D1.3 Legislative and regulatory framework for target value chains

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Acronyms and abbreviations

Acronym	Full name
ABP	Animal by-product regulation EC 1069/2009
ADR	European agreement concerning the international carriage of dangerous goods by road EC 598/2018
BT	Business Tampere
BESS	Battery energy storage system
BMS	Battery management system
CDP	Communication and dissemination plan
CAP	Common agricultural policy
CE	Circular economy
CEAP	Circular economy action plan EC 98/2020
CEN	European committee for standardization
CLIC	CLIC Innovation Ltd
CRMs	Critical raw materials
CSRD	Corporate sustainability reporting directive
CWD	Construction and demolition EC Protocol 2016
D	Deliverable report
DGR	Dangerous Goods Regulations by IATA
DMP	Data management plan
EACHA	European Chemical Agency
EBA	European battery alliance
EC	European Commission
ECO	ECO STOR AS
EEC	European economic community
EEE	Electrical and electronic equipment
EGD	European Green Deal EC 68/2008
EKOF	Ekokumppanit Oy (EcoFellows)
ELV	End-of-life vehicles
EoL	End-of-life
EPR	Extended producer responsibility
ESPR	Ecodesign for sustainable product regulation EC 142/2022
ESS	Energy storage systems
EU	European Union
EV	Electric vehicle
EVB	Electric vehicle battery
EoL EVB	End of life electric vehicle battery
FPR	Fertilizing products regulation EC 1009/2019 EC
GA	Grant Agreement

GD	GreenDelta GMBH
GDPR	General data protection regulation EC 679/2016
GHG	Greenhouse gas
GNI	Gross national income
GPSD	General product safety directive EC 95/2001
IATA	International Air Transportation Association
LPCBs	Lightweight plastic carrier bags
LIB	Li-ion battery
LVD	Low voltage directive EC 35/2014
FAIR	Findable, Accessible, Interoperable and Reusable
Frstad	Fredrikstad kommune
FVH	Forum Virium Helsinki Oy
IEC	International electrotechnical commission
ISO	International organization for standardization
KVC	Key value chain
KVC-DEMO	Key value chain demonstration
MFA	Material flow analysis
MSs	Member states
MTK	The central union of agricultural producers and forest owners
OECD	Organisation for economic co-operation and development
OTIF	Intergovernmental Organisation for International Carriage by Rail
POPs	Persistent organic pollutants EC 1021/2019
PPWD	Packaging and packaging waste directive EC 62/1994
PPWR	Packaging and packaging waste regulation EC 677/2022
PF	Polyfuels Group AB (Previously known as Green Ideas Group GIG)
RDF	Refuse-derived fuel
RED	Renewable energy directive EC 2413/2023
REACH	Registration, evaluation, authorization, and restriction of chemicals EC 1907/2006
RID	Regulation concerning the international carriage of dangerous goods by rail EC 68/2008
RoHS	Restriction of hazardous substances in electrical and electronic equipment EC 65/2011
SAPB	Strategic action plan on batteries EC 176/2019
SDU	Syddansk Universitet
SE	Stakeholder engagement
SE-DEMO	Stakeholder engagement demonstration
SINTEF	SINTEF AS / SINTEF Energy
SoH	State of health
SUP	Single-use plastic

TalTech	Tallinna Tehnikaülikool
TARTU	Tartu Linn (Tartu City)
TLN	Tallinna Linn (City of Tallinn)
VIKEN	Viken Fylkeskommune
VTT	VTT Technical Research Centre of Finland Ltd
WEEE	Waste electrical and electronic equipment
WFD	Waste Framework Directive EC 98/2008

Executive Summary

This deliverable is part of Work Package 1, which focuses on circular economy framework analysis and actions to enhance circular economy. Specifically, the work task involves mapping regulations at EU, national, regional, and local levels regarding the collection, treatment, and recycling of plastics, batteries, and bio-based side and waste streams. This includes reviewing and analysing relevant regulations and standards. Desk research alongside stakeholder engagement workshops was conducted to pinpoint regulatory drivers and barriers, validate these findings, and formulate policy recommendations. Ultimately, the aim of the work is to foster the project's value chain demonstrations and advocate for circularity from a regulatory perspective.

To reach the goal, this deliverable consists of six sections: the first introduces the significance of regulatory frameworks, the second explains the methodology for regulatory analysis, the third maps out regulations, the fourth identifies regulatory drivers and barriers, the fifth proposes policy recommendations, and the final section concludes with strategies for advancing towards a circular economy.

Overall, this deliverable presents a comprehensive analysis of the evolving regulatory framework essential for driving the paradigm shift towards a circular economy. Focused on plastics, batteries, and bio-based side and waste streams, it maps existing and upcoming European regulatory frameworks while examining case studies of national regulatory implementation from Finland, Norway, and Estonia.

Through rigorous desk research and stakeholder engagement for insight validation, key policy drivers and barriers have been identified. These encompass the lack of regulatory framework and alignment, absence of standardized practices, designs not optimized for recycling and repurposing, and the necessity for financial incentives and stakeholder collaboration throughout the value chain.

Eight policy recommendations for plastics, five for batteries, and three for bio-based side and waste streams have been formulated based on these insights. Recommendations encompass eco-design, material traceability, recycled content requirements, quality and safety standards, financial incentives, stakeholder engagement, and consumer awareness. These strategies aim to foster a supportive policy environment that enables sustainable resource management across the entire product lifecycle.

In conclusion, this deliverable provides a robust foundation for policymakers and stakeholders to develop effective policies facilitating the transition to a circular economy. By addressing critical challenges and leveraging opportunities within each value chain, it paves the way towards a sustainable and circular future.

1 INTRODUCTION TO TRESOURCE PROJECT AND THE IMPORTANCE OF UNDERSTANDING REGULATORY FRAMEWORK

This report is part of Work Package 1, which is about the circular economy framework analysis and actions to enhance circular economy. The work task involves mapping the regulatory framework at the EU, national, regional, and local levels for the collection, treatment, and recycling of plastics and batteries, as well as the processing of bio-based side and waste streams. This mapping includes a review of relevant regulations and standards. Through close stakeholder engagement, this task will identify bottlenecks in current policies, regulatory obstacles, and drivers, validate policy framework findings, and formulate policy recommendations. By doing so, the overall aim is to support the further development and implementation of the project's key value chain demonstrations and, more broadly, to promote the transition to circularity within the targeted value chains through regulatory perspective.

This deliverable is outlined into six sections, beginning with Chapter 1, which provides a background introduction and the importance of understanding regulatory framework. Chapter 2 presents the methodology of the regulatory analysis. Chapter 3 presents the regulatory mapping, followed by Chapter 4, which identifies regulatory drivers and barriers. Chapter 5 focuses on the formation of policy recommendations. In Chapters 3, 4, and 5, there are subsections dedicated to plastics, batteries, and bio-based side and waste streams, allowing readers to find information specific to each value chain or gain a comprehensive overview by reading the entire report. The final chapter, Chapter 6, draws conclusions and presents key policy recommendation strategies aimed at advancing the transition to a circular economy.

1.1 TREASoURcE project and the three targeted value chains

TREASoURcE aims to initiate systemic change by developing systemic circular economy solutions in cities and regions for currently underutilised or unused plastic waste, end-of-life electric vehicle batteries and bio-based waste and side streams. Implementing these solutions together with companies, societies (including citizens, consumers, communities and regional actors) and experts in the field is expected to significantly increase product and material circulation in the Nordic and Baltic Sea Regions.

Climate change, environmental degradation and loss of biodiversity are major global threats that require urgent collaborative actions across industry, sectors, cities and regions, communities, and citizens. Half of total greenhouse gas emissions and more than 90% of biodiversity losses come from resource extraction and processing. Global consumption of materials, especially biomass, fossil fuels, metals and minerals are expected to double by 2060 and annual waste generation is estimated to increase by 70% by 2050. TREASoURcE activities aim to create

added value products from currently non-circulated plastic waste to support the market development of recycled plastics and to capture the value lost today by utilising mechanical and thermochemical recycling. TREASoURcE will also evaluate the potential for use of 2nd life electric vehicle batteries as energy storage systems and demonstrate their functionality and sustainability in three demo cases as energy storage for solar power. In addition, TREASoURcE will demonstrate efficient formation of local value chains that utilize local resources for biogasification and recovered fertilizers instead of being unutilized or transported elsewhere.

TREASoURcE brings together a wide range of stakeholders, including businesses, decision makers, consumers and local communities, to innovate collaboratively and cross-sectorally in order to overcome the challenges related to geography or formation of value chains. The combination of the cities and regions will enable large reach and bigger impact and boost the replicability and scalability potential of the circular economy solutions. The systemic circular economy solutions support the regions in introducing circular economy practices to their citizens and businesses to help decouple from fossil virgin resources and excess raw material consumption, increase resilience (self-sufficiency, value chain security, environment, and nature), decrease greenhouse gas emissions, and contribute to climate neutral economies.

Plastics are used in a multitude of applications, thus, also our focus in the project is on different application areas: agricultural plastics, post-consumer packaging waste recycling rejects and industrial plastic waste streams, such as the battery recycling industry. The EU's Strategy for Plastics in the Circular Economy aims to address the increasing consumption of plastics and tackle plastic pollution by supporting the uptake of recycled plastics and contributing towards more sustainable plastics. Actions towards the goal, such as mandatory recycled contents and plastic waste reduction measures for key products, like packaging, construction materials and vehicles will be set. In TREASoURcE, we are also focusing on improving the circularity of current post-consumer packaging waste rejects, which are one of the most challenging packaging types to recycle. Packaging is also listed as one of the key value chains in the Circular Economy Action Plan (CEAP). Packaging materials are used in an ever-growing manner and the amount of raw material needed is increasing. Currently most packaging is single use, which means that the amount of packaging waste is also increasing. In 2017, 173 kg of packaging waste was generated per inhabitant in the EU. The European Union aims to make all packaging either reusable or recyclable by 2030 and reduce (over)packaging and packaging waste. This includes setting waste prevention measures, as well as considering reducing the complexity of packaging materials, such as multilayer solutions. (European Comission, 2022)

Batteries and vehicles are EU's one key value chain listed in the Circular Economy Action Plan. It is seen that sustainable batteries and vehicles support the mobility of the future. A new Batteries Regulation was introduced to enhance sustainability of the emerging battery value chain for electro-mobility and boost circular potential of all batteries. However, it focuses mainly on

mandatory recycled contents and measures to improve collection and recycling rates as the main circular strategy for recovering valuable and critical materials. (European Comission, 2022)

The TREASoURcE project focuses on increasing the circularity of bio-based side and waste streams for biogas and fertilizers. Also, food, water and nutrients are listed in the CEAP as key value chains. Circular economy is seen to have a significant role in reducing negative environmental impacts of resource extractions and use, while contributing towards restoring biodiversity and natural capital. The Bioeconomy Strategy and Action Plan and Integrated Nutrient Management Plan are critical EU-level plans from the Commission to ensure sustainable application of nutrients and stimulating markets for recovered nutrients. (European Comission, 2022)

1.2 The importance of understanding regulatory framework

Understanding the evolving regulatory framework in an interdisciplinary context is crucial for initiating a systemic shift towards a circular economy. The EU's regulatory landscape demonstrates how policy can be a powerful driver of the circular economy. By setting ambitious recycling and recycled content targets, imposing clear extended producer responsibilities, and encouraging innovation, the EU provides a robust framework that guides industries towards sustainability. Furthermore, understanding these regulations allows businesses and stakeholders to align their operations with EU policy goals, ensuring compliance and capitalizing on new market opportunities. Companies that adapt to the EU's stringent plastic regulations, for example, can lead in sustainable product design, gaining a competitive edge.

On the other hand, the challenges posed by regulatory barriers are multifaceted and can significantly impede the development, implementation, and success of policies. A typical regulatory challenge for circular economy initiatives involves the complexity of transforming entire value chains and infrastructures to achieve sustainable outcomes. Moreover, bureaucratic hurdles can slow down the implementation process, leading to inefficiencies. Resource constraints, whether financial, human, or technological, further exacerbate the challenges, particularly in resource-limited settings. Additionally, policies may struggle to gain traction without sufficient public support, facing resistance or skepticism from the community. Institutional fragmentation and legal or regulatory conflicts can further complicate matters, while cultural and social barriers may resist change, impeding policy acceptance and adoption.

Through comprehensive and systemic understanding, taking advantage of regulatory drivers and addressing the regulatory barriers, policy recommendations can be formulated to advance the regulatory environment that supports the transition to a circular economy. By driving innovation, enhancing resource efficiency, and fostering interdisciplinary collaboration, EU regulations are pivotal in initiating and sustaining systemic shifts towards a more circular future.

2 METHODOLOGY

The analysis of legislative and regulatory frameworks for the three targeted value chains are conducted following three main steps of desk research for European regulatory mapping and identification of policy drivers and barriers, stakeholder validation through workshop organization and policy recommendation formation (see Figure 1).

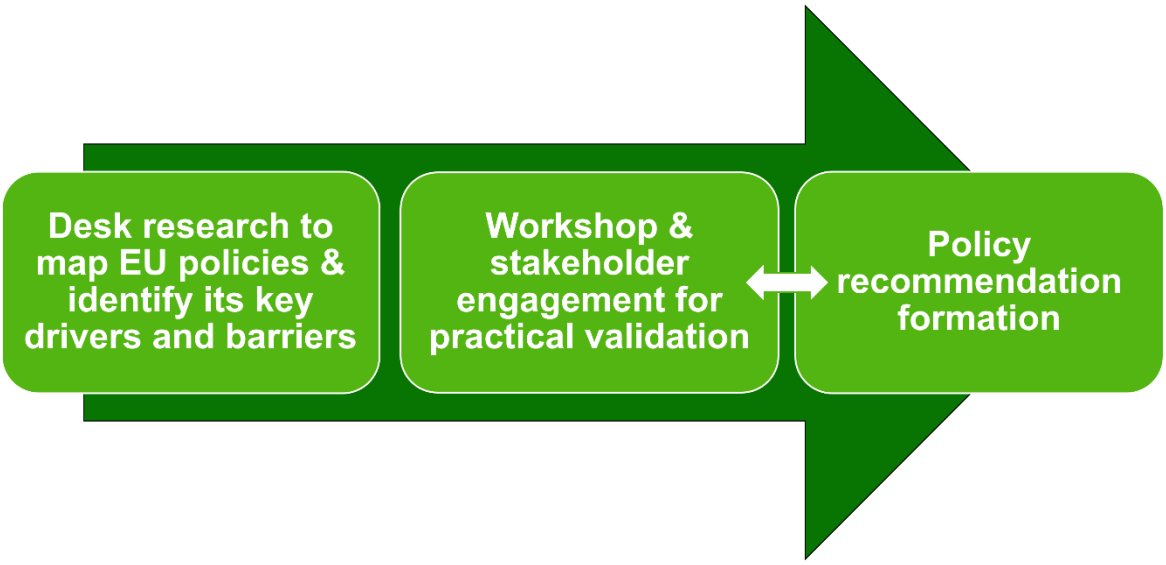

Figure 1. Regulatory analysis and policy recommendation formation process.

Through the desk research, existing and upcoming European regulatory frameworks related to the circular economy across three targeted value chains are mapped with case studies on national policy implementation of EU policies in Finland, Norway, and Estonia. In addition, various policy drivers and barriers surrounding the mapped regulatory framework are identified and analyzed, pinpointing critical areas that either facilitate or hinder progress toward a circular economy. The insights gained from this regulatory mapping and analysis are further validated through stakeholder validation. Involving stakeholders in this process ensures that the perspectives and experiences of those directly affected by these policies are considered. Based on the synthetic results of desk research and stakeholder validation, policy recommendations are then formulated around the identified critical themes for specific value chains. Policy recommendations are continuously validated and improved through another round of stakeholder review, ensuring that the recommendations developed are realistic and impactful. Details on each step are presented in the following sections.

2.1 Mapping of regulatory framework and identification of regulatory drivers and barriers

2.1.1. Mapping of regulatory framework

The regulatory mapping and data collection for relevant policy instruments of the targeted value chains are conducted following the 3 steps below:

1. Policy instrument definition: Define and understand the characteristics of policy instrument types such as directives, decisions, recommendations, communications, and standards. The definition and scope of these legal acts are summarised in Table 1.

Table 1. Types of policy instruments considered in the mapping *(European Commission, 2022)*

Policy instruments	Description	Addresses	Characteristics
Regulation	Immediately applicable in their entirety in national laws	All EU member states	Binding legal act
Directive	Transposed to national laws before application, i.e., member states decide *how* to apply the rules of the directive	All EU member states	Binding legal act
Decision	Directly applicable to whom it concerns, may also grant a permission	One or several EU Member States, companies or individuals, or no specific addressee	Binding legal act
Recommendation	Delivers the views of EU institutions but has no legal consequences. May guide with the interpretation or content of EU laws	Specified addressee(s)	Non-legislative, non-binding legal act
Opinion	Delivers the view of EU committees on the law proposals from regional, economical, and social perspective	Specified addressee(s) or other party requesting the opinion	Non-legislative, non-binding legal act
Communication (from the Commission)	Evaluates or clarifies policies, identifies problems in a certain policy area, frames the direction of future policies (in broad and general terms)	The Council of Ministers, the European Parliament, and other relevant institutions of the EU	Non-binding legal instrument
Priority	Indicates the official political priorities of EU	All EU member states	Non-binding agreement
Strategy, action plan	Sets a guideline for achieving the goals of the priorities	All EU member states	Non-binding legal act
Standard	Standard is a technical document designed to be used as a rule, guideline, or definition. It	Standards are voluntary agreements, developed within an open process. Standards can be	Non-binding agreement

	is a consensus-built, repeatable way of doing something	developed by international, national, or regional organizations and businesses	

2. Scope definition: Define the scope of the analysis by specifying the geographical focus on European Union with case studies of EU policy adaptation in Finland, Norway, and Estonia.

3. Data collection and analysis: Desk research to map and collect data for all relevant legislative documents, policies, and regulations pertaining to the circular economy. This includes both existing laws and upcoming regulatory proposals at the European level as well as national policies for the case studies. Data collected are analysed and stored in a summarised table format (see Figure 2) at first for internal review between the authors and external stakeholder validation before transferring into the deliverable as full text description.

Name of policy instrument, year of publication/entry into force, other general info	Collection and treatment	Recycling	HIGHLIGHTS FOR DELIVERABLE
Plastics Strategy (A European Strategy for Plastics in a Circular Economy) 2018	VISION Separate collection of plastics waste reaches very high levels By 2030, sorting and recycling capacity has increased fourfold since 2015 Thanks to improved separate collection and investment in innovation, skills and capacity upscaling, export of poorly sorted plastics waste has been phased out (by 2030?) Europe confirms its leadership in sorting and recycling equipment and technologies MEASURES To encourage more standardised and effective practices across the EU, the Commission will issue new guidance on separate collection and sorting of waste Commission strongly supports the European Parliament and the Council	VISION By 2030, more than half of plastics waste generated in Europe is recycled Recycling of plastics packaging waste achieves levels comparable with those of other packaging materials (by 2030?) The chemical industry works closely with plastics recyclers to help them find wider and higher value applications for their output. Substances hampering recycling processes have been replaced or phased out. More plastic recycling helps reduce Europe's dependence on imported fossil fuel and cut CO2 emissions. MEASURES Commission is committed to working with the European Committee for Standardisation and the industry to develop quality standards for sorted plastic waste and recycled plastics. Commission is committed to swiftly finalise the authorisation procedures for	COLLECTION AND TREATMENT Sorting of plastics waste needs to be improved through increased capacity and developed technologies for sorting, and by separate collection systems, such as EPR schemes. "By 2030, sorting and recycling capacity has increased fourfold since 2015 and export of poorly sorted plastics waste has been phased out." BY WHOM "The Commission will issue new guidance on separate collection and sorting of waste" "Public authorities need to invest in extended and improved separate collection." RECYCLING By 2030, the recycling rate of plastics is over 50%, and the recycling rate of plastics packaging waste reaches

Figure 2. Data collection table for regulatory framework mapping

2.1.2. Identification of regulatory drivers and barriers

The process of regulatory drivers and barriers identification are conducted following 3 steps:

1. Driver and barriers identification: Analyze the mapped policy instruments and further desk research to identify its policy drivers and barriers that impact the circular economy.

2. Categorization: Categorize the identified drivers and barriers according to their impact on the value chains to define the critical themes and objectives for circular economy transition. This can involve grouping them by type (e.g., financial, regulatory, technical) and by the stage of the value chain they affect (e.g., production, consumption, waste management).

3. Data collection and analysis: The data collected are analyzed and stored in a summarized table format (see Figure 3) for internal review between the authors and external stakeholder validation before transferring into the deliverable as the output from both desk research and stakeholder insights.

Objective	Driver	Barrier
Improving plastic waste collection, sorting and logistics	Revision of the Waste Shipment Regulation banning the exports of plastic waste to non-OECD countries	Intra-EU waste shipment rules complicate and slow down the flow of plastic waste between member states destined for recycling inside EU
		The plastic waste shipments to Turkey, which is the largest importer of plastic waste in the EU and an OECD country, may still continue
	Implementing separate waste collection, waste hierarchy, limiting landfill	Lacking of end of waste criteria to end the waste status and increase uptake for recycling
	Adopting EPR schemes to ensure that producers take on the responsibility for separate waste collection, recovery and treatment in addition to financial contribution (e.g. based on recycled content requirement) to cover the necessary costs of waste management and treatment as well as the costs of awareness raising measures to prevent and reduce plastic waste	

Figure 3. Data collection table for policy drivers and barriers identification

2.2 Workshops and stakeholder validation

The insights withdrawn from the regulatory mapping, policy drivers and barriers analysis and policy recommendation are continuously validated and improved through the stakeholder engagement. In total, 3 workshops for each targeted value chains and 1 review meeting with EU policy makers were conducted to communicate the policy drivers and barriers and policy recommendation with relevant stakeholders and receive improvement feedback.

For the first 2 workshops considering plastics and bio-based side and waste streams, workshop participants were divided into smaller groups with predefined themes, exploring specific policy drivers and barriers. These groups discussed the critical factors hindering the development of their topic and defining solutions to overcome the obstacles. Following the workshops, policy recommendations are formulated and sent to workshop participants for the second round of policy recommendation feedback via email. The third workshop regarding battery value chain

followed the same procedure of group discussion, except for the inclusion of policy recommendation validation in addition to policy drivers and barriers for stakeholder review. The last stakeholder validation workshop targets the EU policy maker representatives. Pre-reading documents for policy drivers and barriers and policy recommendations were sent prior to the meeting. During the workshop, policy drivers and barriers resulting policy recommendations were presented and received feedback from the EU representatives. In addition, detailed written feedback on the pre-reading documents were also received after the meeting. The summary of stakeholder engagement workshops and validation process is presented in Table 2.

Table 2. Stakeholder engagement workshop and validation process.

Workshop	Description	Number of participants	Stakeholder roles
1. Regulatory drivers and barriers for the circular economy of plastics – 08.02.2024	Online workshop with group work for reviewing regulatory drivers and barriers. Second round of stakeholder review for policy recommendation through email after the workshop	33	Industry, municipal government, research and academy, and NGOs
2. Regulatory drivers and barriers for the circular economy of bio-based side and waste streams – 13.02.2024	Online workshop with group work for reviewing regulatory drivers and barriers Second round of stakeholder review for policy recommendation through email after the workshop	37	Industry, municipal government, research and academy, and NGOs
3. Regulatory drivers and barriers and policy recommendation for the circular economy of electric vehicle batteries – 09.04.2024	Face-to-face workshop with group work for reviewing regulatory drivers and barriers and policy recommendations	32	Industry, municipal government, research and academy, and NGOs
4. Review of identified gaps, challenges and proposed policy recommendations – 13.05.2024	Pre-reading documents Online workshop for reviewing policy drivers and barriers and policy recommendations	6	EU policy makers

2.3 Policy recommendation formulation

Following the regulatory mapping and the analysis of policy drivers and barriers with stakeholder validation, the critical themes for specific value chains were identified to develop the policy recommendation framework. For each theme, the policy recommendation framework is formulated

with the description of background context of the policy drivers and barriers, then the practical case studies are presented as an example of the policy environment in action, leading to the policy recommendations (see Figure 4).

5.1.3. Effect of the restriction on waste shipment regulations

Description:

The European Commission has enforced the revision of the Waste Shipment Regulation (Delegated Regulation (EU) 2020/2174) concerning the export, import and intra-EU shipment of plastic waste since January 2021. As per the export rules, a ban on the export of plastic waste from the EU to non-OECD countries has been imposed with an exception for clean plastic waste that is sent for recycling. However, challenges such as intra-EU logistical hurdles and the need for enhanced recycling infrastructure must be addressed. (European Commission, n.d.)

Case study: Impact of increased plastic waste import to Turkey due to waste export banning

The EU's decision to ban plastic waste exports to non-OECD countries is a positive step for responsible plastic waste generation. However, it falls short of a total ban on shipments to Turkey, which is both the largest importer of plastic waste in the EU and an OECD member. Waste management infrastructure and the ecosystem in Turkey may be adversely affected by substantial increased plastic waste imports due to the banning plastic waste exports to other countries.

Recommendations:

- Establish a Pan-European cooperation platform to mitigate plastic waste burden on recycling-destined countries and logistic hurdles in the EU. Develop local and regional roadmaps for specific sectors or materials to enhance waste management knowledge and foster collaboration.
- Create financial instruments supporting investments in plastic waste management infrastructures to ensure efficient waste management in Europe.
- Develop industrial symbiosis models that reuse materials from other value chains to generate economic benefits and promote waste management.

Figure 4. Policy recommendation framework example

3 MAPPING OF REGULATORY FRAMEWORK

This section presents the content of the regulatory framework for each material stream, relevant legislative bottlenecks, and potential regulatory amendments towards sustainability and circularity. The discussion is based on the existing and upcoming policy instruments of the European Commission, standards, and their national implementations (see Table 3).

3.1 Regulatory framework concerning plastics

This chapter presents the policy framework of plastics in a concise manner, to support the further discussion of the drivers and barriers. The focus of the policy framework review is on the circular economy aspects, especially on collection, treatment, and recycling of plastics. The summary of the policy frameworks based on the following discussions is presented in the *Table 3*.

3.1.1 Visions for the circular economy of plastics

The **European Green Deal (EGD)** (EC Communication 640, 2019) comprises a set of policies and initiatives designed to transform the European Union into a modern, resource-efficient, and competitive economy. The primary goals of the EGD involve achieving carbon neutrality by 2050 and decoupling economic growth from resource consumption, with a commitment to inclusivity. A pivotal element within the EGD is the **Circular Economy Action Plan (CEAP)** (EC Communication 98, 2020), which plays a crucial role in guiding the circular transition of various sectors, placing particular emphasis on resource-intensive industries like textiles, construction, electronics, and plastics. Specifically addressing circular plastics, the Commission actively follows up on the **Plastics Strategy** (EC Communication 28, 2018), which targets issues such as intentionally added microplastics and unintentionally released plastic from sources like textiles and tire abrasion. In addition, the Commission is committed to establishing requirements to ensure that all packaging in the EU market is reusable or recyclable in an economically feasible manner by 2030. Furthermore, the Commission develops a regulatory framework for biodegradable and bio-based plastics, along with implementing measures to reduce the usage of single-use plastics.

