high enough environmental standards for companies, meaning that with relatively modest improvements in their business operations, companies can achieve or maintain certification [10]. Hence, voluntary action can not be viewed as the most effective and economically efficient policy tool in addressing environmental issues, but engaging in voluntary activities shows the goodwill and willingness to make efforts to limit their environmental impact [11], [9].

D. Government Expenditure as a Policy Instrument

There is relatively little literature on government expenditure in particular, as it is mainly placed in the same category as market-based or fiscal instruments [1]. However, the authors consider it worthwhile to distinguish it as a separate category of policy instruments, because financial support or investment from the state is likely to be an essential contribution for achieving environmental goals. A classic form of government expenditure is subsidies or grants available for companies or individuals with a relatively small co-payment [4]. Government expenditure may also include public or private investment, for example, in improving infrastructure to produce energy from RES, to charge electric cars or to increase the availability of waste sorting containers to encourage voluntary involvement [4], [12].

Government expenditure, as a financial support mechanism from the national government and EU, can be seen as a positive aspect of promoting sustainable development and helps to achieve long-term goals. State subsidies can positively affect the behaviour of both society and businesses, can bring positive changes in the functioning of the market, and improve performance indicators of sectors that have hitherto been inefficient [13]. The positive effect depends on the government's ability to distribute subsidies efficiently, as well as it is essential to ensure meaningful use of the allocated funding [13]. Additional sectoral funding, for example, to support the transition to climate neutrality, can put additional pressure on national budgets, especially in less developed countries where the focus tends to be on other issues [12].

E. Market-based Instruments

Market-based instruments are classified as an indirect management tool and are also referred to as "cap and trade", "target and trade" measures or financial initiatives [14]. The strength of market-based instruments is that market forces are used to bring about improvements that would not otherwise be achievable - primarily as different types of taxes on polluting activities or products with a negative impact on the environment [14], [1]. For example, the "polluter pays" principle means that producers and consumers are charged extra for over-exploiting scarce resources, air and water, and emitting harmful substances into them [4]. It is directly linked to taxation and the removal of any tax subsidies or rebates for fossil energy sources [8], [9]. The problem, however, is that the amount of the tax needs to be set very precisely so that consumers can continue to use the product or service while at the same time the added tax has to maintain a positive impact on the climate.

"Cap and trade" is a type of market-based instrument that aims to reduce emissions by setting a cap on emissions instead of imposing a tax on a predetermined level of emissions [15]. Emission ceilings can be set using the "grandfathering principle" - allocation of emission allowances according to a specific principle or standards or, according to the "auctioning principle," emissions savings are traded between potential polluters [15]. One of the essential advantages of market-based instruments is the financial side - the government collects additional revenues to continue investing in other environmental or energy efficiency projects [9]. Market-based instruments may also include deposit schemes that facilitate the recycling of packaging - once the packaging has been emptied, the user returns it for recycling in exchange for a small refund [4].

Unlike regulations, market-based instruments are based on theoretical calculations and conjectures, as it is not possible to predict precisely to what extent society and industry are interested in cooperating. Consequently, taxes are often set at a lower level than the actual situation would require because of the fear that there will be too little involvement [4], [15].

TABLE I. POLICY INSTRUMENTS AND MEASURES [1], [4], [5]

Category of policy instrument	Examples of policy instruments
Regulation	Binding legal rules
	Ambient, emission, design standards
	Building codes
	Compulsory energy audits and energy consumption monitoring
	Energy efficiency investment obligation for private enterprises
	Education programmes
Voluntary action	Consumer choices
	Environmental agreements
	Business or industry self-regulation initiative
Government expenditure	Subsidies and incentives
	Investments to encourage voluntary action
	Education. Research and science
	Loans
	Grants for investment in energy efficiency
Market-based instruments	Emission, user-charges, product charges
	Tradeable permits
	Deposit- refunds
	Fines, fees, penalties
	Energy consumption reduction certificates
	Taxes

Each set of four policy instruments described has its strengths and weaknesses, depending on the outcome to be achieved, and often, combinations of policy instruments emerge naturally in policy planning processes [1]. However, it is crucial to identify whether the desired combination of policy instruments or a "policy mix" is formed, to create a sufficient impact [16]. "Regulation" policy instruments play a significant role in setting the basic framework for future development, nonetheless, legislation should be complemented with market-based instruments and sufficiently planned and regulated government expenditure [14], [16]. Moreover, government expenditure policy instruments could be coupled with other mechanisms, for example, public subsidies, additional taxes on GHG emissions, or, conversely, tax incentives for energy efficiency improvements combined with stricter regulation [7], [13].

In the European Commission's Better Regulation Toolbox it is pointed out that not all combinations of policy instruments are successful and deliver the expected results, so it is essential to be careful when combining policy instruments to ensure that they are proportionate and complement each other [1].

II. Methodology

A methodology was developed in which the first step was a literature review of policy instruments used to address environmental and climate issues. A systematic literature review (SLR) of EU regulatory documents that could directly impact energy efficiency improvements was carried out to assess the implementation of EU legislation at the national level.

SLR has its roots in medicine and evidence-based policy and practice. Although it has recently been used to address environmental issues and evaluate policies or policy instruments, this method has been used relatively rarely in political science [17], [18]. SLR seeks answers to a specific question or hypothesis, and the process is very time-consuming [17]. The use of SLR provides a more transparent and accessible explanation of the evaluation of policies and policy instruments when combined with other analysis methods. However, the SLR method is criticized for when being applied inaccurately or carelessly, becoming subjective [17]. The SLR method was chosen to improve the quality of the literature review and the evaluation of policy documents while maintaining the context of the documents.

SLR was used to identify targets and policy instruments to improve energy efficiency in the heating and cooling sector. Five documents were selected:

- A European Green Deal;
- Energy efficiency directive (Directive 2012/27 / EU);
- Directive (EU) 2018/2002 amending Directive 2012/27/EU on energy efficiency;
- Commission Delegated Regulation (EU) 2019/826 of 4 March 2019;
- Commission Recommendation (EU) 2019/1659 of 25 September 2019.

These documents were constructively searched for such information within the context of the text:

- EU targets for climate neutrality;
- achievable goals for improving energy efficiency;
- the objectives to be achieved in the heating and cooling sector;
- policy instruments for achieving the objectives.

The next step was to use the SLR to determine whether the objectives identified in the EU documents and how to achieve them have been taken into account in Latvia's planning documents and development strategies:

- Latvian Sustainable Development Strategy 2030 (Latvia2030);
- Latvian National Development Plan for 2014-2020 (NDP2020);
- Latvian National Development Plan for 2014-2020 mid-term evaluation report;
- Latvian National Development Plan for 2021-2027 (NDP2027);
- Latvian Long - Term Strategy for Energy 2030;
- Latvian National Energy and Climate Plan for 2021–2030 (NECP2030).

In these documents, the following information was sought constructively, taking into account the context of the text:

- how and whether the goals set in the EU regulatory documents are reflected;
- achievable goals for improving energy efficiency;

- the objectives to be achieved in the heating and cooling sector;
- policy instruments for achieving the objectives.

The policy instruments identified in the EU and Latvian documents and the objectives to be achieved were summarized and compared with each other to answer the questions: "Has the implementation of EU legal norms on the national level taken place? Are there policy instruments and goals that Latvia has not implemented?".

Annex 4 "Planned Policies and Measures for their Implementation" of the NECP2030 was analysed with SLR to identify the policy measures and policy instruments to be applied [19]. Higher-level planning documents, such as the Latvian Sustainable Development Strategy 2030 [20] or NDP2027 [21], outline Latvia's development directions in various areas that affect the country's development as such, but NECP2030 focuses specifically on the energy sector and climate change mitigation, so the measures outlined in NECP2030 were selected for in-depth analysis and categorisation by policy instruments. NECP2030 Annex 4 summarizes policies and measures planned for the future development of the heating and cooling sector and the expected improvements which could directly affect the overall reduction of energy consumption [19].

The following information was sought constructively, taking into account the context of the document:

- policy measures directly related to the heating and cooling sector;
- policy measures that indirectly affect the heating and cooling sector and could have an impact on its development.

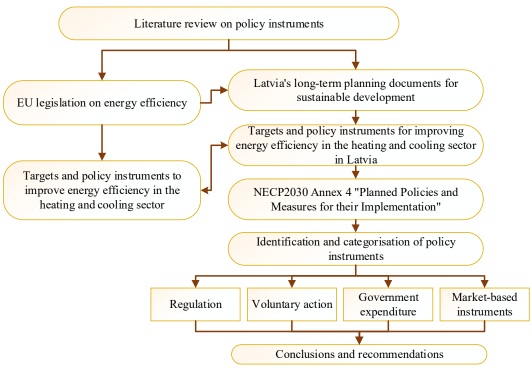

Fig. 2. Overall methodology of research

The identified policy measures were summarized according to previously identified categories of policy instruments - regulation, voluntary action, government expenditure, market-based instruments (Table 1). After compiling the information, the total number of planned policy measures was extracted according to the search parameters. Policy measures in each of the four categories of policy instruments were also counted, thus determining the share of policy measures in each category.

III. Results

Comparing the objectives set out in EU legislation with those set out in Latvian documents, we can see that on average, EU objectives have been implemented (Figure 3). Several aspects were considered, such as financial support for energy efficiency improvements in heating and cooling and insulation of buildings. The need for changes in the tax system and the removal of subsidies for fossil fuels are frequently discussed in Latvian documents. Adoption and implementation of the "polluter pays principle" in a manner that makes it functional, reduction of GHG emissions, and imposing additional taxes on major pollutants. Long-term planning documents focus on improving energy efficiency in both heat generation and transmission, reducing heat losses. Latvian documents provide little information on plans to transfer surplus heat and cold from manufacturing plants to district heating networks, while EU documents often mention this as a possible solution. EU documents emphasize the need for a transparent and fair energy supply system for consumers - end-users should receive clear and detailed invoices for the heat and hot water consumed, a possibility of installing individual meters to account the received heat and influence energy consumption. Latvian planning documents do not mention any information on the need to amend the heating and hot water billing procedures.

A. Analyses of long-term planning documents

Latvia's long-term planning documents mention the principle "energy efficiency first", but at the same time, no indications were found about the need to give a "priority to green and sustainable solutions" which are mentioned in EU regulatory documents. Furthermore, no references to energy labelling or application of the "Think Small First" principle, which urges governments to take into account the capacity and ability to adapt to legislative changes of small and medium-sized enterprises, as they are the main employers in the EU [22], have been found in Latvian long-term planning documents.

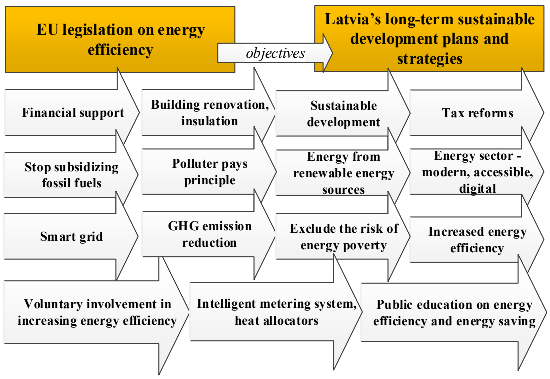

Fig. 3. Implementation of EU objectives in Latvian long-term planning documents

While Latvia's long-term planning documents have implemented EU legislation, there are several aspects where the long-term development strategies issued by the Latvian government lack a coherent vision for the future. Tax incentives for fossil fuels are still granted, but at the same time, there are no tax incentives for using RES or energy efficiency measures [19]. Excise duty is not linked to the created environmental impact by fossil energy resources as well as a principle "energy efficiency first" does not work in practice when assessing the allocation of funding for future development projects [19], [23]. Development directions and plans for achieving them have been set at the national level, but at the same time, a detailed strategy on how to achieve these goals is lacking [19].

B. *Planned policies and measures for their implementation*

After comparing the EU and Latvian documents, the next step was to categorize the policy instruments listed in Annex 4 "Planned policies and measures for their implementation" of NECP2030 that will be used to improve energy efficiency in heating and cooling [19]. A total of 34 courses of action with 110 planned measures that could directly or indirectly affect the efficiency of the heating and cooling sector were identified. Further, the planned policy measures were divided thematically into the four categories of policy instruments, according to Table 1. Planned policy measures included several energy efficiency-related measures, with the main priorities being the improvement of energy efficiency; the implementation of the "energy efficiency first" principle; improvements in the heating sector, and the renovation and extension of heating pipelines to encourage new connections[19]. In addition, NECP2030 emphasizes the need of increased use of RES and changes in the tax regulatory framework [19].

As can be seen in Table 2, the largest number of planned policy measures or policy instruments are under the type "regulation" (69% or 76 measures), the second-largest number of measures are "government expenditure" (20% or 22 measures), followed by "market-based instruments" (7% or 8 measures) and "voluntary action" (4% or 4 measures).

The most frequently mentioned “regulation” policy instruments (37 measures) are the development of new legislation, Cabinet of Ministers Regulations, procedures or guidelines. The next most frequently mentioned instrument is the conduct of various studies and evaluations (19 measures). Only a few times instruments, such as establishing a single point of contact, updating the NECP2030, information campaigns, and developing training materials are mentioned. Measures for “voluntary actions” – to sign at least 10 voluntary agreements, promotion of public participation in the functioning of the ESCO and PESCO market, improving energy efficiency. “Government expenditure” is often mentioned in the context of legislative changes to grant availability of European Structural and Investment Funds beyond 2021 (in connection with 7 measures). Financial support for renovation, insulation, energy efficiency; support for voluntary agreements; creation of a fund to promote RES and energy efficiency; implementation of a specific number of projects are also mentioned as planned government expenditure. Identified measures as “market-based” instruments include assessing whether measures such as cross-trading surplus energy efficiency savings; tax rebates for energy efficiency improvements or the use RES; increasing the tax burden on fossil fuels are listed for assessment as possible changes in legislation.

A mix of policy instruments has been developed for several measures, for example combining legislative regulation with “voluntary actions” and “government expenditure” or “regulation” linked with “market-based” instruments. In fewer cases, “regulation” has been combined with “government expenditure” and “market-based” instruments.

TABLE II. POLICY MEASURES MENTIONED IN NECP2030, ANNEX 4 "PLANNED POLICIES AND MEASURES FOR THEIR IMPLEMENTATION" [19]

Category of policy instrument	Regulation	Voluntary actions	Government expenditures	Market-based instruments
Number of measures planned	76	4	22	8

According to the distribution of measures into the four selected categories of policy instruments, it can be seen that planned policy measures are not distributed evenly amongst them. Emphasis is placed on conducting new regulatory framework and additional research for measures to be undertaken. The second highest figure is for “government expenditure”, in the form of legislative changes to further access European Structural and Investment Funds and to improve energy efficiency in a certain number of projects. “Market-based” instruments and “voluntary actions” received relatively little attention and are applied in combination with regulatory-type policy instruments mostly as changes in tax system.

IV. DISCUSSION AND CONCLUSIONS

EU legislation is being implemented in Latvia's long-term planning documents. Latvia's long-term planning strategies have taken into account the main objectives set at the EU level. Although fragmentation and contradictions have been observed while assessing Latvia's planning documents, for example, the need to promote energy production from RES is underlined, but at the same time, there are no clear support mechanisms. The necessity to stop supporting fossil fuels is identified, but there is no precise plan how this will be done - recognition of the need to move away from fossil fuels in favour of RES was already identified in 2013 in the " Latvian Long - Term Strategy for Energy 2030" and almost a decade later the NEKP2030 highlights the same problem, still without an explicit solution [19], [24].

The policy measures and instruments proposed in NECP2030 place a significant emphasis on "regulatory" type policy instruments, which imply additional work on administrative and regulatory requirements. It could be a potentially distressing indicator, as the analysis of Latvian planning documents repeatedly point to an overly complex bureaucratic process and administrative burden, coupled with a lack of institutional capacity [23], [19], [21]. Under the category "government expenditure", a relatively large number of policy measures are mentioned, indicating national governments' initiative to invest and financially support energy efficiency and improvement measures. A deeper analysis of the planned actions shows that legislative changes are planned to ensure that the financial support from European Structural and Investment Funds can be attracted, rather than the funding itself being guaranteed. No information on the readiness to allocate government funding to promote energy efficiency measures was identified. In long-term development planning little attention to "market-based" and "voluntary" instruments is paid, and measures under these categories lack ambition, for example, increasing the number of voluntary agreements from two to 10, or the reference to tax changes in the next decade as "assess the scope for possible regulatory changes" rather than “make changes” [19].

Even though the Latvian government has identified the same targets as the EU and implemented them in its long-term planning strategies, the identified policy instruments for improving energy efficiency in the heating and cooling sector suggest that they are set modestly. The emphasis is put on new legislation and further assessment, leading to further overburdening of the administrative apparatus and slow implementation of new initiatives. To achieve long-term energy objectives, the policy mix of regulation combined with “government expenditure” or “market-based” instruments needs to move from the protracted “evaluation phase” to a more targeted and formulated “action phase”.

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Assessing Bioeconomy Development Opportunities in the Latvian Policy Planning Framework

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Abstract: The broad spectrum of bioresource use makes it challenging to interconnect strategic objectives and policy planning documents without compromising a coherent development vision. Bioeconomy development directions have been defined at the EU and Latvian levels. Nevertheless, to facilitate their implementation, the goals must be consistent with those specified in relevant national policy planning documents and vice versa. To determine whether internationally defined bioeconomy objectives are implemented in Latvian policy planning documents and what priority is given to them, a mixed methods approach was used—a systematic literature review combined with a keyphrase assignment approach. The results are summarized in an illustrative screening matrix and aggregated using the TOPSIS method to identify in which policy planning documents bioeconomy objectives are prioritized and to what extent. The results have shown a high prioritization of bioeconomy objectives in Latvian policy planning documents, especially in hierarchically higher documents.

Keywords: bioeconomy strategy; policy coherence; policy framework; strategic development

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1. Introduction

The year 2022 marks the 10th anniversary of the first European Bioeconomy Strategy "Innovating for sustainable growth—A bioeconomy for Europe" (further EBS) [1,2]. The EBS sets out a series of objectives aimed at expanding the use of bioresources and underlining the need to move from the "old" to the "new" bioeconomy—knowledge-based and innovative [2,3]. The aim is to improve the current practices in land use and resources sustainably, to reduce emissions during resource extraction and processing, to lessen waste and use by-products to create higher value-added products, to move towards a circular economy, to minimize the use of non-renewable, unsustainable resources and adopt other environmentally friendly practices [2,3]. The bioeconomy has not lost its relevance over the last 10 years. On the contrary, global climate change, the current geopolitical situation, and rising energy prices further emphasize the need for the sustainable use of bioresources and the replacement of fossil fuels [4,5].

The economic impact of the COVID-19 pandemic and the tense geopolitical situation with the active warfare in Ukraine has created a situation where energy and food prices are rising rapidly due to disrupted and uncertain supply. The objectives of the EBS [6] are now central and could be a solution in terms of replacing fossil fuels with renewable resources under the condition of efficient and knowledge-based use of bioresources [5,7]. As the application of bioresources is wide-ranging, the EBS should be seen as a part of a larger equation, which could be solved by attaining coherence between policies affecting the bioeconomy and bioresources management at the international and the EU Member State level. Latvia is no exception. Therefore, bioeconomy development potential in Latvia should be assessed in order to identify the coherence between policy planning documents concerning different domains (external coherence) and also within each policy domain to verify the consistency of expressed policy goals, instruments, and other policy-related signals (internal coherence) [8].

Coherent policy-making across sectors could contribute to environmental sustainability and the development of successful national and regional cooperation mechanisms for forming functional regulation mechanisms and achieving common goals [4,8]. National action plans for the governance of bioresources aligned with international targets could ease food and energy supply risks, promote more rational and efficient use of bioresources, and prevent rapid and unpredictable inflation in Latvia and across the EU [5]. It is essential to identify whether Latvia's policy planning documents are coherent regarding the internal and external policy domains of bioeconomy development opportunities [4,8,9]. Whether the implementation of the overall strategic vision of bioeconomy development is following a top-down approach and maintains coherence at all levels is therefore important to identify [10,11].

2. Materials and Methods

2.1. Systematic Literature Review

A methodology was developed to identify a framework for developing the bioeconomy in Latvia's policy planning documents (Figure 1). The authors first identified internationally important documents that outline the main bioeconomy development trends and priorities. Three documents were selected: the 2009 OECD report "The Bioeconomy to 2030. Designing a Policy Agenda" [12]; EBS (2012) [6] and the EBS Action plan "A sustainable bioeconomy for Europe. Strengthening the connection between economy, society and the environment: updated bioeconomy strategy" (2018) [13]; UN "Transforming our world: the 2030 Agenda for Sustainable Development" (2015) [14,15]. The objectives and action lines for bioeconomy development in these documents were identified through a systematic literature review (SLR). From the identified objectives, keywords were selected for further work with Latvian policy planning documents [16] to determine whether their objectives for bioeconomy development coincide with those set at the international level.

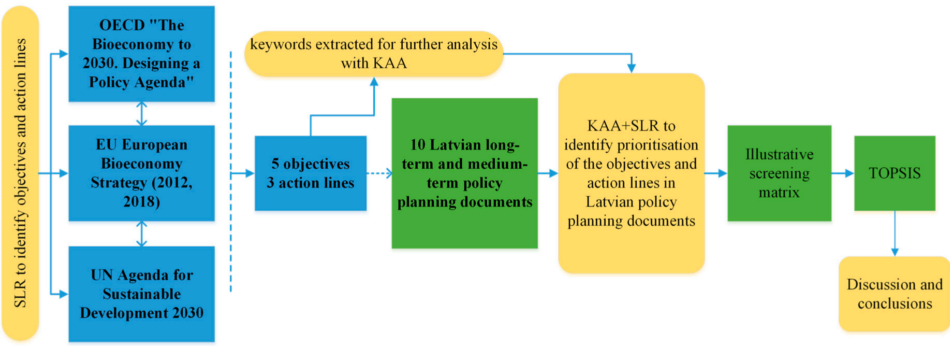

Figure 1. Methodology for assessment of policy planning documents at the international and national level.

The next step was to select Latvia's policy planning documents for further analysis. This step was also necessary to understand whether the documents coincide with the international purpose of the bioeconomy [11,17]. A total of 10 policy strategies and development plans directly related to the bioeconomy were selected (Appendix A) using a hybrid search strategy—SLR in combination with snowballing [18]. The search began with the analysis of the Latvian Bioeconomy Strategy 2030 (further LBS) and expanded the set to policy planning documents in relation to it and to the development of the bioeconomy. Further, a keyphrase/keyword assignment approach (KAA) [16,19,20] in combination with SLR was used to identify the specification of the internationally agreed objectives in the selected

Latvian policy planning documents. This would also allow for assessing the level of priority given to them. The results were presented in an illustrative screening matrix using a Likert-type scale [21], where more mentions of an objective indicated its higher priority. The priority of an objective was determined by the number of times it was mentioned in the policy planning document, as shown in Table 1.

Table 1. Rating scale for the illustrative screening matrix.

Rating	Level of Priority	Interaction
1	not a priority	no mention
2	low priority	1–2 mentions
3	medium priority	3–4 mentions
4	high priority	5–8 mentions
5	essential	9 and more mentions

The SLR has its roots in evidence-based policy and practice. It can be used to address environmental issues and evaluate policies and policy instruments [22–24]. One of the strengths of the SLR is that it allows one to answer a specific question or test a hypothesis [22,24]. Hence, the SLR method was chosen to identify international objectives and later to improve the quality of the illustrative screening matrix, showing the priority given to each of the international objectives identified above in the policy planning documents. SLR can be very time-consuming; therefore, KAA [19,20] was applied to reduce the time needed to review all 10 of Latvia's policy planning documents. The KAA was chosen because it is less time-consuming and helps to revise a document and the issue more closely while maintaining consistency [19,20]. Latvian policy planning documents range in length from 32 pages [25] to 228 pages [26], therefore, looking for pre-assigned keyphrases and keywords (Table 2) identified at the international level helped to maintain the scope and to constrain the study to a concise timeframe.

Table 2. Assigned keyphrases and keywords.

No.	Identified Objectives and Action Lines	Keyphrases and Keywords *
O_1	Ensure food and nutrition security	food security, ensure food, food availability
O_2	Manage natural resources sustainably	natural resources; sustainability; resources; natural
O_3	Reduce dependence on non-renewable, unsustainable resources	dependence; non-renewable; fossil
O_4	Limit and adapt to climate change	climate change; adaptation
O_5	Strengthen European competitiveness and create jobs	employment; jobs; promoting employment; competitiveness
A_1	Strengthen and scale up the biobased sectors, unlock investments and markets	biobased; attracting investment; innovation; investment
A_2	Deploy local bioeconomies rapidly across the whole of Europe	bioeconomy; bioresources; regions
A_3	Understand the ecological boundaries of the bioeconomy	ecological; boundaries; biological

* Keyphrases and keywords searched in documents in Latvian by using the word root.

2.2. Multi-Criteria Decision Analysis

An illustrative screening matrix was developed from the results of SLR and KAA. It shows the priority level of the international bioeconomy development goals in each of Latvia's policy planning documents. To determine which of the ten policy planning documents has the highest level of coherence with the internationally defined bioeconomy development objectives, the authors carried out a multi-criteria decision analysis—the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS).

The advantage of the TOPSIS method is its simplicity and the relatively small amount of data required to apply it [27,28]. The TOPSIS method is used for decision-making in various areas, including the evaluation of strategies by determining the proximity of predefined alternatives to the ideal positive and negative solutions [27–29]. One component of the TOPSIS calculation is the application of weighted criteria values. The calculation is then repeated with equal weights to determine the impact of the weights on the obtained results. [28]. The calculation was performed according to the steps and formulas listed below [30–32].

$$D = \begin{matrix} \\ A_1 \\ \vdots \\ A_m \end{matrix} \begin{matrix} C_1 \ \ldots \ C_n \\ \begin{pmatrix} x_{11} & \cdots & x_{1n} \\ \vdots & \ddots & \vdots \\ x_{m1} & \cdots & x_{mn} \end{pmatrix} \end{matrix} \quad (1)$$

where:
$A_1 \ldots A_m$—comparable alternatives;
$C_1 \ldots C_n$—criteria according to which the comparison is performed;
x_{ij}—performance/value of alternative A_i (where i is alternative 1 to m) according to criterion C_j (where j from 1 to n).

$$D_{\text{norm}} = \begin{matrix} \\ A_1 \\ \vdots \\ A_m \end{matrix} \begin{matrix} C_1 \ \ldots \ C_n \\ \begin{pmatrix} r_{11} & \cdots & r_{1n} \\ \vdots & \ddots & \vdots \\ r_{m1} & \cdots & r_{mn} \end{pmatrix} \end{matrix} \quad (2)$$

The next step is to calculate the normalized rating using the formula:

$$r_{ij} = \frac{x_{ai}}{\sqrt{\sum_{a=1}^{n} x_{ai}^2}} \quad (3)$$

When the normalized evaluation of all alternatives according to the criteria specified in Table 2 is obtained, it is necessary to determine the individual weight w_i of each criterion. Weights are determined by meeting a condition—the sum of criterion weights is equal to 1.

Expert evaluation is used to determine the individual weight of each criterion. As criteria weights, expert evaluation was obtained by Dolge et al. [33], analyzing the national bioeconomy strategies of nine EU countries using the TOPSIS method. The identified objectives and action lines in Table 2 coincide with the evaluation criteria set out in the study by Dolge et al. [33] (EBS objectives and EBS Action plan action areas); therefore, in order to ensure continuity and comparability of the studies, it was decided to use the expert evaluation in this research as well (Table 3). The expert evaluation was obtained through an online survey of industry stakeholders involved in any of the primary bioresources production or processing sectors or in scientific research in the field of bioeconomy, climate, and environmental sustainability [33]. The experts were asked to rate each of the criteria to detect the most important ones for the rapid development of the bioeconomy [33]. The weights of the criteria are the average of the 27 experts' responses for each criterion, giving a total of 1 or 100% for all criteria [33] (Table 3). The criterion weights obtained were inserted into the TOPSIS matrix and used for further calculations. In the next step, the criteria weight values w_i obtained from the expert evaluation are multiplied by the normalized values r_{ia} to obtain the normalized weighted value v_{ai}, as shown in Equation (4):

$$v_{ai} = w_i * r_{ia} \quad (4)$$

Table 3. Expert evaluation used for criterion weights [33].

No.	Criteria	Criterion Weights, w_i
1	O_1—Ensure food and nutrition security	0.11
2	O_2—Manage natural resources sustainably	0.18
3	O_3—Reduce dependence on non-renewable, unsustainable resources	0.19
4	O_4—Limit and adapt to climate change	0.12
5	O_5—Strengthen European competitiveness and create jobs	0.10
6	A_1—Strengthen and scale up the biobased sectors, unlock investments and markets	0.13
7	A_2—Deploy local bioeconomies rapidly across the whole of Europe	0.08
8	A_3—Understand the ecological boundaries of the bioeconomy	0.09
	TOTAL:	1.00 (100%)

When the normalized weighted decision matrix is constructed, the ideal positive solution d_a^+ and the ideal negative solution d_a^- are calculated. Initially, the distance to the ideal solution (MAX) and the distance to the anti-ideal solution (MIN) are determined. Distances are determined by formulas:

$$=\mathrm{MAX}(v_{a1}:v_{a3}) \tag{5}$$

$$=\mathrm{MIN}(v_{a1}:v_{a3}) \tag{6}$$

After determining the distance to the ideal and anti-ideal solution, the next step is to determine the ideal positive and ideal negative solution according to the formulas:

$$d_a^+ = \sqrt{\sum_{j=1}^{n} \left(v_i^+ - v_{ai}\right)^2} \tag{7}$$

$$d_a^- = \sqrt{\sum_{j=1}^{n} \left(v_i^- - v_{ai}\right)^2} \tag{8}$$

The relative proximity of the alternative to the ideal solution is calculated as shown in formula No. 9:

$$C_a = \frac{d_a^-}{d_a^+ + d_a^-} \tag{9}$$

The result is equal to values that show the proximity of the alternative to the ideal positive solution and the distance from the ideal negative solution.

To determine the impact of the weights of the criteria set by the expert evaluation (Table 3) on the evaluation of criteria, a re-evaluation of the criteria is performed, assigning equal values to all alternatives by using the same equations described above.

3. Results

3.1. International Policy Framework of Bioeconomy

Three leading policy planning documents were selected for identifying internationally established directions for bioeconomy development. The 2009 OECD report "The Bioeconomy to 2030. Designing a Policy Agenda" [12] lays the foundations for a strategic view of the bioeconomy and the benefits that could arise from the wider use of bioresources and biotechnologies [15]. The report states that the bioeconomy has all the potential needed to ensure long-term economic and environmental sustainability, however, to achieve this, a broad public and national government support is crucial [12]. The OECD report identifies nine vital challenges in the bioeconomy till 2030 [12] and they are summarized in Table 4.

Table 4. Objectives and actions identified at international level to develop bioeconomy [12] (pp. 287–293), [6,14] (pp. 9–11), [13] (pp. 10–22).

OECD "The Bioeconomy to 2030. Designing a Policy Agenda" [12]	UN Agenda for Sustainable Development 2030 [14]	European Bioeconomy Strategy (2012, 2018) [6,13]
reverse the neglect of primary production and industrial applications;	Goal 2: eradicate hunger, achieve food security and improved nutrition, and promote sustainable agriculture;	*O*1—ensure food and nutrition security;
prepare for a costly but beneficial revolution in healthcare;	Goal 7: ensure universal access to affordable, reliable, sustainable, and modern energy services;	*O*2—manage natural resources sustainably;
manage the globalization of the bioeconomy;	Goal 8: promote sustained, inclusive, and sustainable economic growth, full and productive employment, and decent work for all;	*O*3—reduce dependence on non-renewable, unsustainable resources;
turn the economically disruptive power of biotechnology to advantage;		
prepare for multiple futures;	Goal 12: ensure sustainable consumption and production patterns;	*O*4—limit and adapt to climate change;
maximize the benefits of integration;	Goal 13: take urgent action to combat climate change and its impact;	*O*5—strengthen European competitiveness and create jobs
reduce barriers to biotechnology innovation;	Goal 14: preserve and sustainably use the oceans, seas, and marine resources to ensure sustainable development;	(*A*1)—strengthen and scale up the biobased sectors, unlock investments and markets;
create a dynamic dialogue between governments, citizens, and firms;	Goal 15: protect, restore, and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss.	(*A*2)—deploy local bioeconomies rapidly across the whole of Europe;
prepare the foundation for the long-term development of the bioeconomy.		(*A*3) understand the ecological boundaries of the bioeconomy.

The role of the bioeconomy as a globally significant driver for future development is reinforced and complemented by the plan—"Transforming our world: the 2030 Agenda for Sustainable Development", adopted by the UN in 2015 [14]. The 17 Sustainable Development Goals (further SDGs) include a series of actions aimed not only at eradicating poverty and hunger but also at combating climate change by encouraging responsible and efficient use of resources and other environmentally friendly measures [14]. Seven of the SDGs are more closely linked to bioeconomy development and are summarized in Table 4 [14,25].

In 2012, shortly after the OECD report was published, the EU adopted its first EBS [6] to address ecological, environmental, energy, food supply, and bioresource challenges [15]. As a result, a set of five key objectives for promoting and strengthening the bioeconomy were brought forward (Table 4) [6]. The EBS was designed to complement existing EU policies such as the Common Agricultural Policy and Common Fisheries Policy and invited EU Member States to develop their own national strategies in order to place bioeconomy on their policy agenda [6].

A few years later in 2018, the existing EBS was revised, and the direction of the strategy was adjusted by adding new areas of action [2,6,13]. An updated EBS "A sustainable bioeconomy for Europe. Strengthening the connection between economy, society and the environment: updated bioeconomy strategy", and Action Plan were adopted [13]. The Action Plan identifies three action areas (Table 4), under which a total of 14 sub-activities are identified [2,13]. The EBS Action Plan (2018) is created taking into account and is closely interlinked with the SDGs [2].

The objectives and action lines summarized in Table 4 are listed in the order in which they appear in each document, without attempting to group them thematically or by importance. Table 4 shows the main goals of the documents and, as they do not show conflicting ideas, for further analysis only the objectives and action lines from the EBS and EBS Action Plan will be used in order to reduce the number of keywords to be searched for in the policy planning documents. An additional argument for the keywords being drawn only from the EBS and EBS Action Plan is that the documents adopted by the OECD [12] and the UN [14] have been taken into account in the development of the EBS [6] and later EBS Action Plan [13].

In addition, four keywords were added as the major sources of bioresources: agriculture, forest sector, fisheries, and aquaculture. Hence, it would be possible to determine whether one of these three sectors is being developed more or, on the contrary, neglected.

On average, between 15 and 20 keywords or keyphrases in Latvian were used per policy document, with the potential to indicate the inclusion of the objectives listed in Table 4 or the three bioeconomy-related sectors in policy documents.

3.2. National Policy Framework—The Latvian Bioeconomy Strategy

The LBS was adopted in 2017 [25] in regard to Latvia's highest hierarchical long-term planning document—the Latvian Sustainable Development Strategy 2030 [34]. Latvia's Sustainable Development Strategy 2030 sets a goal "to become the EU leader in the preservation, increase, and sustainable use of natural capital" [25,34], but, to achieve this, the bioeconomy needs to be given a more important role at the national level, and possible directions for development need to be identified. Bioeconomy in Latvia encompasses many economic sectors that can be divided into several groups: primary production of bioresources (agriculture, forest sector, fisheries); processing sectors of bioresources, where operation completely or mainly depend on bioresources; processing sectors of bioresources, where bioresources compete with other raw materials or replace them; service sectors using bioresources [25].

LBS states that Latvia has ample opportunities to successfully develop the bioeconomy and use natural resources sustainably and as efficiently as possible [25]. Through the development of the bioeconomy, land resources could be used in a strategic and sustainable manner and new well-paid jobs could be created [25]. An important future development would be the reduction in waste in manufacturing and processing industries and the substitution of fossil resources for bioresources [25]. Objectives and action directions defined by the LBS are presented in Table 5 [25].

Table 5. Objectives of the Latvian Bioeconomy Strategy 2030 [25] (pp. 5–22).

Latvian Bioeconomy Strategy 2030	
Objectives	**Action Directions**
(1) promotion and preservation of employment in bioeconomy sectors to up to 128 thousand employees	Attractive Entrepreneurial Environment
(2) increasing the added value of bioeconomy products to at least 3.8 billion euros in 2030	Result-oriented Efficient and Sustainable Resource Management
(3) increasing the value of bioeconomy export production to at least 9 billion euros in 2030	Knowledge and Innovations
	Promotion of Manufacturing the Produce in Bioeconomy
	Socially Responsible and Sustainable Development

3.3. Latvian Policy Planning Documents Related to the Bioeconomy

For the analysis of Latvian policy planning documents, 10 long-term and medium-term planning documents (Appendix A) were identified by using SLR in combination with snowballing. Starting with LBS [25], then expanding the selection to the Latvian Sustainable Development Strategy 2030 [34] and documents related to waste management [26], achieving climate neutrality [35], moving towards a circular economy [36], and other thematically related policy planning documents. To determine how the bioeconomy development possibilities are covered and to what extent was prioritized by these documents.

In terms of year of adoption, the earliest document in the set is the Sustainable Development Strategy of Latvia 2030 [34], adopted in 2010, followed by the LBS [25], adopted in 2017 (Appendix A). Other policy planning documents were adopted in 2019 or earlier. Most policy documents in Appendix A set out not only the objectives to be achieved, but also specific action lines and performance indicators. Documents with actions defined in a generic manner, without specific actions, are the Strategy of Latvia for the Achievement of Climate Neutrality by 2050 [35] and the LBS [25]. The Strategy of Latvia for the Achievement of Climate Neutrality by 2050 and LBS are the only policy planning documents in the selection of documents that are "informative reports" and do not have action plans. LBS does not set qualitative or quantitative indicators to measure the achievement of the objectives [25]. An important element in achieving objectives set out in policy planning documents is an interim evaluation to monitor the progress of the implementation. Sustainable Development Strategy of Latvia 2030 [34]; Strategy of Latvia for the Achievement of Climate Neutrality by 2050 [35]; Latvian National Development Plan 2021–2027 [37] and National Energy and Climate Plan for 2021–2030 [38] have incorporated a periodic or mid-term evaluation. Documents that do not include a mid-term assessment are the LBS [25]; Action Plan for the Transition to a Circular Economy 2020–2027 [36], and Environmental Policy Guidelines 2021–2027 [39].

Half of the revised policy planning documents do not have indicative funding for implementation. In addition, the LBS has no indication of the approximate amount or possible sources of funding for the promotion and development of the bioeconomy [25]. Regarding the source of funding, some of the policy planning documents (Appendix A) include a statement that the action lines will be implemented within the existing national budget, putting a particular emphasis on the possibility to attract funding from the EU Structural Funds, as well as other sources of funding, including private finance.

3.4. Implementation of International Objectives in Latvia's Policy Planning Documents

3.4.1. Illustrative Screening Matrix

The results obtained with KAA and SLR on the prioritization of bioeconomy development goals in Latvian policy planning documents were normalized according to Table 1. Acquired ratings were displayed in the illustrative screening matrix (Table 6). The matrix does not analyze the nature of interactions but looks at the priority of objectives (Table 4) in Latvian policy planning documents by counting mentioned keyphrases and keywords in the context of bioeconomy objectives. The assumption is that the more often an objective or action line is mentioned in a policy document, the higher the priority is given to it and the more likely it is to be implemented.

The illustrative screening matrix (Table 6) not only allows one to assess the priorities set in Latvian policy planning documents in relation to internationally defined objectives and action lines but also allows one to estimate the internal and external coherence between different policy domains (Figure 2) [8]. Additionally, vertical interactions can be observed—whether international-level documents are implemented on a national level, and on lower-level planning documents related to the bioeconomy sector [8]. Horizontal interactions show whether there is synergy between the objectives set out on international and local level policy planning documents across external and internal dimensions [8].

Table 6. Illustrative screening matrix.

Long-Term and Medium-Term Planning Documents	**Bioeconomy-Related Objectives and Action Lines Stated in European Bioeconomy Strategy (2012, 2018) (Table 4)**									**Rating Per Document**	**Agriculture**	**Forest Sector**	**Fisheries, Aquaculture**	**Sum for Sectors**
	O1	***O2***	***O3***	***O4***	***O5***	**Sum *O***	***(A1)***	***(A2)***	***(A3)***	**Sum *A***				
Sustainable Development Strategy of Latvia until 2030 [34]	4	5	2	5	5	21	4	3	5	12	5	2	3	10
Strategy of Latvia for the Achievement of Climate Neutrality by 2050 [35]	4	5	5	5	5	24	5	4	4	13	5	4	2	11
Latvian National Development Plan 2021–2027 [37]	3	5	2	5	5	20	5	5	4	14	2	2	2	6
Latvian National Energy and Climate Plan for 2021–2030 [38]	2	3	3	5	4	17	4	3	1	8	4	4	2	10
Latvian Bioeconomy Strategy 2030 [25]	5	5	5	4	5	24	5	5	3	13	5	5	5	15
Latvia's Adaptation to Climate Change Plan for the Period Until 2030 [40]	2	3	2	5	3	15	2	1	3	6	5	4	4	13
National Waste Management Plan for 2021–2028 [26]	2	5	3	4	1	15	4	1	1	6	2	2	1	5
National Industrial Policy Guidelines for 2021–2027 [41]	3	3	1	5	5	17	5	5	4	14	4	3	1	8
Action Plan for the Transition to a Circular Economy 2020–2027 [36]	3	5	1	1	3	13	5	3	3	11	3	1	1	5
Environmental Policy Guidelines 2021–2027 [39]	1	5	1	5	1	13	2	4	5	11	5	3	2	10
Rating per objectives and action lines	29	44	25	44	37		41	34	33		40	30	23	

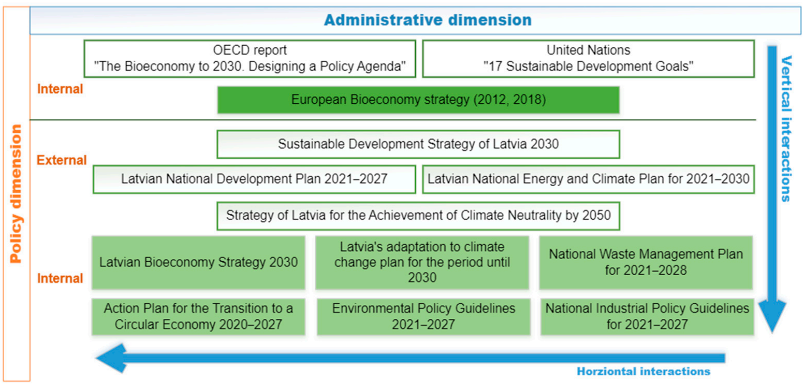

Figure 2. Coherence amongst bioeconomy-related international and national policy planning documents (adapted from [8]).

The illustrative screening matrix indicates that Latvia's long-term and medium-term policy planning documents, in general, prioritize the same objectives and action lines that have been set at the international level by the EU, UN, and OECD. Highest-level policy planning documents such as the Sustainable Development Strategy of Latvia until 2030 [34], Strategy of Latvia for the Achievement of Climate Neutrality by 2050 [35], Latvian National Development Plan [37], Latvian National Energy and Climate Plan for 2021–2030 [38], and the LBS [25] give high priority to the international bioeconomy objectives. However, it was already expected for the LBS to score the highest out of the set of documents considered because the LBS itself mentions that it has been designed taking into account the objectives set by the EBS [25]. A lower level of prioritization can be observed in policy documents that define strategic development in more specific areas such as waste management [26], circular economy [36], and adaptation to climate change [40], because of having more specific deliverables but on average showing high results in the overall policy framework for bioeconomy development.

The results obtained by adding up the objectives (*O*1–*O*5), action lines (*A*1,*A*2), and bioeconomy sectors (agriculture, forest sector, fisheries, and aquaculture) were assessed separately in the illustrative screening matrix (see Table 6). This allowed us to assess the inclusion of the internationally agreed objectives in Latvia's policy planning documents, as well as to identify whether the EBS Action Plan adopted in 2018 is taken into account. The priority given to bioeconomy sectors in each of the documents was also assessed, thus showing which of them is being prioritized.

The evaluation of the policy planning documents (Table 6) by adding up the objectives (*O*1–*O*5) showed that the LBS [25] and the Strategy of Latvia for the Achievement of Climate Neutrality by 2050 [35] have the highest ranking with 24 points. The following documents are next in order of points—the Sustainable Development Strategy of Latvia until 2030 [34] with 21 points, the Latvian National Development Plan 2021–2027 [37] with 20 points, and close behind with 17 points the Latvian National Energy and Climate Plan for 2021–2030 [38], and the National Industrial Policy Guidelines for 2021–2027 [41]. Latvia's Adaptation to Climate Change Plan for the Period Until 2030 [40] and the National Waste Management Plan for 2021–2028 [26] obtained 15 points each. The lowest scores are shown by the Action Plan for the Transition to a Circular Economy 2020–2027 [36] (13 points) and the Environmental Policy Guidelines 2021–2027 [39] (13 points).

The analysis of the inclusion of action lines from the EBS Action Plan (*A*1–*A*3) in policy documents showed that none of the documents scored the highest possible score of 15, but both the Latvian National Development Plan 2021–2027 [37] and the National Industrial Policy Guidelines for 2021–2027 [41] scored close with 14 points each. Two policy documents scored highly, with 13 points the Strategy of Latvia for the Achievement of Climate Neutrality by 2050 [35] and the LBS [25]. The Sustainable Development Strategy of Latvia until 2030 [34] obtained 12 points, and both the Action Plan for the Transition to a Circular Economy 2020–2027 [36] and the Environmental Policy Guidelines 2021–2027 [39] scored 11 points. Policy documents with the lowest scores were the Latvian National Energy and Climate Plan for 2021–2030 [38] (8 points), Latvia's Adaptation to Climate Change Plan for the Period Until 2030 [40] (6 points), and the National Waste Management Plan for 2021–2028 [26] (6 points).

The score per sector (agriculture, forest sector, fisheries, and aquaculture) in policy planning documents shows a bit of a different breakdown. The LBS [25] obtained the maximum score of 15 points. The next highest score is reached by Latvia's Adaptation to Climate Change Plan for the Period Until 2030 [40] (13 points), and the Strategy of Latvia for the Achievement of Climate Neutrality by 2050 [35] (11 points). The Sustainable Development Strategy of Latvia [34], the Latvian National Energy and Climate Plan for 2021–2030 [38], and the Environmental Policy Guidelines 2021–2027 [39] have the same score of 10 points. Other policy planning documents have scored less—the National Industrial Policy Guidelines for 2021–2027 [41] (8 points), the Latvian National Development Plan 2021–2027 [37] (6 points), the National Waste Management Plan for 2021–2028 [26], and the Action Plan for the Transition to a Circular Economy 2020–2027 [36] (5 points).

Despite the fact that the EBS was taken into account in the development of the LBS [25], it has not received the highest possible scores, although it shows the greatest consistency with the internationally defined objectives (*O*1–*O*5) and action lines (*A*1–*A*3). It should be noted that the LBS scored highest in the bioeconomy sectoral assessment, giving equal priority to all three sectors. Comparatively higher scores in the objective assessment were achieved by higher level policy planning documents as well as the National Industrial Policy Guidelines for 2021–2027 [41], which can be considered a positive trend as it shows that internationally defined bioeconomy development objectives are being taken into account. The presence of the National Industrial Policy Guidelines among the highest scoring documents should be seen as a logical outcome, as a knowledge-based innovative bioeconomy is one of the five knowledge areas (RIS3) identified for Latvia and discussed in more detail in the document [41].

The assessment of the implementation of the actions (*A*1–*A*3) of the EBS Action Plan in policy planning documents has shown similar results, with the National Industrial Policy Guidelines [41] scoring second highest. The Latvian National Energy and Climate Plan for 2021–2030 [38] scored relatively low compared to other hierarchically higher documents, possibly due to its thematic focus on energy and energy efficiency issues, with less attention to ecological boundaries. The bioeconomy sectors (agriculture, forest sector, fisheries, and aquaculture) have received varying attention in the policy planning documents reviewed. As already mentioned, the LBS has given equal priority to all sectors. No clear correlation can be discerned between the prioritization of bioresource extraction sectors in higher and lower-level policy planning documents.

Looking at the priority areas assigned to the objectives related to the development of the bioeconomy in the policy planning documents (Table 6—*O*1–*O*5, (*A*1)–(*A*3) vertically) the results indicate that in Latvian policy documents, priority is given to *O*2—"manage natural resources sustainably" (44 points) and *O*4—"limit and adapt to climate change" (44 points). Slightly lower scores are received by (*A*1)—"strengthen and scale up the biobased sectors, unlock investments and markets" (41 points) and *O*5—"strengthen European competitiveness and create jobs" (37 points); (*A*2)—"deploy local bioeconomies rapidly across the whole of Europe" (34 points) and (*A*3)—"understand the ecological boundaries of the bioeconomy" (33 points). The lowest priority was given to objectives *O*1—"ensure food and nutrition security" (29 points) and *O*3—"reduce dependence on non-renewable, unsustainable resources" (25 points).

The priority given to the agriculture, forest sector, fisheries, and aquaculture sectors in Latvia's policy planning documents altogether was assessed to determine whether any bioresource sector is prioritized over others. The assessment shows that the highest priority in the context of the bioeconomy is given to developing the agricultural sector (40 points); the forest sector scores lower with 30 points and the least priority is given to developing fisheries and aquaculture with 23 points.

3.4.2. TOPSIS Results

The TOPSIS criteria were weighted according to expert evaluation [33] (Table 3). The experts determined which of the criteria (Table 2) could play a crucial role in the development of the bioeconomy in Latvia. Thus, the TOPSIS analysis results would reveal which of Latvia's policy planning documents puts the most emphasis on a particular objective.

Therefore, the prioritized bioeconomy development objectives in the policy planning document combined with expert evaluation (Table 3), identifying which of these objectives are most important, were the ideal positive solution. In the evaluation of the Latvian policy planning documents using the TOPSIS method, with criteria weights (Table 3), the LBS [25] (0.98), and the Strategy of Latvia for the Achievement of Climate Neutrality by 2050 [35] (0.98) have the highest score and are the closest to the ideal positive solution for bioeconomy development in Latvia (Figure 3). The Sustainable Development Strategy of Latvia 2030 [34] with 0.58 points and the Latvian National Development Plan 2021–2027 [37] with 0.57 points scored significantly lower; the next closest to the ideal solution was the Latvian National Energy and Climate Plan for 2021–2030 [38] with 0.46 points. The next highest scorers are policy planning documents aimed at developing a specific policy area or sector—the National Waste Management Plan for 2021–2028 [26] (0.38 points); the National Industrial Policy Guidelines for 2021–2027 [41] (0.37 points); and the Environmental Policy Guidelines 2021–2027 [39] (0.23 points). Latvia's Adaptation to Climate Change Plan for The Period Until 2030 [40] and the Action Plan for the Transition to a Circular Economy 2020–2027 [36] received only 0.22 points.

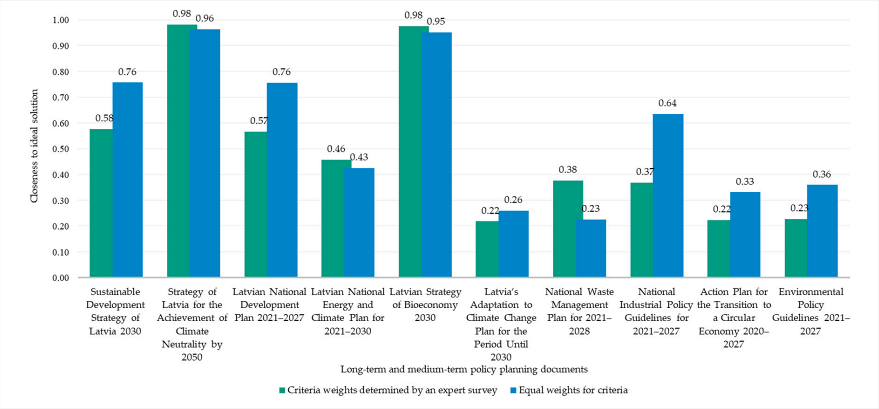

Figure 3. TOPSIS results on prioritized objectives and action lines in the Latvian policy planning documents.

TOPSIS results with applied equal criteria weights show similar results as when applying the criteria weights determined by experts. The policy planning documents closest to the ideal positive solution are the Strategy of Latvia for the Achievement of Climate Neutrality by 2050 [35] (0.96) and the LBS [25] (0.95) (Figure 3). The Sustainable Development Strategy of Latvia 2030 [34] with 0.76 points and the Latvian National Development Plan 2021–2027 [37] with 0.76 points scored significantly higher than in the evaluation with criteria weights set by experts, however, these two documents maintain the third and fourth highest ranking. The National Industrial Policy Guidelines for 2021–2027 [41] showed a better result with equal criteria weights by scoring 26 points higher than in the evaluation with criteria weights determined by expert evaluation (0.64 points). The Latvian National Energy and Climate Plan for 2021–2030 [38] with 0.43 points has almost a similar score as in the previous assessment with weights assigned by experts. Farther from the positive ideal solution are the Environmental Policy Guidelines 2021–2027 [39] (0.36 points), the Action Plan for the Transition to a Circular Economy 2020–2027 [36] with 0.33 points, Latvia's Adaptation to Climate Change Plan for the Period Until 2030 [40] with 0.26 points, and National Waste Management Plan for 2021–2028 [26] with 0.23 points.

The TOPSIS analysis on agriculture, forest sector, and fisheries and aquaculture in Latvian policy planning documents (Figure 4), with equal criteria weights, has shown the following results. One document is the ideal positive solution with 1.00 point—the LBS [25]. Latvia's Adaptation to Climate Change Plan for the Period Until 2030 [40] is the second closest with 0.92 points. Other policy planning documents scored lower in the TOPSIS assessment. The third document that is the closest to the ideal positive solution is the Strategy of Latvia for the Achievement of Climate Neutrality by 2050 [35] (0.52). The fourth is the Latvian National Energy and Climate Plan for 2021–2030 [38] (0.46), and the fifth is the Sustainable Development Strategy of Latvia 2030 [34] (0.45). The Environmental Policy Guidelines 2021–2027 ranked close to this score [39] (0.38). The National Industrial Policy Guidelines for 2021–2027 [41] obtained 0.18 points, the Latvian National Development Plan 2021–2027 [37] 0.08 points, and the National Waste Management Plan for 2021–2028 [26] with 0.03, and the Action Plan for the Transition to a Circular Economy 2020–2027 [36] with 0.01 are the furthest away from the ideal positive solution.

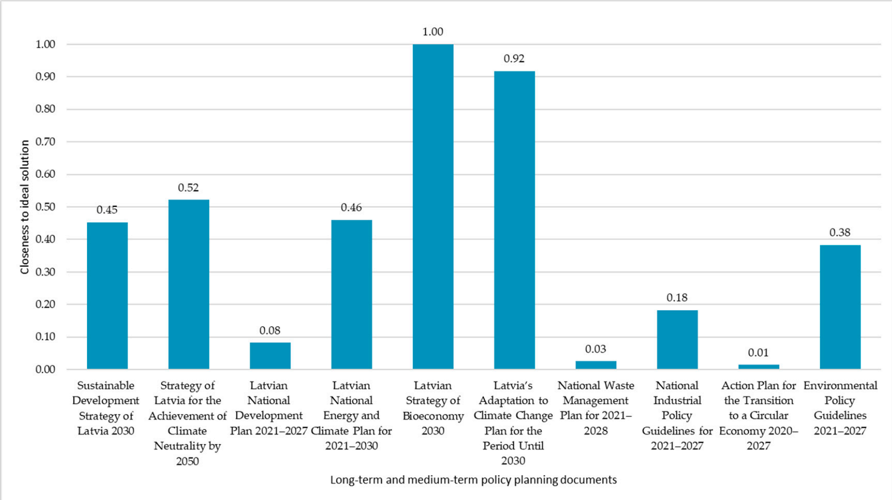

Figure 4. TOPSIS results on agriculture, forest sector, fisheries, and aquaculture.

4. Discussion

The results of the analysis of Latvia's long-term and medium-term policy planning documents by constructing an illustrative screening matrix and a subsequent analysis with TOPSIS indicate a positive trend in the implementation and prioritization of the internationally agreed objectives in Latvia's policy planning. Each of the 10 documents selected for the study could be linked to the international objectives. Notably, the policy planning documents that are higher up the policy planning hierarchy, such as the Sustainable Development Strategy of Latvia until 2030 [34], the Strategy of Latvia for the Achievement of Climate Neutrality by 2050 [35], and the Latvian National Development Plan 2021–2027 [37] performed considerably better than specifically targeted lower-level sectoral plans, as for example the Environmental Policy Guidelines 2021–2027 [39].

Looking at the priority given to each objective and action line in the Latvian policy planning documents, a less thematic elaboration on the objective of *O*1—"ensure food and nutrition security" [6] and *O*3—"reduce dependence on non-renewable, unsustainable resources" can be observed [6]. Food and nutrition safety and food quality are not seen as an issue in Latvia's policy planning, because of a well-developed agricultural sector that is fully capable of meeting current food demand and high EU quality standards [42]. Consequently, it is not considered to be a topical issue that calls for strategic planning at the national level. References to objective *O*1 are found in all the policy planning documents analyzed (Table 6), apart from the Environmental Policy Guidelines 2021–2027 [31].

Despite the negative environmental impact of fossil fuels identified in policy planning documents [26,34,35], there are no concrete actions outlined to phase out fossil fuels. The low priority given to the need to reduce dependence on non-renewable and unsustainable resources (*O*3) could be an indication of the resistance of policymakers to fossil fuel divestment, given the existing infrastructure of fossil energy sources and the year's long low prices of natural gas and oil. This scenario changed rapidly this year.

The development of agriculture and forest sectors was mentioned relatively frequently, whereas the development of fisheries, except for the LBS, received very little attention. Latvia is a water-rich country with a long maritime border, which makes it unclear why fisheries and aquaculture development is given such a low priority in planning documents. The authors suggest that this may be because Latvia's fisheries and aquaculture sectors have historically been based on fishing in the sea [43,44], but the collapse of the Soviet Union and in later years the introduction of EU fishing quotas due to the depletion of significant fish species has led to a stagnation in the development of the fisheries sector [45,46]. However, innovative technologies and a shift towards growing fish and other marine organisms in aquacultures could change the situation [47,48]. The efficient management and use of inland waters and fish, shellfish, and algae these waters contain could be used to produce innovative products [47,48].

Assessment of the Latvian policy planning documents from a technical perspective showed that most of them set specific actions to be taken, and indicators and interim evaluations to track progress (Appendix A). Nevertheless, a critical element for all the policy planning documents is the unclear financing mechanism. The documents mostly indicate that financial resources should be allocated within the existing national budget on an annual basis or applied for from EU Structural Funds or private funding to implement the measures. This raises concerns about the extent to which the objectives and action lines for bioeconomy development could be implemented.

5. Conclusions

The methodology developed in this study allows relatively quick and easy identification of any pre-defined objectives and actions set out in policy documents. It also allows for assessing the level of priority given to such objectives and actions. However, rather than stand-alone research, this methodology can be recommended as a first step in a more in-depth examination of policy planning documents to determine the level of bioeconomy development priorities in them. It can be applied as a valuable help to facilitate the evaluation of a larger set of documents. The main drawback of this methodology is its inability to provide an assessment of direct contradictions that may exist between the elaboration of the objectives and/or the document itself. For a more detailed in-depth study, the documents with the highest or lowest scores determined using this methodology should be selected, depending on the expected outcome.

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Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Table A1. Latvian policy planning documents linked to bioeconomy.

National Policy Planning Documents Related to Bioeconomy	Information about the Document					
	Year	Action Lines to Achieve Objectives	Performance Indicators	Interim Evaluation	Funding Needed	Source of Financial Resources
Sustainable Development Strategy of Latvia 2030 [34]	2010	Specific	Qualitative and quantitative	Yes (every 2 years)	No information	Under available national budget, EU funds, private

Table A1. *Cont.*

National Policy Planning Documents Related to Bioeconomy	Information about the Document					
	Year	Action Lines to Achieve Objectives	Performance Indicators	Interim Evaluation	Funding Needed	Source of Financial Resources
Strategy of Latvia for the Achievement of Climate Neutrality by 2050 [35]	2019	Generic	Qualitative and quantitative	Yes (every 10 years)	Yes	Under available national budget, EU funds, private
Latvian National Development Plan 2021–2027 [37]	2020	Specific	Qualitative and quantitative	Yes (every 2 years)	Yes	Under available national budget, EU funds, private
Latvian National Energy and Climate Plan for 2021–2030 [38]	2020	Specific	Qualitative and quantitative	Yes	Yes	Under available national budget, EU funds, private
Latvian Bioeconomy Strategy 2030 [25]	2017	Generic	Generic	No	No information	Not specified
Latvia's Adaptation to Climate Change Plan for the Period Until 2030 [40]	2019	Specific	Qualitative and quantitative	Yes (mid-term)	Not specified	Under available national budget, EU funds, private
National Waste Management Plan for 2021–2028 [26]	2021	Specific	Qualitative and quantitative	Yes (mid-term)	Yes	Under available national budget, EU funds, private
National Industrial Policy Guidelines for 2021–2027 [41]	2021	Specific	Qualitative and quantitative	Yes (mid-term)	Yes	Under available national budget, EU funds, private
Action Plan for the Transition to a Circular Economy 2020–2027 [36]	2020	Specific	Qualitative and quantitative	No	Not specified	Under available national budget, EU funds, private
Environmental Policy Guidelines 2021–2027 [39]	2021	Specific	Qualitative and quantitative	No	Not specified	Under available national budget, EU funds, private

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A Comparative Analysis of Bioeconomy Development in European Union Countries

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Abstract
Knowledge-based and innovative bioeconomy is a cornerstone for achieving the goals of the European Green Deal. Due to its comprehensive coverage, bioeconomy performance is challenging to assess unambiguously. This paper presents the results of a cross-country comparison of 22 EU countries applying the Complex Bioeconomy Sustainability Index for 2012–2018. Results were compared with results of the TOPSIS multi-criteria decision-making method on national bioeconomy strategies in Finland, France, Spain, Italy, Ireland, and Latvia. The research aims to combine a quantitative assessment of bioeconomy output indicators with a qualitative evaluation of bioeconomy strategies of EU Member States.

Keywords Bioeconomy · Indicators · Multi-criteria · European Green Deal · Circular economy

Introduction

A decade ago, in 2012, the European Commission adopted the first-ever European Bioeconomy Strategy and Action Plan (European Commission 2012) in response to pressing social and environmental challenges, aiming to promote the transition from a fossil-based to a bio-based society and the recovery from the 2008 economic crisis. The currently valid version of the Strategy (European Commission 2018a) and the Action plan (European Commission 2018b) was renewed in 2018. It remained the five headline targets from the initial 2012 version (food security, sustainable natural resource management, increasing bioresources, climate change mitigation and adaptation, and job creation) and expanded focus on three action areas, namely (i) scale-up of bio-based sectors and markets, (ii) deployment of bioeconomies across Europe, and (iii) dealing with the ecological boundaries of the bioeconomy. A new progress report published by the European Commission this year (Directorate-General for Research and Innovation 2022) affirms the need to continue and further strengthen these activities and emphasizes the vital role of the EU Bioeconomy Strategy in achieving the goals of the European Green Deal (European Commission 2019).

The EU Bioeconomy Monitoring System developed by the European Commission's Joint Research Center has been operating since 2020 (European Commission 2022). The monitoring system aims to provide a coherent approach for tracking bioeconomy progress across the EU, reflecting the five objectives of the EU Bioeconomy Strategy and covering all three sustainability dimensions (economic, environmental, and social progress) (Robert et al. 2020). It is expected that the monitoring system will serve as a reasonable way to manage the progress of the bioeconomy sectors based on measurable, comparable indicators and

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help solve the current uncertainties concerning bioeconomy progress evaluation that many authors point to in the academic environment. E.g., recently, Ferreira et al. summarized that there is a lack of a unified approach to the methodology and variables used, which hinders the long-term evaluation and implementation of the bioeconomy (Ferreira et al. 2022). The authors highlight the need for more research on methods and indicators to measure the bioeconomy, considering the diversity of bioeconomy policies and strategies worldwide (Ferreira et al. 2022). Also, O'Brien et al. point out the fragmented research on the bioeconomy and the need for a dashboard of indicators and targets to monitor the progress of bioeconomy development in the EU (O'Brien et al. 2017). Other authors have made similar statements highlighting the lack of systematical analysis (Wei et al. 2022) and missing monitoring, modeling, and evaluation of the sectoral bioeconomy development trajectories (D'Adamo et al. 2020).

This paper aims to fill the gap in the missing field of research on bioeconomy advancement assessment based on a coherent and comparative approach. To the best of our knowledge, this is one of the few studies that offer an indicator-based evaluation and comparison of bioeconomy progress between almost all EU countries. As the literature review shows, previous studies have focused on assessing individual indicators or their groups (i.e., based on the sustainability dimension), bioeconomy policy, or case studies of specific countries. For example, Jander & Grundmann created the Substitution Share Indicator to evaluate transitions from fossil-based to bio-based economies with applications in Germany's transport and plastics sectors (Jander and Grundmann 2019). Blumberga et al. present indicators for assessing the forest bioeconomy sector in Latvia (Blumberga et al. 2017). Wozniak et al. review bioeconomy development indicators on an aggregated EU level compared to Poland (Woźniak et al. 2022). D'Adamo et al. propose a new socio-economic indicator for measuring the performance of bioeconomy sectors (D'Adamo et al. 2020). Ronzon et al. assess the output of the EU bioeconomy in terms of ecosystem services contribution to three key indicators (value added at the industry level, employment, and labor productivity) in the EU Member States over 2008–2017 (Ronzona et al. 2022). Fava et al. assess the driving factors behind the Italian bioeconomy development (Fava et al. 2021).

Although composite indices are widely used in economics and environmental sciences (e.g., Madurai Elavarasan et al. 2022; Edmonds et al. 2020; Dolge et al. 2020; Hryhoruk et al. 2019), their application in the field of bioeconomy is underdeveloped. Kardung and Drabik (Kardung and Drabik 2021) are among the few authors who have compared the progress of EU countries measured by a set of 41 indicators. In their study, the authors empirically investigated the development trajectories of bioeconomy in 10 selected European Union countries from 2006 to 2016. Based on this assessment, the authors highlight Germany as a leader in the circular bioeconomy and also note the progress of Slovakia, Poland, and Latvia. Referring to Ferreira et al (Ferreira et al. 2022), several articles have attempted to analyze some of the published national bioeconomy strategies comparing general aspects, implementation, and other variables. However, a proper framework for measuring the status of bioeconomy progress is missing (Jander and Grundmann 2019).

This article assesses the progress of the bioeconomy in 22 EU member states using a Bioeconomy Sustainability Index. The index measures 13 indicators and their progress among EU countries from 2012–2018. This research is a continuation of the author's first attempt to construct a composite index for the bioeconomy presented in the study by Zihare et al. as part of the project Bioresource Value Model (Zihare et al. 2021). Zihare et al. proposed an indicator-based approach to measure the sustainable development of the bioeconomy considering the aspects of policy, research and innovations, and technology. However, the authors concluded that the proposed Bioeconomy Sustainability Index does not accurately reflect current bioeconomy development trends because the index used outdated data from 2012 to 2015. Furthermore, the authors argued that the index should be supplemented with new indicators (potentially grouped into representative dimensions) and that expert weighting could be applied instead of assigning equal weights, as each indicator could have different impacts on sustainability levels.

This study extends the previously developed Bioeconomy Sustainability Index by addressing all significant limitations identified in the initial research presented by Zihare et al. The novelty of the present study lies within the three most important aspects of the improved Bioeconomy Sustainability Index. First, additional explanatory indicators were added using the latest 2018 data. Second, the indicators were grouped into four dimensions representing sustainable bioeconomy development aspects, and expert weighting was applied to account for the different impacts. And third, the updated composite index is constructed for a 7-year period to assess member states' progress from 2012 to 2018. In addition, the composite index assessment approach is supplemented with an analysis of national member state bioeconomy strategies to look for trends conducive to the bioeconomy, which was not done in the first study.

Further, the paper is structured in the following way. We first describe the methodology, analyze and discuss the results, and finalize with conclusions and policy implications. The description of the methods and results has been divided into two steps to facilitate reading, first describing the Composite Bioeconomy Sustainability Index approach and then continuing with the analysis of national bioeconomy strategies.

Methodology

The research approach in this study is based on two complementary steps. First, we performed a cross-country comparison and analysis among all EU countries applying the Composite Bioeconomy Sustainability Index. Afterward, we studied the bioeconomy strategies of selected countries using the systematic literature review and the TOPSIS multi-criteria decision-making method to collect in-depth insight into synergies with the EU 2018 Bioeconomy Strategy and Action Plan (European Commission, 2018a, 2018b). Finally, we compared the outcomes of both research steps to identify common features promoting the progress of bioeconomy development.

Composite Bioeconomy Sustainability Index evaluation method

Background on composite index theory

The composite index method is used by academics, international organizations, research associations, and institutions worldwide (Dolge et al. 2020). The use of the composite index method has increased significantly over the past decade due to its many advantages. First, composite indicators create a comprehensive framework that can track progress toward specific policies or long-term national and global strategic goals such as economic growth, sustainable development, climate change mitigation, and many others. Second, the method allows multiple dimensions and indicators to be combined into a single measure that comprehensively assesses complex problems. Third, the results of the composite index are easy to interpret and provide valuable insights into the problem under study that policymakers could use to facilitate decision-making and evaluate alternatives accordingly (European Commission et al.).

Composite indices can measure sustainability or performance efficiency in various fields and research areas. Many composite indices can be found in the literature that have been created to assess sustainability in energy systems (Madurai Elavarasan et al. 2022), climate change (Edmonds et al. 2020), energy efficiency (Dolge et al. 2020), and economic development (Hryhoruk et al. 2019).

Development of the Bioeconomy Sustainability Index

This study constructed a Composite Bioeconomy Sustainability Index to monitor performance and evaluate and compare the bioeconomy development trends among EU member states. The index compares the performance of EU member states and ranks countries in terms of their current level of bioeconomy advancement (Dolge et al. 2020). The proposed Composite Bioeconomy Sustainability Index combines 13 indicators grouped into four main dimensions, namely, (i) socio-economic impact, (ii) resource sustainability, (iii) innovation and technology, and (iv) financing and government support, as similarly seen in other studies (Martinez-Hernandez et al. 2022). Such grouping allows for including the most critical multi-dimensional aspects crucial to achieving the intended goal (Madurai Elavarasan et al. 2022). In this way, we limit the possibility of neglecting important indicators and producing an isolated view of the problem. The first two dimensions of the index include indicators characterizing the sustainability of the bioeconomy in terms of economic and social impact (represented by the socioeconomic impact dimension) and environmental impact (represented by the resource sustainability dimension) (Dolge et al. 2020). The innovation and technology dimension measures the development progress of the bioeconomy, and the financing and governmental support dimension measures the political support.

The creation of the Bioeconomy Sustainability Index is based on successive steps, as shown in Fig. 1.

First, a set of indicators representing bioeconomy development were selected based on a literature review and data availability. The selected indicators were grouped into the four main dimensions as described above. Data on the chosen indicators were collected from 22 EU countries using publicly available sources, including Eurostat, OECD, and Data M databases. We excluded the remaining EU member states (Bulgaria, Croatia, Cyprus, Malta, and Romania) from further study due to the non-availability of data. Table 1 summarizes the selected indicators, the belonging dimension, and the data sources used.

Figure 2 illustrates the hierarchy of the proposed composite index.

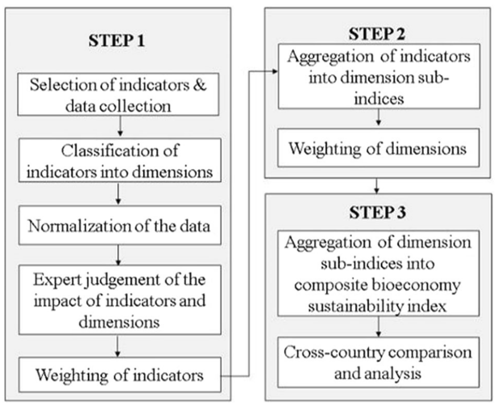


Fig. 1 Research steps to construct the Bioeconomy Sustainability Index

Table 1 Classification and description of selected indicators and data sources used

Dimension	Indicator	Indicator notation	Indicator description	Data source
Socio-economic impact	Bioeconomy resource productivity, value-added /turnover	S1	The share of generated value-added from bioeconomy sectors in total bioeconomy turnover	Data M
	Apparent labor productivity, 1000 EUR per person	S2	The amount of generated value-added at factor cost per people employed in the bioeconomy	Data M
	Location Quotient, ratio	S3	Share of employment in the bioeconomy of a member state divided by the share of employment in the bioeconomy of the EU as a whole.	Data M
Resources sustainability	Biomass contribution, biomass % of DMC	R1	The share of biomass in total domestic material consumption (DMC).	OECD
	Recycling of biowaste, kg per capita	R2	Recycled biowaste in kilograms per number of inhabitants	Eurostat
	Recycling rate of wooden packaging, recycled % of total	R3	Share of recycled wooden packaging from total wooden packaging	Eurostat
Innovation and technology	Development of environment-related technologies, % all technologies	I1	Share of environment-related technology development from total developed technologies	OECD
	Relative advantage in environment-related technology, ratio	I2	Measures the level of specialization in R&D in environment-related technology compared to the global value.	OECD
	Development of environment-related technologies, inventions per capita	I3	The amount of environment-related technology inventions per number of inhabitants	OECD
	Biotechnology patent applications per total government allocations to R&D	I4	The amount of biotechnology patent applications to EPO per total government allocations to R&D	Eurostat OECD
Financing and governmental support	Environmentally related government R&D budget, % total government R&D	E1	Share of environmentally related government R&D budget from total government R&D budget	OECD
	Government budget allocations for environmental R&D per capita, EUR per inhabitant	E2	Share of environmentally related government R&D budget allocations per number of inhabitants	Eurostat
	Total government budget allocations for R&D, % of GDP	E3	The amount of government budget allocations for R&D from the total GDP of a member state	Eurostat

After data collection, indicators were normalized using the min-max normalization technique. Min-max normalization is one of the most commonly used techniques in calculating composite indices because it can scale data values from 0 to 1, allowing a more straightforward interpretation of the results. Since all the selected indicators positively impact the long-term sustainability of the bioeconomy, data were normalized using Eq. (1).

$$I_{Ni} = \frac{I_{act} - I_{min}}{I_{max} - I_{min}} \qquad (1)$$

where

I_{Ni} – Normalized indicator;

I_{act} – Actual value of an indicator;

I_{max} – Maximum value of an indicator;

I_{min}– Minimum value of an indicator.

After the normalization of the data, we performed the weighting of the indicators. There are several techniques for weighting the indicators, such as, for example, equal weighting, AHP weighting, and expert judgment weighting. There is no consensus among researchers and users of composite indexes on choosing the best and most appropriate weighting technique. Some argue that the advantage of equal weighting is that all factors affecting sustainability are equally important. However, others emphasize that expert weighting may be more appropriate for more complicated composite sustainability indexes but could lead to results that are sensitive to subjectivity (Dolge et al. 2020). In this study, we use the expert weighting technique. The indicator weights were collected from the responses of an expert group composed of six representatives working in the field of bioeconomy. The experts were selected based on criteria of their professional experience, including participation in the policy-planning process, implementation of scientific research projects in the fields of bioeconomy, and the number of scientific publications in the last five years. All experts are from Latvia. They were asked to rate the impact of the selected indicators and dimensions on bioeconomy sustainability. The survey was conducted online in two weeks in the spring of 2022. Table 2 summarizes the average values of each dimension and indicator weights according to expert evaluation.

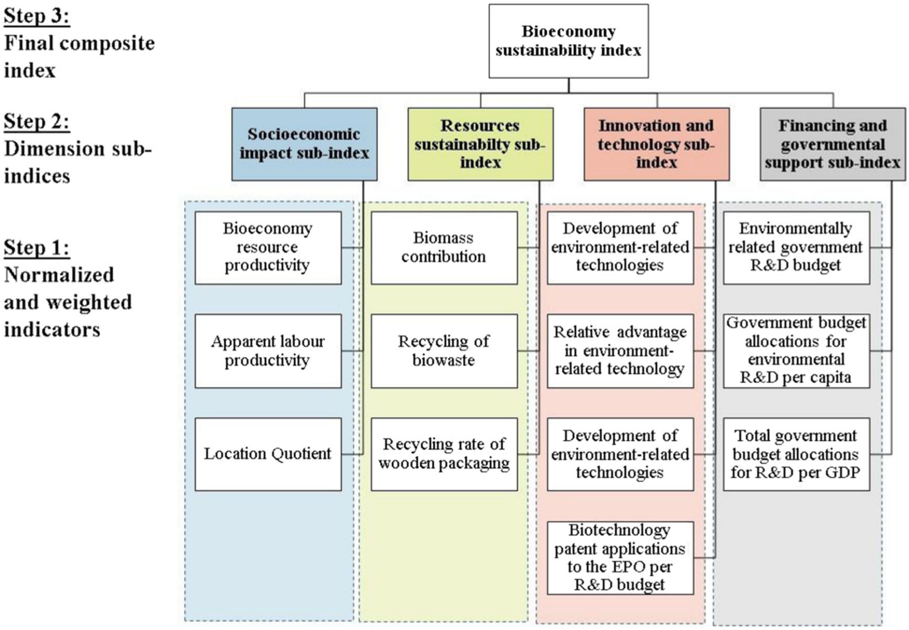


Fig. 2 The hierarchy of the Composite Bioeconomy Sustainability Index

Table 2 Determined indicator and dimension weights (results of the expert survey)

Dimension	Dimension weight	Indicator	Indicator weight
Socioeconomic impact	0.267	S1	0.456
		S2	0.322
		S3	0.222
Resources sustainability	0.225	R1	0.381
		R2	0.356
		R3	0.264
Innovation and technology	0.250	I1	0.242
		I2	0.275
		I3	0.250
		I4	0.233
Financing and governmental support	0.258	E1	0.381
		E2	0.281
		E3	0.339

These weights were further used to obtain sub-index values for the representative sustainability dimensions using Eq. (2) and the Bioeconomy Sustainability Index Eq. (3).

$$I_{Di} = \sum w_i \times I_{Ni}, \quad (2)$$

$$BSI = \sum w_d \times I_{Di}, \quad (3)$$

where

I_{Di} – sub-index of a particular bioeconomy dimension;

w_i– the weight of an indicator;

w_d– the weight of a dimension;

BSI – Bioeconomy Sustainability Index.

The expert survey results do not show much dispersion in the dimension weights. The impact of all dimensions on the sustainability of the bioeconomy was estimated

Table 3 National bioeconomy strategies included in the study

Country	Year	National Bioeconomy strategy
Austria	2019	Austria Bioeconomy A Strategy for Austria (Federal Ministry for Sustainability and Tourism et al. 2019)
Finland	2014 2020	Finland The Finnish Bioeconomy Strategy (Ministry of Economic Affairs and Employment of Finland, Sustainable growth from bioeconomy et al. 2014)
France	2015	A Bioeconomy Strategy for France. Goals, issues and forward vision (Republic French 2015)
	2017	A Bioeconomy Strategy for France (French Government 2017)
Germany	2020	National Bioeconomy Strategy (The Federal Government 2020)
Ireland	2018	Ireland National Policy Statement on the Bioeconomy (Government of Ireland 2018)
Italy	2019	Bioeconomy in Italy (BIT II)
	2017	Bioeconomy in Italy (BIT) (Italian Government 2017)
Latvia	2018	Latvian Bioeconomy Strategy 2030 (Ministry of Agriculture 2018)
Netherland	2018	The position of the bioeconomy in the Netherlands (Ministry of Economic Affairs and Climate Policy et al. 2018)
Spain	2016	The Spanish Bioeconomy Strategy - 2030 Horizon (Ministry of Economy and Competitiveness et al. 2016)

to be almost equally distributed, with the most noticeable differences in weighting between the socioeconomic and resource sustainability dimensions. The socioeconomic dimension of the Bioeconomy Sustainability Index received the highest weighting (0.267), followed by the financing and government support dimension weight of 0.258, the innovation and technology dimension weight of 0.250, and the resource sustainability dimension weight of 0.225.

The results of the final Composite Bioeconomy Sustainability Index values score in the range of 0 to 1. The closer to 1, the higher the advancement level of a country, while a score close to 0 indicates weak performance.

Method for Evaluating National Bioeconomy Strategies

In the second step of the study, we assessed the bioeconomy strategies of EU member states. National bioeconomy strategies were evaluated against the five objectives of the EU 2018 Bioeconomy Strategy (European Commission 2018a) and its supplementary Action Plan (European Commission 2018b). The study aimed to identify goals and action lines within the national bioeconomy strategies that could be the most important in achieving the bioeconomy objectives, as the EU Bioeconomy Strategy itself does not make a prioritization. The limiting factor for the strategy to be included in the analysis was its public availability in English.

First, the goals of the EU Bioeconomy Strategy (European Commission 2018a) and the Action Plan (European Commission 2018b) were identified. The 2018 Action Plan (European Commission 2018b) sets out three action lines and 14 sub-activities. Although these sub-activities were considered, they were not addressed in the subsequent analysis of strategies, assuming they are directly linked to the three main action lines. The next step was identifying the EU member states with national bioeconomy strategies. According to the European Commission's official website, nine countries have developed and adopted a national strategy for bioeconomy, namely, Austria, Finland, France, Germany, Ireland, Italy, Latvia, the Netherlands, and Spain.

Further, a systematic review of the nine strategies was conducted to screen which of the EU's bioeconomy objectives and action lines have been implemented in the national strategies. The national strategies' main goals and action lines were grouped according to the objectives and action lines of the European Bioeconomy Strategy (Table 3). Analysis was limited to the strategic vision since not all countries have a complementary action plan accompanying the bioeconomy strategy. Actions mentioned in national bioeconomy strategies that could not be directly linked to objectives and action lines of the EU Bioeconomy Strategy were listed under "Other measures".

The full texts of the national bioeconomy strategies were reviewed to determine their consistency with EU-level objectives and action lines. Each time a link was found, it was registered, giving a value of one, and the numbers were added up. This provided an overview of the national focus in the planning process and the broader action areas to be supported.

Obtained values from the national bioeconomy strategies (Table 3) were further analyzed with Multi-criteria analysis method Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) to determine which of the

Table 4 Criterion weight matrix for objectives and action lines specified in the European Bioeconomy Strategy (European Commission, 2018a) according to expert evaluation results

No.	Action line	Criterion weights, w_i
1	Ensure food and nutrition security	0.11
2	Manage natural resources sustainably	0.18
3	Reduce dependence on non-renewable, unsustainable resources	0.19
4	Limit and adapt to climate change	0.12
5	Strengthen European competitiveness and create jobs	0.10
6	Strengthen and scale up the biobased sectors, unlock investments and markets	0.13
7	Deploy local bioeconomies rapidly across the whole of Europe	0.08
8	Understand the ecological boundaries of the bioeconomy	0.09
	TOTAL	1.00 (100%)

objectives and actions identified in the European Bioeconomy Strategy (European Commission 2018a) could be the most appropriate ones to achieve effective bioeconomy development in the EU and the EU member states.

Multi-criteria analysis TOPSIS is often used to assess environmental strategies for sustainable development. The main advantage of this method is the possibility to compare and choose between several alternatives (D'Adamo et al. 2020; Zihare et al. 2021). The ideal positive and negative results are determined at the end of the calculation process (D'Adamo et al. 2020; Zihare et al. 2021). TOPSIS calculations are performed according to the steps and formulas listed below (D'Adamo et al. 2020; Zihare et al. 2021):

$$D = \begin{matrix} & \begin{matrix} C_1 & \cdots & C_n \end{matrix} \\ \begin{matrix} A_1 \\ \vdots \\ A_m \end{matrix} & \begin{pmatrix} x_{11} & \cdots & x_{1n} \\ \vdots & \ddots & \vdots \\ x_{m1} & \cdots & x_{mn} \end{pmatrix} \end{matrix}, \quad (4)$$

where

$A_1 \ldots A_m$ – comparable alternatives;

$C_1 \ldots C_n$ – criteria according to which the comparison is performed;

X_{ij} – performance/value of alternative i (where i is alternative 1 to m) according to criterion j (where j is from 1 to n).

A decision-making matrix was compiled. The TOPSIS analysis excluded those plans mentioned in the national bioeconomy strategies that were not aligned with the EU level and were categorized under "Other measures". Values were normalized, and the normalized decision matrix was compiled, as shown in Eq. (5).

$$D_{norm} = \begin{matrix} & \begin{matrix} C_1 & \cdots & C_n \end{matrix} \\ \begin{matrix} A_1 \\ \vdots \\ A_m \end{matrix} & \begin{pmatrix} r_{11} & \cdots & r_{1n} \\ \vdots & \ddots & \vdots \\ r_{m1} & \cdots & r_{mn} \end{pmatrix} \end{matrix}, \quad (5)$$

The next step was calculating the normalized rating using Eq. (6).

$$r_{ij} = \frac{x_{ai}}{\sqrt{\sum_{a=1}^{n} x_{ai}^2}} \quad (6)$$

When the normalized evaluation of all alternatives according to the criteria was obtained, it was necessary to determine the individual weight wi of each criterion. We used an expert survey method to determine the criteria weights. An online questionnaire was developed and distributed to 35 industry and academia experts based on personal contacts. The prerequisite was expert activity in one of the priority bioeconomy sectors (agriculture, forestry, or fisheries aquaculture sectors) or scientific research in bioeconomy, climate, and environmental sustainability fields. Complete questionnaires were received from 27 experts. The interviewed experts had to evaluate which of the five goals and three areas of action of the EU Bioeconomy Strategy (European Commission 2018a) are the most important to achieve rapid development of the bioeconomy. The average percentage of each obtained rating was further used as a weight of the TOPSIS criteria with a total sum of 100%. The results of the expert survey are shown in Table 4.

The criterion weights obtained from the expert surveys were further processed with TOPSIS. The criteria weight values w_i were multiplied by the normalized values r_{ia} to obtain the normalized weighted value v_{ai}, as shown in Eq. (7):

$$v_{ai} = w_i * r_{ia} \quad (7)$$

When the normalized weighted decision matrix was constructed, the ideal positive solution d_a^+ and the ideal negative solution d_a^- were calculated. Initially, the distance to the ideal solution (MAX) and the distance to the anti-ideal solution (MIN) was determined using Eqs. (8) and (9):

$$= MAX(v_{a1} : v_{a3}) \quad (8)$$

$$= MIN(v_{a1} : v_{a3}) \quad (9)$$

The next step after determining the distance to the ideal and anti-ideal solution was to determine the ideal positive and ideal negative solution according to the formulas:

$$d_a^+ = \sqrt{\sum_{j=1}^{n} (v_i^+ - v_{ai})^2} \quad (10)$$

$$d_a^- = \sqrt{\sum_{j=1}^{n} (v_i^- - v_{ai})^2} \quad (11)$$

The relative proximity of the alternative to the ideal solution was calculated as shown in Eq. (12):

$$C_a = \frac{d_a^-}{d_a^+ + d_a^-} \quad (12)$$

The result is equal to values that show the proximity of the alternative to the ideal positive solution and the distance from the ideal negative solution. To determine the impact of the weights of the criteria set by the experts on the criterion evaluation, a criterion was re-evaluated, assigning equal values to all alternatives.

Results

Composite Bioeconomy Sustainability Index Results

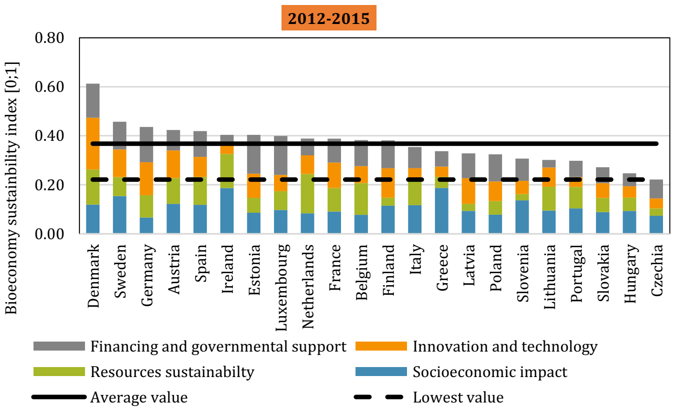
Annual Bioeconomy Sustainability Index values are calculated for each country from 2012 to 2018. Results are presented in two parts to obtain benchmarking values and rank countries according to their performance. First, the average values of the Bioeconomy Sustainability Index are calculated from 2012 to 2015 (4 years). Then, the same procedure is done for the average values of the Bioeconomy Sustainability Index from 2016 to 2018 (3 years). Such a division into two periods was made to investigate the possible impact of introducing national bioeconomy strategies in EU countries on bioeconomy development since the first version of the EU Bioeconomy Strategy was published in 2012 (European Commission 2012), and most countries' individual national bioeconomy strategies were published only in 2016. Figure 3 shows the Bioeconomy Sustainability Index's average values from 2012 to 2015. The average aggregated index value for 22 EU countries is 0.37, with 0.22 being the lowest (for the Czech Republic) and 0.61 being the highest (for Denmark).

In general, the results show a large dispersion between countries, which is reflected in different contributions of the sub-index values of the dimensions to the overall bioeconomy index. On average, the sub-indices of the socioeconomic dimension (0.11) and the financing and government support dimension (0.09) make the most considerable contribution to the overall composite index. On average, the dimensions of resource sustainability (0.08) and innovation and technology (0.08) contributed equally to the index score.

Figure 4 shows the average bioeconomy Sustainability Index scores from 2016 to 2018. The average value of 22 EU countries has increased compared to the period from 2012 to 2015, reaching a value of 0.39, with the lowest value being 0.26 (for Latvia) and the highest being 0.64 (for Denmark).

In the period from 2016 to 2018, the socioeconomic dimension had the highest contribution to the Bioeconomy Sustainability Index (0.12), similar to what was observed in the period from 2012 to 2015. The financing and government support (0.09) and innovation and technology (0.09) dimensions contributed equally to the index from

Fig. 3 Average aggregated Bioeconomy Sustainability Index scores from 2012 to 2015



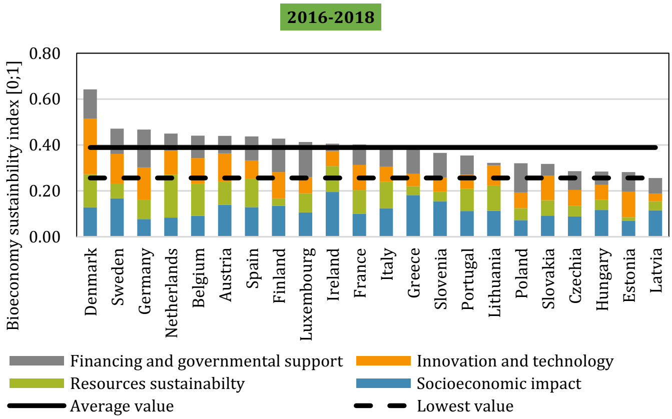


Fig. 4 Average aggregated Bioeconomy Sustainability Index scores from 2016 to 2018

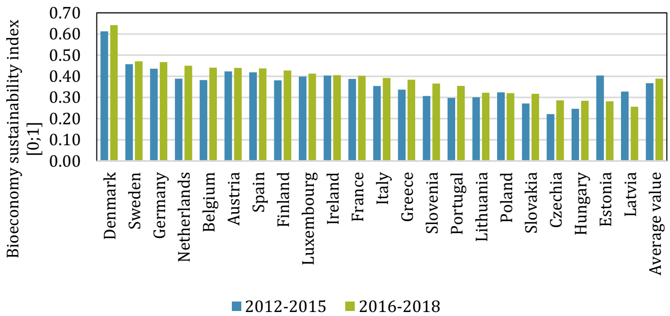


Fig. 5 Comparison of the average aggregated Bioeconomy Sustainability Index scores between the two selected study periods

2016 to 2018. It can be concluded that the importance of innovation and technology dimension in the development of the bioeconomy has increased. The resource sustainability dimension makes the smallest contribution (0.08) to the Bioeconomy Sustainability Index.

Figure 5 compares average aggregated composite index scores between the two selected study periods. Most countries have managed to improve the overall value of the Bioeconomy Sustainability Index. In general, the average value of the index in the European Union has increased over the years. However, two countries, Latvia and Estonia), show a negative development trend.

The Netherlands, Belgium, Slovenia, Portugal, and the Czech Republic made the most significant progress in improving the index score from 2012–2015 to 2016–2018.

In the Netherlands, the increase was caused by significant increases in the innovation and technology dimension (improvement in the relative advantage in the environment-related technology ratio) and the resource sustainability dimension (increase in the share of recycled biowaste and wooden packaging). In Belgium, the growth in the Bioeconomy Sustainability Index was driven by the rise in the indicators of the socioeconomic dimension – bioeconomy resource productivity and apparent labor productivity. For Slovenia rise in the Bioeconomy Sustainability Index value is explained by the increase in financing and governmental support dimension indicators – environmentally related government R&D budget (% total government R&D) and government budget allocations for environmental R&D per capita (EUR per inhabitant). In Portugal, the increase in the Bioeconomy Sustainability Index was determined by the rise in innovation and technology dimension indicators (development of environment-related technologies (inventions per capita)) and financing and governmental support dimension indicators (environmentally related government R&D budget (% total government R&D) and government budget allocations for environmental R&D per capita (EUR per inhabitant). For the Czech Republic increase in the Bioeconomy

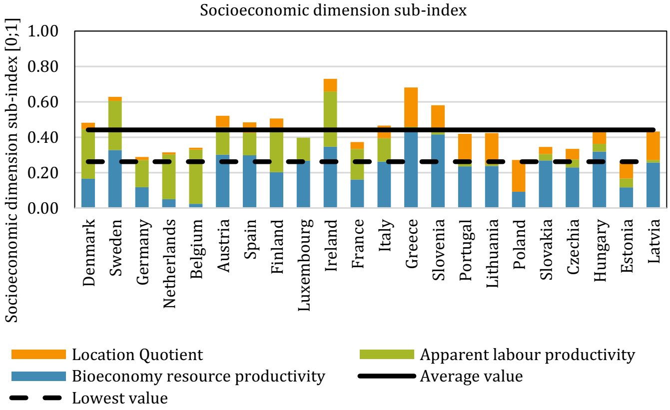


Fig. 6 Average socioeconomic dimension sub-index values from 2016 to 2018

Sustainability Index value was driven by the rise in innovation and technology dimension indicators – relative advantage in environment-related technology and development of environment-related technologies (inventions per capita).

For Latvia, a substantial decrease in the Bioeconomy Sustainability Index value is explained by a significant decline in innovation and technology dimension indicators (development of environment-related technologies (% all technologies), relative advantage in environment-related technology, development of environment-related technologies (inventions per capita), biotechnology patent applications to the EPO per billion EUR total government budget allocations for R&D) as well in financing and governmental support dimension indicators (environmentally related government R&D budget (% total government R&D)).

Socioeconomic dimension sub-index

Figure 6 illustrates the average socioeconomic impact dimension sub-index values from 2016 to 2018. Ireland, Greece, and Sweden were leaders in the socioeconomic impact sub-index. In Ireland and Sweden, apparent labor productivity and resource productivity of the bioeconomy were the main factors in achieving the highest scores in this dimension.

For Greece, however, the location quotient and bioeconomy resource productivity achieved the most competitive values compared to the other countries, placing Greece second in socioeconomic impact.

Due to one of the lowest apparent labor productivity in the European Union, Latvia has an average score in the socioeconomic impact index. Although Denmark leads in the overall Bioeconomy Sustainability Index, it does not rank high in the socioeconomic impact indicators because the bioeconomy location quotient and resource productivity are significantly lower.

Resources sustainability dimension sub-index

Figure 7 illustrates average resources sustainability dimension sub-index values from 2016 to 2018. The Netherlands, Belgium, and Denmark achieved the highest overall scores for the sub-index of the resource sustainability dimension. All three countries showed competitive positions on all three indicators of the resource sustainability dimension – biomass contribution, biowaste recycling, and wood packaging recycling.

Estonia, Spain, and Greece have the lowest scores for the resource sustainability sub-index compared to the other EU countries. Lithuania shows the most competitive scores for resources sustainability dimension indicators compared to other Baltic states – Latvia and Estonia.

The indicators – recycling of biowaste and recycling rate of wood packaging – show more significant fluctuations in indicator values compared to the biomass contribution indicator. This indicates that the development trends and the required infrastructure for recycling bio-waste are different in the individual member states.

Innovation and technology dimension sub-index

Figure 8 illustrates average innovation and technology dimension sub-index values from 2016 to 2018. Denmark is the absolute leader in the innovation and technology dimension sub-index with an overall score of 0.97 (1 is the maximum possible subindex score). Denmark holds the most competitive positions in all indicators of the innovation and technology dimension – development of

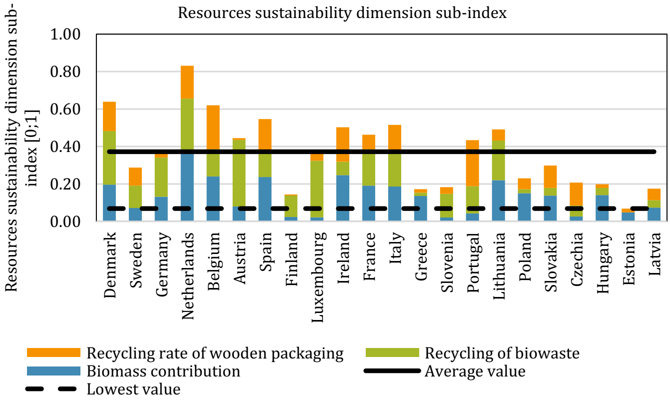


Fig. 7 Average resources sustainability dimension sub-index values for 2016 to 2018

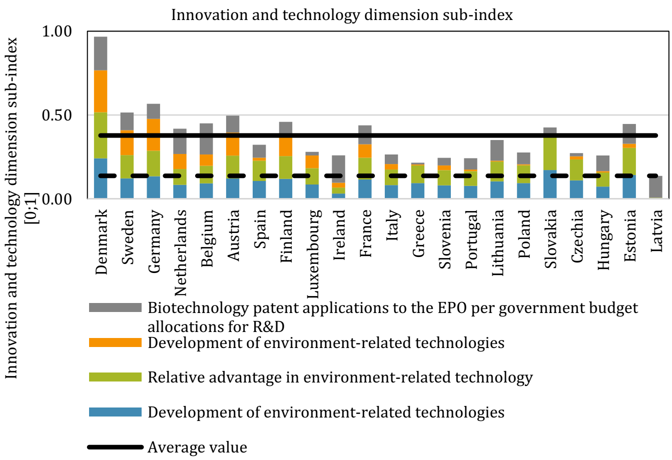


Fig. 8 Average innovation and technology dimension sub-index values for 2016 to 2018

environment-related technologies, relative lead in environment-related technology, which has consequently led to a high number of biotechnology patent applications to the EPO, from billion EUR total government budget allocations for R&D.

Germany and Austria hold second and third best positions in the innovation and technology dimension sub-index, but with significantly lower relative biotechnology patent applications to the EPO and development of environment-related technologies compared to Denmark.

Latvia has the lowest sub-index value for the innovation and technology dimension. Despite a significant competitive advantage in biotechnology patent applications to the EPO per billion EUR of government budget allocated to R&D, Latvia has the lowest scores on the other three indicators that measure the speed of development of environment-related technologies.

Generally, the innovation and technology dimension sub-indices show the largest variation across countries. This indicates significant differences between countries' development speed in green innovations and biotechnologies. The results show Denmark could be used as the benchmark for green innovation in EU countries.

Financing and governmental support dimension sub-index

Figure 9 illustrates average financing and governmental support dimension sub-index values from 2016 to 2018. Germany, Luxembourg, and Finland reached the highest values in the financing and governmental support dimension

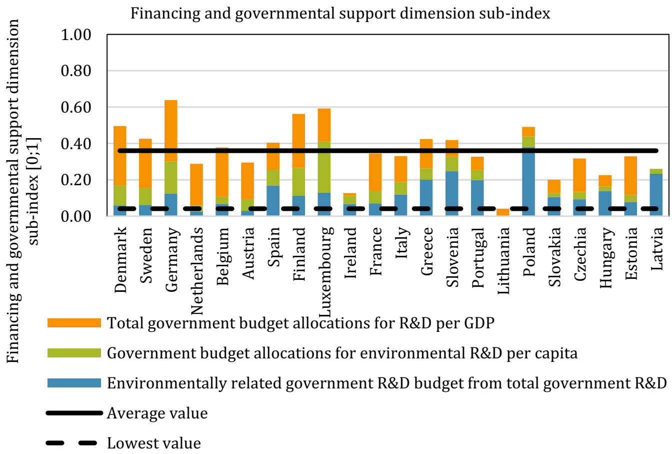


Fig. 9 Average financing and government support dimension sub-index values from 2016 to 2018

sub-index. Despite showing considerably lower values for environmentally related government R&D budget (% total government R&D), these three countries showed one of the highest values for government budget allocations for environmental R&D per capita and total government budget allocations for R&D, % of GDP.

Ireland and Lithuania show the lowest values in the financing and governmental support dimension sub-index. Latvia scores high in environmentally related government R&D budget (% total government R&D). However, compared to other EU countries, extremely low for total governmental budget allocations to R&D per capita and GDP.

In general, most countries that scored above the EU average value in the financing and government support dimension sub-index also scored above the EU average in the innovation and technology dimension sub-index. Since financing and governmental support are direct inputs in the development of the bioeconomy, developed inventions and technological innovations are direct outputs of the bioeconomy.

Analysis of National Bioeconomy Strategies

The comparison of countries using the Bioeconomy Sustainability Index approach was supplemented by an analysis of national bioeconomy strategies in countries whose strategies are available in English (nine countries in total). The goals and action directions set in the national strategies were grouped using the five goals and three priority areas of the EU Bioeconomy Strategy (European Commission 2018a) and Action Plan (European Commission 2018b) as a basis. Table 5 summarizes the results of the national strategy analysis.

Practically all reviewed national bioeconomy strategies have implemented the objectives and action lines set at the EU level, as only 1% of the objectives and action lines mentioned in the national strategies were not directly linkable to those set by the EU. National bioeconomy strategies focus mainly on areas of rapid deployment of local economies (27%) and strengthening and scale-up the bio-based sectors, unlocking investment and markets (23%). Another critical area of action is understanding the ecological boundaries of the bioeconomy, which ranks third (19%). National bioeconomy strategies focus less on areas relevant to ensuring food and nutrition security (4 %) and limiting and adapting to climate change (4%).

In Fig. 10, all nine countries are compared based on their contribution to the eight criteria. The results show that the national strategies focus on the three defined action lines, with less emphasis on the five objectives of the EU Bioeconomy Strategy. Of the five bioeconomy objectives defined at the EU level, the national strategies focus most on the objective of "Manage natural resources sustainably". Especially Latvia (18%), France (14%), and Ireland (14%) have paid the most attention to this objective.

National strategies have placed the most significant emphasis on implementing action lines. This is probably because most of the national strategies were developed around 2018, when the updated version of the European Bioeconomy Strategy (European Commission 2018a) was adopted, where these action areas were defined.

Figure 11 shows which of the three action areas each examined country has placed the most emphasis on. Overall, of the three action areas, the most emphasis is placed on the action "deploy local bioeconomies rapidly across the whole of Europe" (27%). Countries with the highest priority

Table 5 Emphasis on objectives and action lines in national bioeconomy strategies

Objective and action line	Targets mentioned	%
Ensure food and nutrition security	23	4%
Manage natural resources sustainably	69	11%
Reduce dependence on non-renewable, unsustainable resources	35	6%
Limit and adapt to climate change	23	4%
Strengthen European competitiveness and create jobs	39	6%
Strengthen and scale up the biobased sectors, unlock investments and markets	145	23%
Deploy local bioeconomies rapidly across the whole of Europe	170	27%
Understand the ecological boundaries of the bioeconomy	117	19%
Other measures	8	1%
TOTAL	629	100%

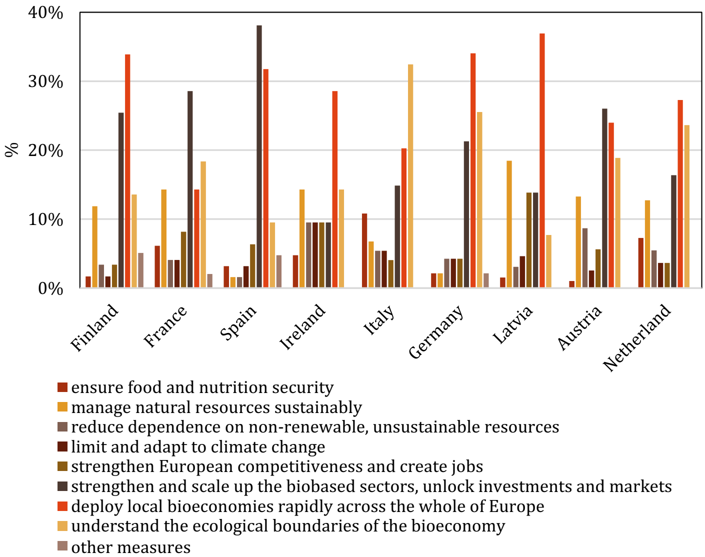


Fig. 10 Distribution of emphasis in national bioeconomy strategies towards the objectives and actions defined at the EU level

on this action are Latvia (37%), Germany (34%), Finland (34%), and Spain (32%). Of the three action areas, “understand the ecological boundaries of the bioeconomy” (19%) has the lowest focus, with Italy (32%) being the only country to have placed a significant emphasis on this action in its strategy.

Following, the countries’ performance was compared with the expert’s assessment of the priority directions of action for developing the EU bioeconomy. According to the expert evaluation, with respective scores of 0.18 and 0.19, objectives related to the sustainable management of natural resources and reduced dependence on non-renewable resources should be placed among the top priorities. Meanwhile, the lowest weight rating was given to the action line “deploy local bioeconomies rapidly across the whole of Europe” (0.08) and the action line “understand the ecological boundaries of the bioeconomy” (0.09). Figure 12 shows the main objectives and action lines based on the expert survey results and the extent to which these targets are addressed in national bioeconomy strategies.

It is found that the above objectives have been implemented relatively little in the national strategies. No direct correlation can be seen between the experts’ assessment and the objectives mentioned in the national strategies. E.g., the two objectives said as the most influential drivers of the bioeconomy by experts (“manage natural resources sustainably” and “reduce dependence on non-renewable, unsustainable resources”) received relatively less attention in the national strategies (11% and 5%, respectively).

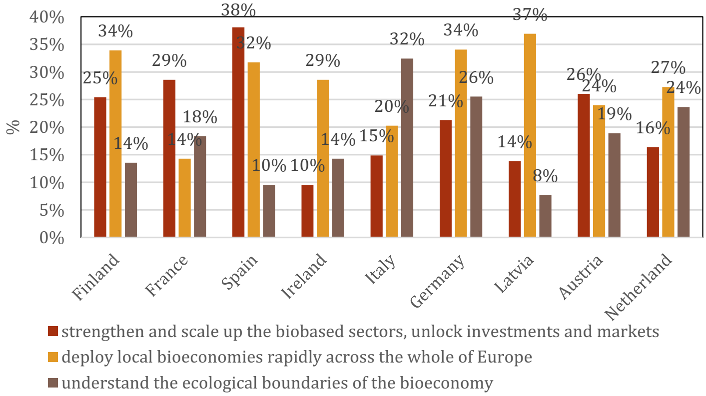


Fig. 11 Proportion of areas of activity in national bioeconomy strategies

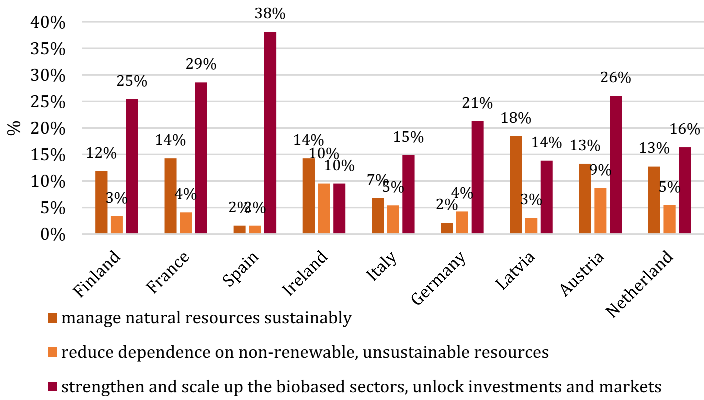


Fig. 12 Actions and goals with the highest weights based on the expert survey

However, if viewed in the context of five objectives, the objective "manage natural resources sustainably" received the highest score (11%). The third highest weight (0.11) was given by the experts to the area of action "strengthen and scale up the biobased sectors, unlock investments and markets" (23%), which scored the second highest percentage from all the eight criteria.

TOPSIS calculations were based on the number of targets identified in the national bioeconomy strategies, divided by the eight criteria, which were further summed and the information presented in Table 5 obtained. Results obtained from the national bioeconomy strategies were processed with the TOPSIS decision-making matrix and weighted according to the experts' evaluation results. In addition, the calculation was repeated using equal criterion weights to determine the influence of the experts' evaluation on the overall result.

According to TOPSIS results, Austria scored the highest (0.94), with Italy the second best (0.20), although well behind the leader. The third closest score to the ideal positive solution is Latvia (0.13). The Netherlands (0.07), France (0.05), and Spain (0.04) have lower scores than the leaders. However, the countries with the lowest scores are Germany (0.01) and Ireland (0.01). Looking at the results obtained, the highest results were obtained by the three analyzed countries that mentioned the most goals and actions in their strategies – Austria 196, Italy 74, and Latvia 65 actions. Austria's high performance is because it has put far more action lines and objectives to reach in its national bioeconomy strategy than other member states.

The same parameter does not work for the lowest-performing countries, where the distribution of the proposed actions concerning the weights of the criteria has played a more significant role than the number of

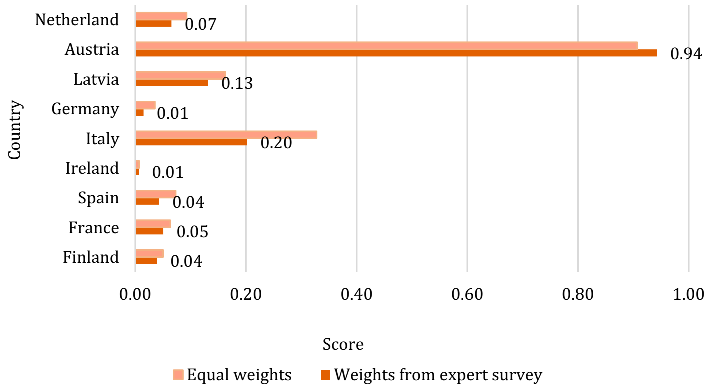


Fig. 13 TOPSIS evaluation results

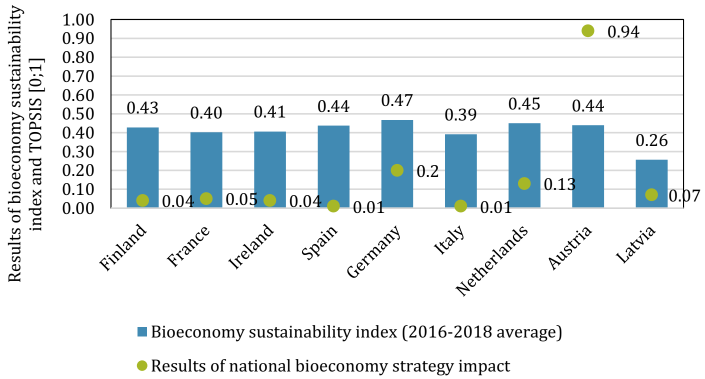


Fig. 14 Combined results from the Bioeconomy Sustainability Index and national bioeconomy strategy impact results

activities proposed concerning the country's closeness to the ideal solution. Figure 13 shows that the expert evaluation affects the results obtained but not so much as to change the overall results.

Synergies between the Bioeconomy Sustainability Index results and the national bioeconomy strategies

Figure 14 illustrates the combined results from the Bioeconomy Sustainability Index and national bioeconomy strategies. No strong linkage was found between the index values and the results of national bioeconomy strategies. It could be explained since the index covers the period 2016–2018, while most national bioeconomy strategies have been adopted in the same period or even later. Table 3 shows that Finland (2014) and France (2015) adopted their national bioeconomy strategies earlier, while Austria and Italy adopted their strategy in 2019 and Germany in 2020. Not enough time has passed since countries adopted the strategies, and such linkages should be sought five or ten years later. Bioeconomy involves many complex processes, including the transition from traditional farming methods to innovative and knowledge-based ones, and the reorientation could take some time.

Austria obtained the closest to the ideal positive result on the national bioeconomy strategy impact score, but it ranked 6th on the Composite Bioeconomy Sustainability Index evaluation. Austria and Spain ranked 3rd among the countries that developed a national bioeconomy strategy. Among the countries whose bioeconomy strategies were analyzed, Germany scored the highest result on the composite index with 0.47 points. Germany achieved the second-highest score in the national bioeconomy strategy impact assessment. The Netherlands had the 2nd highest score in the composite index among the nine countries and ranked 3rd among the national bioeconomy strategy result assessment. Thus, while there is no direct correlation between the results of the two methods, the three countries that scored highest on the national strategy scores also scored highest on the Bioeconomy Sustainability Index among the nine countries.

Despite Spain and Italy's lowest national bioeconomy strategy impact scores, both countries achieved remarkably high results in the Bioeconomy Sustainability Index. Thus, while it was possible to see some link between the ranking of Austria, the Netherlands, and Germany, there is no link between the countries' scores on bioeconomy strategies and their scores on the Bioeconomy Sustainability Index. For example, Latvia scored fourth highest on national strategies rankings and lowest on the composite index out of the nine countries examined.

Discussion

This study demonstrated the development and application of a novel Composite Bioeconomy Sustainability Index to measure and monitor the progress of bioeconomy development in European Union countries. The Bioeconomy Monitoring System (Robert et al. 2020) created by the EU is the basis for the availability of uniform and consistent data in the bioeconomy sector, based on which countries' progress can be assessed with the help of the Bioeconomy Sustainability Index. The results revealed the main drivers and cornerstones of the bioeconomy in each country and thus pointed out specific directions for national policy-makers for further bioeconomy development. The proposed composite index could also help establish EU-wide benchmarks that can be used to set more precise long-term strategic goals.

Nevertheless, some limitations were encountered in creating the composite index and analyzing the results that could be addressed and improved in further research. First, regarding the indicators included in the Bioeconomy Sustainability Index. The authors express their gratitude to the anonymous reviewer of the article, who pointed out the need for an in-depth evaluation of the indicators to more precisely characterize the nature of the complex index and evaluate the mutual effects between the indicators. For example, the reviewer mentioned the share of biomass in total domestic material consumption (indicator R1). On the one side, it has the highest weight in resource sustainability. But when biomass is produced with unsustainable practices or imported from tropical regions causing land use change or biodiversity loss, increasing its share in material consumption does not improve the sustainability of the bioeconomy. Considering the complex nature of the bioeconomy, authors suggest that further research could focus on an in-depth systemic analysis of the Bioeconomy Sustainability Index, for example, using the system dynamics modeling approach (Runge et al. 2017) or elements of the life cycle analysis (Diaz et al. 2022). Further, Calicioglu & Bogdanski (Calicioglu and Bogdanski 2021) suggest that bioeconomy strategies can be linked with several UN Sustainable Development Goals, thus improving bioeconomy sustainability monitoring and evaluation, especially concerning economic development, food security, and sustainable consumption.

This issue is also primarily related to data availability. Due to a lack of data availability, social and environmental factors were poorly represented in the Bioeconomy Sustainability Index. The resource sustainability dimension should be complemented by additional indicators that measure the extracted bioresources' environmental impact, considering possible emissions and pollution throughout the biomass production chain. The socio-economic impact dimension should be complemented by social indicators such as public acceptance, knowledge transfer, potential conflicts of interest, and others. All in all, the issue of sufficient data availability is one of the essential cornerstones in the development of composite sustainability indices. More sufficient and descriptive databases should be created and maintained to measure the factors affecting sustainable bioeconomy development in different countries.

Another limitation is related to the applied expert weighting technique. Although the expert survey was one of the prerequisites for improving the initial composite index, as concluded by Zihare et al. (Zihare et al. 2021), the weights obtained from the expert survey showed very similar results; as a result, sensitivity analysis showed no significant disparities in results if equal weighting is applied instead of expert weights. Further research should increase the number of experts surveyed and include experts from different countries to represent a broader range of backgrounds and challenges related to bioeconomy policy. A higher number of experts might produce different average weights for each indicator and dimension of the Bioeconomy Sustainability Index.

Evaluation of national bioeconomy strategies with a mixed methods approach, combining the systematic literature review with TOPSIS, showed that the method can be used to assess whether and to what extent the priorities set in higher-level policy planning documents are implemented in hierarchically descended documents. This allowed us to determine the priorities of each evaluated EU member state bioeconomy strategy and compare them. Thus, demonstrating coherence not only between higher and lower-level policy planning documents but also enabling an assessment of coherence and priorities in documents at the same policy planning level. However, some limitations were identified that could be addressed and improved in further research. Identifying coherence between documents at different levels may be relatively straightforward, but there may be cases where contradictions could play a decisive role in realizing a shared EU vision. Future research should thus emphasize possible contradictions and assess causal links between the European Bioeconomy Strategy (European Commission 2018a), the Action Plan (European Commission 2018b), and national strategies. While this study attempts to identify both the five objectives and the three action lines from the EU Bioeconomy Strategy in the national bioeconomy strategies, for a more in-depth exploration and assessment of possible gaps in policy coherence, it could be suggested narrowing the scope of the study and looking specifically at how the sub-activities of each action line are implemented in practice. One could potentially gain valuable complementary insights at this level of study. E.g., Singh et al. reviewed existing European policies relevant to the biomass value chains and concluded that out of almost 90 policies, many still lack complete coherence with the core bioeconomy objectives and mutual synergies (Singh et al. 2021). Literature review research can be supplemented with other research methods, similar to what has been done, for example, by Bogner & Dahlke, who proposed a bioeconomy policy assessment framework in Germany based on an examination of policy strategies and publicly funded research projects complemented with in-depth expert interviews (Bogner and Dahlke 2022).

The method of strategy analysis allows us to assess the priorities for national action and how much emphasis countries have placed on these priorities. Countries with more detailed and developed national bioeconomy strategies scored highest in TOPSIS. However, the fact that strategies quantify a number of planned action lines and sub-actions does not guarantee that these strategies are more likely to achieve their objectives than strategies that are briefer and more specific. To obtain more accurate and comprehensive information on national bioeconomy strategies, future studies should analyze bioeconomy Action plans for bioeconomy strategies. Bioeconomy Action plans identify particular actions, responsible authorities, expected results, and deadlines. An analysis of the bioeconomy Action plans would provide more detailed insights into whether the targets and objectives set out in the bioeconomy strategies are achievable through the actions identified in them. It also involves the transfer of the national bioeconomy strategies to hierarchically lower implementation levels, which was beyond the scope of this study but should be further researched. For example, Marcone et al. compared the bioeconomy strategies of nine EU countries to evaluate synergies of national and urban circular bioeconomy transitions looking for indicator sets and found that only Italy and Germany provide bioeconomy assessment framework with a high overall quality rating (Marcone et al. 2022).

Conclusions and Policy Implications

In this study, a Bioeconomy Sustainability Index was created consisting of 13 indicators grouped into four main dimensions of the sustainable bioeconomy – socioeconomic impact, resource sustainability, innovation and technology, financing, and government support. The index was used for cross-country comparison of bioeconomy sustainability in 22 EU countries. The Bioeconomy Sustainability Index scores show that Denmark, Sweden, Germany, the Netherlands, and Belgium are leaders in bioeconomy sustainability from 2016 to 2018. Meanwhile, Latvia, Estonia, and Hungary achieved the lowest scores. The results show that socioeconomic impact and financing, and government support play the most critical role in improving the overall sustainability of the bioeconomy for countries.

Denmark is an absolute leader in bioeconomy innovation and technology, contributing significantly to the most competitive positions in the Bioeconomy Sustainability Index. Denmark can be used as a benchmark for ratios such as the development of environment-related technologies (% of all technologies and inventions per capita), the relative advantage in environment-related technology, and biotechnology patent applications relative to total government allocations to R&D. The results show that bioeconomy development outputs such as the development of environmental technologies and biotechnologies are strongly related with bioeconomy inputs, such as total government allocations to R&D and environment-related government R&D budget.

In general, all countries in the study have high untapped potential for bioeconomy development, which is reflected in relatively low average bioeconomy sustainability scores. The average Bioeconomy Sustainability Index score from 2016 to 2018 is 0.39, well below the maximum possible score of 1. The composite index scores vary widely, with 0.64 being the highest (for Denmark) and 0.26 (for Latvia) being the lowest, indicating significant differences between countries and highlighting the key drivers and cornerstones for developing a sustainable bioeconomy.

The results can be used to determine benchmarks for the European Union. The comparison of the results shows which countries lag behind the average development speed of the EU's bioeconomy and which are drivers and innovators of the bioeconomy.

The analysis of the objectives and action lines prioritized in the national bioeconomy strategies showed that the focus lies on the action lines defined in the EU 2018 Bioeconomy Strategy Action Plan (European Commission 2018b). As anticipated, national bioeconomy strategies adopted before 2018 (Finland (2014), France (2017), and Spain (2016)) show a stronger focus on the five objectives set in the European Bioeconomy Strategy (European Commission 2012).

While the national strategies adopted after the release of the 2018 Action Plan (European Commission 2018b) show a distinct emphasis on advancing the strategic vision in line with the adjusted EU course for the future development of the bioeconomy. This demonstrates the capability and willingness of EU Member States to align their strategic direction with that of the EU, thereby strengthening the overall EU policy coherence.

The evaluation of the strategies concludes that the priorities identified at the EU level have been implemented in the national strategies. This was demonstrated by the fact that only eight actions, or 1% of all actions mentioned in the strategies, could not be linked to them. Significantly, national strategies have implemented the priorities and actions identified at the EU level, showing that member states are moving in the expected direction set by the EU. The analysis of the strategies' actions and activities showed that the most significant emphasis was placed on the action lines identified in the renewed EU Bioeconomy Strategy 2018 (European Commission 2018a). One reason could be that most of the national strategies analyzed were adopted around the same time. It also reaffirms that the priorities set by the EU are recognized as necessary in national countries, and progress is being made toward achieving them.

A broadly described strategic direction and objectives alone do not ensure growth in the bioeconomy, as the comparison of the bioeconomy sustainability index with the results of national bioeconomy strategies shows: a well-defined national strategy does not guarantee high performance in this area. Or conversely, a bioeconomy strategy is needed to achieve high performance in bioeconomy development. It is demonstrated by Denmark, which ranks highest in the Bioeconomy Sustainability Index but does not have a national bioeconomy strategy, and Austria, which has developed a nuanced strategy with different priorities, is only sixth in the Bioeconomy Sustainability Index.

A comparison of the two methods shows that there is no direct link between the Bioeconomy Sustainability Index and the results obtained from the analysis of national bioeconomy strategies, most likely because the composite index analyses data from 2016–2018 and most of the national bioeconomy strategies analyzed were adopted in this period or later. It would be advisable to make the same comparison after a particular time. It should be noted that among the nine countries, the three countries with the highest scores in both methods are Austria, the Netherlands, and Germany. However, these three countries are not the leaders in the overall Bioeconomy Sustainability Index assessment.