The new **Circular Economy Action Plan (CEAP)** (EC Communication 98, 2020) was adopted by the European Commission in 2020 aiming at accelerating the transformational change required by the European Green Deal (EC Communication 640, 2019), while building on the existing circular economy actions implemented since 2015. The plan focuses on establishing a sustainable product policy framework to normalise sustainable products, services, and business models, with an overarching goal of preventing waste generation. This framework includes measures to promote sustainable product design, empower consumers, and enhance circularity in production processes, with a gradual rollout and priority attention to key product value chains.

One focal point within CEAP (EC Communication 98, 2020) is the plastics value chain. The **Plastic Strategy** (EC Communication 28, 2018), as part of CEAP, has initiated a comprehensive set of initiatives in response to a significant public concern. To promote the uptake of recycled plastics and enhance the sustainability of plastic usage, the Commission will propose mandatory requirement of recycled content and waste reduction in key plastic products such as packaging, construction materials, and vehicles, while considering the Circular Plastics Alliance's activities. CEAP also addresses plastic litter and microplastics by introducing measures like restrictions on intentionally added microplastics, the development of labelling and certification standards, and addressing gaps in scientific knowledge regarding the risks and occurrences of microplastics in the environment, drinking water, and food. Additionally, CEAP tackles emerging sustainability challenges related to bio-based and biodegradable plastics, ensuring environmental benefits, and preventing misleading product labelling. The plan further commits to the timely implementation of directives, including the Single Use Plastic Products Directive, to combat marine plastic pollution while upholding the single market through standardised interpretation, labelling regulations, and the measurement of recycled content in products (EC Communication 98, 2020).

Adopted in January 2018 as part of the CEAP, the **Plastics Strategy** (EC Communication 28, 2018) outlines a comprehensive plan to foster a smart, innovative, and sustainable plastics industry, prioritising reuse, repair, and recycling. The overarching goal is to transition towards a circular plastics economy, bringing forth economic growth and job opportunities, while simultaneously contributing to a reduction in the EU's greenhouse gas emissions and decreasing dependence on fossil fuels. By 2030, the vision is for 100% plastics packaging placed on the EU market to be either reusable or economically recyclable, and more than 50% of plastics waste generated in Europe is recycled. By 2030, sorting and recycling capacity is envisioned to increase fourfold compared to 2015, leading to the creation of 200 000 new jobs spread across Europe, while saving around a hundred euros per ton of collected plastic.

To actualise this vision, the strategy focuses on making recycling economically viable by enhancing the recyclability of plastics and stimulating demand for recycled content. It promotes eco-design and innovation in plastic recycling, alongside the establishment of standardised systems for separate waste collection and sorting. To curb plastic waste, the strategy addresses single-use plastics and fishing gear through EU-wide regulations and implements measures to restrict microplastics and introduce labels for biodegradable and compostable plastics. Commitment to stop littering at sea involves measures to ensure waste generated on ships or gathered at sea is returned to land and adequately managed. Moreover, the strategy advocates for driving investment, with a dedicated €100 million fund supporting the development of recyclable plastics materials innovation and efficient recycling processes. Global engagement is a key component, involving collaboration with international partners to establish standards and solutions, ultimately promoting new business models for the circular economy of plastics (EC Communication 28, 2018).

3.1.2 Management of plastic waste

Plastic waste being an escalating concern, requires comprehensive regulatory strategies and collaborative approaches from different actors of the value chain including government officials, policy makers, industries, civil societies, and individuals. The policies should emphasise on monitoring and controlling the generation, handling, and disposal of plastic waste, ensuring sustainability and circularity in the material stream. The **Waste Framework Directive** (WFD) (EC Directive 98, 2008) amended in 2014, 2015, 2017 and 2018 is a key legislation in EU offering legal framework for management of waste. As per the directive, waste hierarchy should be applied on a priority basis in waste prevention (e.g., through re-use and repair), management legislations and policies. The Member states should focus on implementation of economic instruments and other incentive-based measures to encourage alternatives delivering the best overall environmental outcomes. In addition, the respective Member states may take legislative or non-legislative measures to deploy extended producer responsibility (EPR) schemes. The directive serves as an umbrella for packaging waste, construction, and demolition waste (CDW), end-of-life vehicles (ELV), and waste electrical and electronic equipment (WEEE). By 2020, it is expected that the preparation for reuse and the recycling of waste materials (including plastics) from households should be increased to a minimum of 50 % by weight. From 2025 to 2035, the preparation for reuse and recycling of municipal waste is expected to increase to a minimum of 55 % (2025), 60 % (2030), and 65 % (2035) by weight (EC Directive 851, 2018).

Landfilling is the least preferred waste management strategy with objectives to protect human health and mitigate the environmental impact. However, in 2018, about 24 % of the total municipal waste generated in the EU was landfilled. The repercussions of this practice could create leachates possessing a risk of groundwater contamination, and the production of methane, a potent greenhouse gas, thus increasing environmental concerns. When recyclable material waste is landfilled, valuable materials are needlessly lost from Europe's economy. To mitigate these problems, a new **Landfill directive** (EC Directive 850, 2018) was introduced by the EU in 2018. As per the directive, landfills were classified for non-hazardous, hazardous, inert waste. The application of national strategies by EU countries is to gradually control the amount of biodegradable waste sent to landfills. Landfills may not accept used tires or waste that is liquid, flammable, explosive or corrosive, hospital waste or other waste generated in medical or veterinary practice. Only treated waste is suitable for landfill. By 2035, the maximum share of municipal waste going to be landfilled is 10 %, thus promoting higher end-of-life measures of waste hierarchy such as reuse and recycling.

In addition to landfill directive, European Commission has enforced **regulation for export, import and intra-EU shipment of plastic waste** (EC Regulation 2174, 2020) since January 2021. As per the export rules, a ban on the export of plastic waste from the EU to non-OECD countries has been imposed with an exception for clean plastic waste that is sent for recycling. Exporting and importing clean, non-hazardous waste (which is destined for recycling) from the EU to

OECD and non-OECD countries will also be more strictly monitored. For importing of plastic waste, the destination country will be responsible for highlighting the set of rules to be applied for the corresponding imports to the European Commission. The export from a partnering EU member state will only be permitted under the desired set of guidelines laid down by the importing country. For countries which do not provide information about their legal regime, the “prior notification and consent procedure” will apply.

The export and import of hazardous plastic waste and non-recyclable plastic waste between EU countries, EU and OECD countries, or between EU and third countries will be subjected to the “prior notification and consent procedure”. Based on this procedure, both the importing and exporting country must authorise the shipment. However, all intra-EU shipments of non-hazardous waste for recovery will be exempted from these new controls. These new rules provide guidelines about the export of plastic waste to third countries that often do not have the capacity and standards to manage it sustainably (EC Regulation 2174, 2020).

Furthermore, to **manage and categorise the economic resources used for plastic waste, a European Council decision** (EC Decision 2053, 2020) was made with reappealing the earlier 2014/335/EU decision. The first step included the establishment of a new category of funding resources derived from national contributions which were calculated based on the volume of non-recycled plastic packaging waste. By connecting national contributions to the amount of unrecycled plastic packaging waste within each member state, incentive-based systems can be fostered to reduce the use of single-use plastics (SUPs), accelerate the recycling strategies, and promote the concept of a circular economy. The right to design and implement the framework will be retained within the Member States, thus accomplishing most suitable measures in accordance with the subsidiarity principle.

To avoid disproportionately impacting Member States (MSs) with a 2017 Gross National Income (GNI) per capita below the EU average, an adjustment mechanism will be applied involving an annual fixed reduction in contributions calculated based on the population of corresponding Member States in 2017 and multiplying it by 3.8 kg. As per Article 2 of the decision, each Member State will be creating an application of a uniform call rate (which will be € 0.80/kg) to the weight of unrecycled plastic packaging waste. The weight of unrecycled plastic packaging waste will be determined by calculating the disparity between the weight of plastic packaging waste generated within a Member State during a specific year and the weight of plastic packaging waste recycled during the same year (EC Directive 62, 1994). The approach of Council aligns with the European Plastics Strategy and the scope of EU budget is planned in a way to contribute to curbing plastic packaging waste pollution (EC Decision 2053, 2020).

3.2.2.1 Limitations of waste plastic packaging regulations

Many of the policy instruments concerning the circular economy of plastics fall under the category of packaging, which can be explained by the regulatory needs raising from the constantly increasing generation of plastic packaging waste in the EU (Eurostat, 2023). The core of the regulation concerning plastic packaging (among other materials used in packaging) is formed by the **Packaging and Packaging Waste Directive (PPWD)** (EC Directive 62, 1994). The PPWD establishes rules for the management of packaging and packaging waste, aiming at harmonised measures between member states and at reducing the impacts of packaging and packaging waste on the environment. A few years after the publication of the PPWD, a **Commission decision establishing the identification system for packaging materials** (EC Decision 129, 1997) was laid down to harmonise the labelling of the variety of packaging materials. The decision sets a systematic identification coding for packaging materials, including plastics. A heavier emphasis on the circular economy of packaging materials has been laid by the latest amendment to the directive (EC Directive 852, 2018), highlighting the prevention of generated packaging waste and introducing ambitious material-specific recycling targets, including a 50% recycling target for plastic packaging waste by 2025, and 55% by 2030.

Certain measures indicated in the PPWD aimed to increase the collection and recycling rates of plastic packaging have been seen as a threat to other fundamental EU policies. For example, the EU Commission considers that a mandatory deposit and return system for non-refillable beverage packaging poses trade barriers because such systems prohibit selling the same product in identical packaging across multiple member states (EC Communication 107/1, 2009).

The PPWD is currently under revision by the proposition of the European Commission in 2022. The aim of the revision is to answer to the objectives related to the reusability and recyclability of plastic packaging as set in the European Green Deal, the New Circular Economy Action Plan, and the Plastics Strategy (European Environment Agency, 2022). The **Proposal for a Regulation on Packaging and Packaging Waste** (or Packaging and Packaging Waste Regulation, PPWR) repealing the PPWD is currently going through the standard legislative procedure through the European Parliament and the Council. The proposed regulation would establish guidelines regarding sustainability, encompassing aspects such as managing substances of concern, promoting recyclability, enforcing recycled content requirements (e.g., mandating 30% recycled material for single-use plastic beverage bottles), and minimizing packaging. It also covers regulations on labelling, marking, and providing information regarding packaging material composition. Economic operators would face obligations including banning specific packaging formats, establishing targets for reuse and refilling, and managing packaging waste. This includes setting targets for reducing packaging waste, implementing deposit and return systems for single-use plastic beverage bottles and metal beverage containers, and promoting green public procurement. (Guillaume, 2024)

3.2.2.2 Limitations of WEEE and ELV regulations

The management of plastic waste in waste electrical and electronic equipment (WEEE) and end-of-life vehicles (ELV) presents complex challenges due to the variety of polymer structure and additives involved leading to the difficulty in recycling them effectively (Buekens & Yang, 2014). To address these challenges, policymakers are establishing key measures through **WEEE Directive** (EC Directive 19, 2012), **ELV Directive** (EC Directive 53, 2000) and **Directive on the type-approval of motor vehicles regarding their reusability, recyclability, and recoverability** (EC Directive 64, 2005) to promote plastic recycling and the use of recycled plastics, aiming to enhance the circularity of materials.

The **WEEE Directive** (EC Directive 19, 2012) underscores critical aspects concerning the circularity of WEEE plastics and product integration. It emphasises collaboration between manufacturers and recyclers for eco-design, urging member states to encourage measures facilitating the design for reuse, dismantling, and recovery of WEEE. The directive promotes effective measures for separate collection, ensuring proper handling and accessibility of collection facilities for end-users and distributors. Additionally, it forbids disposal of separately collected WEEE before designated treatment and enact extended producer responsibility for collection, treatment, and recovery of WEEE, with obligations for financial support. The directive mandates appropriate treatment for collected WEEE, specifying the removal of fluids and selective treatment for hazardous substances. The directive establishes targets for collection and recovery of WEEE. Collection targets should constitute either 65% of the average weight of electrical and electronic equipment placed on the market or 85% of the WEEE generated within member states, while recovery and recycling targets range from 50% to 80% and 20% to 75%, respectively, for separately collected WEEE (EC Directive 19, 2012).

The **ELV Directive** (EC Directive 53, 2000) mandates the reduction of hazardous substances in manufacturing and setting clear goals for reuse, recycling, and recovery. It applies to passenger vehicles and small trucks but excludes certain types like big trucks, vintage vehicles, special-use vehicles, and motorcycles. Several revisions and associated regulations have been introduced, including an early evaluation in 2021 and a new regulation proposal in 2023. Key points include the directive's requirement for vehicles to be reusable and/or recyclable to a minimum of 85% by weight and reusable and/or recoverable to a minimum of 95% by weight per vehicle. It also mandates manufacturers to prioritise dismantling, reuse, and recovery in design and production, requiring coding standards for identification of reusable elements. The directive outlines obligations for establishing collection systems, with manufacturers responsible for transportation costs. Moreover, the directive sets standards for storage and treatment, emphasising the stripping of vehicles and hazardous material removal. In addition, there is a requirement to report implementation progress every three years, and producers must disclose information on vehicle design, environmentally sound treatment, and progress in recovery and recycling.

The **proposed new ELV Regulation** (EC Communication 451, 2023) aligns with the **European Green Deal** (EC Communication 640, 2019) and the **Circular Economy Action Plan** (EC Communication 98, 2020), focusing on circular design, increasing recycled content, smarter collection methods, improved treatment practices, and making producers financially responsible for waste vehicles. Key proposals include a mandate for at least 25% recycled plastic in vehicles, restrictions on landfill usage, and a 30% plastics recycling rate (EC Communication 451, 2023). Additionally, it encourages cooperation between manufacturers and recyclers and aims to incentivise the sale of spare parts for better raw material retrieval.

Directive on the type-approval of motor vehicles regarding their reusability, recyclability, and recoverability (EC Directive 64, 2005), developed in conjunction with **ELV Directive** (EC Directive 53, 2000), establishes criteria for type-approved vehicles to be placed on the market. It requires that categories M1 (passenger cars) and N1 (light commercial vehicles) vehicles must meet minimum reusability (85%) and recoverability (95%) by mass, ensuring environmental sustainability. Moreover, it emphasises the necessity for vehicle manufacturers to integrate considerations of reusability, recyclability, and recoverability at the initial stages of vehicle design to facilitate efficient end-of-life vehicle treatments. This directive operates within the framework of EU approval and market surveillance measures for motor vehicles and their trailers (EC Regulation 858, 2018), extending the vehicle type-approval system to cover more vehicle categories. To achieve type-approval, manufacturers must provide detailed technical data on constituent materials and masses, with validation through established procedures to manage supplier information, and propose an end-of-life vehicle treatment strategy. While N1 vehicles are not fully covered yet under the system, manufacturers must provide technical information on constituent materials aligned with ISO 22628:2002. Furthermore, measures are implemented to prevent the reuse of specific component parts from end-of-life vehicles in new vehicle construction, ensuring road safety and environmental protection (EC Directive 64, 2005).

3.2.2.3 Limitations of CDW regulations

Construction and demolition waste is one of the priority waste streams under the WFD (EC Directive 98, 2008). This waste category is not separately regulated by a directive unlike WEEE and ELVs. According to WFD, by 2020, a minimum of 70% by weight of non-hazardous CDW is expected in the preparation for reuse, recycling, and other material recovery, including backfilling operations using waste to substitute other materials. Practical guidance for the CDW management is provided by the **Construction and Demolition Waste Management Protocol** (EC Protocol, 2016), which highlights the importance of valid pre-demolition audits as a prerequisite for a proper CDW management and to improve waste identification, separation, and collection. **Guidelines for the waste audits before demolition and renovation works of buildings** (EC Guideline, 2018) further specifies the guidance, but neither of these documents emphasise the circular economy of plastics in construction. Only sorting of plastic packaging waste (among other packaging waste types) is encouraged, and recycling of polyvinyl chloride (PVC) is raised

as an example (EC Guideline, 2018). Moreover, plastics are mainly considered suitable for refuse-derived fuel (RDF) rather than for recycling (EC Guideline, 2018).

3.1.3 Tackling plastic pollution

A part of the regulatory framework for plastics aims to reduce the impacts on the environment caused by plastic items more susceptible to entering nature. **Directive on the reduction of the impact of certain plastic products on the environment** (EC Directive 904, 2019), i.e., Directive on single-use plastics (SUP), focuses on plastic products found most often on beaches, on plastic-containing fishing gear and on oxo-degradable plastic products. The directive bans certain SUP products (such as SUP cutlery, straws, and take-away food containers made of expanded polystyrene), and all products made of oxo-degradable plastic. It directs the costs of clean-up of some other SUP products, such as tobacco filters, wet wipes, and balloons, to producers through EPR schemes, alongside awareness raising campaigns. EPR schemes are also to be established by member states for certain food and beverage containers, plastic bags, and fishing gear containing plastic. The directive lays down collection targets for SUP beverage bottles (up to 3 L) as follows: (a) 77% by 2025, and (b) 90% by 2029 (EC Directive 904, 2019). In addition, member states having marine waters must establish a minimum annual collection rate for recycling waste fishing gear that contains plastic. The implementation of the SUP directive in Finland, Estonia and Norway is further discussed in the section 3.2.6 on this report.

Plastic Bags Directive (EC Directive 720, 2015), an amendment to the PPWD (EC Directive 62, 1994), recognizes the currently low recycling rates of lightweight plastic carrier bags (LPCBs). However, the directive aims at reducing the consumption of LPCBs under certain limits per person per year and does not consider the collection, treatment, or recycling of these bags.

As a measure for battling against microplastic pollution, **Commission regulation amending Annex XVII of REACH as regards synthetic polymer microparticles** (EC Communication 6419, 2023) has been established. The regulation amends Annex XVII by restrictions for intentionally added microplastics in, e.g., encapsulated fragrances, rinse-off cosmetics, and fertilising products and therefore it does not relate with the collection, treatment, or recycling of plastics.

3.1.4 Towards safe and sustainable plastics

The plastic waste management can be carried out by both implementation of desired policy instruments as well as modifying the material and product development strategies. A policy proposal was published on 30 March 2022 for establishing **new sustainable products regulation (ESPR)**. The proposal builds on the existing **Ecodesign Directive** (EC Directive 125, 2009) covering energy-related products and serving as a cornerstone of the EC's approach for more environmentally sustainable and circular products. The proposal establishes a framework to set ecodesign requirements for specific product groups, introduce requirements not only for energy

efficiency but also for circularity and reduction of the environmental footprint of products. This will enable the setting of a wide range of requirements, including: (a) product durability, reusability, upgradability, and reparability; (b) presence of substances that inhibit circularity; (c) energy and resource efficiency; (d) recycled content; (e) remanufacturing and recycling; (f) carbon and environmental footprints; and (g) information requirements, including a Digital Product Passport. The "**Digital Product Passport**" will serve as a tool in providing information about products' environmental sustainability. The information generated can be easily accessible by scanning a data carrier consisting of different attributes such as the durability and reparability, the recycled content, or the availability of spare parts of a product. The passport will improve transparency about products' life cycle impacts on the environment between suppliers and end consumers when purchasing products, facilitate repairs and recycling. The product passport should also help public authorities to better perform checks and controls.

Furthermore, the EU's **Chemicals Strategy for Sustainability** (EC Communication 667, 2020) is a cornerstone in the pursuit of a toxic-free environment and sustainable practices. In navigating the complex landscape of chemical management, a crucial aspect lies in harnessing the potential of mechanical and chemical recycling to advance the circular economy of plastics. Integrating plastic recycling into the new vision for the EU's chemical policy will not just be an environmental imperative but a strategic opportunity. Investing in the development of infrastructure for chemical recycling facilities, creating a robust network capable of handling diverse plastic waste streams will facilitate public-private partnerships to accelerate the establishment of chemical recycling plants across the EU (EC Communication 667, 2020). Industrial collaborations will help in promoting the circular design principles as well as encourage the production of plastics that are optimized for chemical recycling processes. Additionally, establishing incentive-driven policies for manufacturers adopting circular design practices will foster a market shift towards sustainable and recyclable plastic products. Educating and engaging different stakeholders (such as consumers, businesses, and policymakers) by implementing awareness campaigns for chemical recycling will assist in developing performance metrics to monitor the growth of chemical recycling facilities and the volume of chemical waste diverted from traditional disposal methods. Furthermore, conducting periodic assessments for the effectiveness of regulatory enhancements and infrastructure investments will help in adapting strategies based on evolving technologies and challenges. By prioritizing safe and sustainable recycling practices, the EU can lead the way in eliminating harmful chemicals from the plastics lifecycle, fostering a circular economy that benefits society, the environment, and the global competitiveness of the EU industry.

To track, assess and mitigate certain chemicals and their secondary products/pollutants, various EU policy instruments are defined:

1. **Persistent organic pollutants (POPs)** (EC Regulation 1021, 2019). It was accomplished under the European Green Deal program based on the Stockholm Convention and Aarhus Protocol to control and mitigate pollutants containing harmful and toxic chemical substances that are resistant to degradation via chemical, biological, or photolytic means. These pollutants also hold a possibility of accumulation in the living organisms through different media. The POPs were classified based on their elimination and restrictions from production and use, unintentional production, and substances that are currently under investigation. European Chemical Agency (ECHA) is responsible to identify, track, inform, and act on the current as well as the incoming POPs (EC Regulation 1021, 2019). It was reported that tracking and assessing continuous presence of POPs in different waste material streams such as construction materials, textiles, WEEEs, and ELVs could be challenging. This is due to lack of robust waste collection and sorting strategies required for the retrieval, recycling, reclamation, or reuse of POPs. Furthermore, the concentration levels of POPs found in these waste streams will play a crucial role in determining the suitable treatments and handling procedures, depending on whether the specific concentration thresholds are surpassed or not. However, determining minimum and maximum concentration thresholds for waste plastics would assist in selection of appropriate treatment methods.
2. **Restriction of Hazardous Substances in electrical and Electronic Equipment (RoHS)** (EC Directive 65, 2011). It is classified into two directives: RoHS 1 (2002/95/EC) and RoHS 2 (2011/65/EU). The RoHS 2 directive is a recast for the RoHS 1 directive and aims to develop more efficient regulatory conditions and practices, enhance the level of legislative clarity and certainty, adapt the directive to technical and medical processes, align the RoHS with other EU legislation, and prevent risk to human health in EEE waste management. The substances restricted in EEE as per RoHS include Lead (Pb), Cadmium (Cd), Mercury (Hg), Hexavalent chromium, Polybrominated biphenyls (PBP), Polybrominated diphenyl ethers (PBDE), Bis(2-ethylhexyl) phthalate (DEHP), Butyl benzyl phthalate (BBP), Dibutyl phthalate (DBP), and Diisobutyl phthalate (DIBP). The directive sets a maximum concentration value for the restricted substances which must not be exceeded. For instance, the value for Cd is 0.01 wt.%, and 0.1 wt.% for the rest of the substances. By restricting the use hazardous substances, the directive also promotes the recyclability of EEE and is, thus, closely linked to the WEEE Directive.
3. **Registration, Evaluation, Authorization, and Restriction of Chemicals (REACH) Regulation** (EC Regulation 1907, 2006)**.** It aims at protecting human health and the environment from the potential risks posed by chemicals. The role of REACH in the recycling of plastics would be to ensure that the recycled materials comply with EU chemical legislation and are safe for use. In the context of plastic recycling, REACH establishes certain criteria and exemptions for recycled or recovered chemical substances: (i) Exemption from registration; (ii)

Criteria for exemption; and (iii) Avoiding substances of very high concerns (SVHCs). REACH underscores the importance of conducting investigations at chemical recycling facilities to determine the efficacy of various techniques in removing concerning substances. Registration and assessment of concentration levels of these secondary chemical substances that inhibit circularity is important to carry out appropriate safety measures. The regulation further highlights the potential of digital technologies in enhancing the traceability of concerning substances in recycling processes.

Recently, European Commission has also developed a **policy framework on biobased, biodegradable and compostable plastics** (EC Communication 682, 2022). This framework aims to foster the systemic understanding of these green and sustainable material streams, challenges and benefits associated with their usage. If designed and produced safely using the sustainable feedstocks, these materials can bring multiple advantages over the conventional, fossil-based plastics, thus contributing heavily towards circular economy. Implementation of this framework would assist in reducing, reusing, and recycling of plastics to minimize the use of energy and resources and keep materials in the economy for as long as possible, while pursuing a toxic-free environment. For designing end-of-life (EoL) strategies such as recycling, it is important to understand the umbrella term “bioplastics”. It is often used to describe different class of materials. The terms such as “biobased”, “biodegradable” and “compostable” can be sometimes misleading. Biobased plastics can be completely or partially synthesized using biobased feedstocks, instead of fossil-based raw materials. However, they are not necessarily completely biodegradable or compostable. The objective of this policy framework is to provide clarity and deeper understanding of these types of plastics. This understanding would serve as a reference for shaping future EU policies, including those related to ecodesign requirements for environmentally friendly products, the EU Taxonomy for sustainable investments, funding initiatives, and conversations in global forums.

3.1.5 CEN standards for plastics recycling

The European Committee for Standardization (CEN) has published a family of standards on plastics recycling (see Table 3). The family covers standards for the characterization of specific plastic types (namely polystyrene, polyethylene, polypropylene, polyvinyl chloride, and polyethylene terephthalate) as well as standards harmonizing plastics recycling on a more general level. This review focuses on the latter type of standards.

EN 15343 Plastics. Recycled Plastics. Plastics recycling traceability and assessment of conformity and recycled content aims to outline the required procedures for the mechanical recycling of products that are manufactured from recycled plastics and require a proof of traceability. **EN 15347 Plastics. Recycled Plastics. Characterization of plastics wastes** establishes a framework for characterising plastic wastes, specifying the properties for which the waste supplier must provide information to the purchaser. Additionally, it identifies relevant test

methods where applicable. **CEN/TR 15353 Plastics. Recycled plastics. Guidelines for the development of standards for recycled plastics (technical report)** provides guidelines for the development of standards related to recycled plastics. It ensures consistency in terminology, methods, and specifications across the industry. This consistency is essential for creating a common understanding and facilitating the widespread adoption of recycled plastics in various applications.

In addition to above-mentioned standards, CEN has also published technical specifications related to plastics recycling. **CEN/TS 16010 Plastics. Recycled plastics. Sampling procedures for testing plastics waste and recyclates** and **CEN/TS 16011, Plastics. Recycled plastics. Sample preparation** set the technical requirements related to sampling and sample preparation, respectively, of plastics waste and recyclates.

All the standards related to plastics recycling have the potential to increase the traceability and transparency in the recycling process. They enable the tracking of key properties of waste plastics in a systematic manner, allowing stakeholders to understand the origin and history of the material. This, in turn, can increase the market confidence for recycled plastics. When suppliers consistently provide accurate and relevant information about their recycled materials, it helps building trust among stakeholders which may promote the use of recycled plastics in various applications. However, if the standardised procedures, for example sampling and sample preparation, are seen overly complex or require investments in new equipment, standardisation may also pose challenges, particularly for smaller recycling facilities.