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Compliance with Ethical Standards

Conflict of Interest The authors declare no competing interests.

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Full-length article

Renewable energy project implementation: Will the Baltic States catch up with the Nordic countries?

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ABSTRACT

The research identifies and describes administrative procedures for implementing RES electricity generation infrastructure projects in Baltic and Nordic countries. The administrative processes of installing small to large solar parks and onshore wind farms for electricity generation were assessed, looking at several criteria such as the timeline, complexity, information availability, impact of public opinion, and local authorities (municipalities). The methodology developed allows evaluating administrative procedures using a multi-criteria analysis method, resulting in a single-score quantification that can be further utilized in complex energy simulation models. The obtained results allow identifying the potential recommendations for process optimization in the analysed countries. For instance, the introduction of a single point of contact as in Norway, the consolidation of the environmental impact assessment and spatial planning phases as in Finland, and the simplification of the microgeneration and small-scale installation permitting process as in Lithuania.

1. Introduction

Increasing the share of renewable energy generation is one of the main goals on the way to climate-neutral energy systems in the future. The European Green Deal focuses on sustainable development and halting climate change while preserving the people's best interests of the European Union (EU) Member States (European Comission, 2019). It must not disadvantage people and put them at risk of energy poverty by transitioning to energy produced from renewable energy sources (RES) (European Comission, 2019). There should thus be a balance between the increased share of RES installations and fair energy planning that does not result in harmful environmental impacts.

The implementation process of projects using renewable energy source technologies for electricity generation may both promote or hinder the speed of transformation toward climate-neutral energy systems depending on process steps and the transparency of procedures (Schumacher, 2019), (González et al., 2020). This is mainly because unnecessary administrative obstacles or incomprehensible procedures for grid connection may delay the implementation of RES projects (Schumacher, 2019). Unclear and complex administrative procedures (Enzensberger et al., 2002), unreliable regulatory framework or public perception may impact investors' willingness to develop RES projects in a particular country (Serrano González and Arántegui, 2015), which may in the long term harm achieving the climate objectives of the EU in the transition from fossil fuels to RES (Seetharaman et al., 2019). Therefore, Directive 2018/2001 of the European Parliament and of the European Council of December 11, 2018 on the promotion of the use of energy from renewable sources (hereafter: RES Directive) describes the improvements to be made to the administrative procedures and the time limits for RES project implementation (European Parliament and the European Council, 2018).

In the context of this study, administrative process refers to the set of processes that a wind farm (WF) or solar PV project developer must undertake to implement a project from project conception to the production of electricity. In this study, administrative processes include the duration of the connection process, transparency of the process, curtailment and grid expansion, fair and independent regulation of the energy sector, complexity of the administrative process, land use and environmental planning, duration of the processes, public perception, communication between relevant stakeholders (Enzensberger et al., 2002), (Serrano González and Arántegui, 2015), (Lüthi and Prässler, 2011), (Wüstenhagen et al., 2007). Some specific barriers affect onshore wind energy and solar PV in different ways (Serrano González and Arántegui, 2015). The duration of administrative procedures and the incorporation of RES in spatial and environmental planning are more of a problem for WF than for solar PV, suggesting that these issues should be prioritized in order to create favourable conditions for wind power

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Nomenclature

DSO	distribution system operator
EIA	environmental impact assessment
EU	European Union
GHG	greenhouse gas
NVE	the Norwegian Water Resources and Energy Directorate
PV	photovoltaic
RES	renewable energy sources
RES Directive	Directive 2018/2001 of the European Parliament and of the Council of December 11, 2018 on the promotion of the use of energy from renewable sources
SPP	solar power systems
TSO	transmission system operator
USA	United States of America
WF	wind farm

development (BoieIngaHeld et al., 2014).

The installation process for RES technologies, specifically solar PV panels and WF, can be divided into the following process stages: the preliminary or feasibility stage, the installation and power generation stage and the end of operation or termination stage (Fig. 1). Each of these stages can be broken down into more detailed elements, consisting of almost identical steps, except that the installation of solar PV panels does not require, for the most part, the approvals associated with spatial planning and EIA.

Each of these three stages of the project implementation process (Fig. 1) is important and the regulatory framework should cover all stages of the process to avoid problems in the future when equipment reaches the end of its lifespan (González et al., 2020).

RES technology deployment begins with a comprehensive feasibility analysis or preliminary research (Fig. 1, Stage 1). In this phase, WF developers should carefully select the territory for the WF based on several criteria, including wind speed in the selected area, inviting an expert to conduct a preliminary assessment of the plant's potential environmental impacts, whether the WF can be connected to the nearest electricity network and at what cost, and the project's economic viability (European Commission et al., 2021). Wind turbines of a particular height may not be permitted within the radar range if they are too close to military installations or radars. The feasibility analysis of solar PV plants is primarily concerned with the techno-economic evaluation of the solar power station (SPP), which involves analysing the prospective costs and advantages of electricity trading (European Commission et al., 2021). The most important factor is the expenditure required for solar panels, cabling, and transmission infrastructure.

Stage 2 (Fig. 1) starts with Initial EIA, and if necessary, a full EIA procedure is initiated, and an EIA report is drafted. Moreover, conformity with spatial planning documents must be ensured (Schumacher, 2019), (European Commission et al., 2021). If the development of the WF is not permitted in a specific territory, the municipality's spatial plan must be modified, which will need more time to implement the project (European Commission et al., 2021), (Guan, 2020). The most time-consuming phases of the implementation process are the EIA

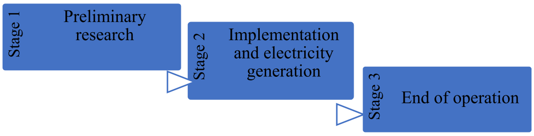

Fig. 1. Implementation steps of RES technologies for electricity generation (author's elaboration).

procedure and changes to the detailed plan (European Commission et al., 2021). Receiving a permit to increase energy production capacities or introducing new production equipment is the next step after completing the previous ones (European Commission et al., 2021). The following step in WF installation is obtaining a construction permit and initiating the construction phase (European Commission et al., 2021). The duration of WF construction and electricity network connection is project-specific and dependent on various factors, including the availability of financial resources, procurements, and project planning (European Commission et al., 2021). After constructing the power plant, many tests must be conducted to connect it to the electrical grid (Lüthi, Prässler), (European Commission et al., 2021). Before beginning operations, electricity producers and traders are required to register as electricity producers and retailers (European Commission et al., 2021). Implementation of SPP is shorter and less bureaucratised. All the steps described for Stage 2 (Fig. 1) may only apply to solar PV parks with larger capacity and a more complex installation process.

Stage 3 in Fig. 1 refers to the end of the operational life cycle of RES technologies. This stage could involve the decommissioning of the installed technologies and the return of the site to its pre-installation state (González et al., 2020). Or the installed RES technologies could be upgraded to match today's technological norms (European Commission et al., 2021).

1.1. Analyses of administrative barriers

A critical step in reducing administrative burdens is the identification of barriers that currently hinder the deployment of RES technologies. A study by González and Arántegui (2015) on the regulatory framework for wind energy in EU Member States finds that the success of support mechanisms for RES depends not only on the amount of compensation offered (Serrano González and Arántegui, 2015). The structure and regulation of the market, as well as the infrastructure and grid, significantly impact the spread of RES technology (Serrano González and Arántegui, 2015). Interviews and surveys conducted with RES stakeholders in Europe revealed that the political and economic framework is the most influential aspect, although market structure, grid regulation, and administrative processes play an important role (Serrano González and Arántegui, 2015), (Lüthi, Prässler), (BoieIngaHeld et al., 2014). The regulatory framework and compliance with the minimum actions needed to achieve optimal solutions are essential to promote the implementation of RES projects (González et al., 2020). Stakeholders and investors benefit from clear and transparent regulations about the implementation of RES projects would maximise the predictability of project success and limit the number of unrealized projects (González et al., 2020). The literature emphasizes evaluating and modelling the implementation process of the offshore and onshore WF projects (Guan, 2020; Geiβler et al., 2013; Vuichard et al., 2022), paying less attention to the evaluation of administrative procedures of SPP (Pascaris, 2021). Therefore, this study also includes the evaluation of permitting process for SPP.

Studies assessing the implementation of RES projects focus mainly on comparing existing support measures and subsidies; tariff reductions for RES energy; administrative procedures and the duration and cost of connecting to the network (Borozan et al., 2021). However, less attention has been paid to coordinating the project construction process and obtaining other permits, which have been examined in detail as part of this study.

Previous studies have focused on the EIA procedure and the fragmentation of the process between national, regional and local authorities, as well as other public administrations involved, whose approval is required for the project to proceed (Schumacher, 2019), (Gałaś et al., 2015). EIA is seen as essential to implementing large-scale projects, as it is time-consuming and directly linked to the general public attitude towards RES technologies (Schumacher, 2019). Environmental groups, as well as the public, often criticise and are against RES projects and the idea of simplifying the EIA procedure, which is presented as a dilemma of "green versus green" (Schumacher, 2019), (Straka et al., 2020). Hence, changes to the EIA procedure are a way to shorten the timeframe for deploying RES technologies and are important for increasing energy availability from RES (Schumacher, 2019). Administrative fragmentation and procedural transparency can be a disincentive for developers of large-scale RES projects when they choose to develop projects in one or the other country, as it can lead to longer permitting and approval processes (Schumacher, 2019), (Valença and Bernard, 2015; Nasirov et al., 2023; Sataøen et al., 2015). The EIA process could be optimised through regulatory instruments, such as maximum time limits for examining submitted documents, clear rules for carrying out EIAs and the prioritisation of RES projects (Schumacher, 2019), (Valença and Bernard, 2015).

It has been argued that policymakers and wind project developers often lack awareness of the attitudes and potential resistance to large-scale RES projects at the local level (Breukers and Wolsink, 2007). Public attitudes, particularly those of local communities, play a key role in implementing wind power projects (Serrano González and Arántegui, 2015), (Stephens and Robinson, 2021). Betakova et al. (2015) and other authors (Molnarova et al., 2012) have examined the visual implications of wind turbines as one of the primary social acceptability barriers. The number, height, and distance of wind turbines as primary influencing factors that could be further considered to increase public acceptance were analysed. Project developers should engage with the local community during the first stage of the project (Fig. 1) to ascertain general attitudes towards the technology to be installed (R. et al., 2019). Negative attitudes in the local community can later make the project impossible or delay its implementation (R. et al., 2019), (Inderberg et al., 2020). The influence of local authorities and communities is undeniably relevant to implementing the WF and SPP projects and has therefore been considered. In this case, however, from the point of view of the administrative process, the formal and legal influence of local authorities and communities on the progress of the WF processes was evaluated. The legal and formal influence of municipalities and communities was assessed in the study in terms of the right of municipalities to grant, or not grant permits for certain activities, e.g., land use planning, EIA, construction, or the ability of communities to influence these activities through participation in public hearings.

A relevant aspect of evaluating administrative processes and transparency of processes is the various nuances embedded in the regulation that project developers may later seek to override. In the case of Brazil, it has been argued that large WF covering a wide area can be formally subdivided into smaller WF, thus avoiding the requirements of an EIA (Valença and Bernard, 2015). Consequently, one evaluation consideration must be the regulatory framework's readiness. By accumulating knowledge on deploying a given RES technology, identifying administrative framework flaws, and implementing timely adjustments (Sen and Ganguly, 2017), (Silva, 2022). Therefore, in this study, authors have included the accumulated knowledge as one of the evaluation criteria.

Hua et al. (2016) have compared the development trends of renewable energy in Australia and China by evaluating the support measures, grid connection and coordination between different levels of government institutions. From the qualitative studies, it has been determined that strengthening a simplified grid connection and coordination between local and national authorities were recommended for both countries analysed (Hua et al., 2016). Swider et al. (2008) have conducted a study comparing the costs and conditions for renewable electricity grid connections in several EU countries. These authors conclude, that in some countries obtaining the grid connection permit can be a very time-consuming process due to specific technical requirements issued by the grid operator (Swider et al., 2008). Al-Shetvi et al. (Al-Shetwi et al., 2020) have performed a more detailed study on the key requirements for grid connection related to voltage stability, frequency stability, voltage ride-through, power quality, and active and reactive power regulations towards grid stability to harmonize the requirements among different countries (Al-Shetwi et al., 2020). Consequently, this study identified a time milestone for all WF and SPP implementation and permitting steps to determine which of the RES project implementation steps is most time consuming and in need of optimization.

The literature analysis shows that the previous research has focused on certain parts of the RES implementation process without analysing the whole implementation steps from both WF and SPP of different scales.

1.2. Methods used for assessing the role of administrative procedures

Previous studies distinguish several elements for analysing documents regulating the implementation of RES technologies, which should be considered, including regulatory framework, public influence on site selection/approval, available economic support mechanisms and indirect support mechanisms (González et al., 2020). Accordingly, the following elements can be used to compare legal frameworks (González et al., 2020), (Valença and Bernard, 2015):

- the responsible public authorities and agencies involved in issuing permits and licences for RES projects;
- the level of governance at which the permit or licence is issued (national, regional, local);
- the necessary permits, licences and procedures for issuing them;
- cross-comparison of standards and procedures in force in different countries to determine variables at a specific stage of a project (e.g., cross-comparison of EIA procedures);
- connection to the electricity distribution or transmission grid;
- support mechanisms.

Specific project implementation steps and accompanying legislation or regulation may also be analysed compared to the existing regulation in other countries. The study carried out by Valenca and Bernard (2015) analysed the practices of several countries (USA, Canada, Portugal) regarding the EIA of WF (Valença and Bernard, 2015). It assesses whether the EIA procedure is a mandatory step for WF in the countries studied and whether their impact on bats has to be assessed as part of the EIA (Valença and Bernard, 2015). This example shows that an assessment of administrative procedures can analyse a specific aspect of the regulatory framework, rather than the whole life cycle of a project or just a single stage of implementation.

When looking at administrative processes, projects and the possibility of optimising administrative processes, the literature is dominated by best practice analysis (Schumacher, 2019), (González et al., 2020). Indicators for selecting a country to define as a best practice can vary, e.g., amount of energy generated from RES; installed capacity of RES technologies; national sustainable development plans to reduce GHG; increasing the amount of electricity generated from RES (Schumacher, 2019), (González et al., 2020), (Valença and Bernard, 2015). Case studies can be conducted for multiple or single countries, analysing in greater depth the RES policies and regulatory framework - the initial framework when RES technologies were initially introduced, as well as the modifications made throughout time and their impact on future developments (Biehl et al., 2021). By breaking down and comparing specific project implementation steps, it is possible to assess and compare the administrative process implemented in each country using the same criteria (Schumacher, 2019). The comparison of administrative procedures between countries focuses on how the harmonisation process works and how shortcomings in procedures are addressed over time, including fragmentation and improved coordination at different levels of project implementation - national, regional or local (Schumacher, 2019).

In the Schumacher study (2019), the criteria for selecting and comparing countries are based on a simple principle - two examples of good practice: New Zealand and the EU are compared with the USA and

Japan, which are less advanced in the development of RES technologies (Schumacher, 2019). A multi-level mixed methodology approach was applied to assess the strengths and weaknesses of the EIA procedure, where the first step consisted of an in-depth analysis of the literature and legislative analysis of the existing regulatory framework (Schumacher, 2019). Schumacher divided the assessment into two distinct phases, initially describing each country's EIA procedure, as well as the regulatory changes planned and already in place. The next step was to compile the relevant legal and procedural frameworks, which made it possible to assess the essential requirements set out for the EIA procedure and the individual stages specific to project promoters. Finally, the identified information was used in the comparative analysis of qualitative data to identify the strengths and weaknesses of legislation and regulation (Schumacher, 2019). Thus, it was possible to identify barriers that exist in the regulatory framework and potentially hinder the implementation of RES projects.

In addition, an important aspect when assessing the administrative procedure for the implementation of RES projects in EU Member States is the compliance of the process with the EU regulatory framework (European Comission, 2019), (European Parliament and the European Council, 2018), (European Comission, 2020), (The European Parliament and the Council, 2012). EU countries do not have to transpose and implement directives directly into law - they can choose the most appropriate approach for their national situation and enforce it (European Union, 2021). Fitch-Roy (2015) in a study compared the regulatory frameworks of five EU countries (Germany, Denmark, the Netherlands and Belgium) regarding the authorisation procedure; connection to the network and economic mechanisms, which led to the conclusion that the regulatory frameworks of all the countries are eventually becoming more procedurally similar (Fitch-Roy, 2015).

1.3. *Aim and scope of research*

The main objective of the study is to compare the implementation of RES electricity generation projects in the Baltic States (Latvia, Lithuania, Estonia) and Nordic countries (Finland, Norway, Sweden) by analysing the administrative procedures for obtaining the necessary permits and licences, including spatial planning, EIA, construction permits and establishing a grid connection. The study also identifies the barriers that may hinder the implementation of RES projects (Lu et al., 2020). The in-depth analyses allowed us to assess the critical points in the procedures needed for the implementation of RES electricity generation projects and highlight the potential improvements toward higher RES power shares (Newell et al., 2017).

The research focuses on electricity generation, as the implementation procedure is relatively complex compared to the installation of heat generation plants. This is also because there are several examples of RES power plants (mainly wind) not being installed due to opposition from local communities and municipalities (Wüstenhagen et al., 2007), (Segreto et al., 2020; Baxter et al., 2013; Scherhaufer et al., 2017). Therefore, the administrative processes in the Baltic and Nordic countries were studied to determine the procedures for the introduction of WF and SPP with varying capacities for electricity generation.

This study will examine Stage 1 and Stage 2 (Fig. 1) of the whole operational lifespan of RES technologies for electricity production, from project planning to grid connection. Only these stages will be examined, as the authors consider them the most administratively and procedurally complex and should be given the most attention. The complexity of administrative procedures and the length of the licensing process are mentioned as one of the main challenges for deploying RES technologies, e.g. building permits can take two to 154 months in different EU Member States (Serrano González and Arántegui, 2015). The permitting and licensing process mainly involves an EIA, coordination with the spatial plan, and project approval by the responsible public authorities (Serrano González and Arántegui, 2015). In Estonia, problems with obtaining permission for planned WF projects near military objects and radars are mentioned as an administrative obstacle (Serrano González and Arántegui, 2015).

In addition, the study provides an assessment of different RES technologies, highlighting the similarities and differences between them and the potential barriers that project developers must overcome. The study does not analyse the implementation procedure of offshore WF, as there is no offshore WF in operation in the Baltic States, and the regulatory framework for offshore WF was still under development in Lithuania and Estonia at the time of the research. The literature review shows (Schumacher, 2019), (Serrano González and Arántegui, 2015), (European Commission et al., 2021), (Valença and Bernard, 2015), (Fitch-Roy, 2015) that a large number of analyses have been carried out on the main barriers to the implementation of wind energy projects related to administrative procedures. However, the previous research mainly focuses on a qualitative assessment by applying in-depth analyses of different information sources. Therefore, this article proposes a methodology for the evaluation of implementation process complexity by applying quantified criteria resulting in a single score evaluation which can be further used in more complex forecasting models or broader comparisons of different countries.

The structure of the paper is as follows: in the following sub-sections, a literature review of particular project implementation phases and supporting legislation or regulations, as well as implementation barriers for SPP and WF projects, has been conducted. In Section 2, the research methodology is described, including data on the countries analysed, quantitative and qualitative criteria for comparing administrative frameworks for the implementation of RES electricity generation infrastructure projects, and the use of the multi-criteria decision-making techniques (TOPSIS and AHP) for comparison of the obtained results. In Section 3, both qualitative and quantitative evaluations of administrative procedures in the examined Baltic and Nordic countries are presented. Section 4 summarises the key findings from the preceding sections and is separated into subsections regarding microgeneration and medium- and large-scale onshore WF and SPP, as well as the constraints encountered during the research and suggestions for future research.

2. Methodology

Analysis to compare the countries included in the study involves a qualitative comparison, discussing the administrative barriers in each country, and a quantitative comparison, assigning quantitative values to defined criteria. The quantitative criteria analysis is carried out using a multi-criteria decision-making approach to compare different aspects of the RES implementation process. The result of the quantitative analysis is a country ranking.

2.1. *Profiles of the countries analysed*

As a group of small, energy-importing nations, also known as an "energy island" (Zepa, 2022) the Baltic States were chosen for a detailed investigation because small states face more difficulties achieving energy security (Augutis et al., 2020). One option to increase energy independence in the Baltic States would be to intensify power generation from domestic RES, such as SPP and WF. Integration of solar and wind energy into the electricity markets of the Baltic States is already happening, with Lithuania and Estonia experiencing a substantial increase in installed solar capacity (Estonia, 2022; Official statistics portal, 2020; Official statistics portal of Lithuania, 2022; IRENA, 2022a; IRENA, 2022b; Eurostat, 2022). Although, the integration of wind and solar energy systems in Latvia is proceeding more slowly. Despite the rise in wind and solar power generation capacity installed in the Baltic States, the existing capacity is insufficient to provide complete energy independence. Because the installed capacities and electricity production of SPP and WF are much higher in the Nordic countries (Finland, Norway, Sweden), the administrative procedures of the Baltic States are compared with those of the Nordic countries. Thus, Finland, Norway, and Sweden have accumulated knowledge and experience with administrative processes and transparency in permitting procedures. Table 1 shows the key indicators of installed solar and wind power capacity and electricity generation in 2019. Sweden has the largest installed solar capacity (714 MW); however, it provides only 0.2% of final power consumption (IRENA, 2022a), while Lithuania has managed to meet 0.8% of its final electricity consumption with solar technologies (Official statistics portal of Lithuania, 2022). Another analysed parameter is the increase in installed capacities during recent years (from 2015 to 2019), presenting the actual development trends. The highest figures are found in Latvia, which had almost no installed solar capacity in 2015 (Official statistics portal, 2020), while Finland's installed solar capacity increased from 17 MW in 2015 to 222 MW in 2019 (IRENA, 2022a).

Sweden had the largest installed onshore wind capacity in 2019, accounting for almost 16% of final energy consumption (IRENA, 2022b). Lithuania has also achieved a high share of wind power generation compared to total final energy consumption (Official statistics portal of Lithuania, 2022). The Nordic countries have achieved the highest growth in installed wind capacity in recent years, which could be the result of both support policies and an optimised approval and installation process (IRENA, 2022b), (Eurostat, 2022).

The planning and future development of RES policy in the Baltic States was assessed in the context of the European Green Deal (European Comission, 2019) and the RES Directive (European Parliament and the European Council, 2018), considering the potential development goals outlined in these documents. The prospective action steps embedded in the National Energy and Climate Plans 2021–2030 (NECP) (Geissler et al., 2022), (Aboltins and Jaunzems, 2021) of the Baltic States provide insight into the implementation of EU-level targets at the national level, along with electricity generation using RES technologies. Not only are specific development objectives and their incorporation into policy planning documents essential for mapping the technological shift to RES, but also for attracting investment (Masini and Menichetti, 2013), (Polzin et al., 2015).

According to the NECP of Latvia (Ministry of Economics, 2020), modifications to the current administrative process are required because there is currently no transparent and systemic RES use promotion support policy. In its NECP, Lithuania has set ambitious goals for using RES for energy generation (Government of Lithuania, 2020). In order to increase the use of RES technologies in Lithuania, neutral auctions for the allocation of allowances and the widespread deployment of small-scale RES installations owned by private energy consumers and communities are anticipated (Government of Lithuania, 2020). According to Estonia's NECP targets for the next decade, wind energy will have the greatest growth potential, while solar energy will remain significant (Ministry of Economic Affairs and, 2019), (Shabbir et al., 2022). In the NECPs adopted by the Baltic States, the primary goals for the development of RES are as follows:

- accelerate and simplify the deployment of RES technologies (including permitting) and ensure public benefits from RES projects by establishing a single point of contact (Ministry of Economics, 2020; Government of Lithuania, 2020; Ministry of Economic Affairs and, 2019);
- simplifying administrative procedures and creating publicly accessible descriptions and instructions for acquiring the required authorizations (Ministry of Economics, 2020; Government of Lithuania, 2020; Ministry of Economic Affairs and, 2019);
- motivating local governments and the local community with the benefits that renewable energy production units provide (Ministry of Economics, 2020; Government of Lithuania, 2020; Ministry of Economic Affairs and, 2019);
- review spatial planning, building code, and land use constraints on RES technology development (Ministry of Economics, 2020), (Ministry of Economic Affairs and, 2019);
- develop a conceptual solution for developing onshore wind parks by creating the possibility and conditions for constructing wind parks on agricultural lands and forest land (Ministry of Economics, 2020). Provide public support for RES technology developers (Ministry of Economic Affairs and, 2019);
- state, local agencies, and entities must create, provide, and publish information on permit, license, and certificate issuance; certification application review; applicant assistance; and incentive programs. Agencies, institutions, businesses, organizations, and commercial enterprises should be motivated to share experiences and publish best practices on using RES (Government of Lithuania, 2020).

Lithuania is the only Baltic State to have issued a separate legal document establishing future targets, regulating the introduction of renewable energy, and simplifying procedures for installation of technologies from RES "The Law on Energy from Renewable Sources" (Lietuvos Respublikos Seimas, 2011), whereas electricity generation from RES is embedded in separate rules and regulations in Estonia and Latvia.

2.2. *Criteria for comparison*

Comparing administrative frameworks for the implementation of RES electricity production infrastructure projects is based on defined and agreed criteria. Five main dimensions have been identified for procedure comparison (see Table 2) by considering the timeline, complexity, information availability, impact of public opinion, and local authorities (municipalities). Each of the analysed criteria includes one or several sub-criteria described below.

2.2.1. *Timeline of the implementation process*

An analysis of the administrative procedures was carried out to determine whether the implementation procedure of wind and solar projects in the Baltic and Nordic countries follows the RES Directive (European Parliament and the European Council, 2018). RES Directive establishes a maximum time limit for the implementation of RES projects and stipulates that the approval process for processes applicable to power plants, including all relevant procedures of the competent authorities, shall not exceed two years (European Parliament and the European Council, 2018). The permitting process for installations with an electricity generation capacity of less than 150 kW shall not exceed one

Table 1
Overview of RES power profiles in each analysed country in 2019 (Estonia, 2022; Official statistics portal, 2020; Official statistics portal of Lithuania, 2022; IRENA, 2022a; IRENA, 2022b; Eurostat, 2022).

Country	Installed capacity, MW	Produced energy, GWh	Share of final consumption, %	Installed capacity increase, MW	Installed capacity, MW	Produced power, GWh	Share of final consumption, %	Installed capacity increase, MW
	Solar				**Onshore wind**			
Lithuania	103	91	0.8%	39%	534	1499	13.1%	3%
Estonia	74	48	0.6%	303%	316	687	8.1%	2%
Latvia	3	3	0.0%	2900%	78	154	2.3%	1%
Finland	222	149	0.2%	171%	2284	6535	8.4%	12%
Sweden	714	623	0.5%	193%	8681	19768	15.7%	31%
Norway	120	107	0.1%	167%	5212	5040	4.1%	49%

Table 2
Overview of criteria for comparing implementation procedures for RES power generation infrastructure projects in different countries.

Dimension	Criteria	Type of evaluation	Units of measurement	Data source
Timeline of the implementation process	Time for standardisable process steps;	Quantitative	Days	National legislation, regulatory documents, and information from authorities
	Time for non- standardisable process steps;	Quantitative	Days	National legislation and regulatory documents, information from authorities, project descriptions
	Total time for project implementation.	Quantitative	Days	Realised project information
Complexity	Number of contact points (contact institutions);	Quantitative	Number of contact institutions	National legislation and regulatory documents, information from authorities
	Several indirectly involved institutions.	Quantitative	Number of involved institutions	National legislation and regulatory documents, information from authorities
	Several necessary documents to be prepared.	Quantitative	Number of different types of documents	National legislation and regulatory documents, information from authorities
Information availability	Availability of public information	Qualitative	3-point scale	Expert evaluation based on available information
	Accumulated knowledge of the project implementation.	Quantitative	Indicator (kW/thousand inhabitants)	Statistical data
Impact of public opinion	Number of public discussions to be carried out during the project implementation process;	Quantitative	Number of public discussions	National legislation and regulatory documents, information from authorities
	The opportunity for local society to influence the implementation of RES projects.	Qualitative	3-point scale	Expert evaluation based on available information
Impact of local authority	The opportunity for the municipality to influence the implementation of RES projects.	Qualitative	3-point scale	Expert evaluation based on available information

year (European Parliament and the European Council, 2018). The analysis is based on national legislation and regulatory documents, with additional information on the process obtained from the authorities' websites where necessary.

Some project implementation permitting procedures are project-specific and depend highly on local conditions and project developers (Valença and Bernard, 2015), (Abranches et al., 2020). Therefore, the timeframe is analysed separately for processes with standardisable and clearly definable rules and separately for non-standardisable permitting or approval procedures, which consider various project-specific elements as well as the developer's ability to meet the authorities' requirements promptly.

Fig. 2 shows standardisable processes with predictable variables and a fixed timeframe for implementation - permits for increasing electricity production capacities or the introduction of new production equipment, construction permits and electricity trading permits. These permits are

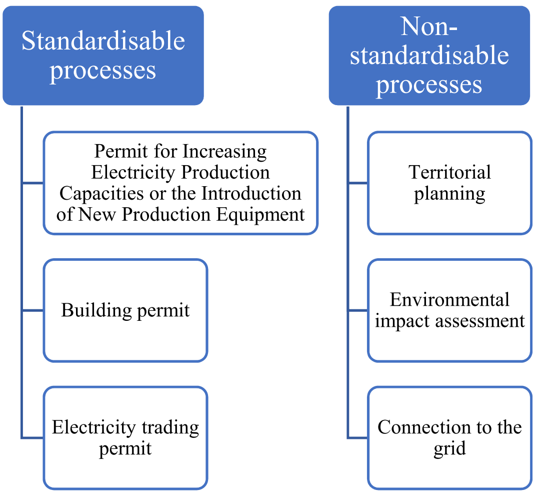

Fig. 2. Timeline analyses depending on the implementation process (author's elaboration).

issued by the government ministries or government agencies responsible for the sector, or by local authorities, and the length of the process depends mainly on the capacity of the authorities, but should not exceed the number of days specified in the regulatory documents (usually 30–70 days). The timeframes for processing applications and issuing relevant permits have been identified through an analysis of regulatory documents and the authorities' websites.

Processes such as EIA, spatial planning changes and grid connections are project-specific and require additional experts such as ornithologists, bat experts, and planners and approvals from nearby landowners to meet legal requirements and obtain approvals. These processes are therefore described as "non-standardisable" because, despite the regulatory time frames for examining applications and granting approvals, they will vary slightly from project to project (Gulbrandsen et al., 2021), (Schütz and Slater, 2019).

Project implementation timeframe for "standardisable" and "non-standardisable" processes was identified. "Standardisable" processes, in this case, refer to intra-organisational processes where a single administrative authority is involved in issuing a permit or licence (Ziekow, 2021). In this case, inter-organisational procedures for issuing the necessary permits are understood as "non-standardisable" processes because they involve two or more administrative entities, making it challenging to define a single time and complexity frame for these procedures (Ziekow, 2021). The total project implementation time was also identified from the case studies carried out, through interviews with wind and solar park developers, and from a literature analysis on the implemented projects in the countries analysed.

2.2.2. *Complexity*

One perspective for the RES project implementation process analysis is the complexity of the coordination process. One of the critical parameters is the number of authorities to which the project developer must apply for permits or approvals for the activities carried out as part of project development (Yaqoot et al., 2016), (Spodniak and Viljainen, 2012). The RES Directive recommends that for smoother implementation of RES projects, there should be a single point of contact to obtain the necessary approvals or permits to facilitate the implementation of projects (González et al., 2020), (European Parliament and the European Council, 2018). Hence, the first criterion in the "complexity" dimension is the number of contact points (contact institutions). The inventory of existing contact points in the countries included in the study will make it possible to determine which countries have implemented the requirement of the RES Directive (European Parliament and the European Council, 2018) to move to a single contact point and whether fewer contact points can facilitate or shorten the lead time for renewable electricity generation installations.

The RES project implementation process sometimes indirectly involves other institutions whose opinion or approval is necessary to move forward. The number of institutions indirectly involved has, therefore, been chosen as a second criterion. For example, in the case of WF, this could be the military authorities, as the installation of WF at certain heights could interfere with radars, or in the case of SPP near an airport, the glare from the panels could pose a threat to air traffic safety.

The third criterion is the approximate number of documents required for project approval, identified through an analysis of the legislation or found on the official websites of the authorities involved in the project approval process. This also specifies the administrative load put on the procedure for RES project implementation. The assumption is that the more documentation necessary, the more difficult and time-consuming the implementation process will be (Yaqoot et al., 2016).

2.2.3. Information availability

Another essential aspect for a successful implementation of RES projects is information available on the administrative procedures and approvals and permits required (Kudurs et al., 2020). Authors have rated information availability by using a 3-point scale where 3 points are attributed if the information is easily accessible, can be found in one source about the whole coordination process and deadlines but 0 points if information cannot be found, is not publicly available.

Authors also include accumulated knowledge of the project implementation process as a criterion because if there are more implemented RES projects, the developers and authorities have more precise un deep knowledge of the implementation process. In the context of this study, the accumulated knowledge about the implementation of RES is proportional to the installed capacity, as a larger number of implemented RES makes the implementation process more transparent for both project implementers and licensors. However, the analysed historical period is condensed to three years to evaluate the implemented projects under the most recent regulatory framework. The hypothesis is in line with the previous research by Kobos et al. (2006) (Kobos et al., 2006) which uses the historical data of installed capacities of solar and wind energy to quantify the learning process and impacts on RES technology development. Other authors focus on expenditures of RES technologies as one of the main indicators presenting the research and development (Miremadi et al., 2019). For the Baltic States, although, data on investments in solar and wind technology were unavailable. Consequently, writers place additional emphasis on installed capacity as representative criteria.

2.2.4. Impact of public opinion

The local society can substantially impact the realisation of RES projects (Stephens and Robinson, 2021), (Polzin et al., 2015). Therefore, the authors have identified local societies' influence on the RES project permitting process and evaluated the impact of public opinion on the project implementation The first identified criterion is the maximal number of public discussions about the RES project implementation approval, which was identified through legislation analyses and publicly available information on official websites.

The second criterion is the possibility of influence of the local society on the implementation of the projects of RES (Spodniak and Viljainen, 2012). It is assessed through legislation and case study analyses by using a qualitative 3-point scale where 3 points mean that the local society has sufficient opportunities to listen to the project implementers and influence the progress of the project, but there is no possibility to unreasonably suspend the implementation of the project, 1 point if it can unreasonably suspend the project, but 0 points if the public discussions are not organised, although RES projects significantly impact the environment.

The authors consider that the possibility of local society to participate in the project implementation by obtaining in-depth information is valuable and necessary.

2.2.5. Impact of municipality

The success and speed of the implementation of the RES project highly depend on the local authority's experience in coordinating this type of project and its attitude towards the technology, and therefore its ability to influence the process (Stephens and Robinson, 2021), (Inderberg et al., 2020), (Geissler et al., 2022), (Inderberg et al., 2019).

The criterion has been determined by careful legislation and case study analyses and the qualitative assessment has been done by assigning points from a 3-point scale like that used for local social impact evaluation. As with the evaluation of public opinion, the authors believe that the ability of local authorities to engage in the project implementation by getting detailed information is vital for municipalities. However, unreasonable delays in project implementation caused by the municipality should be avoided.

2.2.6. Definition of microgeneration

In the case of microgeneration, the additional criterion of the research is the capacity breakdown of micro and small-scale electricity generators because it is subject to a simplified installation and approval process. The microgeneration installations are defined beyond the following levels:

- Latvia - 11.1 kW;
- Lithuania– 30 kW;
- Estonia– 15 kW;
- Finland - 100 kVA;
- Norway - 100 kW;
- Sweden - 43.5 kW.

In the Nordic countries, microgenerators are either not categorised by capacity or are considered with larger capacities than in the Baltic States (Fredriksen et al., 2015).

2.3. Process comparison methodology

The obtained criteria values are evaluated using a multi-criteria decision analysis Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) and Analytic Hierarchy Process (AHP) methods. Multi-criteria decision analysis TOPSIS is a frequently used method to evaluate environmental strategies for sustainable development. The primary purpose of TOPSIS is to allow comparison and choice between several alternatives (Zlaugotne et al., 2020). TOPSIS and AHP methods were chosen for this study because they are relatively more straightforward and better enable the comparison of qualitative and quantitative criteria.

The main steps within the multi-criteria assessment are the normalisation of the criteria values by developing a normalised decision-making matrix, calculation of normalised rating, the weighting of criteria according to the AHP method, and determination of the positive-ideal (best) and the negative-ideal (worst) solutions (Chatterjee and Chakraborty, 2014). Finally, the relative proximity of the alternative to the ideal solution is calculated (Balioti et al., 2018; Krohling and Pacheco, 2015; Pachemska et al., 2014).

The AHP method was used to determine the degree or weight of criteria using a pairwise comparison matrix, which reflects the decision maker's choice of the relative importance of the various criteria. The pairwise comparison matrix and the alternative scoring matrix are developed based on the methodology described by Samal and Kansal (2015) (Samal and Kansal, 2016). When comparing the two alternatives, a peer-to-peer rating is entered into the corresponding cell where these alternatives intersect. Five independent experts developed their weighting matrix, and the average weighting rates were used to assess the RES implementation process.

The obtained weights for different criteria are shown in Fig. 3. The weights have been determined from the project developer's perspective. Therefore, the highest values have been assigned for the number of contact points, public information available, and necessary documents.

The comparison has been prepared to assess separately different technological solutions of power production: microgeneration, large and average scale SPP, and large and average scale WF projects. WF and SPP are considered medium-sized plants with a capacity of up to 10 MW and large-sized plants with a capacity of more than 10 MW; this breakdown was based on the generation capacity to be connected to the TSO, which in most countries starts from 10 MW.

3. Results

This section presents the results of qualitative and quantitative procedures assessment in the analysed Baltic and Nordic countries.

3.1. RES project implementation process in analysed countries

The study concluded that the legislative framework and the administrative procedures for installing WF and SPP in the countries studied are practically the same in terms of project implementation phases and required permits, with some minor differences (Table 3). Typically, in literature, administrative procedures have been assessed separately for wind and solar installations, but during the study, authors identified identical project implementation steps for both technologies, with the main difference being that SPP mostly are not subject to spatial planning restrictions and do not require an EIA. The implementation phases of RES projects for power generation are as follows: feasibility study; coordination of the project idea; power generation and grid permits; construction and commissioning (Fig. 4), thus almost covering two of the three project implementation stages listed in Fig. 1 up to the start of power generation.

The feasibility phase of the project was not examined in detail on a country-by-country basis. During the case study analyses RES project developers mentioned the following feasibility studies: wind speed or shading in the selected area; restrictions on spatial planning; preliminary assessment of possible environmental impacts; noise measurements; connection to the network and connection costs; infrastructure for transporting technology; economic viability of the project, as well as the distance from military installations and radars.

In Sweden permitting process for WF development may only be started if the municipality has approved (Wretling et al., 2022), (Larsson and Emmelin, 2016). Otherwise, the first step in implementing a RES project is either to amend the spatial plan or to carry out an EIA procedure, if necessary (Wretling et al., 2022), (Larsson and Emmelin, 2016).

The legislative framework for spatial planning usually determines the general requirements for spatial development planning - spatial use and restrictions for construction. Municipalities may designate certain areas in their spatial plans or detailed plans where the construction of WF is allowed or prohibited. In some cases, municipalities also include restrictions on the installation of SPP.

In the Baltic States, if the municipality does not foresee the installation of WF on the selected plot of land according to the spatial plan or detailed plan, the project developer must submit an application to the municipality requesting an amendment to the detailed plan (Cabinet of Ministers, 2013a) (Parliament of Estonia, 2019). In addition, land lease agreements must be concluded in case any part of the planned site is not already in the possession of the project developer, as well as agreements with adjacent landowners must be concluded. The administrative procedure for making changes to municipal spatial plans can include public consultation (Cabinet of Ministers, 2013a) (Parliament of Estonia, 2019).

In Norway, municipalities are responsible for spatial planning in all sectors except for energy, where project developers turn to the Norwegian Water Resources and Energy Directorate (NVE) (Inderberg et al., 2019), (Saglie et al., 2020). Municipal involvement is only part of the EIA process (Inderberg et al., 2019). The law of the Republic of Lithuania on Energy from Renewable Sources determines simplified spatial planning conditions for small-scale systems under 500 kW using RES – no need for detailed spatial plans or change of the primary land use, provided that it does not conflict with the regulations on local management land use (Lietuvos Respublikos Seimas, 2011).

The next step for medium and large –scale WF usually is an Initial EIA or a mandatory EIA, depending on the power plant capacity to be installed (Inderberg et al., 2019). The EIA procedure can also be carried out before changes are made to the municipality's spatial plan, or both procedures can be carried out in parallel. EIA usually is carried out in accordance with national Law on Environmental Impact Assessment. SPP usually are not subject to the EIA procedure, however, in Estonia it is possible that an Initial EIA could be required for the construction of a SPP plant as a part of the construction permit granting process, if the municipality concerned decides that the activity could have a negative impact on the environment (Consultare OÜ, 2020). Swedish municipalities have the right to speak, including the right to appeal, in matters concerning permits under the Environmental Code in order to protect

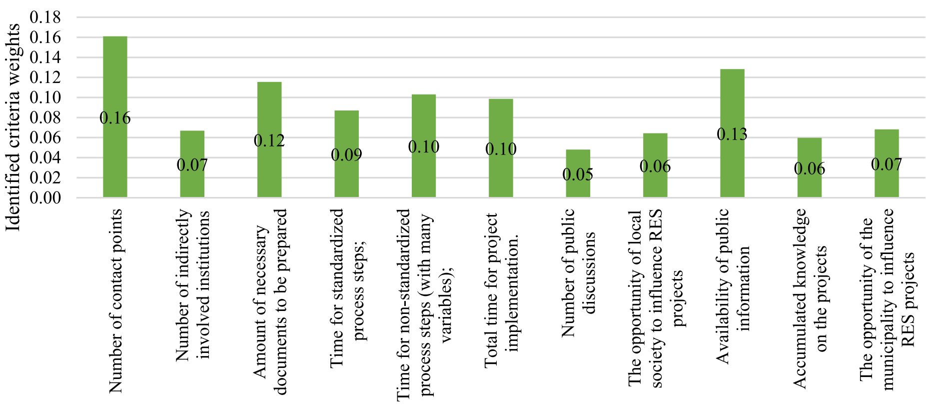

Fig. 3. Identified criteria weights (author's elaboration).

Table 3
The regulatory framework assessed to identify administrative procedures (2021).

	Territorial planning	EIA	Permits	Connection to the grid
Latvia	1. Spatial Development Planning Law (The Saeima, 2011); 2. Cabinet of Ministers Regulation No.240 "General Regulations on Spatial Planning, Use and Construction" (Cabinet of Ministers, 2013b);	1. Law on Environmental Impact Assessment (Saeima, 1998a)	1. Cabinet of Ministers Regulation No. 559 "Regulations Regarding Permits for Increasing Electricity Production Capacities or the Introduction of New Production Equipment" (Cabinet of Ministers, 2020) 2. Construction Law (Cabinet of Ministers, 2014a) 3. Cabinet of Ministers Regulation No.500 "General Construction Regulations" (Cabinet of Ministers, 2014b)	1. Energy Law (Saeima, 1998b); 2. Electricity Market Law (Saeima, 2005); 3. Decision No 1/10 of the Council of the Public Utilities Regulatory Commission "Rules for System Connection to the Electricity Transmission System" (The Public Utilities Regulatory Commission, 2021) 4. Law on Regulators of Public Utilities (Saeima of Republic of Latvia, 2000)
Lithuania	1. Law of the Republic of Lithuania on Energy from Renewable Sources (Lietuvos Respublikos Seimas, 2011); 2. Law on Territorial Planning (Lietuvos Respublikos Seimas, 1995) 3. Law on Special Conditions for The Use of Land of The Lithuanian Republic (Lietuvos Respublikos Seimas, 2019)	1. The Law on Environmental Impact Assessment of Proposed Economic Activities (Seimas of the Republic of Lithuania, 2017)	1. Law of the Republic of Lithuania on Energy from Renewable Sources (Lietuvos Respublikos Seimas, 2011); 2. Law on Construction (Lietuvos Respublikos Seimas, 1996); 3. Law on Electricity (Seimas of the Republic of Lithuania, 2000)	1. Law of the Republic of Lithuania on Energy from Renewable Sources (Lietuvos Respublikos Seimas, 2011); 2. Law on Electricity (Seimas of the Republic of Lithuania, 2000)
Estonia	1. Planning Act (Parliament of Estonia, 2019);	1. Environmental Impact Assessment and Environmental Management System Act (Riigikogu, 2005)	1. Building Code (Riigikogu, 2015); 2. Electricity Market Act (Riigikogu, 2003); 3. General Part of the Economic Activities Code Act (Riigikogu, 2011)	1. Electricity Market Act (Riigikogu, 2003)
Finland	1. Land Use and Building Act (Finnish Parliament, 1999)	1. Law on the Environmental Impact Assessment Procedure 5/5/2017/252 (Finnish Parliament, 2017)	1. Land Use and Building Act (Finnish Parliament, 1999)	1. Electricity Market Act (Parliament of Finland);
Norway	1. Planning and Building Act (Ministry of Local Government and Modernization, 2021);	1. Regulations on Impact Assessment (Ministry of Climate and Environment and Ministry of Local Government and Modernization, 2017);	1. Planning and Building Act (Ministry of Local Government and Modernization, 2021)	1. Act on production, transformation, transfer, sale, distribution and use of energy (Energy Act) (Ministry of Petroleum and Energy, 1990);
Sweden	1. Planning and Building Act (Ministry of Finance, 2010); 2. Environmental Code (Ministry of the Environment, 1998)	1. Environmental Code (Ministry of the Environment, 1998)	1. Planning and Building Act (Ministry of Finance, 2010);	1. The Electricity Act (Ministry of Infrastructure, 1997)

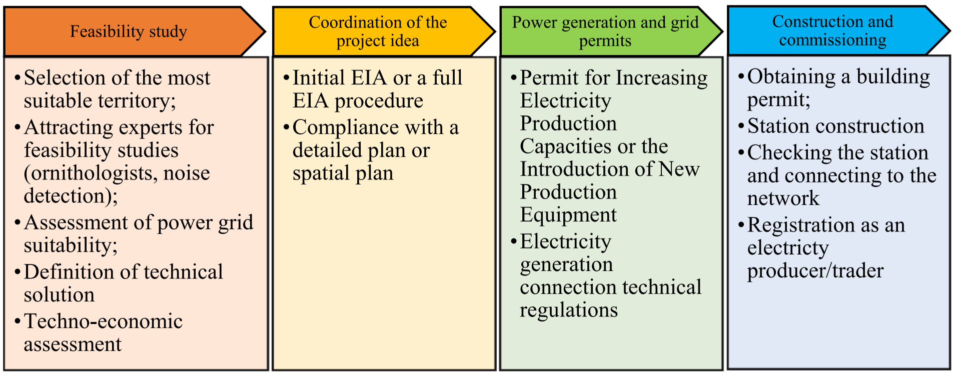

Fig. 4. General steps for RES project implementation and approval process (author's elaboration).

environmental and other public interests within the municipality (Swedish Energy Agency, 2020a), (Cross et al., 2015). Finnish municipalities can facilitate the development of WF by adopting a wind power-directing local master plan, in which most of the required environmental assessments have already been carried out (Bergmann, 2018).

In most cases, around three public consultations are carried out during the Initial EIA and EIA procedure (Saeima, 1998a) (Riigikogu, 2005), whereas, in the Lithuanian EIA procedure, five public consultations can be identified, as well as the possibility for the responsible authority to return the report several times for correction (Seimas of the Republic of Lithuania, 2017).

Once the EIA report has been approved and the installation of RES technologies has been agreed upon by the spatial plan in Latvia, Lithuania, a permit for the introduction of new power generation equipment must be obtained (Cabinet of Ministers, 2020), (Seimas of the Republic of Lithuania, 2000), (Rozentale and Blumberga, 2019). In Finland, power plants with an electrical capacity of at least 1 MVA must notify the Energy Agency of the power plant construction plan or the decision to increase capacity (Jaaskelainen et al., 2017).

The next step for WF and SPP installations is to obtain a building permit and start the construction works (Cabinet of Ministers, 2014a), (Lietuvos Respublikos Seimas, 1996), (Riigikogu, 2015). Microgeneration installations are often exempt from the obligation to obtain a building permit (Inderberg et al., 2018). For example, in Lithuania, SPP and WF with an installed capacity of up to 30 kW, not exceeding the noise level, can be installed on buildings or integrated into buildings without a building permit (Lietuvos Respublikos Seimas, 2011). In Estonia, where possible, the EIA procedure is combined with the Building Code procedures; in that case, the requirements of both procedures must be met (Riigikogu, 2015), (Jansone et al., 2012). The Land Use and Building Act of Finland states that a building permit for a WF may be issued if a legally binding master plan stipulates that the plan or part thereof is the basis for the building permit (Finnish Parliament, 1999).

In Sweden, if there is a plan to build something that requires building permission, the developer can apply for prior notification first to find out early on whether it is possible to build the project on the particular site (The National Board of Housing Building and Planning, 2020a; Noardo et al., 2022; Granath Hansson, 2017). A favourable prior decision gives the developer the right to carry out a particular measure on the site, provided that the developer applies for a building permit within two years (The National Board of Housing Building and Planning, 2020a). Before the construction works begin, the developer must apply for and wait for a decision on a building permit and planning permission (The National Board of Housing Building and Planning, 2020a).

Finland has a one-stop digital service portal, "Lupapiste", for managing building permits and other license-related services to allow municipalities to act according to the Land Use and Building Act; this service is scaled for the individual needs of municipalities, developers and others in the permitting procedure involved parties (Heiskanen, 2018), (Helander et al., 1012).

In Lithuania and Estonia, a permit for electricity generation must be obtained (Riigikogu, 2003), (VERT, 2019), (Pažėraitė et al., 2014). Before starting their activities, electricity producers or traders must register accordingly in a register of electricity producers or traders (Saeima, 2005), (Riigikogu, 2003), (Riigikogu, 2011). Electricity trading in Finland does not require a separate licence for trading activities, whereas, in Norway, a trading licence is required (Ministry of Petroleum and Energy, 1990), (The Energy Agency, 2021), (Banet, 2017).

In most countries covered by the study, small and medium-sized power plants with up to 10 MW capacity are connected to the DSO, while large power plants with capacities above 10 MW are connected to the TSO. In Lithuania, project developers must obtain a letter of intent to connect a power plant to the electricity grid (Lietuvos Respublikos Seimas, 2011), (Seimas of the Republic of Lithuania, 2000). The number of DSOs varies widely among the countries included in the study – Latvia 11; Lithuania 6; Estonia 34; Finland 77; Norway over 120; Sweden 170 (Paiho et al., 2021; GM. and Prettico, 2021; Sareen, 2020).

Norway is the only country in the study with a single point of contact - the NVE, which coordinates the development of SPP and WF and issues the necessary permits (Inderberg et al., 2019). The Swedish Energy Agency is currently working on setting up a digital contact point covering permits, exemptions and notification procedures for RES installations and their connection to the grid (Swedish Energy Agency, 2021).

3.2. *Obtained values of analysed criteria*

3.2.1. *Timeline for the project implementation*

Table 4 shows the duration of the standardised processes for the different RES projects, comparing the countries analysed. In Norway and Estonia, installing microgenerators is the most time-consuming due to the lengthy building permit process. The longest timeframes for large and medium-sized SPP are in Lithuania and Estonia and for WF in Lithuania and Sweden.

The estimated timeline for non-standardisable processes is based on the legislative framework and several assumptions, as the precise duration for such processes as EIA or changes in spatial planning documents is project-specific and within the same country can differ not only by days but by months. Nevertheless, because of the above, the authors have estimated the duration of each RES project by using the maximal timeframe.

The real-time it takes for a RES technology project development depends on different aspects; therefore, the implementation differs for each project. The performed case study analyses of 14 different solar and wind projects in different countries show that, on average, onshore wind projects take five years to complete (Eesti Energia Windaparks, 2011; Fortum to build; Paldiski Onshore; Raggovidda Wind Farm; Construction; The Sjisjka wind farm; The Windfarm; Windfarm Design). Solar PV development projects are mostly completed within 1–2 years (Atria expands Finland, 2021; Estonia's; Latvenergo starts; Nya Solevi; Solar collector).

3.2.2. *Complexity*

Table 5 shows the number of contact points (local and national authorities, agencies) involved in the project's implementation process and obtaining all necessary permits. The identified institutions are summarised in Appendix A, B and C. As can be seen, the number of contact points for installing microgenerators is limited to one or two authorities. The first authority is usually the local municipality or the municipal building authority. In all cases except Sweden, the second point of contact is the DSO, which coordinates the connection to the electricity grid. Finally, in the Swedish case, an electrical installer at an electrical installation company should be contacted for the connection establishment.

The number of contact points during the implementation process of SPP and WF projects overlaps in all the countries assessed. The most contact points are in the Baltic States, particularly Latvia. Norway is the only country in the study that has conceptually implemented the coordination process through a single contact point (Inderberg et al., 2019). The NVE is the central point of contact, but in some cases, the local municipality must be contacted to install smaller power plants (The Norwegian Water Resources and Energy Directorate, 2021a), (The Norwegian Water Resources and Energy Directorate, 2021b).

Identifying the exact number of institutions indirectly involved during the study was impossible, as they are not always listed in the legislation or other officially available information. It may be that, in considering whether to grant a permit, the authorities directly involved in the approval process themselves contact the authorities indirectly involved, who then give their opinion on environmental and technical aspects. The identified number of indirectly involved authorities is roughly the same in all the countries included in the study.

The number of documents required for implementing RES technologies was obtained from the analysis of legislation or found on the official web pages of authorities. The data is summarised in Table 5 and shows that developers in the Baltic States must submit more documents than developers in the Nordic countries. This difference could be because, in the Baltic States, the legislation lays down specific documents that need to be prepared and submitted to obtain permits. In contrast, the Nordic regulatory system does not require this; however, clarification on the required documents can be obtained by contacting the relevant authorities. Most often mentioned documents are

Table 4
Average duration (days) of different types of RES projects (2021).

	Standardisable processes Days			Non-standardisable processes, days			Estimated real project time, days	
Country	Microgeneration	SPP	WF	Microgeneration	SPP	WF	SPP	WF
Latvia	30	91	91	30	343	1676	300	3285
Lithuania	0	89	89	48	519	1878	365	2920
Estonia	60	165	165	30	720	1817	273	3650
Finland	14	58	180	30	720	1268	365	2920
Norway	0	103	154	90	638	822	365	1460
Sweden	70	70	100	90	430	1247	365	2920

Table 5
Number of contact points indirectly involved institutions and necessary documents for RES projects (2021).

Number of contact points				Number of indirect institutions			Number of necessary documents		
Country	Microgeneration	SPP	WF	Microgeneration	SPP	WF	Microgeneration	SPP	WF
Latvia	2	6	8	0	2	4	2	15	16
Lithuania	1	4	5	0	2	2	1	18	20
Estonia	2	4	5	1	2	2	2	17	30
Finland	2	4	4	1	1	2	1	3	7
Norway	1	1	1	2	3	3	1	4	4
Sweden	2	3	3	0	3	3	1	2	5

applications for issuance of the necessary permits - building permits; permits for energy production; permits for selling electricity; application and technical documentation for connection to the network, and EIA programs and reports. Installation of microgeneration equipment requires only a few documents that vary depending on the installation's technology, capacity, and location. For medium and large-scale SPP, WF, the number of documents required is quite similar, mainly depending on the constraints for the chosen site, as there are areas where additional permits are required.

3.2.3. *Information availability*

The information available about the RES project implementation process has been evaluated using a scale described in the Methodology section. The accessibility ratings were obtained by analysing the information available on each country's official websites and, where necessary, reviewing the legislation. The analysis aimed to find comprehensive and explanatory official information in one place. In particular, to find official and transparent information on the stages of the administrative process and the authorities to turn to, if necessary, to install RES technologies.

The results have been summarised in Table 6. As seen from the evaluation, the most comprehensive information about necessary permits and implementation processes can be found in Norway because the project development process for SPP and WF is managed by one contact point – the NVE (The Norwegian Water Resources and Energy Directorate, 2021a), (The Norwegian Water Resources and Energy Directorate, 2021b). Although Sweden does not yet have a single contact point system and the approval process for RES power plant development projects is the responsibility of the municipalities, comprehensive information on the implementation of SPP and WF projects can be found on The Swedish Energy Agency's website (Cross et al., 2015), (Swedish Energy Agency, 2019, 2020b, 2020c, 2020d, 2020e). Sweden has also developed a handy tool for using the Planning and Building Act, "PBL Knowledge Bank" (*Boverket*) (PBL knowledge bank, 2020), (The National Board of Housing Building and Planning, 2020b) which explains in great detail the application and interpretation of the Planning and Building Act depending on the activity to be carried out concerning territorial planning and construction.

The accumulated knowledge indicator is based on the number of implemented RES project capacities from 2015 to 2019 and the country's population (Estonia, 2022; Official statistics portal, 2020; Official statistics portal of Lithuania, 2022; IRENA, 2022a; IRENA, 2022b; Eurostat, 2022). If more RES projects are implemented, more knowledge and experience will be gained, which be helpful for future project development. Norway and Sweden have the best knowledge and experience. Estonia has seen the highest growth in installed capacity among the Baltic States in recent years, but this can still be considered low compared to the Nordic countries.

3.2.4. *Impact of public opinion and municipalities*

The impact of public opinion has been evaluated through two criteria – the number of public discussions regarding RES project implementation and the possibility of society to impact the implementation of the RES project. Since there is no public discussion about installing microgeneration technologies in the countries studied, these criteria were excluded from further analysis.

The summary of obtained criteria values can be seen in Table 7. The lowest societal impact of SPP has been identified for Latvia, where there

Table 6
Summary of qualitative evaluation on information availability (2021).

	Information availability evaluation			Accumulated knowledge, kW/ thousand inhabitants	
Country	Microgeneration	SPP	WF	SPP	WF
Latvia	2	2	1	2	5
Lithuania	3	2	2	12	35
Estonia	1	1	1	51	12
Finland	1	2	1	37	232
Norway	1	3	3	20	384
Sweden	2	3	3	60	280

Table 7
Overview of society and municipality impact evaluation (2021).

	Municipality impact evaluation		Society impact evaluation		Number of public discussions	
Country	SPP	WF	SPP	WF	SPP	WF
Latvia	3	1	0	2	0	3
Lithuania	3	1	3	2	1	5
Estonia	1	1	2	2	2	2
Finland	3	2	2	3	2	2
Norway	3	3	2	3	2	2
Sweden	1	1	2	3	1	2

is no necessity to organise public discussions regarding SPP installation. The highest social impact scores are found for WF in Finland, Norway, and Sweden, where the local population is well-informed and generally supportive of RES technologies, leading to higher installed capacities in these countries. We find this even though in Sweden, the municipality has a veto (Wretling et al., 2022) and in Norway, the municipalities and residents have informal rights to influence decisions about WF installation (Saglie et al., 2020).

Regarding the municipality impact, the highest score is attributed to SPP installation in Latvia, Lithuania, Finland, and Norway, where the local government has vast opportunities to listen to the project implementers and influence the project's progress (see Table 7).

3.3. Multi-criteria analyses results

The obtained criteria values have been normalised and weighted according to the methodology described in Section 2.2.

Fig. 5 shows the multi-criteria decision analysis results for different technologies. Regarding microgeneration, Lithuania scored the highest among all countries because of the Law of the Republic of Lithuania on Energy from Renewable Sources (Lietuvos Respublikos Seimas, 2011) which clearly describes the regulatory framework for microgeneration installations - capacity limits, simplified installation process in terms of territorial and building permits. Such a legislative act summarising regulation for RES technologies can be seen as a facilitating factor for developing and installing RES technologies and contributes to the transparency of the processes. Finland has the second-highest score, while Sweden is not far behind. According to the multi-criteria decision analysis, Latvia scores the lowest in implementing microgeneration projects.

Nordic countries have obtained the highest rank for large and average size SPP- Sweden and Norway with the highest score, followed by Finland due to the lower number of contact points for the necessary permit receiving and the high information availability. The Baltic States have received the lowest results, with Lithuania behind Finland, Latvia, and Estonia. Estonia is ranked lowest because SPP projects can be subject to EIA compared to other countries, and a change in spatial plans is required. As for WF, the assessment results show higher scores for the Nordic countries, as fewer institutions are involved in the implementation process and shorter project implementation periods. Also, the implementation of WF projects in Norway is smoother due to the optimised permitting processes.

4. Conclusions and policy implications

Administrative procedures and the regulatory framework should be adapted to the potential target audience to avoid unnecessary administrative barriers– generation of electricity for private use (including small power plants) through microgeneration; small and medium capacity power generation facilities providing electricity for enterprises or community; large capacity plants designed to generate income from the sale of electricity. Such an approach could help to increase the share of electricity generated from RES in different sectors.

The study compares the implementation process of different capacity SPP and WF projects in Baltic and Nordic countries by considering 11 criteria and applying multi-criteria decision-making methods. The comparison has been made by considering the project implementation timeline, complexity, information availability, and the impact on local society and municipalities. In addition, the number of contact points, public information available, and the number of documents necessary for the project's approval have been identified as the primary evaluation criteria.

4.1. Microgeneration

The study evaluated the information on installing microgenerators and found little difference in administrative procedures. Installing a microgenerator is between one and three months, indicating a simplified process for installing and connecting microgenerators to the grid. The comparative part of the research has shown that Lithuania has the most favourable administrative conditions for installing microgenerators of all the countries included in the study and the highest permitted capacity of microgenerators of all three Baltic States. Installing a microgenerator is not restricted by spatial planning restrictions and does not require a building permit. In other countries, on the other hand, a building permit or notification from the authority responsible for construction may be required.

The analysis shows that the Baltic States classify equipment as microgenerators with a much lower capacity than the Nordic countries. Therefore, given the recent increase in electricity prices (European Commission, 2021), the installed capacity of a microgenerator in a household may not be able to cover the amount of electricity consumed. Thus, the authors suggest 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 the DSOs on the requirements for connecting microgenerators to the power grid and the process descriptions can be evaluated as comprehensive and helpful. However, the study found that the general information on installing WF and SPP microgenerators is incomplete in almost all countries covered. Guidelines on the administrative procedures for installing microgenerators or small-scale WF and SPP (for each technology separately) with explanatory information on the administrative process and specific requirements would improve transparency and potentially speed up the

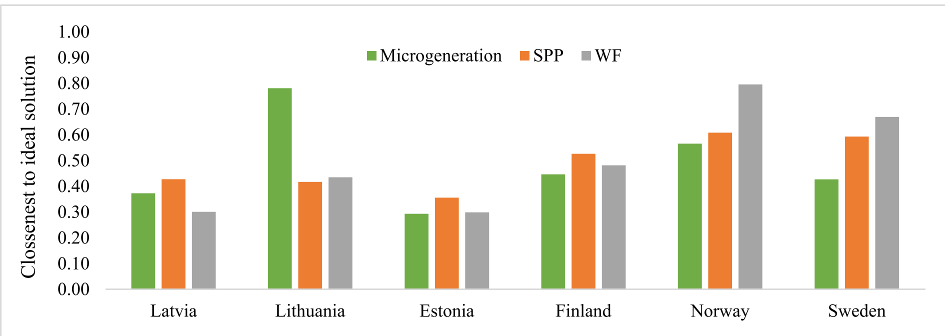

Fig. 5. Multi-criteria analysis results for different RES projects (author's elaboration).

process.

4.2. Medium and large-scale onshore wind and solar PV installations

Article 16 (1) of the RES Directive (European Parliament and the European Council, 2018) proposes that Member States establish one or more single points of contact where developers of RES projects can obtain the necessary advice and permits in one place without going to other authorities. Establishing a single point of contact also complies with the objectives and measures to be carried out under the National Energy and Climate Plan of Latvia and Lithuania (Ministry of Economics, 2020), (Government of Lithuania, 2020).

Authors recommend following the example of the Swedish and Norwegian Energy Agencies, which maintain detailed information on the deployment of RES technologies, the administrative process and the regulatory framework (Cross et al., 2015). Therefore, the establishment of single points of contact under national energy agencies or municipalities administering permits and licences should be considered, as both the literature analysis and the study have confirmed that it accelerates the pace of RES project deployment (Schumacher, 2019), (González et al., 2020), (Polzin et al., 2015).

The case studies conducted in the Baltic States revealed a high public resistance to installing RES technologies, possibly based on misinformation and stereotypes regarding SPP and WF. Energy agencies could be the national organizations in the Baltic States to promote confidence in solar and wind energy through transparent and trustworthy explanatory information (Polzin et al., 2015).

Municipalities are responsible for ensuring that the location of WF or SPP complies with existing spatial planning, issue building permits and are involved in the EIA process, which is a large part of the project implementation process. Given the relative lack of explanatory information on the websites of public administrations in the Baltic States, the authors recommend following the example of Sweden and Norway and publishing more comprehensive and explanatory information about the administrative procedures for installing RES technologies.

Information about the necessity and the conditions for issuing building permits was one of the most challenging parts of the administrative procedure in all the countries studied, except for Sweden. To improve the administrative process related to the construction process, the authors suggest setting specific requirements for the installation of RES technologies (Polzin et al., 2015), in this case specifically SPP and WF, making the rules related to the construction process more understandable and transparent (Cross et al., 2015), (Leiren et al., 2020). Alternatively, explanatory information about the rules and the correct interpretation of the legislation can be made publicly available (Silva, 2022), (Kudurs et al., 2020), as in the handbook produced by The National Board of Housing Building and Planning of Sweden (*Boverket*), which explains how the Planning and Building Act should be interpreted (The National Board of Housing Building and Planning, 2020b).

The study did not find the reasons and practical necessity of the permit for introducing new generation equipment that must be obtained in Latvia and Lithuania, nor the criteria considered when assessing whether such permits should be granted (Rozentale and Blumberga, 2019). According to the authors, such a permit could therefore be combined with an application for grid connection, included in a building permit, or if a single point of contact is created, the need for such a permit could be automatically integrated into the overall coordination of SPP or WF project implementation.

In order to collect and compile the necessary information, a large number of documents in several languages (Latvian, Lithuanian, Estonian, Finnish, Swedish, and Norwegian) had to be analysed. This process was particularly challenging for the Baltic States, as almost all process schemes and stages had to be developed from scratch as a primary source using legislation. It was not always clear how to interpret the legislation appropriately, especially regarding procedures for obtaining building permits for installing SPP and WF. Another limitation is that spatial planning regulations in the countries covered by the study could differ from municipality to municipality, so the sequence and duration of the implementation process may vary. For this reason, the study was generalised at the national level and not at the municipal level. Another limitation is that the study was conducted in 2021, ending just before the geopolitical crisis in Ukraine escalated in February 2022, which led to a significant increase in fossil fuel energy prices. The dramatic increase in energy prices was followed by rapid legislative amendments that simplified the requirements for installing SPP and WF and a sharp increase in households installing SPP for self-consumption, which increased the installed RES technology capacity in the countries covered by this study.

4.3. Further research

The article contains detailed analyses of the administrative process of the RES project implementations. However, further research would be needed to determine whether the required permits and the complex permitting process are the main barriers to increasing the share of solar and wind energy in the Baltic States. A deeper understanding of the bottlenecks could be gained through the number of applications received for installing RES technologies at each stage of project implementation; the rejections received and the reasons for rejections, and the need to correct the resubmission application. In this way, it would be possible to identify the most delayed stages of the administrative process and analyse their reasons. In-depth interviews with staff of the responsible authorities could provide insight into all the nuances of the administrative process and the authorities indirectly involved. Future studies should also investigate whether the legislation of the Baltic States includes well-formulated provisions for the final stage of WF and SPP, i.e., decommissioning.

The analyses of historical and existing support measures for WF and SPP are out of the scope of this study. However, the complex assessment of administrative barriers and support measures could provide additional examples of good practices for implementing RES.

The existing legislation and administrative procedures for developing RES projects in the Baltic and Nordic countries are changing and evolving rapidly, so an up-to-date analysis of the actual situation should be conducted in due course.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: Krista Laktuka reports financial support was provided by European Social Fund.

Data availability

Data will be made available on request.

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Appendices

Appendix A
Summary of involved institutions for microgeneration project implementation

Country	Contact points	Indirectly involved institutions
Latvia	County Construction Board – DSO	
Lithuania	DSO	
Estonia	Local municipality DSO	Local building authority
Finland	Local municipality DSO	One licence point
Norway	Local municipality DSO	
Sweden	Local municipality Electrical installation company	The Planning and Building Agency

Appendix B
Summary of involved institutions for average and large-scale solar power plant project implementation

Country	Contact points	Indirectly involved institutions
Latvia	Ministry of Economics – Local building authority – The State Inspection for Heritage Protection – Public Utilities Regulatory Commission – DSO or TSO – Local municipality	Civil Aviation Agency Ministry of Defence
Lithuania	The National Energy Regulatory Council – DSO or TSO – Local municipality – Local building authority	The Lithuanian National Commission for Cultural Heritage Lithuanian Armed Forces
Estonia	Local municipality – DSO or TSO – Environmental Board – The Competition Authority – JSC Elering	Geologists The Ministry of Defence The Register of Economic Activities
Finland	Energy Market Authority – The Energy Agency – The Ministry of the Environment – Local building supervision authority	The Centre for Economic Development, Transport and the Environment The regional environment centre, the regional council and the local authority
Norway	The Norwegian Water Resources and Energy Directorate (NVE) – Local municipality – Statnett – DSO	The Ministry of Petroleum and Energy
Sweden	Local municipality or region – Municipality’s building committee – Electrical installation company registered with the Swedish Electrical Safety Agency	The National Board of Housing, Building and Planning Energy and climate advisor DSO

Appendix C
Summary of involved institutions for average and large-scale wind farm implementation

Country	Contact points	Indirectly involved institutions
Latvia	Ministry of Economics – Local building authority – DSO or TSO – Public Utilities Regulatory Commission – Local municipality – The State Inspection for Heritage Protection – Environment State Bureau – State Environmental Service	Ministry of Defence Civil Aviation Agency State Environmental Service regional environmental board
Lithuania	State Energy Regulatory Council – DSO or TSO – Local municipality	Commander of the Lithuanian Armed Forces Minister of Health of the Republic of Lithuania
Estonia	Local municipality – JSC Elering – Environmental Board – The Competition Authority	Eight different Ministries Geological surveys
Finland	The Energy Agency – The Ministry of the Environment – Local building supervision authority – DSO or TSO	The Centre for Economic Development, Transport and the Environment The regional environment centre, the regional council and the local authority
Norway	The Norwegian Water Resources and Energy Directorate (NVE)	Pollution authority
Sweden	Local municipality or region – County Administrative Board – The Swedish Environmental Protection Agency – Municipality's building committee – Electrical installation company	The municipal board City Council Municipality's environmental and health protection board DSO

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Driving Sustainable Practices in Vocational Education Infrastructure: A Case Study from Latvia

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Abstract: A vital component of achieving climate neutrality in the future involves bolstering energy efficiency measures in educational institutions and improving the overall knowledge on sustainable solutions. To achieve fruitful outcomes, the active involvement of various stakeholders, such as managers, teaching staff, and students, is indispensable. By implementing energy-efficient building systems, advancing the use of renewable energy sources, and incorporating sustainable practices into the curriculum, educational institutions can decrease their environmental impact and conserve resources for future generations. Active participation from all stakeholders, including managers, teaching staff, and students, is essential for the success of these efforts. Providing students with a comprehensive education on sustainability equips them to apply this knowledge in their future professions, thus contributing to a more sustainable society. To gain insights into the existing state of sustainability within educational systems, a comprehensive study of educational institutions was undertaken. To assess and compare schools' sustainability, a composite indicator was developed. The study's findings reveal that the implementation of mandatory and optional measures can lead to a substantial reduction in primary energy consumption by 39% and greenhouse gas emissions by 34% in educational institutions. The average abandonment costs for mandatory measures are 5.87 EUR/kgCO_2/year, but the average value for optional measures is 33.80 EUR/kgCO_2/year. It is suggested demonstration projects be implemented in institutions where specialists in RE, mechatronics, building engineering systems, and environmental technologies are trained by showcasing technologies needed for the transition to climate neutrality.

Keywords: composite indicator; energy efficiency; environmental impact; greenhouse gas emissions; optimization; policy; primary energy consumption; renewable energy; survey

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1. Introduction

The Sustainable Development Goals (SDGs), adopted by the United Nations (UN) in 2015, include SDG 4 on education. Other goals, such as SDG 7 on affordable and clean energy, SDG 11 on sustainable cities and communities, and SDG 13 on climate action [1], mutually influence sustainable education and building energy consumption. Furthermore, the Paris Agreement, adopted in 2015, strives to reduce the global temperature rise to 1.5 degrees Celsius above pre-industrial levels, with 2 degrees Celsius being the maximum level allowed [2]. Reducing emissions is significant to achieving this goal, and buildings were responsible for 27% of the total energy sector emissions in 2021 [3].

Nevertheless, sustainable education empowers students with the knowledge, values, and skills required for informed decision making and enhancing quality of life while ensuring the needs of future generations [4], and can thus significantly impact the move towards climate neutrality [5,6]. However, only in recent years has the role of education been emphasized in the context of achieving climate goals [7]. Improved sustainability requires significant transformations in organizations, supply chains, and communities, and this can only be achieved through continuous learning and innovation [8]. Therefore, a strong vocational education system can provide many benefits, such as supporting green growth and boosting labor productivity [9]. A heightened understanding of climate change can inspire students to actively engage in carbon neutrality education, and this result is facilitated by environmental responsibility [10–12]. Teachers can leverage this information to enhance students' comprehension of the impact of climate change and inspire them to embrace energy-conserving behaviors through educational initiatives that raise environmental consciousness [11].

In addition to promoting sustainable education, educational buildings themselves play an essential role in reducing primary energy consumption and providing a sustainable and motivating learning environment [13]. They have the potential to make a significant impact on reducing greenhouse gas emissions (GHGs) through energy efficiency measures and renewable energy (RE) production [14,15]. Various studies have analyzed the potential energy savings achievable in educational buildings. For example, implementing energy rehabilitation in educational buildings in Spain resulted in a 66% reduction in non-renewable primary energy consumption and a 71% reduction in CO_2 emissions [16]. A multi-objective optimization of scenarios, including district heating and ground-source heat pumps in combination with photovoltaic panels (PVs), provides multiple cost-optimal solutions while resulting in a primary energy consumption equal to or below 170 kWh/m^{2}a [17]. However, investment costs and energy tariffs significantly impact Pareto optimality in energy efficiency and energy production measures [18]. An improvement in building energy consumption grade from level G to B can be achieved through a combination of energy efficiency measures, such as external insulation of building envelopes and installation of new windows and doors, with RE production measures such as PVs, biomass heating systems, combi-solar systems, and replacement of lighting appliances [19]. In a case study of the Kazakh-German University in Almaty, Kazakhstan, retrofitting measures were found to reduce CO_2 emissions by 48–82%. [20]. In general, educational buildings have great potential as locations where GHG emissions can be reduced through energy efficiency measures and RE utilization.

This research paper explores ways to increase sustainability in Latvia's vocational education buildings through a composite indicator with a specific focus on reducing energy consumption in buildings, increasing the use of RE and providing a sustainable learning environment. Through an examination of 23 educational institutions, the current state of energy management in the educational system is analyzed and optimization of energy efficiency and RE production measures is performed. The composite indicator is used to rank and compare educational institutions based on the selected cost-effective measures and survey results. The research findings provide valuable insights for policymakers and educational institutions hoping to implement sustainable practices and contribute to a more sustainable society.

2. Methodology

The research methodology (see Figure 1) consisted of three key components: an analysis of energy consumption, on-site visits, and surveys, determining the energy efficiency and RE production potential, optimization, and the ranking of professional schools using a composite indicator. The analysis of energy use revealed the current level of energy efficiency in educational institutions and pointed out areas for potential development. Information was gathered about the educational institutions' current energy efficiency practices, RE sources, and environmental policies through on-site visits and surveys. Each institution consisted of several buildings, e.g., study buildings with classrooms, kitchens, workshops, dormitories, sports halls, and administration buildings. Each building had a unique construction project with a different area, location, enclosing structures, and engineering communication systems. Most of the buildings were renovated, but four were newly built. The building area ranged from less than 200 m^2 to 12,555 m^2 for large educational buildings. Therefore, individual energy efficiency assessment was necessary to identify potential sustainability measures.

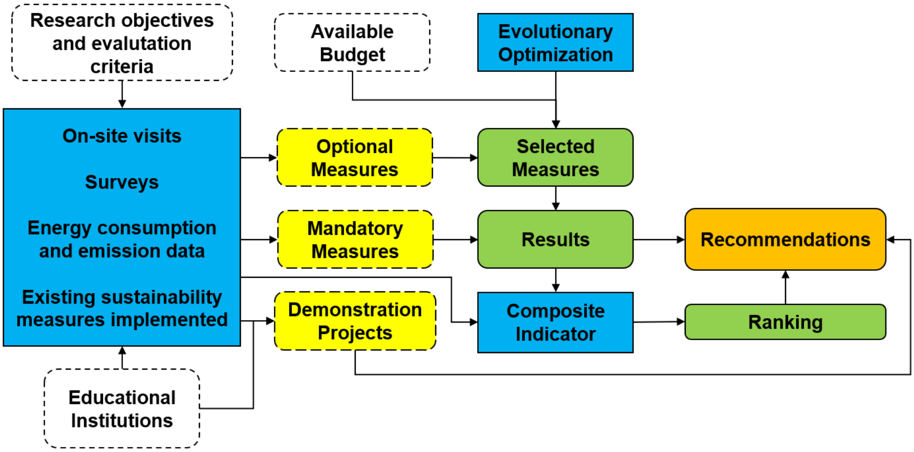

Figure 1. Research methodology.

From the on-site visits, survey results, and energy consumption and emission data, potential measures were identified. The recommended measures were split into two groups: mandatory and optional. In addition, innovative demonstration projects were suggested to schools that have specific educational programs (e.g., building construction technicians, heat supply and heating systems technicians, car mechanics) to demonstrate innovative solutions for building energy efficiency, installation of RE systems, development of electric vehicles, and similar future technologies.

Further, the energy efficiency and sustainability measures were optimized to select the best available measures due to the limited available budget of vocational education institutions. The potential reduction in total primary energy consumption (both renewable and non-renewable) and annual emissions were calculated for the identified measures. These, when merged with the survey results, were used in a compositive indicator to determine the educational institutions in which measures should be implemented with higher priority. Based on the survey results and developed demonstration projects, the recommendations were given.

This methodology provides a thorough overview of the existing sustainability situation in Latvia's vocational education system and proposes viable solutions for lowering energy consumption, increasing the usage of RE sources and improving the overall quality of education related to future energy systems.

2.1. Data Gathering

Detailed data were collected to evaluate the energy consumption patterns within the educational institutions and their sub-departments. This comprehensive data set included information from 167 buildings across all 23 educational institutions and constituted building area, monthly heat, and electricity consumption from 2017 to 2022, as well as the source of heating and electricity for each building.

Figure 2 summarizes the obtained energy consumption data for the analyzed educational buildings. The specific energy consumption for most of the buildings was in the range of 48 to 93 kWh/m^2/year, which indicates relatively high energy efficiency. Only for 30% of buildings was the specific energy consumption greater than 100 kWh/m^2. The preliminary data analyses indicated that most of the buildings had already gone through complex renovation measures, and to further improve the overall efficiency of buildings, it is necessary to identify other potential energy-saving activities, for which the methodology is described below.

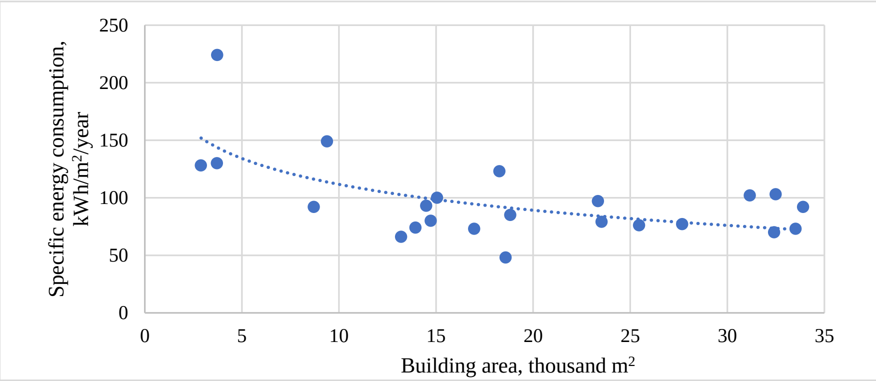

Figure 2. Regression analyses of building-specific energy consumption in relation to total building area.

2.2. On-Site Visits and Survey

The evaluation of educational institutions was performed through on-site visits. During these visits, a survey was given to each educational institution's representative. The survey consisted of identical questions for each educational institution prepared according to the methodology described by [21].

The survey comprised four distinct categories of questions:

(1) Energy use and behavior;
(2) Environmental policy and education;
(3) Main electricity consumers;
(4) Energy efficiency and production measures that have been implemented thus far.

The questionnaire was designed to elicit both technical information on the primary energy consumers in buildings and their operational conditions, as well as more general information on organized environmental activities, environmental topics integrated into educational programs, waste management, and the engagement of teaching staff in sustainability initiatives.

Responses were quantified using a binary scoring system, with positive answers earning a score of 1 and negative answers earning a score of 0 [22]. This systematic approach provided an understanding of the current energy and environmental management practices within educational institutions, which allowed the selection of possible primary energy consumption reduction measures.

2.3. Sustainability Measures

The selection of sustainability measures was based on a comprehensive literature review analysis, energy consumption data, building energy audits, on-site visits, and surveys carried out at each educational institution. To address the identified problems in most educational institutions, similar solutions need to be employed, while individual measures should be tailored accordingly. Various measures can be divided into two groups: (1) measures similar to the majority of educational institutions (mandatory measures), and (2) individual measures (optional measures). Given the available funding, the first group of measures takes priority for financing, while the allocated funds for the second group of measures represent the difference between the total funding amount and the required funding for the first group. The prioritization of the optional measures is determined through the optimization technique described in the next section. This approach resulted in a targeted selection of cost-effective measures, maximizing their impact on a reduction in energy consumption and a decrease in GHG emissions. The main identified measures are described below.

Further, a cost–benefit analysis was performed to identify measures by quantifying the potential energy savings and necessary investment costs. Table 1 summarizes the cost assumptions for the main identified energy measures.

Table 1. Overview of cost assumptions for main identified measures.

Energy Efficiency Measure	Specific Costs	Source
Appointment of an energy management employee and training	1173 EUR/year	[23]
Introducing a building management system	7.6 EUR/m^2	[23]
Implementation of environmental policy	1000 EUR per building	Survey results
Indoor temperature control	0	Building energy audits
Informative materials	0.01 EUR/m^2	[24]
Mechanical ventilation with recuperation	30 EUR/m^2	[23]
Modernization of lighting	8.9 EUR/m^2	[25]
Wall insulation (inside)	from 9 to 60 EUR/m^2	Building energy audits
Roof insulation	from 0.3 to 2.7 EUR/m^2	Building energy audits
Plinth insulation	4.3 EUR/m^2	Building energy audits
Window replacement	from 28.9 to 88.8 EUR/m^2	Building energy audits
Replacement of heating elements with thermoregulators	7.4 EUR/m^2	Building energy audits
Replacing the heat exchanger	0.03 EUR/m^2	Building energy audits
Renovation of the heat substation	0.8 EUR/m^2	Building energy audits
Installation of new boilers	3.6 EUR/m^2	[26]
Solar collectors	1169.8 EUR/m^2	[26]
Installation of solar panels	308.2 EUR/m^2	[26]
Connection to the district heating network	24.5 EUR/m^2	[26]

2.4. Optimization

The optimization of optional measures was carried out on Microsoft Excel Spreadsheet Software [27] using a data solver tool, with an evolutionary optimization technique [28]. Evolutionary optimization refers to a group of algorithms developed after a biological evolution, following natural selection, reproduction, and mutation [29]. It works by having a set of candidate solutions to a problem and applying operations that resemble natural evolution selection, recombination, and mutation to produce new solutions. The objective is to discover the optimal solution to the problem by repeatedly enhancing the set of candidate solutions through these operations [30]. The optional measures were represented as binary variables, with a value of 1 indicating that the measure has been applied and a value of 0 indicating otherwise. This is called binary decision making [31]. The optimization aims to maximize the reduction in primary energy consumption. The available budget was EUR 19.14 million. This budget was divided into three parts: EUR 203 thousand for demonstration projects, EUR 10.4 million for mandatory measures, and EUR 8.54 million for the optimization of individual measures. The objective of the optimization was to determine the most effective combination of available optional measures that would reduce energy consumption while staying within the EUR 8.54 million budget constraint.

Ranking Educational Institutions

The ranking of the 23 educational institutions was performed with a composite indicator, using a Simple Additive Weighting (SAW) technique that considered three critical factors. A factor can be considered a "Benefit attribute" if an increase in its value is desirable, and a "Cost attribute" if otherwise [32]. These factors were as follows:

- The number of survey points achieved during an on-site visit, which is a benefit attribute and given a weight of 0.1;
- The reduction in primary energy consumption per euro invested; this is a benefit attribute, and was assigned a weight of 0.45;
- The required investment in euros to reduce annual emissions by one kilogram; it is a cost attribute, and was also given a weight of 0.45.

By taking these three criteria into account and weighting them, an overall ranking of the educational institutions was performed, providing an objective evaluation.

The SAW method is a multi-attribute decision-making procedure that is based on a weighted summation of the normalized values for each alternative on all criteria [33]. The objective is to find the highest score, and therefore the best alternative. This method normalizes the decision-making matrix to a comparable scale. This method is mainly used to solve multi-criteria decision-making problems.

A decision matrix is an $(m \times n)$ matrix in which each element x_{ij} represents the value of alternative A_i based on the decision criterion C_j. The alternatives are represented by $i = 1, 2, 3, \ldots, m$ and the criteria are represented by $j = 1, 2, 3, \ldots, n$. Each element has a numerical weight w_j assigned for each criterion [33,34].

The first step is to normalize the decision matrix using Equation (1) for the benefit attribute and using Equation (2) for the cost attribute [33].

$$r_{ij} = \frac{x_{ij}}{Max\left(x_{ij}\right)}, \quad (1)$$

$$r_{ij} = \frac{Min\left(x_{ij}\right)}{x_{ij}}, \quad (2)$$

where r_{ij} is the normalized value of the i^{th} alternative for the j^{th} criterion.

The overall score for each alternative is calculated by multiplying the normalized data for each criterion by its weight. The weight is subject to constraints in Equations (3) and (4). The result of the overall score is shown in Equation (5) [33].

$$\sum_{j=1}^{n} w_j = 1, \quad (3)$$

$$0 \leq w_j \leq 1, \quad (4)$$

$$S_i = \sum_{j=1}^{n} w_j r_{ij}, \quad (5)$$

where S_i is the overall score of the i^{th} alternative.

The alternatives are ranked based on their overall scores, with the alternative with the highest overall score being the best [33].

3. Results

3.1. Applied Measures

The on-site visits and survey results indicated that most educational institutions face similar issues. During the on-site visits, renovation and improvement points were identified, and measures were chosen appropriately, taking into consideration the needs and specifics of each institution. The most common measures are described below.

Appointment of energy managers and introduction of the EMS

Each educational institution has an employee responsible for energy systems and engineering communications. During visits, it was observed that these employees have varying levels of knowledge about energy conservation and the operation and regulation of different systems. The motivation to save energy also varies among these employees. On the other hand, in other institutions, a lack of motivation correlated with a lack of knowledge.

The appointment of energy managers would allow the achievement of significant energy savings and determine those responsible for energy system maintenance and implementation of energy-saving activities. Defining and implementing the functions of the energy manager require a change in attitude and management processes. For now, the technical staff in educational buildings are mainly responsible for the smooth operation of equipment without the goal of seeking energy efficiency improvements. If possible, there should be a motivation system based on linking the obtained energy savings with remuneration. Alternatively, it would be possible to introduce an energy manager position in the responsible ministry, who would oversee the energy management of all institutions. The creation and implementation of an EMS would ensure a 15–30% reduction in energy consumption in those educational institutions where the functions of the energy manager or BMS have not been implemented. In other institutions, energy savings could reach 5–10%.

Introduction of a BMS

Only some educational institutions have installed building management systems (BMSs) that allow for obtaining energy consumption data, analyzing them, and taking measures to reduce energy usage. In most educational institutions, heating radiators are only partially equipped with thermostatic regulators. This is either because they are not installed due to system incompatibility and the need for system reconstruction, or because they are installed but students remove the thermostat heads. In some educational institutions, it is necessary to replace old heating substations with new ones to enable automatic heating regulation.

According to the European standard [35], BMSs are divided into four categories: A—high energy efficiency control; B—semi-optimized control; C—standard control; D—no automation. A class A BMS can provide a 30% reduction in energy consumption in those educational institutions where no energy manager functions or no BMSs have been implemented (compared to class D), but in other institutions, it results in 20% savings (compared to class C).

This measure should be carried out together with the creation of an EMS since the BMS is a tool that ensures the daily operation of the energy manager, as many functions are performed automatically, and the number of man-hours required for manual work is significantly reduced.

Improving the operation of the mechanical ventilation system

The use of mechanical ventilation systems in some educational institutions poses difficulties, and in some they are only partially utilized. Challenges include increased noise levels that disrupt the educational process, high costs, lack of information about daily usage, physically inaccessible equipment, improper use of air filters, and the inability to operate the systems in individual rooms while others are occupied.

In educational buildings where mechanical ventilation systems are installed, an audit should be carried out to assess the difficulties encountered by building users when using equipment and find a solution to eliminate them (e.g., installation of air silencers, air pre-filters, a frequency converter on the supply and exhaust fans). Some of the recommended measures do not reduce energy consumption, but they are essential to achieving optimal air quality in the classrooms. Energy savings can be achieved through several improvements in ventilation systems:

- Installation of a heat utilizer: a 50% reduction in heat consumption for ventilation;
- Training of personnel, preparation of technical information and instructions for use: depending on the situation, energy consumption may decrease or increase, since it depends on how the equipment has been used before (if it is used rarely, then consumption may increase, by improving indoor air quality; if it is used inappropriately, then energy consumption may decrease);

- Provision of access to ventilation units: depending on the situation, energy consumption may decrease or increase, as it depends on how the equipment has been used in the past;
- Installation of valves in each of the rooms that provide variable airflow, depending on the level of CO_2 in the room, and a frequency converter on supply and exhaust fans: it is possible to achieve a 30% reduction in energy consumption for ventilation in those educational institutions where the functions of an energy manager have not been performed or there is no BMS, and in other institutions, the savings could reach up to 20%. If a BMS is installed, this measure does not need to be carried out separately.

This measure should be taken simultaneously with the establishment of an EMS for buildings and the introduction of a BMS.

Replacing lighting bulbs with LED bulbs

In most educational institutions, only a partial transition has been made from traditional light bulbs to LED lights. Some institutions gradually replace them using accumulated funds.

In all educational institutions where this has not been carried out, it is necessary to replace the inefficient light bulbs with LEDs and carry out the installation of light sensors in places where it is needed. Replacing light bulbs will reduce the total electricity consumption by 10% if 50% of the bulbs in the institution need to be replaced.

Installation of solar panels

Solar energy technologies have been installed in several educational institutions, but only one institution utilizes them for energy generation, while the others do not use them. Therefore, in all educational institutions, where the roof structures of buildings allow it, solar panels should be installed to cover part of the building's electricity consumption. The installation of solar panels will reduce the primary energy factor from 2.5 to 1 and reduce the CO_2 emission factor from 109 g CO_2/kWh to 0 gCO_2/kWh [36].

Establishing an environmental policy

Environmental policies or their elements have been partially implemented in some educational institutions, while the majority have not implemented them. Environmental issues are incorporated into various subjects in some educational institutions.

It is necessary to establish an environmental policy and a plan for its implementation, which determines how various measures related to environmental aspects are implemented in an educational institution, reducing the overall environmental impact of the educational institution. The existence of an environmental policy demonstrates to learners, employees, and the public that it is an environmentally friendly institution that understands and demonstrates its responsibility for reducing its impact on the environment. This includes three aspects:

- Whether the learners in the educational institution have a healthy and sustainable quality of life (e.g., indoor microclimate and air quality, food quality, outdoor quality).
- How well the educational institution prepares learners for work in the 21st-century economy, which is on the way to climate neutrality, and ensures the development of learners' citizenship to live in a world where the challenges and opportunities related to environmental problems are increasingly gaining importance.
- How environmentally friendly the policy of the educational institution is (e.g., with respect to energy consumption, waste management, water circulation, preservation of biodiversity, environmentally friendly habits, reduction in impact on climate, adaptation to climate change).

This measure would reduce energy consumption, which depends on the behavior of individuals, such as their water consumption, use of a bicycle or public transport as opposed to a car, and room temperature regulation, as well as reduce environmental pollution by reducing the amount of waste, impact on biodiversity, air pollution, etc.

The mandatory measures for each of the 23 educational institutions comprised several components aimed at increasing energy efficiency and reducing the environmental impact of the institutions. These measures included the introduction of an EMS and appointment of an energy management employee, the installation of a BMS, implementing PVs, providing informative materials on-site highlighting energy-saving measures, and the adoption of an environmental policy. These mandatory measures aim to create a more sustainable and environmentally friendly environment for educational institutions while reducing their energy costs.

The optional measures were tailored to the individual needs of each educational institution and aimed to further increase energy efficiency and reduce energy consumption. Some of the specific measures included upgrading the lighting system, modernizing the boiler house, adding insulation to the attic and inner walls, switching from individual heating to more efficient district heating, installing a ventilation system, transitioning from natural gas to renewable biomass in the boiler house, and renovating the heating unit. These measures offered additional opportunities for the institutions to decrease their environmental impact and conserve resources for future generations. The applied optional measures are provided in Figure 3.

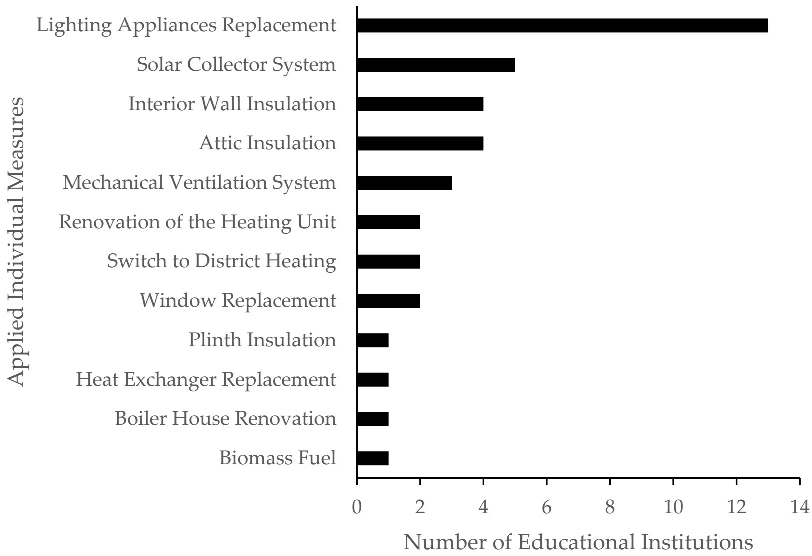

Figure 3. The number of implemented optional measures in educational institutions.

Figure 4 shows the comparison of calculated primary energy savings per necessary investments for different analyzed educational institutions. The mandatory energy efficiency measures led to higher energy savings per capital investment due to improved energy management, which does not require high financial support. The average energy savings from these activities would bring 1.99 kWh/year/EUR invested. However, the same value for optional measures is 0.6 kWh/year/EUR, showing that the identified measures would require a higher amount of investment to reach the same energy savings compared to mandatory measures. For some buildings, the energy savings are even negative due to the installation of mechanical ventilation, which would require extra energy consumption but, on the other hand, would improve the overall air quality.

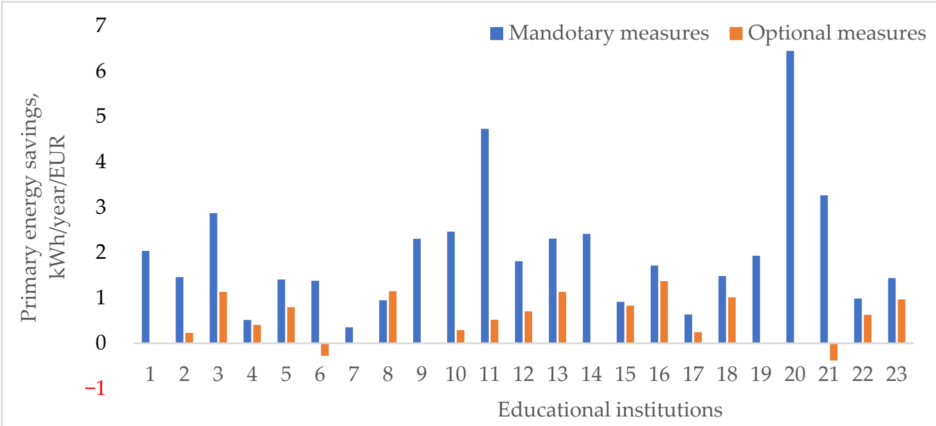

Figure 4. Comparison of primary energy savings from mandatory measures and optional measures.

The results for the indicated CO_2 abandonment costs can be seen in Figure 5. Emission reduction can be achieved through energy consumption reduction and the installation of RE technologies. The average abandonment costs for the mandatory measures are 5.87 EUR/kgCO_2/year, but the average value for optional measures is 33.80 EUR/kgCO_2/year.

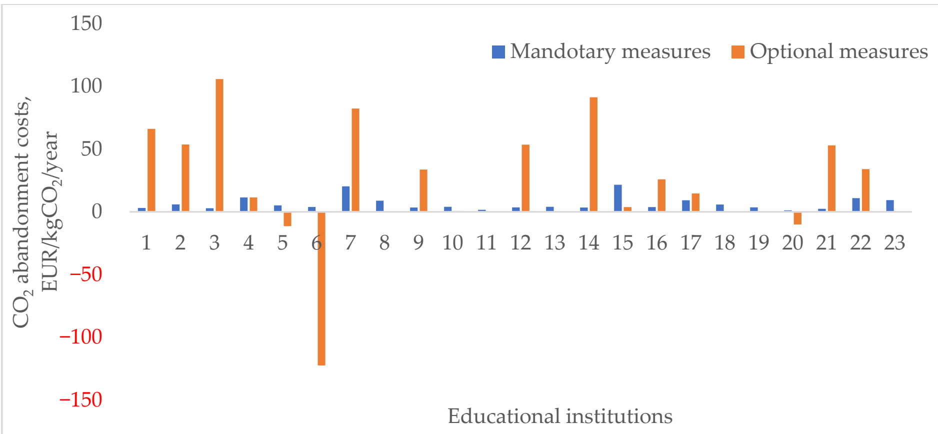

Figure 5. Comparison of CO_2 abandonment costs for mandatory measures and optional measures.

3.2. Demonstration Projects

In Latvia, specialists in RE, mechatronics, building engineering systems, and environmental technologies are trained in 9 out of 23 educational institutions. These institutions have demonstration projects designed to enhance educational programs by showcasing technologies needed for the transition to climate neutrality [37] and incorporating them into their education process. This hands-on approach provides students with practical experience in fields such as RE, mechatronics, and environmental protection, preparing them for careers in these areas, and aligns with SDGs [38].

The demonstration project system includes small-scale RE sources, energy storage technologies, the consumer side of energy use, and technologies to improve energy efficiency in heating, cooling, and electricity consumption. A smart control system is also included. The demonstration project system is given in Figure 6.

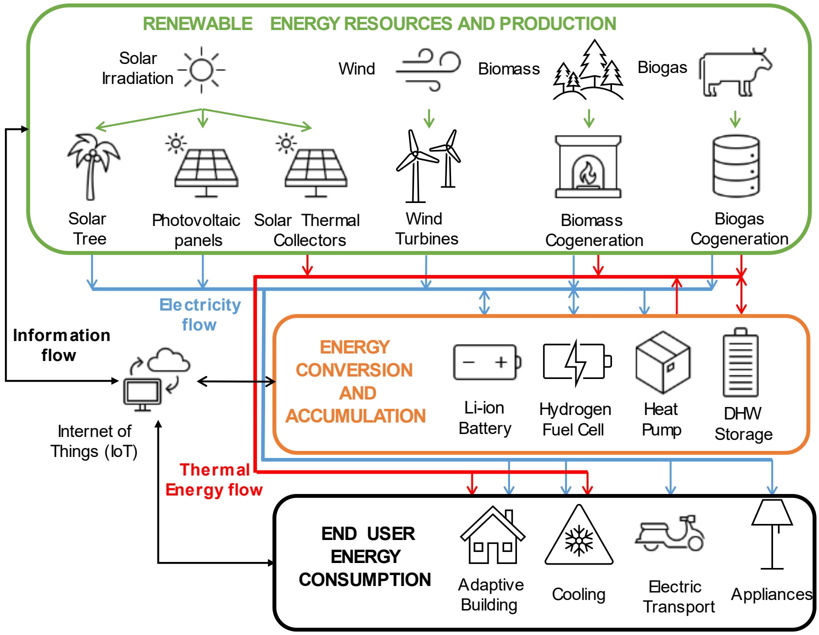

Figure 6. Demonstration project system scheme.

The demonstration project should be small and include the following:

- RE technologies (e.g., solar panels 2.4 kW, tree of solar panel 1.8 kW, solar collectors 1 kW, wind generator 1 kW, biogas tank 100 L and gas combustion plant 1 kW, biomass boiler 10 kW);
- Energy storage technologies (e.g., hydrolysis plant, hydrogen storage tank, fuel cell: 10 kW; hot water storage tank 100 L; lithium-ion batteries 1 kW)
- Energy consumers (electric vehicles (scooters, cars, mopeds); solar-powered air-cooling unit; heat pump);
- Technologies for improving the energy efficiency of final energy consumption: technologies for reducing heating and cooling consumption (mock-up of the building (2 m^3), smart water distributors, heat recovery from sewer water with a heat exchanger 200 W, efficient household electrical equipment, ventilation unit with efficient heat utilizer and motors with frequency converters;
- Smart control system with class A building control system and renewable energy management, data reading and monitoring system, Internet of Things.

Reduction in primary energy consumption and Emissions

The introduction of mandatory and selected measures could lead to a substantial decrease in energy consumption, primary energy consumption, and annual emissions. The energy consumption decreased by 9.7 GWh/year, which is 25% of the total energy consumption; the primary energy consumption also decreased by 21.5 GWh/year, which is 39% of the initial primary energy consumption, and the annual emissions also decreased significantly, with a decrease of 2.5 ktCO_2/year, which is 34% of the total annual emissions before the implementation of sustainability measures. Decrease percentages in educational institutions ranged from 11 to 66% for annual GHG emissions and 20%–55% for primary energy consumption. The pre-implementation and post-implementation values for these measures are demonstrated in Table 2.

Table 2. Energy consumption and emission data before and after implementing sustainability measures.

	Energy Consumption, GWh/Year	Primary Energy Consumption, GWh/Year	Annual Emissions, $ktCO_2$/Year
Before	38.4	55.2	7.41
After	28.7	33.7	4.91
Absolute decrease	9.7	21.5	2.5
Percentage decrease, %	25%	39%	34%

3.3. Educational Institution Ranking

The composite indicator results are shown in Figure 7. The results are given as a percentage. Institution No. 20 had the highest result at 95%. Institution No. 7 had the lowest result at 8%. The educational institutions are listed in descending order by their composite indicator result. The highest-ranking educational institutions scored a high number of points in the survey and implemented various energy efficiency measures and utilized RES before this study, and the main benefits came from implementing mandatory measures. Educational institutions with the lowest and middle scores should additionally implement optional measures. This results in a lower ranking because the reduction in primary energy consumption and emissions per investment of optional measures compared to mandatory measures is lower. The lowest-ranking educational institutions have not implemented or improved their mechanical ventilation systems, resulting in a smaller decrease in primary energy consumption and emissions compared to the decrease achieved with other measures.

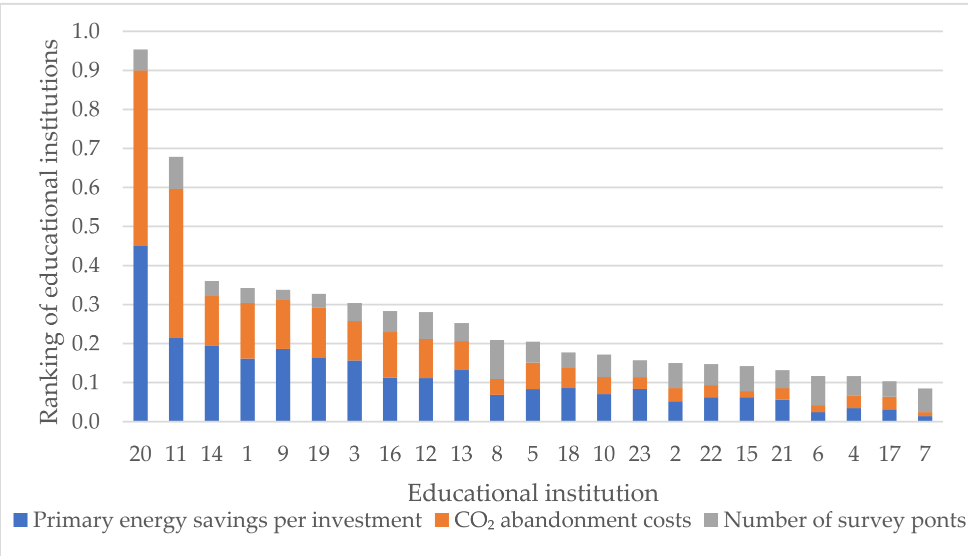

Figure 7. Composite indicator ranking of educational institutions based on the sustainability criteria.

4. Discussion

There is a dilemma in balancing the need for energy efficiency with the requirement for proper ventilation systems in educational institutions. On the one hand, the aim is to reduce energy consumption through energy-efficient building systems and the use of RE sources.

On the other hand, it is important to maintain proper indoor air quality for the health and safety of students and staff, which often requires energy-consuming ventilation systems and equipment [39–41]. Thus, educational institutions mandated to install ventilation systems rank poorly according to composite indicator criteria.

The interviews and survey were conducted with representatives of educational institutions. Afterwards, building and energy system inspections were carried out during the on-site visit. During these inspections, it was found that the information given during the interviews was not accurate. The representatives may have given positive answers to present their institution favorably and to avoid negative feedback. Nevertheless, it is possible that they sincerely believed the information they were presenting was true [42–44]. Regardless, it is important to consider the potential biases and motivations of the interviewees when analyzing the authenticity of their responses.

During the on-site visits to the educational institutions, some representatives showed a comprehensive understanding of the EMS and energy sources in the educational institution, while others proved otherwise. Energy illiteracy can result in poor decisions regarding energy use and management or neglect of energy efficiency measures, and lead to reliance on inefficient energy sources [45–47]. Therefore, it is important to ensure that representatives are educated on sustainable practices in educational institutions [48]. Further research could be conducted on representative energy awareness levels and educational institutions' energy consumption.

The expenses regarding sustainability measures can have had a significant impact on the results. For this study, measures with a positive discounted payback time during their economic life were selected. Changes in energy tariffs can create financial incentives for educational institutions to adopt or reconsider the adoption of energy efficiency measures. These changes can also impact behavior related to energy conservation. Similarly, changes in the price of energy efficiency can impact affordability, return on investment, and competition among providers and manufacturers, potentially leading to changes in the availability of products and services, and changes in the price of energy efficiency measures can impact the speed of their implementation, resulting in delays until the prices become cost-effective [49–51]. Therefore, educational institutions need to select measures according to their availability and needs.

The only measure regarding climate change adaptation taken so far by some educational institutions is planting trees for shading and cooling. Although trees additionally provide carbon sequestration and biodiversity, these answers have not been given by the representatives of educational institutions. Representatives were not interested in adaptation to climate change because they do not see any benefit as of this moment. If the educational buildings are not adapted to climate change, students and staff may face health risks, such as exposure to a hot indoor climate and air pollution [52]. This can also result in a decreased quality of education. Increasing resilience to climate change demands understanding, organization, collaboration, and foresight from educational institutions [53]. Education and awareness of climate resilience could be provided to representatives and students to improve the resilience of educational buildings [54–56]. Hence, educational institutions must deliver more effort regarding climate change adaptation.

5. Conclusions

This research paper aimed to explore strategies to increase sustainability in Latvia's vocational education system by conducting a comprehensive assessment of potential energy efficiency and sustainability measures. The effectiveness of these measures was quantified using a composite indicator.

To accomplish this, a thorough assessment of 23 educational institutions was conducted to examine the current state of energy management in the educational system. Optimization of energy efficiency and RE production measures was then carried out.

The composite indicator was used to rank and compare educational institutions based on the provided measures and survey results. Our analysis revealed that primary energy consumption was reduced by 39%, while annual emissions were reduced by 34%. The reduction in primary energy consumption and annual GHG emissions in individual educational institutions ranged from 20 to 55% and 11 to 66%, respectively.

This research paper proposes using a composite indicator to compare educational institutions based on their current energy efficiency and environmental practices, as well as the efficiency of their implementation of energy efficiency and RE production measures. The composite indicator enables the comparison of current practices and future sustainability measures in a single result.

The results reveal that educational institutions with higher composite indicator scores perform better than those with lower scores. Specifically, the investment variable in the composite indicator criteria can be used to allocate investments to prioritize implementing mandatory or selected measures when financial constraints arise.

The composite indicator can be used as a decision-making tool to identify educational institutions that require financial incentives to implement energy efficiency and RE production measures. By focusing on the highest-ranking educational institutions, financial resources can be allocated more efficiently to achieve the best possible outcomes.

In conclusion, the composite indicator is a valuable tool for evaluating and comparing energy efficiency and environmental practices in educational institutions. The results of this research paper suggest that financial incentives for implementing mandatory and selected measures should be allocated to educational institutions with the highest composite indicator scores to ensure the most effective allocation of resources. Further research is necessary to evaluate the long-term effectiveness of this method. Based on the composite indicator results, it is recommended that educational institutions implement the mandatory measures suggested in this study. These measures aid in managing energy consumption by changing the paradigm shift in traditional energy consumption behaviors, such as requiring educational institutions to switch to an automated EMS. The inclusion of PV systems provides a beneficial reduction in primary energy consumption during the summer months and is included in the mandatory measures together with an improved EMS. The identified optional energy efficiency measures can be used as further solutions in educational institutions to decrease energy consumption and increase energy efficiency, but these measures are less financially efficient compared to the mandatory measures.

Demonstration projects have been tailored to specific educational institutions in Latvia. This system is potentially different from projects based on the climate, available resources, and learning environment implemented in other educational institutions. Further studies could include the effects of implementing demonstration projects and analyzing the change in students' attitudes towards sustainability. Different measures could be applied to educational institutions, and sensitivity analysis on selected measures could be performed.

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Review

Towards the Sustainable Intensification of Aquaculture: Exploring Possible Ways Forward

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Abstract: Meeting the global demand for aquatic products while maintaining sustainability is a critical challenge. This review article examines global practices of land-based aquaculture systems that could be implemented in the EU, as the EU has not yet fully realized its potential in developing the aquaculture sector. Therefore, the article examines different aspects (aquaculture systems, technological solutions and improvements, and best management practices) in achieving sustainable aquaculture and emphasizes the need for innovation and cooperation in the face of increasing environmental concerns and resource constraints. There is no one-size-fits-all solution for the sustainable intensification of aquaculture. The way forward requires a combination of different and improved-upon technological solutions complemented by technological innovation and better management practices. The sustainability of aquaculture requires a broader application of the ecosystem approach to aquaculture and the promotion of energy and resource efficiency measures in aquaculture systems.

Keywords: land-based aquaculture; aquaculture systems; technologies; EAA; bio-economy

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1. Introduction

The terms "sustainability" and "sustainable" have become frequently used words today, both in relation to environmental issues and processes and activities in connection with future development. This statement is well illustrated by the ScienceDirect search function for scientific articles. For example, when entering the phrase "sustainable" or "sustainability" in the search bar, the following message is displayed: "Due to the large number of search results, only the last three years are included" [1], and it is indicated that there are more than 1,000,000 existing results these three years. It has been argued that the term "sustainability" has lost its deeper meaning and has become an alienated cliché that is overused both inside and outside of its intended context [2]; nevertheless, the principles of sustainable practices are indisputable and need to be discussed. Despite the importance of the notion and widely discussed concept of sustainability, the meaning of the term "sustainable aquaculture" has not been clearly defined, and it is not clear when it is appropriate to refer to aquaculture as sustainable [2].

In the past, aquaculture systems were viewed as environmentally friendly because they operated according to the circular economy principle—mainly by utilizing agricultural and locally available waste and by-products, such as crop residues and animal or human manure, as nutrients [3]. Unfortunately, presently, things have changed. Although only the production of pelleted feed has been introduced relatively recently, it is already widely used in modern aquaculture systems due to its ease of handling [3]. Pelleted feed is one of the reasons why aquaculture production has made a huge leap forward in recent decades and has become the fastest-growing food production sector in the world, and it is expected that its growth will continue to increase [4–6]. This process is also known as the "Blue Revolution"—specifically, the rapid growth and intensification of fish, shellfish, and aquatic plant aquaculture production from the mid-20th century to the present day [3,7,8].

However, the increase in pond productivity has come at a cost—the excessive amount of pelleted feed in water has led to an overabundance of nutrients, affecting water quality and posing serious environmental risks [3].

Although there is a trend towards the expansion of offshore aquaculture due to the high quality of water suitable for farming, the unlimited potential, and the natural treatment of waste in aquaculture systems, it is more likely that land-based aquaculture will remain the main source of fish, shellfish and aquatic plants as opposed to mariculture [3]. This is due to the significant technological, operational, economic, legal, and political barriers that still need to be overcome before the oceans may be utilized as a significant source of farmed fish [3]. It is, therefore, estimated that the majority of farmed fish will continue to be reared in inland waters for the foreseeable future [3].

Producers' views on the need to develop aquaculture systems to increase resource use efficiency and reduce environmental impacts are changing in favor of sustainable solutions [2]. This is due to promising technologies that combine traditional and modern aquaculture practices, reducing the negative environmental impacts of modern pellet-fed aquaculture [3]. Although intensification leads to higher production and, consequently, higher profits, such practices need to be strictly monitored in order to maintain environmental sustainability [2]. The challenge for the future, therefore, is to increase production per hectare by increasing resource efficiency and resource consumption (kilograms per hectare) [2].

In tropical developing countries, fish and shellfish can generally be farmed at a lower cost, and to date, transporting these products to economically developed consumer countries has not been a significant cost factor [2]. This puts developed, temperate countries at a disadvantage due to higher cultivation, production, and labor costs, as it is difficult to compete with developing countries, which may produce and transport the products at a fraction of the cost [2]. At the same time, the proximity of developed countries with temperate climates to markets with a high demand for live and fresh produce should be seen as an advantage to be capitalized on in the future [2]. To do so, a way must, therefore, be found to reduce the costs of farming and intensify aquaculture while, at the same time, maintaining a sustainable approach to ensure continuity.

Aquaculture and the EU

The European Union (EU) has exclusive competence for marine plants and animals, governed according to the Common Fisheries Policy [9]. For aquaculture, the EU shares competence with Member States, which then set their own specific requirements enshrined in regulations and legislation [9,10]. However, at the same time, aquaculture farms and their activities are subject to several EU regulations that govern certain aspects of their activities, such as farmed fish welfare, environmental impact, water quality, spatial planning, feed requirements, and other standards [10,11]. To contribute to the implementation of the core objectives of the European Green Deal and the resulting Farm-to-Fork Strategy, the European Commission adopted, in 2013, a Communication entitled "Strategic Guidelines for the sustainable development of EU aquaculture" and, subsequently, in 2021, a Communication, entitled, "Strategic guidelines for a more sustainable and competitive EU aquaculture for the period 2021 to 2030" (hereafter referred to as the Strategic Guidelines) [10,12,13].

In the 2013 Strategic Guidelines, the EU aquaculture sector was assessed as stagnating despite the high environmental standards and the high quality of aquaculture production [13]. A similar conclusion was reached in the latest Strategic Guidelines [12], adopted in 2021, which recognize that the EU aquaculture sector is still "far from reaching its full potential in terms of growth and meeting the increasing demand for more sustainable seafood" [12]. To better illustrate the situation, according to the 2023 report "The EU Fish Market" by the European Market Observatory for Fisheries and Aquaculture Products (EUMOFA), aquaculture production and catches from the Asian continent accounted for 74% of the global market in 2021, while Europe accounted for only 8% [14]. In Asia, catches account for 30% of the total volume, while 70% of the total volume comes from aquaculture [14]. In Europe, the ratio is reversed, with 81% of the volume coming from catches and only 19% from aquaculture production [14].

The aim of this review article is, therefore, to look at and analyze global practices for land-based aquaculture systems that could be adopted in the EU. The article mainly focuses on scientific articles and solutions from Asian countries, as they are world leaders in aquaculture production [14], as well as several articles from the U.S., where several technological solutions for aquaculture (e.g., aerator technologies [15,16] and partitioned aquaculture systems [17,18]) have been developed, as well as improved. This article focuses on sustainable aquaculture practices related to the growth phase of an aquatic organism in an aquaculture system, from egg to adult [19], and the technological elements of aquaculture systems, without a detailed discussion of the feed and disease control measures or consideration of the harvesting practices and the downstream stages of the product value chain. Throughout this article, the authors will address the following subjects:

- Aquaculture systems—the most appropriate farming method;
- Technological solutions for aquaculture systems;
- Technological solutions—future perspectives;
- Development of the aquaculture sector through good management practices.

The sustainability and environmental impact of individual aquaculture systems or technologies can be measured using a variety of tools and methods. In addition, the environmental impact and sustainability of aquaculture operations depend on a variety of factors [5]: (1) species or type of aquatic organism being farmed; (2) intensity of the production system—extensive, semi-intensive or intensive; (3) density of cultivation; (4) quality of the feed; (5) management practices; (6) wastewater treatment, etc. [5]. The scientific literature refers to methods such as the life-cycle assessment (LCA) [5], emergy analysis [5], ecological footprint [5], Ecopath model [20,21], dynamic simulation models [22], and many others, depending on the research topic.

Dong et al. [20] suggest that the Ecopath model, proposed by Polovina in 1983 [21], is an effective way to assess the sustainability and environmental impact of integrated pond aquaculture systems in the context of an ecosystem. The Ecopath model quantifies factors that represent the characteristics of an ecosystem by simulating food chains, energy flows, and the trophic structure [20,21]. In their study, Dong et al. [20] propose to complement the Ecopath food web model with an evaluation index system to enable improvements in pond aquaculture—for resource and energy efficiency and environmental protection.

2. Aquaculture Systems

Traditional aquaculture consists primarily of integrated agricultural–aquaculture systems that utilize by-products, manure, and plant material from farming or agricultural activities [3]. Integrated peri-urban aquaculture systems are primarily nourished by municipal effluent and agricultural by-products [3]. Fertilized ponds, in particular, ponds fertilized with waste from other activities, are attractive because of their low dependence on external resources for food, energy, and waste treatment [2]. However, putting more feed in the ponds does not increase fish production, as most of the feed ingested is not converted into harvest but is discharged into the water as waste material, which can have a negative impact on the environment in which the fish are farmed [2]. For example, nutrient wastes such as nitrogen, phosphorus, and other minerals, as well as organic wastes such as excrement and uneaten food, stimulate biological activity within the rearing system, which can significantly lower the dissolved oxygen level, endangering the culture grown there [2]. Aquaculture wastes include uneaten feed, nitrogenous metabolites, excreta, chemicals, and therapeutics, and they produce mainly two types of residues: liquid and solid [5,23]. Liquid residues are wastewater and discharged water from operations [5,23]. Solid residues consist of feces, feed, and other solid materials [5,23]. However, aquaculture ponds are unique in that if the right balance is struck between intensification and sustainability, residues can be treated in the pond using internal processes without additional stress on external ecosystems [2].

Fertilizing ponds with organic or chemical fertilizers that stimulate plant growth can also boost pond productivity [2]. The productivity of fertilized ponds is variable. Sometimes, it may be as high as 4 to 6 t/ha, depending on the duration of the growing season, the species cultivated, and the type of fertilization program applied [2]. In stillwater ponds, 8–10 t/ha or more can be produced with additional feeding and aeration, again depending on the length of the growing season and the physiological characteristics of the species being cultivated [2]. However, the amount of plant material that can be produced in fertilized ponds is eventually restricted by the amount of solar radiation that is available; this places a maximum limit on the amount of plant material that can be produced [2]. To improve the productivity of aquaculture beyond what is possible simply through fertilization, the essential ingredients for development must be obtained from sources other than the water itself and then transformed into feed that is both attractive and nutritious [2]. Mixtures of various plant and animal feed constituents are used in the production of commercial aquaculture feeds [2]. Not only the sustainability of the aquatic organisms produced but also the sustainability and safety of feed ingredient production, environmental impacts, potential import dependency, and food security are becoming increasingly important [2].

New filtration, recirculation, and water treatment will enable better purification of used water so that it can be re-used [2]. On the other hand, there is a lack of land resources to develop new aquaculture systems—there is no suitable land available, either the land has limited access to suitable water sources, or it is too expensive to be economically viable for conversion into an aquaculture system [2]. The release of nutrients from ponds to the external environment is inversely proportional to the rate of water exchange, as a significant amount of waste is treated on site in ponds with standing water [3]. In low-intensity pond culture, there is minimal wastewater discharge with little to no negative impact on the environment, as the pond ecosystem processes significant amounts of waste during the culture cycle [3].

In the following subsections (Sections 2.1–2.4), different technologies will be discussed and described for cultivating aquatic organisms—monoculture, polyculture, as well as three more advanced technologies such as integrated multitrophic aquaculture, aquaponics, and biofloc technologies (Figure 1).

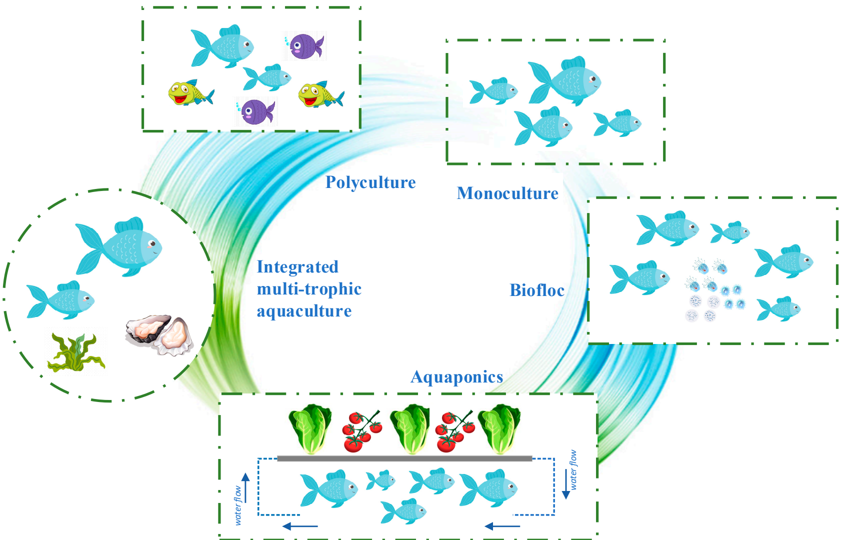

Figure 1. Simplified depiction of aquatic organism cultivation technologies.