Table 3. Summary of the EU's regulatory frameworks concerning plastics

Name of policy instrument, publication year	Linked with	Focus of policy instrument	Quantified recycling targets for plastics	Means to execute plastics' CE
European Green Deal, 2019		Carbon neutralisation by 2050		Recycled content requirements, recyclate market development, tax and incentive reform
Circular economy action plan, 2020	European Green Deal	Circular economy, waste reduction		Circular value chain establishment, recycled content requirements, eco-design, awareness raising
Chemicals strategy for sustainability, 2020	European Green Deal	Safe and sustainable use of chemicals		Eco-design, safety, and quality of recyclates, reduction of plastic waste exports
Plastics strategy, 2018	Circular economy action plan	Circular economy	By 2030, the recycling rate of plastics is over 50%, and the recycling rate of plastics packaging waste reaches similar level as other packaging materials	EPR, recyclates quality, separate collection system, modernisation and scale-up of recycling plants
Waste Framework Directive, 2008		Waste management, circular economy	No targets specifically for plastics, but general reuse, recycling and recovery targets for municipal and construction and demolition waste	EPR, end-of-waste criteria
Packaging and Packaging Waste Directive, 1994	Waste Framework Directive	Waste management Circular economy Waste reduction	By December 31, 2025, the minimum recycling rate of 50% of plastics should be achieved; followed by 55% recycling rate by 2030.	EPR, sorting at source, material identification and traceability, recycling standards
Proposal for a Regulation of the European parliament and of the council on packaging and packaging waste, 2022	Packaging and Packaging Waste Directive, European Green Deal, New circular economy action plan	Circular Economy Waste reduction Functioning of the internal market	All packaging to be fully recyclable by 2030 Several targets on reuse and refill for different sectors and packaging formats A reduction in packaging waste generation, compared to 2018, by 5% by 2030; 10% by 2035; 15% by 2040.	Recycled content requirements, requirements for recyclability and reusability, EPR, Material identification and traceability

Communication from the Commission – Beverage packaging, deposit systems and free movement of goods, 2009	Packaging and Packaging waste Directive	Functioning of the internal market	None	Tax incentives and reform, manufacturers' voluntary initiatives
Plastic Bags Directive, 2015	Packaging and Packaging Waste Directive	Waste reduction Conservation of the environment	None	Reduction of the consumption of plastic bags
Directive on single-use plastics, 2019	Plastics strategy, Waste Framework Directive, Packaging and Packaging waste Directive	Conservation of the environment Circular Economy	The collection targets for plastic beverage bottles (up to 3 L) are as follows: (a) 77 % by 2025, and (b) 90% by 2029 MSs having marine waters must establish a minimum annual collection rate for recycling waste fishing gear that contains plastic	EPR (polluter pays), separate collection, awareness raising
Decision establishing the identification system for packaging materials, 1997	Packaging and Packaging waste Directive	Harmonisation of material identification	None	Material identification codes
Construction and Demolition Waste Management Protocol, 2018	Waste Framework Directive, Circular Economy Action Plan	Waste management	None	Improved waste identification, sorting and collection, recyclates' quality
Guidelines for audits before demolition and renovation works of building, 2018	Waste Framework Directive, Circular Economy Action Plan	Waste management	None	Waste audits
Directive on end-of-life vehicles, 2000	Circular Economy Action Plan	Waste management	Current ELV: • reusable and/or recyclable to a minimum of 85% by weight per vehicle • reusable and/or recoverable to a minimum of 95% by weight per vehicle. Proposed new ELV: • require a 30% plastics recycling rate • ensure that 25% of plastic used to build a vehicle comes from recycling (of which 25% from recycled ELVs)	Current ELV: EPR, eco-design, material identification and traceability Proposed new ELV: Recycled content requirement, quality requirements

Directive on the type-approval of motor vehicles regarding their reusability, recyclability and recoverability (consolidated version), 2005	Directive on EOL vehicles	Circular economy Conservation of the environment	Several plastic-containing components have been exempted from reuse in construction of new vehicles	End-of-waste criteria, improved waste handling strategies (except reuse)
Waste Electrical and Electronic Equipment Directive, 2012	Circular Economy Action Plan	Waste management	Yearly minimum collection target should be either 65% of the average weight of EEE placed on the market in the three preceding years in the relevant Member State, or alternatively, 85% of the WEEE generated within that Member State's territory. Separated WEEE targets of 50% to 80% for recovery and 20% to 75% for recycling	Eco-design, separate collection, recycled content requirements, EPR, awareness raising
Landfill Directive, 1999	Waste Framework Directive	Waste reduction Conservation of the environment	Share of municipal waste landfilled is limited to 10 % by 2035.	Waste hierarchy
Regulation on persistent organic pollutants (POPs), 2019	European Green Deal	Environmental assessment and management of POPs entering in ecosystem	No specific targets for plastics. However, the regulatory framework was classified based on the elimination of production and use of POPs, restriction in production and usage, unintentionally generation of POPS, and chemicals under investigation.	End-of-waste criteria, traceability of POP contaminated materials
Regulation on plastic waste shipments, 2006		Waste reduction Conservation of the environment	None	Reduction of plastic waste exports
RoHS Directive, 2003		Waste management Conservation of the environment and human health	None	Material identification and traceability
Proposal for new Ecodesign for Sustainable Products Regulation, 2022		Design for circularity	None	Eco-design, material identification and traceability
Registration, Evaluation, Authorisation, and Restriction of Chemicals (REACH) Regulation, 2006	Chemicals Strategy for Sustainability	Conservation of the environment and human health	None	Material identification and traceability

Commission regulation amending Annex XVII of REACH as regards synthetic polymer microparticles, 2023	REACH	Conservation of the environment and human health Harmonisation of measures between member states	None	Reduction of microplastic pollution
Communication from the Commission: EU policy framework on biobased, biodegradable and compostable plastics, 2022	European Green Deal, Circular economy action plan, Plastics strategy, Zero pollution action plan	Conservation of the environment Circular economy Policy guidance	None	Impact assessment, Ecodesign, awareness raising
Council decision on the system of own resources of the European Union, 2020		Harmonisation of financial resources for plastic waste management	None	Tax and incentive reform
EN 15343 Plastics. Recycled Plastics. Plastics recycling traceability and assessment of conformity and recycled content	CEN publications on plastics recycling	Harmonisation of plastic recycling procedures	None	Material identification and traceability, recyclates' quality control
EN 15347 Plastics. Recycled Plastics. Characterisation of plastics wastes	CEN publications on plastics recycling	Harmonisation of plastic recycling procedures	None	Material identification and traceability, recyclates' quality control
CEN/TS 16010 Plastics. Recycled plastics. Sampling procedures for testing plastics waste and recyclates (technical specification)	CEN publications on plastics recycling	Harmonisation of plastic recycling procedures	None	Recyclates' quality control
CEN/TS 16011, Plastics. Recycled plastics. Sample preparation (technical specification)	CEN publications on plastics recycling	Harmonisation of plastic recycling procedures	None	Recyclates' quality control
CEN/TR 15353 Plastics. Recycled plastics. Guidelines for the development of standards for recycled plastics (technical report)	CEN publications on plastics recycling	Harmonisation of plastic recycling procedures	None	Standards development

3.1.6 Case study of national implementations of the EU's regulatory framework: SUP directive

The SUP directive (EC Directive 904, 2019) was selected for the analysis because it allows some flexibility on the implementation of its objectives, which makes it an interesting policy instrument to compare from the national perspective. In addition, it has raised a lot of discussion mainly due to the product bans it involves, and the extension of the producer responsibility concept.

The implementation of the SUP directive in Finland, Estonia and Norway was analysed through three themes based on selected articles of the directive that allowed more variation in the implementation of the respective objectives. The questions and implementations in each country are presented below.

As Norway is not an EU member state, the SUP directive is not binding to Norway. Norway, however, has laid down its own regulations and actions that share many of the objectives set in the SUP directive. As the SUP-related regulations in the Norwegian policy framework cannot always be directly associated with particular articles of the SUP directive, the questions are in some cases answered more broadly in the case of Norway. This also serves for providing a wider outlook for the SUP-related policies in Norway.

Theme 1: Which measures have been adopted to reduce the consumption of single-use plastics?

In relation to SUP directive, Article 4 – Consumption reduction: *Member States shall take the necessary measures to achieve an ambitious and sustained reduction in the consumption of the single-use plastic products listed in Part A* of the Annex, in line with the overall objectives of the Union's waste policy, in particular waste prevention, leading to a substantial reversal of increasing consumption trends. Those measures shall achieve a measurable quantitative reduction in the consumption of the single-use plastic products listed in Part A of the Annex on the territory of the Member State by 2026 compared to 2022.*

*) The single-use plastic products listed in Part A of the Annex are take-away cups and food containers allowing immediate consumption without any further preparation.

FINLAND

Voluntary Green Deal (Finnish Ministry of Environment, 2022) between the Ministry of the Environment and certain stakeholders in the food, catering, tourism, and packaging business to reduce the consumption of SUP packaging was signed in 2022. The primary aim of the green deal is to reduce the consumption of SUP packaging and relevant environmental effects “ambitiously and permanently”. The secondary aim is to reduce the amount of plastics used in the SUP packaging (Finnish Parliament, 2022).

National waste plan (Finnish Ministry of the Environment, 1096, 2022) defines also other actions to reduce the use of SUP products. For example, public administration offices stop using single-use plastic-containing dishes in their spaces and events. Instead, single-use dishes will be replaced by reusable dishes. In addition to measures directly related to fulfilling the obligations of the Article 4 of the SUP directive, the national waste plan also suggests measures contributing to it, such as measures related to increasing the recycling and reuse of packaging.

The two above-mentioned measures to reduce consumption are also the ones that were suggested in the report that was ordered by the Ministry of the Environment to map the alternatives for the implementation of the SUP directive. The report by Ekroos et al. (Ekroos, Haaksi, Lilja, Seppälä, & Matias, 2019) brings out that the SUP Directive itself does not define the desired percentage of consumption reduction, nor does it address how the reduction is distributed among the product categories to which desired reductions apply. The authors further suggest that the reduction could also be targeted at the plastic content in take-away cups and food containers in addition to reductions in the number of these items. This interpretation had seemingly made its way to the secondary objective in the Green Deal (Finnish Ministry of Environment, 2022) aiming for consumption reduction.

ESTONIA

Since May 2023, the packaging company must provide the end user and consumer with information about the availability of reusable food containers and cups at the point of sale. In addition, the information must be provided regarding under what conditions the point of sale accepts the sale of ready-made food and drink (that is not packaged in the sales package) in the consumer's reusable food container or cup (Estonian Ministry of Climate, 2023).

The packaging companies must take measures to achieve an ambitious and continuous reduction in the consumption of SUP food containers and cups in accordance with the general goals of the waste policy, especially the prevention of waste generation, which should significantly reverse the trend of ever-increasing consumption. This requirement applies to packaging companies that use SUP food containers and cups for packaging their goods (including when filling takes place at the point of sale). Packaging companies can choose which specific measures to adopt. The choice of measures may vary by activity area, and flexible options have been left for this (Estonian Ministry of Climate, 2023).

With these measures, a measurable reduction in the consumption of SUP food containers and cups must be achieved by 2026 compared to the calendar year for which the packaging company is obliged to submit the data on SUP products to the packaging register for the first time. In order to describe the

measures, the packaging company must prepare an action plan, which should be published on the company's website if it exists. The action plan must be drawn up no later than 01.09.2023 (Estonian Ministry of Climate, 2023).

Packaging companies must submit data on the consumption of SUP (including partly plastic) food containers and cups to the national packaging register. The first period for which data needs to be provided is 2023 (data for 2022 on a voluntary basis) (Estonian Ministry of Climate, 2023). From 01.01.2024, it is allowed to use only reusable containers and cutlery for serving food and drink at public events (Estonian Ministry of Climate, 2023). From 01.01.2024, it is allowed to use only reusable containers and cutlery for serving food and drink at public events (Estonian Ministry of Climate, 2023).

NORWAY

The ban on placing certain SUP products on the market has been implemented in Norwegian law in Norwegian Product Regulations § 2b-3 and entered into force on 3 July 2021 (Lovdata, 2020). The prohibition list contains products such as cutlery, plates, straws, balloon sticks, mixing sticks and cotton swabs with plastic, EPS food containers, drinking cups and beverage packaging made of EPS, and disposable products made of oxo-degradable plastic. In Norway, this ban could reduce 1.9 billion single-use items annually, corresponding to an annual reduction of 3600 tons (The Norwegian Ministries, 2022).

The Norwegian Product Regulations § 2b-5 introduces the labelling requirements for certain products made wholly or partly of plastic and are intended for single use, such as sanitary towels, tampons, tobacco products with filters, wet wipes and drinking glasses. The labelling must inform consumers that the product contains plastic and about the negative environmental effects of littering and unwanted waste management, e.g., thrown in the toilet or discarded in nature (Lovdata, 2020).

In 2018, the Norwegian Environment Agency ordered a report about mapping and analysis of potential measures to reduce the littering of certain single-use plastic products (Briedis, et al., 2019), which focuses on comparing two possible scenarios for SUP products, a complete transition to single-use non-plastic products and a complete transition to reusable items. The report concluded that the transition to reusable products yields the highest overall benefits in most cases, especially in the number of items bound to the marine environment.

In 2019, the Norwegian Ministry of Climate and Environment established a working group with the private sector to propose voluntary measures to reduce consumption and the environmental impacts of single-use plastic items (Norwegian Ministry of Climate and the Environment, 2019). The industry group prepared a report with voluntary measures to reduce the environmental effects of single-use plastic products and proposed a possible agreement on plastic products (Norwegian Ministry of Climate and the Environment, 2020).

Norway has a long tradition of using EPR schemes and is responsible for covering expenses associated with litter clean-up. The Norwegian Environment Agency is reviewing and considering improvements to extended producer responsibility schemes for the product groups of fast food and take-away

food containers, wet wipes, and balloons, filtered tobacco products and filters for tobacco products (The Norwegian Ministries, 2022).

Advances have also been made in plastic carrier bags. The Norwegian Retailers' Environment Fund set a target of reducing plastic carrier bag use by 20 % by 2020 compared to 2015. The board adopted a new target of reducing the use of plastic carrier bags by 50 % from 2016 to 2025 (The Norwegian Ministries, 2022).

Theme 2: What is the set minimum annual collection rate for fishing gear? Are there any specific plans for organising the collection and end-of-life management of fishing gear?

In relation to SUP directive, Article 8 – Extended producer responsibility: *Member States that have marine waters as defined in point 1 of Article 3 of Directive 2008/56/EC shall set a national minimum annual collection rate of waste fishing gear containing plastic for recycling.*

FINLAND

According to the report by Ekroos et al. (2019), the most problematic sources of pollution from fishing gear in Finland are ghost nets, as well as ropes and floats. The report estimates that the total amount of plastic fishing gear waste in Finland is however so minimal that separate collection may not be feasible (Ekroos, Haaksi, Lilja, Seppälä, & Matias, 2019).

The Finnish Environment Institute has coordinated a project in 2018–2020 that mapped the “ghost” fishing gear present in the coastal areas of the Bothnian Sea. The project concluded that professional fishing is not a significant source of ghost nets in Finland's maritime areas and the focus should be shifted to the collection, recycling, and reuse of unused gear on land (Finnish Enviornment Institute, 2019).

During the preparation of the implementation of the SUP directive, the Ministry of the Environment stated that the implementation will apply to both inland and marine waters, because there would be no means to distinguish which fishing product is applicable to which kind of water environment, and thus the producer responsibilities would become difficult to arrange if the implementation would cover only fishing gear in marine waters (Finnish Ministry of the Environment, 2021). This was strongly opposed by The Federation of Finnish Fisheries Associations which advocated for the application of the directive only to fishing gear used in commercial fishing in maritime areas as required per the directive (The Federation of Finnish Fisheries Associations, 2022). The organisation suggested that the practical management of plastic waste collection arising from maritime fishing should have been left to the industry to arrange in an economically sustainable manner.

Despite the opposition, broader implementation than stipulated in the directive was decided in Finland (Finnish Ministry of Environment, 2022), i.e., the producer responsibility for fishing gear containing plastic does not cover only fishing gear used in marine fishing but also fishing gear used in inland freshwater fishing.

The national separate collection rate for fishing gear waste was set at 10 percent (Finnish Ministry of Environment, 2022). The government noted that there is no reliable research data on the amount of fishing gear waste. Through the separate collection network, information on the quantity of fishing gear waste will be obtained in the future, and as data accumulates, the minimum collection rate can be updated (Finnish Ministry of the Environment, 1096, 2022).

ESTONIA

From 31.12.2024, manufacturers of fishing gear containing plastic must register in the problem product register and submit data on the quantities placed on the market. They must also bear the costs related to awareness-raising measures, including providing the user of the product with information about the impact of waste generated from the product on the environment and organising information campaigns to raise environmental awareness among users. Furthermore, they must organise the handling of waste arising from problematic products placed on the market and bear the resulting costs, including organising the collection and further handling of fishing gear waste and ensuring the recycling of fishing gear to a certain extent (Estonian Ministry of Climate, 2023).

NORWAY

EPR schemes for fishing gear containing plastic should be in place in the EU and Norway by 1 January 2025. The EPR aims to set requirements for collecting, reusing, and recycling used fishing equipment. In the meantime, Norway has legal requirements to collect and report data on placed or lost fishing gear and waste fishing gear (containing plastic) (The Norwegian Ministries, 2022).

The Norwegian Marine Resources Act considers it illegal to dump or abandon fishing gear at sea, and commercial fishers who lose fishing gear are obliged to perform a search. If the search is unsuccessful, the loss shall be reported to the Coast Guard or through electronic logbooks, with information about the type and amount of gear and location (Norwegian Directorate of Fisheries, 2008).

The Norwegian Directorate of Fisheries performs yearly clean-up expeditions of fishing grounds along the Norwegian coast since the 1980s. In 2020, around 100 tonnes of waste were collected. When found, the fishing gear is returned to its owner for reuse or subject to recycling (Norwegian Directorate of Fisheries, 2008). Norway's Annual Fishing Gear Recovery Program, coordinated by the Norwegian Directorate of Fisheries, utilises advanced tracking technology to locate and recover lost gear more efficiently. Integrating innovative tracking systems can potentially increase the recovery rate of lost gear to 100% (Ocean Space Acoustics, 2023).

Another prevention measure is the publication and access to real-time information on where fishing gear has been placed and when these have been removed through the interactive web portal BarentsWatch (BarentsWatch, 2024). The Norwegian Directorate of Fisheries has developed the

Fritidsfiske application (Norwegian Directorate of Fisheries, 2021) for recreational fishing. The application allows recreational fishers to report lost and found fishing gear (Norwegian Directorate of Fisheries, 2021).

The plastics from the commercial fishing sector have been quantified in one study using a material flow analysis (MFA) (Deshpande, Philis, Brattebo, & Fet, 2020). The result showed that 381 tons of fishing gear are assumed to be lost yearly, accounting for 2% of the fishing gear stock. However, this number does not account for undocumented losses and wear & tear (de Sadeleer;Askham;& Bjerkvik Alnes, 2021). The study by Deshpande et al. also showed that 4381 tons of plastic in fishing gear entered the market, 18413 tons fishing gear were used, and 4055 tons were collected and delivered for further end-of-life processing. Of the plastic waste generated from commercial fishing in Norway, 55% was segregated for recycling, 26% was landfilled, and 19% was incinerated.

Theme 3: Which measures have been adopted to improve the separate collection of plastic beverage bottles and what is their current collection rate?

In relation to SUP directive (EC Directive 904, 2019), Article 9 – Separate collection: *Member States shall take the necessary measures to ensure the separate collection for recycling: (a) by 2025, of an amount of waste single-use plastic products listed in Part F* of the Annex equal to 77 % of such single-use plastic products placed on the market in a given year by weight; (b) by 2029, of an amount of waste single-use plastic products listed in Part F* of the Annex equal to 90% of such single-use plastic products placed on the market in a given year by weight. In order to achieve that objective, Member States may inter alia: (a) establish deposit-refund schemes; (b) establish separate collection targets for relevant extended producer responsibility schemes.* The summary of discussions in this section is presented in the *Table 4. The measures to implement the Articles 4, 8 and 9 of the SUP directive in Finland, Estonia and Norway*.

*) Beverage bottles with a capacity of up to three liters, including their caps and lids, excluding beverage bottles intended and used for food in liquid form for special medical purposes.

FINLAND

The report by Ekroos et al. (Ekroos, Haaksi, Lilja, Seppälä, & Matias, 2019) about the alternatives for the implementation of the SUP directive states that the requirement for the separate collection of beverage bottles is one of the actions that has little effect in Finland. The reason for this estimate is assumably the fact the deposit-refund schemes for PET bottles have already been in place since 2008 (Suomen Palautuspakkaus Oy, 2024). The return rates for plastic bottles have been 90–92% in 2020–2022 (Suomen Palautuspakkaus Oy, 2023), which means that Finland already fulfils the collection target for beverage bottles to be achieved by 2029.

ESTONIA

This part of directive was directly transposed into Estonian law (the Packaging Act, paragraph 36) (Estonian Parliament, 2024) indicating the same collection rate as established in Article 9 – 77% by

01.01.2025 and 90% by 01.01.2029. The packaging company that places single-use plastic beverage bottles on the market must ensure the separate collection of beverage bottles. There is well-functioning deposit packaging system in Estonia and according to National Waste Plan 2022-2028 (Estonian Minister of Climate, 2021) around 90% of the plastic bottles put on the market are being collected using this system.

NORWAY

The regulations on single-use beverage plastics packaging encompass requirements for separate collection, material design (level of content of recycled plastics and that caps and lids remain attached to the containers during the products' intended use stage), extension of EPR and efforts to raise awareness. Norway's deposit return system for bottles and cans has produced good results and is regarded as a recovery and recycling role model (TOMRA, 2022). For 2022, the statistics of Infinitum (the company owning and managing the Norwegian deposit return scheme) highlight that almost 600 million plastic bottles were returned, comprising 92.8% of all sold bottles (Infinitum, Annual Report, 2022). The amount equals 22,145 tonnes of returned and recycled plastic.

Plastic beverage bottles, with other beverage containers, are subject to EPR under the Norwegian Waste Regulations (Confederation of Norwegian Enterprise, 2022). At the same time, an environmental tax is calculated according to the number of bottles and cans returned, which is waived completely when a return rate of 95 % is reached. Cumulatively, this forms a strong economic incentive for collecting beverage containers. In addition, all single-use beverage packaging is taxed if not reused in its original form.

The implementation of the SUP directive's Articles 4, 8 and 9 in Finland, Estonia and Norway are summarised in the Table 4.

Table 4. The measures to implement the Articles 4, 8 and 9 of the SUP directive in Finland, Estonia and Norway.

Country	Consumption reduction (Article 4)	EPR scheme for fishing gear (Article 8)	Separate collection of plastic beverage bottles (Article 9)
Finland	• Voluntary green deal between the Ministry of Environment and businesses • Public administration offices must replace single-use plastic items for serving food by reusable ones	• Applies to both inland and marine waters • 10% collection target	Well-functioning deposit system, about 90 % collection rates
Estonia	• Only reusable containers and cutlery allowed for serving food and drink at public events • At the point of sale, consumers must be informed about the availability of reusable food containers and cups, and under which conditions the point of sale	• EPR to be applied from 01.01.2025 • No information about the collection target	Well-functioning deposit system, about 90 % collection rates

	accepts the sale of ready-made food and drink in the consumer's own container		
Norway	• No specific reduction targets for the SUP products referred to in Article 4 • Reviewing and improving EPR schemes for a wider SUP range such as take-away food containers, wet wipes and balloons and tobacco products	• EPR to be applied from 01.01.2025. • Extensive national measures for gathering data about placed or lost fishing gear and locating and recovering lost gear • No information about the collection target	Well-functioning deposit system, about 90 % collection rates

3.2 Regulatory framework concerning batteries

3.2.1 Visions for the circular economy of batteries

One of the first strategic actions taken by the EU regarding the battery value chain was the launch of the European Battery Alliance (EBA) with key industrial stakeholders, interested Member States, and the European Investment Bank. The main goal of the EBA was to handle the immediate challenge of creating a competitive and sustainable battery manufacturing industry in Europe. The European Commission's approach is to promote a cross-border and integrated European battery ecosystem, covering the whole value chain, and focusing on sustainability, starting with the extraction and processing of raw materials, the design and manufacturing phase of battery cells and battery packs, and their use, second use, recycling, and disposal in a circular economy context (EURACTIV, 2024). The **Strategic Action Plan on Batteries (SAPB)** (EC Communication 176, 2019) was launched in July 2019 as a result of a collaborative effort within the EBA. Both industry stakeholders and Member States took part in the development of the SAPB, and many EU industry players started early adoption of the targeted actions set out in the SAPB. As mentioned, the SAPB targets the whole battery value chain, including research and innovation, financing and investments as well as standardization and regulatory framework. One of the main goals of the SAPB is to "support the sustainability of EU battery cell manufacturing industry with the lowest environmental footprint possible, for example by using renewable energy in the production process. This objective should be notably implemented through setting out requirements for safe and sustainable batteries production." (EURACTIV, 2024).

European Green Deal (EC Communication 640, 2019) and the **Circular Economy Action Plan (CEAP)** (EC Communication 98, 2020) are also highly relevant for the battery value chain. As part of the EGD, the European Union has implemented new regulations to ensure that batteries are more sustainable, circular, and safe. The new **Batteries Regulation** (EC Regulation 1542, 2023) is the first piece of European legislation taking a full life-cycle approach in which sourcing, manufacturing, use, and recycling are addressed and enshrined in a single law. The main objectives of the Battery Regulation are to ensure that, batteries have a low carbon footprint, use minimal harmful substances, need less raw materials from non-EU countries, and are collected, reused and recycled to a high degree in Europe. This will support the shift to a circular economy, increase security of supply for raw materials

and energy, and enhance the EU's strategic autonomy. The contents relevant to 2nd life and reuse of EV batteries will be described in more detail further down.

Other plans and strategies which are also relevant for the battery value chain include the **Chemicals Strategy for Sustainability** (EC Communication 667, 2020), and the **EU Action Plan: 'Towards Zero Pollution for Air, Water and Soil'** (EC Communication 400, 2021). The Zero Pollution Action Plan is an initiative by the European Commission designed to reduce and eliminate pollution in Europe, ultimately improving air, water, and soil quality. It encompasses various sectors and activities, including agriculture, industry, and transportation, aiming to implement stringent environmental standards and promote cleaner technologies. The plan also sets ambitious targets for zero pollution by 2050. In order to promote the worldwide transition to zero pollution, the Commission will provide support for initiatives aimed at improving the traceability of waste batteries and enhancing their management, especially through the Basel Convention. Specific attention is given to end the informal recycling of used lead acid batteries.

Chemicals are key elements of battery production, and there are currently several toxic chemicals used in many of the common commercial battery technologies. The aim of the Chemical strategy for sustainability to transition towards safer and more sustainable chemicals is therefore highly relevant for batteries. However, no specific visions related to the circular economy of batteries are described, even though it sees batteries as one of the key applications enabling the achievement of the sustainability goals set in the European Green Deal and seeks to secure the availability of critical chemicals for these applications.

3.2.2 Regulatory framework for batteries

Part of the text in this chapter is an excerpt from Nina McDougall's thesis titled "The operational environment for repurposing electric vehicle lithium-ion batteries for energy storage applications in the EU" (McDougall, 2023). In addition, the scope has been expanded to also include regulations and directives related to chemicals, relevant product safety, transportation, and storage of batteries.