2.1. Intensively Fed Monoculture and Polyculture

Some species, such as filter-feeding mollusks and algae, feed on the waters around them and do not need to be fed, even in extremely dense populations [2]. Other species, including most fish and crustacean species, require external food sources and are usually cultivated in intensively fed monocultures [2]. Monoculture, the cultivation of a single aquatic species at varying densities, is widely practiced throughout the globe—Europe, North America, China, and Australia [2,24,25]. Monocultures are characteristic of intensive recirculated aquaculture systems in which a species with a high market value is cultivated in high density [24]. High-quality commercial feed is fed to monocultures and usually accounts for 50–80% of production costs, and the main products are high-value fish and crustaceans [2].

Monoculture aquaculture is based on the concept of linear economy, which is not the most sustainable approach [2]. By cultivating only one species, the aquatic organisms that are farmed cannot consume all the food given to them, which is disadvantageous from the point of view of resource efficiency [24]. Monocultures have lower resistance to pathogens and viruses [24].

Polyculture can be described as the rearing of two or more species, the combination of plants and animals, fish or plants, and even aquatic and terrestrial species in the same fixed space [24,26]. Polyculture has its roots in China, where several species of carp were reared in one pond or fish farming was combined with rice cultivation [26,27]. Today, the concept of polyculture has evolved considerably, trying to combine different aquatic organisms, but the basic principle remains the same: the aquatic organisms to be cultivated must occupy different ecological niches and must not compete with each other for nutrients [26]. The simultaneous cultivation of more than one aquatic organism offers advantages such as additional resource efficiency and economic benefits from all species farmed and sold, as well as improved water quality [26].

2.2. Integrated Multitrophic Aquaculture

Integrated multitrophic aquaculture (IMTA) is an old and, at the same time, a new concept based on the principle that more than one species is farmed in the same aquaculture system (pond, tank, or cage) [3,25]. IMTA can be seen as an advanced version of polyculture, where the cultivation of fish or shrimp is supplemented by algae, which can remove inorganic nutrients, and sediment eaters such as shellfish and/or sea cucumbers, which can remove organic nutrients [5,25,26]. Another difference between polycultures and IMTAs is that polycultures have different species growing in the same body of water [27]. However, this does not mean that they form an ecosystem in which one species feeds on the waste of another [27]. One of the biggest challenges for IMTA is to create a balanced system of aquatic organisms, as it requires knowledge of each species' trophic level, feeding habits, oxygen requirements, and other specific requirements that vary from species to species [5,28].

IMTAs can be land-based and established in ponds, tanks, or open water (sea, ocean) [28]. Land-based IMTA consists of ponds or tanks arranged in order to facilitate the flow of water in a flow-through system or recirculating aquaculture system [28,29].

Research carried out by several scientific groups [25,30,31] points to the positive impacts of IMTA in all three dimensions of sustainability—environmental, economic, and social. Furthermore, IMTA systems operate according to the principles of the circular economy, improving not only resource efficiency but also energy efficiency and reducing the risk of pollution [27,32]. The resource efficiency of the IMTA system is demonstrated by its ability to produce more protein from a given amount of feed than other conventional production systems [2]. Research by Alexander et al. [32] on the perception of the European public towards IMTA showed that the level of public knowledge and awareness of this farming method is generally low. At the same time, after receiving additional information about the principles of IMTA, respondents expressed more approval than disapproval of this farming method [32].

IMTA systems are considered to be under-researched, not only in Europe but also on a global scale [30]. There are drawbacks, such as high initial costs as well as the subsequent operating costs of the system, that should be addressed in the future [28,33]. Additional support from national governments and industry, as well as evidence of financial benefits, could encourage the adoption of IMTA [28,30,33].

2.3. Aquaponics

Aquaponics is defined as the cultivation of vegetables in a soilless nutrient solution by fertilizing the plants with nutrients from fish tank effluent [3,5,23]. Aquaponics can be considered to be a derivative of IMTA, supplemented with elements from combining recirculating aquaculture systems and hydroponics [3,5,23,34]. The benefits of aquaponics systems include nutrient uptake by the plants and improved quality of the water that is returned to the fish tanks [5,23]. The water from aquaponics systems can be used to grow a variety of vegetables such as lettuce, spinach, tomatoes, cucumbers, and other plants like water hyacinth (*Eichhoria crassipes*) or water fern (*Azolla* sp.) [5,35]. Henares et al. [5] and Zimmermann et al. [34] point out that closed aquaponics improves the quality and productivity of vegetables through a better controlled nutritional value and reduces the spread of pests and diseases.

Aquaponics is one of the latest trends that has attracted the attention of both scientists and companies. Nevertheless, there are currently very few commercially successful aquaponics systems [3]. Aquaponics systems primarily produce vegetables, not fish, so the high-quality fish feed used to “fertilize” the plants is not cost-effective [3]. Moreover, aquaponic systems have greater capital and operating costs, energy consumption, and greenhouse gas emissions per unit of production than pond and cage culture [3,23]. It is, therefore, argued that growing hydroponic vegetables with inorganic fertilizers in fertilized low-cost farming systems are more cost-effective and simpler than integrating them into a fish recirculation system [3].

Aquaponics is predominantly practiced as a hobby and in small-scale backyard agriculture [3]. Although aquaponics may have potential in countries with limited freshwater resources or in the commercialization of fish and vegetables produced in such systems as niche products for which consumers would be willing to pay a higher price, it is not expected that such systems will be intensified in the near future [3].

2.4. Bioflocs

Biofloc aquaculture or biofloc technology (BFT) consists of a controlled environment system that combines suspended phytoplankton, heterotrophic bacteria, algae, protozoa, feces, and uneaten food to produce an organic fish diet [2,5,23,36]. The concept of BFT was developed in the 1970s and aims to solve the two main environmental problems in aquaculture: wastewater recovery and protein extraction [23,26]. There are several reasons there is hope for the BFT to be one of the primary aquaculture paths to a sustainable future [36–39]:

- minimal or no external water exchange;
- less feed is needed, which reduces feed costs by 30%;
- natural microbial biomass improves water purification;
- enhanced growth, performance, and immunity of cultured aquatic organisms;
- some bacterial species are useful in sequestering atmospheric CO_2.

In addition to the waste treatment function of BFT, it is a nutrient-rich food source made entirely from recycled waste materials and can be used as an in-pond food source or supplement [2,5,23,39]. Plant-based proteins as a supplementary feed source can be used in BFTs to make the system as environmentally friendly and sustainable as possible [37]. The nutritional value of BFT is largely determined by the microbial community in the water body [37].

The construction and operation of BFT are both very costly and energy-intensive. Therefore, it requires a high level of technical competence [2,37]. Outdoor BFT can be established in tanks or ponds as well [36]. However, when deploying outdoor BFT systems, the location of the water body, the light intensity, and the time of year should be carefully considered, as these factors can have a strong influence on the internal balance of the system [37]. BFT needs to be monitored as it tends to accumulate [36]. Water quality parameters, especially dissolved oxygen, pH, and ammonia levels, must be monitored regularly as elevated levels can stress aquatic organisms and impair their growth [5,36]. Therefore, BFT must be supplemented with intensive aeration [5,26,36].

From a consumer perspective, the preference for aquatic organisms cultured in BFT could be undermined by the presence of metabolites such as geosmin and 2-methylisoborneol in the water, which give the cultured product a muddy or earthy taste [37,40,41]. In addition, consumers may be skeptical of aquaculture products from BFT, as nutrient extraction is based on converting the excreta of aquatic organisms into feed [39].

The use of BFT can be combined with IMTA, therefore increasing economic benefits [37]. Although BFT applications are no longer rare, further research is needed to balance and improve understanding of the microscopic mechanisms involved in bioflocculation [36,39]. It is also important to explore the microbial sources responsible for the formation of geosmin and 2-methylisoborneol in BFT and to find ways to eliminate them [41]. Ogello et al. [36] point to the need to improve aquaculture policies to promote innovative aquaculture techniques for sustainable production and the viability of aquaculture enterprises.

3. Engineered Ponds and Tanks for Increased Productivity

The regenerative capacity of pond ecosystems is not unlimited, and this limit of self-regeneration coincides with the upper limit of intensification of aerated aquaculture ponds [2]. To go beyond the limit of self-regeneration, it is necessary to find a way to clean the water mechanically or to increase the self-cleaning capacity of the ponds [2]. The internal waste removal capacity of a pond can be increased by using BFT or by redesigning the pond and using different technologies to gain more control over the internal biological processes [2]. The environmental impacts of ponds with water exchange are different from those of ponds with no or limited water exchange [2]. The amount of water exchanged in different types of ponds can vary from none to several volume exchanges per day [2]. Water exchange increases water consumption, the risk of runoff, and the spread of infectious diseases, and shifts the environmental and economic burden of waste treatment from the pond to other water bodies, which has ethical implications and may be subject to legal regulation [2].

Promising technologies that reduce or even eliminate the negative impact of pond effluent on the environment are the partitioned aquaculture system—split ponds and in-pond raceway system—both closed aeration systems that do not discharge water [3].

3.1. Traditional Pond Aquaculture Systems

Surprisingly, there is not much scientific literature dealing specifically with pond types and their hydrological systems, apart from simplified manuals or guides by FAO [42] and C.E. Boyd of Auburn University. Boyd et al. [43,44] describe three main commonly used hydrological pond types—watershed ponds, embankment ponds, and excavated ponds (Figure 2). The average depth of aquaculture ponds varies between 1 and 4 m, and ponds in intensive aquaculture systems are typically no larger than 1 ha [44].

Watershed ponds, also known as rain-fed ponds or terrace ponds, are created by building an embankment to collect runoff [43,44]. These types of ponds are usually filled with water throughout the year because water is constantly flowing in from nearby springs or streams or mechanically fed from other nearby external sources [43]. Water levels may fluctuate seasonally due to evaporation or lack of rainfall [43,44]. Runoff from this type of pond either percolates into the groundwater or seeps through dams into the surrounding area, where it evaporates or flows downstream [43].

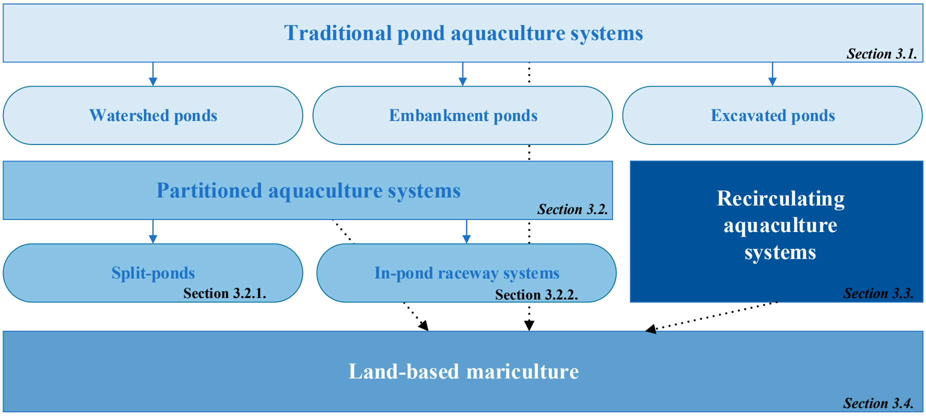

Figure 2. Land-based aquaculture systems (freshwater and saltwater). The blue arrows in the figure indicate a further breakdown of the above aquaculture systems. The black dotted arrows indicate the possibility of using these aquaculture systems as land-based mariculture.

The embankment ponds are constructed on flat ground by removing enough topsoil to build dams that enclose the area where the water is discharged [43]. At their highest point, the embankments are usually 2–3 m high and 2–5 m wide [44]. The water catchment areas of the reservoirs are formed by the inner slopes of the dams and the tops of the dams [43]. It is difficult to fill and maintain embankment ponds with rainwater alone, so water to fill the pond is taken from nearby streams, wells, lakes, and river estuaries [43]. The advantage of this type of pond is that the water level can be more easily controlled, and the aquatic organisms can be harvested by draining the pond [43,44].

The excavated pond is formed by creating a basin in the ground [43,44]. If the groundwater level is high enough, the excavated pond fills up to the current groundwater level and is also replenished by rainwater [43]. The main disadvantage of this type of pond is that the water level cannot be controlled, so the water must be mechanically pumped out of the pond to collect the cultured organisms [43,44]. This type of pond is more suitable for small-scale farming due to its small size and lack of water level control [43,44].

More attention should be paid to the environmental impact of pond aquaculture to avoid endangering nearby ecosystems, as nutrient-rich pond water and organic matter can lead to eutrophication of the watershed [44].

3.2. Partitioned Aquaculture Systems

The main feature of partitioned ponds, also known as partitioned aquaculture systems (PAS), is the partitioning or physical separation of the pond between the fish farming and water treatment areas [45]. PAS was developed in the 1990s to allow water to be recirculated between intensive fish farming raceways and effluent treatment channels to treat effluent without discharging it [2,34,46]. PAS can be characterized by the use of shallow tanks, pond-wide mixing, and continuous cultivation of phytoplankton and zooplankton biomass [45]. Fish are reared in concrete tanks divided into raceways, smaller channels, or ponds that occupy about 5% of the total tank area, with the remaining 95% used for water circulation and re-use [34].

PAS use the high productivity of phytoplankton to extract inorganic nutrients from fish cultivation, increase algal growth, remove waste, and produce oxygen while serving as a water filter [45,46]. Fish aquaculture waste is recycled through a large, well-mixed pond modeled on the "high-rate algal ponds," originally developed to treat wastewater from municipal sources [2,34]. PAS allow for higher capacity ponds and operate without water exchange, allowing for higher fish production per unit area [17]. Tilapia is the most commonly farmed species in PAS, with the main advantage being its adaptability and lower feed quality requirements [45].

3.2.1. Split Ponds

According to Tucker et al. [47], split ponds based on PAS were introduced in the US in the 2000s. Its main objective was to make the management of the system easier for catfish farmers. Split ponds are essentially a lower-cost version of PAS, consisting of two ponds with different functions working in tandem [2,18,45,47]. The smaller pond, which is about 15–20% of the total area of the two ponds, is used for rearing [17,18,48]. The other pond is about four times the size of the first one, contains no fish or other cultured organisms, has a high algae density, and is used for water treatment [2,18,45]. The load of nitrogen, phosphorus, and other plant nutrients is higher in split ponds than in traditional catfish ponds because fish stocking and feeding rates are higher [18,47].

Split-pond construction involves the construction of an earthen levee to divide an existing pond into two unequal sections, with high-volume turbines circulating water between the two sections [2,18,34]. It is not always necessary to build a new pond to switch from a traditional pond system to a split-pond system [49,50]. It is possible to upgrade an existing pond to a split-pond system by renovating it and adding the necessary elements [49,50]. When constructing split ponds, the openings between the ponds should be separated so that fish cannot migrate from the smaller pond to the larger pond [2,49]. If necessary, the flow of water between the two ponds can be stopped completely so that the smaller pond can be harvested without draining the larger pond [2,49]. Water is circulated between the two basins of the split ponds using water circulators, which increase water mixing during the day [18,48]. At night, water exchange between the two ponds is stopped, and aerators are switched on in the small pond to maintain the required dissolved oxygen (DO) concentration [17,47]. For water circulation, farmers usually choose circulators/aerators with a large slow-rotating paddlewheel, a modified paddlewheel aerator, a screw pump, or an axial-flow turbine pump [17,48]. One of the disadvantages of split ponds is the high initial cost, which is quickly recouped through high productivity [17,47,50].

Interestingly, Schrader et al. [18,51] describe cases where geosmin and 2-methylisoborneol, off-flavor metabolites that are more common in traditional ponds, were detected in fish from some of the split ponds. This means that the conversion of aquaculture from traditional ponds to split ponds is not an absolute escape from these "earthy" and "musty" flavors [51]. Therefore, even in the case of a split-pond system, it is recommended that samples are taken before harvesting to determine the presence of off-taste cyanobacteria in the farmed fish [51]. Also, the use of algicides such as diuron and copper-based products in pond management practices is recommended [51].

3.2.2. In-Pond Raceway Systems

In-pond raceway systems (IPRS) have their roots in the U.S., where they were developed for channel catfish aquaculture [34]. Research on a floating IPRS began in the 1990s at Auburn University, where attempts were made to build an improved version of cage culture systems to increase fish production and to be able to collect and remove fish waste [52,53]. The successful design and ability to integrate the IPRS into existing infrastructure have led to its widespread and successful use in the farming of carp, tilapia, and other omnivorous fish [34,54].

Only 5% of the total surface area of the IPRS is used for fish cultivation, with the remainder used for water treatment [34]. The IPRS consists of a water flow mechanism that circulates the water around the fish, which are enclosed in a flowing water system [55]. The IPRS consists of a floating rectangular box or container equipped with air-lift pumps at one end and a water discharge system at the other end of the container [52,53]. The advantage is that the floating IPRS containers can be made in different sizes and materials—plastic or plywood—which are then attached to a floating pier [53,56]. The containers are closed with openable lids to prevent fish from escaping or, conversely, to prevent access by various predators [53,56]. In addition, walkways are added to the fish-holding tanks to allow workers to access the fish [53,56]. Air-lift pumps, usually powered by a high-volume, low-pressure regenerative blower, move the water through the container, ensuring water flow and necessary DO level [53,54]. Water treatment in IPRS is managed by various mechanical and biological systems [53,56].

IPRS offer comparable advantages to PAS, including simplified feeding, sped-up harvesting, improved fish protection, and more cost-effective construction [2,53]. One of the major advantages of IPRS is that they can be deployed in almost any body of water [53]. They have higher yields than traditional ponds and can be operated with less labor force [53,56]. IPRS systems can recover waste from cultured aquatic organisms, making the system environmentally friendly [53,56,57]. Masser and Lazur [56] point out that IPRS systems can be used as a caging system for already cultured fish, where the grown fish can be purged of off-flavors developed during farming within about a week.

A disadvantage of the IPRS is the need for constant water circulation, and water circulators are usually powered by electricity [55]. It is, therefore, important to install emergency power systems so that cultured aquatic organisms are not affected in the event of a power failure [55,56]. Like the other PAS mentioned in earlier chapters, IPRS have high initial and operating costs (although these vary depending on the technological solution of the IPRS containers and energy source used to power the water circulators) [52,55]. With IPRS, as with other PAS, the potential impact on the control of environmental parameters such as light, temperature, and water quality is limited [54].

An interesting result by Nagy et al. [54] is a study on the possibility of farming pikeperch (*Sander lucioperca*) in Central and Eastern European countries using IPRS. The study confirms that high-value fish species such as pikeperch can be farmed in IPRS, and in this system, it even shows better growth performance than the same fish species farmed in a recirculating aquaculture system [54]. Although Nagy et al. [54] point out that further research is needed in winter conditions, IPRS is considered to be a potential future development option.

3.3. Recirculating Aquaculture Systems

Recirculating aquaculture systems (RAS) can be characterized as intensive closed-system aquaculture [23,58]. The main advantage of RAS is the relatively low environmental impact, as 90–99% of the water can be re-used in the more efficient systems, and they require less territory compared to a flow-through system [3,23,35,59]. On the basis of the water exchange rate of the system, the following classification of RAS is proposed: flow-through (>50 m^3/kg feed); re-use (1–50 m^3/kg feed); conventional recirculation (0.1–1 m^3/kg feed) and “next generation” or “innovative” systems (<0.1 m^3/kg feed) [60]. RAS typically consists of elements such as rearing tanks, solid waste removal, wastewater treatment, filtration systems, power generators, oxygen suppliers, water pumps, etc. [23,34,58]. Disinfection can be achieved by ultraviolet treatment, which destabilizes the microbial composition and inactivates pathogenic bacteria [34,58]. Tanks for rearing fish and other aquatic organisms can be placed indoors or outdoors, depending on what species are being reared and their temperature requirements [60].

The most distinctive feature of RAS is the high density of fish cultivated in a relatively limited volume of water [3,5,60]. The water is treated to remove the toxic metabolic wastes of the fish and is then re-used in the system [3,5,35]. RAS can be very simple, with the water passing through a single biological filter, or complex, with multiple treatment steps such as mechanical, biological filters, oxygen enrichment, and ultraviolet disinfection [5]. Unlike ponds, a RAS system is isolated from the external environment, allowing better control of water quality, temperature, and nutrients and reducing the risk of exposure to pathogens and parasites from wildlife, as well as the environmental impact of the systems themselves [5,60,61].

The disadvantage of RAS is the relatively high initial and operating costs, as well as the complexity of the system, which discourages companies from opting for such aquaculture systems [3,5,34,35,60]. The material flow processes and the constant supply of oxygen in RAS make the system very energy-intensive and require structural and functional coordination of several mechanical units [23,35]. The RAS can accumulate toxic waste and sludge that need to be removed periodically [3,61]. In the event of a power failure, the system may shut down with serious consequences [23].

Due to the small amount of additional water required and the high level of wastewater treatment, RAS is considered an environmentally friendly and sustainable system [35,61]. From a circular bio-economy perspective, RAS is not optimal because the nutrients (nitrogen, phosphorus, carbon) in the water are not returned to the production cycle after treatment [23]. However, in terms of promoting a circular bio-economy, hazardous nitrogen waste from aquaculture could be collected and converted into high-value-added, protein-rich products [23,60].

The search for more sustainable and environmentally friendly solutions for RAS continues and is also described in the scientific literature. For example, it is possible to combine RAS with constructed wetland systems, where pollutants are absorbed by plant roots and leaves [5,35]. Bio-RAS or systems combining BFT and RAS technologies have been explored with the aim of achieving zero water exchange and reduced disease risk [62]. Monocultures are characteristic of RAS, but to optimize water use, the possibility of using RAS as a polyculture cultivation mechanism is being explored [24]. Xu et al. [63] briefly describe the recirculating pond aquaculture system (RPAS) as "an innovative mode of pond culture for its environmentally friendly characteristics". In a pilot study, Xu et al. [63] compared the performance of a traditional pond with an RPAS design, where the RPAS developed consisted of elements such as rearing ponds, a treatment pond, an inlet ditch, an outlet pipe, an ecological ditch, and an electrically driven pump. In the experiment, the RPAS showed improved water quality, growth, and muscle quality, as well as physiological conditions [63]. These are just a few examples of attempts to optimize and improve RAS.

3.4. Land-Based Mariculture

Mariculture is seawater aquaculture that can take place in the sea, in the ocean, or even on land [64]. Setting up land-based mariculture systems a few kilometers inland and pumping seawater into specially designed ponds or tanks could be an option for developing aquaculture in coastal regions. Mariculture farms on land are considered to be a more environmentally friendly and sustainable option, as wastewater management, nutrient recycling, and improved feed conversion are easier and cheaper on land than in open water [65]. Transmission of pathogens and genes between cultivated and wild species is prevented, there is no need to worry about weather damage, and the public's right to access the sea is not compromised [65]. Land-based mariculture can be designed according to IMTA principles, for example, by combining marine fish and mollusks with phytoplankton as a biofilter and food for the mollusks in a single system, making it even more sustainable [64,65].

The construction of a land-based mariculture is technically not very different from the construction of a freshwater aquaculture, except for the need to establish it near the coast and to find a good location for a pumping station [2]. Establishing mariculture inland is less environmentally damaging, and pumping costs are predictable [2]. However, local conditions and the mechanics of filtering and pumping huge volumes of saline water must also be assessed [2]. The hydrogeology of potential pumping sites must be thoroughly investigated, as pumping seawater inland could contaminate freshwater [2]. Cultured organisms can be managed, fed, and harvested in raceway systems, but raceways produce effluents [2]. However, these can be treated with halophytic plants, which are suitable for the treatment of saline wastewater [35,66]. To treat wastewater with halophytic plants, a wetland system can be constructed where the plants act as biofilters [35,66]. Another option could be RAS, which can provide near-zero water exchange, but investment and operating costs are relatively higher [2]. Another advantage of recirculation systems is that they do not require seawater, so the marine organism farming facility does not need to be on or near the coast [2]. Ponds are probably the best option for establishing a marine aquaculture system, although there are several difficulties with their installation [2]. In addition, the split-pond system may be the optimal production system for near-shore facilities [2]. If the soil is barren, the bottom of ponds constructed near the coast often needs to be lined with a special material [2].

4. Technological Improvements—Energy Efficiency and Renewable Energy Resources

Developments in aquaculture technology over the last century have led to an intensification of pond production processes [3]. Although manure and chemical fertilizers were initially used to supplement natural feed, pond farms later switched to pelleted feed to provide more valuable nutrients to the fish [3].

Improving resource and energy efficiency in aquaculture operations has been identified as key to optimizing operations, although energy accounting has been relatively underrepresented in the scientific community [23]. The sources and intensity of energy used in aquaculture vary from system to system, ranging from renewable solar energy to nonrenewable fossil fuels [23].

4.1. Technological Solutions—Aeration

The amount of dissolved oxygen (DO) required is different for different aquatic organisms. To maintain viable conditions for fish, the DO concentration in the water must generally be 5 mg/L or more for warm-water fish, the same for a raceway or circular tank, and 6 mg/L or more for cold-water fish at their optimum temperature [67–69]. Sustained oxygen concentrations below 3 mg/L are potentially lethal, while oxygen concentrations of 0.5 mg/L are considered non-survivable for most aquatic organisms [67,70–72]. Aerators are devices that introduce oxygen into the water by mechanical circulation [5], increasing the amount of dissolved oxygen, which means better water quality and more nutrients [3,67]. This also means improved fish health, which is a critical factor in achieving economic sustainability [2]. Aeration also allows for much more efficient use of land and water at an agricultural level, supporting sustainable production practices compared to the level achievable in unaerated ponds [2].

In the past, fish farmers sometimes added more organic matter to ponds than the ponds could assimilate, resulting in low DO concentrations or other water quality problems [2]. It was not until fish farmers started using commercially produced feeds in the 1950s and 1960s that low DO concentrations became a common problem hindering the success of pond aquaculture [2]. In the early days, aeration equipment was primitive and often made from farm equipment available on the farm [16]. This later led to the invention of the tractor impeller-powered aerator [2]. The tractor-powered paddlewheel aerator consisted of a trailer with a truck differential and axles that supported the impeller [2]. The trailer was driven backward into the water, and the water was agitated by the impeller wheels, causing oxygen exchange [2]. Later, farmers began to use tractor-powered pumps mounted on a trailer and fitted with a hose to distribute the water into the air for aeration [16].

Initially, the tractor impeller-powered aerator was a good solution to provide DO to the fish during the warm season and prevent them from dying, but it was expensive and inefficient to use over long periods [16]. Therefore, aquaculture quickly moved to permanently installed electric aerators that could provide a constant supply of oxygen [16]. In later years, various types of floating electric aerators were invented, but most were not efficient enough [16]. Research at Auburn University, in close collaboration with several engineering firms interested in manufacturing fish farming equipment, led to the development of an efficient floating electric paddlewheel aerator [2,16].

The choice of the right aerator model for aquaculture farms today depends on several factors, such as the aquatic organisms to be cultured in the pond, the geometry of the pond, and the type of water treatment or water exchange, not least the cost of purchasing and installing the aerator, the cost of its operation and maintenance, and finally the energy consumption of the aerator [67]. More energy-efficient use of aerators reduces maintenance costs, saves energy, and reduces emissions [67]. Therefore, the criteria for selecting an aerator cannot be limited to the most efficient improvement in the DO concentration in the water [67].

Ponds are naturally aerated by atmospheric diffusion and plant photosynthesis, which contributes to a natural increase in DO [72]. Natural aeration alone is not sufficient to intensify cultivation in ponds and during warmer seasons; mechanical aerators must be used to increase DO concentrations [72]. According to Boyd et al. [16] and Roy et al. [72], in addition to natural aeration, there are three main aeration systems or types of aerators used in aquaculture: splash aerators, aerators that release air bubbles into water or bubbling aeration, and gravity aerators. The most common types of aeration systems are summarized in Table 1, and the main components, as well as the advantages and disadvantages of each type of aerator, are described. Technology is constantly evolving, and improvements are being made to existing types of aerators, as well as improved designs and solar-powered aerators. For example, the Solar Updraft Aeration (SUpA) system, which passively promotes DO destratification using solar heat [73]. As proposed by Mahmoud et al. [73], the SUpA is powered by a solar thermal collector that heats a metal pipe immersed in a pond, heating the lower layers of oxygen-poor water. This creates a natural convection current that drives the oxygen-poor cold water to the surface [73]. The supersaturated water sinks to the bottom, reducing oxygen losses and increasing total DO [73]. Existing types of aerators are being improved in terms of efficiency and functionality [67,74–76], as is the off-grid use of aerators with renewable energy sources, particularly solar energy [77–79].

Table 1. Types of aeration systems used in aquaculture ponds.

Mechanical Aeration Systems	Aerator Types	Basic Information about Aerator Type	Pros	Cons
Splash aeration	Vertical turbines/pumps	Basic configuration consists of an impeller connected to a shaft and a submersible motor [72]. Water is splashed into the air from the center of the float through an opening [72]. Photovoltaic panels can be used for power supply [72].	useful in aeration of hatcheries [72]	improved DO concentration in aerator proximity and near the surface [78]
	Pump-sprayer	Submerged propeller in a vertical tube attached to an electric motor suspended by floats. Propeller draws water into the vertical tube and pumps it upwards. Water is then discharged at high velocity, deflected radially through orifices, and falls back on the water surface in an umbrella-like pattern. [72,77,78].	very effective in aerating the bottom part of the pond [77] simple and do not require much maintenance [72,77]	increase the DO in a small area, but a large area cannot be aerated [72]; horizontal influence is very limited [72]
	Paddlewheel aerator	Surface aerators, can be divided into 2 broad groups: electrical floating and power takeoff driven [72]. Consists of a frame, motor, floats, coupling, speed reduction mechanism, bearing, and paddle wheel [72]. The most commonly used type of aerator for ponds larger than 0.5 ha [43].	the most effective surface aerators performance−wise [72] high standard oxygen transfer rate, suitable for use in emergency situations [72]; solar−powered aerators are a result of recent research [80]	high purchase and operating costs of a tractor impeller-powered aerator [16] sometimes powered by a diesel generator, which releases emissions and increases operating costs [80]

Table 1. *Cont.*

Mechanical Aeration Systems	Aerator Types	Basic Information about Aerator Type	Pros	Cons
	Spiral aerator	Aeration obtained by constant splashing of water into the atmosphere by the spiral rotation (tangential) of the impeller. Consists of an electric motor, a reduction gearbox or a reducer, handles, cups, connecting shaft, a base frame, movable joints, cover spines, and floats [72].	can be used in intensive and semi−intensive cultures [72]; solar−powered aerators are a result of recent research [80]	sometimes powered by a diesel generator, which releases emissions and increases operating costs [80]
Bubbling aeration	Diffused-air systems/diffused aerator	Releases air bubbles to affect aeration near the bottom or top of a water body using a blower or compressor to supply air to diffusers [72]. High oxygenation rates can be achieved if diffusers use pure oxygen [72].	energy-efficient and with lower operating costs compared to other aerators [72] can be used for sensitive cultured animals as it has no moving parts [72]	pipelines installed at the pond bottom hinder pond management [72]; high cost if pure oxygen is used [72]; not suitable for shallow ponds [74]
	Propeller-aspirator	Consists of a frame, air suction pipe, propeller, and a motor [72,81]. The pump draws in atmospheric air through a rotating hollow shaft connected to an electric motor at one end and a propeller at the other end submerged under water [15,81]. Propeller accelerates the water to create a pressure drop across the diffuser surface [15,81]. This forces air to pass through a diffuser in the hollow shaft and enter the water as fine bubbles [15,81].	used in small water bodies [72]; one of the most often used aerator type [74]; suitable for use in intensive aquacultures [74]	performance depends on the shaft submergence depth, positional angle, propeller design, and rotational speed [72]
	Submersible aerators	Consists of a hollow pipe above the water, a submersible pump attached to the propeller [72]. As the propeller rotates in the water, it sucks in air and mixes it with the water, which facilitates aeration [72].	efficiency depends on angular position and submergence depth of the propellers [72]	
Gravity aeration—Cascade aeration	Weir aerator	Aeration takes place above a dam by splashing, where gravity breaks up the water droplets, which then flow over various screens [72]. These water droplets are sucked under the dam in a current, creating a large inflow of air [72]. Used for general water treatment, fish hatcheries, and flowing water or in raceways [72].	no additional power supply needed [72]	feasible for small ponds [72]
	Circular stepped cascade	The system consists of a circular stepped cascade and a pump. The pump lifts the water to the top of the cascade and drops it over the steps of the aerator. This creates turbulence in the water, breaking the air-water interface and resulting in aeration [75]. Used to treat wastewater before or after filtration [72].	no pumping is required if natural elevation is available for gravity flow [72]; very economical [72]; most economical for ponds with less than 1000 m^3 capacity [76]	low efficiency, has to be combined with other aerator types [72]

It is particularly important to study the relationship between aeration and water velocity to manage DO and improve optimum growth conditions and other factors relevant to pond intensification [2]. A possible disadvantage of excessive use of aerators is that the water currents generated can lead to severe erosion of the pond bottom and, in particular, the inside of the embankments [5]. Meanwhile, water velocity that is too high or too low can hinder the growth and well-being of the fish to be cultured or cause additional stress [82,83]. Research to determine the conditions under which water circulators could be effectively combined with aeration practices should be given high priority [2], as different species of aquatic organisms require different water flow rates for optimal living conditions [2,82–84].

Automatic aerator control systems have been developed to activate and deactivate aerators in response to signals from a DO monitoring probe placed at a selected location in the pond [2]. Switching to automatic operation of aerators based on the DO concentration in the pond saves energy [43] and thus improves the sustainability of aquaculture.

Wiranto et al. [85] describe an automatic aerator control system using wireless sensors and an application as a monitoring tool for an aquaculture system measuring four water quality sensors (pH, temperature, conductivity, and DO). The measured data are transmitted via a wireless transmitter to a smart data logger and then a web server [85]. The study concluded that the smart data logger was able to activate the aeration system automatically to reduce the energy consumption of the aquaculture [85]. Several similar studies have been carried out to develop remote measurement, reading, and operation of aerators [86–88]. However, it has been pointed out that the monitoring programs still need to be improved to ensure the accurate and reliable operation of aeration control systems [2,86].

The knowledge required to contribute to sustainable production systems through the effective use of aerators is not yet fully established [2]. This includes the need for further research into the placement of aerators in ponds, as different aquaculture species require different minimum DO concentrations that can be maintained without reducing feed consumption and feed conversion efficiency and without increasing disease susceptibility to disease [2]. Research is strongly dominated by studies and trials carried out in Asian countries, while in the EU, technological developments in aquaculture—in this case, aeration—can be considered to be under-researched. For a sustainable intensification of the existing aquaculture in the EU, additional attention should be paid to necessary research and updating the development of knowledge-based aquaculture systems.

4.2. *Energy from Renewable Sources*

Aquaculture faces sustainability barriers due to its inability to transition away from fossil fuels as a primary energy source [2]. Ideally, aquaculture should reduce the use of fossil resources at all stages of production and replace them with bio-based and renewable resources [2]. Currently, fossil fuels are still used as the main energy source in aquaculture, although the use of renewable energy sources, especially solar energy, is increasing due to the advantages of low operating costs, long life-cycle, environmental friendliness, no CO_2 emissions and low soil pollution [79]. Solar energy applications in aquaculture continue to develop and include power generation, aeration systems, feed dispensers, pumps, and water-heating systems [79]. Tropical aquaculture ponds have the advantage of sunny weather and can use dynamic waste treatment powered by solar energy with a minimal environmental footprint and a nature-based approach [23]. On the other hand, countries without year-round sunshine are still lagging behind in introducing solar energy or other renewable resources into their energy mix.

Another reason for integrating energy production and aquaculture is the increased use of water surface, which allows land to be used for other purposes, such as agriculture [79,89]. Aquaculture systems combined with solar PV technologies are referred to as floatovoltaics (FV) [79,89], while other sources refer to them as aquavoltaics or AquaPV [90]. FV systems consist of the same photovoltaic panels as land-based PV systems, but the panels float in the water, usually attached to floats or moored to land [79]. The advantage of such systems is that installation is not limited by the body of water, and they can be installed in different bodies of water, inland as well as on the sea or ocean [79,89]. More importantly, aquaculture can be developed in combination with FV in sparsely populated areas with no or poor grid access [89]. In addition, PV installed on the water surface also has a direct practical benefit, reducing water loss through evaporation by up to 70–85% [89,90] and can reduce algal growth rates [90,91].

Badiola et al. [92] suggest that geothermal energy can be used to produce both electricity and hot water, as well as waste heat from other industries. The use of waste heat in aquaculture is not new, and the scientific literature dates back to the 1970s [93–95], although it has become relevant again due to climate change and the high cost of energy sources [96,97]. According to Lund and Toth [98], the use of geothermal energy in aquaculture has actually increased over the years, with an installed capacity of 950 MW in 2020. Leading countries using geothermal energy in aquaculture systems are China, the United States, Iceland, Italy and Israel [98]. Instead of geothermal energy, solar collectors and heat pumps can also be used to keep the water at the right temperature for the aquatic organisms being cultured [92,97].

4.3. High Technologies and Aquaculture

The Internet of Things (IoT) and artificial intelligence (AI) are expected to become more widespread in the future and are the way forward for sustainability [23,76,99]. Modern technologies have the potential to be used to collect and analyze data, communicate with process supervisors, and even make decisions [23,76]. This is because AI systems are now so advanced that they can predict the exact amount and timing of feeding based on fish movements, growth rates, and other technical data [23]. Sensor-based AI systems can predict potential water quality deteriorations and disease outbreaks [23]. High technologies in aquaculture have been and are being developed in the following main categories: water quality, nutrition, water recirculation, transport and traceability, and welfare [100].

Technological advances are also increasing, with the development of new hatchery technologies, automated feeding, sensors to monitor water quality, and CCTV cameras to monitor feeding [101]. The latest technologies help automate processes and enable the regular, comprehensive, and reliable collection, storage, and analysis of data on water quality, cultured fish, energy, and feed consumption [76]. Innovative sensors can accurately measure variables such as dissolved oxygen, temperature, pH, ammonia, turbidity, and water level [100]. AI can be combined with solar PV to provide power for aquaculture, e.g., to monitor feeding, growth, and health status [101]. Some commercial aquaculture operations use drones to monitor fish health and growth, helping to determine optimal feeding tactics and reduce feed waste [23]. Drones also facilitate regular water quality monitoring and record real-time data for decision-making [23].

Automation of various processes and information technology (IT) have been slow to take off in aquaculture because most aquaculture owners, especially in developing countries, are reluctant to invest large sums of money in new technology for fear of not recovering their investment if the technology fails [23,99,101]. At the same time, further research is needed to improve the quality of sensors and minimize their cost to make them more affordable for smaller aquaculture operations [100,102].

The high-tech solutions mentioned above are just some of those available to today's aquaculture farms. Other more specific solutions can modernize, optimize, and make aquaculture more sustainable, such as cloud computing, machine learning, Big Data, virtual reality, robotics, cyber-physical systems, etc. [103]. In addition to high-tech advances, research is also addressing challenges such as the development of genomic platforms to accelerate genetic improvement, molecular methods to identify genes for resistance to iridoviruses and other diseases [101], selective breeding [104], sustainable fish feeds [105] and many other advances.

5. Towards Best Management Practices

The development of the aquaculture industry in the 1970s could be described as a "technological regime with a poor degree of control and labor-intensive production processes" [19], whereas the aquaculture industry today can be described as "biological manufacturing" [19,106]. Sustainability is a growing concern that is driving innovative best management practices (BMP) for the benefit of the environment, economy, and society [23]. In aquaculture, BMP means that aquatic organisms are farmed according to standards set by various governmental and non-governmental organizations with the aim of reducing the environmental impact, reducing harm to local communities, and controlling and improving animal welfare [5]. There have been improvements in the use of renewable energy sources and the primary production of alternative feed sources—wastes and by-products of human activities such as insects, algae, molds, fungi, bacteria, etc. [2].

The Strategic Guidelines, adopted by the European Commission, provide a vision for the future and encourage the use of BMP for sustainable development at the national level [12]. One of the directions is to build resilience and competitiveness, which includes the need to coordinate spatial planning for both freshwater and land-based aquaculture systems based on several criteria, such as the impact on the local ecosystem, the carrying capacity of the area, water quality indicators, etc. [12]. At the same time, licensing procedures should be facilitated by providing legislation and administrative guidance for aquaculture activities, if possible, through the establishment of a one-stop shop in the public administration [12]. There should be a focus on animal health and public health research to improve breeding and husbandry conditions, reduce the use of various types of pharmaceuticals, and improve disease control, data collection, and monitoring [12], adaptation to and mitigating climate change, and participating in the green transition in line with the objectives of the Green Deal [12]. Promoting social acceptance and recognition of the benefits and value of aquaculture activities and EU aquaculture products [12]. One of the ways to achieve greater public support for aquaculture products is to integrate aquaculture systems into local communities, increase knowledge of sustainable practices and products, and promote innovation [12].

One way to incentivize BMPs is through appropriate national policies. Afewerki et al. [19] describe the case of Norway, where development licenses were introduced as one of the innovation policy instruments to promote further sustainable development of the aquaculture industry, including pollution control and reduction [107]. The introduced licensing scheme was designed to actively encourage aquaculture enterprises to participate in the development of new knowledge and/or to use existing knowledge from research or practical experience to develop new sustainable aquaculture production technologies [19]. According to Afewerki et al. [19], there are several aquaculture licensing schemes in Norway, with each license having its own objective, such as limiting the amount of fish to be farmed, the location, the technological solution to be applied or, like the development license mentioned above, the development of technologies that can address important challenges for the sustainability of the industry.

The environmental, animal welfare, and social standards of aquatic food products are increasingly important considerations for producers, buyers, and sellers [6]. Sustainable aquaculture certification schemes (also eco-certification schemes) incorporate the concept of sustainability by requiring aquaculture producers to comply with a set of pre-defined indicators, which are then measured and monitored, thus providing a method to influence the adaptation of BMPs and sustainable practices [6,108,109]. International certification schemes put sustainability into practice, provide clear sustainability roadmaps, and encourage the adoption of BMPs [108]. They also allow producers to communicate their standards and values to stakeholders and consumers [108]. The solution would, therefore, be to encourage aquaculture companies to certify their activities and thus take the initiative to move towards sustainability and safe production for consumers [109]. Sustainability certification should preferably be combined with the principles of the ecosystem approach to aquaculture (more on this in Section 5.2) in order to improve social and environmental sustainability at different levels [109]. The role of certification in promoting sustainable aquaculture could also be strengthened by involving local communities (social sustainability) in the certification process and using criteria that promote continuous improvement of the business [109].

Information and communication technology (ICT) is one of the easiest ways to improve BMPs in small-scale pond farms [110]. Ntiri et al. [110] describe a case study conducted in Ghana where fish farmers using ICT were found to harvest 0.5 kg more fish per square meter than those not using ICT. The biggest contributors to the adoption of BMPs and increased productivity were mobile phone users (SMS and WhatsApp, the free messaging application owned by Meta (formerly Facebook)) and TV [110]. Therefore, for the development of small and less intensive aquaculture farms and the wider use of BMPs, educational materials on disease control, feed, markets, etc., can also be developed and disseminated using ICT technologies [110].

In addition to the development of BMPs, proteomics (the study of all the proteins present in a cell, tissue, or whole organism to identify and quantify their structure and function) could improve disease diagnosis and targeted drug delivery and reveal potential protein biomarkers of stress, reproduction, disease or the immune system, in the aquaculture industry, according to Jaiswal et al. [111].

5.1. Traceability and Transparency

As consumers become more affluent, there is growing concern about ethical issues related to the welfare of those involved in the production and distribution of aquatic food, the environmental sustainability of production systems, the use of genetically modified feed or fish, and animal welfare [6]. Safe food and food supplies ensure nutritional value while minimizing risks to consumer health [6,108]. Traceability of products in supply chains is therefore essential to ensure that contaminated products or products at high risk of contamination, including substandard products, are not passed off as products without such risks [6,112]. Meat from farmed fish can be contaminated during production with a variety of chemicals, including authorized veterinary pharmaceuticals, disinfectants, other biocidal chemicals used for disease control, feed additives, contaminated feed ingredients, and antifouling agents used on farms (e.g., copper oxide) [6,112]. Even though the EU strictly regulates and controls food growing conditions to prevent the presence of various harmful substances and contaminants in food, unscrupulous producers continue to find ways to circumvent the system. It is, therefore, very important to know “where” (traceability) and “how” (transparency) food has been produced and to be able to trust the information provided by the farmer or producer [2,112]. Traceability and transparency are essential to demonstrate accountability and the pursuit of sustainability [2,108]. Therefore, the aquaculture industry should adopt radical transparency and traceability as the absolute standard [2]. Radical transparency means owning both your sustainably farmed product and its environmental impact while encouraging others to help find solutions to improve the sustainability credentials of your products [2]. Thus, one of the future challenges for sustainable aquaculture is the implementation of transparency and traceability as well as corporate social responsibility through open dialogue with relevant stakeholders [2,113].

At the same time, significant quantities of fish and other aquatic organisms are imported into the EU from other countries [114], some of which have been criticized for lack of transparency and traceability in their operational systems [112]. One example is the Global Aquaculture Alliance, which owns and manages the certification of best aquaculture practices [2]. In addition to certifying aquaculture companies, it also certifies its own board members [2]. At the same time, consumers are not sufficiently informed about human rights violations in Asia, the environmental damage caused by the West African fishing industry, “the salmon wars” in Norway, and the apparent lack of traceability of many seafood products [2,113]. Even in relatively well-regulated supply chains, food fraud in aquaculture is a common phenomenon [6,112]. The visual similarity of white muscle from different fish species makes fraud possible, and there are many processed fish products whose appearance or taste is altered by the addition of other ingredients [6]. In the near future, food fraud could be prevented, and traceability and transparency could be improved through blockchains, as this technology can record different transactions such as values, different complementary information, or digital events without the possibility of deleting them [115]. Currently, the lack of knowledge about blockchains and the resulting lack of trust in them is an obstacle to their wider use [115]. This could be changed by further research into how aquaculture companies and farmers perceive blockchain technologies and how they implement them in practice [115].

In the future, it would be important to ensure that the aquaculture industry drives the idea of sustainability rather than expecting consumers to regulate it through their demand [112]. Through national government and regulatory frameworks, it is possible to give the industry an additional push towards more sustainable farming and production practices [112].

5.2. Ecosystem Approach to Aquaculture

As defined by the Food and Agriculture Organization of the United Nations (FAO), the ecosystem approach to aquaculture (EAA) is "a strategy for the integration of the activity within the wider ecosystem such that promotes sustainable development for both present and future generations, equity and resilience of interlinked social-ecological systems" [116,117]. The EAA and the technical guidelines for its implementation have been developed in particular to support Articles 9 and 10 of the FAO Code of Conduct for Responsible Fisheries [117]. There is a strong link between science, policy, and governance, as well as the integration of the concept into national development policies, strategies, and plans for EAA implementation [11,117]. The main objective of the EAA guidelines [117] is to assist countries, institutions, and policymakers in developing and implementing sustainability in the aquaculture sector, the integration of aquaculture with other sectors, and its contribution to social and economic development [7].

In principle, EAA is not a new concept, as aquatic organisms have been farmed on a small scale in inland aquaculture in the past, especially in Asian countries [118]. Aquaculture of carp and other freshwater fish has typically used poultry or other organic waste as a feed source [118]. However, in modern times, it is difficult to implement EAA when intensive and industrial farms are operated in this way [118]. In addition, the regulatory framework in many countries prohibits or discourages the circulation of resources and by-products or residues of bioresources that would allow aquaculture to operate under the EAA [118]. In addition, the ecosystem approach requires that community development planning include physical, ecological, social, and economic systems, as well as other stakeholders, thus addressing all three dimensions of aquaculture sustainability in a social, economic, and environmental context [118]. Figure 3, based on the table created and described by Soto et al. [118], shows the three main principles on which the EAA is based, the degree of its impact, and the main problem areas that need to be addressed for the further development and sustainability of the EAA. Another obstacle to the development of economically sustainable aquaculture is currently the lack of a sufficiently efficient calculation of environmental services [3]. Aquaculture systems are mainly evaluated in terms of financial benefits to farms and businesses but not in terms of socio-economic benefits to society, which could be completely transformed by the introduction of the EAA [3].

A significant shift towards more environmentally sustainable aquaculture could be achieved by implementing policies that require companies to externalize the costs of environmental services in a realistic way, i.e., a properly functioning polluter pays principle [3]. The EAA can overcome the identified barriers by implementing a precautionary approach and adaptive management [118,119]. This approach is crucial for managing ecosystem changes that are slow to reverse, difficult to control, and poorly understood [118]. Adaptive management is the best approach, and interdisciplinary research is essential for long-term success [118].

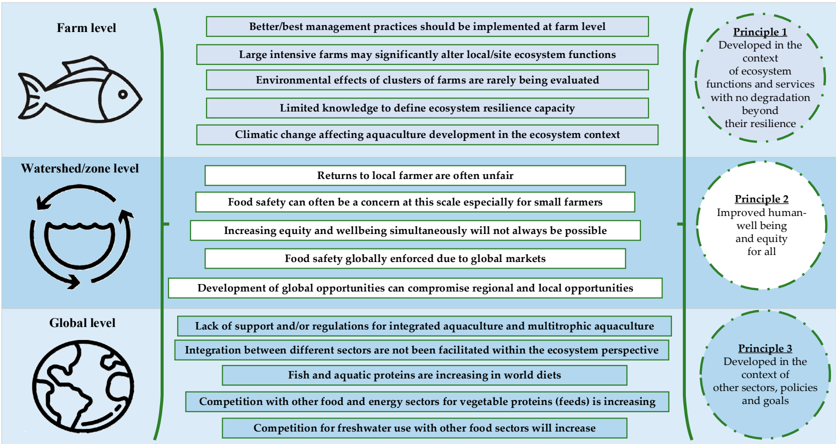

Figure 3. EAA development—scales (on the left), key issues across all three levels and principles (center), and three guiding principles (on the right) (adapted from Soto et al. [118]).

Simulation models can be used to support decision-making tools at different scales, and research on ecosystem service valuation is critical for effective planning and mitigation [118]. Integration of aquaculture, including integrated multitrophic aquaculture (IMTA), is essential to increase productivity and reduce risks associated with by-products [118].

Proactive management agencies should ensure effective training of all staff involved in EAA implementation [118]. Policymakers should ensure that farmers, workers, and other stakeholders are adequately involved in policy decisions and regulations [118]. Incentives should be participatory, timely, and transparent, involve other stakeholders and sectors, and should focus on watershed certification, eco-labeling, eco-certification, and promoting integration and awareness of the ecosystem approach [118,119]. Education and training should be targeted at the farm level and focus on management-oriented knowledge and collective values [118]. At the same time, global consumer and public education are crucial to promoting sector integration [118].

According to Brugere et al. [120], on the relevance of the EAA topic in the scientific literature, the concept has had the greatest impact on spatial planning for aquaculture, including site selection and ecosystem carrying capacity at both the watershed and farm levels. Although EAA has also led to significant advances in land use and spatial planning in practice [11], it has not been used by decision-makers and planners to understand and resolve the more complex institutional issues that also influence aquaculture development [120].

6. Discussion

At this stage, none of the options described above is universally applicable to meet the growing global demand for food from aquatic organisms. In the future, this could be achieved mainly through the combination and improvement of different technological solutions, better management practices, and better siting of aquaculture farms so that they do not exceed the carrying capacity of ecosystems. Henares et al. [5] discuss that the potential sustainability of an aquaculture enterprise could be improved by the choice of aquatic species and location, as well as production and management practices before production begins. Such a practice would be in line with Edwards [3], who argues that the future belongs to the EAA, which promotes ecologically and socially responsible development and operation of aquaculture systems. However, there are still several challenges that need to be overcome if the EAA is to become the future of sustainable aquaculture governance. One of these is balancing the different levels of impact (farm, watershed, global) to minimize the impact at each level. Solutions could include eco-certification schemes that, under the guidance of qualified auditors, can assess the impact of aquaculture on ecosystems at the farm or organizational level over a period of time.

Roy et al. [72] note that farmers often empirically use aeration systems without considering suitability, efficiency, and management costs, which can lead to high management costs and prevent maximum efficiency. In addition, energy efficiency measures should be promoted in aquaculture businesses, especially in RAS, to help business representatives identify weaknesses and improve electricity and heating consumption behavior. Energy efficiency measures have helped to address the energy consumption patterns of several other energy-intensive industries [121–123].

Aquatic organisms cultured in ponds or recirculation systems integrated into a farming operation can be compared to the same principles used by IMTA. Integrated farming models maximize the use of infrastructure, labor, and natural resources in a circular and resource-efficient manner, therefore increasing the environmental and economic sustainability of aquaculture. Das et al. [23] argue that circular aquaculture can improve fish productivity, provide livelihoods and food, reduce environmental impacts, and make aquaculture cost-effective. Circular aquaculture practices can help address climate change, resource scarcity, environmental challenges, and high cost of living [34].

For sustainable land-based aquaculture under changing conditions, research on scientific and management aspects of the bio-economy needs to be more collaborative and involve stakeholders. Technology transfer from universities and research institutes to aquaculture companies is inefficient [5]. More attention should be paid to practical research on technical improvement of aquaculture systems, as some of the most significant research dates back to the 1970s to 1990s [15,56,93,95,124], but since then, there has been a huge leap in technology development, especially in the field of IOT. The scientific field is also dominated by some scientific heavyweights, notably Boyd of Auburn University, USA, who, according to the authors, has made an invaluable contribution to the technological development of aquaculture.

To overcome the identified barriers and challenges, the literature mentions solutions such as better cooperation between universities, research institutes, and aquaculture companies to improve knowledge transfer. A quick look at the education opportunities for aquaculture or aquaculture engineering in Europe does not seem to offer much—training in this area is available in Norway, Denmark, Spain, and the Netherlands. Consequently, the authors are of the opinion that aquaculture education needs to be expanded and promoted at the same time to contribute to the growth of the sustainable aquaculture sector as a whole.

Edwards [3] argues that future contributions to the global fish supply from aquaculture technologies such as RAS, aquaponics, and IMTA are doubtful. This is because of the technological improvements required, which make the end product less competitive due to high production costs. This is in line with Henares et al. [5], who argue that more research is needed to develop and improve aquaculture systems and that it is then quite possible that these systems will prove competitive in the future. If the necessary leap forward in aquaculture technology is achieved, it is possible to talk about forward-looking options for developing aquaculture in line with trends in food production, which are increasingly taking place in cities, by growing aquatic organisms on the rooftops of supermarkets and in urban industrial facilities, where the future circular economy is represented by advanced technologies that combine aquaponics, RAS, industrial waste heat and renewable energy sources [34].

7. Conclusions

A potential obstacle to the development of aquaculture in the EU is probably the lack of relevance of the sector so far, as well as the changing seasons and cold winters, which make it impossible to farm aquatic organisms in open systems and ponds all year round. RAS, on the other hand, are often complex and energy-intensive. The EU's long coastline and access to the seas and oceans have probably also played an important role in the lack of development of fisheries in the past. In the future, there is an urgent need for more in-depth case studies of land-based aquaculture enterprises in Europe to determine the current state of knowledge on available technical solutions and the interest and need for technical solutions. To keep pace with the global leap in aquaculture production, the EU should emphasize the need for practical research to improve the energy and resource efficiency and utilization of renewable resources of the technologies used in aquaculture.

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The Role of Environmental Communication in Advancing Sustainability in Fisheries and Aquaculture: A Case Study of Latvia

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Abstract: Latvia has abundant water resources, but the aquaculture sector has been slow to adopt technological advances and innovations. To address this gap, the Latvian Aquaculture Development Plan for 2021–2027 aims to improve the competitiveness and sustainability of the sector. An essential component of this effort is the establishment of effective communication channels that bridge the knowledge gap between the general public, industry professionals and researchers. To promote consumer interest in sustainable aquaculture products, an environmental communication framework to assess their sustainability was used. This assessment utilised a multi-criteria analysis technique complemented by an online survey to formulate an effective communication strategy. According to the multi-criteria analysis, canned fish emerges as the most sustainable product, while fish oil, fish meal and spirulina show promise. The online survey identifies the most appropriate communication channels: social media, audio and video. To facilitate engagement and information sharing, we advocate for the practice of communication, which can effectively facilitate the sustainable use of biological resources and serve as a channel for knowledge sharing.

Keywords: aquaculture; bioeconomy; biodiplomacy; environmental communication; communication strategy; fisheries

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1. Introduction

Recognising climate change and its potential threats to the environment, economy and society, the European Union (EU) has set itself the goal of becoming the first climate-neutral part of the world in terms of net greenhouse gas (GHG) emissions by 2050 [1]. This goal is to be achieved gradually, starting with a 55% reduction in GHG emissions by 2030 compared to 1990 levels [1]. To achieve this objective, the EU has adopted a number of strategies and policy planning documents over time [2]. The European Bioeconomy Strategy "Innovating for Sustainable Growth: A Bioeconomy for Europe" [3] and the updated version "A sustainable Bioeconomy for Europe: Strengthening the connection between economy, society and the environment" [4] are some of these policy documents. The bioeconomy is one of the cornerstones of the transition to climate neutrality. It promotes the application of sustainable practices in bio-based resource sectors such as agriculture, the forest sector and fisheries and aquaculture, maximises the use of extracted resources for the production of food and raw materials and reduces dependence on non-renewable energy sources [2,5,6]. The successful integration of the bioeconomy into the different sectors requires a specific approach to raise awareness in society and convince governments and companies to adopt new governance tools that contribute to building a sustainable-minded society [7].

A shift to more sustainable and environmentally friendly production of food, manufactured goods and energy is necessary to ensure that the current rate of global population growth does not deplete the regenerative capacity of the environment, threatening the existence of all living things and ecosystems [8,9]. Experts with a broad range of expertise are needed here to advocate for sustainable resource use in dialogue with society and the economy and to help achieve the goals of the bioeconomy and circular economy [7,8,10].

Diplomacy can be employed as a means to foster a shift in thinking among diverse stakeholders in the bioeconomy. The Oxford Advanced Learner's Dictionary and the Cambridge Dictionary define the term "diplomacy" in two ways: (1) "the activity of managing relations between different countries; the skill in doing this" [11] and (2) "skill in dealing with people in difficult situations without upsetting or offending them" [11,12]. Science diplomacy, as defined in the scientific literature, refers to the application of knowledge-based decision-making to promote the alignment of local and international interests in order to achieve global sustainability [13–15]. The term is defined explicitly and also in different ways, but the literature review looks at the origins of the term and its use.

The origins of biodiplomacy lie in the concept of biopolitics, which is part of the "bios theory" developed in the late 1980s by A. Vlavianos-Arvanitis [16]. *Bios* is translated from the Greek meaning "life", and the proposed theory is based on the belief that humans should be able to interact in harmony with the environment and all living beings [16]. However, the threat to this harmonious interaction is the impact of human activities on the environment, which is exacerbated by geopolitical conflicts [17]. The solution to the paradigm shift lies in proper education, interdisciplinary communication and concerted action by universities and government [17,18]. Although A. Vlavianos-Arvanitis does not provide a definition of "bio-diplomacy", it is rather seen as a vision of the future: "[. . .] bio-diplomacy which will be involved in enhancing international co-operation on environmental issues and will actively support all efforts to protect and maintain biodiversity. At the same time, biodiplomacy will seek to improve human relations and attain the goal of world peace, by replacing current diplomatic attitudes with a complete international and intercultural perspective [18]".

Nearly three decades later, the concept of biodiplomacy is regaining prominence [19,20] as a communication tool aimed at raising global public awareness of the concepts of the circular economy and the more sustainable use of bioresources [19,21]. In the context of the bioeconomy, biodiplomacy refers to a mode of communication and negotiation between many parties involved to advance the utilisation of bioresources in accordance with globally and nationally accepted norms that promote environmental sustainability and climate neutrality [19].

The concept of biodiplomacy is used internationally, and the previous paragraphs have given an overview of the use and meaning of the term, and that it is mainly used as a form of communication between parties. In this publication, a national case study has been carried out for Latvia, which may also be transferred internationally, but in the following, the term environmental communication will be used for communication between parties. This includes the type of communication, how easy or difficult it is to reach the social side (the consumer of the products), which are the best types of communication and what needs to be thought about in order to ensure a sustainable product chain in the economy in the future.

In this case, (to develop the concept) an attempt was made to develop a communication strategy for environmental communication at the national level. Methods were used that can also be applied internationally, such as a multi-criteria analysis of selected criteria and online surveys. Developing a communication strategy at the Latvian level is important because fish stocks in the Baltic Sea are declining [22,23] and the growth of aquaculture should be encouraged to be sustainable, while consumers and the industry lack confidence in the science and scientists [24,25], which hinders the necessary growth. Therefore, a Latvian case study was chosen to test the developed methodology and to disseminate it on a larger scale in future research. The United Nations Bruntland Commission is credited with providing one of the best-known definitions of sustainability [26]. The Bruntland Commission defined sustainable development as "meeting the needs of the present without compromising the ability of future generations to meet their own needs" [27]. In public perception, however, sustainability is more often understood as "the capacity of human activities to persist in time while maintaining a healthy environment" [26]. The contemporary understanding of sustainability is sometimes ambiguous and therefore requires a close examination of what sustainability means in the economic, environmental and social domains.

The three domains or pillars of sustainability are economic sustainability, the ability of people to continue to earn a living from an activity; social sustainability, which is based on public acceptance of a particular activity; and environmental sustainability, the ability to engage in an activity without harming the environment while not compromising the extraction of necessary resources so that they can be used [26]. At the same time, it is imperative to comprehend that the three components of sustainability are intricately linked and indivisible [26,28]. Nevertheless, the increasing global demand for fish and other aquatic goods poses a challenge to achieving a balance between these three domains [26,29].

Environmental sustainability and policies that mitigate pollution or improve the natural environment have been on the EU agenda since the 1970s [30], while national governments have only recently recognised the importance of environmental challenges and the importance of environmental sustainability [31,32]. In the field of ecology, sustainable biological systems are characterised by their diversity, adaptability, resilience and productivity over extended periods of time [26]. In practice, this means the presence of thriving biological systems and ecosystems, such as seas, lakes, rivers and forests [26]. In contrast, this definition of environmental sustainability is difficult to apply to food production systems, including aquaculture [26]. In the case of aquaculture, environmental sustainability should be understood as the impact of its production processes on the specific place where it is located, in addition to the pressures on natural resources used in the production, handling and processing operations [26]. Environmentally sustainable production is essential to maintain the productivity and diversity of food resources and the ecosystems that support them and to ensure that food production does not compromise other ecosystem services [33,34]. The direct and indirect environmental impacts of production systems and supply channels, including those related to energy demand, threaten environmental sustainability [33,35].

The definition of sustainable development in economic theory explains sustainable economic development as an economic system in which the production base or total capital remains constant over time [26]. Capital in this case refers to the comprehensive wealth of a system, including its human, environmental and economic components [26]. The planet's limited resources do not allow for unlimited growth, but at the same time, it is not possible to clearly define the limits of the system and to quantify the consequences for the elements that are not directly linked to it [26].

Social sustainability can be interpreted as enhancing or maintaining the well-being of the members of a community [26]. Social sustainability focuses on ensuring fair labour practices and efforts to reduce social inequalities, improve quality of life, protect human rights and prevent risks by promoting the adaptation of just and equitable social, economic and environmental policies [26,36]. Social sustainability in the context of aquaculture could also take the form of product accessibility to local communities, both in terms of the price and physical availability of the product [36]. Socially sustainable aquaculture would also contribute to the strategic objectives of the Farm to Fork Strategy [37]. Low financial profitability of production systems and a lack of resilience to disruption pose a threat to social and economic sustainability [33].

The EU Bioeconomy Strategy Progress Report "European Bioeconomy policy: stocktaking and future developments" (further: Progress Report), published in June 2022, states that all bioeconomy policies are interlinked and must be based on all three dimensions of sustainability mentioned above [38]. In this context, the sustainability dimensions mentioned in the Progress Report are defined as follows:

- Environment: management of land and biological resources within ecological limits;

- Economy: sustainable value chains and consumption;
- Society: social justice and fair transformation [38].

Examining the broad concept of sustainability in its three aspects provides a clearer understanding of the criteria against which aquaculture practices should be assessed and the variables that need to be considered. Given the strict environmental regulations of the European Union [30] and its ambitious goals for the future, it is essential that the assessment of sustainability focuses on the complex elements described in the Progress Report [38]. At the same time, it is important to avoid isolating one facet of sustainability from the other two but instead to look at the whole system as a multi-faceted concept [26].

Various stakeholders support the concept of sustainable aquaculture, but in practice, the concept of sustainability is often forgotten, resulting in the loss of one or more sustainability dimensions [26]. Sometimes one of the pillars of sustainability is placed above the others, leading to an imbalance in the development and maintenance of truly sustainable aquaculture [26].

Sustainability vs. Fisheries and Aquaculture

The European Bioeconomy Strategy "Innovating for Sustainable Growth: a Bioeconomy for Europe", adopted in 2012, addresses the need to use biological resources sustainably and to try to produce "more from less" [3]. Promote the creation of higher added-value products in the aquaculture sector through a knowledge-based approach and by encouraging innovation [3]. The strategy identifies a number of measures that should be taken to improve the production of sustainable and healthy aquaculture products. These include better control of reproductive processes, innovative methods for selective breeding, optimisation of feed and industrial processing, monitoring of animal health and welfare, disease control and mitigation, and conservation and bioremediation of aquatic ecosystems [3]. Sustainability has gained importance not only as an ideological vision for future growth but also as a result of efforts to develop and implement sustainability assessments [39–41]. It argues that future bioeconomy development should focus more on sustainability assessment, including sustainable management and the use of biological resources [38]. The future development prospects and competitiveness of fisheries and aquaculture require the application of assessment techniques based on sustainability assessment. Sustainable food production is an inherently subjective concept that describes how the planet enables people to use raw materials from which a variety of goods and services are produced and to benefit from them in ways that are theoretically compatible with the continued provision of these environmental services [26]. Food industry stakeholders have recognized that the amount of food produced per unit of land must be increased to meet the protein needs of a growing world population [26]. Increasing intensification could be a solution, but it has already and will continue to have negative impacts on natural habitats and the ecosystem as a whole, which, combined with climate change, will have a long-term negative impact on food availability [26,42].

The bioeconomy, as discussed in the context of the European Bioeconomy Strategy, is innovative, knowledge-based and circular and conceptually departs from the principles of the conventional and resource-inefficient bioeconomy [6]. In contrast, in the case of inland aquaculture systems, conventional farming methods used historically may be considered more sustainable than modern intensified aquaculture systems [43]. This is because traditional aquaculture systems were deeply integrated into the functioning of the farm, and the by-products and residues were used to feed the farmed aquatic organisms [43]. Aquaculture should ideally mimic the natural conditions that aquatic organisms would find in the wild, but this approach is not always compatible with intensification and the expected increase in production [26]. Therefore, sustainable aquaculture practices should be able to provide a continuous supply of nutrients from aquatic organisms without damaging existing ecosystems and without exceeding the planet's capacity to replenish the natural resources needed to cultivate aquatic organisms [26,33]. Especially since aquaculture production is no longer an insignificant market share compared to animal protein and has overtaken beef production over the last decade [26,33,44]. The increasing demand for sustainably produced protein has fuelled the rapid growth of aquaculture and encouraged its intensification [26]. However, increased intensification is not always compatible with the concept of sustainability [26].

The pathway for aquaculture to achieve its sustainability goal should be the same as for any other form of food production, namely limiting, preventing or isolating local pollution and accelerating the efficient use of natural resources, in a way that does not conflict with any of the dimensions of sustainability [26]. Consequently, a sustainability assessment for aquaculture should take into account the different perspectives of stakeholders and try to identify where they intersect, as well as draw red lines where these intersections of interests lie outside the dimensions of sustainability, in order to be able to address the problem.

This study employs a mixed-methods approach to analyse the sustainability of the fisheries and aquaculture sector and to determine the most communication channels for biodiplomacy. The methodology was used to identify sustainable fish and aquaculture products and assess the basic concepts on which to build an environmental communication strategy to send appropriate signals to both the public and the industry.

2. Materials and Methods

The study followed a two-part strategy (Figure 1). The main objective of the first part was to identify the best environmentally and economically sustainable approach to using fish or aquaculture products. To achieve this goal, a total of six different fishery and aquaculture products were selected. Of these, three were categorised as fish products, while the other three were algae products. A comprehensive comparison was made between these commodities using the TOPSIS multi-criteria analysis method based on specific criteria established for this study.

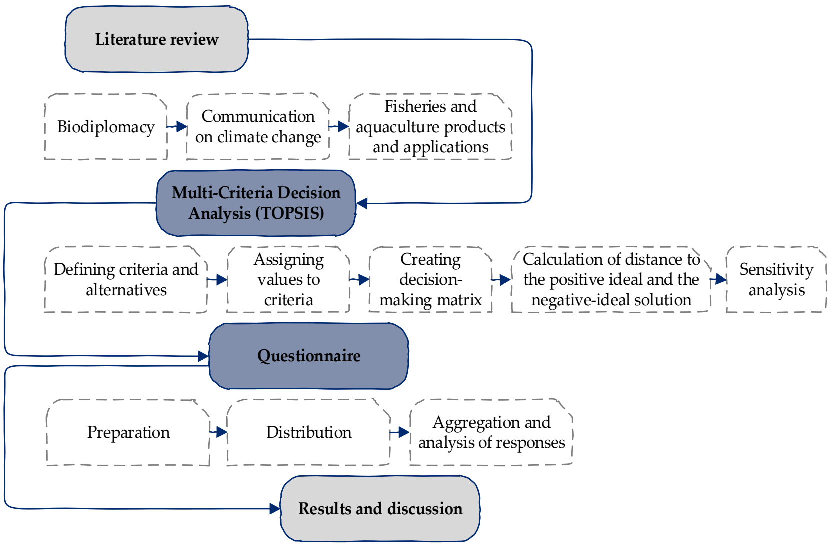

Figure 1. Research algorithm.

The second part of the methodology was to select the most appropriate method to communicate the sustainable use of fisheries and aquaculture production to the public. A questionnaire was chosen as the most appropriate means of collecting information to achieve the objective. In order to obtain the largest possible number of respondents and answers, the survey was conducted in electronic form. The questions were designed to best understand the communication channels, the patterns of use of the educational content and the public's attitude towards environmental and climate change communication in general.

The findings facilitate the effective development of communication materials in terms of content, type and format that can effectively disseminate knowledge-based information to the general public. This will enable customers to make more informed decisions and choose sustainable goods or materials.

2.1. Aquaculture Products Selected for Comparison

The study compared six alternatives for the use of fisheries and aquaculture products. The algae products proposed were biogas, spirulina as a food supplement and algae fertiliser. The fish products selected were fish meal and oil, biodiesel from fish and canned fish. The study looked at both innovative and traditional alternatives, as the innovative alternatives offer the possibility to optimise existing processes and develop the sector, while the existing alternatives are more reliable and have more accurate data.

In order to compare the alternatives, the raw material quantities for the alternatives studied were set at 1 tonne of algae and 1 tonne of fish.

2.2. Selection of Sustainability Criteria

Assessing the sustainability of a product or process involves economic, social and environmental considerations and therefore requires the use of criteria related to these aspects. In order to achieve the most impartial results possible, a combination of quantitative criteria, which were subjected to quantification or calculation, and qualitative criteria, which were scored on a scale of one to five (with higher scores indicating greater sustainability of the chosen option), was established. The criteria were divided into four different categories, namely economic, environmental, technical and social.

Economic criteria have significance as they demonstrate the economic use of a specific product and its capacity to align with broader economic progress. Economic criteria include economic indicators assessed by experts and the selling price of the product.

The social factors examined in the study exhibit a strong correlation with the economic criteria. These elements encompass the perceptions and opinions held by the general public towards a certain product and exert a direct influence on consumer habits and behaviours. In addition to the other ethical aspects, possible employment opportunities were considered, since they are closely associated with economic growth and the long-term viability of the product.

The current state of the world's climate, combined with a growing population and increasing resource consumption, has led to a need for sustainable products that have minimal impact on the environment. Consideration of environmental variables is crucial in assessing the sustainability of various goods. Research includes expert assessments of environmental and climate performance as well as analyses of their impact on biodiversity.

Finally, it is important to consider technological variables, as they provide information on the long-term viability and durability of the technology used in the production process. Technological elements include the degree of technological advancement as assessed by experts in the field and indicate the level of knowledge and expertise related to a particular technology. In addition, these variables include the energy consumption associated with the manufacturing or extraction processes of a particular product. The level of understanding of a particular technology correlates directly with its reliability and potential for optimisation to increase operational efficiency.

2.3. Qualitative Criteria

In the multi-criteria analysis, six of the eight criteria were determined by calculating the arithmetic mean of the experts' ratings. A total of 28 experts were interviewed and rated the impact of each criterion on the alternative on a scale of one to five. The only exception was the criterion "impacts on biodiversity". For this criterion, the rating scale ran in reverse order: the higher the numerical value, the more negative the rating. This can be justified by the fact that a sustainable alternative has the lowest possible impact on biodiversity. Of course, there can also be positive impacts on biodiversity, but the study concluded that, in this case, it would be more appropriate to rate the impact on biodiversity as negative. An analysis of the experts' assessments shows that the results are similar, although the experts specialise in different areas.

2.4. Quantitative Criteria

The study examines two quantitative criteria, namely the price and the energy consumption of the selected products (Table 1. Regarding the selected quantities of 1 tonne of algae and 1 tonne of fish, it is imperative to verify the units of measurement provided in the sources and perform any required conversions. The selling price was determined by calculating the average price of the product. To achieve this, data were collected from many online marketplaces, and the necessary conversions were made.

Table 1. Quantitative criteria.

	Biogas	Spirulina	Fertiliser	Fish Oil and Flour	Biodiesel	Food (Canned)
Selling price (EUR/t)	67 [45,46]	30,000 [47]	100 *	2350 [48]	57.21 [49]	4750 [50]
Energy consumption (kWh/t)	220 [51]	2180 [51]	350 [52]	32 ***	187.7 [53,54]	170 **

* For fertiliser, seaweed and algae washed from the sea are taken, and only transport costs are included. ** from BAT. *** calculations.

2.5. Evaluating Aquaculture Products Using TOPSIS

The Technique of Order Preference Similarity to the Ideal Situation (TOPSIS) method is used to find the solution that is closest to the ideal positive option [55]. This method uses the numerical values of the previously identified qualitative and quantitative criteria [55]. The TOPSIS multi-criteria analysis requires five sequential steps that can be used to determine the sustainability score of the indicators (Figure 2).

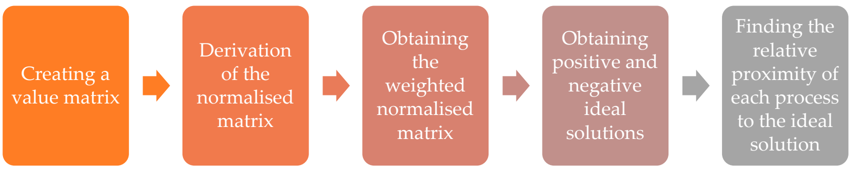

Figure 2. Toolbox for applying the TOPSIS method.

The first step is to create a matrix of values based on the previously mentioned criteria. Table 2 shows the aggregated data used for the TOPSIS multi-criteria analysis method. To make the matrix transparent, the criteria are grouped according to their factors: economic, environmental, technological and social. The alternatives are also ordered by the type of aquaculture product concerned, with algae alternatives first, followed by fish alternatives.

Upon completion of the construction of the matrix of values, a normalised matrix is generated by calculating the values in accordance with Equation (1), whereby each value is divided by the sum of all square roots associated with the respective criterion.

$$r_{ai} = \frac{x_{ai}}{\sqrt{(\sum_{a=1}^{n} x_{ai^2})}} \quad (1)$$

where

a—alternative;
i—criterion;
r_{ai}—normalised value;
x_{ai}—indicator value.

Table 2. Data collected for TOPSIS analysis.

	Biogas	Spirulina	Fertiliser	Fish Oil and Flour	Biodiesel	Food (Canned)
Economic indicators	3.39	3.82	2.75	3.64	3.38	3.36
Selling price (EUR/t)	67	30,000	100	2350	57.21	4750
Environmental and climate indicators	3.39	3.39	3.11	3.20	3.54	3.04
Impacts on biodiversity	2.96	3.29	3.04	3.43	3.32	3.29
Technology development level	3.54	3.32	3.43	3.57	2.98	4
Energy consumption (kWh/t)	220	2180	350	32	187.7	170
Potential number of jobs	2.93	3.54	2.74	3.54	3.18	4.07
Ethical aspects	3.6	4.3	3.6	2.67	2.08	2.85

The normalised matrix values are further used to create a weighted normalised matrix. The weighted normalised matrix values are obtained by multiplying each rai value by the weighting value w. The total weighting value for all criteria should be one. In the normalisation method of the TOPSIS multi-criteria analysis, all criteria have been given the same weight of 0.125. This value is obtained by dividing the number of all criteria, which is eight, by one.

After obtaining the weighted normalised matrix, the positive ideal and negative ideal solutions are determined. This is performed by taking the maximum and minimum values from the weighted normalised values obtained earlier. In all cases, except for the calculation of energy consumption its and impact on biodiversity criteria, the maximum numerical value from the weighted normalised matrix was taken as the positive ideal value and the minimum numerical value as the negative ideal value. In the case of energy consumption and its impact on biodiversity, it should be noted that the higher the energy consumption or biodiversity impacts, the more negative the impact on the sustainability rating of the product or process. Therefore, when determining the positive and negative ideal values for these two criteria, the minimum of the weighted normalised values was taken as the positive ideal value and the maximum of the weighted positive values as the negative ideal value.

Next, the distance of the numerical value of each alternative from the positive ideal solution and from the negative ideal solution is determined. Equation (2) was used to determine the distance from the positive ideal solution, and Equation (3) was used to determine the distance from the negative ideal solution.

$$da+ = \sqrt{\left(\sum_{j=1}^{n} (\ v_i^+ - v_{ai}\ )^2\right)} \tag{2}$$

$$da- = \sqrt{\left(\sum_{j=1}^{n} (\ v_i^- - v_{ai}\ )^2\right)} \tag{3}$$

where

d_a^+—distance to the positive ideal solution;
d_a^-—distance to the negative ideal solution;
v_i^+—positive ideal value;
v_i^-—negative ideal value;
v_{ai}—weighted value.

Once the distances to the positive and negative values have been determined, the relative proximity coefficient is calculated according to Formula (4):

$$C_a = \frac{d_a^-}{(d_a^+ + d_a^-)} \tag{4}$$

where

C_a—coefficient of relative proximity.

The value of the relative proximity coefficient lies between zero and one, and the closer it is to one, the more favourable the alternative is and the more sustainable it can be evaluated as. Using the above equations, the calculations are carried out, and the values are presented in Tables 3–5. In all tables, the alternatives are marked with the letter A, and the criteria are marked with K. The alternatives and criteria are arranged in the same order as in Table 2.

Table 3. Normalised matrix.

	A1	**A2**	**A3**	**A4**	**A5**	**A6**
K1	0.4063	0.4579	0.3296	0.4363	0.4051	0.4027
K2	0.0022	0.9847	0.0033	0.0771	0.0019	0.1559
K3	0.4216	0.4216	0.3867	0.3979	0.4402	0.3780
K4	0.3753	0.4160	0.3844	0.4341	0.4205	0.4160
K5	0.4140	0.3889	0.4015	0.4182	0.3491	0.4684
K6	0.0985	0.9761	0.1567	0.0143	0.0840	0.0761
K7	0.3557	0.4295	0.3329	0.4295	0.3861	0.4946
K8	0.3910	0.4425	0.3832	0.4025	0.3794	0.4455

Table 4. Weighted normalised matrix.

	A1	**A2**	**A3**	**A4**	**A5**	**A6**
K1	0.0508	0.0572	0.0412	0.0545	0.0506	0.0503
K2	0.0003	0.1231	0.0004	0.0096	0.0002	0.0195
K3	0.0527	0.0527	0.0483	0.0497	0.0550	0.0473
K4	0.0469	0.0520	0.0480	0.0543	0.0526	0.0520
K5	0.0518	0.0486	0.0502	0.0523	0.0436	0.0585
K6	0.0123	0.1220	0.0196	0.0018	0.0105	0.0095
K7	0.0445	0.0537	0.0416	0.0537	0.0483	0.0618
K8	0.0489	0.0553	0.0479	0.0503	0.0474	0.0557

Table 5. Positive and negative ideal solutions.

	Positive Ideal Solution	**Negative Ideal Solution**
K1	0.0572	0.0412
K2	0.1231	0.0002
K3	0.0550	0.0473
K4	0.0469	0.0543
K5	0.0585	0.0436
K6	0.0018	0.1220
K7	0.0618	0.0416
K8	0.0557	0.0474

The values given in Table 5 are further used to determine positive and negative ideal values, which are then used to derive the relative proximity coefficient. To better analyse the results, the relative proximity coefficient is presented in a graph. A sensitivity analysis is then carried out to check which of the results obtained is the most consistent.

2.6. Sensitivity Analysis

To determine the stability of the given criteria, a sensitivity analysis was carried out after the TOPSIS multi-criteria analysis. The sensitivity analysis shows how much the results of each alternative in the TOPSIS analysis change when the weighting of the criterion is changed. For this purpose, a matrix was created for each criterion showing the values of the relative closeness coefficient of each alternative when the weighting of the criterion is changed. As mentioned earlier, the total value of the weighting of all criteria should be one. This means that by changing the weighting of a particular criterion, the remaining weighting value is evenly distributed among the other criteria. The weighting value of the criterion in question, i.e., the value of the weighting of the criterion in question, was changed in steps of 0.1 from 0.1 to 0.9. The weighting value of the remaining criteria was calculated according to formula 1.5 by subtracting the value of the criterion in question from one and then dividing by seven. The remaining weighting value thus obtained is distributed equally among the remaining seven criteria.

$$w = \frac{1 - w_0}{7} \tag{5}$$

where

w—weight of each remaining criterion;

w_0—weight of sensitivity analysis criterion.

After the calculation, a diagram is created from the changed matrix of each criterion, which can be used to see how the results and the ranking of the alternatives, in terms of sustainability, change as a result of the change in a particular criterion. According to the sensitivity analysis, the most sustainable outcome is the one that adapts best to the changes in the criteria, i.e., the one with the most upward curves. To calculate this, the number of upward curves for each alternative was subtracted from the number of downward curves. The most sustainable alternative is the one with the highest numerical result.

2.7. Questionnaire

To determine public attitudes, information-gathering habits and the most appropriate form of biodiplomacy, a survey was conducted via Google Forms and disseminated through Facebook. By creating an electronic version of the survey and disseminating it through social media platforms, a wider population can be effectively targeted and included in the data collection. A total of 140 respondents of different ages were surveyed. Most of the respondents were between 18 and 55 years old.

The questionnaire included questions on the respondents' regular communication patterns and information consumption habits, as well as their views on the concept of biodiplomacy.

3. Results

3.1. Analysis of TOPSIS Results

The results of the TOPSIS multi-criteria analysis calculations carried out to assess the six fisheries and aquaculture products against the stated sustainability criteria are shown in Figure 3.

It can be seen that, of the values obtained for the coefficient of relative proximity, canned fish comes closest to the ideal result, with a value of 0.56 according to the given criteria, which means that canned fish can be considered the most sustainable product among the given alternatives according to the given criteria. However, it should be noted that the relative coefficient values are similar for all alternatives. The value of fish meal and oil differs from canned fish by only 0.03, and spirulina comes in third, differing from canned fish by 0.04.

The results show that the alternatives or products whose values are closest to the ideal result (Ca: coefficient of relative proximity) are widely known and used. This means that they have a high level of technological development, high market demand and proven stability. However, it can be seen that the values for biodiesel from fish products and biogas from algae are relatively close to those for fishmeal, canned fish and spirulina, which means that the ranking of alternatives in the sustainability assessment may change over time as the technologies for producing biodiesel and biogas evolve.

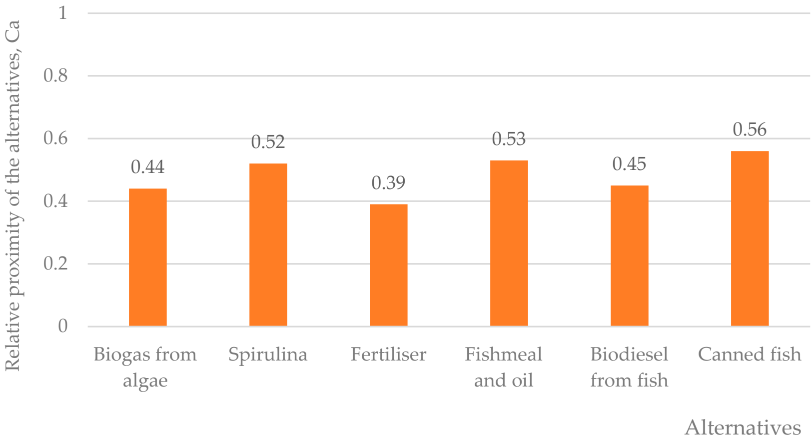

Figure 3. TOPSIS analysis results.

3.2. Results of Sensitivity Analysis

To enhance the clarity of the sensitivity analysis findings, our team conducted criteria sensitivity analyses for distinct groupings of criterion components, including economic, environmental, technical and social aspects.

The graphs of the changes in the economic factor criteria are shown in Figures 4 and 5. Figure 4 shows the change in results when the weighting of the economic indicator criterion is changed, and Figure 5 shows when the weighting of the sales price criterion is changed. Although the change in the relative proximity coefficients between the two criteria is mostly different for all alternatives, it can be observed that the spirulina score increases for both criteria. This shows that spirulina is potentially the more economically viable alternative.

It can also be observed that the values for fishmeal and oil increase significantly as the weight of the economic performance criterion increases. The difference between the graphs of the two economic factor criteria could be explained by the fact that economic indicators can take into account several factors that could differ between alternatives, such as profit, payback period, production costs and others. In the case of the selling price, on the other hand, only the value of the selling price is taken into account, regardless of other costs.

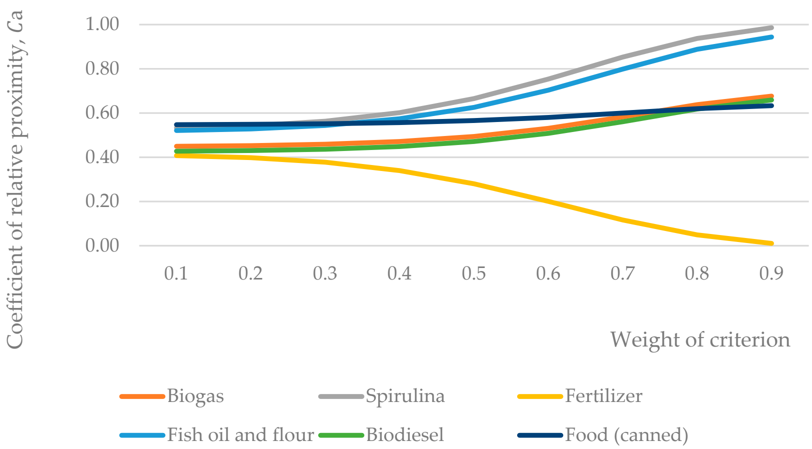

Figure 4. Changes in results by changing the weight of economic indicators.

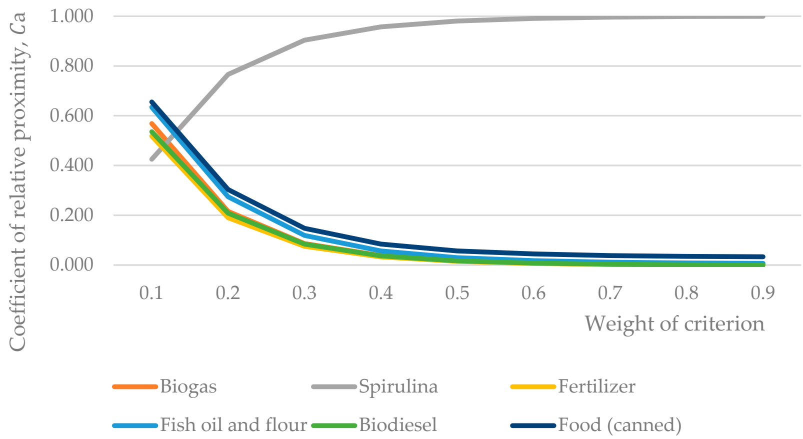

Figure 5. Change in results due to a change in the weight of the selling price.

Increasing the criterion weighting values for the group of environmental factors, Figures 6 and 7 show that the value for biogas increases towards the ideal value, while the positions for canned fish and fish oil and meal decrease significantly. Fish biodiesel increases in value because it is a new, innovative product produced from fish by-products and is in line with the basic principles of the bioeconomy.

Figure 7 also shows that the relative proximity coefficients of all alternatives decrease as the weight of the biodiversity impact criterion increases, with the exception of algal biogas and fertiliser production. The absence of direct environmental impacts in biogas production due to anaerobic digestion and the use of algae and seaweed found on the coasts as fertilisers, which mitigates the risks of eutrophication and promotes biodiversity, are the reasons for these results.

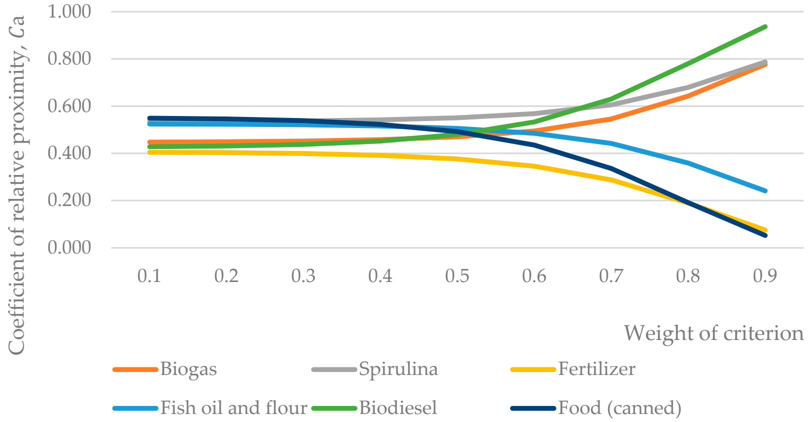

Figure 6. Changes in results by changing the weight of environmental and climate indicators.

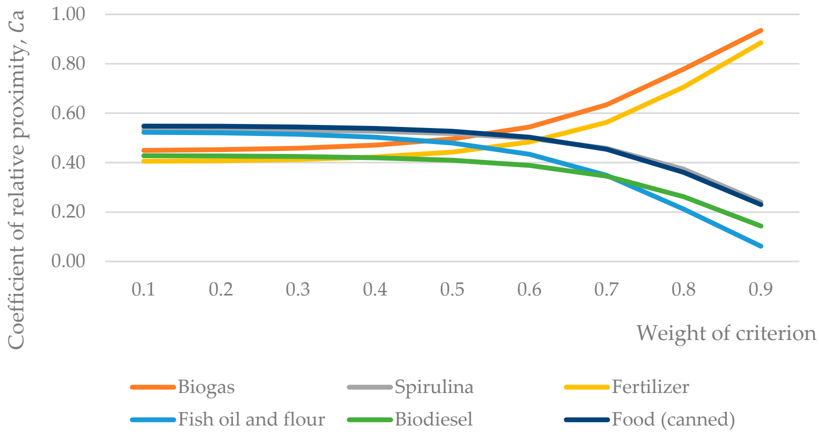

Figure 7. Changes in results by changing the weight of impacts on biodiversity.

In the technological criteria, the evaluation of canned fish is highest when the weight is changed. In Figure 8, increasing the weight of the level of technological development leads to a decrease in the scores of alternatives where the production technology is still underdeveloped, not widely used or may require an optimisation process. An example is biodiesel from fish, which is a relatively new, unexplored product for which the production technology is not yet developed. The spirulina curve for a food supplement is probably sloping downwards because the production process needs to be optimised and is currently not efficient enough.

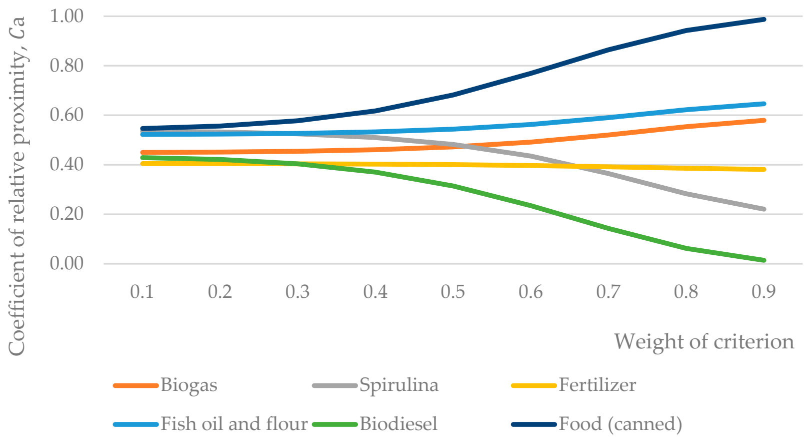

Figure 8. Changes in results as the weight of the technology development level changes.

The increase in energy consumption weight shows that the results of all alternatives increase, with the exception of spirulina, which can be explained by the fact that the production process of spirulina consumes significantly more energy than the other alternatives.

The impact of changes in the weighting of the social criteria on the alternatives is shown in Figures 9 and 10. As can be seen, as the number of potential jobs increases, so does the number of alternatives whose production process requires more people either to perform the work manually or supervise the process. Biogas and biodiesel are produced through a biochemical process, while algae and seaweed for fertiliser are currently harvested for free by local coastal people, either manually or with simple machinery.

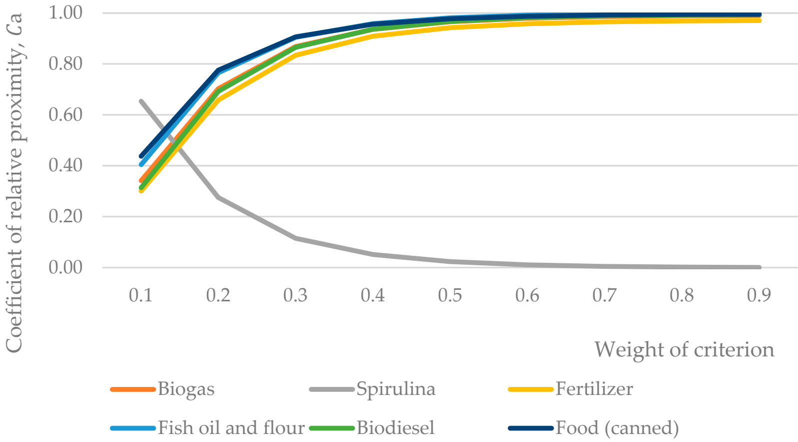

Figure 9. Changes in results by changing the energy consumption weight.

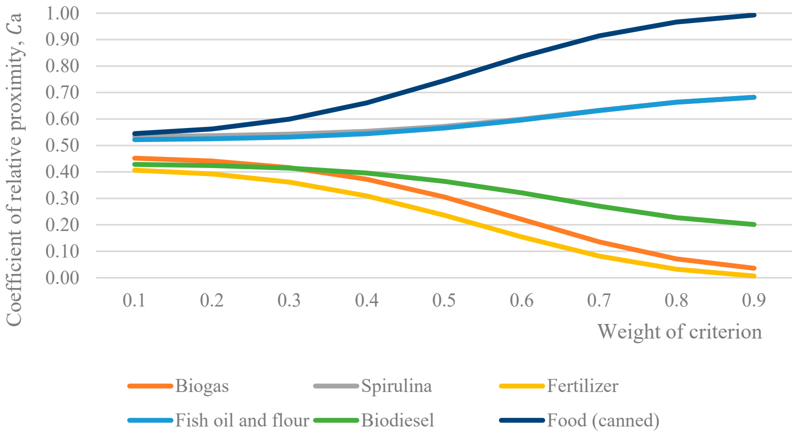

Figure 10. Changes in results by changing the weight of the potential number of jobs.

Changing the weight (Figure 11) of ethical aspects diminishes the value of alternatives to the use of fish products that can be associated with the process of harvesting and killing fish.

The sensitivity analysis depicted in the graphs demonstrates that alterations in the weight assigned to each criterion exert a substantial influence on the deviation of alternative values from the desired outcome. Notably, no scenario is observed where the value of the alternatives remains unaffected or exhibits negligible sensitivity to modifications in the criteria. The graphs illustrate that notable variations in the outcomes are attributed to criteria in which a certain alternative has a considerably superior performance. In the context of the cost of sales, it is seen that the selling price of the spirulina food supplement surpasses that of all other alternatives, indicating the substantial superiority of this particular option. Table 6 shows the calculations for the differences between the quantities of the positive and negative curves.

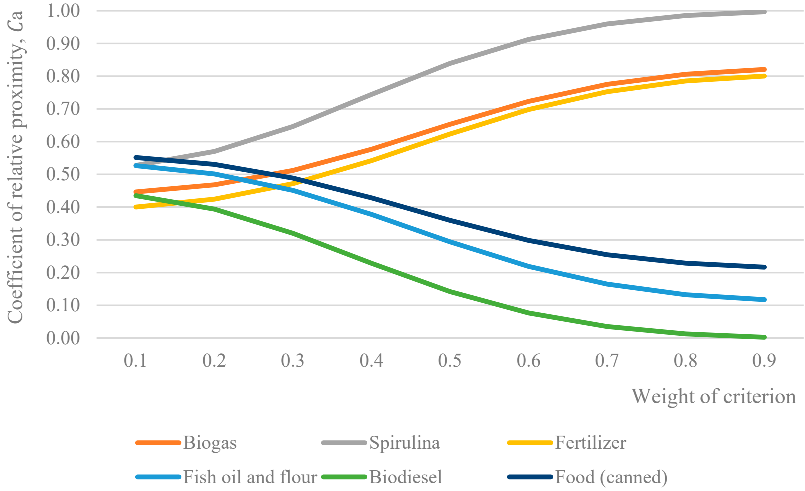

Figure 11. Changes in results by changing the weight of ethical aspects.

Table 6. Sensitivity analysis results.

	Biogas	Spirulina	Fertiliser	Fish Oil and Flour	Biodiesel	Food (Canned)
Number of upward curves	6	4	2	4	3	4
Number of downward curves	2	4	6	4	5	4
Margin	4	0	−4	0	−2	0

The alternative with the highest score is biogas. It is followed by canned food, spirulina and fishmeal and oil. Overall, the most favourable alternatives are canned fish, fishmeal and oil, food supplements (spirulina) and biogas.

3.3. Survey Results Analysis

The first step was to find out which sources of information the respondents prefer to use in their daily lives. Since most people use several sources of information for different purposes in their daily lives, there was more than one answer option. From the respondents' answers, the three most popular sources of information they use on a daily basis are social networks, news portals and television. This is followed by radio, newspapers and others. It should be noted, however, that the survey was distributed via Facebook, which could be related to the fact that people prefer to obtain their information from social networks.

To understand which communication channel or platform builds trust and helps people absorb information more easily, it is necessary to find out how people communicate with each other and what kind of communication they prefer in everyday life. This question could be even more relevant for communication with industry or companies to develop a personalised approach and convince them as effectively as possible to reconsider the sustainability of the industry or company. Means of communication can vary depending on who you are communicating with, for example, in a work environment, information is often shared differently with colleagues than with friends or family members. For this reason, respondents were given the option to choose multiple answers at the same time. From the results, it appears that the majority prefer WhatsApp, Messenger, etc., and face-to-face meetings for interpersonal communication, suggesting that both written and verbal information is easily perceived.

However, despite the fact that the majority of respondents use various platforms on the internet, it is important to understand whether they also like to consume educational content and, if so, in what format. Almost 93% of the respondents answered that they consume educational content, preferring mostly visual and audiovisual material. This could be explained by the fact that they are easier to understand and usually do not take as long as reading blogs or scientific publications, for example. However, it should also be clear that there are several factors that influence this.

The most effective way to inform the public about the environment, sustainable development and climate change is through visual and audiovisual materials (34%). This is followed by environmental actions (20%), such as "The Great Cleanup" (Lielā talka), "Don't Eat the Globe" (Neapēd zemeslodi), etc. A smaller number of respondents chose the following communication formats: 17% visual materials/infographics; 14% motivational speeches by public figures; 8% informative articles; 4% educational seminars and lectures; 3% other.

The function of biodiplomats is crucial in facilitating the efficient exchange of information. This must not only be someone with a broad knowledge of a particular sector or environmental issue but also someone who has credibility in the community. Public figures and influencers, despite their potential lack of technical or scientific expertise, possess the ability to effectively communicate information and demonstrate a greater receptiveness to alternative viewpoints. Promoting environmental awareness and sustainable development among public figures and influencers has the potential to enhance outreach efforts. Therefore, a survey was conducted to find out which communicators would be most likely to raise public awareness. A number of options were given, including public institutions, environmental organisations, scientific institutions, influencers, etc. The majority of respondents, 46%, chose local and international environmental organisations. Public figures and influencers came in second with 29%, followed by administrative authorities (ministries, EU authorities), who came in third with 19%. Interestingly, scientists and scientific organisations were found to have the lowest level of public trust, with just 3% of respondents expressing confidence in them. Similarly, other media sources also received a mere 3% of public trust.

However, the influence of the intended audience must also be taken into consideration. For instance, those engaged in scientific pursuits exhibit a higher propensity to place faith in the information and experts endorsed by scientific establishments. Perhaps better results can be achieved if all or at least some of the communicators work together, aligning the information conveyed and developing a coherent biodiplomacy communication strategy. By tailoring the information to the respective target audience without changing the content of the message conveyed, communicators have a better chance of gaining the trust of different social groups.

The portrayal of climate change, environmental challenges and sustainable development exhibits variation among different sources, mostly based on the assessment of advantages and possible drawbacks. These sources highlight the potential gains or losses that may arise if these aspects are not effectively addressed. There exist sources that emphasise the adverse aspects of climate change through the dissemination of diverse photographs or movies that elicit potent negative feelings, including dread, among individuals. These visual representations often depict natural disasters and the melting of glaciers, among other phenomena. But there are also sources that encourage people to change their daily habits and use renewable energy, with the idea of a beautiful, pollution-free future. Consequently, the questionnaire incorporated an inquiry on the optimal strategy, as seen by respondents, for promoting contemplation of the significance of climate change, environmental predicaments and sustainable modes of living. The results show that the majority of respondents, about 43%, still prefer to highlight the negative impacts of climate change, while almost 36% of respondents want to focus on the benefits of environmentally friendly measures. A total of 18.6% of respondents think that scientifically proven facts showing the impact of human activities on the environment would be the most appropriate content to raise awareness. As the results are relatively close, a coherent biodiplomacy should preferably include both the negative sides of climate change and the benefits of a sustainable lifestyle.

The questionnaire included a question on biodiplomacy as a concept for dialogue between society, industry and science to understand whether such communication on climate change could help raise awareness among the general public and industry. The results of the survey show that the majority of respondents, 95%, are positive about the idea of biodiplomacy and its importance in the context of sustainable development. This means that the concept of biodiplomacy has overall potential, and the results indicate that the public is willing to be educated. However, it is important to ensure that the information being distributed is presented in a clear and comprehensible manner in order to maintain public support and interest.

4. Discussion

Due to the decline of fish stock in the seas and oceans, aquaculture has been one of the fastest-growing sectors in recent decades [39,56]. Although the sector is developing rapidly in a global context, the level of development in Latvia in terms of technology and innovation is still low [57]. Given the high availability of water resources in Latvia, the current limited development of the sector suggests that there is still room for growth. The Latvian Aquaculture Development Plan 2021–2027, prepared in 2021, aims to "further develop competitive, growth-enhancing aquaculture through innovative, cost-effective and environmentally friendly solutions" [57]. This goal is positive in terms of both economic growth and sustainability. Nevertheless, concerns have arisen that the aquaculture sector and the broader bioeconomy policy planning framework in Latvia are not sufficiently integrated. This potential divergence could hinder the future development of the aquaculture sector. Therefore, an environmental communication approach was used to take a step towards the development of the sector by assessing the sustainability of fisheries and aquaculture products and finding the most appropriate communication channels and ways to communicate information about sustainable products to the public. There is still frustration in sustainable consumption research and practice that public (consumer) oriented impacts are not easily translated into action [58].

First, a multi-criteria analysis was conducted to find the most sustainable aquaculture and fisheries product. Multi-criteria analysis has been widely used to compare different alternatives [59,60]. TOPSIS showed that canned fish is the most sustainable product, but fish oil and flour and spirulina also have potential. The use of a multi-criteria analysis in the study enables the comparison and evaluation of alternatives against specific criteria [60]. In order to evaluate the alternatives in a multi-criteria analysis as objectively as possible, it would be necessary to introduce additional quantitative criteria, such as emissions (t/year), capital investment and payback period (EUR), for the alternatives after additional data have been collected.

The use of a multi-criteria approach and the evaluation of alternatives enable a valid assessment of the alternatives from the researcher's point of view. The inclusion of an assessment of the alternative options by industry representatives in the research is a viable approach. However, it is currently difficult to gain access to the fisheries and aquaculture sector, resulting in limited information and data on these industries. This includes data that would allow for a proper assessment of the energy efficiency, resource efficiency and sustainability of the sector.

A multi-criteria analysis was used to derive results and identify products that then had potential for the future, but did the results align with the pillars of sustainability? The pillars of sustainability were labelled in the literature review as three sustainability domains—economic sustainability, social sustainability and environmental sustainability—and explained in the context of sustainability [26]. The link between economic growth and the analysis and results can be linked to the TOPSIS result that canned fish (0.56) has the highest score, so fish production is a product that will continue and has potential and people will continue to make a living in this activity. Statistics show that the canned food market was worth around EUR 28 billion in 2016 and will be worth around EUR 34 billion by 2021 [61]. The social sustainability pillar was well aligned with the 'new' products that are yet to be developed and will play an important role in people's daily lives and economic growth. For example, the TOPSIS results showed that both fish oil and flour (0.53) and spirulina (0.52) have potential. The analysis and results on the sustainability of aquaculture and fishery products indicate the sectoral trend towards sustainability as well as the interactions between the pillars. Social sustainability, based on public acceptance of a particular activity, was in line with the environmental sustainability pillar. Whatever a person chooses to do with a particular product, environmental sustainability is often not a consideration; the products analysed, fish oil and flour and spirulina, are products that are produced in an environmentally friendly way without compromising the extraction of necessary resources. Linking the multi-criteria analysis to the sustainability pillars, it can be concluded that the results with sustainable aquaculture and fisheries products were in line with the economic sustainability pillar as well as the social and environmental pillars. At the moment, Latvia is on the way to developing the aquaculture sector, which can be justified by the development of new companies in Latvia (SpirulinaNord), the inclusion of new products on the market and the important scientific research (K. Spalvins et al. [62]) being carried out to think about the growing demand for easily obtainable proteins.

The pursuit of sustainability in a sector, in this case, aquaculture and fisheries, involves not only analysing products and justifying their sustainability but also transferring the results to society. To transfer knowledge to society, we need to work on it, both in terms of research, which approach works better, and financially, to make knowledge-driven societies [63]. In this study, a survey was conducted to find out what would be the most effective communication format and way to promote public preference for sustainable products and solutions. The public often does not receive information from researchers, and the survey showed a trend towards information from social media, audio and video. Currently, there is a "gap" between the public, industry and researchers [64]. To bridge this gap, it is necessary to promote the concept of biodiplomacy and develop its diplomatic action directed at industry and society, with the aim of using bioresources as efficiently, and as sustainably, as possible [21]. It is necessary to create a knowledge transfer bridge that forms a triple helix and can strengthen interaction and information transfer between society, industry and research. The public overwhelmingly prefers to obtain information from social networks. Summarising the results of the survey, it can be concluded that the most effective way to educate the public about climate change and sustainability would be through visual or audiovisual materials that include the benefits of a sustainable lifestyle. A common message across different media could be the most effective way to reach a wider audience and build trust among different groups in society. The main objective of further studies is to identify potential opportunities and risks in the aquaculture sector, taking into account existing challenges and aiming for sustainable practices.

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Strategic pathways for a bioeconomy with high value-added products: Lessons learnt from the Latvian forest sector

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ABSTRACT

Climate change, the increasing global demand for food and feed and the loss of biodiversity, requires a shift towards a sustainable, innovative and knowledge-based bioeconomy. Simultaneously, the implementation of a strategic approach to the utilization of the sector and associated bioresources that aligns with the principles of sustainability represents a significant challenge. The aim of this study is therefore to develop a methodology for policy and decision makers to facilitate a knowledge-based bioeconomy policy planning framework. To map the development opportunities of the bioeconomy, a detailed analysis was conducted on the Latvian forest sector. This entailed an examination of the system's components within the sector, which involved the collection and analysis of statistical data, reports, and official information from forest sector stakeholders, with the objective of obtaining a comprehensive overview of Latvia's forest sector. Following the identification of the current enablers and constraints of the sector, a selection of niche products with high value-added for sector development was made. During group model building experts: (1) developed a SWOT matrix for the Latvian forest sector; (2) selected three wood-based high value-added products – textile from trees; particle board; natural thermal packaging; (3) elaborated SWOT/TOWS analysis to facilitate strategy development for the niche products. The developed methodology incorporates a synthesis of established scientific methods, including SWOT, TOWS, and AHP, with a bioeconomy system component analysis approach. The methodology therefore not only systematises the process of forest sector analysis, but also applies the findings to the development of sector development pathways aimed at shifting from low value-added to high value-added production. The innovation of the methodology lies not only in the combination of methods used, but also in the insights gained, which allow for a narrower product development perspective to be taken in order to understand the enablers and constraints of the sector and vice versa.

1. Introduction

The role of the bioeconomy is becoming increasingly important in the context of the European Green Deal and the achievement of climate neutrality [1,2]. The sustainable development of a circular bioeconomy would bring about change in traditional sectors (agriculture, forest sector) and enable new cross-sectoral actor networks that create new ecosystem services and products, improve resource efficiency and allow industry and consumers to choose products with higher added value and lower environmental impact while ensuring a just transition for all [1,3,4]. Despite the adoption of the first European Bioeconomy Strategy more than a decade ago [5,6], EU Member States (further EU-27) are still discussing and searching for the best transformation pathways to reconcile intensive bioresource extraction methods with a sustainable and ecosystem-based approach [2,7].

As the bioeconomy is driven by academic and political interest [1,3], there is an opportunity to facilitate the transition through knowledge-based bioeconomy strategies at national and/or regional levels [8,9]. In Latvia, a national bioeconomy strategy was developed and adopted in 2017 [10], nevertheless, the recognition and application of the concept of a sustainable bioeconomy in practice has not progressed as quickly as hoped. This is reflected in the bioeconomy value added, where Latvia has one of the lowest value added generated in 2020 compared to other EU-27 [11].

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There are different ways to analyse the bioeconomy and its development rates. Grouiez et al. [12] analyse the pace of development of the bioeconomy in France from the perspective of Social Ecological Economics by examining the functioning of the current system [12,13]. The study is based on a case study in the Grand Est region of France and data sources such as grey literature, interviews, participant observation and focus groups. Grouiez et al. [12] map the process of ecological transition of the economy and integrates the relationship between different stakeholders and their sustainability strategies for bioeconomy development. Mauno et al. [14] analyse the opportunities for forest bioeconomy development by identifying weak and strong signals using social science methods, including Real-Time Delphi, combined with creativity and imagination. In this way, weak signals in the sector can be identified early and decision-makers can prepare for changes in the bioeconomy environment. System dynamics modelling techniques can also be used to model the development of the bioeconomy [5,15,16]. In their study, Dolge et al. [17] model the effects of the European Green Deal on the bioeconomy and how a development of the bioeconomy of more than 10 % compared to the baseline scenario can be achieved with the help of various policy measures or support mechanisms.

Despite identifying knowledge-based bioeconomy development pathways and opportunities, both the European Bioeconomy Strategy and the Latvian Bioeconomy Strategy 2030 (further - LIBRA) lack specificity. This deficiency in actionable guidance hinders the identification of specific bioeconomy development pathways at the national or regional level, as well as the assessment of opportunities and limiting factors that would affect the practical implementation of the priorities set forth [18,19]. Therefore, authors aimed to develop a knowledge-based methodology that would be understandable and easy to apply in practice, in order to create a dialogue between researchers, decision and policy makers, and entrepreneurs during the strategy development phase. Critically assessing the capacities and constraints of each party involved. The first part of the methodology is based on the approach to bioeconomy analysis developed by Maciejczak [20] and extended by Wreford et al. [18], which analyses the various factors influencing the bioeconomy. Nevertheless, the mere identification of factors affecting the bioeconomy is insufficient for the purpose of setting specific directions for further development and their potential impacts. This was complemented by the determination of specific bio-based products to be promoted and the elaboration of development strategies using the Strengths, Weaknesses, Opportunities, and Threats (further - SWOT) and Threats, Opportunities, Weaknesses and Strengths (further -TOWS) analysis methods. TOWS is SWOT spelled backwards and supports strategy development by matching internal strengths and weaknesses with external opportunities and threats [21]. The proposed methodology will be subjected to rigorous testing in the analysis of the Latvian forest sector, with a particular emphasis on the identification and selection of niche products that can contribute to the advancement of a sustainable bioeconomy. On this basis, the authors have devised and validated a case study-based approach that can be used to identify the strategic actions required for the development of a bioeconomy strategy at both national and regional levels, as well as for the formulation of a comprehensive action plan to effectively implement such a strategy.

This paper has five sections. After an introduction with contextual information, the methodology and methods used in the study are described. The third section comprises the initial phase of the study, which involves an analysis of the Latvian forest sector system components. These include finance and governance, renewable resources, knowledge, innovations, technologies, processes, products, services, research and development, and private and public expectations. The fourth section outlines the second phase of the study, which identifies transformative pathways for the niche products in question. This is achieved through an analysis of the niche products and the development of future scenarios for the forest sector. The section entitled "Discussion and Conclusions" presents a detailed analysis of the study's findings and offers a critical examination of the methodology developed.

2. Methods and methodology

This study employs a mixed-methods approach, wherein the first phase is primarily based on statistical data and grey literature, including government and public authority research and secondary data, as well as research databases such as Scopus, Semantic Scholar, and Google Scholar. These resources were utilised to identify articles reflecting the current discourse on the forest sector system components of Latvia (Fig. 1). Phase one employs a systematic methodology to collate data on the extant situation within the sector. This encompasses the identification of sector enablers and constraints, which collectively form the basis for the subsequent development of pathways in phase two. In the second phase of the research, niche products and sector transformation pathways are identified through group model building (further-GMB) with experts from industry and policy and decision makers in the bioeconomy and forest sector (Fig. 1).

2.1. *Group model building*

The expert GMB were conducted in accordance with the principles of the focus group method, with the key distinction being that in focus groups, participants typically adopt a more passive role, whereas in the case of the SWOT, Analytic Hierarchy Process (further - AHP) and TOWS matrices, the experts were required to engage in active interaction with one another. Focus groups are a widely used method in social and behavioural science to understand the beliefs, motivations and attitudes of individuals that influence their behaviour in response to specific social phenomena [22,23]. A focus group discussion can be seen as an exchange and sharing of opinions between a number of individuals to explore different aspects of a topic or a matter of knowledge [22,23]. Important to note that the aim of the discussions is not to reach a consensus on the topic, but to capture the various facets of the topic and to evaluate the different perspectives on the subject [22,23]. Focus group discussions usually involve people who do not know each other and are familiar with the topic, and they are often a series of discussions [24].

2.2. *Strengths, weaknesses, opportunities, threats*

The SWOT matrix is a widely used method for evaluating internal and external influences and for decision-making [25,26]. The SWOT matrix can be seen as a strategic planning element that enables a timely assessment of the measures to be taken for future development [26,27]. At the same time, the SWOT matrix has the disadvantage that it generalises the factors listed in the matrix without examining the individual factors in more detail [25,26].

2.3. *Analytic Hierarchy Process*

In order to evaluate the factors contained in the SWOT matrix in a more analytical way, the SWOT method was combined with the AHP method for factor ranking [25–28]. AHP is one of the most widely used multi-criteria decision analysis techniques that can be used in decision-making processes to evaluate social and political issues [29,30]. Once the SWOT matrix had been constructed, the experts were requested to rank the identified impact factors in order of importance and impact. Ranking the SWOT factors and limiting them to five was necessary to ensure greater consistency in the results [31,32]. This resulted in the five most significant S, W, O, T factors being identified in each of the SWOT matrices. These factors were then subjected to further ranking using the AHP method. In the context of this study, the selected factors were subjected to an additional pair-wise hierarchical comparison by the experts using Saaty scale of relative importance levels (1–9) as it allows for the inclusion of multiple views or perspectives in the evaluation [28,29,33].

The initial stage of the process entailed the definition and valuation

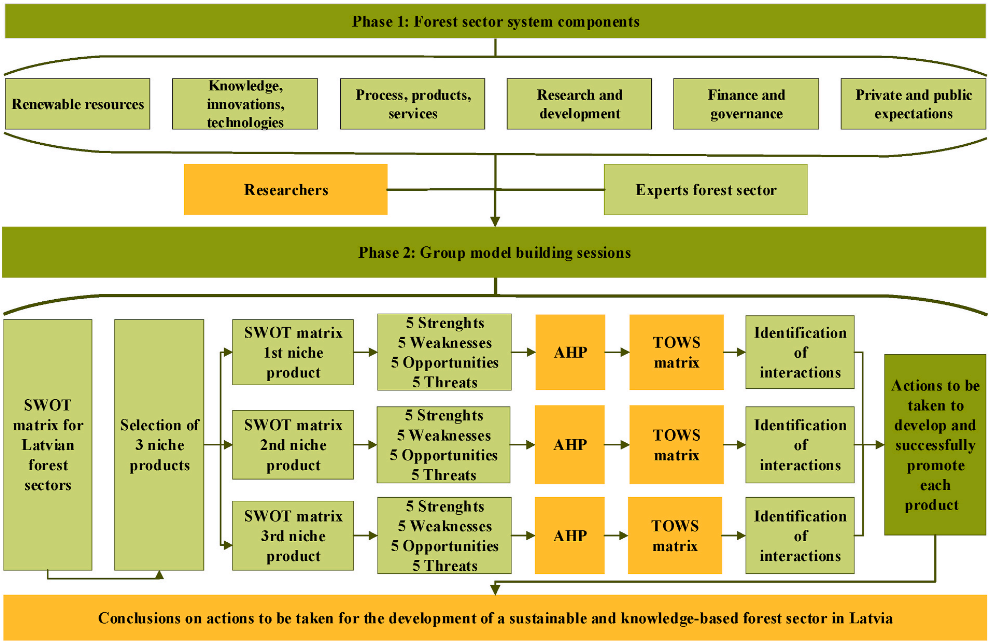

Fig. 1. Methods and methodology (author's elaboration).

of the criteria (1–9). This was conducted for each SWOT matrix, with the five most highly ranked S, W, O, and T factors being identified. This resulted in a total of 12 AHP matrix rankings. The following equations were used to construct the AHP matrix and determine the factor values [31,32]:

For calculation of normalized matrix using Eq. (1):

$$X_{ij} = \frac{C_{ij}}{\sum C_{ij}} \tag{1}$$

where:

Cij – criteria value;

∑Cij - column sum.

For calculation of priority vector from Eq. (2):

$$W_{ij} = \frac{\sum X_{ij}}{n} \tag{2}$$

where:

∑Xij – normalized matrix column sum;

n – number of criteria.

The resulting values of the factors or criteria were subsequently incorporated into the TOWS matrix, with the most significant influencing factors being those that had the highest value or weight in the AHP assessment.

2.4. Threats, opportunities, weaknesses, strengths matrix

A complementary element to the SWOT and AHP method was the TOWS matrix, which was created to determine the interactions between the factors identified in the SWOT matrix and thus increase the added value of the strategic measures to be developed [26,30]. TOWS was introduced by Weihrich in 1982 [34] as a situational analysis suitable for strategic planning and applicable in different types of organisations. The acronym TOWS is made up of the same elements as the SWOT matrix, but with a different approach, allowing external threats and opportunities, as well as internal weaknesses, to be linked to the organisation's strengths [34–36]. In this study, the matrix is created by combining the most influential factors from SWOT, ranked with AHP and then inserted into the TOWS matrix. Applying this procedure the authors supported the process for strategy development and the formulation of recommendations for different stakeholder groups (maxi-maxi (SO) strategy: maximising opportunities by using particular strengths, mini-maxi (WO) strategy: minimizing weaknesses by using opportunities, maxi-mini (ST) strategy: using particular strengths to minimise threats, mini-mini (WT) strategy: minimizing weaknesses and avoiding threats.

A hybrid approach combining SWOT, AHP and TOWS methods was used to identify niche products and develop more suitable strategies. Similar approach has been taken in a study by Kurttila et al. [26], who used these methods as part of the strategic planning process for forest certification. The study concluded that the combination of these methods improves the information available for strategic planning and strengthens the decision-making process [26].

3. Forest sector system components

In the 20th century, the forest sector or forest-based sector included timber products, pulp and paper products, and forestry associated with these [37]. Currently, forest-based bioeconomy encompasses much more - construction, bioenergy, biochemicals, and textiles, among others [37]. Forestry encompasses everything involved in the management of forest land, from infrastructure to the seeding and harvesting of trees [38]. Although the sustainability of forestry is important for the steady supply and availability of the raw material, it is the processing that adds value to the wood [39]. Nevertheless, forestry, forest sector and forest-based industries are sometimes mistakenly confused with each other [40]. In this paper, the term "forest sector" is used to describe the entire value chain of the forest-based sector, including the non-wood goods.

The territory of Latvia is rich in forests, agricultural land and water bodies [41], forests occupy the largest area by type of land use, accounting for about 48 % of the total area [42]. The next largest area is occupied by agricultural land, which accounts for about 35 % of the land area [42]. In comparison to EU-27, the proportion of forest cover in Latvia is amongst the highest in relation to the country's total area [41, 43]. The Latvian state possesses a substantial amount of forest land, amounting to 1521 thousand hectares or 46 % of the total forest area [44]. Latvia's State Forests (further - LVM), a state-owned joint-stock company, is responsible for managing state forests in Latvia [45]. In addition to forestry, LVM provides hunting and recreational services, produces selected seeds and seedlings, and markets subsoil resources such as sand, gravel and peat [46]. LVM conducts and funds contract research on the forest sector. LVM invests an average of 0.2%–0.5 % of its turnover per year in funding and organising scientific research to increase the capital value of forests and makes the results of the research publicly available [47]. This provides an opportunity for the national government to implement a coherent management strategy to efficiently promote the sector - economic growth and the creation of value-added goods [48–50]. Sustainable use of forests could be crucial to maximise social and economic benefits for industry, private and public actors, while maintaining environmental sustainability [48,51].

In Latvia, the primary sub-sectors comprising the forest sector are the forestry sector and the timber industry [52]. Forestry and logging encompass the management of forest land throughout the silvicultural cycle. This includes, but is not limited to, the preparation and marketing of forest products, as well as tourism and sports-related services [51,52]. Forest products are measured in terms of tangible values such as wood, mushrooms, berries, nuts and intangible values such as forest biodiversity, recreational opportunities and services, skills etc. [52,53].