The Waste Framework (EC Directive 98, 2008) is relevant because it defines the general definition of waste, introduces the waste hierarchy, and establishes a common framework for the extended producer responsibility (EPR). Article 3 defines waste as "any substance or object which the holder discards or intends or is required to discard". Article 4 sets the foundation for waste management with a five-step waste hierarchy; prevention, preparing for reuse, recycling, other recovery, and disposal. However, reuse is defined as "any operation by which products or components that are not waste are used again for the same purpose for which they were conceived" (EC Directive 98, 2008). This would imply that EoL EVBs should be reused for the same purpose, i.e., as the power source for EVs. Although the waste hierarchy does not explicitly mention repurposing, it strives for the best environmental outcome, so repurposing should take place before recycling. This reasoning is supported by an example of the waste hierarchy concept for EoL EVBs, where the reuse segment also includes repurpose applications. Moreover, EVBs are under EPR, which means that the producer of the EVB

(manufacturer or importer of the car) must take care of waste management of EoL EVBs at their own expense; the common practice is to pay for EVB recycling (S. Roschier, 2020).

The following safety legislations are also relevant for repurposing EVBs. **The General Product Safety Directive (GPSD)** (EC Directive 95, 2001) aims to ensure that only safe products are sold on the market. Objectives of the GPSD includes ensuring the safety of all products, including those linked to new technologies, addressing challenges posed by the growth of online sales and in particular via online marketplaces; ensuring a better enforcement of the rules, and more efficient and even market surveillance; improving the effectiveness of recalls of dangerous products in the hands of consumers.

The Low Voltage Directive (Ec Directive 35, 2014) sets safety requirements for electrical equipment. This directive applies to electrical equipment with voltage over 50V AC or 75V DC, so systems for reuse/repurposing of batteries for energy storage may be covered by this directive. Most battery system standards are not harmonized under LVD, so the application of LVD for battery systems/installations is unclear. However, the directive can apply to parts of battery systems and certain components.

Registration, Evaluation, Authorization, and Restriction of Chemicals (REACH) Regulation (EC Regulation 1907, 2006) is relevant due to the chemical substances present in batteries. There are also many standards related to battery safety, which can be found on the EU's battery standards info website (S. Roschier, 2020). Management of chemicals in batteries are covered also in the Battery Regulation and duplicates the existing REACH restriction process in Annex XVII of Regulation (EC) No 1907/2006. The Battery Regulation covers to a great extent what is covered by REACH. Additionally, the Battery Regulation covers the waste phase, which is not covered in REACH. Certain restricted substances have maximum concentration limits by weight in homogenous materials, such as lead and its compounds (1 mg/kg after extraction), and N-Methylpyrrolidone (NMP) (3000 mg/kg). Other materials listed as a potential hazardous chemical with a concentration limit include Nickel (Ni), Cobalt (Co), Copper (Cu), and Zinc (Zn). Batteries also contain fluorine-based compounds, which are restricted. This includes the electrolyte ($LiPF_6$ salt) and the binder. All the mentioned chemicals require specific safety measures during handling and are subject to concentration limits in waste products.

There are directives and regulations regarding labelling, recyclability, and recycling efficiencies. This include the **Directive on the type-approval of motor vehicles regarding their reusability, recyclability and recoverability (consolidated version)** (EC Directive 64, 2005), is a directive is for manufacturers to ensure that vehicles are "reusable", "recyclable", and "recoverable". Electric vehicles are not specified (this was in 2005). However, recycling targets are given for the whole mass of the vehicle. The **Regulation** (EC Regulation 493, 2012) **rules on calculating recycling efficiencies of the recycling processes of waste batteries and accumulators** defines how recycling efficiency are calculated in the Battery Directive 2006/66/EC. It does not however, specify targets for recycling, and it does not mention reuse. **Regulation - rules on capacity labelling of portable secondary (rechargeable) and automotive batteries and accumulators** (EC Regulation 1103, 2010) states that batteries need a label stating its energy capacity. The goal is to increase it lifetime. It is, however, unclear if this regulation also covers EV batteries.

The Ecodesign Directive (EC Directive 125, 2009) has aimed at improving energy efficiency by integrating environmental issues and life cycle thinking in the product design phase. In March 2022, the EU Commission established a proposal for a new regulation, **Ecodesign for Sustainable Products Regulation to repeal the Directive 2009/125/EC**. The new regulation will apply also to electric vehicle batteries (EVBs) and emphasizes circular economy more thoroughly. It aims to provide products that have less environmental impacts, use less energy and natural resources, have long lifetime, as well as being easy to repair and recycle. Current EVBs are not made with ecodesign in mind, and quite a few modifications would have to be implemented for EVBs to meet the criteria set in the Ecodesign for Sustainable Products Regulation (ESPR).

There are also various legislations related to the transportation of EoL EV lithium-ion batteries (LIBs). **Safety standard IEC EN 62281: Safety of Primary and Secondary Lithium Cells and Batteries During Transport** is made for harmonizing tests and requirements relevant to transport and is closely related to UN38.3. The **Directive on the inland transport of dangerous goods 2008/68/EC,** the **IATA Dangerous Goods Regulations (DGR),** the **Regulations concerning the international carriage of dangerous goods by rail (RID) – (by Intergovernmental Organization for International Carriage by Rail (OTIF))**, and the **European Agreement concerning the International Carriage of Dangerous Goods by Road (ADR)** have packing and storage requirements related to logistics. The requirements vary depending on whether the battery is transported inside a product or separately, and whether it is an EoL battery or not. The ADR agreement includes detailed requirements for proper labelling, packaging, transportation units and the vehicle itself, crew trainings & certification as well as for prohibition to drive through tunnels. Additionally, the IATA DGR describes the requirements related to transportation of lithium batteries and lithium-ion batteries by air, which also has limitations on size of the battery to be transported in terms of energy stored. All LIBs must also pass the **UN 38.3 test** before they can be transported. Here, the batteries are tested against, among others, shock, external short circuit, impact, crush, and forced discharge. An important thing to note is that if the battery management system (BMS) of the EVB is replaced during the repurposing process, the UN 38.3 test must be redone, which is expensive and results in additional costs.

For installing and implementing stationary battery systems into buildings or in other applications, there is no specific governing legislation. However, some international standards are in place and many more are under development. The international standards are in many countries translated and adapted into national standards. Although some standards currently exist for 1st life batteries, there are no standards in the EU that cover repurposed battery systems. However, in the US and Canadian markets, there is the **UL 1974: Standard for Evaluation for Repurposing Batteries**, which deals with aspects such as safety, disassembly, examination, analysis of BMS data, and testing related to the repurposing of EVBs for energy storage systems (ESS). Legislation about ESS is also relevant, as EVBs are repurposed for different energy storage applications. However, there is no existing legislation focusing on the safety of ESS. Thus, other existing safety standards related to, e.g., the fire safety of buildings, are applied for ESS. Furthermore, there is currently no legislation concerning the long-term storage of EoL EVBs (S. Roschier, 2020). The most important standards concerning installations and implementation which are currently under development, are together with all other legislation summarized in the table at the end of this chapter.

EU Battery Regulation is adopted by the European Council since the middle of 2023 (EC Directive 98, 2008). This new regulation comes to update the previous Battery Directive from 2006, and it covers all types of batteries, including all chemistries and from small portable applications, mobility, and medium and large size stationary energy storage applications. The entire life cycle of batteries is covered, from production, use, reuse, and recycling.

The Battery Regulation aims to contribute to meeting the European internal demand for batteries while increasing resilience and sustainability of batteries put into the market. It aims to increase battery sustainability, increase resilience, and close material loops, and reduce environmental and social impacts. The following actions are introduced in this regulation:

- Separate battery classification category for EVBs.
- Requirement for recycled content in new batteries with mandatory minimum levels.
- Safety requirements for stationary battery energy storage system (BESS).
- Increased recycling efficiencies, and specific material recovery targets for Cobalt, Copper, Lead, Nickel, and Lithium.
- Requirements for repurposing industrial batteries and EVBs for a second life.
- Requirements for labelling and information.
- BMS, electronic battery passport and a QR code.

Different articles of the new Battery Regulation mention aspects relevant to stationary BESS and 2nd life of EVBs. The safety aspects of stationary BESS, such as the need for technical documentation demonstrating their safety for normal operation and use and the tests for safety parameters set out in Annex V, are covered in article 12. The safety parameters to be demonstrated include thermal shock and cycling, external short circuit protection, overcharge protection, over-discharge protection, over-temperature protection, thermal propagation, mechanical damage by external forces, internal short circuits, and thermal abuse.

Batteries should be labelled with a QR code providing information regarding battery type, model, chemistry, and critical raw materials (CRMs) composition, which should be in place by the start of 2027, as stated in article 13. Article 14 sets the requirements for BMS. All EVBs must include a BMS that stores relevant parameters for determining state of health (SoH) and remaining useful life of the EVBs, so that repurposing operators can access these data. Parameters for SoH include remaining capacity, overall capacity fade, remaining power capability, power fade, remaining round trip efficiency, actual cooling demand, the evolution of self-discharging rates, and ohmic resistance and/or electrochemical impedance. Parameters for determining remaining useful life include manufacturing date of the EVB, date it was put into service, energy throughput, and capacity throughput. The BMS should also include a software reset function, in case used batteries require different BMS software. If the reset function is used, the original battery manufacturer shall not be held liable for any breach of safety or functionality of the battery occurring during 2nd life use. This latter addition relating to a shift in producer responsibility could potentially make it easier for the original equipment manufacturers to provide used EVBs for the 2nd life BESS market.

The responsibility of battery producers and economic operators is further elaborated on article 56, which sets the requirements for the Extended Producer Responsibility (EPR) scheme for EVBs. This article states that the responsibility for EVBs lies with the economic operators that put the products into the European market for the first time. This includes new batteries and battery systems based on reused, repurposed, or remanufactured batteries. Article 45 describes the responsibilities of economic operators providing 2nd life battery solutions regarding performance testing, safe packing, and shipment, and that the companies selling the batteries must ensure that the batteries comply with all the requirements of the Battery Regulation. Documentation stating that EVBs have been remanufactured in accordance with the Battery Regulation must be provided by remanufacturing companies. Obligations regarding the documentation of SoH and general conditions of the battery to prove it is suitable for reuse and repurposing, as well as documentation of safe handling and transportation of used batteries, are covered in article 73.

Article 74 states requirements for handling waste batteries and repurposing EVBs, describing the information which must be available to waste management operators and to companies preparing batteries for reuse or repurposing. Among these, it is noteworthy citing information regarding proper treatment of end-of-life batteries regarding dismantling and safe removal of the battery, as well as protective measures regarding safety and fire protection during storage, transport, and handling.

All batteries larger than 2 kWh put in the market in Europe from 2027 must have a digital battery passport, as described in articles 77 and 78, with publicly available data as well as sensitive data with restricted access. Details of information that should be available are listed in Annex XIII.

While no quantitative requirements are set for the amount or end-of-life batteries set for repurposing and 2nd life, the Battery Regulation has set targets for recycling rates and recycled contents for all batteries in article 71 and Annex XII. By 2025, 65% of all end-of-life Li-ion batteries should be sent to recycling, and this share increases to 70% by 2030. The targeted recovery rates for CRM from Li-ion batteries are shown in the Table 5, with material recovery rates ranging from 50% to 90% in 2027, and 80% to 95% by 2031. In addition, new industrial batteries, EVBs, and light mobility batteries put into the market from 2031 have a minimum mandatory recycled content for Cobalt, Lead, Lithium and Nickel, as shown in the Table 5, and should have accompanying technical documentation demonstrating the recycled material content.

Table 5. Minimum recycled content and material recovery targets set in the Battery Regulation.

Target	Year	Cobalt	Copper	Lead	Lithium	Nickel
Minimum recycled content in new batteries	2031	16 %	-	85 %	6 %	6%
	2036	26 %	-	85 %	12 %	15%
Material recovery targets for end-of-life batteries	2027	90 %	90 %	90 %	50 %	90%
	2031	95 %	95 %	95 %	80 %	95%

3.2.3 Case study of national implementations of the EU's regulatory framework

Which measures have been adopted to ensure safe installation and operation of repurposed stationary battery system?

FINLAND

Requirements for stationary battery systems are divided under various acts and standards. Repurposed battery systems do not have specific regulations, but they are covered with the same regulation as new batteries. Standard SFS-EN IEC 62485-5:2021 Safety requirements for secondary batteries and battery installations. Part 5: Safe operation of stationary lithium-ion batteries applies the installation of stationary secondary batteries having a maximum 1500 VDC to any part of the power network. It describes the principal measures for protection during normal operation or under expected fault conditions against hazards generated from electricity, short-circuits, electrolyte, gas emission, fire, and explosion. The standard also specifies some requirements for the proper location of the system (SFS-EN IEC 62485-5, 2021).

Electrical safety act includes all electrical equipment such as BESS that has rated power 50 – 1000 VAC or 75 – 1500 VDC. Act determines certain safety criteria for equipment such as compliance with EU requirements. Based on the act, all devices need documented commissioning inspection and verification inspection made by certified person (Finnish Ministry of Economic Affairs and Employment, 2016). Decree of the Ministry of the Environment (Finnish Ministry of Environment, 2018) on fire safety of buildings defines building's safety requirements based on the fire load. Requirements include topics such as fire classification, prevention of containment of fire, exit routes and maintenance of fire suppression systems. Rescue act gives power to rescue authority to inspect the location, give statement to construction authority as well as to order the operator to acquire appropriate firefighting system (Finnish Ministry of the Interior, 2011).

The Security Services' Partnership network has created recommendations for Solar system's safety. It includes recommendations for batteries and battery rooms: Battery room is recommended to be placed separately from the building, in an easily accessible place and at least to 8 meters from the

building. Batteries should not be placed near buildings, emergency routes, or main routes, streets, or gates. Two alternative routes should be available for the emergency team. If batteries are inside the building, they should be accessed directly from outside. In houses, batteries are recommended to be placed in spaces that are not living spaces or in direct connection with them. An appropriate placement location could be a fire compartmentalized technical space with separate ventilation from living spaces. The space should be arranged in such a way that no fire load can accumulate near the batteries. It is appropriate to arrange a visit to the premises directly from the outside without going through the living spaces (Finnish Security Services' Partnership network, 2023).

NORWAY

The new Battery Regulation will be enforced in all 27 EU Member States. However, Norway is not a member of the EU. Instead, it is one of the four members of the European Free Trade Association (EFTA), an intergovernmental organization established to promote free trade and economic integration between its Member States within Europe and globally. Furthermore, the European Economic Area (EEA) Agreement unites the EU Member States and three EFTA countries – Norway, Iceland, and Liechtenstein – in the Internal Market. The EEA Agreement requires incorporating EU legislation regarding the four freedoms, state aid, competitions, and horizontal policies (The European Free Trade Association, 2023). Thus, Norway must implement EU laws concerning competition, investments, labour, procurement and sale of services, banking and insurance, and trade in goods (The Explorer, 2020). The proposal of the Battery Regulation is marked with “Text with EEA relevance,” which implies that the new Regulation will be incorporated into the EEA Agreement (Brick Court Chambers, 2016). Therefore, once the Battery Regulation enters into force, its contents will be updated in the legislation of Norway. For instance, currently, Norway’s waste recycling and treatment regulation, **Forskrift om gjenvinning og behandling av avfall** (avfallsforskriften), follows the requirements of the EU Batteries Directive (Lovdata, 2004).

An unregulated market for EoL EVBs is growing in Norway due to the absence of a regulatory framework. Car wreck companies and private people sell EoL EVBs online, and the highest bidder gets the battery. As a result, many do-it-yourself (DIY) projects are taking place, such as reusing EVBs for EVs or repurposing them for residential energy storage applications (Grudzień, P., 2022). This is problematic because EVBs unsuitable for reuse or repurpose applications may be used due to the absence of safety protocols and standardized procedures. Also, since anyone in principle can buy and assemble used EVBs, the knowledge of the people handling the batteries is not necessarily sufficient for ensuring proper and safe use. Thus, it is crucial to include the safety aspects of both reuse and repurpose in the legislative framework to avoid accidents when working with EVBs and to ensure adequate safety of second-life applications (S. Roschier, 2020). Installation of both new and 2nd life BESS in Norway are governed by standards which are set by NEK (Norsk Elektroteknisk Komité). The most relevant standard is **NEK 486** which concerns stationary Li-ion batteries and is normative reference in **NEK 400:2022**. This standard is relevant for stakeholders within real-estate development and planning, battery installation, operation and maintenance for UPS, emergency power, and energy storage for private and public buildings. NEK 486 is a Norwegian translation of the international standard **IEC 62485-5:2020 Safety requirements for secondary batteries and battery installations**. There is also **NEK 487** which states safety requirements for secondary batteries and battery installations. This

is a collection of recommendations which also includes content from NEK 486. Although there are standards describing safe installation of secondary Li-ion battery systems, none of the standards are specific to 2nd life batteries.

In June 2022, Norway launched its first national battery strategy, part of Norway's green industrial initiative (EC Communication 98, 2020), to develop a complete, profitable, and sustainable battery value chain (BVC), from mineral extraction to recycling. The contents of the battery strategy include the Norwegian Government's vision for a sustainable BVC, a description of the BVC and Norwegian actors, technology development, market conditions, trends, European mobilization, and Nordic cooperation, as well as ten actions for sustainable industrialization. However, the main goal of the strategy is to make Norway an attractive host country for private capital and significant investments throughout the entire BVC, which would create thousands of new jobs and lead to an estimated turnover of 90 billion NOK in 2030 (EC Communication 28, 2018).

The strategy also presents the entire BVC. Once the EoL battery is collected, there are two alternative options. The battery can either be repurposed for a second-life battery system or recycled into materials that can be reused for battery manufacturing or used for other purposes. However, the second-life battery systems will eventually face recycling. The strategy also discusses the different Norwegian repurposing actors. For second-life battery systems, it mentions ECO STOR, Evyon, Alternative Energi, and Marna Energi, which provide BESS for households, often in combination with solar and wind power production, and Hagal, which offers single-cell monitoring to maximize the utilization of used and new batteries. It also identifies that repurposing of batteries could be an attractive opportunity for value creation in Norway, as they are at the forefront of EV adoption (EC Communication 28, 2018).

The main recycling actors Hydrovolt, Glencore Nikkelverk, and Resitec are also introduced. The strategy emphasizes that Norway has an excellent starting point for recycling due to its specialized competence and industrial facilities already in operation. The new recycling requirements of the Battery Regulation are also acknowledged. Many of the ten actions introduce supporting measures for large-scale establishments such as recycling facilities. For instance, action four discusses the financial challenges of establishing large facilities, which is why the Government is considering granting guarantees, loans, and equity to support major investment projects. In addition, action seven aims to provide access to industrial areas with adapted infrastructure, especially for new large-scale establishments. Also, action nine emphasizes supporting pilot municipalities hosting major industrial establishments (EC Communication 28, 2018).

In conclusion, the battery strategy recognizes that repurposing is an opportunity to manage EoL batteries. It also acknowledges that various actors are already in the field and that repurposing is a potential new area in which Norway could thrive. However, the ten actions do not introduce support intended explicitly for repurposing. Instead, the support is aimed at large establishments like recycling. Still, it is essential to note that even though the ten actions do not specifically focus on repurposing, this does not mean that the supportive measures cannot be applied to repurposing operations. The Norwegian battery strategy does not introduce targets or requirements for repurposing EVBs.

Therefore, the current and upcoming regulatory environment created by EU legislation also applies in Norway.

ESTONIA

An electronic vehicle battery is classified according to Estonian legislature as an industrial battery, i.e., a battery designed exclusively for industrial or professional use or used in any type of electric vehicle (Estonian Ministry of Climate, 2021). In general, handling of batteries and accumulators is governed by the Estonian Waste Act (The Estonian Parliament, 2004). In addition, there are several government regulations that set the requirements and procedures for the collection, reuse and disposal of batteries (Estonian Government, 2008), handling requirements for used batteries and accumulators (Estonian Ministry of Environment, 2008), procedures regarding marking of batteries (Estonian Ministery of Environment, 2007) as well as several regulations on problematic product, such as register of problematic products (Estonian Government, 2006), methods of providing information to the user of problematic product (Estonian Ministry of Environment, 2013). and the presence of hazardous substances in problematic products (Estonian Ministry of Environment, 2016).

The manufacturer and distributor are obliged to take back portable and motor vehicle batteries and accumulators from the user free of charge through the distributor's sales points. This implies that battery can be returned to any store and kiosk that sells batteries of this type. Hence, the distributor must collect battery at his point of sale together with the manufacturer. The distributor may not refuse to cooperate with the manufacturer in the collection of waste batteries and accumulators whose batteries and accumulators can be purchased at his point of sale (Estonian Ministry of Climate, 2021).

Furthermore, an important part of the take-back system is the raising of awareness of users of batteries and accumulators to ensure more efficient collection of battery and accumulator waste. From September 26, 2008, all portable and motor vehicle battery and battery sales points must display notices that battery can be returned to the point of sale. Notices must be in a place visible to everyone and in sufficiently large letters (Estonian Ministry of Climate, 2021). In addition, users of batteries or accumulators must be informed through nationwide information campaigns. The topics discussed in the information campaign are stipulated by the regulation of the Minister of the Environment. Information campaigns do not have to be carried out solely by the manufacturer of an industrial battery and accumulator, who may make available the information other than through an information campaign (Estonian Ministry of Environment, 2013).

The summary of the EU’s regulatory frameworks concerning batteries and their national implementations based on case studies in Finland, Norway, and Estonia are presented in the Table 6.

Table 6. Summary of the EU's regulatory frameworks concerning batteries

Name of policy instrument	Launch year	Linked with	Value chain parts concerned and main implications
European Green Deal	2019		Will cover the whole value chain for batteries, from materials sourcing to reuse and recycling.
Chemicals strategy for sustainability	2020	Priority: European Green Deal	Materials sourcing and production, as well as battery cell manufacturing and recycling. No specific visions related to circular economy of batteries but sees batteries as one of the key applications for achieving the sustainability goals set in the European Green Deal.
Circular Economy Action Plan	2020	Priority: European Green Deal	Will cover the whole battery value chain.
Zero Pollution Action Plan	2021	Priority: European Green Deal	Will promote electrification and implementation of batteries in more sectors to reduce pollution from fossil fuels. Commission will provide support for initiatives aimed at improving the traceability of waste batteries and enhancing their management, especially through Basel Convention. Specific attention is given to end the informal recycling of used lead acid batteries.
Strategic Action Plan for Batteries	2018	Developed by the European Battery Alliance in a response to Asian dominance in the battery market	The Strategic Action Plan for Batteries presents a comprehensive framework of regulatory and non-regulatory measures to support all segments of the battery value chain. Specific areas in focus are securing access to raw materials, supporting large-scale European battery cell manufacturing and a full competitive value chain in Europe. Significant resources are allocated to research and innovation projects and disruptive technologies in the battery sector. Sustainability of battery manufacturing is in focus as well as strengthening a highly skilled workforce.
EU Battery Regulation	2023	European Green Deal and Strategic Action Plan for Batteries	The new regulation covers the entire life cycle of the batteries, including production, use, reuse, and recycling, ensuring safe, sustainable, and competitive batteries. All types of batteries are covered by the new regulation, including all chemistries and from small portable applications to medium and large size stationary energy storage applications. Specific collection targets are set: 45% in 2023, 63% in 2027, 73 % in 2030. Recycling targets are set for Ni, Co, Cu, Pb, Li. Additionally, targets for amounts of recycled materials used in new batteries are implemented gradually. For 2nd life purposes, it will be required to have a reset button in the battery management system.

			A battery passport containing all information from cradle to grave will be implemented from 2027 for all batteries larger than 2 kWh.
Waste Framework Directive	2008, latest amendment in 2023		Relevant for 2nd life batteries and end of life batteries. Defines the general definition of waste, introduces the waste hierarchy, and establishes a common framework for the extended producer responsibility (EPR). EVBs are under EPR, which means that the producer of the EVB must take care of waste management of EoL EVBs at their own expense.
General Product Safety Directive 2001/95/EC	2001	Will be replaced by the General Product Safety Regulation (GPSR) starting Dec. 13th, 2024	Relevant for down-stream part of the value chain, including implementation, use, 2nd life and recycling. Objective is to ensure safety of all products, including those linked to new technologies. This also addresses challenges posed by the growth of online sales and marketplaces, which is a challenge for many EoL batteries being sold by private persons and non-certified actors.
Low Voltage Directive 2014/35/EU	2014		Concerns implementation and use of batteries. Sets safety requirements for electrical equipment with voltage above 50V AC or 75V DC. It is unclear if the directive applies to batteries, but it could apply to parts of a battery system.
Registration, Evaluation, Authorization, and Restriction of Chemicals (REACH) Regulation (EC) No 1907/2006	2006		Relevant due to the chemical substances present in batteries and will include materials sourcing and production as well as battery cell manufacturing and recycling. The REACH Regulation includes rules on the registration of substances, bans or other restrictions on substances, authorisation requirements for particularly dangerous substances and rules on informing customers.
Directive on the type-approval of motor vehicles regarding their reusability, recyclability and recoverability (consolidated version)	2005		This directive is for manufacturers to manufacture vehicles that are “reusable”, “recyclable”, and “recoverable”. Electric vehicles are not specified (this was in 2005). However, recycling targets are given for the whole mass of the vehicle.
Regulation - rules on capacity labelling of portable secondary (rechargeable) and automotive batteries and accumulators	2006		This regulation only states that batteries need a label stating its energy capacity. The goal is to increase its lifetime. It is unclear if this regulation covers EV batteries. However, this labelling will also be covered by the EU Battery regulations, which entered into force in 2023.
Regulation - rules on calculating recycling efficiencies of the recycling processes of waste	2012	Battery Directive 2006/66/EC (now replaced	Defines how recycling efficiency are calculated in battery directive 2006/66/EC. Does not specify targets for recycling. Does not mention reuse

batteries and accumulators		by the EU Battery Regulation)	This regulation is likely to be replaced by new enforcements in the EU Battery directive.
Regulation on Eco design for Sustainable products	2009	EU Commission has proposed a new regulation Ecodesign for Sustainable Products Regulation to repeal the Directive 2009/125/EC	Aimed at improving energy efficiency by integrating environmental issues and life cycle thinking in the product design phase. The current regulation does not cover EVs. However, the new regulation will apply also to electric vehicle batteries (EVBs) and emphasises circular economy more thoroughly. It aims to provide products that have less environmental impacts, use less energy and natural resources, have long lifetime, as well as being easy to repair and recycle.
Directive on the inland transport of dangerous goods 2008/68/EC	2008		Includes rules for transportation of hazardous goods by road, rail and inland waterway. Based on the directive Member States shall bring into force the laws, regulations and administrative provisions necessary comply with the directive. The directive is heavily leaning on ADR, RID and ADN agreements (described below) and based on it, member states should be compliant with them.
European Agreement concerning the International Carriage of Dangerous Goods by Road (ADR)	1968, latest amendment in 2023		Describes guidelines for transport of batteries to disposal or recycling as well as new batteries. Lithium and lithium-ion batteries are handled as hazardous goods and stricter requirements apply compared to other batteries (i.e. Pb-acid, NiCd). Batteries are categorized according to chemistry, power and total energy stored. Proper labelling, packaging, transportation unit, vehicle, crew training and certification are all described.
European agreement concerning the international carriage of dangerous goods by inland waterways (ADN)	2008		Enforces all member states to follow UN's Requirements for transportation for hazardous goods. Classification of lithium batteries similar to ADR and RID. Includes detailed requirements related to for example labelling, packing, documentation, safety equipment and required training.
Regulations concerning the international carriage of dangerous goods by rail (RID) – (by Intergovernmental Organization for International Carriage by Rail (OTIF))	2023		Requirements for transportation for hazardous goods by rail by OTIF. EU's directive on inland transport of dangerous goods enforces all member states to follow the agreement. RID is harmonized with ADR and ADN and for example classification of lithium batteries is similar in these documents. Includes detailed requirements related to for example labelling, packing, documentation and required training.