Agricultural and forest sectors represent the contributors to the Latvian bioeconomy [10,54]. Value-added in the bioeconomy increased by 11.6 % in 2021 compared to 2020, reaching 4.6 % of the total value-added in Latvia's gross domestic product (GDP) [55]. This increase is partly due to a surge in inflation in the second half of 2021, which peaks in 2022 [56]. The forest sector and the resources obtained from it play a vital role in the Latvian bioeconomy, notwithstanding the current underutilization of the potential of both wood and non-timber resources [54,57]. LIBRA highlights the importance of the Wood Processing and Furniture Industry of Latvia, as raw materials of different qualities that are currently exported could be replaced by high value-added products manufactured in Latvia, such as fibreboard, furniture or prefabricated wooden buildings [10,58]. The cellulose industry could also be developed [10].

3.1. Renewable resources

3.1.1. Wood resources

The data on the distribution of standing timber by tree species shows that pine accounts for the largest share with about 39 % of the total stand in 2020 [59]. Birch, accounts for about 26 % of all standing timber, spruce within the total standing wood stock is approximately 19 % [59]. Aspens account for about 7 % of the total standing timber stock in 2020, grey alders for about 5 % and black alders for about 3 % of it [59]. In 2020, the standing wood stock share of tree species, including oak, ash, linden, maple, elm, white elm and other rather rare species, constituted less than 1 % of the total standing timber stock in Latvia [59].

3.1.2. Non-wood resources

In addition to the abundance of timber, Latvian forests possess a diverse array of non-timber resources that are not accounted for in official statistical records [60]. The available resources encompass a diverse range of berries, including blueberries, lingonberries, cranberries, bilberries, blackberries, and others [60,61]. Additionally, a variety of edible and inedible mushrooms that can be used in both the food and pharmaceutical industries can be found [61]. The forest's important resources encompass a diverse array of plant species, including junipers, mosses, and lichens [60].

It is not possible to provide an accurate estimation of the volume and productivity of non-timber forest resources. However, a study conducted by Donis and Straupe [60] estimated the approximate value of non-timber forest products and services at approximately MEUR 100 in 2010 [52,60]. Most of the non-timber forest resources are used for own consumption, but about 13 % of the total forest products are sold in the market [52,60]. The most important forest products are mushrooms, wild berries and birch sap whose extraction value accounts for half of the value of the non-timber forest products [52,60].

3.1.3. Biomass flows

The 2015–2020 data on the volume of forest stock harvested in the state forests indicates that the primary species being harvested are pine, birch, and spruce [62]. In the private forests, the harvested stock in the same period from 2015 to 2020 consisted mainly of birch [62]. Pine is the second most frequently harvested tree species, while grey alder takes third place [62]. Fig. 2 "Main timber products exported by Latvia" demonstrates that wood sawn or chipped lengthwise has the highest value share, with exports of MEUR 683 in 2020, followed by softwood lumber [63]. Firewood; wood chips or particles rank third in 2020 exports [63]. Wooden products; veneer and plywood, and veneered sheets and similar laminated wood materials are also exported [63]. The total value of exported wood and wood products has increased significantly, from MEUR 2362 in 2015 to MEUR 2992 in 2020 (Fig. 2), [63].

Fuel wood, including firewood, wood by-products, fuel wood chips, wood briquettes, and wood pellets, constitutes a significant component of Latvia's renewable energy sources [64]. In 2020, 82.5 % of residential buildings used wood as an energy source for heating purposes, mainly for indoor and cooking stoves [65]. Since 2015, the proportion of families buying firewood has decreased slightly, while the proportion of households preparing firewood themselves has increased accordingly [65].

The extraction of non-timber forest products is an important part of the rural economy, especially for the livelihood of individual households [52,61,66]. Mushroom and berry picking is an integral part of Latvian culture and, in rural areas, offers the opportunity to generate additional income by selling the mushrooms and berries collected [61,66]. Hunting is also of great socio-economic importance in Latvia, where most of the game hunted is used to produce a variety of meat products, which are then used in the household or sold at local markets [67,68].

3.2. Knowledge, innovations, technologies

The forest sector in Latvia has developed in a market economy supported by factors such as an accessible and high-quality raw material base, years of experience, knowledge and tradition [69]. Latvia's Forest policy provides for the state to play a supporting role in the forest sector through its institutions and financial resources in order to promote sustainable forestry and also to support the development of the private sector [69]. Support functions include vocational and academic training, forest owner training, advisory systems, research, forest inventory, statistical data collection and information systems, monitoring and protection against various diseases, forest fire protection, control of reforestation materials and forest monitoring [69].

Unlike many other EU-27 countries, the forest industry and wood processing in Latvia are dominated by small and medium-sized enterprises, and there are relatively few companies that cooperate with scientists not only for routine analysis and expertise, but also for the development of innovative technologies and new products [52]. Therefore, the Forest Sector Competence Centre (FSCC) was established in 2011 to promote the development of the forestry, timber and related industries through the development and introduction of new products and technologies [52,70]. The FSCC promotes cooperation between the

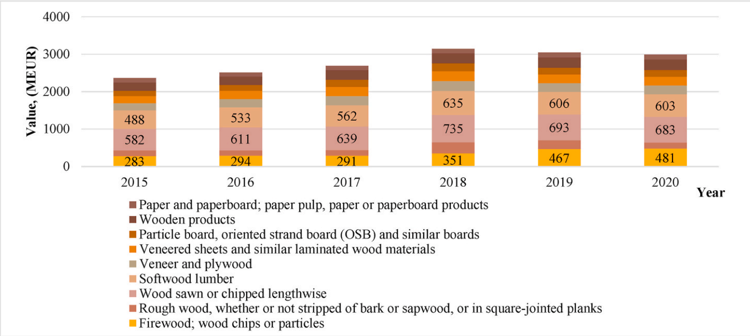

Fig. 2. Main timber products exported by Latvia (MEUR) (author's elaboration) [63].

research and industrial sectors in the implementation of industrial research, development of new products and technologies [52,70].

A variety of educational pathways are available for those wishing to pursue specialised studies in the forest sector in Latvia. These range from vocational programmes to higher education institutions (Fig. 3). Higher and vocational education institutions are geographically dispersed throughout the country.

It is widely acknowledged among industry experts that the forest sector's achievements to date have been largely attributable to the success of competitive practices and the production of relatively low-value added products derived from wood. The Guidelines for the Development of Forest and Related Sectors for the period 2015–2020 state that the use of cutting-edge technology and the development of new goods and markets should be at the heart of future developments in order to maximise value creation [52]. The availability of skilled labour would therefore be an important factor for the development of the sector [52,73]. However, the recruitment and preparation of trained and qualified workforce is hampered by the underfunding of higher education and science, which has a significant impact on the skills of teaching staff and the quality of higher education itself [52,73]. Lack of resources to attract young professionals into scientific and academic work [52].

3.3. *Process, products, services*

In this section, the authors conducted research and sought to present the principal actors in the Latvian forest sector, namely forest sector federations, associations and unions, as well as their members, within a unified framework. The information summarised in Fig. 4 demonstrates the high innovation potential of the forest sector, while simultaneously indicating its fragmentation. In 2000, a number of companies operating within the forest industry collectively established the Association of Latvian Forest Industry Federation (*Latvijas Kokrūpniecības federācija*) [71] (indicated with A in Fig. 4). The Association's mission is to promote the sustainability of the Latvian forest industry in cooperation with interested institutions, to create a stable economic environment for the development and competitiveness of forest industry enterprises, to ensure the international representation of the interests of the Latvian timber industry and to develop and coordinate the activities of the associations [71]. The Latvian Forest Industry Federation brings together associations of timber processing companies such as Association of Furniture Manufacturers in Latvia (H in Fig. 4); Latvian Timber Producers and Exporters Association (B in Fig. 4); Latvian Association of Wood processing Entrepreneurs and Exporters (C in Fig. 4); Association „Latvian Wood" (D in Fig. 4); Latvian Union of Timber Harvesting Enterprises (E in Fig. 4); Latvian Association of Independent Timber Harvesting Companies (F in Fig. 4); Latvian Association of Biomass "LATbio" (I in Fig. 4); Latvian Wood Construction Cluster (G in Fig. 4) [71]. Associations of timber processing companies under Latvian Forest Industry Federation represent areas such as manufacturers of furniture, furniture parts and components [74]; softwood sawn timber, plywood, OSB and pellet producers [75]; producers of picture frames and sauna decoration materials, finger-jointed materials and components; gardening products, kiln-dried products for indoor use; manufacturers of wooden houses [76] profiled wooden materials for interior finishing, tool shafts, floor covering; wooden windows, doors, stairs and wood carvings [77]; forestry machinery sales and maintenance; freight transport services; timber harvesting; forest estate management; roundwood freight services [78]; use and production of biofuels [79]; educational and research institutions, and other related companies [76].

An examination of the 25 largest companies in Latvia (ranked by turnover in 2020) reveals that the primary business sectors are forestry, logging, timber sales, the production of wood chips, wood pellets, plywood, and veneer sheets [80]. Sawmills are often at the centre of the business activities of wood processing companies [80]. Relatively few of the products manufactured have high value-added. There is a small proportion of innovative and niche wood products that are manufactured locally [80]. Many of the leading companies use the principle of cascading and wood residues from the manufacturing process to produce products such as wood briquettes or pellets. Recently, development has increasingly focused on product longevity, recyclability and environmental impact throughout the value chain [80]. Wood processing companies are exploring development areas such as garden and "Do It Yourself" products and the production and marketing of prefabricated wooden houses [80].

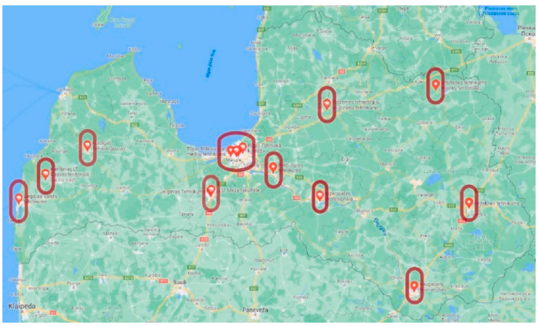

Fig. 3. Location of forest sector related educational establishments (author's elaboration based on [71,72]

Fig. 4. Latvian forest industry associations under the Latvian forest industry federation (author's elaboration) [71,74–79]

3.4. Research and development

Research in Latvia is highly dependent on public funding. Several ministries are responsible for forest research in Latvia - the Ministry of Education and Science, the Ministry of Agriculture, the Ministry of Environmental Protection and Regional Development and the Ministry of Economics [81]. Various funding mechanisms are available, the most important of which are core research funding, public grants and projects, as well as EU Structural Funds [81]. Research and development funding in Latvia fluctuates widely, from the lowest point in 2016 at 0.44 % of GDP to 0.71 % of GDP in 2020 and 2021 [82]. The Science, Technology and Innovation Guidelines 2021–2027 target funding of 1 % of GDP in 2024 and 1.5 % in 2027 [83]. However, this is still low compared to the average share of R&D spending in the EU-27 countries, which reached 2.32 % in 2020 [84]. Although both public and private institutions conduct research in Latvia, only public institutions are entitled to the national budget [81]. The national research budget allocated by the Ministry of Education and Science is primarily intended to support the basic operation of research institutions, while these institutions must raise research funds themselves through national and EU calls for proposals, making research in Latvia heavily dependent on EU funding [81]. In recent years, due to funding shortages and government measures, research institutions have increasingly competed for funding from national funding programmes and international funding programmes such as Horizon2020/Horizon Europe, Interreg and other EU research programmes [81].

The Latvian Timber Industry Federation, has signed a Memorandum of Cooperation with LVM in 2021 with the aim of increasing the share of renewable resources and bioeconomy in the Latvian economy [85]. The Memorandum sets out three strategic objectives for the sector: (1) double the value-added per job in the forest sector by 2030; (2) to double the value of forest products by 2030; (3) make forest stands 25 % more productive [85]. This could be achieved by science-based forest management models, support the construction of wooden houses, including the construction of high-rise buildings [85]. The European Commission's European Innovation Scoreboard 2021 praises Latvia's performance on a number of innovation indicators [86,87]. However, the lowest indicators for Latvia in 2020 are R&D investment, the share of innovative small and medium-sized enterprises and the number of PhDs, which calls for further action to promote R&D and innovation and thus improve these indicators [86,87].

3.5. Finance and governance

The Ministry of Agriculture is responsible for the bioeconomy and for the growth and monitoring of the forest sector [52]. The Ministry is advised on forestry-related issues by the Forest Advisory Council, which aims to promote the development and implementation of a balanced forest sector policy in Latvia [88]. The Advisory Council brings together various stakeholders - representatives of private, state and municipal forest owners and managers, timber industry and others [88]. The State Forest Service monitors compliance with legislation on forest management and use, fire protection and hunting, participates in the development and implementation of forest sector policy, and monitors compliance with requirements by operators placing timber and timber products on the market [89]. Ministry is also a state shareholder in joint-stock companies LVM and Ltd "Latvian Rural Advisory and Training Centre Forest Advisory Service Centre" which aims to contribute to rural prosperity by providing clients with access to knowledge, advice and other services related to the sector [52,90].

There are a variety of policy and development planning documents at the national level that influence and guide the development of the forest sector and the wood processing industry. Annex 1, Table 1.1 shows the most important national documents and a brief overview of their impact on forest sector development.

3.6. Private and public expectations

The forests in Latvia are a favourite recreational destination, a place to pick berries or go for a walk. As part of a study conducted by LVM and Latvian State Forest Research Institute “Silava” [91], Latvian residents were asked about their habits when visiting the forest [92]. Depending on the time of year, up to 53 % of the population surveyed go to the forest on weekdays to relax, while 69 % do so at least once at the weekend, spending around 1.5–2 h in the forest [92]. In winter, spring and autumn, people go to the forest to hike, cycle or observe and photograph nature, although mushroom and berry picking (40–50 %) predominates in summer [92]. According to the survey, people in Latvia are most reluctant to go to forests where deforestation is taking place [92]. Research carried out by Vidale et al. [93] shows that in Latvia, compared to the other EU-27 countries, most households (67.5 %) go to the forest to collect wild forest products, while the EU average is only 24.5 %.

The regularity and frequency with which Latvians visit the forests shows that they appreciate local forests, and also their commitment to sustainable forest management and the preservation of the forest landscape [94]. Over the past decade, the public and environmental activists have aggressively campaigned against deforestation and clear-cutting, citing unsustainable forest management and biodiversity decline [95–98]. At the same time, the LVM and a number of wood processing companies deny such claims and emphasise that the logging and management methods used are not only harmless, but will improve the situation in the forests in the long term [99,100]. There is also contradictory information in the Latvian media about the environmental impact of clear-cutting, to the extent that it gives the impression that LVM is engaging in censorship by actively opposing the use of the term “clearcutting” Gelzis [101]. As a result, two fronts are emerging in the public sphere: one side claims that Latvian forests are managed with respect for nature and sustainability, while environmentalists and recreational forest users remain sceptical [95][94,98,101].

3.7. State of the bioeconomy in Latvia

After defining Latvian forest sector system components (see Sections 3.1 to 3.6), it is possible to identify the strongest enablers and constraints affecting the growth of the Latvian forest sector (see summarised in Table 1).

LIBRA has pointed out the potential for development of the wood processing and furniture industry. This is also in line with the need to use wood more efficiently for higher value-added products [63]. Society’s resistance to the rapid increase in logging intensity and concerns about future resource efficiency and availability make it necessary to use wood residues and low-grade wood resources for the production and marketing of high value-added export items.

The above Table 1 points to another problem, namely the lack of current strategic steering of the forest bioeconomy (as well as the bioeconomy as a whole) in Latvia towards high value-added products. It is undeniable that Latvia’s Forest and Wood Processing sector is strong due to the local availability of resources, the knowledge and skills accumulated over the years, and the strong companies that are able to compete price-wise in the market (both due to the availability of resources and low labour costs) due to the infrastructure that has historically existed.

In 2020, the forest sector accounted for 1.9 % and the wood processing sector for 3.1 % of the value-added of the entire economy in Latvia [86,87]. Moreover, the wood processing industry accounts for almost a quarter (24.8 % in 2020) of the manufacturing industry in Latvia [86,87]. However, as defined in the National Industrial Policy [86,87], the value-added per employee in bioeconomy production in Latvia still does not reach the industry average in the EU [86,87]. These policy guidelines also call for a wider use of innovation as a possible solution to improve productivity and resource efficiency in the bioeconomy [86,87].

Overall, the main obstacles and constraints hindering the development of an innovative bioeconomy in Latvia include lack of financial resources – for infrastructure, for innovation funding, for capacity in science and education, and for communication and awareness. There are also sector-specific problems of the bioeconomy: there is a lack of a comprehensive definition of the boundaries of the sector (some attribute a role only to the traditional branches of the bioeconomy; the modern bioeconomy does not yet have enough lobby) and thus a lack of effective governance of the whole sector. Knowing that an innovative bioeconomy based on the concept of engineered wood, wood biorefinery and improved cascade use of resources, focusing on the use of low-

Table 1
System components of Latvian forest sector (based on [18] and elaborated by authors).

System component	Categories	Enablers	Constraints
Renewable resources	Raw material	High forest coverage Valuable non-timber resources – game, mushrooms, berries, lichens	Non-timber resources of Latvia’s forests can neither be quantified nor assessed Excessive timber extraction could have a negative impact on biodiversity
Knowledge-innovations-technologies	Expertise, Technology	Long-standing traditions Schools offer vocational training in forestry and wood processing	Industry operates according the principles of the “old” bioeconomy Industry-qualified educators are hard to find due to low salaries
Products & services	Market Customers	Wood processing companies located all over Latvia Economically important primary sector	Production focuses on low value-added wood products 90 % of harvested wood is exported, causing domestic competition for raw material
Research and development	Research and development	Many high-level research institutions specialise in or conduct research on forest sector and related industries	Research depends almost entirely on public funding Low indicators in R&D investment and the share of innovative SME’s
Finance & governance	Collaboration Financing (public/private) Legislation Policies	Sectoral development included in RIS3 and other policy planning documents Half of the forest area state-owned and managed by a single company (LVM)	Sector-specific policy planning documents outdated Strong lobby towards more intensive logging Little financial support for innovation
Public, private expectations	Risk averse culture, Sustainability	Forests play an important role in the extraction of non-timber resources for domestic use Conserving forests is important for society	Economic interests take precedence over public interests (intensive logging) Current forest management practises split public opinion, biodiversity conservation concerns

quality wood biomass for the production of higher value-added products, is not yet sufficiently developed in Latvia, it can be said that the cumulative effect of all the above-mentioned limitations hinders its development.

Nevertheless, Latvia's achievements in numerous areas of research and innovation are remarkable, especially considering the science base funding. The experience gained in Latvian and high-level international scientific projects makes it possible to advance scientific research towards a knowledge-intensive bioeconomy. To further promote knowledge transfer, the cooperation between efficient research institutions and successful wood-processing companies must be strengthened.

4. Transformation pathways for forest bioeconomy

4.1. Promising opportunities in the bioeconomy for niche products

A group of five experts in the Latvian forest sector, wood processing and sustainable product development was formed to identification and prioritization of innovative bio-based products with high value-added. This therefore would contribute to the country's economic growth and the sustainable use of resources, in contrast to the current situation whereby large volumes of wood are exported as a low value-added raw material. The discussions were moderated by the researcher, who provided an initial overview of the task at the beginning of each session and steered the discussion in a manner that would facilitate the completion of the specified task. GMB had the optimal approach to designing and analysing niche product development scenarios. Furthermore, consultations were conducted with experts from a range of relevant fields, including energy, the bioeconomy, resource efficiency, waste management and policy, with the objective of optimising the effectiveness of the study.

GMB were organised in person. During the sessions, experts were invited to discuss and express their views on specific topics, each meeting lasted 1–2 h. In the first session, the experts were introduced to the research question and the work done so far, including the system components of the Latvian forest sector. The SWOT analysis method was presented and the experts filled in the SWOT matrix for the forest sector in Latvia (Fig. 1). In the following sessions, the experts identified three potential wood or non-wood products and developed SWOT matrices for all three niche products. They discussed which five factors from each part of the SWOT matrix had the greatest potential impact on product development. Then those five factors were ranked using AHP. The results obtained were inserted into the TOWS matrices for each of the innovative products and possible interactions were identified. Then, necessary steps to develop the three niche products and to open up new market opportunities were identified based on the TOWS matrix for each product. Priority actions for the development of innovative high value-added products and long-term solutions in the forest sector and bioeconomy were prioritised.

GMB started with an outline of the methodology (Fig. 5) and the experts were informed about the system components of the Latvian forest sector, as well as the enablers and constraints identified in a later phase. In order to stimulate the discussion and identify additional factors that influence the forest sector and can play an important role in the development of the sector or directly hinder it, a SWOT matrix was created.

The debates that took place during the GMB and the created SWOT matrix showed both opportunities and strengths of the Latvian forest sector. The strengths of the Latvian forest sector are the availability of forest resources (timber) and a well-developed access infrastructure. This includes an accessible export infrastructure by land and sea. Forest resources (wood) are recognised as important resources in regional and national policy planning documents. At the same time, experienced research institutes and the associated accumulated knowledge and experience of forests and forest management have been recognised by experts as a strength. Forests have historically characterised the cultural values of Latvia, and Latvians appreciate the intangible values and resources that forests provide. This wealth of available resources and the growing demand for sustainable woody biomass, together with technological developments, could provide Latvia with excellent opportunities for economic growth. Experts emphasise the need to use the existing forest potential to promote the production of high value-added

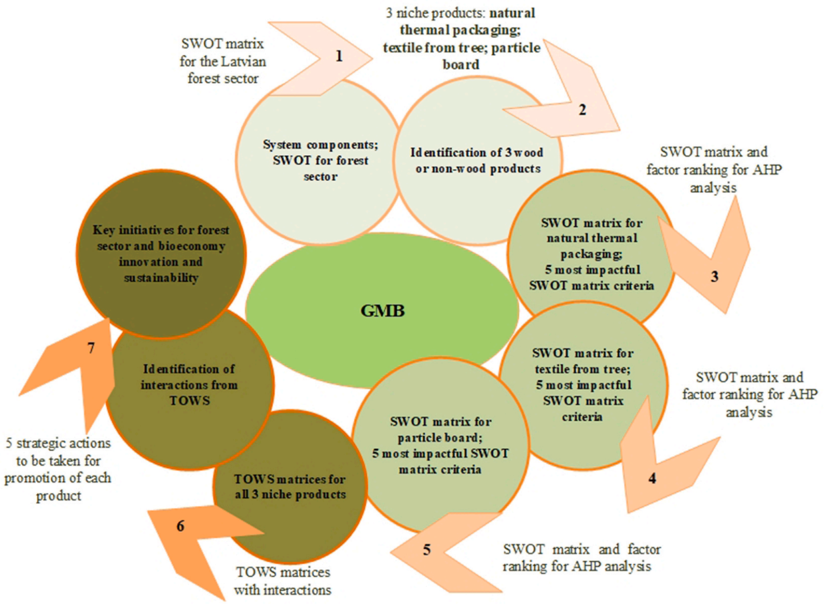

Fig. 5. Topics and results of the GMB (author's elaboration).

products from low-grade wood through technological developments, such as engineered wood-based products or innovative forest products from non-wood resources. At the same time, Latvia should also emphasise the intangible value of forests through recreational forest services. To achieve this, the existing weaknesses in the legal framework need to be addressed and the commitments and policy direction of the legislation updated in line with the European Green Deal. Another weakness is that half of Latvia's forest land is owned by the state, which leads to slower decision-making and possible politicisation of decisions. Greater use of innovation in the application of forest resources should be encouraged. Reduce the heavy reliance on public funding for research and increase teachers' salaries to strengthen vocational training and thus contribute to the training of skilled labour, of which there is currently a shortage. The increasing use of wood with low value-added, for example for energy production and exports, is also seen as a threat as competition for raw materials increases. Also, the economic growth opportunities arising from the intensification of logging pose a significant threat to existing forest ecosystems and biodiversity. Biodiversity loss affects the entire forest ecosystem and not necessarily only at the local level, so a balance between economic and ecological aspects must be sought.

As the next step after the creation of the SWOT matrix for the forest sector, the experts had to identify promising niche products that would meet the principles of an innovative, knowledge-based and sustainable bioeconomy. They were asked to select products that could be produced either from wood or from non-wood resources (berries, mushrooms, plants, game) based on the four transformation pathways in the bioeconomy proposed by Dietz et al. [102]. These transformative pathways are: "(1) substitution of fossil fuels with bio-based raw materials; (2) productivity increase in bio-based primary sectors; (3) increasing efficiency in biomass utilization; and (4) value creation and addition through the application of biological principles and processes separate from large-scale biomass production" [102] which are closely linked to the Sustainable Development Goals defined by the United Nations [103]. At the same time, every choice of direction harbours not only advantages but also potential risks [102]. Therefore, after much discussion, the experts identified three wood products with higher added value for further analysis that correspond to different transformation pathways (see Table 2).

Table 2
Three niche products selected by the experts (adopted from Ref. [102]).

Transformation pathway	Description	Product identified
TP1 **TP3**	Triggered by increased oil prices. Increased demand for bioenergy, with direct and indirect impacts on land use, depending on land availability and the effectiveness of environmental and economic governance systems. Innovations in downstream sectors to increase biomass use efficiency and waste stream recycling. Could replace a widely used unsustainable or fossil-based product in the foreseeable future.	**Textile from tree**
TP2	Technological innovation to increase productivity in forest sector, which can unleash transformative forces that open up new production methods. A product already on the market with high demand and a wide range of applications, whose environmental performance could be improved in line with the principles of sustainability and circular bioeconomy.	**Particle board**
TP3	Innovation in downstream sectors to increase biomass use efficiency and waste stream recycling. Innovative product that could come into the market in the coming years.	**Natural thermal packaging**

Although the potential of non-wood resources found in Latvia's forests has not yet been fully utilised, the experts still leaned in favour of three products that can be made from wood, including low-quality wood or wood residues. This could be due to more familiar technological processes and an established supply and processing infrastructure. While there are many unknowns in the development of higher value-added non-wood products, including the volumes to be sourced and their seasonal nature.

4.2. *Textile from tree*

The extraction of textile fibres from wood dates back to the late 19th century, when viscose – the first man-made fibre - was made from cellulose [104,105]. It was relatively cheap and easy to produce, as a large amount of chemicals were used in its production, which was not considered a problem at the time. However, growing concerns about environmental pollution in the 1970s prompted companies such as the Austrian manufacturer "Lenzing" to focus on biorefinery and closed-loop production, which led to the creation of Lyocell [104]. The European Commission's "Guidelines on biomass cascading with selected best practices for the use of woody biomass" mentions the shift towards the production of textiles made from wood as an example of best practice [106]. "Lenzing" which processes sulphite cellulose into standard and special cellulose fibres is thus one of the good examples of environmentally friendly and energy-efficient production plants for wood-based man-made fibres [106]. Another is "Spinnova", a Finnish company that produces textile fibres from spruce and pine cellulose using a dry spinning process from mechanically obtained pulp. Therefore, no chemicals or excess water are used [106]. Such bio-based textiles can replace other synthetic fibres made from fossil resources or even natural cotton fibres, the cultivation of which has a heavy impact on the environment [106]. Therefore, the production of textiles from wood and wood residues was considered as one of the possible niche products that could be developed in Latvia in the future.

The SWOT matrix (Annex 2, Table 2.1) on textile from tree is concise and the discussion on the production of textiles from wood was not too extensive. This can probably be explained by the fact that Latvia does not have a production site and it is difficult to fully grasp the potential opportunities, threats and disadvantages that would be associated with the transfer and adoption of technological know-how from countries where such sites are already established. After developing a SWOT matrix for the textile from tree, the experts identified which five factors from each category (strengths, weaknesses, opportunities, threats) could have the greatest impact on production and market entry for further analysis. For the identified five factors from each category, an AHP matrix was created to quantitatively characterize the impact of the factors. After ranking the factors and creating the AHP matrix (see Table 3), the results were inserted into the TOWS matrix.

A further task for the experts was to identify the interaction between the factors that were prioritised and ranked in the AHP matrix. Firstly, a TOWS matrix was created by inserting the factors ranked with the AHP method. Experts had to identify interactions between the factors listed (Strength-Opportunity; Strength-Threat; Weakness-Opportunity; Weakness – Threats strategies) e.g. for strength-threats how the strengths could be used to minimise the identified threats [34]. After completing the TOWS matrix, the experts were given time to discuss which of the identified interactions could play a decisive role in enhancing the production of the product, and these are summarised in Table 4.

Building a production plant for textiles from trees and implementing the technology, including research, would require financial support and some government guarantees to ease the administrative burden, at least for a pilot project. A national commitment to the targets set out in the European Green Deal, as well as a commitment to gradually replace unsustainable and fossil-based textiles, would go a long way towards attracting investment. The development of cooperation mechanisms between research institutions, companies and investors should be

Table 3
Factor ranking with AHP for textile from tree.

STRENGHTS	AHP	WEAKNESSES	AHP
S2 Smaller negative environmental impact than from cotton or fossil-based fibre	**39 %**	**W4** High initial investment to build a production site	**32 %**
S4 Developed production technologies	**20 %**	**W3** Technology availability, validation, testing	**28 %**
S5 Locally available resource	**14 %**	**W1** High energy and water consumption	**22 %**
S1 Stable and growing demand for bio-based fibres	**14 %**	**W5** Public ignorance about the origin, environmental impact, sustainability of the textiles on the market	**10 %**
S3 Raw material cultivation does not compete for agricultural land	**13 %**	**W2** There is no technology yet to fully utilize production residues	**8 %**
OPPORTUNITIES	AHP	THREATS	AHP
O1 Development of innovation to make the production fully sustainable and environmentally friendly	**31 %**	**T5** Insufficient funding may stop technological progress	**38 %**
O4 New job opportunities in Europe	**23 %**	**T3** Government decisions, legislative changes	**25 %**
O5 Potential to achieve high energy efficiency, resource efficiency, etc.	**23 %**	**T1** Competition for raw material	**18 %**
O2 Growing market pull for sustainable products compliant with circular economy	**17 %**	**T2** Public dislike of large factories, NIMBY phenomenon	**11 %**
O3 Reduced microplastics by replacing fossil-based fibre with natural fibre	**6 %**	**T4** Excessive pressure on forest ecosystems (overexploitation of resources)	**7 %**

strengthened in order to promote innovation and licensing of wood-based textile fibres. This could also be achieved through increased knowledge transfer to Latvia from other countries with experience in wood-based textile fibre production technologies. The experts also noted a lack of public awareness of the environmental impacts of widely used textile production and its life cycle, which could only be changed in the long term by supplementing educational content and additional outreach work at different levels of education.

4.3. Particle board

In the production of wood-based panels, different types and qualities of wood are used - thin wood, wood residues from tree felling, sawmill residues (sawdust and wood chips), post-production wood residues, etc. [106]. Boards are divided into two main categories: particle board and fibre board [106]. The main difference between them is in the size to which the wood particles are reduced before drying and compacting into the finished boards [106]. Particle boards are manufactured from low quality wood particles heat-pressed together using adhesive – usually melamine of formaldehyde based [107,108]. Although adhesive comprises only 2 %–5 % of the final wood-based board, it makes up for up to 25 % of the product costs, therefore making a great impact on production profitability [107,108]. This promotes the research and development of new and improved adhesives, nevertheless popular synthetic adhesives are industry standards – providing durability and resistance to water [107,108]. The particle board making process represents cascading and more efficient use of wood [106]. Today, recycled wood content in particleboard is around 70 % or more, extending the carbon cycle and creating new opportunities to add economic value [106]. The negative side is that the production of wood-based panels is both capital and energy intensive [106]. The energy for the production processes is often obtained from wood biomass, which makes the process CO_2-neutral, although the production process is energy-intensive [109–112].

Table 4
Strategic actions to be taken for textile from tree.

System component	Category	Interactions	Action to be taken
Finance & governance	Financing (public/private)	S3+O4 W5+T3	Implement public financial support/grants/research projects for the construction of new technological solutions and product production facilities (funding for pilot projects) contributing to the development of the circular economy.
Finance & governance	Collaboration Legislation Policies	S2+S5+S3+T3 W4+W5+T3	Commitment by the government (ministries responsible for developing the bioeconomy) to adhere to/implement the objectives of the European Green Deal and the European Bioeconomy Strategy, promoting the circular bioeconomy and sustainable solutions in practice. Guarantee a safe investment environment and provide local businesses with clarity on the government's long-term priorities.
Finance & governance	Legislation Policies	S2+S1+T3+T2	Legislation to replace unsustainable textiles with sustainable ones by a certain deadline. This could also contribute to changing public perception and thus the demand/supply structure.
R&D	R&D	S4+S1+O1 S5+O1+O4 W4+W4+W1+O1 W1+T1	Establishment of cooperation links and mechanisms between companies, investors, and research institutions for innovation development (e.g., energy, and resource efficiency). Companies contract research institutions for specific services
Knowledge Innovations technologies	Expertise	W5+W2+O4+O5 W4+W5+T3	Education (higher education, lifelong learning programmes) on the circular bioeconomy and the latest technological developments for circular and sustainable resource use. Circular bioeconomy as an advanced learning programme/course and as a general education course in other scientific fields

Environmental aspects and effects on human health include dust, which can be carcinogenic or cause respiratory problems due to the resins contained in the material (aminoformaldehyde or phenolic resins) [109–112]. Important to emphasise that the development of innovations has made it possible to make the particle boards environmentally and human health friendly [106] and to reduce the energy intensity of the production process.

After developing a SWOT matrix for particle board (see Annex 2, Table 2.2), the experts identified which five factors from each category could have the greatest impact on production and an AHP matrix was created to determine which of the factors would have the greatest impact. After ranking the factors and creating the AHP matrix (see Table 5), the results were inserted into the TOWS matrix.

Another task for the experts was to identify the interaction between the factors that were prioritised and ranked using the AHP matrix. Again, a TOWS matrix was created in which the factors ranked with the AHP method were inserted. The experts had to identify the interactions between the listed factors [34]. After completing the TOWS matrix, the experts had time to discuss which of the identified interactions could play a crucial role in producing a product with better environmental performance and improved or even bio-based adhesives. These are summarised in Table 6.

Table 5
Factor ranking with AHP for particle board.

STRENGHTS	AHP	WEAKNESSES	AHP
S3 Competitive price, cheaper than solid wood	31 %	**W4** High energy consumption (drying, milling) to produce the product	37 %
S1 Because of their light-weight nature, the furniture made is relatively easy to lift and transport	24 %	**W3** Low durability and a shorter lifespan than medium density fiberboard and plywood	19 %
S7 Products standardised and certifiable	24 %	**W2** Since the manufacturing process involves the usage of urea-formaldehyde resin and can be toxic	18 %
S2 Created using wood chips and sawdust or other lumber products	13 %	**W6** When exposed to a considerable amount of moisture, expands, warps and discolours easily	16 %
S4 Locally available resource	8 %	**W9** Low density makes them easily damaged during shipping	11 %
OPPORTUNITIES	**AHP**	**THREATS**	**AHP**
O8 Intrinsic properties can be improved using raw materials that are derived from natural fibres, such as wheat, barley, rice, cotton gin, banana, and coir and kenaf, to launch diverse product	34 %	**T2** Competition for raw materials - decreasing availability of wood raw materials and increasing demand for products	36 %
O4 Currently used binders can be replaced in the production process with bio-based binders that are environmentally and human health friendly	21 %	**T3** Increase in raw material cost	19 %
O5 Potential to replace existing plastic furniture on the market	16 %	**T1** Often advertised as environmentally friendly due to the fact that it they're made from wood residues, although urea-formaldehyde resin is used as a binder (greenwashing)	19 %
O7 As the world's population, housing building, and income levels rise, the need for furniture such as chairs, tables, mattresses, sofas, shelves, and cupboards has risen dramatically	15 %	**T4** Competition in the foreign market (Asia), cheaper but less environmentally friendly product	14 %
O2 Financial resources available to further develop product features	15 %	**T5** Higher demand in countries with few or no forests, such as China, could result in an increased interest in panels made from agricultural lignocellulosic materials, competing with boards made entirely from wood residues	12 %

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 [113].

4.4. *Natural thermal packaging*

Thermal packaging made of logging residues and an organic binder that is suitable for transporting various temperature-sensitive goods (visual representation in Fig. 6), can protect goods from external temperature fluctuations during transport or storage and is resistant to mechanical damage is the third niche product chosen by experts [114–117]. Currently, thermal packaging is mostly made of expanded polystyrene (EPS) [114–117]. The main value of this newly developed material is that it has no negative impact on the climate, environment and human health during its life cycle [114–117]. The material can be utilised to manufacture thermal packaging boards, which can be inserted into boxes for the transportation of goods. The laboratory studies indicate that the boards possess characteristics of being lightweight, resilient, and exhibiting low heat conductivity and being biodegradable [114–117]. Market research shows a wide range of applications for thermal packaging, especially in the pharmaceutical and biomedical sectors, to make the delivery of medicines and vaccines more environmentally friendly [114–117]. Natural thermal packaging material is a new product licensed at TRL6 level, awaiting development, demo plant construction, and production piloting offering to customers [114–117].

After developing a SWOT matrix for the natural thermal packaging (see Annex 2, Table 2.3), the previously described workflow was applied. Table 7 displays factor ranking with AHP for natural thermal packaging.

Another task for the experts was to identify the interactions between the factors prioritised and ranked in the AHP matrix by developing a TOWS matrix. The results of expert discussions on TOWS are summarised in Table 8.

The priority actions include the creation of infrastructure for the collection of secondary and tertiary wood resources in rural areas. Encouraging the collection of low-value wood residues, not only to ensure the full utilization 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.

4.5. *Strategic actions to be taken*

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 authors suggest developing national guidelines for companies to promote the use of lower quality wood for higher value-added products. These guidelines

Table 6
Strategic actions to be taken for particle board.

System component	Category	Interactions	Action to be taken
Finance & governance	Financing (public/private) Legislation policies	S2+O5 S2+S4+T2+T3	Shifting subsidies from less efficient uses of biomass to higher value-added uses of bioresources and biomass
Finance & governance	Legislation policies	S2+S4+O5 S2+S4+T2	National guidelines for companies to switch to lower quality wood for higher value-added products. Optimisation and transition to cleaner production through legislation - stricter regulation that provides for a sufficiently long transition period.
Knowledge innovations-technologies	Expertise, Technology	S7+O7, W4+O5 W4+O2, S7+T1+T4 W4+W2+W6+W9+T2 W4+T2	Introduce Environmental and Energy Management Systems in companies to boost competitiveness and improve production processes.
Knowledge – innovations-technologies Public/private expectations		W2+W6+O4 W2+O5, S7+T1+T4 W2+T1	"Recognise Greenwashing" information campaign involving various organisations. Aims to highlight the distinction between justified higher prices for greener products and profit motives.
Products & services Public/private expectations	Market, customers Sustainability	S7+O4 S2+O4 S3+S1+S7+O5+O7 W2+W6+O4 W2+O5	Companies should be encouraged to certify their products to ensure consumer confidence. Raise public awareness of product certification schemes and their importance for consumers to identify eco-products and the companies that produce them. Marketing campaigns on the life cycle of products to explain why furniture made from biomass is preferable to plastic.

Fig. 6. Natural thermal packing material [114,115]

Table 7
Factor ranking with AHP for natural thermal packaging.

STRENGHTS	AHP	WEAKNESSES	AHP
S3 Production price similar to EPS packaging	40 %	**W4** High energy consumption (drying, milling) to produce the product	47 %
S1 High demand for thermal packaging	36 %	**W1** Piloting the production the innovative product requires time and financial investment	29 %
S5 CO_2 is stored in the product - CO_2 valorisation	10 %	**W3** Technology readiness level is in "the valley of death" (TRL6)	15 %
S2 Replaces thermal packaging currently produced from fossil resources	7 %	**W5** Raw material market not developed	4 %
S4 Made from widely available low-quality forestry, and agricultural residues (secondary and tertiary bioresources)	7 %	**W2** Consumers lack information on the product's positive features	4 %
OPPORTUNITIES	**AHP**	**THREATS**	**AHP**
O2 "Latvian NOKIA" - gain visibility and international market opportunities	43 %	**T1** Necessary funding will not be attracted and TRL will stay in "the valley of death"	33 %
O3 Rural, regional development - creating jobs, raising living standards, etc.	35 %	**T2** Possible negative public attitudes towards the material (lobbying and marketing of fossil resources)	26 %
O1 Bioresources are used to produce a product with higher added value	9 %	**T4** Increase in raw material cost	23 %
O4 Widespread use of the material would contribute to sustainability goals	7 %	**T3** Competition for raw material	11 %
O5 Develop innovation for further product improvement	6 %	**T5** Potential changes in the regulatory framework that may hinder the introduction or use of the product	6 %

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 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 [54]. 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 [54]. The weaknesses of Latvian bioeconomy enterprises are partly related to

Table 8
Strategic actions to be taken for natural thermal packaging.

System component	Category	Interactions	Action to be taken
Finance & governance	Legislation Policies	S4+O3+O1 W5+T4+T5	Promote the development of infrastructures for the collection of tertiary and secondary residues by integrating this into policy planning documents. Build logistics chains to maximise the efficiency of tertiary and secondary residue collection.
Finance & governance	Legislation Policies	S3 + S1 +S2 + O2 W1+O4+O5	Reduce the administrative burden for the market entry of products (green corridor) that replace fossil-based products, provided they meet certain quality requirements and comply with the principles of the circular bioeconomy.
R&D	R&D	S3 + S1 +S2 + O2 S3+S1+S5+O1	Public grants/subsidies to companies for further development of products/processing technologies if this achieves the objectives of the Green Deal and the European Bioeconomy Strategy by simplifying the criteria and application mechanism for support.
Knowledge–innovations-technologies	Expertise	S4+O3+O1 S3+S5+S1+T3	Workshops and training for companies, associations and the general public on the wide use of wood waste (and beyond) in products with higher added value and in line with the circular bioeconomy. Thus, shifting from conventional methods to knowledge-based and innovative ones.
Products & services	Market Customers	S3+S5+S1+T3	Promoting the product and its positive attributes - a campaign to show that natural thermal packaging complies with Article 9 of the EU taxonomy, thus helping the company to make the transition to sustainable economic activity.

the energy intensity of the technology and insufficient energy and resource efficiency. The introduction of environmental and energy management systems in companies can help to increase competitiveness and promote efficiency and innovation culture.

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 [118].

General awareness of the importance of the bioeconomy in society should be raised and to clarify the difference between low value-added biomass applications and technologically innovative high value-added bioeconomy, as well as to promote sustainable products and businesses [57,118]. The concepts to popularise the bioeconomy should be complemented by explaining the importance of carbon neutrality, the use of renewable energy and the overall objectives of the European Green Deal.

5. Discussion and conclusion

An assessment of national-level policy planning documents related to the bioeconomy, carried out as part of a previous study [119], has shown that the objectives for bioeconomy development set at the international level are generally included in Latvian policy planning documents at a high level. The main concern, however, is the policy planning documents dealing specifically with the forest sector. At the time of this research, 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. During GMB sessions experts suggested developing national guidelines (BREF) for companies to use lower quality wood for higher value-added products, taking into account Latvia’s low industrial capacity. The guidelines could be adapted to local conditions and ensure political will to develop the bioeconomy and implement the goals of the European Green Deal in Latvia.

Funding for research and education in Latvia is insufficient and unpredictable, especially in the field of bioeconomy. To ensure continuity of research and strengthen R&D, it would be necessary to break the cyclical nature of funding and shift subsidies from less efficient biomass uses to higher value-added uses. Introducing financial support mechanisms such as public grants, subsidies and research projects can steer research and innovation initiatives towards higher value products, overcoming financial bottlenecks. Experts suggest that subsidies should be shifted from the less efficient use of biomass to the more value-added use of bioresources and biomass.

Industry needs clear signals from government on long-term planning and commitments to meet and implement the objectives of the European Green Deal and the European Bioeconomy Strategy, which promote the circular economy and sustainable solutions in practise. This would guarantee a safer investment environment and provide clarity to local businesses about the government’s long-term priorities, especially in higher risk novel industries.

The knowledge-based bioeconomy should be promoted in society to distinguish between low-value biomass applications and high-value, technologically innovative applications. This includes promoting sustainable products and businesses, combating “greenwashing” certifying higher value bioeconomy products and providing workshops and training on the use of wood residues in higher value-added products in line with the circular bioeconomy.

The developed methodology for the analysis of the bioeconomy and the identification of specific niche products, with the objective of promoting a knowledge-based bioeconomy. The developed methodology combines several well-known scientific methods such as SWOT, TOWS and AHP, with a less well-known bioeconomy analysis method developed by Maciejczak [20] and extended by Wreford et al. [18]. The initial phase of the study, which involved the analysis and compilation of data and information, afforded a comprehensive overview of the forest sector system components. This approach enabled the authors to gain a comprehensive understanding of the sector from the perspective of different system components, and to identify the enablers and constraints affecting it. It also provided the basis for the second phase of the study, which examined the development opportunities of the forest sector from a narrower product development perspective. It should be noted that the conclusions of the second phase of the study, in which GMB experts assessed the potential of the three identified niche products to emerge and grow in the market, exhibited a high degree of alignment with the results of the first phase on the barriers to forest sector development in general. The methodology developed therefore serves two purposes: firstly, it allows to assess the development of specific bio-based products; and secondly, to identify the underlying issues that are hindering the development of the sector as a whole. To illustrate, the specific outcomes of this study indicate that, when considering the strategic direction of bioeconomy development, the critical factors are not necessarily the selection of a particular group of products, but rather the ensured availability of raw materials, the consistency of political commitment and legislation, and the predictability and accessibility of funding.

The developed methodology was subjected to practical testing during the analysis of the forest sector system components and within the GMB process. In this process, different sector experts utilised SWOT and TOWS matrices to develop strategic pathways for niche products. The results were favourable, indicating that the methodology was effective in achieving the intended results. Despite the time investment required, the methodology was found to be both understandable and implementable by the GMB participants. One identified limitation of the time intensive nature of both the analysis of the forest sector system components and the multiple GMB sessions. In the initial phase, the analysis was conducted by a team of scientists, and the findings were subsequently presented to the GMB participants, which could have influenced the subsequent expert discussion. To further refine and evaluate the methodology, it is recommended that a follow-up study be conducted with two separate groups of experts. Such a comparison would enable an evaluation of whether the absence of initial sector-wide feasibility study findings (Phase 1) affects the identification of sector-wide issues related to product development and promotion (Phase 2). The methodology developed is designed to be simple for policy and decision makers, to facilitate feasibility studies and to allow in-depth involvement of different stakeholder groups in the development of strategic pathways.

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Availability of data and material

Upon request.

Statement

During the preparation of this paper, the author(s) used paid versions of the DeepL translation tool and the DeepL writing tool, the Quillbot paraphrasing tool and the InstaText text editing tool in order to improve the use of English, grammar and the formulation of the ideas expressed, due to the fact that none of the authors is a native speaker of English. After using these tools/services, the authors reviewed and edited the content as necessary and take full responsibility for the content of the publication.

CRediT authorship contribution statement

Krista Laktuka: Writing – original draft, Visualization, Validation, Investigation, Formal analysis, Data curation. **Anna Kubule:** Writing – review & editing, Validation, Investigation, Formal analysis. **Ilze Vamza:** Writing – original draft, Validation, Formal analysis, Data curation. **Stelios Rozakis:** Supervision, Methodology, Conceptualization. **Dagnija Blumberga:** Writing – review & editing, Validation, Supervision, Project administration, Methodology, Funding acquisition, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Annex 1.

Table 1.1
Latvian policy and development planning documents related to the forest sector (2022)

Policy document	Matters pertaining to forest sector or the wood industry
Latvia's Sustainable Development Strategy 2030 (Latvia2030) Adoption year: 2010	Sustainable forest use is crucial for national and rural development because forests are strategic resources[120]. Transforming the forest sector to focus on advanced wood processing and high-value, internationally competitive end goods [120]. Transfer of knowledge and innovation in forest sector. Afforestation of low-value and unused agricultural land [120].
National Development Plan for 2021–2027 (NDP2027) Adoption year: 2020	Green infrastructure, sustainable natural resource management, and biodiversity and landscape diversity protection [121]. Fund corporate, public, and academic collaboration, business-focused research and innovation, and targeted investment across the business cycle, from knowledge generation through development and sales[121]. From short-term profitability to long-term productivity [121]. Carbon sequestration commitments and the sustainable and efficient use of natural resources [121]. Governance that balances economic activity, social interests, carbon sequestration, and biodiversity conservation [121].
National Energy and Climate Plan 2030 (NECP2030) Adoption year: 2019	Achieve investment in R&D of 2 % of GDP, with 25 % of total R&D investment going to the development and deployment of climate technologies and achievement of climate targets, including forest management [122]. Ensure the use of forest land for wind farm development [122]. Sustainable forest management, taking into account climate, environmental, economic and social aspects [122]. Maintaining forest cover at existing levels to ensure Carbon sequestration, contribution to bioenergy [122]. Increasing bioresource usage and the use of wood as a material, private forest production, and climate change adaptation [122]. Improve forest drainage, plant high-quality seedlings, enhance soil quality, and manage young stands to promote carbon sequestration [122].
LIBRA Adoption year: 2017	Potential to increase harvesting volumes in forests that have reached the appropriate age structure (Ministry of Agriculture, 2018). Great potential to increase the economic value of forests by creating and restoring nature-friendly drainage systems and forest roads, by targeted planting and cultivation of native tree species that are more economically valuable and ecologically suited to Latvia's climate, without reducing the area available for growing and harvesting wood (Ministry of Agriculture, 2018). Convert agricultural land overgrown with low-value tree species and shrubs into economically valuable forests (Ministry of Agriculture, 2018). Wood processing and furniture sectors may expand by increasing primary manufacturing and employment, exports of forestry and wood by-products can be replaced by goods produced in Latvia, and using sawn timber and boards as raw materials for higher-value products instead of exporting them (Ministry of Agriculture, 2018). Knowledge transfer from the conventional bioeconomy to a knowledge-based one, and collaboration between scientists, entrepreneurs, and forest owners (Ministry of Agriculture, 2018). Replace fossil fuels with low-quality wood or wood leftovers. (Ministry of Agriculture, 2018). Certification of forest owners, logging and processing companies according to internationally agreed standards (Ministry of Agriculture, 2018). GHG emissions reduction and disposal (Ministry of Agriculture, 2018).
Latvian Forest Policy Adoption year: 1998	Sustainable management of forests and woodlands [69]. Ensure that existing forest cover is not reduced; maintain and enhance the productivity and value of forest land; promote afforestation of unusable land [69]. As a forest owner, the state's main

(*continued on next page*)

Table 1.1 (*continued*)

Policy document	Matters pertaining to forest sector or the wood industry
	interest is to increase the value of its forests and to make a profit from the forests it owns [69]. The development of a market economy and free competition in the forest sector, the regulation of forest use principles to stabilise the sustainable availability of timber resources, the financing needed for forest management to be obtained from trade [69]. Promoting the use of wood as an environmentally friendly material, wood residues for panel and pulp production, electricity, etc., through an incentive-based tax policy[69]. Preserving and maintaining biodiversity at current levels [69]. Balancing society's and forest owners' interests in using forests' social values and developing forest sector working relations, with forests freely available to everybody, regardless of ownership [69]. Forest education, science, and information could enhance forest policy, law, and practice and sustainably manage forests [69].
Guidelines for the development of forests and related sectors 2015 – 2020 *Adoption year: 2015*	*At the time of this study, the guidelines for forest development planning after 2020 had not yet been updated.*
LVM medium-term action strategy Adoption year: 2020	To implement sustainable, economically viable, environmentally friendly, socially responsible management of state forest estate and to develop the necessary infrastructure, services and knowledge [123]. Forestry shall be carried out within the framework of sustainable forest management [123]. The multiple values of the forest for future generations, ensuring resource sustainability; biodiversity conservation; outdoor recreation opportunities; public participation in forest management; adaptation of forestry to mitigate global climate change; leadership and staff management; and social responsibility [123]. New higher value-added products from woody biomass, peat for energy production, extraction of subsoil products and geospatial solution development services, and offer consulting services [123]. Supply energy to local heat and power producers by increasing production and sales from managed land and timber from other owner's resources [123]. Boost woody biomass utilization for green energy to reduce fossil carbon and increase Latvia's energy independence [123]. Investment projects for energy production from RES and the use of wood in chemical processing, including biofuels production [123]. Investing in research to create new knowledge that can be transferred to production [123]. Priorities for knowledge transfer include forest stand growth patterns, harvesting technologies under low carrying capacity conditions, soil fertility improvement, landscape ecology planning, forestry adaptation to global climate change, and remote sensing to generate forest data for forestry planning [123].

Annex 2.

TABLE 2.1
SWOT for textile from tree

STRENGHTS	WEAKNESSES
S1 Stable and growing demand for bio-based fibres;	**W1** High energy and water consumption;
S2 Smaller negative environmental impact than from cotton or fossil-based fibre;	**W2** There is no technology yet to fully utilize production residues;
S3 Raw material cultivation does not compete for agricultural land;	**W3** Technology availability, validation, testing;
S4 Developed production technologies;	**W4** High initial investment to build a production site;
S5 Locally available resource;	**W5** Public ignorance about the origin, environmental impact, sustainability of the textiles on the market
S6 Both wood and pulp can be used;	
S7 The technology can be used for recycling textile waste (circular economy);	
S8 Lower quality raw material may be used;	
S9 Competitive market price	
OPPORTUNITIES	**THREATS**
O1 Development of innovation to make the production fully sustainable and environmentally friendly;	**T1** Competition for raw material;
O2 Growing market pull for sustainable products compliant with circular economy;	**T2** Public dislike of large factories, NIMBY;
O3 Reduced microplastics by replacing fossil-based fibre with natural fibre;	**T3** Government decisions, legislative changes;
O4 New job opportunities in Europe;	**T4** Excessive pressure on forest ecosystems (overexploitation of resources);
O5 Potential to achieve high energy, and resource efficiency, etc.	**T5** Insufficient funding may stop technological progress

TABLE 2.2
SWOT for particle boards

STRENGHTS	WEAKNESSES
S1 Because of their light-weight nature, the furniture made out of these boards is relatively easy to lift and transport;	**W1** Not recyclable;
S2 Created using wood chips and sawdust or other lumber products;	**W2** Since the manufacturing process involves the usage of urea-formaldehyde resin, can be toxic;
S3 Competitive price, cheaper than solid wood;	**W3** Low durability and a shorter lifespan than medium density fiberboard and plywood;
S4 Locally available resource;	**W4** High energy consumption (drying, milling) to produce the product;
S5 CO_2 is stored in the product (CO_2 valorisation);	**W5** Low on strength, hence cannot support heavy loads;
S6 Due to their lightweight properties, easily transported and handled;	**W6** When exposed to a considerable amount of moisture, expands, warps and discolours easily;

(*continued on next page*)

TABLE 2.2 (*continued*)

STRENGHTS	WEAKNESSES
S7 Products standardised and certifiable;	**W7** Susceptible to attacks by different microorganisms and insects;
S8 Can be used in making home furniture, such as kitchen cabinets, bookcases, doors, windows, and wall and floor coverings, in the commercial and residential sectors across the globe;	**W8** Raw material market not developed;
S9 Can be easily laminated, painted, and wallpapered to improve their overall aesthetic value;	**W9** Low density makes them easily damaged during shipping
S10 Any wood species could be used for particle boards, although softwoods and lower-density hardwoods are preferred	
OPPORTUNITIES	THREATS
O1 Bioproduct with a higher added value;	**T1** Often advertised as environmentally friendly due to the fact that it they're made from wood residues, although urea-formaldehyde resin is used as a binder (green washing);
O2 Financial resources available to further develop product features;	**T2** Competition for raw materials - decreasing availability of wood raw materials and increasing demand for products;
O3 Innovations can be developed for further product feature improvement;	**T3** Increase in raw material cost;
O4 Currently used binders can be replaced in the production process with bio-based binders that are environmentally and human health friendly;	**T4** Competition in the foreign market (Asia), cheaper but less environmentally friendly product;
O5 Potential to replace existing plastic furniture on the market;	**T5** Higher demand in countries with few or no forests, such as China, could result in an increased interest in panels made from agricultural lignocellulosic materials, competing with boards made entirely from wood residues;
O6 Machine manufactured to desired dimensions. Standard pieces of furniture can be efficiently mass-produced;	**T6** Research efforts have been shifted to agriculture-based materials, with the advantages of the built-in insulation, sound suppression characteristics, and low cost;
O7 As the world's population, housing building, and income levels rise, the need for furniture such as chairs, tables, mattresses, sofas, shelves, and cupboards has risen dramatically;	**T7** Concerning chemical health hazards among workers
O8 Intrinsic properties can be improved using raw materials that are derived from natural fibres, such as wheat, barley, rice, cotton gin, banana, and coir and kenaf, to launch diverse product	

Table 2.3
SWOT for natural thermal packaging

STRENGHTS	WEAKNESSES
S1 High demand for thermal packaging;	**W1** Piloting the production the innovative product requires time and financial investment;
S2 Replaces thermal packaging currently produced from fossil resources;	**W2** Consumers lack information on the product's positive features;
S3 Production price similar to EPS packaging;	**W3** Technology readiness level is in "the valley of death" (TRL6);
S4 Made from widely available low-quality forestry, and agricultural residues (secondary and tertiary bioresources);	**W4** High energy consumption (drying, milling) to produce the product;
S5 CO_2 is stored in the product - CO_2 valorisation;	**W5** Raw material market not developed;
S6 Easily obtainable raw material/resource;	**W6** More difficult for a manufacturer to form or change the shape of the material than for EPS;
S7 Locally, widely available resource;	**W7** Less visually appealing in comparison to EPS;
S8 Experienced woodworking industry in Latvia;	**W8** Higher density compared to EPS increases transport costs
S9 Customizable shape and functionality;	
S10 Safe for environment and human health, biodegradable at the end of its life	
OPPORTUNITIES	THREATS
O1 Bioresources are used to produce a product with higher added value;	**T1** Necessary funding will not be attracted and TRL will stay in "the valley of death";
O2 "Latvian NOKIA" - gain visibility and international market opportunities;	**T2** Possible negative public attitudes towards the material (lobbying and marketing of fossil resources);
O3 Rural, regional development - creating jobs, raising living standards, etc.	**T3** Competition for raw material;
O4 Widespread use of the material would contribute to sustainability goals;	**T4** Increase in raw material cost;
O5 Develop innovation for further product improvement;	**T5** Potential changes in the regulatory framework that may hinder the introduction or use of the product;
O6 Product's market entry would promote transition from fossil resources;	**T6** Shortages of current legislative framework;
O7 Bringing the product to market would reduce the negative impact on climate change from temperature sensitive goods transportation;	**T7** Intellectual property violation;
O8 Qualify for green certification (eco-label)	**T8** Alternative production facilities and products will enter the market

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Policy Coherence of the EU Carbon Removal Certification Framework: Integration of Carbon Farming in Climate and Agricultural Policy

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***Abstract* — Adoption of the "Regulation (EU) 2024/3012 of the European Parliament and of the Council establishing a Union certification framework for permanent carbon removals, carbon farming and carbon storage in products" represents a significant policy shift, introducing a voluntary, harmonised EU certification framework. This study assesses the policy coherence of the CRCF Regulation and related EU regulatory and policy documents, examining how the certification framework for carbon removals, including carbon farming, is integrated into the EU' broader climate and agricultural policy landscape. A qualitative content analysis was conducted on 31 EU documents, which were selected using snowballing sampling approach and nine search terms related to carbon removals, soil emissions and carbon farming. The identified text fragments were coded and grouped into nine thematic groups and qualitatively analysed to assess whether they reflect horizontal and vertical policy coherence or, indicate gaps and ambiguities. The results highlight a high degree of horizontal coherence with key EU documents, including the EU's Land Use, Land Use Change and Forestry Regulation and the Common Agricultural Policy. However, several gaps and ambiguities remain, particularly regarding baseline methodologies, potential overlaps in funding mechanisms, and practical implementation pathways. These findings underscore the need for stronger vertical integration and methodological clarity to ensure that certified activities effectively support EU climate goals.**

Keywords – **Carbon farming; certification framework; CRCF regulation; EU climate policy; SDG 13.**

1. INTRODUCTION

The United Nations Framework Convention on Climate Change (UNFCCC) adopted in 1992 and the subsequent Kyoto Protocol in 1997 marked the first international steps to combat climate change [1]–[3]. The Paris Agreement which entered into force in November 2016 and was replaced the Kyoto Protocol sets the goal of keeping the global temperature increase well below 2 °C, aiming for 1.5 °C above pre-industrial levels [4], [5]. These international commitments are complemented by the 17 Sustainable Development Goals (SDGs), adopted through the United Nations "2030 Agenda for Sustainable Development" in 2015 [6]. Among these, SDG 13 calls for urgent action to combat climate change and is closely linked to other

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goals such as life on land (SDG 15), zero hunger (SDG 2), and responsible consumption and production (SDG 12) [6].

Under the Paris Agreement the EU has committed to reduce greenhouse gas (GHG) emissions by 55 % by 2030 compared to 1990 levels [7], [8]. These reductions also apply to the Land Use, Land Use Change and Forestry (LULUCF) sector [1]. The EU's internal commitments on climate neutrality by 2050 are set out in the European Green Deal and made legally binding by the European Climate Law. These objectives are operationalised through the legislative package "Fit for 55 %" [8]–[10]. While it was initially expected that the EU's climate targets could be met through incremental mitigation measures, it is now clear that this will not be sufficient, and large-scale carbon removal will be necessary [9]. One potential pathway is the wider application of carbon farming practices. The importance of the LULUCF sector for carbon sequestration in natural ecosystems has long been recognised: as early as 2004, Lal [11] demonstrated that the conversion of natural ecosystems to agroecosystems can lead to a decline in soil organic carbon (SOC) stocks by up to 60–75 %, while also identifying a range of land management practices with high carbon sequestration potential [11]. Two decades later, carbon sequestration in ecosystems is no longer solely a scientific concern – it is increasingly framed as a strategic policy tool [12].