Standard DIN VDE V 0510-100: 2023-04 Safety of lithium-ion batteries from the vehicle sector for use in stationary applications.	2023	Will be used as a basis for other European standards on the subject. Covering the safety assessment, testing and design for batteries approved for vehicle use to be approved for stationary applications. Specifically for repurposing, not reuse, and not relevant for aging	Requirements are specified that consider the safety of traction batteries during their complete life cycle - storage, transportation, installation, operation, maintenance, disassembly and feeding for recycling. However, the document does not cover the requirements for battery energy storage systems (BESS) that use the traction batteries described here. These requirements are defined in other codes. The document focuses on industrial applications that are not accessible to non-experts. Home storage systems are not considered in this edition. Will be very important for approval of EV batteries for repurposing in stationary application, as the foundation for standards for safety assessments/design/testing.
Safety standard IEC EN 62281: Safety of Primary and Secondary Lithium Cells and Batteries During Transport	2019	Closely related to UN38.3	Sets standards for packaging of batteries during transport. The UN38.3 is a test protocol which batteries must pass in order to be approved for transport.
Standard IEC 62933-5-3 Performing unplanned modification of electrochemical based system	2023	Related to IEC 62933-5-2, which contains general safety requirements for grid-integrated ESS	This document provides safety requirements, considerations, and process steps when unplanned modifications of the BESS are to be carried out. IEC 62933-5-3 is relevant if an existing ESS is getting reused/repurposed batteries installed. For new ESS using reused/repurposed batteries, it does not apply. Only relevant for changes to existing ESS or ESS designs that were originally made/designed for 1st life batteries.
Committee IEC TC 21: IEC 63330 (Requirements of reuse of secondary batteries)	Upcoming		Will be one of the central standards for reuse/repurposing of Lithium-ion batteries. Very general, states that batteries must be tested, and safety must be assessed, and some requirements of what information is needed for repurposing.
IEC 61427-2 Secondary cells and batteries for renewable energy storage	2015		Can be used, but not specific for reuse/repurposing. Mostly test criteria for performance. Not specific for 2nd life.
IEC 62660 Secondary lithium-ion cells for the propulsion of electric road vehicles	2022		Cell level, automotive, but results can be relevant for recertifying. One of many standards for safety certification of new batteries. Results can be relevant to determine safety of reuse/repurposing.
IEC 62485 Safety requirements for secondary	2020		Can be used for the system, but not specific for reuse/repurpose.

batteries and battery installations			
IEC 62619:2022 CMV, Safety requirements for secondary lithium cells and batteries, for use in industrial applications	2022		This standard addresses new (1st life) batteries, not reuse/repurposing. Still, approval to this standard in the 1st life informs the reuse/repurposing operators of the safety design of the battery.
IEC 63338 General guidance for reuse of secondary cells and batteries	Upcoming		This standard will be an important part of the guidelines for reuse/repurposing of Lithium-ion batteries. Guidance around safety risks, agreements between original producer and repurposed application manufacturers. Guidance for repurposing, mainly intended for original manufacturers as well as qualified reuse/repurpose application manufacturers.
Norway's waste recycling and treatment regulation, Forskrift om gjenvinning og behandling av avfall (avfallsforskriften)	2004		This regulation follows the requirements of the EU Battery Directive. Since the EU Battery Directive has been replaced by the EU Battery Regulation, the Norwegian waste and recycling regulations needs an update. Also, since Norway is not a member of EU, the EU Battery Regulation does not automatically apply as is in Norway. New legislation is being developed concerning sustainable products and value chains, which was sent for evaluation in summer/fall of 2023. The Ministry of Climate and Environment plan to put forward a motion for a new directive in 2024, and the EU Battery Directive cannot be implemented until this new legislative framework for sustainable products and value chains is in place. Implementation of the EU Battery Regulation in Norway also depend on evaluations done by the EEA countries.
Finnish Government Act on batteries, Valtioneuvoston asetus paristoista ja akuista (2014/520) (Battery Directive)	2014		As Finland is part of the EU, it currently follows the Battery Directive. The Finnish Government Act on batteries, Valtioneuvoston asetus paristo-ista ja akuista (2014/520), has incorporated requirements of the Battery Directive.
Finnish Waste Act, Jätelaki (646/2011)	2011, latest amendment in 2022		States that operators other than the producer may offer services related to the reuse of products or their preparation, so it is not limited to the manufacturer's right. Therefore, operators other than battery manufacturers should have the opportunity to establish reuse or repurpose services for EoL batteries.

3.3 Regulatory framework concerning biobased side and waste streams

The EU has set several policy instruments which affect the circulation of biobased side and waste streams in EU member states. The TREASoURcE project concentrates mainly on biobased side and waste streams generated from agriculture, but also on biowaste, wastewater and forestry residues. EU level regulatory framework was assessed to examine to which extent it influences or controls the circulation of biobased side and waste streams. Collection, treatment, and recycling were aspects concentrated on. The EU instruments assessed included directives, strategies, action plans, and standards (see the summary presented in Table 7).

3.3.1 Visions for the circular economy of biobased side and waste streams

The European Green Deal is the EU's strategy to reach climate neutrality by 2050 and a large amount of legislation has recently been adopted or is being developed. From the perspective of circulation of biobased side and waste streams the following strategies and action plans relevant for this task were examined:

- EU Biodiversity Strategy for 2030
- Farm to Fork Strategy
- New Circular Economy Action Plan
- Chemicals Strategy for Sustainability
- Bioeconomy Strategy (EC Directorate-General for Research and Innovation, 2018)

Common for all the strategies and action plans are the aims of ensuring safe livelihood and sustainable development in the sectors they cover. All of them recognize the potential of bioeconomy in creating new circular business models and bio-based innovations and have a vision to promote these. Some measures in the strategies contribute indirectly to circularity. The target to increase the percentage of agricultural land under organic farming (Farm to Fork Strategy), for example, will also most likely increase demand for biobased fertilizers, thus, increase circularity in the field. Recycling biobased residues to recover nutrients and to produce bioenergy is mentioned in several of the papers. The strategies examined do not specify actions for collection, treatment nor recycling of biobased side and waste streams, but rather draw a wider image of the bioeconomy sector's development potential. Concrete targets for circulation of these materials are lacking from these papers, which could slow down transition to circular economy.

Even though the action plans and strategies emphasize different aspects, they are in line with several key values regarding the bioeconomy sector. Bioeconomy is seen as an important sector for business and employment growth. Interest in bioenergy is mentioned in several of the action plans and strategies and especially advanced bioenergy options which utilize waste and residues are considered important. Circular nutrient cycles are also mentioned in all the strategies. Based on the strategies and action plans, an increase in utilization of bio-based side and waste streams can be expected to enhance usage of fossil-free products and to promote sustainability. Increased demand for biobased products has raised contradictions with sustainability targets, for example, potential negative affect on biodiversity (European Environment Agency, 2023).

The standardization of collection, sorting or recycling of biowaste and bio-based side streams is still in preliminary stages (Kemesta ry, Finland; Minna Annala), but there are standards for bio-based products. CEN has technical committees for biogas, solid waste, or biofuels, sustainably produced biomass for energy applications (standards related to RED II), and for bio-based products; and ISO has committees for Solid Biofuels, Biogas; Sustainable processes for wood and wood-based products.

3.3.2 Regulation of biobased side and waste streams

3.3.1.1 Agricultural by-products (animal by-products and plant-based residues)

The **animal by-products regulation framework,** consisting of **animal by-product (ABP) regulation** (EC Regulation 1069, 2009), complemented by **Commission Regulation** (EC Regulation 142, 2011) and **Commission Delegated Regulation** (EC Regulation 1605, 2023), governs the entire process of handling, gathering, processing, and trading animal by-products and its derived products. The key principles of this regulatory framework revolve around ensuring safe sourcing, treatment, and end usage of these products. This is accomplished through implementing traceability and risk-assessment measures throughout the processing and application of both raw materials and derived products. This legislation sets technical standards for animal by-products, applies enforcement measures proportionate to risk, conducts official control in laboratories and processing sites. In addition, it emphasizes traceability from food production, tailoring solutions for transport, processing, and imports based on risk levels. Notably, the regulatory framework designates the end point in the manufacturing chain, which marks the release of certain animal-derived products such as pet food, biodiesel, hides, skins, fertilizers from ABP regulation, enabling their free trade within the EU without restrictions. Specifically, the **Commission Delegated Regulation** (EC Regulation 1605, 2023) streamlines access to certain animal-derived fertilizers and soil improvers (processed manure, compost and residues resulting from the transformation of animal by-products in a biogas plant) while ensuring no risk to human or animal health through scientific insights. This marks a significant advancement in facilitating access to organic fertilizers and promoting the recovery of animal by-products.

The recently updated **Renewable Energy Directive** (RED) (EC Directive 2413, 2023) sets EU-level sustainability criteria for biomass used for energy production, including agricultural biomass. The aim is to ensure that the use of bioenergy provides reductions in greenhouse gas (GHG) emissions compared to fossil fuels and that biodiversity is protected. It requires a 50-70% reduction on biomass-based energy (depending on the year the biogas plant was built, reduction of 80% is required for biogas plants built after 1.1.2026) compared to fossil fuels. The RED III, published in autumn 2023, has increased objectives to increase the amount of renewable energy of energy consumed to 42,5% by 2030, from the previous target of 32% in RED II (2018/2001). The increased objectives can be expected to increase the demand for bio-based waste and side streams utilized for energy.

The directive also regulates grass utilized for energy production. It has been considered challenging to achieve the emission reductions required by the directive if grass is grown solely for energy

production (Rasi, et al., 2019), and particularly for electricity and heat production, for which emission reduction requirements are higher than for transport fuel production (ibid.). From the perspective of agriculture, the directive requires biogas plants to determine GHG emission savings and to prove the sustainability of the plant which utilizes crop biomass extensively. RED III introduces maximum time limits for authorization processes for biogas plants, which should speed up the processes. Lengthy processes to get required permissions and the complexity of required permissions has been a challenge.

In relation to energy production and other industrial operations, **Industrial Emissions Directive** (EC Directive 75, 2010) establishes regulations on the comprehensive prevention and control of pollution. The directive requires member states to implement actions to guarantee that permit applications for industrial operations include, among other things, strategies for preventing, preparing for re-use, recycling, and recovering waste generated by the facility. In addition, it demands that residues are to be minimised both in amount and harmfulness, and they are to be recycled where appropriate.

In addition to the policy instruments described, financial instruments influence transition towards circular economy. **Common agricultural policy (CAP)** is the main funding source for agriculture, and for example, for implementing the Farm to Fork Strategy targets (Midler;Pagnon;Nadeu;& Aaron, 2023). Due to the central role of CAP, it has significant influence on the promotion of CE practices in agriculture. Other financial instruments potential to affect CE include taxation (VAT exemptions, for example), targeted subsidies, incentives for specific activities, investments in relevant infrastructure, startup funding, and payments for ecosystem services (Green Budget Europe, The Ex'tax Project, Institute for European Environmental Policy, 2018).

3.3.1.2 Biowaste

Waste Framework Directive (WFD) (EC Directive 851, 2018) is the legal framework for treating and managing waste in the EU. The directive introduces an order of preference for waste management called the "waste hierarchy" ranking from most preference of prevention, reuse, recycling, recovery, to disposal. Concerning the biowaste, WFD sets all member states legally binding to separate biowaste at the source for collection by 31st December 2023. In addition, WFD requires at least 55% the municipal waste must be recycled by 2025, with the increase to 60% by 2030 and to 65% by 2035. As biowaste is the main composition of municipal waste generation, these practices drive circular bioeconomy transition by improving biowaste separate collection and its further recovery and utilization. Moreover, WFD lays down the end-of-waste criteria which defines when waste ceases to be waste and becomes the product or secondary materials. According to Article 6 of the WFD, certain specified waste ceases to be waste when it has undergone a recovery operation and complies with existing legislation and standards applicable to products (EC Directive 851, 2018). The mandate to set end-of-waste criteria was introduced to leverage waste hierarchy and foster material circularity. However, while set of end-of-waste criteria for priority waste streams such as iron, steel, and glass have been laid down, end-of-waste criteria for BSWS are still lacking (Urban Agenda Partnership on Circular Economy, 2020).

Landfill Directive (EC Directive 850, 2018) sets out operational requirements for landfill sites with the objective to protect both human health and the environment. It aims to ensure a progressive reduction of landfilling of waste, particularly of waste that is suitable for recycling or other recovery, and to provide for measures, procedures, and guidance to prevent or reduce as far as possible negative effects on the environment. The Landfill Directive fosters the circular economy for bio-based materials and waste streams by requiring a progressive reduction in biodegradable waste sent to landfills, setting limit of municipal waste landfilling to 10% by 2035. Starting from 2030, it imposes strict restrictions on landfilling any waste suitable for recycling or other material or energy recovery, incentivizing the diversion of recyclable materials from landfills. In addition, the directive requires that only treated waste be landfilled, ensuring proper processing before disposal. This initiative promotes the responsible management of bio-based waste streams, with the goal of minimizing their environmental impact and redirecting them toward production cycles or energy generation. Furthermore, Landfill Directive encourages EU countries to employ economic measures to apply waste hierarchy, prioritizing waste reduction, reuse, recycling, and recovery over landfilling.

3.3.1.3 Municipal sludge

Urban waste-water treatment Directive (EC Directive 271, 1991) prioritizes the conservation of natural water bodies. It requires the collection and (at least secondary) treatment of urban wastewaters from populated areas. Member States are also responsible for ensuring that the release of industrial wastewater into collection systems and municipal wastewater treatment facilities is subject to prior regulations and approvals. The directive encourages the reuse of treated wastewater and sludge in broad terms: “reused whenever appropriate”.

In January 2024, the European Commission and Parliament have reached an agreement on the revision of the Urban Wastewater Treatment Directive. The proposal put forth by the Commission aims to enhance the removal of nutrients from urban wastewaters within the EU while imposing new standards on micropollutants. Under the revised directive, following the 'polluter pays' principle, responsible industries will be obligated to partially contribute financially to the protection measures outlined, thus reducing the burden from water tariffs and public budgets. Furthermore, the legislation is set to propel the wastewater sector towards achieving energy and climate neutrality (EC Press Release, 2024).

By the year 2035, all EU member states will be required to eliminate organic matter from urban wastewater before its release into the environment in communities with populations exceeding 1000 people. Subsequently, by 2045, the directive mandates the removal of nitrogen and phosphorus from all treatment plants serving populations greater than 10000 people. An additional treatment targeting a broad range of micropollutants, known as 'quaternary treatment', will become mandatory for plants servicing over 150000 people (and over 10000 people based on a risk assessment), by the year 2045. (EC Press Release, 2024)

Sewage Sludge Directive (EC Directive 278, 1986) determines the conditions under which the agricultural use of sludge from sewage plants treating domestic or urban wastewaters is allowed. The

directive aims to protect the soils by establishing limit values for heavy metal concentrations in the soil which shall not be exceeded by sludge application. The directive requires sludge to be treated (stabilized) before recycled back to agricultural soil. However, member states do have the option to permit the use of untreated sludge, subject to specific conditions they establish, if it is either injected or incorporated into soil. The directive requires regular follow-up and reporting of several parameters of the sludge, and monitoring of heavy metal concentrations of the soil where sludge is to be applied. The up-to-datedness of Sewage Sludge Directive was evaluated in relation to the New Circular Economy Action Plan in 2023. The conclusion was that the directive is still applicable, but a wider scope of pollutants to be regulated should be considered, for example pathogens, pharmaceuticals, and microplastics (EC SWD, 2023).

3.3.1.4 Recycled fertilizers

The Fertilizing Products Regulation (FPR) (EC Regulation 1009, 2019) sets forth EU guidelines for market access of fertilizing products. Its primary objectives are to ensure the safety, efficacy, and efficiency of fertilizing products while promoting their role in the circular economy. By promoting organic and waste-based fertilizers, the FPR seeks to diminish the environmental impact of these products (EC Regulation 1009/2019 Consolidated Text, 2023).

Since 2022, the amended FPR has opened the market to organic fertilizers, organo-mineral fertilizers, growing media, and bio-stimulants, provided they comply with the legislation's environmental and safety requisites (Fertilizers Europe, 2024). The revised regulations include CE labelling requirements for a wide array of bio-based fertilizers and specify safety and quality standards. This shift towards legalizing the market for BSWS recovery products improves circular business models and fosters BSWS recovery practices (EC Regulation 1009/2019 Consolidated Text, 2023).

However, the FPR excludes coverage of animal by-products or derived products falling under the ABP regulation when they enter the market (EC Regulation 1009/2019 Consolidated Text, 2023). Notably, while the FPR facilitates market access for fertilizers derived from bio-based municipal waste that includes an inevitable amount of manure, such products remain strictly regulated by the ABP (Urban Agenda Partnership on Circular Economy, 2020).

3.3.1.5 Digitalization & data

In the context of data-driven circular economy, the European Union has been working towards a more sustainable and resource-efficient future. For instance, The Digital Decade Policy Programme 2030 emphasizes the compliance with European Green Deal, it is stated that “The Union needs a digital sector that puts sustainability at its heart, including in its supply chain, preventing excessive reliance on critical raw materials, ensuring that digital infrastructures and technologies become verifiably more sustainable, renewable and energy- and resource-efficient, contributing to a sustainable circular and climate-neutral economy and society in line with the European Green Deal” (EC Report, 2023).

The Circular Economy Action Plan (EC Communication 98, 2020), emphasizes the importance of using data and digital technologies to enhance circular practices. The EU's General Data Protection

Regulation (GDPR) is a crucial framework for data protection, ensuring that any data collected and utilized in the circular economy complies with privacy and security standards. Additionally, the European Commission has been promoting initiatives to address specific sectors, such as bioeconomy, to enhance sustainability and to reduce waste. (EC Directive 98/2008 Consolidated Text, 2024). The key aspects to consider regarding CE-related data collection and handling include:

Privacy and Security: Ensuring compliance with data protection regulations, such as GDPR, to protect individuals' privacy and maintain data security.
Interoperability and Standardization: Promoting standardized data formats and interoperability to facilitate seamless data exchange and collaboration across various stakeholders in a circular economy.
Transparency and Traceability: Establishing transparent processes and traceability mechanisms for the collection, sharing, and utilization of data to build trust among stakeholders.
Innovation and Research: Encouraging innovation and research in data-driven technologies to optimize resource use, waste reduction, and overall circular economy practices.
Stakeholder Engagement: Involving various stakeholders, including businesses, policymakers, and the public, in the development and implementation of data-driven circular economy initiatives to ensure diverse perspectives and inclusivity.

3.3.1.6 Future Regulations

In addition to the policy instruments listed above, the EU is developing more legal framework to meet the goals set in the European Green Deal. Several new regulations regarding sustainability have already been adopted or are about to be implemented by 2027. By 2027 50000 companies will be impacted by the European Sustainability Reporting Standards under the Corporate Sustainability Reporting Directive (CSRD). The CSRD includes for example, EU Taxonomy and CSDD (EU's Directive on Corporate Sustainability Due Diligence) which will increase the need for sustainability reporting. Even though the reporting is mainly required only from large companies (CSRD for example), these are likely to force their subcontractors to report on CSR because of their own obligations, i.e., large companies are effectively forcing their subcontractors to report on CSR issues relevant to their own operations. These will include several stakeholders working in the ecosystem of bio-based side and waste stream circulation, such as farmers, forest owners and local waste management operators.

Soil monitoring law is under preparation, proposal for a directive was published in July 2023 (EC Communication 416, 2023). and monitoring obligations are currently under development. The soil monitoring law can affect utilization of different biobased side and waste streams. In terms of different manures - if there are contaminants or other risk factors for the soil, they are subject to analysis under the Directive. For soil use, moving soil masses or soil materials, a health certificate might be needed. As there are already limits on the harmful substances in recycled nutrients used for fertilization, the Direct should not affect the use of recycled nutrients.

3.3.3 Standards and technical reports

EN ISO 20675:2021 Biogas. Biogas production, conditioning, upgrading and utilization. Terms, definitions and classification scheme (European Standard was approved by CEN on 29 November 2021 based on ISO 20675:2018) defines terms and describes classifications related to biogas production by anaerobic digestion, gasification from biomass and power to gas from biomass sources, biogas conditioning, biogas upgrading and biogas utilization from a safety, environmental, performance and functionality perspective, during the design, manufacturing, installation, construction, testing, commissioning, acceptance, operation, regular inspection and maintenance phases. It lists biomass containing substrates for anaerobic digestion: manure, sludge, organic waste, and residues: household waste, agricultural residues, industrial residues, industrial effluent, food residues, landfill, compost, wastewater, and energy crops. Manure, sludge and various organic waste and residues are suitable as substrate for gasification. Standard emphasizes different feedstock types available for biogas production, as well as different applications of biogas in heating, electricity production, and transportation.

CEN/TC 411 Technical committee "Bio-based products" has developed a set of standards for biobased products, covering horizontal aspects. Standards give a common basis on the following aspects:

- Common terminology
- Bio-based content determination
- Life Cycle Assessment (LCA)
- Sustainability aspects
- Declaration tools

EN 16760:2015 Bio-based products - Life Cycle Assessment gives requirements and guidance for life cycle assessment of bio-based products, excluding food, feed, and energy. This European Standard aims to provide specific life cycle assessment requirements and guidance for
bio-based products, based on EN ISO 14040 Environmental management — Life cycle assessment — Principles and framework and EN ISO 14044 Environmental management — Life cycle assessment — Requirements and guidelines. This European Standard covers bio-based products, derived wholly or partly from biomass. Inadequate or unreliable data can hinder the accuracy and credibility of the LCA results. Factors such as land use change (land occupation and land transformation), water inventory, carbon sequestration, and indirect impacts associated with agricultural practices can complicate the LCA process. Standard discusses for instance, modelling agricultural systems. Agriculture can have positive and negative impacts on the environment, considering for instance, use of fertilisers, irrigation, land use, soil management, and use of mineral fertilisers and fuels. Agricultural produce can be used as raw materials in bio-based products. Agricultural field work is complex, and practices vary significantly. Guidance is intended for practitioners that have to create a new unit process for an agricultural product; in other cases, such data sets, however, can be extracted from existing databases (life cycle inventories).

EN 16751:2016 "Bio-based products. Sustainability criteria" aim is to identify sustainability aspects applicable to all bio-based products, covering all three pillars of sustainability (environmental, social, and economic). Standard emphasizes ways to communicate information along the value chain, to exchange and share information, assess, and manage, and to report. Chain-of-custody may be used to transmit information through the supply chain. This standard can be used for developing product specific standards and certification schemes. Standard suggests indicators for each pillar, for reporting sustainability and on measures and procedures to mitigate risks or minimize negative impact. Environmental sustainability criteria include aspects of climate protection and air quality (GHG and other air pollutants emissions), water, soil (quality and productivity), biodiversity (within the area of operation), energy and material resources (resource depletion), and waste management. Social sustainability criteria include aspects of labour rights, land use rights and land use change (local food security), water use rights (water scarcity), and local development. Economic sustainability criteria include fair business practices and measures to reduce risks related to them.

CEN has released **Technical Report, CEN/TR 13097:2010** "Characterization of sludges. Good practice for sludge utilisation in agriculture". While Directive (EC Directive 278, 1986) sets a regulatory framework for sewage sludge usage, the technical report introduces more detailed guidelines and requirements, also to other types of sludges. It provides comprehensive guidelines for the characterization of sludges and their safe utilization in agricultural practices. It outlines the necessary procedures and parameters to assess the quality and suitability of sludges for agricultural use, emphasizing environmental protection and human health. The document covers various aspects such as physical, chemical, and biological characteristics of sludges, as well as methods for sampling, analysis, and interpretation of results. The use of all types of sludge should follow good practice to maximise benefits for the crops or soils, to minimise potential risks of environmental contamination and adverse impacts on plant, animal, and human health, and to ensure sustainability, energy efficiency and cost-effectiveness. Following with these guidelines may induce enhanced characterization requirements, increased technical expertise and skills needs, including educational needs, as well as communicational needs for public awareness and acceptance, verifying market demand for sludge. Meeting these requirements may necessitate additional treatment processes or investments in infrastructure, increasing the overall cost. The summary of discussions on CEN standard along with other relevant regulatory framework concerning biobased side and waste streams is presented in the Table 7.

Table 7. Summary of the EU's regulatory frameworks concerning bio-based side and waste streams

Name of policy instrument	Launch year	Linked with	Value chain parts concerned	Quantified recycling targets	Measure to execute CE
Bioeconomy Strategy	2018		Primary production, organic residues		In primary production: Innovations to bioeconomy & biorefineries to better utilize organic waste and residues, develop markets for bio-based products, enhance investments, deploy local bioeconomy
Farm to Fork Strategy	2020	European Green Deal	Food chain from primary production to consumption and waste management		Increase organic farming to cover 25% of agricultural land, more biorefineries to produce bio-fertilizers, farmers to utilize biobased side and waste streams to produce biogas
EU Biodiversity Strategy for 2030	2020	European Green Deal	Land-use sector		At least 25% of agricultural land to organic farming management, produce bioenergy from residues and waste. Nutrient management and reduction of synthetic fertilizers,

					reduced impacts to biodiversity and ecosystem functioning
New Circular Economy Action Plan	2020	European Green Deal	Covers all sectors		Enhance circularity in all sectors, boost circular business models and enable circular practices for businesses, Bioeconomy Strategy and Action Plan regarded as information source for sustainable bio-based sector
European Green Deal	2019				Circular bioeconomy and sustainable bioenergy regarded as key elements in the path to sustainability
Chemicals strategy for sustainability	2020	European Green Deal			Enhance markets for secondary raw materials
Waste Framework Directive	2018		End of life management	WFD requires at least 55% the municipal waste must be recycled by 2025, with the increase to 60% by 2030 and to 65% by 2035	WFD sets all member states legally binding to separate biowaste at the source for collection by 31st December 2023 WFD lays down the end-of-waste criteria which defines

					when waste ceases to be waste and becomes the product or secondary materials
Sewage Sludge Directive	1986, latest amendment in 2019		Sludge producers (WWTPs)	None	Defines the terms for using sewage sludge in agriculture based on heavy metal concentrations of the sludge and soil
Fertilising Products Regulation	2019, latest amendment in 2022		Fertiliser production and market access		Open market to organic fertilizers derived from BSWS, provide CE labelling requirements, ensure compliance with the environmental and safety requisites
Urban waste-water treatment Directive	1991, latest amendment in 2015	European Green Deal, Circular economy action plan, Zero pollution action plan			The reuse of treated wastewater and sludge is encouraged in broad terms
Landfill Directive	2018		End of life management		Requiring a progressive reduction in biodegradable waste sent to landfills, setting limit of municipal waste landfilling to 10% by 2035

					From 2030, it imposes strict restrictions on landfilling any waste suitable for recycling or other material or energy recovery
Industrial Emissions Directive	2010, latest amendment in 2012	European Green Deal, Zero pollution action plan	Industrial operators	None	Permit applications for industrial operations must include, among other things, strategies for preventing, preparing for re-use, recycling, and recovering waste
Animal By-products Regulation	2009, latest amendment in 2023		Animal by-product recovery and usage		Streamlining market access to certain animal-derived products like fertilizers and soil improvers Designating endpoints in the manufacturing chain for certain animal-derived products, allowing their release from ABP regulation with safety and quality assurance
Green Paper on the Management of Bio-waste in the EU	2008		Bio waste management	Do to strong regional differences, binding legislation for recycling	Holistic view on waste management with focus on local dimensions,

				targets considered potentially inefficient	arranging collection for separate waste streams highlighted important in reducing emissions
Renewable Energy Directive	RED III 2023	Clean energy for all Europeans package	Renewable energy sources		Target to increase renewable energy of overall energy consumed to 42,5% by 2030
Digital Decade Policy Programme 2030	2023	EU Green Deal	All	Traceability and material efficiency throughout the value chain, more efficient and safe use of materials	Framework for digital transformation of businesses and secure and sustainable digital infrastructures
General Data Protection Regulation	2018		All	Data protection, privacy, and security	Data protection, privacy, and security
Sustainable Products Initiative	2022	EU Green Deal, European Circular Economy Action Plan	All	Ecodesign, material efficiency, extended lifecycle	Aims to enhance the sustainability of products by promoting circular practices, reducing waste, and minimizing environmental impact i.e., by gradually introducing digital product passports
Digital Strategy	2020		All	Digital product passports, transparency of	Provide information about a product's environmental sustainability, outlines Europe's

				data, reliability of data, safety of data	digital ambitions, emphasizing data-driven innovation and connectivity
Data Strategy	2020		All	Transparency of data, reliability of data, safety of data	Aims to unlock the potential of data while ensuring privacy, security, and trust.
Data Governance Act	2020		All	Transparency of data, reliability of data, safety of data	Establishes rules for cross-border data sharing, fostering data-driven innovation
EN ISO 20675:2021 Biogas. Biogas production, conditioning, upgrading and utilization. Terms, definitions, and classification scheme (European standard approved 2021 based on ISO 20675:2018)	2021	Technical Committee ISO/TC 255 "Biogas" of the International Organization for Standardization (ISO) and has been taken over as EN ISO 20675:2021 by Technical Committee CEN/TC 408 "Natural gas and biomethane for use in transport and biomethane for	Harmonisation of biogas production, upgrading and utilization.		Enhancing utilization of manure, sludge, and organic waste and residues to biogas production

		injection in the natural gas grid"			
EN 16760:2015 Bio-based products - Life Cycle Assessment	2015	CEN Technical Committee CEN/TC 411 "Bio-based products"	All value chain actors		Improving accuracy and credibility of the LCA results and building market reliability on sustainability claims of bio-based products
EN 16751:2016 "Bio-based products. Sustainability criteria"	2016	CEN Technical Committee CEN/TC 411 "Bio-based products"	All value chain actors		Enhancing communications of information along the value chain, to certify sustainability, to exchange and share information, assess and manage, and to report
CEN/TR 13097 2010 Characterization of sludges. Good practice for sludge utilisation in agriculture	2010	CEN Technical report	Harmonisation of sludge utilization practices		Enhancing safe utilization of sludges

3.3.4 Case study of national implementations of sewage sludge utilization

National aspects to sewage sludge utilization in Estonia, Finland, and Norway. In relation to Sewage Sludge Directive:

1) To what extent is sewage sludge utilized currently and what prohibits the use (such as heavy metal restrictions)?
2) How different countries justify the use of sewage sludge?
3) Are there plans regarding the usage of sewage sludge?

FINLAND

The annual amount of sewage sludge produced in Finland in 2021 was 1073857 tons (wet weight) and the dry weight of it was 169081 tons. There is no data available of the utilization amount for the same year, but in 2020, 135000 tons (dry weight) was utilized. The majority of the utilization happened in agriculture (61900 tons), but another big utilizer was landscaping (55000 tons) (Finnish Ministry of the Environment, Ramboll Finland Oy, 2023). In Finland, municipal sludge regulation is based on EU regulation, but it includes stricter standards and limits in some cases. Waste is regulated in Waste Act (646/2021) and Waste Decree (978/202), and the environmental impact of waste is regulated in the Environmental Protection Act and Environmental Protection Decree (Finnish Ministry of the Environment, 1096, 2022).

The national implementation of the EU's Sewage Sludge Directive 86/278/EEC is based on the recent Decree on Fertilizer Products (Finnish Ministry of Agriculture and Forestry, 2023). Sewage sludge must be treated before use and the use of sewage sludge in agriculture is regulated by fertilizer legislation. The decree lists the allowed treatment methods, which are digestion, composting, aging, lime stabilization, acid and oxidation treatment and drying. Sewage sludge treated with these methods following the demands of the decree can be used in any fertilizer products with certain exceptions (anaerobically digested, thermically dried, acid and oxidation treated, and lime stabilized sewage sludge can't be used as an ingredient in substrate). The decree states that sludge has to meet the stability requirements and the allowed levels of impurities and pathogens of its ingredient class as well as the heavy metal restrictions based on the intended use of the fertilizer product (Finnish Ministry of Agriculture and Forestry, 2023). This differs from the EU's Sewage Sludge Directive, which allows the use of sewage sludge only in certain fertilizer products and allows more freedom in the use of sewage sludge in fertilizer products sold only nationally.

The decree also gives some limitations to the application of sewage sludge -based fertilizers, and the maximum permitted application of treated sewage sludge is 6000 kg per year or 30000 kg of dry matter

per hectare over a five-year period. Fertilizer preparation containing treated sewage sludge shall only be applied to arable land where the concentrations of harmful metals do not exceed the maximum permitted concentrations. The cropland to which a fertilizer preparation containing treated sewage sludge is applied shall be analysed in accordance with the decree and the samples should be taken before the first application of sewage sludge. In agriculture and horticulture, on arable and pastureland, where fertilizer products containing sewage sludge are used, a withdrawal period of one-year for feed and two-year withdrawal period for food has to be applied. During the withdrawal period, plants that can be eaten fresh and their edible parts can be in direct contact with the ground or plants whose underground part is intended to be eaten must not be cultivated for human consumption or for animal feed (Finnish Ministry of Agriculture and Forestry, 2023). The decree also gives some limitations to the application of sewage sludge -based fertilizers, and the maximum permitted application of treated sewage sludge is 6000 kg per year or 30000 kg of dry matter per hectare over a five-year period. Fertilizer preparation containing treated sewage sludge shall only be applied to arable land where the concentrations of harmful metals do not exceed the maximum permitted concentrations.

Some minor parts of EU's Sewage Sludge Directive are also implemented in the Government Decree on Waste 978/2021 (reporting obligations of the Member State) and the Government Decree on the Restriction of Certain Emissions from Agriculture and Horticulture 1250/2014 (restrictions on application periods etc.).

Factors restricting the use recycled fertilizers in Finland are contamination risks with harmful substances, lack of regulating standards, and the efficiency of sludge-based fertilizer for plants. The conversation around recycled fertilizers in Finland has been two-folded: using waste-based, recycled fertilizers is seen to help with closing nutrient cycles, but there's always the risk of them containing harmful substances that should be removed from circulation. The concentration of harmful substances in sewage sludge -based fertilizers has especially been a concern among policymakers, operators of the industry and the public. Based on research, heavy metal concentrations in sewage sludge only rarely exceed the allowed concentrations in Finland, but the concern has shifted to other harmful, organic substances. According to Äystö et al. (Äystö, Högmänder, Fjäder, & Salminen, 2022) for Finnish Environment Institute, current processing technologies are only able to remove part of the harmful substances in wastewater and sewage sludge, and there's a risk of these substances ending up in the aquatic system and the soil.

Based on Finnish Ministry of Environment's recent report (Finnish Ministry of the Environment, Ramboll Finland Oy, 2023) on the utilization methods of sewage sludge, these harmful substances in the sewage sludge and especially the lack of associated standards regulating them is the most significant factor slowing the utilization of sewage sludge -based fertilizers. According to the Finnish Environment Institute (Lehtoranta, et al., 2021), this even limits the markets for grains cultivated with sewage sludge -based fertilizers, since many major grain buyers have created their own policies restricting the use of these grains. The main concern with harmful substances is microplastics and organic compounds such as pharmaceuticals and flame retardants. The report also addresses the need for a shift in consumer attitudes

towards sewage sludge-based fertilizers. As a solution to all these factors slowing and inhibiting the use, the report calls for more research, industry-wide standards for safe concentrations of the substances and an EU-wide consensus on these issues (Finnish Ministry of the Environment, Ramboll Finland Oy, 2023). Another factor inhibiting the use is the usefulness of sewage sludge-based fertilizer for plants and the proportion of soluble nutrients in the final fertilizer product. This factor is highlighted by the recent Government Decree on the Use of Fertilizer Preparations and Manure Containing Phosphorus (Finnish Government 64, 2023), which states that in agriculture and landscaping, 60% of the total phosphorus in sewage sludge is taken into account in fertilization. This might make it more difficult or even prohibit the use of sewage sludge especially in landscaping, since the phosphorus in sewage sludge is chemically precipitated with strong chemical bonds, which limits the usefulness of phosphorus for plants (Finnish Ministry of the Environment, Ramboll Finland Oy, 2023).

The future plans regarding sewage sludge treatment in Finland is focused on recovery of nutrients and organic materials. In the Nutrient Recycling Action Plan for 2019-2030 prepared by several ministries together with Business Finland, the use of sewage sludge is named as one of the focus points of general promotion. In the plan, the emphasis of promoting is seen on defining the objectives of policies and strategies for the recovery of nutrients (phosphorus and nitrogen) and organic matter in waste waters and sewage sludge rather than them focusing on advanced processing. The plan also states that research and development funding should be available for further development of existing treatment methods for sewage sludge, for the removal and reduction of contaminants and microplastics in sewage sludge and for the risk assessment of sludge use (Finnish Ministry of the Environment, 2019).

Recently however, the stance of Finnish Ministry of Social Affairs and Health has been that incineration, together with pyrolysis is the only tried-and-tested treatment of municipal sludge that can significantly reduce the spread of pathogens, microplastics and harmful organic compounds into the environment in accordance with the ‘no significant harm principle'. The biggest potential in sewage sludge recycling is seen in phosphorus, and for its recycling incineration is seen as a suitable method. This has resulted in intentions to change, for instance the current financing criteria of recycling nutrients of sewage sludge to only support these treatment methods based on the ‘no significant harm principle’. The current implementation of the Sewage Sludge Directive in Finland is summarised in the Table 8.

ESTONIA

When reusing sewage sludge compost, it is important to know whether it is intended to be used as waste or as a certified product. If sewage sludge compost is used as waste based on the requirements of the decree *“Quality limit values and requirements for use of sewage sludge used in landscaping, recultivation and agriculture”* (Estonian Ministry of Environment, 2023), this means that the sewage sludge has not been issued with a product certificate and the activity must be registered with the Environment Agency in advance and a diary of the use of the sludge must be kept later. Such sewage sludge compost is also subject to limits for heavy metals and pathogens, but they are not as strict as compost produced from sewage sludge, which is the product. If sewage sludge compost is used as a product for which a product

certificate has been issued in accordance with the requirements of the decree *"Requirements for the production of products from sewage sludge"* (Estonian Ministry of Environment, 2023), then the activity does not need to be registered with the Environment Agency in advance and additional monitoring of farmland is not required. A product that has already received a certificate meets all requirements (Estonian Ministry of Climate, 2023).

The presence of a certificate provides assurance that the product itself and the process of its production meet certain conditions. For example, limits have been set for pollutants that may pose a threat to the environment and human health. At the same time, certain limitations of use must be taken into account when using both composts. For example, during the year after the use of sewage sludge, vegetable, or berry crops and medical or aromatic plants must not be grown on the same land. Also, animals must not be grazed or stocked with animal feed on such land within two months after spreading (Estonian Ministry of Climate, 2023).

Compost produced from sewage sludge is assessed for compliance with the requirements and production is controlled by the accredited certification body *SA Taaskasutatavate Materjalide Sertifitseerimiskeskus* (Certification Center for Recycled Materials, 2024).

The study "*Sewage sludge handling - main problems and possible solutions*" (Estonian Ministry of Climate, 2017) revealed that Estonia has a great potential to use treated sewage sludge in agriculture, landscaping and recultivation. However, the amounts of sediment generated in Estonia are too small to be used in other areas (construction, production of building materials, etc.). Approximately 150000 m^3/a (wet weight) of sewage sludge is produced in Estonia. Based on surveys conducted among water companies in 2014-2015, at that time no use was found for approximately 11% of the sediment and it accumulated at the sewage treatment plant.

The National Waste Plan 2023-2028 (Estonian Ministry of Climate, 2023) states that according to the information of the Environmental Agency, in recent years the largest amount of biodegradable waste in Estonia has been sewage sludge, mainly municipal treated sewage sludge (generation in 2020 of nearly 171740 tons). The amount of municipal sewage sludge has increased in recent years and during the period of validity of the waste plan increase is also expected. The amount of sewage sludge is primarily influenced by water use and population changes, but the quality of reporting is also important.

According to the National Waste Plan 2023-2028 (Estonian Ministry of Climate, 2023), sewage sludge was not recycled in 2020, i.e., the products that would comply with the already mentioned decree "*Requirements for the production of products from sewage sludge*" were not manufactured. The municipal sewage sludge was directed to recycling i.e., aerobic, or anaerobic treatment, 77641 tons or 45% of the total production. Sewage sludge is mostly processed by composting. Since no certified products were made from sewage sludge, all sewage remained after treatment as waste, and compost made from sewage sludge is also treated as waste. In 2020, sewage sludge compost in waste status was used in

landscaping, recultivation and in agriculture (72795 tons). Also, in previous years there were no certified products made from sewage sludge, and the interest in certification has been very low. Certification is considered expensive or also because the quality limits is too difficult to achieve due to the technology used in sediment management. Some water companies have highlighted the fact that getting rid of sewage sludge in waste status is not a problem, if there is a certain cooperation partner engaged in landscaping or agriculture.

As mentioned earlier, the requirements applicable to sewage sludge as a waste are stated in the decree "*Requirements for the production of products from sewage sludge*". Also, sewage sludge in waste status must achieve heavy metals and pathogens quality limits and the sediment must be stabilized. However, there is an increasing trend in the awareness among the users of sewage sludge regarding persistent organic pollutants and drug residues in sewage sludge, which neither of the regulations currently deals with separately. There are many fears associated with the use of sewage sludge, and product certification would help to ensure that it is a product that meets the applicable safety and quality requirements. It is also important to raise awareness that a product made from sewage sludge that meets the quality requirements is suitable to increase soil fertility.

NORWAY

Sewage sludge is currently used for agricultural purposes. Approximately 59% (65000 Mt) of sewage sludge was utilized for agricultural purposes in 2018, but with substantial regional differences (Statistics Norway, 2020). It was the counties surrounding the Oslofjord, meaning parts of Viken county (Østfold and Akershus), Vestfold-Telemark county, and parts of Agder county accounted for 94% (61200 Mt) of the sludge that was used in agriculture. The remaining 41% (46700 Mt) of the total municipal sludge (111700 Mt) was used for other purposes. The use of sewage sludge in agriculture is regulated by Forskrift om gjødselvare mv. av organisk opphav (Regulation on fertilizer etc. of organic origin), which implements the Council Directive 86/278/EEC (the Sewage Sludge Directive) into Norwegian Law. The regulation came into effect in 2003, replacing the previous regulation on Sewage Sludge from 1995).

The purpose of the regulation is to ensure satisfactory quality of products covered by the regulation, to prevent pollution-related, health-related and hygienic disadvantages in the manufacture, storage and use of fertilisers, etc. of organic origin and make it possible for these products to be used as a resource. The regulation shall also contribute to an environmentally responsible management of the soil and ensure consideration of biological diversity. (§1in the Regulation on fertilizers etc. of organic matter) (The Ministries of Health and Care Services, Climate and Environment, and Agriculture and Food, 2003).

The regulation provides quality demands in terms of heavy metal content (which stems from tertiary treatment) and provides maximum limits for Cd, Pb, Hg, Ni Zn, Cu, Cr. And sets up quality segments from 0-III. The use of sewage sludge in agriculture is regulated by The Food Authority which apply the following conditions:

- Are suitable for annual fertilization where the annual usage quantity of the sewage sludge component is less than 100 kg of dry matter per hectare.
- Have a content of available nitrogen, phosphorus and potassium that is balanced and adapted to the crops' annual agronomic needs.
- Are in solid form and are suitable for even spreading on the area to be fertilized.
- Have been treated with methods where the temperature is at least 55 °C during the hygienisation period.

The use of fertilizers of organic origin must be part of a fertilizer plan, which is regulated by the regulation on fertilizer planning (The Ministry of Agriculture and Food, 1999).

A new regulation is under preparation and has been sent to public consultation in March 2024 by the Norwegian Food Safety Authority. This new proposed regulation is guided by circular economy principles, including more provisions for waste and by-products to be used in fertilizers.

The remainder of the sewage sludge that is not used in agriculture is mostly used for biogas production. Of the 57 biogas plants in Norway, 27 of them only use sewage sludge part of the substrate used for biogas production, whereas 2 additional plants combine sewage sludge and food waste (Norwaste, 2022). The current implementation of the Sewage Sludge Directive in Norway is summarised in the Table 8.

Table 8. National implementations on Sewage Sludge Directive 86/278/EEC.

Country	Sewage sludge used for agriculture	Restrictions for utilisation	General perceptions, future plans
Finland	37%	- Stricter national standards and heavy metal restrictions - Fear of harmful substances, microplastics and organic compounds, and lack of associated standards regulating them - Consumer attitudes - Amount of P in soluble form for plants	- Sewage sludge utilization a key focus in the Nutrient Recycling Action Plan for 2019-2030 prepared by several ministries - Recent stance of Ministry of Social Affairs and Health to treat sewage sludge with pyrolysis to reduce harmful compounds, however, does not promote efficient nutrient recycling
Estonia	19%	- Utilization is regulated by product certification or waste status based on the type of sewage sludge compost - Costs to achieve quality limits of certificates - Concerns about organic compounds	- Aim to increase awareness about product certification to address fears associated with sewage sludge use, such as persistent organic pollutants and drug residues
Norway	59%	- National regulation with quality demands on heavy metal content and specific conditions for agricultural, such as hygienization and maximum application quantities	- Ongoing utilization for agricultural and biogas purposes - New regulation under preparation, with a public consultation happening throughout the first semester of 2024

4 REGULATORY DRIVERS AND BARRIERS

4.1 Plastics

This review explores the regulatory framework's drivers and barriers affecting plastic value chain circularity. It focuses on two interconnected aspects: the circular practices of plastics for general application in Table 9 and those tailored for specific applications (construction, medical and healthcare, packaging, etc.) in Table 10.

4.1.1. Circularity of plastics for general application

The management of plastic waste has emerged as a critical challenge with profound environmental, economic, and social implications. It necessitates policy actions the revision of policy drivers and barriers across key thematic areas. The regulatory analysis of circular plastic drivers and barriers in general application focuses on four main themes:

1) Plastic waste collection, sorting, and logistics;
2) The feasibility of recycled content and bio-based plastics;
3) Plastic recyclability, including design for recycling and advanced solutions; and
4) The economic profitability of circular plastic solutions.

Table 9. Drivers and barriers of plastic circularity in general application.

Policies	Drivers	Barriers
1. Plastic waste collection, sorting and logistics		
Waste Shipment Regulation	Revision of the Waste Shipment Regulation banning the exports of plastic waste to non-OECD countries	Intra-EU waste shipment rules complicate and slow down the flow of plastic waste between member states destined for recycling inside EU
		The plastic waste shipments to Turkey, which is the largest importer of plastic waste in the EU and an OECD country, may continue.
Waste Framework Directive **Packaging and Packaging Waste Regulation**	Implementing separate waste collection, waste hierarchy, limiting landfill	Lacking end of waste criteria to end the waste status and increase uptake for recycling
Waste Framework Directive **Packaging and Packaging Waste Regulation**	Adopting EPR schemes to ensure that producers take on the responsibility for separate waste collection, recycling in addition to financial contribution (e.g., based on recycled content requirement) to cover the necessary costs of waste management and treatment as well as the costs of awareness raising	Limited or lack of traceability and transparency of amounts and types of substances and materials used in plastic containing products creates a gap in knowledge and results in safety and quality issues and therefore, inhibits producing high-quality recyclate.

Single Use Plastic Directive **RoHS**	measures to prevent and reduce plastic waste	Plastic products require the use of different types of additives, e.g., to reach wanted properties such as durability, flexibility, longevity, heat/flame resistance, and so on. Several additives are not regulated, hence, there is a lack of information about additives in the final products. Without transparency and traceability, the recyclers are challenged with lack of information about the substances and materials the plastic waste contains, which can have implications on safety and quality of the recyclates, but also on the safety of the processing and risk to equipments
ESPR (Ecodesign for Sustainable Products Regulation), DPP (EU Digital Product Passport, under the ESPR)	Promoting material traceability and transparency through the value chain via an information register system and proposed digital product passport to improve sorting and recycling	
2. The feasibility of recycled content and bio-based plastics		
Waste Framework Directive **Packaging and Packaging Waste Regulation** **Ecodesign Directive**	End-of-waste criteria for different plastic types/applications (in preparation by the EC)	Feasibility, viability and availability of recyclates is creating challenges to meet the minimum recycled content targets. The targets have not been developed in conjunction with ecodesign, recycling capacities and PCR plastic market
		To successfully meet the targets, new systems thinking, mindset and behavioral changes, higher performing products, eco-design innovation, and new infrastructure are needed.
Food Contact Plastic Regulation	Standardised practices for recycling and recyclate quality management	Food contact plastics regulation (EU 10/2011) provides a list of substances that are permitted or restricted for use in plastic food contact materials. Most recyclates do not comply with this regulation, mainly due to the risk of contamination. This means that a closed loop recycling is out of reach despite the minimum recycled content requirements for (food) packaging.
Packaging and Packaging Waste Regulation		Proposal for the packaging and packaging waste regulation does not address well enough the entrance of new types of packaging materials, especially biobased and biodegradable, for which it will be difficult to reach the recyclability target in the near future. This is seen as a driver to continue using the prevalent fossil-based plastics instead of biobased options.
3. Plastic recyclability, including design for recycling and advanced solutions		
Ecodesign Directive **WEEE Directive** **ELV Directive**	Targeting design for dismantling (e.g., EEE waste), design for recycling (e.g., packaging) to increase recyclability of plastics	Majority of plastic products are designed with advantageous properties from a use-phase perspective such as durability, low density, and non-degradability but not so much for recycling. A high variety of plastic applications and in compositions creates a complex challenge for waste management.
	Lacking standardization and certification system for plastic recycling process and plastic-derived products (e.g., pyrolysis oil) hinders technological investment and market adoption	

4. The economic profitability of circular plastic solutions.		
European Green Deal	EGD aims to reduce greenhouse gas emissions by at least 55% by 2030.	To achieve this, plastic packaging manufacturers will be forced to use carbon capture technologies in plastic recycling facilities or R&D innovation to reduce carbon footprints and this will lead to higher cost of recyclable plastic packaging. Higher cost will be a challenge for developing PCR plastic market
Plastic Strategy	Taxation of the use of virgin resources, removal of fossil fuel subsidies or preferential tax treatment of the use of recycled plastics	Low production cost of virgin plastics
European Council decision 2020/2053	Providing funding resources for plastic waste management derived from national contributions. These resources are calculated based on the volume of non-recycled plastic packaging waste	Low market value of plastic inhibits the private actors to invest in R&D and bigger capacity without an incentive or enforcement from regulations.

Plastic waste management and recycling practices are influenced by various policy drivers and hindered by significant barriers. Key drivers include the revision of waste shipment regulations to ban exports of plastic waste to non-OECD countries and the implementation of separate waste collection systems within the EU. Additionally, end-of-waste criteria for different plastic types and applications, along with Ecodesign Directives aimed at increasing plastic recyclability, play pivotal roles. However, barriers such as the lack of material transparency and traceability pose challenges to informed decision-making, while the feasibility of implementing recycled plastic content requirements is hindered by regulatory authorization issues and inconsistent batch qualities. Compliance issues with food contact plastics regulations further complicate recycling efforts, while inadequate regulations for new packaging materials like bio-based plastics may hinder progress. These factors highlight the need for comprehensive policies addressing both drivers and barriers to effectively manage plastic waste and promote circular plastic solutions.

4.1.2. Circularity of plastics for specific applications

Plastic waste management presents a pressing global challenge, with various sectors dealing with the consequences of insufficient recycling and disposal systems. From construction and agriculture to healthcare and packaging, each domain confronts unique hurdles in handling plastic waste effectively. Policy drivers generally include collection and recycling targets and recycled content requirements while the barriers in specific applications of plastic waste management vary significantly.

In construction and demolition, the lack of promotion of plastic recycling in essential documents, inefficient recycling targets in the Waste Framework Directive, and the absence of incentives in policies hinder progress. In healthcare, the lack of regulation and guidelines on waste management, along with inconsistencies in waste classification and separation methods, pose challenges. Agricultural plastics face obstacles due to the absence of incentives in policy frameworks, underscoring the necessity for tax

incentives and certifications to promote sustainable practices. Durable goods encounter hurdles such as insufficient standards and labelling, impeding effective recycling efforts. In packaging, recycling efforts are hindered by inadequate standards and labelling, which make it difficult to identify materials and cause confusion among consumers. Lack of system transparency and data traceability further obstruct progress, hindering policy design and equitable distribution of responsibilities among stakeholders. The absence of ecodesign standards limits innovation in packaging design for recyclability, while inadequate funding for recycling infrastructure, particularly for flexible packaging, undermines recycling initiatives and perpetuates environmental impact. Lastly, in EEE and EV waste, barriers such as complex product design and insufficient recycling infrastructure hinder effective plastic recycling and reuse in these waste streams. The application specific drives and barriers for circularity of plastics are summarised in the Table 10.

Table 10. Drivers and barriers of plastic circularity in specific applications.