Despite the well-documented potential of carbon farming [13]–[15], the EU lacked a harmonised framework to quantify and reward the uptake of such practices. This gap is now being addressed by "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" (CRCF Regulation) [16]. This development builds on a broader shift in EU climate un agricultural policy, shaped by several strategic initiatives – most notably the European Commission Communication "Sustainable Carbon Cycles" (COM (2021) 800 final) [17]. Earlier policy frameworks, such as the Circular Economy Action Plan (COM (2020) 98 final) [18] and the Farm to Fork Strategy (COM (2020) 381 final) [19], had already emphasised the need to align food supply chains, land use and product design with climate and environmental goals, laying important groundwork for the CRCF Regulation and its integration with the greening of the Common Agricultural Policy (CAP) [9].

The CRCF Regulation is positioned not only as a new green business model for farmers and land managers, but also as a mechanism to support EU Member States (MS) in meeting their emission reduction targets under the revised LULUCF Regulation EU 2018/841 [20]. It requires that carbon removals be quantified using methodologies consistent with the 2006 Intergovernmental Panel on Climate Change Guidelines for National Greenhouse Gas Inventories (IPCC guidelines), which also underpin national GHG inventory reports [21]–[23]. Since certified activities and associated removals will follow the same methodological basis, they may be integrated into MS reporting obligations under the UNFCCC, the Paris Agreement, and Regulation (EU) 2018/1999 on the Governance of the Energy Union [23], [24].

While this study focuses on the application of carbon farming practices under the CRCF Regulation, it is important to note that the CRCF Regulation also encompasses permanent carbon removals and carbon storage in long-lasting products [16], [25]. Technological solutions such as Direct Air Carbon Capture and Storage (DACCS) and Bio-Energy Carbon Capture and Storage (BECCS) are considered vital for the EU's long-term decarbonisation strategy [17], [25]. In parallel, the CRCF Regulation promotes the use of bio-based construction materials, effectively transforming buildings into long-term carbon storage units [25].

The reminder of this paper is structured as follows: Section 2 provides a theoretical overview of carbon farming, focusing on definitional variations and implementation challenges. Section 3 outlines the research methodology, including document selection, search term identification, and application of the qualitative content analysis (QCA). Section 4 presents both quantitative and qualitative findings derived from the QCA, including document characteristics, search term frequency, and a synthesis of findings structured into eight thematic groups. Finally, Section 5 summarises the main insights, discusses regulatory and policy implications in the context of EU climate and agricultural policy, and reflects on implementation challenges at the MS level.

The aim of this study is to evaluate the policy coherence of the newly adopted CRCF Regulation and the certification framework it introduces for carbon removals, including carbon farming. The analysis focuses on both horizontal coherence – the alignment of the CRCF Regulation with other EU climate and agricultural policy instruments, and vertical coherence, referring to the consistency between EU level objectives and potential implementation at the national level. The following research questions were formulated to guide the analysis: (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 when implementing the CRCF Regulation at the national level?

2. THEORETICAL BACKGROUND: CARBON FARMING

In order to understand how carbon farming is operationalised within the CRCF Regulation and related EU regulatory and policy documents, it is essential to examine how the term is defined and conceptualised in different sources. Carbon farming practices are defined in various ways in EU documents, research reports and scientific articles. These definitions range from descriptions of farm-level activities aimed at managing carbon pools, flows, and GHG fluxes, to more conceptual framings that emphasise climate change mitigation and new green business models [26], [27]. Therefore, to understand the activities addressed by the CRCF Regulation, a comparative analysis of carbon farming definitions was conducted (see Table 1). Definitions were drawn from core EU documents published in 2021, including the Communication "Sustainable Carbon Cycles" and the European Parliament ENVI Committee study "Carbon farming – Making agriculture fit for 2030", as well as from the proposal and final version of the CRCF Regulation. These policy-based definitions were complemented by three peer-reviewed scientific publications selected for their conceptual relevance and academic visibility.

When comparing the definitions based on the GHGs they cover, it becomes evident that most regulatory and policy documents, as well as the Carbon Cycle Institute [30], focus primarily on CO_2 emissions, referring to their removal, reduction or storage. Only one definition, provided by McDonald *et al.* [29] (a), explicitly includes all three major GHGs (CO_2, CH_4, N_2O). Panchasara *et al.* [32] refer more generally to GHG emissions without specifying individual gases, suggesting a broader but less clearly defined scope. In terms of content, the definitions vary in scope, ranging from general to specific, and differ in the mechanisms they emphasise. Some definitions include a combination of carbon removal, emission reductions and carbon storage, while others refer only to one or two of these. As shown in Table 1, several definitions (e.g., McDonald *et al.* [29] (b), Cavallin [21]) do not specify which part of the carbon cycle they target. Instead, they frame carbon farming as a business model rather than a set of quantifiable climate actions. It is also notable that the definitions differ in terms of their focus.

TABLE 1. COMPARATIVE OVERVIEW OF CARBON FARMING DEFINITIONS IN POLICY AND SCIENTIFIC SOURCES

Source	**Definitions of carbon farming**	**GHGs covered**	**Emission reduction**	**Carbon removal**	**Carbon storage**	**Business model**	**Environment***
Communication *"Sustainable Carbon Cycles"* [17]	"a green business model that rewards land managers for taking up improved land management practices, resulting in the increase of carbon sequestration in living biomass, dead organic matter and soils by enhancing carbon capture and/or reducing the release of carbon to the atmosphere, in respect of ecological principles favourable to biodiversity and the natural capital overall"	CO_2	X	X	–	X	T
Proposal for CRCF regulation [28]	"… a carbon removal activity related to land management that results in the increase of carbon storage in living biomass, dead organic matter and soils by enhancing carbon capture and/or reducing the release of carbon to the atmosphere"	CO_2	X	X	X	–	T
CRCF Regulation [16]	"… any practice or process carried out over an activity period of at least five years, related to the management of a terrestrial or coastal environment and resulting in the capture and temporary storage of atmospheric or biogenic carbon in biogenic carbon pools, or in the reduction of soil emissions"	CO_2	X	X	X	–	T C
McDonald *et al.* [29]	"(a) … farm management practices that aim to deliver climate mitigation in agriculture. This involves the management of both land and livestock, all pools of carbon in soils, materials, and vegetation, plus fluxes of carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). It includes carbon removal (sequestration and permanent storage of carbon in soils and biomass), avoided emissions (preventing the loss of already stored carbon), and emissions reductions (i.e., reductions of GHGs below current levels of farm emissions)"	CO_2 CH_4 N_2O	X	X	X	–	A
McDonald *et al.* [29]	"(b) … also refers to the business model that aims to upscale climate mitigation by paying farmers to implement climate-friendly farm management practices"	–	–	–	–	X	A
Carbon Cycle Institute [30], Harman un Uphoff [31]	"Implementation of agricultural practices that are known to improve the rate at which CO_2 is removed from the atmosphere and converted into plant material and/or soil organic matter, such as agroforestry and conservation agriculture"	CO_2	–	X	–	–	A
Panchasara *et al.* [32]	"a way to reduce GHG emissions by capturing and holding the carbon in vegetation or soils. Carbon farming seeks to reduce the emissions in its production stage while still managing to increase the yield production, sequestering carbon within the landscape"	GHG	X	X	X	–	T
Cavallin [21]	"… in the context of agricultural soils is meant to leverage the carbon cycle in relation to soils to make the farmland more fertile and more resilient and take advantage of its potential for climate change mitigation, with the added benefit of generating opportunities for the agro-food chain" [33]	–	–	–	–	X	A

Where the term "carbon" is used without further specification, it is assumed to refer to carbon dioxide (CO_2), consistent with common usage in EU policy documents.

*Abbreviations used: T – terrestrial (land-based); A – agriculture/ agricultural soils; C – coastal

Some refer explicitly on agriculture, agricultural land, and agricultural soils and biomass, while others extend the scope to include other land managers and landscapes. The definition in the CRCF Regulation [16] is the only one that specifies activities in coastal environments. It also stands out as the only definition to introduce a time constraint, requiring that measurable carbon removal or emission reduction be achieved within a five-year period. However, this definition narrows the emission reduction objective to a specific category – soil emissions, rather than addressing the full set of emissions from agricultural or land management activities, such as those related energy and fuel use.

This definitional diversity reflects the fragmented nature of carbon farming as a policy and scientific construct. While the CRCF Regulation provides a specific and legally binding definition focused on measurable removals and soil emission reductions, scientific literature reveals a much broader and diverse set of related concepts, such as: climate-smart agriculture; soil-based carbon farming; regenerative agriculture; agroecological agriculture; green agriculture; organic regenerative agriculture; sustainable agriculture [26], [34]–[36]. These overlapping and sometimes ambiguous terms vary in scope, underlying principles, and implementation contexts. As a result, the alignment between the CRCF Regulation's definition and the science-based practices described in the literature may be limited. This misalignment could pose challenges for the practical implementation of carbon farming measures, especially in terms of translating evidence-based approaches into certifiable actions under the CRCF framework.

To better understand the nature of carbon farming, it is essential to consider not only how it is defined but also the practical methods it encompasses. These methods are grounded in effective land management practices that enhance carbon sequestration while generating co-benefits for ecosystems and biodiversity [17]. "Technical Guidance Handbook - setting up and implementing result-based carbon farming mechanisms in the EU" [27], along with the "Sustainable Carbon Cycles" Communication [17], identify several priority methods appropriate for the EU context. These include: (a) conversion of arable land to grassland to sequester SOC; (b) new agroforestry; (c) wetland/peatland conservation/restoration; (d) woodland planting; (e) management of existing woodland, hedgerows, woody buffer strips and farmland trees; (f) reduced and minimum tillage; (g) leaving crop residues on the soil surface; (h) optimised feeding strategies for livestock; (i) improved on-farm energy efficiency, etc.

Transitioning from conventional farming to carbon farming practices often entails significant upfront costs and risks. Therefore, the development of effective support mechanisms is critical. For this reason, three models of support payments for carbon farming practices can be distinguished: action-based, where payments are made for following a particular practice and are already supported by the CAP; results-based, where payments are made for the amount of carbon sequestered; and hybrid schemes, which combine both approaches [21], [27].

Despite growing interest in carbon farming, its practical implementation faces several challenges. One of the most significant is the accurate measurement, monitoring and verification of carbon sequestration [21], [34], which is often hampered by technical constraints, high costs related to measurements, and the temporal variability of SOC changes over time [13], [21], [34]. In addition to these technical barriers, the broader uptake of carbon farming practices is constrained by low carbon credit prices, high transaction costs, lack of information and awareness among land managers, and uncertainty about long-term policy and market conditions [21], [26]. A key conceptual and methodological challenge is the demonstration of additionality, that is, proving that the observed carbon removal or emission reduction would not have occurred without the implementation of specific carbon farming practices. Ensuring the long-term permanence of stored carbon in soils or biomass is another major concern [13], [26]. Baumber *et al.* [26] highlight that insufficient awareness, knowledge and understanding are among the main reasons why many farmers remain disengaged from carbon farming schemes. Strengthening stakeholder collaboration [26], particularly through bottom-up initiatives [37], is therefore seen as essential. Bento *et al.* [38] emphasise the importance of establishing robust, credible baselines that accurately reflect business-as-usual emission levels. More credible baselines can reduce the need for conservative methodological assumptions, thus improving the financial attractiveness of carbon farming projects [38]. To further support uptake, a variety of modelling tools, including DayCent, COMET-Farm, Cool Farm and WaCSE, have been developed to estimate SOC sequestration potential over a period of time [34]. These models differ in terms of input data requirements, level of detail and whether they are tailored to the farm level or regional level [34]. However, existing models cannot capture the high level of process complexity, meaning they cannot be used as the sole quantification tool without additional on-the-ground measurements [22].

2.1. International Context and Critiques of the CRCF Regulation

Before drawing conclusions on the CRCF Regulation's policy coherence, it is important to position it within a broader international context and reflect on critical viewpoints concerning its conceptual and practical implementation. Several comparative insights and critiques help to contextualise the CRCF framework's scope, limitations, and the challenges of operationalisation.

The design of carbon farming schemes varies across jurisdictions. For example, Australia, for example, has been a global frontrunner, first through its Carbon Farming Initiative (2011), later replaced by the Emission Reduction Fund in 2015, under which carbon credits are purchased via auctioning [26], [39]. Although similar credit-based mechanisms have been introduced in other countries such as Canada (Alberta), India and China [26], they differ in terms of scale, governance structures, credit calculation methodologies, and eligibility criteria.

Although the CRCF Regulation is expected to promote carbon farming in the EU, several studies have raised concerns about the CRCF Regulations approach. Brad and Schneider [9] claim that the EU missed the chance to adopt robust carbon removal measures in the early stages, instead choosing offsetting mechanisms. They also highlight the lack of clear separation between emission reduction and removals in the European Climate Law, which may enable large emitters to offset rather than actually reduce their emissions [9], as also noted by Landers *et al.* [36]. Cavallin [21] highlights methodological robustness and accountability gaps in the CRCF Regulation, and challenges the assumption that increased soil carbon content necessarily indicates sustainable soil health. There are ongoing concerns about the reversibility of sequestered CO_2 and the limited clarity on surrounding the functioning of carbon credits under the CRCF framework [21]. Similarly, Paul *et al.* [13] are sceptical, warning that the framework may not lead to effective mitigation and suggesting that funding should focus directly on emission reductions instead.

These international experiences and critical assessments provide an important basis for evaluating the coherence of the CRCF Regulation. The next section outlines the methodology employed to analyse EU policy and regulatory documents within the CRCF framework.

3. MATERIALS AND METHODS

QCA was chosen as a suitable method for analysing EU regulatory and policy documents, as it enables systematic identification of themes, meanings and underlying patterns across a diverse set of texts [40], [41]. This method was considered appropriate because it supports the structured analysis of regulatory and policy documents, and is particularly useful for exploring policy formation and coherence in the context of policy development and implementation [40], [41]. As defined by Mayring [42], QCA is a systematic, rule-guided method for interpreting textual material. It allows for an empirical, theoretically grounded analysis without premature quantification. QCA is reliable and transparent [43] and is particularly suitable for examining the normative and interpretative aspects of grey literature, such as policy documents [43], [44]. The method enables analytical categories to be developed based on the research question and these can be adjusted as new insights emerge [44]. Coding units are not predefined but are created during the coding process [43]. The research question guided the development of the coding structure and subsequent thematic analysis, ensuring alignment between the analytical process and the study's objectives [43]. This study used a hybrid categorisation approach, combining deductive and inductive strategies [43]. The deductive approach is based on an existing theoretical framework and is used to develop the initial categories [43] derived from EU regulatory and policy context of the CRCF Regulation and its expected operational elements. By contrast, an inductive (data-driven) approach was employed to identify additional themes or concepts that emerged during the analysis process [43].

The research began with the definition of the research question (see Section 1), followed by the selection of five initial search terms via a deductive approach. These were searched for in the CRCF Regulation to identify relevant text passages. The snowballing approach [45], [46], was used, whereby references to other policy or regulatory documents found within the text passages were included in analysis. Thus, a further 14 documents were selected for the next stage of analysis, along with two additional search terms. In the third iteration, a further 16 EU regulatory or policy documents were identified, bringing the total to 31 EU regulatory and policy documents. Nine search terms were applied across these documents in total. Figure 1 summarises the process and methodological steps of the QCA. The top part of the figure shows the search term and document selection steps. Text fragments were initially grouped into 17 codes, which were then reviewed and structured into nine broader thematic groups (categories) based on recurring topics. The corresponding analysis steps are indicated at the bottom.

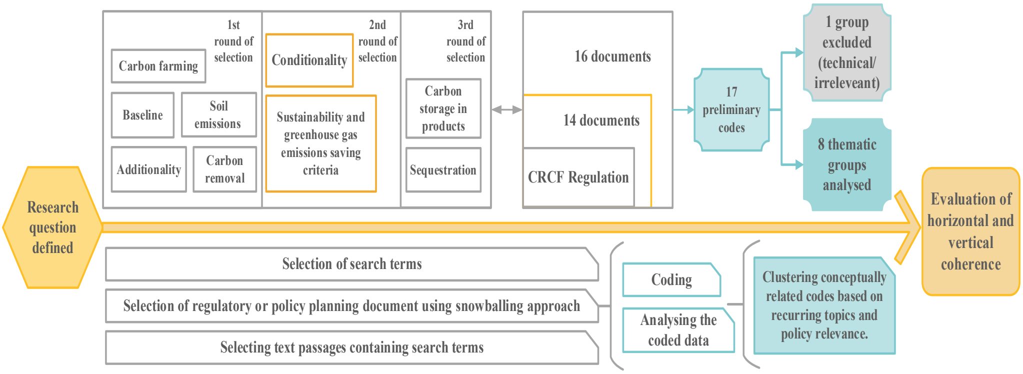

Fig. 1. Research process methodology (above the arrow: search terms and their selection stages, document selection phases, and the nine identified thematic groups; below the arrow: corresponding methodological steps).

The search terms are intentionally formulated as compounds phrases, with extensions applied in only selected cases. The search terms for which no extensions were applied were – carbon farming, baseline, conditionality, sequestration. The search term “additionality” was used with and extension to capture related references to additional actions, even where the full term itself was not explicitly mentioned. For the search terms “carbon removals” and “soil emissions”, an extension was applied to include singular uses (“carbon removal”, “removal”, “soil emission”). During the analysis it was also found that the search term “sustainability and greenhouse gas emissions saving criteria” sometimes appeared with the additional article “the” (sustainability and the greenhouse gas emissions saving criteria), so this variation was included in the search extension. For the search term “carbon storage in products”, the extension “carbon storage” was used to include a wider range of text on carbon storage options in products and, where possible, other wording related to carbon storage options that may have been omitted previously.

Relevant text fragments were manually selected and entered into an Excel database. They were then grouped according to search terms and initially coded thematically. Text fragments that were clearly unrelated to the research question or contained technical information were excluded. The remaining fragments were compiled into a single spreadsheet and duplicates were deleted. In the next step, each text fragment was manually assigned a short descriptive title summarizing its main theme (e.g., rules for defining baseline; reversal of previous removals; definition and explanation of carbon farming practices; blue carbon, etc.). This inductive process resulted in 17 preliminary codes. These were then reviewed and merged into broader themes, to reduce overlap and provide a clearer analytical structure for the study. The final coding framework consisted of nine thematic groups, created by clustering conceptually related codes based on recurring topics, contextual links, and policy relevance observed across the data set. Eight of these groups are described in detail in the results section, including the number of text fragments per group. The ninth group, consisting of text fragments not directly related to the research question, is not discussed further. The full coding structure, including the initial 17 codes, the final nine thematic groups and all analysed text fragments, is available in the accompanying open-access Excel file on Zenodo https://zenodo.org/records/15012191.

The results section presents and overview of the analysed documents, the frequency and distribution of search terms, and the thematic synthesis derived from the coded text fragments.

4. RESULTS

4.1. Overview of Selected Documents

In this study, QCA was used to analyse 31 regulatory and policy documents, including one international treaty (the Paris Agreement) and one Proposal for a Regulation. Documents closely related to the CRCF Regulation included three directives and nine regulations, while the largest number of documents (17) were European Commission Communications. The structure of the documents analysed by type of document is shown in Fig. 2.

In terms of timeframe, the oldest document is from 2003, “Directive 2003/87/EC of the European Parliament and of the Council establishing a scheme for greenhouse gas emission allowance trading within the Community” [39], and the latest is from 2024. Comparing the number of documents by year, only five documents were included from 2003 to 2017, while 26 documents were adopted from 2018 to 2024, which shows the rapid development of regulatory and policy documents in the context of the research question.

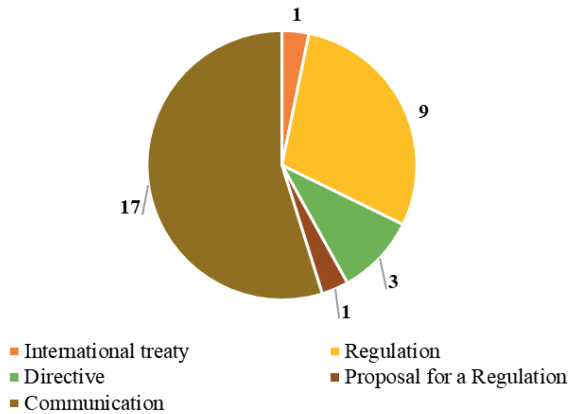

Fig. 2. Documents analysed by type of document.

4.2. Analysis of Search Term Frequency and Distribution

Research question is not only reflected in the number of documents analysed, but also in the frequency of the search terms used in them. Comparing the two periods of adoption of the documents 2003–2017 and 2018–2024, there is a significant increase in the number of mentions. In the first period (2003–2017), the documents analysed contain a total of only 26 mentions of search terms, whereas between 2018 and 2024, the number of mentions increases to 1473. It should be stressed that these data reflect the unfiltered frequency of search terms across all 31 documents, before the exclusion of technical and irrelevant passages during content analysis. The sharp increase in search term mentions from 2018 onwards coincides with the change in EU climate policy following the Paris Agreement at the end of 2015. The transition period following the adoption of the Paris Agreement reflects a typical cycle of regulatory revision and policy adaptation, in which the EU started to flesh out new policies and policy instruments to mitigate climate change and promote carbon removal and sequestration.

Summarising the frequency of mentions of search terms (Table 2) across the documents analysed (before data filtering), search terms are mentioned a total of 1499 times. The most frequently used search terms are “carbon removals” (535 times), “additionality” (388 times) and “carbon farming” (194 times). It should be noted that the extended search term “additional” was used to search for “additionality”, which increased the frequency of mentions unrelated to the research question. Other search terms were “baseline” (93 times), “soil emissions” (77), “sequestration” (67) and “carbon storage in products” (60). The least frequently mentioned search terms were “conditionality” (53 times) and “sustainability and greenhouse gas saving criteria” (32 times), which were added at a later stage of the analysis to further explore the relationship of the CRCF Regulation with the CAP and other regulations. A detailed breakdown of mentions is shown in Fig. 3.

The dispersion of search terms across documents was highly uneven, with the number of mentions per document ranging from 1 to 387. The five documents with the highest mention frequency: the CRCF Regulation [16] (387 times), “Sustainable Carbon Cycles” [17] (199 times), and key legislative documents such as Regulations (EU) 2021/2115 [47] (107 times), Regulation (EU) 2018/1999 [48] (98 times) and Regulation (EU) 2018/841 [49] (94 times). This is understandable given that the CRCF Regulation [16] was the starting point of the analysis and the basis for the research question, while “Sustainable Carbon Cycles” [17] provided the conceptual basis for the development of the CRCF Regulation. Almost half of the documents analysed (15 out of 31 documents) contain less than 20 mentions of search terms, indicating their limited relevance to the research topic.

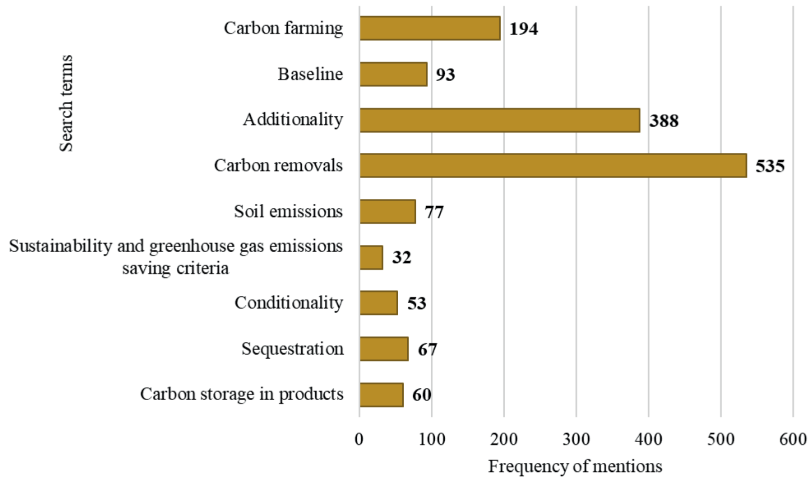

Fig. 3. Frequency of search term mentions in the set of documents analysed.

The lowest number of mentions (1) is found in the Communication "Innovating for Sustainable Growth: A Bioeconomy for Europe" (COM/2012/060 final) [50], where the search term "sequestration" is mentioned. This is followed by Directive 2003/87/EC [51]; Directive 2009/31/EC [52] and Communication "New European Bauhaus" (COM/2021/573 final) [53], where search terms are mentioned five times in each document. Most of these documents were adopted before 2018, which coincides with the observed increase in thematic relevance in recent years. Looking at individual search terms in more detail, the words "carbon farming" and the search extension "carbon storage" appear in documents for the first time in 2018 in the Communication "A sustainable Bioeconomy for Europe" (COM (2018) 673 final) [54]. The search term "removal" on the other hand, is already mentioned in the 2009 Directive 2009/31/EC [52]. Search term "soil emissions" is only found in two documents: the 2018 Communication "A Clean Planet for all" (COM/2018/773 final) [55] and the CRCF Regulation [16] (76 times). Detailed number of mentions per document and search terms are available in the attached Zenodo open access repository https://zenodo.org/records/15012191.

4.3. Thematic Groups of Extracted Text Fragments

Thematic analysis of the coded text fragments resulted in their classification into nine thematic groups (Table 2). 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. The thematic groups were formed based on their relevance to the research question and help illustrate how the CRCF framework is structured and horizontally integrated across EU policy instruments, as well as its links to practical implementation. Eight of the nine themes are described in detail below, while the ninth includes fragments that were excluded due to their technical character or lack of direct relevance the research question.

TABLE 2. THEMATIC GROUPS OF TEXT FRAGMENTS IDENTIFIED IN THE DOCUMENTS

No.	Thematic group	Number of text fragments	Documents from which text fragments were extracted*
1.	General information on EU GHG emission reduction targets	117	[10], [16], [17], [19], [47], [48], [49], [50], [54], [55], [56], [57], [58], [59], [60], [61], [62], [63], [64], [65], [66], [67], [68]
2.	The CRCF Regulations certification framework as an instrument for implementing EU climate objectives	42	[16], [17], [18], [19], [54], [58], [61], [63], [64]
3.	Certification framework, monitoring, support tools	84	[16], [17], [19], [54], [62], [64]
4.	Quantification, baseline, reversal of previous removal	53	[16], [17], [49], [58], [65]
5.	Links and interactions between CRCF and CAP	42	[17], [19], [47], [60], [61], [62], [63], [67], [69], [70], [71]
6.	Carbon farming as a business model	34	[17], [19], [54], [58], [60], [61], [62], [64], [65], [67]
7.	Carbon farming and carbon storage in ecosystems and products	29	[16], [17], [18], [49], [53], [54], [55], [60], [61], [63], [69]
8.	Sustainability, additionality and activities with co-benefits	14	[10], [16], [57]
9.	Text fragments excluded from further analysis**	485	–

* The references refer to the documents that are listed in the bibliography.

** A detailed description of thematic group 9 is not provided because it contains text fragments that were excluded from further analysis due to limited relevance of the research question or highly technical content.

It should be noted that although thematic group eight "Sustainability, additionality and activities with co-benefits" was initially identified as conceptually distinct, further analysis revealed that its content did not form a self-contained theme directly addressing the research question. Instead, insights from group eight were found to reinforce and overlap with themes already covered in other groups, especially in relation to certification principles and quantification (thematic group two and three), and carbon storage in ecosystems and products (thematic group seven). Therefore, thematic group eight is not discussed as a standalone section, and its relevant content has been integrated where appropriate in the respective thematic discussions.

4.3.1. Thematic group 1: General information on EU GHG emission reduction targets

Thematic group one included the largest number of text fragments (117), summarising the overarching climate policy goals that shape the context in which the CRCF Regulation is implemented. It illustrates how the CRCF Regulation fits into the broader EU regulatory and policy framework for reducing GHG emissions, enhancing carbon sequestration and ensuring long-term storage, particularly within the bioeconomy, LULUCF, renewable energy and related sectors. This thematic group assists in assessing the degree of horizontal policy coherence between the CRCF Regulation and other key EU climate and energy policies on a broader, strategic level. More specific dimensions of policy coherence are examined in the subsequent thematic groups.

The European Green Deal sets a target of climate neutrality by 2050, made legally binding for MS by Regulation (EU) 2021/1119 [10], [65], along with an interim target of a 55% reduction in GHG emissions by 2030 compared to 1990 levels [65]. Under the UNFCCC, the EU and its MS are required to prepare, regularly update, publish and report national GHG inventory reports, quantifying anthropogenic emissions and carbon sinks [48], [49], [67]. A common methodology developed by the IPCC ensures the comparability and consistency of reporting in line with the requirements of the UNFCCC and the Kyoto Protocol [48], [49]. In addition, Regulation (EU) 2018/1999 obliges the MS to develop and regularly update integrated national energy and climate plans outlining their contributions to the EU's Energy Union objectives [48].

The bioeconomy contributes to climate targets by reducing fossil fuel emissions through replacing GHG-intensive materials with bio-based and sustainable products in the energy, transport, chemical and construction sectors [17]. Bioresource extraction sectors, such as agriculture and forest sectors currently sequester around 300 Mt CO_2e per year [55], but national GHG inventories also indicate decline in net removals over the past decade, mainly due to degradation of forest ecosystems [17]. MS are therefore encouraged to promote the sustainable use of resources, increase mobilisation and develop new forestry and agricultural production systems [60] that meet sustainability and GHG reduction criteria, thereby ensuring positive environmental and climate impacts [57].

The CRCF Regulation complements other instruments that support forest-based carbon sequestration. These include the new EU Forest Strategy [61], which promotes sustainable forest management, afforestation, agroforestry practices, and biodiversity conservation [59], [61]. It also aligns with the Renewable Energy Directive 2018/2001 [57], introducing additional safeguards for the use of wood and other bio-based fuels. It implements enhanced sustainability and GHG emission saving criteria for biofuels, bioliquids and biomass fuels, and establishes voluntary certification schemes to ensure the traceability of biomass extraction [57]. These measures are directly relevant to the CRCF Regulation, as certifiable operations must also comply with the sustainability criteria [16], [57]. Although severely affected by climate change, the LULUCF sector is essential for the long-term storage of carbon stocks with minimal risk of leakage [49]. Improving the productivity and regeneration capacity of the LULUCF sector through sustainable land management practices would reduce its carbon and environmental footprint [49], making it possible to achieve the LULUCF Regulation's target of 310 Mt CO_2e net carbon sequestration by 2030 [17], [60], [61]. Additional carbon sequestration is also anticipated through ecosystem restoration initiatives outlined in the EU Biodiversity Strategy 2030 [67].

Alongside nature-based approaches, the EU is also exploring industrial carbon removal technologies, such as DACCS or BECCS [58]. However, deployment remains limited due to the associated costs, energy intensity and volatile prices of the CO_2 removal [58]. Nevertheless, the European Commission has set a target to ensure that at least 20 % of the carbon used in the chemical industry is sustainable by 2030, as well as achieving at least 5 Mt CO_2e capture and storage [58].

4.3.2. Thematic group 2: The CRCF Regulations certification framework as an instrument for implementing EU climate objectives

Thematic group two focuses on the strategic role of the CRCF Regulation's certification framework within the EU policy architecture, moving beyond its technical functions to examine how it contributes to long-term climate governance and policy coherence. While the thematic group one outlined the general alignment of the CRCF Regulation with high-level EU climate goals, this group explores its functions as a structural instrument underpinning multiple regulatory and policy pathways, particularly its relevance for the European Climate Law, LULUCF Regulation, Renewable Energy Directive, and international commitments under the Paris Agreement. This group highlights both horizontal policy coherence with parallel EU strategies (e.g., biodiversity, bioeconomy, forest and agricultural policies) and vertical alignment with international climate compliance systems. It builds upon the earlier policy vision laid out in the "Sustainable Carbon Cycles" Communication, but shifts the focus form methodological development to the broader governance function of the CRCF certification framework.

The activities certified under the CRCF Regulation must demonstrate a clear and measurable climate benefit, while also avoiding the risk of greenwashing [16]. Priority is given to solutions that remove CO_2 from the atmosphere and ensure its long-term storage in ecosystems or products, provided they preserve biodiversity and ecosystem integrity, and respect the precautionary and the "do no significant harm" principles [16], [17]. This aligns the CRCF Regulation with broader EU climate policy framework, including 2050 climate neutrality target set by the European Climate Law (Regulation (EU) 2021/1119) [16], [65]. The certification framework should initially focus on solutions implemented within the EU that provide sufficient guarantees on storage duration, accuracy of measurements and management [17]. Certified carbon removal under the CRCF Regulation could potentially support the EU's Nationally Determined Contributions under the Paris Agreement, depending on how they are integrated into the EU's official GHG accounting and reporting framework, particularly under the Regulation (EU) 2018/1999 [16], [48].

The CRCF Regulation is an essential tool for the implementation of other EU policies, particularly those addressing land use, sustainable bioeconomy, climate change mitigation and rural development [50], [54], [59]–[63], [67], [69]. It is closely aligned with the LULUCF Regulation (EU) 2018/841 [49], which already provides a binding governance framework for monitoring and incentivising land-based carbon sinks at the MS level. In the industrial sector, the 2023 revision of the EU Emission Trading System Directive recognises that carbon stored in certain products can be considered permanent [58]. The CRCF Regulations certification framework extends this recognition by allowing the certification of industrial activities that store atmospheric or biogenic CO_2 in products in a way that prevents re-emission to the atmosphere [58].

4.3.3. Thematic group 3: Certification framework, monitoring, support tools

The third thematic group focuses on the operational principles of the CRCF Regulation's certification framework, its monitoring procedures, and support instruments for practitioners. With 84 text fragments, primarily from the CRCF Regulation and the "Sustainable Carbon Cycles" Communication, this group reflects how the political commitments made at the strategic level have been operationalised into regulatory practice. Thematic group three provides insight into how definitions, prioritisation criteria for eligible activities, monitoring tools, and advisory measures are structured to ensure the functionality of the certification framework. It illustrates a key aspect of horizontal policy coherence: the alignment of the CRCF Regulation with other EU strategies relating to agriculture, forest sector, and digitalisation. In particular, it reflects to continuation and concretisation of goals set out in earlier policy documents, such as the "Sustainable Carbon Cycles" Communication. Moreover, the inclusion of digital innovation, traceability, and support services connects the CRCF regulation to broader EU policy frameworks, demonstrating a coordinated approach to carbon farming implementation.

The CRCF Regulation provides definitions of permanent carbon removals, carbon farming and carbon storage in products, their criteria and certification requirements, additionality and concepts related to accounting methodologies are defined [16]. The above and other related definitions define the requirements for activities to be certifiable and for methodological consistency with IPCC guidelines, LULUCF Regulation requirements and other binding regulatory documents [16]. The CRCF Regulation should encourage land managers to undertake activities that go beyond standard practices and legal requirements, i.e. activities that are not already mandated by existing legislation [16]. Certification methodologies should be developed first for activities that are at the highest stage of maturity, can deliver the highest co-benefits, contribute to biodiversity conservation and meet sustainability and GHG emissions saving criteria [16], [57]. In addition, certified activities must not cause significant environmental damage and must deliver at least one of the sustainability objectives listed in the CRCF Regulation Article 7 [16]. With regard to carbon storage in products, the development of certification methodologies for wood and bio-based building materials is a priority [16]. To ensure transparency and avoid fraud and double counting, the CRCF Regulation foresees the establishment of an EU registry within four years of its entry into force [16]. Certified units will be issued only upon verified net benefit of CO_2 removal or soil emission reduction [16]. In parallel, additional requirements may be needed to align the CRCF Regulations framework with the Paris Agreement and best practices from voluntary carbon markets, particularly regarding methodology, monitoring, baselines, additionality and emissions leakage [16].

The successful implementation of the CRCF Regulation will depend heavily on the use of advanced technological solutions to minimise the cost of on-site measurements. Digital technologies, geographic information systems, remote sensing and innovative on-site quantification systems for CO_2, as well as artificial intelligence and machine learning solutions, will play a pivotal role in monitoring and verifying GHG emissions and removals. These technologies enhance the accuracy, efficiency and comparability of CO_2 accounting by combining on-site measurements with remote sensing and modelling [16], [17], [62], [64]. The promotion of such digital tools is consistent with broader EU policy directions. For example, the EU Strategy to Reduce Methane Emissions envisages a digital carbon navigator template to support farm-level carbon balance calculations [62]. Proposal for a Regulation on a Monitoring Framework for Resilient European Forests highlights the need to standardise remote sensing data products to support climate and biodiversity indicators, including carbon removals and certification [64]. Similarly, "The Future of Food and Farming" Communication emphasises the importance of digital technologies, big data and precision agriculture to enhance the sustainability and climate resilience of farming systems [70]. Taken together, these initiatives reinforce the horizontal policy coherence of the CRCF Regulation, aligning digitalisation objectives across climate, forest and agricultural strategies.

To support broader uptake carbon farming, the CRCF Regulation emphasises the need for tailored advisory services, improved data management, and reduced administrative burdens for farmers and foresters [16], [17]. Particular attention should be paid to small-scale land managers who often lack the experience and resources to implement carbon farming practices and meet certification requirements [16], [17]. They require tailored support through guidance, digital tools, and monitoring systems to assess the performance and ensure compliance with quality criteria [16], [17]. Targeted education and training in sustainable practices can enhance understanding and engagement [16], [17]. These support measures also reflect horizontal alignment with other EU policies, such as the CAP and the new EU Forest Strategy, which highlight the role of capacity building and digital innovation in sustainable lang management [47], [61]. The Horizon Europe mission "A Soil Deal for Europe" identifies carbon farming as a hotspot for research and innovation [17], while the European Climate

Pact encourages knowledge exchange among land managers through initiatives such as the European Climate Pact Ambassadors [17].

4.3.4. Thematic group 4: Quantification, baseline, reversal of previous removal

This thematic group summarises the CRCF Regulation's methodological framework for quantifying net carbon removals and soil emission reductions. It comprises 53 text fragments and outlines the use of standardised and activity-specific baselines, the requirements for consistency with IPCC guidelines, and the risk of reversal of previously certified removals. These elements are critical for ensuring the credibility of certified carbon removals and for aligning the CRCF Regulation with broader EU's climate governance framework. The thematic group focuses on vertical coherence between the CRCF Regulation certification framework and the application of international and EU-level reporting obligations at the MS level. These obligations are as set out in the Paris Agreement, the LULUCF Regulation EU 2018/841 and the Regulation (EU) 2018/1999 on the Governance of the Energy Union and Climate Action. At the same time, it demonstrates methodological consistency with internationally acknowledged standards, such as the IPCC guidelines, which are recognised by the UNFCCC and form the basis for GHG accounting under Paris Agreement transparency framework.

For the calculation of CO_2 removals and GHG emission reductions from carbon farming practices, the Tier 3 methodology should be applied in accordance with the IPCC guidelines. This ensures consistency with national GHG inventories and compliance with both Regulation (EU) 2018/841 and Annex V, Part 3 of Regulation (EU) 2018/1999 [16]. The requirements of Regulation (EU) 2018/841 apply to GHG emissions and removals from the following land inventory categories: afforested land; deforested land; cultivated arable land; cultivated grassland; cultivated forest land; cultivated wetland [49]. These land areas are vulnerable to natural disturbances such as forest fires, insect and disease outbreaks, extreme weather events and geological disturbances, which may lead to increased GHG emissions or the reversal of previous removals [49]. Reversals may also result from management decisions, such as tree felling or planting. To avoid double counting, it is important to ensure that emissions and removals are not recorded in more than one land accounting category [49].

The CRCF Regulation sets out calculation formulae to quantify the permanent or temporary CO_2 removal or storage resulting from an activity [16]. An activity is considered a net CO_2 removal benefit if the CO_2 removal above the baseline is greater than the increase in GHG emissions associated with its implementation, including machinery use, indirect land use change emissions and carbon leakage [16]. Additional GHG emission reductions (excluding agricultural soil emissions) should be considered as co-benefits for the sustainability objective of climate change mitigation and can increase the value of the certified carbon sink [16]. Calculation formulas defined in the CRCF Regulation for carbon removal and soil emission reduction activities are summarised in Table 3.

The calculations will be performed on the basis of a pre-defined baseline. The reference values (CR_{baseline}, LSE_{baseline}, ASE_{baseline}) should reflect the standard performance levels of comparable activities and processes under similar social, economic, environmental, technological and regulatory conditions [16]. Such baselines must account for applicable legislation and market conditions, include geographical and local pedoclimatic factors [16]. If an activity is mandatory and does not require incentives, it should be considered part of the standardised baseline, with the corresponding baselines defined by the European Commission in the relevant certification methodologies [16]. Once an activity becomes common practice, it can no longer be certified [16]. Standardised baselines will facilitate the demonstration of additionality and reduce the administrative burden, which is particularly important for small land managers [16]. Where justified (e.g., due to lack of data or comparable activities), an activity-specific baseline may be used and updated regularly [16]. The baseline emissions from agricultural soils ($ASE_{baseline}$) and the total emissions from agricultural soils (ASE_{total}) should be consistent with the IPCC agricultural source category, subcategory 3.D Agricultural soils [16]. Additionally, emission reductions from agricultural soils under subcategory 3.D should be included in the quantification of carbon farming activities, in accordance with the IPCC guidelines [16].

TABLE 3. QUANTIFICATION FORMULAS FOR CARBON REMOVAL AND SOIL EMISSIONS UNDER THE CRCF REGULATION [16]

Activity type	**Quantification formula**
Permanent net carbon removal benefit	$CR_{baseline} - CR_{total} - GHG_{associated} > 0$
A carbon farming activity: (a) temporary net carbon removal benefit	
Carbon storage in product activity: temporary net carbon removal benefit	
where: $CR_{baseline}$ – the amount of carbon removals under the baseline; CR_{total} – the total amount of carbon removals of the activity; $GHG_{associated}$ – the increase in direct and indirect GHG emissions over the entire lifecycle of the activity which are attributable to its implementation, including indirect land use change, calculated, where applicable, in accordance with the protocols set forth in the IPCC guidelines and any further refinements.	
A carbon farming activity: (b) net soil emission reduction benefit:	
$LSE_{baseline} - LSE_{total} + ASE_{baseline} - ASE_{total} - GHG_{associated} > 0$	
where: $LSE_{baseline}$ – the amount of LULUCF soil emissions under the baseline; LSE_{total} – the total amount of LULUCF soil emissions of the activity; $ASE_{baseline}$ – the amount of agricultural soil emissions under the baseline; ASE_{total} – the total amount of agricultural soil emissions of the activity; $GHG_{associated}$ – the increase in direct and indirect GHG emissions over the entire lifecycle of the activity which are attributable to its implementation, including indirect land use change, calculated, where applicable, in accordance with the protocols set forth in the IPCC guidelines and any further refinements.	

Quantifications are given a negative sign (–) for GHG removals and a positive sign (+) for GHG emissions, and are expressed in tonnes of CO_2e [16]. Quantification must be appropriate, conservative, accurate, complete, consistent, transparent and comparable, in accordance with the best available science [16]. While carbon farming generally improves soil quality, it can sometimes reduce food production and lead to indirect land use changes and carbon leakage, therefore, the associated indirect emissions must be considered [16]. Monitoring should be based on an appropriate combination of on-site measurements and remote sensing or modelling, in accordance with the applicable methodology's provisions [16].

Carbon removals from atmospheric or biogenic sources may be reversed due to natural or anthropogenic causes; therefore, preventive measures and continuous monitoring are required throughout the designated monitoring period [16]. To account for potential reversals, both carbon sequestration unit and the unit for carbon storage in products are subject to expiry dates, with a minimum of 35 years [16]. By 2028, all land managers should have access to verified emissions and removals data to facilitate the widespread adoption of carbon farming and achieve and additional 42 Mt CO_2e in net removal [17].

4.3.5. Thematic group 5: Links and interactions between CRCF Regulation and CAP

Thematic group five explores the linkages between the CRCF Regulation and the new CAP (2023–2027), focusing on their overlapping objectives and implementation mechanisms related to carbon farming. While the CAP remains predominantly action-based support scheme, the CRCF Regulation introduces a result-based approach. This creates both opportunities and challenges for coordination, particularly where practices may be eligible under both instruments. The 42 text fragments in this group reflect an emerging horizontal policy coherence between the two frameworks, especially in how they incentivise sustainable land management, enhance climate and environmental performance, and promote the uptake of carbon farming through national CAP Strategic Plans.

The new CAP (2023–2027) sets higher environmental and climate targets, including reducing GHG emissions, promoting CO_2 sequestration and sustainable energy, halting biodiversity decline, and improving ecosystem services [47], [67]. The measures set out in Regulation (EU) 2021/2115 are closely linked with carbon farming practices, which will be promoted through CAP Strategic Plans of MS [47]. Voluntary eco-schemes are expected to support environmental and climate performance beyond minimum requirements, and cover at least two key sustainability areas, including: "(a) climate change mitigation, including reduction of GHG emissions from agricultural practices, as well as maintenance of existing carbon stores and enhancement of carbon sequestration; (b) climate change adaptation; (c) protection or improvement of water quality and reduction of pressure on water resources; (d) prevention of soil degradation, soil restoration, improvement of soil fertility and of nutrient management and soil biota; (e) protection of biodiversity, conservation or restoration of habitats or species, including maintenance and creation of landscape features or non-productive areas; (f) actions for a sustainable and reduced use of pesticides; (g) actions to enhance animal welfare or combat antimicrobial resistance" [47]. These areas substantially overlap with the sustainability criteria set out in Article 7 of the CRCF Regulation, which highlight similar domains including climate change mitigation and adaptation, water and marine protection, biodiversity and ecosystem restoration, soil health and land degradation prevention [16]. This alignment demonstrates horizontal policy coherence and potential synergies in the implementation of carbon farming practices across both frameworks.

The new conditionality system for CAP support includes statutory management requirements (SMRs) and good agricultural and environmental conditions (GAEC) [47]. The SMRs cover a range of legislation on the environment, animal welfare, plant health, food safety and land requirements [47]. The GAEC in turn aims to contribute to climate change mitigation and adaptation, water management, soil protection and quality, and biodiversity protection and quality [47]. Several CAP impact and performance indicators directly relate to carbon farming activities covered by the CRCF Regulation. These include impact indicators: I.10 Contribution to climate change mitigation: GHG from agriculture; I.11 Enhancing carbon sequestration: SOC in agricultural land [47]. As well as performance indicators R.14PR Carbon storage in soil and biomass, emission reduction or carbon stock increase, and R.17 Afforested land – afforestation, agroforestry and restoration [47]. These shared monitoring objectives illustrate the potential for coordinated implementation and coherent reporting between the CAP and the CRCF Regulation. This is further supported by tools un the reformed CAP such as the Farm Sustainability Tool (FaST) for nutrient and integrated GHG accounting at farm level [17].

Although the CAP and CRCF Regulation are based on different support concepts – action-based and results-based – there is currently no clear delineation between the two financing approaches. MS may include action-based CAP payments in their CAP Strategic Plans to support carbon farming practices, while the CRCF certification framework is designed to operate on a results-based mechanism, where certified carbon removals may serve as the basis for issuing tradable units. Those units could potentially be sold to private buyers or counted towards climate targets, depending on future policy arrangements. Therefore, a clear distinction between the financing approaches is essential to avoid double funding [19].

The growth of the bioeconomy through sustainable entrepreneurship should be a priority in the CAP Strategic Plans, supporting the development of the circular economy and new business models [70]. By promoting clean energy production and the use of sustainable biomass, the CAP can contribute not only to rural development and increased farm income, but also to broader EU objectives such as the Energy Union and industrial policy [70]. In this context, several other EU strategies reinforce the integration of carbon farming within agricultural policy. The "EU Strategy to Reduce Methane Emissions" encourages MS to incorporate carbon farming practices into their CAP Strategic Plans [62], while the "EU Soil Strategy" sets out actions to support climate-neutral soil management and adaptation to climate change [60]. Rural areas are further acknowledged for their role in biodiversity restoration and climate mitigation, with legally binding targets under discussion to limit the drainage of wetlands and organic soils, restore peatlands and conserve carbon stocks [55], [60].

4.3.6. Thematic group 6: Carbon farming as a business model

Thematic group six explores carbon farming as a potential business model for farmers and foresters, highlights how the CRCF Regulation could monetise environmental services and incentivise CO_2 removals beyond traditional products. This thematic group contributes to answering the research question by evaluating the extent to which the CRCF certification framework is aligned with existing EU climate and market policies. It reflects horizontal policy coherence with EU strategies on industrial carbon management, forest resilience, environmentally friendly food systems, and the bioeconomy. It also addresses gaps, particularly the current absence of carbon removals from compliance markets like the EU Emission Trading System (EU ETS). In this context, the CRCFR Regulation serves as a bridging mechanism between climate action, agricultural entrepreneurship and voluntary carbon market development.

Switching to carbon farming practices offers the potential for an environmentally sustainable business model that rewards land managers for increasing carbon storage in living biomass, dead organic matter, and soil, while respecting biodiversity and ecosystem protection principles [17], [19], [60]. Certified carbon credits could serve as an additional "product" for land managers alongside food and biomass, while buyers may include bioeconomy actors, such as food processing companies aiming to decarbonise their supply chains [17].

The "Proposal for a Regulation on a Monitoring Framework for Resilient European Forests" is expected to create new opportunities for small and medium enterprises in terms of access to digital services for forest monitoring, and innovation in monitoring technologies [64], [65]. In addition, forest stakeholders will benefit from the additional income generated by the certification framework established by the CRCF Regulation [16], [64]. While the EU ETS does not currently recognise negative emissions, biogenic and atmospheric carbon capture and storage have not yet been incentivised through a carbon market price for compliance [58]. The voluntary EU certification framework under the CRCF Regulation can help to address this gap by mobilising funding while ensuring environmental integrity [58]. In parallel, the banking and financial sectors are increasingly investing in sustainable agriculture, creating market-based incentives for carbon sequestration [60].

Unlocking the potential of carbon farming requires overcoming several barriers identified prior to the adoption of the CRCF Regulation, especially the fragmentation of existing private carbon schemes, which apply widely differing methodologies and criteria, undermining trust in credit quality [17], [62]. The EU certification framework is therefore expected to provide a harmonised and transparent standard, ensuring environmental integrity and methodological consistency. This would support the emergence of credible carbon market by enabling land managers to estimate potential revenues, allowing policymakers to align activities with regulatory frameworks, and increasing buyer confidence [17]. As a business model, carbon farming could offer farmers and foresters an additional source of income, while simultaneously incentivising emission "insetting" - allowing companies in the agri-food and bioeconomy sectors to reduce their carbon footprint through carbon removal within their own operations. Unlike the EU ETS, which targets emission reductions, the CRCF Regulation introduces financial incentives for the removal and long-term storage of already emitted CO_2.

4.3.7. Thematic group 7: Carbon farming and carbon storage in ecosystems and products

This thematic group focuses on the types of carbon farming activities that could be eligible for certification under the CRCF Regulation, emphasising their environmental potential as well as their policy alignment across EU frameworks. It demonstrates horizontal coherence between the CRCF Regulation and other EU strategies on biodiversity, sustainable land use and product circularity. The group illustrates how land and product-based sequestration options, ranging from soil management to wood use in long-lived products, are gradually being integrated into broader EU environmental, climate and product policies. However, some gaps were identified, especially with regard to blue carbon, suggesting a need for more balanced integration across domains.

The CRCF Regulation covers a wide range of land-based carbon farming practices also identified in the "Sustainable Carbon Cycles" Communication, including afforestation, reforestation, and sustainable land management; as well as agroforestry; intercropping, cover crops, conservation tillage and increasing landscape elements. It also covers the conversion of arable land to fallow land or permanent grassland; and the restoration of peatlands and wetlands [16], [17], [55], [69]. Actions with the highest potential for positive co-benefits should be prioritised for certification [16], [17], [55]. Maintaining and enhancing carbon stocks in mineral soils is crucial for supporting soil biodiversity, health, and fertility [60]. Unsustainable land use leads to annual losses of approximately 7.4 Mt CO_2e across the EU, yet a wider uptake of climate-smart management practices could enable mineral soils to sequester between 11 and 38 Mt CO_2e annually [60].

In addition to terrestrial practices, the CRCF Regulation also extends to carbon farming activities in marine and coastal ecosystems, where "blue carbon" is sequestered by algae, seagrasses, mangroves and salt marshes [16], [17]. While the CRCF Regulation recognises the potential of these ecosystems, other EU regulatory and policy documents rarely emphasise blue carbon, suggesting a potential mismatch in policy attention. Nature-based solutions such as regenerative aquaculture and marine permaculture could enhance sequestration, biodiversity and coastal resilience [17], [63]. Further development would require targeted investments in habitat restoration and improved data collection for robust quantification of blue carbon stock.

Although carbon storage in products is not a primary focus of this study, it represents a relevant aspect of the CRCF Regulation's broader scope and its alignment with other EU policy initiatives. Certification methodologies should contribute to food security, biodiversity and ecosystem protection [16], [55], [69], but they are also expected to align with the Corporate Sustainability Reporting Directive (EU) 2022/2464, which promotes transparency in corporate reporting and encourages carbon sequestration in durable products [17]. This enables recognition in product-specific regulations such as the Construction Products Regulation and the Sustainable Products Initiative [17]. CO_2 accounting should also be reflected in the EU's Product and Organisation Environmental Footprint methodologies [17]. The new European Bauhaus initiative supports the conversion of woody biomass into durable wood products and buildings as a means of extending carbon storage [53], [61]. Furthermore, the LULUCF Regulation requires MS to report changes in carbon stocks for harvested wood product categories (paper, wood panels, sawn timber) [49], [61], while the EU is developing a comprehensive strategy for a sustainable built environment, promoting life-cycle assessment, circularity, and sustainable financing [18].

5. DISCUSSION AND CONCLUSIONS

This study addressed two research questions: (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 when implementing the CRCF Regulation at the national level? These questions were explored through a QCA of 31 policy and regulatory documents. The terms "carbon farming" and "carbon storage" were first introduced in the 2018 "A sustainable Bioeconomy for Europe" Communication [54] where they were identified as innovative approaches with high potential for climate change mitigation. This marked their entry into EU policy landscape, where they were framed as economically viable, result-based public goods provision models for farmers and foresters, and linked with broader policy domains such as the bioeconomy, circular economy and climate neutrality [54]. Similarly, the term "soil emissions" first appeared in the 2018 "A Clean Planet for all" Communication [55], but was further elaborated in the CRCF Regulation, where it is included as a separate carbon sink category [16]. In earlier EU policy documents terms such as "carbon sequestration" were used broadly to describe the process of storing carbon in soil or biomass, often in connection with land management practices [17], [18], [55]. In the CRCF Regulation, however, a conceptual shift is evident: "carbon removal" and "soil emission reductions" are introduced as distinct, process-based certification categories, while "sequestration" refers to a quantifiable outcome (sequestration unit), which represents a verified result of these practices [16]. This evolution in terminology illustrates the move towards greater precision, methodological differentiation, and market applicability in EU carbon management frameworks.

An assessment of horizontal policy coherence based on the first four thematic groups (Table 2) provides an understanding of the role of the CRCF Regulation in the broader context of EU climate, agriculture, LULUCF, and energy policy. These groups highlight the link between the CRCF Regulation and strategic objectives, including increasing carbon removal, developing the bioeconomy, and achieving climate neutrality. The methodological approach of the CRCF Regulation is illustrated, including the certification framework, monitoring, the need for innovation and digitalization, which are part of the overall vision for the development of EU policy and regulatory documents. Strengthening the knowledge and capacity of land managers, their involvement and trust building. The CRCF Regulation builds on the political vision set out above, in particular in the Communication on "Sustainable Carbon Cycles", and complements existing tools 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 CAP, and the development potential of carbon farming as a green business model. Horizontal policy coherence between the CAP and the CRCF Regulation was identified in relation to sustainable land management, climate objectives and improved environmental performance. 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, including industrial carbon management, promoting forest resilience, decarbonising food chains and bioeconomy development. At the same time, it reveals shortcomings of the existing system: the EU ETS was designed to focus on incentivising emission reductions by large emitters, where the mitigation outcomes are relatively easy to quantify and verify. However, the EU ETS does not currently recognise negative emissions, such as CO_2 removal from the atmosphere, as eligible units for compliance purposes. Consequently, no market-based mechanism was in place to signal or financially reward investments in land-based or technological carbon removal. In this context, 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 CO_2 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 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. This could be linked to a lack of scientifically based knowledge regarding the sequestration potential of marine and coastal ecosystems, monitoring methods and practical implementation options, which could hinder their inclusion in climate policy action plans.

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 two, four, five and six, as seen in Table 2. The second and fourth thematic group explores vertical coherence between the CRCF Regulation's certification framework and the application of international and EU-level reporting obligations at MS level. These obligations arise from the Paris Agreement, the LULUCF Regulation EU 2018/841 and the Regulation (EU) 2018/1999 on the Governance of the Energy Union and Climate Action. 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. However, the CRCF Regulation also introduces a degree of methodological uncertainty. It requires the use of a predefined baseline (CR_{baseline}) for calculating carbon removal benefit, in accordance with the provisions of Regulation (EU) 2018/841. Although this regulation establishes overall carbon removal targets for the LULUCF sector at the EU and MS levels, it does not define specific baselines by land use type or removal activity [49]. Consequently, it remains unclear whether the indicators used to set the LULUCF targets will also be used to establish baselines under the CRCF Regulation. At the same time, the CRCF Regulation stipulates carbon removal and soil emission reduction benefit must be calculated in line with IPCC guidelines and the LULUCF framework, suggesting that the CR_{baseline} and LSE_{baseline} baselines are expected to align with existing data structures. This situation highlights the uncertainty around how methodological consistency will be achieved between the certification framework and MS reporting mechanisms.

Thematic group five 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? Will land managers be expected to choose between guaranteed, action-based CAP payments, the more unpredictable, results-based CRCF certification framework, which requires the demonstration of a net carbon removal benefit over a five-year period and the ensured permanence of stored carbon? 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. While the study could not provide definitive answers to these questions, the certification methodologies, which were still under development at the time of the study, are likely to contain the necessary details to resolve these ambiguities.

Thematic group six 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 approach encourages the adoption of climate-smart agriculture and forestry practices and reflects a growing corporate responsibility for Scope 3 emissions further down the supply chain [72]. This model exemplifies vertical policy coherence, as it links EU-level regulatory efforts under the CRCF Regulation with national-level implementation through private sector engagement and value chain-based emission reduction strategies. Fig. 4 summarises the thematic groups identified during the coherence assessment, along with the types of policy and regulatory documents analysed, and search terms used to structure the QCA.

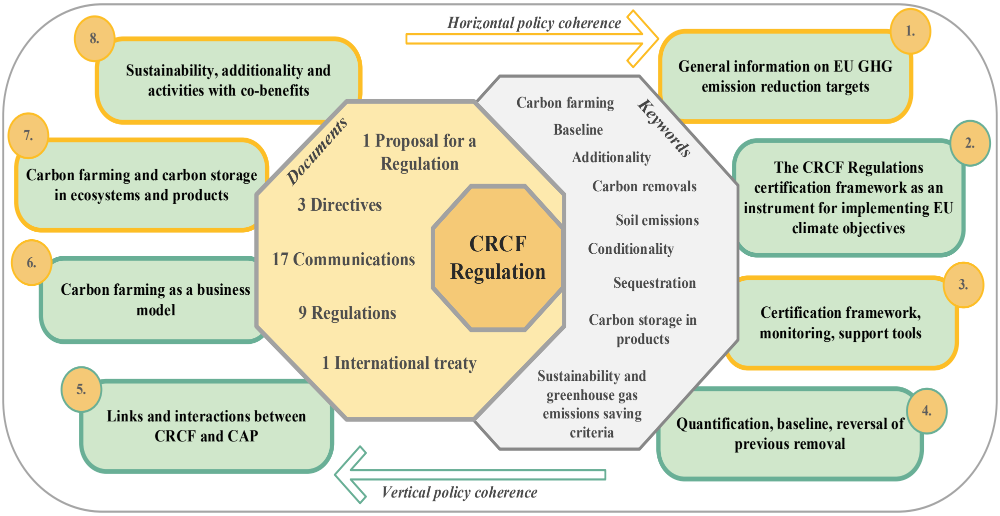

Fig. 4. Overview of analysed documents, search terms and thematic groups (thematic groups indicating horizontal coherence are marked with a yellow frame; those also showing vertical coherence are framed in green).

The certification framework established by the CRCF Regulation is not applied as a penalty or a mandatory obligation. Instead, it upholds the voluntary principle, functioning as an incentive mechanism to encourage farmers and other land managers to engage in carbon farming activities, while simultaneously delivering co-benefits such as biodiversity conservation and enhanced ecosystem services. While this approach positions the CRCF

Regulation as a constructive and flexible policy tool, it also raises a critical question regarding its sufficiency: would embedding such mechanisms into the mandatory structure of the CAP be more effective in achieving the EU's long-term climate objectives? The CRCF Regulation nevertheless represents a pivotal step toward positioning the EU as a global leader in the certification of carbon removals, spanning both land-based and industrial domains.

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 MS. 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.

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STATEMENT

During the preparation of this paper, the author(s) used paid versions of the DeepL translation tool and the DeepL writing tool, in order to improve the use of English, grammar and the formulation of the ideas expressed, due to the fact that none of the authors is a native speaker of English. After using these tools, the authors reviewed and edited the content as necessary and take full responsibility for the content of the publication.

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Krista Laktuka dzimusi 1989. gadā Talsos. Baltijas Starptautiskajā akadēmijā ieguvusi sociālo zinātņu bakalaura grādu politoloģijā (2019), Rīgas Tehniskajā universitātē (RTU) un Viļņas Ģedimina tehniskajā universitātē – dubulto maģistra grādu vides zinātnē (2021) un vides inženierzinātnē (2021). Kopš 2015. gada strādā RTU, kopš 2021. gada ir RTU Vides aizsardzības un siltuma sistēmu institūta pētniece. Zinātniskās intereses saistītas ar klimata politikas un normatīvo dokumentu analīzi, ilgtspēju un aprites bioekonomiku (meža un akvakultūras nozares, oglekļsaistīgas lauksaimniecības prakses), kā arī siltumnīcefekta gāzu emisiju uzskaiti.