Policies	Drivers	Barriers
Construction and demolition plastic waste (CDW)		
Construction and Demolition Waste Management Protocol	N/A	Recycling of plastics in CDW is not promoted in the essential documents related to CDW management, i.e., in the CDW management protocol and Guidelines for waste audits before demolition and renovation works of buildings
		The combined recycling rate target for all CDW (70% by weight by 2020) in Waste Framework Directive does not sufficiently encourage the recycling of plastics due to the light weight of plastics in comparison to other CDW material types
		The CE marking for construction products is not allowed for reused products
Agricultural plastics		
Waste Framework Directive	Establishing collection schemes (e.g., through EPR)	No incentives in the policy framework
	Voluntary initiatives of producers of agricultural plastics for collection schemes	
Durable goods made of plastic (e.g., toys, kitchenware, other utility articles)		
Proposal for new Ecodesign for Sustainable Products Regulation (ESPR)	Establishing collection schemes (e.g., through EPR)	No incentives in the policy framework
	Ecodesign requirements for durable goods	Insufficient standards and labelling: Information about which products contain which types of substances and materials is insufficient for recyclers due to missing labelling, guidelines, and frameworks (proposed in the context of packaging but applies to durable goods, or all applications)
Medical or healthcare plastics		

N/A	N/A	The lack of EU legislation on the handling, transportation, and disposal of (hazardous) healthcare waste, leading to discrepancies between countries on how waste types are categorised
		There is both a lack of EU guidance as well as national guidance in legislation, which means that hospitals are left with their own interpretation of what is considered hazardous and non-hazardous waste.
		The same lack of clear categorization can be found in sorting and recycling practices by waste processors. This leads to a lack of visibility on the amount of hazardous and non-hazardous waste, thereby hiding the true scale of opportunity that exists in sorting and recycling healthcare waste. Moreover, the public perception of what healthcare waste is comprised of has an impact on decision-making due to a lack of clear definitions and categorizations in legislation.
Plastic packaging waste		
Packaging and Packaging Waste Regulation (PPWR) **Directive on single-use plastics (SUP)**	50% recycling target for plastic packaging waste by 2025, and 55% by 2030 in PPWR	Insufficient standards and labelling: Information about which products contain which types of materials is insufficient for recyclers due to missing labelling, guidelines, and frameworks. Non-recyclable packaging, e.g., multi-material and multilayer packaging. Also, consumers are often confused by inappropriate or misleading information on packaging, which leads to improper collection and further, separation. A lot of the recyclable packaging is also ending up into mixed waste/waste streams ending up in incineration or landfilling
	Directive on single-use plastics SUP lays down collection targets for SUP beverage bottles (up to 3 L) as follows: 77% by 2025, and 90% by 2029.	Lack of system transparency and data: Authorities are unable to collect sufficient data necessary to design appropriate policies. Waste management and recycling systems tend to be perceived as non-transparent—for example, with respect to fees for EPR schemes.
		No eco-design standards for flexible packaging prevailing
		No funding for the development of high-value end markets for recycled material, which is especially lacking for recyclates from municipal household waste. Insufficient funding in recycling infrastructure, e.g., flexible packaging is not even collected in some EU countries
		Lack of alternatives to mechanical recycling: Mechanical recycling for flexible packaging is challenging, but feedstock from chemical recycling is not accepted for food-grade applications, e.g., in Germany
Electrical and electronic equipment (EEE) and electrical vehicle (EV)		

WEEE Directive	EPR for separated collection and recycling Collection targets of 65% of the average weight of electrical and electronic equipment placed on the market or 85% of the WEEE generated within member states, while recovery and recycling targets range from 50% to 80% and 20% to 75%, respectively, for separately collected WEEE	Design not for dismantling and recycling (multilayer and material, additives, different component sizes and configurations)
Proposed new directive on end-of-life vehicles (ELV)	25% recycled plastic in vehicles, restrictions on landfill usage, and a 30% plastics recycling rate target.	

4.2 Batteries

The following chapter highlights the drivers and barriers for accelerated implementation of 2nd life batteries as stationary energy storage. Seven main themes have been identified, and several circularity drivers and barriers for each theme are listed in the Table 11. With the exponential increase in EV sales, the number of used EV batteries which need to be handled will also increase accordingly. The use, reuse and recycling are to a great extent covered by the new EU Battery Regulation. In addition to the EU Battery Regulation, there are several international and national standards governing the safe installation of large battery energy storage systems (BESS). However, as the stationary energy storage market and particularly BESS based on the 2nd life EV batteries are still in its infancy, there is a lack of regulatory environment ensuring safe installation and operation of large BESS. There are also many aspects of EV battery reuse which is not considered in the EU Battery Regulation, specifically concerning eco-design and safety related to installation and operation of BESS. The EU Battery Regulation also seems to favour recycling over reuse. While reuse is encouraged to extend battery lifetime, there are no specific targets set for EV battery reuse. While for recycling, there are specific targets set for amount of recycled materials from each battery as well as percentage of recycled materials to be used in new batteries.

Table 11. Drivers and barriers for circularity of batteries.

Themes	Drivers	Barriers
Increase the number of used EV batteries being reused or repurposed for other applications before recycling.	With increasing number of EVs on the road, large amounts of used EV batteries will be available and need to be handled. Used batteries are a huge resource.	
	Extended EV battery life will reduce the need for critical raw materials required for battery production.	
	Extended EV battery life will reduce the overall environmental footprint of the battery over the lifetime.	
		High cost of reuse/repurposing due to lack of standardization and eco-design.
	EU Battery Regulation will through the Battery Passport ensure 2nd life operators access to state of health data and other important information about the batteries.	Battery Passport will be enforced starting Feb. 2027. It will take many years from now until these batteries go into 2nd life applications. Currently, there is laws or regulations ensuring access to state of health data of historical user data for 2nd life operators.
	EU Battery Regulation promotes reuse and repurposing.	No specific targets set for reuse and repurposing, while specific targets are set for both recycling and amounts of recycled materials to be used in new batteries.
		Rapid development in EV battery technology causes an even larger difference in battery performance between new and used batteries. May also cause incompatibility with respect to BMS of batteries from different makes and models.
	According to the Waste Framework Directive, EV battery manufacturers must take care of waste management of EoL EVBs at their own expense. If used batteries can be sold to 2nd life stakeholders, this could be an advantage over direct recycling.	
	People are in general more concerned with saving energy and reducing cost of consumed energy. BESS can contribute to load shifting, peak shaving, better utilization of renewable	Still relatively expensive to buy BESS, both new and 2nd life batteries.

	energy, and significant savings for the end user.	
	Used LFP batteries and other chemistries with little valuable metals (without Co, Ni) will have negligible recycling value, reducing the market value and thus making them an affordable choice for 2nd life.	
	Insufficient knowledge amongst end users about how to optimize use of batteries. And different business models are still immature and needs more verification.	
Reduce cost of repurposing for 2nd life applications	Costs of new cells are going down will promote purchasing new rather than used batteries.	Costs of new cells are going down, which lowers price of 1st life battery systems, in turn reducing the economic benefit of 2nd life batteries.
		Lack of standardization and eco-design make disassembly of batteries time-consuming and costly. Much of the work must be done manually.
		Due to the wide variety of cell chemistries, cell form factors, and battery pack design, coupled with technological advancements, life-extending circular activities need to be customized for each battery manufacturer and constantly evolve to keep up with the fast pace of innovation.
	More companies on the market will increase competition and reduce prices.	
	More used EV batteries on the market will increase availability.	Cell manufacturers are not interested in promoting 2nd life use and are lobbying against it.
		Restricted accessibility to historical data stored in the BMS hinders down-stream value chain actors from utilizing valuable information about the battery's past performance.
	Battery Passport, which will be required for all EV batteries from Feb. 2027, will provide important information to repurposing companies with regards to state of health of the batteries. This will reduce the cost of battery	This is only valid for batteries placed on the market after Feb. 2027, and it will take many years before these batteries are available for 2nd life use. No temporary solution in the meantime.

	diagnostics currently required before reuse/repurposing.	
	Lower degree of disassembly of the EV battery pack gives reduced cost of repurposing but reduce the number of reused/repurposed batteries as more of them will go directly to recycling.	Higher degree of disassembly in the reuse/repurposing process will increase the number of battery cells being reused (faulty single cells or modules can be removed, while good cells/modules are reused), but increase the costs.
		Disassembling the battery pack and reassemble into new battery system requires re-certification of the battery. This is a costly procedure.
	Batteries are considered dangerous goods and shipping and handling of batteries is therefore more costly due to additional packing and transportation restrictions.	
Promote eco design of EV batteries		Due to the emphasis on low cost and weight, certain EVBs are designed and manufactured in a manner that poses challenges when it comes to disassembly, making the process difficult and potentially time-consuming. Such as Cell-to-Pack design and batteries as part of the vehicle structural design.
	The proposal for a Regulation on Ecodesign for Sustainable Products sets new requirements to make products more durable, reliable, reusable, up-gradable, reparable, easier to maintain, refurbish and recycle, and energy and resource efficient. Based on the objectives of the new proposal, repurposing EVBs is desirable as the battery ex-tends its life cycle.	
	The new Battery Regulation aims to support the practical application of the waste hierarchy, where repurposing takes place before recycling.	
Ensure safe operations of stationary 2nd life batteries.	In the US and Canada there is a standard "UL 1974: Standard for Evaluation for Repurposing Batteries", which deals with aspects including safety, disassembly, examination, analysis of BMS data, and testing related to repurposing. This standard does, however NOT address the safety design for a battery when	The absence of a regulatory framework in the EU, adequate testing protocols, and established safety standards hinders the repurposing of electric vehicle batteries. There is work ongoing within the field.

	it is being repurposed into a new type of application, such as from EV to Stationary.	
	There are standards for electrical installation (NEK 400) which points to other standards for battery installations (NEK 487, corresponding to IEC 62485-2 and –5). Other standards exist for battery systems (e.g., IEC 62933-5-2, UL1973).	No existing legislation focusing on the safety of energy storage systems.
		Lack of knowledge of how to operate batteries safely amongst end users
		Lack of proper fire extinguishing agents or agents to hinder fire propagation
		Lack of standards and recommendations for battery room construction.
	Battery Passport will provide important information to repurposing companies with regards to state of health, composition of the batteries, historical use data, etc. This makes it easier to build safe battery systems from the used batteries and tailor the system to the appropriate end user according to battery properties and SoH.	
		There is no official certification of 2nd life batteries which can ensure the end user of the safety of the BESS
More positive public perception of Li-ion stationary batteries with regards to safety and reliability.		EoL batteries pose risks of damage and fire hazards, necessitating proper collection and storage protocols that are crucial to mitigate the inherent dangers associated with handling these potentially hazardous batteries.
		Insufficient understanding of battery room construction, including the selection of appropriate construction materials, implementation of effective fire-suppression systems, and adequate ventilation, can lead to critical gaps in ensuring the safety and optimal functioning of battery storage facilities.
		Reliability of second life BESS is a concern due to the potential for sudden loss of energy capacity in lithium-ion batteries.
	Increased awareness and information about BESS provided	

	through extensive exposure of battery industry in media.	
	People are in general used to handling LiBs in their daily life and perceive it as safe, and they are thus more likely to accept it for larger installations as well.	
	Ongoing work with standards, norms and regulations which can increase people's sense of safety with BESS	
Reduce environmental foot-print	2nd life batteries have inherently lower environmental footprint compared to new batteries	
	Advanced BMS and smart charging can contribute to opti-mized use of the battery in the grid, with PV panels or other re-newable energy sources.	
	Battery passport will have to in-clude information on the envi-ronmental footprint of batteries, which will give customers/con-sumers better data to choose batteries with low footprint. LCA method is defined in Battery Regulation.	
		Environmental footprint in the user phase is highly dependent on the source of electricity used for charging. Electricity losses can be higher for old batteries due to higher resistance and less streamlined design.
Improved logistics and waste handling for used batteries	With increasing number of 2nd life battery companies in the market, the transportation may be easier due to reduced trans-portation distances.	Batteries are considered dan-gerous goods and must pass specific tests prior to transporta-tion (i.e., UN 38.3 test). Trans-portation of EV batteries are complex and cause safety haz-ards.
		Too little knowledge on proper storage of LIBs (used and new)
		When batteries are defined as waste, a lot more regulation ap-plies to e.g., shipping them.
		Companies that collect waste batteries tend to treat them as waste, which could lead to the batteries being damaged, it be-ing impossible to have enough information about the state of the battery, and the repurposing process can also be very ineffi-cient.

4.3 Biobased side and waste streams

The use of biobased side and waste streams is heavily regulated to ensure the safety of the environment and safety of the commodities produced from these materials. Biobased side and waste streams cover a wide range of sectors, and therefore a wide range of regulations. Most of the drivers identified were related to new regulations enabling market entry and trade of new biobased products, strategies to increase the use of biobased side and waste streams – or to ban the fossil alternatives, and to incentives to support development. These were policy instruments considered to have the potential to increase recycling of the biomaterials. Markets for recycled fertilizers, regulations for sewage sludge and use of data were brought up as potential facilitators for the industry. In Table 12 the drivers and barriers for specific themes are presented.

Table 12. Drivers and barriers to recycle biobased side and waste streams.

Themes	Driver	Barrier
Biogas	Distribution obligation is an efficient policy tool which can increase demand for biogas.	Although the target is to increase the production of biogas, there is not much funding available for it (Finland). Also, the amount of funding has been decreasing recently, unpredictability of funding instruments hinder development. Transport/distribution of biogas in areas without gas pipes is a challenge. It is not profitable to transport biomass to a biogas plant for biogas production long distances.
Promotion of renewable energy	Targets to increase biogas (e.g., RED III, Green Deal, EU & national level targets). Ban of use of fossil fuels for heating/energy in industry from 2030 (Norway)	
Limiting bioresource use for energy		Policy intentions to restrict the use of bioresources for energy production do not consider the efficiency of waste recovery for bioenergy. Waste-based biogas is grouped with other types of biofuels produced, such as HVO, RME.
Sewage sludge utilization and nutrient recovery	Fertilizer regulation allows the use of struvite from sewage sludge to be used as fertilizers.	The Sewage sludge directive is partly outdated and does not take e.g., organic pollutants and microplastics into account. The discrepancy between the requirements of the directive and recent scientific evidence of the potential threat that these pollutants may cause in soils has led to the situation where incineration of sewage sludge has increased. This compromises the recycling of the sludge which would be

		important not only because of securing nutrient cycle but also to supplement soils with carbon. Also, Urban waste-water treatment directive encourages reusing sewage sludge without giving any advice how this should be done. The directive is not very strict. If it was, it could better encourage use of sewage sludge as fertilizer. This is because a strict law would make people trust the safety of the final product more. Lack of determination in regulations for efficient utilization of sewage sludge hinders the development as well. Investment costs for extracting i.e., N or P from the sewage water are too high for a municipality to cover. Requires national incentive funds.
Bio-based recovery products and market development (fertilizers, soil improvers)	The Commission Delegated Regulation (EU 2023/1605) streamlines access to certain animal-derived fertilizers and soil improvers (processed manure, compost and residues resulting from the transformation of animal by-products in a biogas plant) in the EU market while ensuring no risk to human or animal health. FPR opens the market for bio-based fertilizer to trade freely in EU, provide CE labelling for wide range of fertilizing products and rules of safety and quality. Animal Byproduct Regulation (ABP) designates the end point in the manufacturing chain with scientific insights, which marks the release of certain animal-derived products such as pet food, biodiesel, hides, skins, fertilizers from ABP regulation. Specifically, the Commission Delegated Regulation (EU 2023/1605) streamlines access to certain animal-derived fertilizers and soil improvers (processed manure, compost and residues resulting from the transformation of animal by-products in a biogas plant) in the EU market while ensuring no risk to human or animal health through scientific insights. WFD, FPR, RED promote waste reduction and recovery as alternatives or	

	mixing with virgin materials for fertilizer, biogas, and biofuel productions.	
Target of increasing organic farmland	Farm to fork strategy target to increase organic farmland to 25% by 2030 is expected to boost bio-based side and waste stream recovery for organic fertilizers and soil amendments.	Recent decrease of organic farming reduces demand for certain recycled fertilizers.
Phosphorus limits to prevent excess use		Processed manure considered manure in the Nitrates Directive so same nitrogen limit
Landfill	Prohibition of taking biobased materials to landfills.	
Data management and digital traceability	Enhanced information of materials for circular economy purposes, more transparency on material stream providers and value chains, enhanced reliability, and safety for optimal CE efficiency. Data usage rules give security.	Strict regulation on GDPR regulation and data security hinder development in certain cases. Lack of data to support decision making. Lack of data available of bio-based side streams to optimize locations for biorefineries and biogas plants.
Emphasis on the lowest possible costs in public procurement		Public procurement often uses low costs as a primary selection criterion. Small scale production has difficulties to compete. Utilization of recycled fertilizers or biogas are not emphasized in procurement, even though it could significantly increase demand.
Environmentally harmful subsidies		Environmentally harmful subsidies (e.g., for fossil fuels) hinder the development of renewable energies and recycled fertilizers.

The use of biobased side and waste streams involves various stakeholders from primary producers to industrial actors and energy users. Due to the diverse nature of the field, it is regulated by several different administrative sectors. Many of the issues raised in the study were related to the diversity of the sector and the consequent complexity of its governance. In addition to the overall complexity, the constantly changing regulatory instruments were identified as key issues affecting the sector, mainly by hindering trust towards it, and consequently the number of investments. Profitability of the sector is low, and incentives have been considered inadequate. Table 13 presents the main findings on these issues.

The various drivers and barriers for the use of biobased side and waste streams presented in Table 12 and Table 13 reflect the diversity of the sector. Depending on the source materials, applications, and end uses, the regulations that apply to a particular project can be very different. Certain aspects have been excluded from the tables due to conflicting opinions from different stakeholders. In some cases, stakeholders might wish for more stricter regulations, while others consider them to be already too strict. Too strict requirements have been perceived in the Fertilizing Products Regulation (e.g., pollutant limits, nutrient content, hygienisation standard (1h 70°) for manure in the Animal By-Products Regulation, and regarding sewage sludge regulations. All these can have potential safety risks, which end-users wish to

avoid as much as possible. On the other hand, the ones producing and or treating the materials in some cases consider costs from treatment methods to be too expensive.

Based on the findings, three themes were chosen to be the most important, for which policy recommendations were formulated. These three were: 1) Complexity and low predictability of policy instruments; 2) Insufficient support for the biogas sector; and 3) Sewage sludge - from waste to fertilizer. These three themes were also considered to be highly topical in the spring of 2024. The European Commission has a simplification project to reduce the bureaucracy burden from farmers. In addition, utilization of sewage sludge has been discussed recently widely and the Urban Wastewater Treatment directive is about to be updated. In Finland the new government is developing their programs for the coming years and simultaneously implementing a cost cutting exercise, and therefore it is of special interest to raise political awareness of the critical nature of subsidies to the biogas sector.

Table 13. Drivers and barriers to recycle bio-based side and waste streams regarding policymaking.

Themes	Driver	Barrier
Complexity of regulations for bio sector	'One service desk' institution about to come into force in Finland	Policy framework (regulation and investment support system) is complex. Complexity of regulations hinder the development of utilizing biobased side and waste streams. The ecosystem of biobased side and waste streams is regulated by several policy sectors, which sometimes give different outputs in different regions (law is being interpreted differently by the authorities). Practitioners find it difficult to understand the regulatory framework as a whole - which slows down possibilities to develop new business models in the industry. Examples: Definition of waste has been considered difficult for an individual practitioner to determine when a certain side stream is considered to be waste and when it is not. Regulations differ greatly between these. Lack of end-of-waste criteria at national level in certain cases complicates the situation even more. On farm level farmers already have a burden of bureaucracy regarding support from CAP and procedures, rules and reporting requirements linked to it.
Authorization processes	Aims to shorten authorization processes (in RED III, for example) to e.g., one year maximum. 'One service desk' institution about to come into force in Finland	Lengthy authorization processes for several permits required.
Updating policy instruments		Low predictability of policy instruments, lack of long-term decision-making for the development of the whole value chain – both regulations and funding instruments. Biorefineries are long-term investments, require predictability.

		Long-term predictability of policy and regulation activity would encourage long term investments (e.g. biogas plants, solar/wind energy, on farms for equipment suitable for digestate, etc.) Discontinuity of some funding forms and mechanisms. Distribution obligation for fuels an example (has been lowered in Finland).
Profitability of utilizing bio-based side and waste streams	"Fertilizer crisis" (Russian sanctions, increased prices and shortage of synthetic fertilizers) Use of recycled fertilizers is a voluntary measure in CAP. Could be emphasized more for greater influence.	High costs for biobased industry from processing, new technologies, logistics, and administrative requirements. The sector is heavily regulated, and relatively costly to enter. Difficulty of market-creation in the immature market, especially in rural areas. Small scale and early-stage biofuel development may be more expensive than traditional fuels, and the market development phase would need incentives. Regulations may require costly certifications of biowaste processing and recycling processes and impose monitoring requirements to ensure compliance and environmental safety. CAP doesn't significantly encourage the use of recycled fertilizers (it is a voluntary measure among many others) ‘’One of the biggest barriers for circular bio economy is lost business opportunities due to lack of money, time, personnel, and machinery’’. Funding does not encourage to make investments to biogas. Currently mainly new technologies can have funding in Finland, and not so much ordinary biogas plants.
Investments/incentives		Lack of investment support reduces profitability. In some cases, continuous support might be required (biogas production support in Sweden). **I**ncentives are needed also for small-scale recycling and circulation of materials. Start-up companies have challenges regarding funding for their innovative alternative fertilizers. Getting to commercialization stage takes time and resources. Some recycled materials might be more expensive than virgin materials. Thus, incentives are needed for the use of recycled materials until the market has grown enough to become financially viable and profitable. Low success rate for project funding, high workload for funding applications and high competitiveness for the calls. Difficulties understanding rating criteria for project proposals and why they are accepted or rejected. In Finland, agriculture and farmers' joint ventures can in principle receive funding for building biogas plants,

		but the money allocated for this does not seem to be enough for all who are interested. On the other hand, there is currently only one funding instrument available for municipalities and municipally owned wastewater treatment plants, and the last application opportunity is in the summer of 2024. After this, it is only possible to receive funding for biogas plants that use some new technology. The funding budget will also drop significantly from 100 million euros to 14 million euros annually starting in 2024, so there will not be enough money for many investments.
Reducing virgin material usage		Even though legislations support waste reduction, the critical sustainability issue of the linear economy relating to the extraction and processing of raw materials remains un-addressed in mandatory legal.

5 POLICY RECOMMENDATIONS

Through the mapping of regulatory frameworks, policy drivers and barriers impacting circular economy practices are identified within three key value chains. By unveiling these insights with stakeholder validation, policy recommendations are formulated to foster the circular economy transition, particularly focusing on critical areas such as eco-design, recycled content mandates, standardization, incentives, and financial instruments tailored for circular plastics, batteries, and bio-based waste streams.

5.1. Plastics

Plastics are used in a variety of different applications, there are also many types of polymers and additives that are used to produce the plastics. Different legislation is affecting different types of applications and waste sectors. There is no single solution legislation wise to transform linear use of plastics into circular, rather, multitude of solutions are needed, and they need to be always considered case-specifically with the key stakeholders and value chain actors.

Following the regulatory analysis of circular plastic drivers and barriers, the policy recommendations are formulated in four main themes:

1) Plastic waste collection, sorting, and logistics;
2) The feasibility of recycled content and bio-based plastics;
3) Plastic recyclability, including design for recycling and advanced solutions; and
4) The economic profitability of circular plastic solutions.

Topic 1: Plastic waste collection, sorting and logistics.

5.1.1. Enhancing collection and separation rate of plastic waste, reducing waste incineration

Description:

The Waste Framework Directive mandates the application of a waste hierarchy and lays down end-of-waste (EoW) criteria for waste management. Member states are empowered to enact legislative measures to facilitate the implementation of extended producer responsibility (EPR) schemes for waste collection and management. However, lack of EoW criteria for diverse plastic waste categories followed by low price for municipal mixed waste collection hinder the plastic waste separated collection and recycling. It has led to valuable plastic waste ending up in incineration and landfilling.

Case study: Inclusion of incineration in European Emission Trading system

The European Parliament has approved the reform of the EU Emissions Trading System (ETS), which will include municipal waste incineration plants as of 2028 (Directive (EU) 2023/959) (EUR-Lex, 2023). Sweden and Denmark have introduced an ETS for incineration voluntarily and it has had big impacts of the management of plastic wastes. Inclusion of waste incineration plant in ETS fosters municipal waste segregation and recycling. EU ETS implements sanctions for burning fossil-based materials and makes burning of plastics less profitable, which leads to increased separation of plastics after collection. However, the lack of impact assessment prior to inclusion might slow down the investment readiness within the sector and raise the disposal costs, which in turn leads to direct consequences for European citizens. (Zero Wate Europe, 2021)

Good practice: Efficient collection PET bottle to bottle

PET bottle recycling system is the most developed of every PET product. Average collection rate of PET bottles in European countries which have implemented deposit return system (DRS) is estimated at 96% and for those who do not have DRS at only 48%, making the average collection rate of around 60% (Zero Waste Europe & Eunomia, 2022).

Remaining 40% of PET bottles placed on the market are leakage from circulation and ending up in landfills, incineration, or environment (see Figure 5).

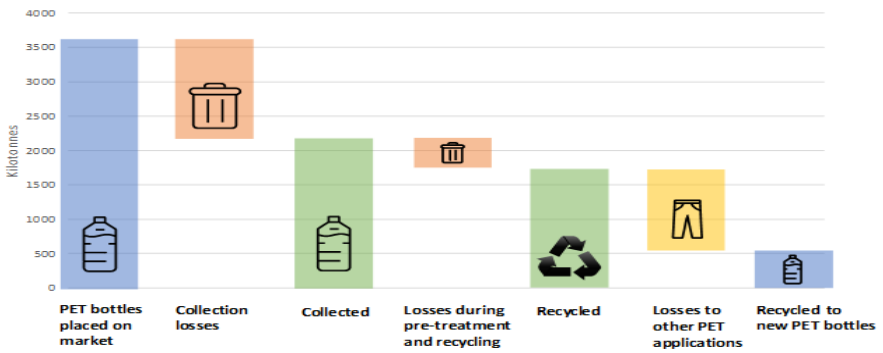

Figure 5. Current state of PET bottle recycling *(Zero Waste Europe & Eunomia, 2022)*

Typically recycling rates are reported as equivalent to the collection rates, however material losses also happen during recycling process. Additional leakages come from pre-treatment and recycling in a form of lost caps, lids, and labels, and during sorting, washing, flake and extrusion losses. These losses are estimated to be around 15% of collected PET bottles. Around 50% of PET bottles placed on the market end up in recycling. However, majority (69%) of it is downcycled for other applications such as trays or textiles and thus lost from circular bottle system. (Zero Waste Europe & Eunomia, 2022)

High success and positive impact of DRS on PET bottle collection will likely attract the rest of European countries to implement the system. More adoption of DRS will improve the quality of collected bottles and reduce contamination caused by separately collected bottle streams. Continued widespread of DRS could result in less material losses due higher collection rates and better quality. (Zero Waste Europe & Eunomia, 2022)

Recommendations:

- Boost recycling rate of plastic waste by the enactment and harmonization of European plastic EoW criteria with flexible case-by-case national criteria.
- Establish financial and policy incentives to enhance the plastic waste collection, separation, and recycling and to reduce plastic incineration and landfilling (e.g., through ETS for reducing waste incineration and EPR for handling waste collection, separation, and recycling)
- Standardize the types of plastics used across different applications and create deposit return systems for diverse plastic waste types, not just PET bottles.
- Develop a digital product passport system across the EU and improve the labeling system to enable better traceability of substances and materials. Collecting and sorting technologies need to be tailored to function with these systems.

5.1.2. Eco-modulation for plastic recyclability by design

Description:

Extended Producer Responsibility (EPR) is an environmental policy instrument, which places the responsibility for managing the product's end-of-life on the producer. Producers pay EPR fees based on quantities of packaging or products put onto market. Presently, in most European Member States, EPR fees primarily cover downstream costs of waste management, in particular collection, transport, sorting and recycling/treatment. However, upstream processes, such as raw material extraction, manufacturing processes, and design for recyclability, reparability, and reusability are seldom considered, which hinders the transition toward circular economy. Eco-modulation scheme in which recycling fees are determined by the recyclability of the product, is a crucial step towards promoting sustainability in product design and manufacturing.

Good practice: Eco-modulation in EPR schemes for packaging in Finland

Eco-modulation was introduced in Finland at the beginning of 2023. The requirement for eco-modulation comes from EU legislation and is included in the amended Finnish Waste Act in 2021. It is a key component of the extended producer responsibility (EPR) scheme. Eco-modulation aims to encourage companies to introduce packaging to the market that is easier to recycle and, consequently, contributes to achieving the recycling targets for packaging waste. (Niemelä, 2023)

This system involves setting different fees for various types of packaging materials and designs, with the goal of incentivizing producers to prioritize recyclability and environmentally friendly packaging solutions. Eco-modulation is assessed based on criteria such as recyclability, sortability, recycled content, and transparent compliance checks by the Producer Responsibility Organisation (PRO). Under Finland's EPR framework, all packaging materials are covered, and producers and importers with a net revenue exceeding EUR 1 million are obligated to manage the waste generated by their packaging materials. This responsibility can be fulfilled by joining a PRO, handling the treatment independently, or establishing a PRO collectively with other packaging producers. PROs in Finland, such as Mepak-Recycling Ltd for metals and Finnish Plastics Recycling Ltd for plastics, oversee the execution of producer responsibility, with support from Finnish Packaging Recycling RINKI Ltd, the joint service operator. (European Environment Agency, 2022)

Recent amendments to Finnish Waste Act have also introduced stricter requirements for eco-modulation, mandating PROs to develop detailed criteria for each packaging material type. Producers are now required to report their fee modulation annually to the supervisory authority, and PROs must establish self-monitoring plans to ensure compliance. Additionally, the revised legislation extends producer responsibility to foreign online sellers, requiring them to join PROs and meet EPR obligations. These regulatory measures aim to foster greater environmental responsibility within the packaging industry and drive progress towards a more sustainable circular economy in Finland. (European Environment Agency, 2022)

Recommendations:

- European and national governments can create incentives for circular design (e.g., compensations or fines) by developing eco-modulation fees based on plastic recyclability.

- EPR schemes have been noted to cause additional uncertainties, e.g., in the ownership of plastic waste. Careful planning and co-development are needed for EPR schemes to not complicate the already complex waste management systems.

5.1.3. Effect of the restriction on waste shipment regulations

Description:

The European Commission has enforced the revision of the Waste Shipment Regulation (Delegated Regulation (EU) 2020/2174) concerning the export, import and intra-EU shipment of plastic waste since January 2021. As per the export rules, a ban on the export of plastic waste from the EU to non-OECD countries has been imposed with an exception for clean plastic waste that is sent for recycling. However, challenges such as intra-EU logistical hurdles and the need for enhanced recycling infrastructure must be addressed. (EC Directive 850, 2018)

Case study: Impact of increased plastic waste import to Turkey due to waste export banning

The EU's decision to ban plastic waste exports to non-OECD countries is a positive step for responsible plastic waste generation. However, it falls short of a total ban on shipments to Turkey, which is both the largest importer of plastic waste in the EU and an OECD member. Waste management infrastructure and the ecosystem in Turkey may be adversely affected by substantial increased plastic waste imports due to the banning plastic waste exports to other countries. (Rethink Plastic, 2023)

Recommendations:

- Establish a Pan-European cooperation platform to mitigate plastic waste burden on recycling-destined countries and logistic hurdles in the EU. Develop local and regional roadmaps for specific sectors or materials to enhance waste management knowledge and foster collaboration.
- Create financial instruments supporting investments in plastic waste management infrastructures to ensure efficient waste management in Europe.
- Develop industrial symbiosis models that reuse materials from other value chains to generate economic benefits and promote waste management.

Topic 2: The feasibility of recycled content and bio-based plastics

5.1.4. Gap between recycled content requirement and recycle quality management

Description:

The sustainability initiatives within the proposed Packaging and Packaging Waste Regulation (PPWR) and Plastic Strategy are facing a critical hurdle: the gap between recycled content requirements and recyclate quality management. The recycled content requirement framework lacks alignment with essential factors like eco-design, recycling options, infrastructure, and recyclate quality. Particularly, the concern is the inadequate consideration of recyclate quality, which poses safety risks due to contamination. This challenge significantly limits the utilization of recyclates, especially in sensitive packaging areas such as food packaging.

Case study: Fulfilling recycled content requirement for PET facing contamination risk

Polyethylene terephthalate (PET) is a commonly used plastic in food and beverage packaging, particularly in the form of bottles for water, soft drinks, and other beverages. In the proposed PPWR, the European Union has set ambitious targets for the recycling and recycled content of contact-sensitive packing made from PET at the rate of 30% by 2030 and 50% by 2040. It aims for a circular economy where PET bottles are collected, sorted, and recycled into new bottles or other products. (Guillaume, 2024)

However, achieving closed-loop recycling and recycled content requirements of PET bottles raises contamination and food safety concerns. PET bottles collected for recycling often retain residues of beverages, labels, adhesives, and other materials. These residues may contain substances not approved for direct contact with food, such as dyes, adhesives, or chemicals from the beverage contents. Even trace amounts of contaminants can violate the Food Contact Regulation (EU 10/2011). Furthermore, chemicals from PET drink bottles can migrate into their contents, and recycling processes may either concentrate existing chemicals or introduce new ones into the PET value chain. Several studies indicate a higher migration of substances like antimony (Sb) and Bisphenol A in recycled PET (rPET) compared to virgin PET. This higher migration is attributed to various contamination sources and the variability in collection, sorting, and decontamination efficiency. (Gerassimidou, et al., 2022)

Recommendations:

- RDI funding and investment support to advance knowledge and understanding of recyclate quality control and safety.
- Update Plastic Recyclate Regulations (EU 2022/1616) to facilitate advanced recycling routes (mechanical, chemical recycling, or combination) that improve recyclate quality and safety, thereby enabling their use in added value applications, e.g., contact-sensitive packaging.

5.1.5. Lack of regulatory framework for bio-based materials as an alternative to plastic packaging

Description:

The lack of a regulatory framework for bio-based materials as alternatives to traditional plastics in packaging presents a challenge in addressing use of virgin fossil resources and related environmental issues. Without clear guidelines and standards for the production, utilization, and end-of-life management of bio-based polymers, the widespread adoption of sustainable packaging solutions is hindered. Policymakers and regulatory bodies at both the EU and national levels need to address this gap by conducting thorough assessments of bio-based materials to determine their viability and environmental impact. By establishing comprehensive regulatory frameworks tailored to bio-based polymers, including labeling systems and disposal processes, policymakers can create an enabling environment for the transition to sustainable packaging solutions.

Case study: Bio-based packaging regulatory framework

The Proposal for Packaging and Packaging Waste Regulation (COM/2022/677) lacks the integration of new packaging materials, particularly bio-based alternatives. The absence of clear regulatory guidelines for these materials hampers their adoption, leading to continued reliance on virgin fossil-based plastics. Moreover, the absence of end-of-life strategies for bio-based materials exacerbates the challenge, with recycling codes only applicable to virgin commodity plastics (e.g., PET, HDPE, PVC, LDPE, PP, PS), excluding bioplastics (e.g., cellulosic derivatives, PLA, PHAs), and their mixtures (e.g., PLA/LLDPE, paper/LDPE). This perpetuates the use of traditional plastics and undermines efforts to replace virgin fossil-based plastics with sustainable alternatives.

Recommendations:

- Address legislation gaps to include provisions for bio-based alternatives.
- Establish regulatory frameworks tailored to bio-based polymers covering production, utilization, quality control, and end-of-life management.
- Policymakers, in collaboration with the industry, should develop standards, guidelines, and labelling systems specific to bio-based materials to facilitate their integration into the industry and end-of-life management systems.
- Fund RDI on the viability of new bio-based materials, to gain insights into predicting the quality, properties, and environmental impact.
- Promote market penetration of bio-based materials through regulatory support and incentives for manufacturers and consumers.

Topic 3: Plastic recyclability, including design for recycling and advanced solutions

5.1.6. Lack of standardized plastic recycling practices and recyclate quality management

Description:

Chemical recycling of plastic waste involves breaking down plastic polymers into their constituent molecules through various chemical processes, such as pyrolysis. These processes allow for the conversion of plastic waste into raw materials or feedstocks that can be used to produce new plastics, fuels, or other valuable products. Pyrolysis is considered as a complementary technology to mechanical recycling of plastics. Pyrolysis oil, derived from the thermal decomposition of plastics, is a promising avenue for waste management and resource recovery. However, the lack of standardized practices in chemical recycling and output quality control hinders the market penetration and complicate significantly regulatory compliance and certification processes.

Case study: Plastic-derived pyrolysis oil standardization from Polyfuels

Polyfuels, one of TREASoURcE partners, is an industrial operator specializing in the pyrolysis of plastic waste, producing plastic recyclate pyrolysis oil. Pyrolysis oil, classified under UN 3295 – Hydrocarbons liquid, N.O.S., lacks a universal definition due to its diverse origin from various plastic waste feedstocks. Unlike typical commodity products, pyrolysis oil quality and composition depend heavily on the types of plastics used in the pyrolysis process.

The diverse nature of the pyrolysis oil hinders the establishment of standardized classification and quality control measures for pyrolysis oil. In addition, many challenges arise from the varied applications of pyrolysis oils, including plastic production, chemical recycling, steam cracking, petrochemical product refinement, and fuel production. Each application demands specific quality parameters, leading to differing specifications among customers. Consequently, there is no uniform standard for pyrolysis oil, complicating regulatory compliance and certification processes.

To address this issue, companies adhere to individual customer-defined quality and analysis specifications. These specifications often require compliance with regulations such as REACH registration and, increasingly, ISCC+ certification. As an example, in Table 14, the following analysis methods and analysis parameters are typical for pyrolysis oil used for plastic production.

Table 14. Analysis methods and parameters for pyrolysis oil in plastic production

Analysis Method	Typical range for analysis parameters
GC MS and GC FID	Pyrolysis oil contains at least 50 % of Naphta range oils: C8 – C14
Boiling point curve according to ASTM D2887	Preferably lower than 350 °C – ideally around 270 °C
Bromine number	Maximum 70 g/100 g

Recommendations:

- Establish a stakeholder cooperation platform to develop industry-specific standards and certification schemes for plastic recycling processes and recyclate quality management.
- Create flexible standards that adapt to the dynamic nature of recyclates based on the feedstock composition.
- Periodically review standards to incorporate advancements and market demands as the field of chemical recycling is advancing rapidly.
- Invest in RDI on recycling routes in combinations of mechanical, chemical, and other forms of recycling, with attention to system design.

5.1.7. Complexity of product and process design affecting the possibilities of effective recycling

Description:

The complexity and heterogeneity of the plastic waste significantly affect the possibilities of effective waste management and recycling process design. This complexity leads to gaps between product design and the feasibility of recycling, exemplified by issues such as additives, black plastics, and multi-layer/material structures. Plastic products require the use of different types of additives, e.g., to reach wanted properties such as durability, flexibility, longevity, heat/flame resistance, and so on. Several additives are not regulated, hence, there is a lack of information about additives and other substances used in the final products. The complexity is further amplified by different chemicals and contaminants, e.g., that enter the streams during collection. Limited or lack of traceability and transparency of amounts and types of substances and materials used in plastic containing products creates a gap in knowledge and results in safety and quality issues and therefore, inhibits producing high-quality recyclates.

Case study: Pyrolysis for challenging plastic waste from TREASoURcE project experiments

The heterogeneity of waste feedstock directly impacts the yield, composition of end products, and energy consumption during pyrolysis. There exists a reverse correlation between catalyst quality and cost, posing economic considerations for the industry. Tailoring catalyst designs to accommodate the diverse nature of waste feedstock is imperative for optimizing the pyrolysis process. However, collaboration between academia and industries needs to be fostered to enhance process optimization and common understanding. Additionally, the lack of consensus on ideal pyrolysis oil quality among the industries can impede market acceptance and consumption. Furthermore, the absence of a definitive reactor technology underscores the early stage of development in pyrolysis technology. Contamination avoidance, particularly from metals and hazardous materials, is crucial to ensuring the quality and safety of pyrolysis processes and their end products.

Case study: Mechanical recycling and VTT's advanced mechanical recycling line

The mechanical processing of mixed plastic waste is complicated as the properties such as melting points will differ according to the plastic type and the output will be a polymer blend often with low-quality properties. The lack of information of additives complicates the processing of plastic waste. Hence, the output of mechanical recycling will often be lower quality and contain the market-average of additives if not sorted and purified from the additives. Currently only a minor fraction is recycled in a closed loop. Foreign materials are also contributing to contamination of plastic waste stream. Contamination can be consequence of designed and created factors. Designed factors can be for example labels, adhesives, or additives. Created factors on the other hand are results of mismanaging the plastic waste for example by mixing with other materials at the collection point. Contaminants can affect the properties of plastic recyclates. A critical challenge regarding mechanical recycling is degradation of polymers caused by the high temperature and mechanical shear force of the process. Value Retention Extruder extrusion line is an advanced mechanical recycling technology developed by VTT. With this innovative tandem extrusion line, the properties of mechanically recycled plastics can be upgraded to reach ideally virgin-like properties by using in-line measurement of melt rheological properties. The process is adaptive which allows it to be modified and to reach desired target viscosity of recycled plastic via smart addition of various compounds within the batch or batch to batch variations. However, if the feedstock is severely degraded or contaminated to begin with a high-quality product is not likely to be achieved, unless significant amount of virgin polymer is added.

Recommendations:

- Enact eco-design, SSbD as well as traceability to improve the sustainability and knowledge of the plastic waste feedstock, and moreover, improve and increase recycling and inherently, the safety and quality of the recycled plastics.
- Funding for RDI to do innovation-oriented and scalable technological development for sustainable materials and advanced recycling processes.
- Create a collaborative platform for stakeholder engagement in technical innovation and standardized developments.
- Advancements in RDI are needed to improve mechanical recycling for processing more problematic waste fractions, complemented by chemical recycling to handle the most challenging waste fractions. However, actions to redesign and limit the amount of problematic waste should be a priority. Improvements on every stage of plastics value chain are needed to facilitate its recyclability into stable recycled plastic in terms of quality and quantity. For instance:

    - Issues relating to sorting: modernization of sorting technologies, increase sorting capacity without compromising quality.
    - Issues relating to feedstock analysis: Lack of proper methods for sampling and analysis. Challenges in ensuring compliance with safety and absence of substances of concern as there is a lack of information about the plastic waste. E.g., full guarantee of absolutely no such substances is needed, which is also regulated in the regulation on plastic material intended to contact with food. Currently no such guarantee can be given without knowing exactly the origin and composition of the feedstock. Research on identification and extraction of such substances from the recycled plastic is needed.
    - Issues identified with mechanical recycling: ability to treat more challenging waste fractions, and degradation of materials.
    - Issues identified with chemical recycling: high energy demand, material losses, uncertainties on a large scale, high environmental footprint, and high investment costs. Currently it is challenging to assess the full impacts of the chemical recycling as the technology is novel and there is yet to be an operation at significant large-scale. Thus, more research and experience are needed to be able to estimate the impacts. Also, use of catalysts (chemical recycling, upgrading) and reactor design need further development.
    - Recyclates related issues: insufficient quality, unstable quality, unstable quantity especially for large volume buyers, price to quality ratio, inapplicable material for current production lines or product designed for virgin-based plastics.

Topic 4: The economic profitability of circular plastic solution

5.1.8. Consumer acceptance and cost-effective circular plastic solutions

Description:

Several challenges impede the widespread adoption of cost-effective circular plastic solutions. Recycled plastic often commands a higher price than virgin plastics due to the costs associated with collection, sorting, and processing. Additionally, inconsistencies in the quality and quantity of recycled plastic present hurdles for large-volume buyers, impacting their willingness to invest in recycling. The perception of recycled plastic as low quality also poses a challenge to consumer acceptance. Furthermore, the incompatibility of recycled plastics with existing production lines and product designs hinders their adoption.

Case study: Managing Plastic Waste Economic Resources in the EU

The European Council decision 2020/2053 introduced measures to manage economic resources related to plastic waste management. A new funding category, linking national contributions to non-recycled plastic packaging waste volumes, was established to foster incentive-based systems for reducing single-use plastics and promoting circular economy concepts. An adjustment mechanism protected Member States below the EU average gross national income, while a uniform call rate of €0.80/kg was applied to unrecycled plastic packaging waste. Member States retained decision-making authority to tailor and implement the measures under the subsidiarity principle. Overall, the decision aimed to align with the European plastics strategy and contribute to tackling plastic packaging waste pollution within the EU budget scope. (EUR-Lex, 2020)

Recommendations:

- Establish national and EU economic schemes to provide funding for plastic waste management and recycling practices:
    - Type of Scheme:
        - Policy Scheme: Establish rules, regulations, and guidelines to govern waste management and recycling practices, including recycled content requirements, mandate for recycling and landfill targets.
        - Governmental and EU Programs: Launch specific initiatives and projects to tackle waste management and recycling issues, such as RDI funding for new recycling technologies and waste treatment facility infrastructure.
    - Type of Funding:
        - Loans: Offer low-interest loans to SMEs, industries, or municipalities for scale-up, infrastructure upgrades, or innovative recycling technologies.
        - Grants: Allocate direct grants to support projects aimed at improving waste management and recycling practices.
        - Public-Private Partnerships (PPPs): Foster collaborations between government entities and private companies to implement effective waste management solutions leveraging both public funding and private sector expertise.

    - Scope:
        - National Level: Implement the scheme at the national level by the government to ensure uniform regulations and support across the entire country.
        - EU Level: Implement the scheme at the European Union level to harmonize waste management practices across member states, promote standardized regulations and funding mechanisms, and facilitate cross-border collaborations.
        - Enforce sanctions on virgin fossil-based plastics following the existing polluter pay principles.
- Implement consumer protection laws and develop sustainability labeling and certification schemes to ensure transparency and fairness in the marketplace.
- Invest in consumer education programs to empower individuals to make informed decisions, including:
    - Knowledge on plastics (great diversity of different elements, properties, and characteristics)
    - Knowledge and training on handling plastic waste
    - Training and education for circular design
- Establish a public procurement scheme to create demand for recycled plastic market.
- Funding for recyclate quality RDI

5.2. Batteries

The battery market is rapidly developing, and the legislative landscape is struggling to keep up with the continuous change. With the newly adopted EU Battery Regulation, many of the challenges currently encountered will be addressed through the next few years. However, not all countries are EU members and thereby automatically covered by the new regulations. Additionally, several areas identified in this report, are not well covered or covered at all by the Battery Regulation. In this report, five areas have been found in need for further regulations or standards to accelerate uptake of 2nd life BESS. Eco-design and a circular strategy (including reuse and repurposing) as well as laws regulating trading of used batteries should be addressed on an EU level, while safety in installation and operation, and incentives for implementing 2nd life BESS should be considered on a national level. The policy recommendations are formulated in four main themes:

1. Safety in installation and operation of BESS;
2. Eco-design of EV batteries;
3. Incentives for installing 2nd life BESS;
4. Laws and regulations regarding trading used batteries; and
5. Legislation drives recycling over higher-level circular strategies like repurposing.

5.2.1. Safety in installation and operation of BESS

Description:

Safety is one of the key issues for end-users for battery energy storage systems (BESS). Although the probability of a thermal event is low for Li-ion batteries, the severe consequences make end-users very cautious. Most of the regulatory framework for battery installations is based on international standards, and many new standards have been implemented recently or are under development. The UL 1974: Standard for Evaluation of Repurposing Batteries, which is in place for Canada and the US, is a driver for accelerating installations. There are also standards concerning electrical installations, which is also valid for BESS. The recently implemented EU Battery Regulation will enforce a Battery Passport, which will make it easier for second life battery stakeholders to build safer and lower-cost systems. However, the battery passport will not be enforced until February 2027, and even after that it will take many years before significant amounts of batteries with battery passports are available for second life applications. Also, there is a lack of knowledge regarding requirements for battery installations such as room size and location, ventilation, and construction materials for battery rooms. And extinguishing is difficult as there is currently no efficient extinguishing agent for Li-ion batteries.

Case study:

There is a lack of regulatory framework and standards for installation and operation of BESS. From interviews with stakeholders and experience with the three KVC demos in TREASoURcE, safety concerns have appeared as the greatest challenge to handle. There are several standards either in place or under development for the battery system itself for first life and some for second life batteries. These include DIN VDE V 0510-100: 2023-04, IEC TC 21: IEC 63330, IEC 61427-2, IEC 62660, IEC 62485, IEC 62619:2022, and IEC 63338. However, all these standards only concern the battery or battery system performance, state of health and safety of the batteries and battery system. There are no standards or regulations describing:

- How to perform a proper safety assessment for the installed battery system
- How to design the battery room with regards to size, construction materials, ventilation, access regulation, fire extinguishing, placement in the building
- How to handle incidents for building operators, maintenance staff, and firefighting crew

Recommendations:

- Establish an EU-level research program on knowledge generation of battery room requirements and battery thermal events.
- A regulatory framework with focus on national or international standards regulating the minimum requirements for a battery room should be developed. This should also include a standard for risk assessment for installation of large BESS.
- Minimum requirements for training of building maintenance staff and BESS operators should be implemented.

5.2.2. Eco-design of EV batteries

Description:

EVBs can be eco designed by considering the materials selection, module, and pack design, and standardization of battery pack design and BMS. Environmentally benign and non-hazardous materials should be selected to minimize the environmental impact. The biggest challenge with reuse and recycling of EVBs is the non-standardization of EVB modules and pack designs. Standardization of battery pack design and BMS will make it significantly easier and less costly to repair, remanufacture, refurbish, or repurpose EVBs from several different makes and models. The disassembly process for EVB packs and modules must be quick and low cost, and the components must be possible to replace or reuse.

Case study:

The Ecodesign Directive has been implemented in the EU to improve energy efficiency by integrating environmental issues and life cycle thinking in the product design phase. In March 2022, the EU Commission established a proposal for a new regulation Ecodesign for Sustainable Products Regulation. This regulation will include electric vehicle batteries (EVBs), considering circular economy more thoroughly. It aims to provide products that have less environmental impacts, use less energy and natural resources, have long lifetime, as well as being easy to repair and recycle. Based on the objectives of the new proposal, repurposing EVBs is desirable as the battery extends its life cycle.

Recommendations:

- Enforce standardized solutions for battery systems in electric vehicles. This includes both battery cell format and battery module geometry as well as cooling system, sensors, and electronic components.
- Regulate use of glues, epoxies or welding which makes the battery difficult to remove or disassemble.
- A temporary solution should be implemented, enabling access to historical user data and battery state of health for second life battery stakeholders. When the Battery Passport becomes effective, this will ensure future access to required information.

5.2.3. Incentives for installing 2nd life BESS

Description:

Due to lack of standardization for EV battery systems in addition to use of glues, epoxies, and welding in assembly, much of the disassembly process is done manually, which makes it time-consuming and costly. Additionally, 2nd life BESS still does not benefit from the economy of scale that new batteries experience. It is generally more expensive to produce lower volumes. Until many of the challenges are solved, particularly those related to technical and eco-design issues which contribute to significantly increased costs, there should be incentives in place for end users wishing to install 2nd life batteries.

Case study:

The high adoption of EVs in Norway, making it the highest battery electric vehicle fleet per capita in the world, was largely driven by incentives to final consumers, such as tax exemptions for the purchase and annual road tax, exemption from toll roads, and free parking.

In Norway, the organization ENOVA provides incentives for industries and consumers to transition to energy efficiency equipment and clean energy, and BESS can be covered in some cases. However, there are currently no specific incentives targeted to 2nd life BESS.

Recommendations:

- Incentives from EU or national governments for buying and installing 2nd life BESS.
- Incentives could be implemented in different ways. One example is to cover a specific percentage of the cost related to the purchase and installation of a 2nd life BESS. But there could also be other effective means to accelerate 2nd life battery installations. This should be evaluated on a national as well as European level.

5.2.4. Laws and regulations regarding trading used batteries

Description:

The challenges lie in the lack of laws regulating trading of new and used batteries. This is a huge safety concern and can lead to severe incidents. These incidents could cause large economic losses and fatal accidents. Although most large BESS are handled and sold by serious companies with the required competence, incidents caused by less serious actors may lead to poor public perception of the use and safety of both new and used batteries. This will in turn hinder and slow down implementation of 2nd life BESS.

Case study:

In Norway it is currently quite easy to buy and sell used EV batteries. This can for example be done through the platform finn.no. This means that there is no control over who sells and who buys these batteries, and people with no or little competence on handling batteries are now able to do so in their own garage or basement. A Li-ion battery, new or used, which is not handled or used correctly can lead to severe incidents which can cause large economic losses and even be life-threatening.

Recommendations:

- There is a need for laws that can regulate sales of Li-ion batteries, at both cell, module, and system level.
- Certification should be required to handle Li-ion battery systems and their installation.
- Private persons and non-certified companies should be prohibited from manipulating, building, and re-building Li-ion batteries for either private or commercial use.

5.2.5. Legislation drives recycling over higher-level circular strategies like repurposing.

Description:

Until recently the Batteries Directive 2006/66/EC has been the primary EU legislation concerning batteries. The new Battery Regulation adopted in 2023 covers the entire life cycle of the battery, including production, use, reuse, and recycling, ensuring safe, sustainable and competitive batteries. The Battery Regulation has no requirements or targets regarding repurposing EVBs for other applications. Instead, the focus is on recycling.

Case study:

While promising ways to mitigate some of the challenges that EoL EVBs are facing, the new EU Battery Regulation prioritizes material recycling of batteries over activities aimed at extending their lifespan in a circular manner (repurposing), by mandating a minimum proportion of materials in new batteries to be sourced from recycled materials.

No quantitative requirements are set for repurposing, e.g., X% of EVBs deemed suitable for repurposing should be repurposed before recycling. Instead, the Battery Regulation has introduced several targets for recycling. Article 71 and Annex XII sets targets for recycling efficiency of all batteries. For Li-based batteries, the target is 65% by 2025, and will be further increased to 70% by 2030. For industrial batteries, EVBs, and light mobility batteries that contain cobalt, lead, lithium, or nickel in the active materials shall be accompanied by technical documentation demonstrating that those batteries contain the mandatory minimum shares of recycled content, as described in Article 8. (EC Directive 98, 2008)

Recommendations:

- Implement quantitative targets for repurposing of EoL EV batteries, setting a minimum percentage of batteries deemed suitable for repurposing to be repurposed before recycling.
- Provide incentives or subsidies for manufacturers to invest in repurposing technologies and infrastructure, encouraging them to explore alternative uses for batteries with remaining capacity.
- Introduce regulations or standards to promote the design of EV batteries with repurposing or a higher circularity strategy in mind, such as modular designs that facilitate easy disassembly and component reuse.
- Foster collaboration between industry stakeholders, policymakers, and research institutions to share best practices, knowledge, and resources for optimizing the circularity level of battery systems.

5.3. Biobased side and waste streams

In the dynamic landscape of sustainable resource use, the value chain of the bio-based industry stands out for its complexity, involving various stakeholders from primary producers to energy users. However, this intricate network faces ongoing challenges due to an ever-changing regulatory framework driven by increasingly ambitious sustainability targets. At the same time, sewage sludge, which is rich in nutrients but underutilized, is a promising source of agricultural fertilizer. Despite its potential, concerns about contaminants are hampering its widespread use, highlighting the crucial role of regulation in promoting efficient nutrient recovery. In addition, the growing biogas sector, which is key to increasing energy self-sufficiency and reducing emissions, faces hurdles due to uncertainties about profitability and political support. As various biogas projects progress, ensuring stable incentives and a secure role within the policy framework will be essential to maintain momentum and promote the development of the sector. Below are three policy recommendations about these three topics, of which two first are considered on the EU-level and the third is an example at national level from Finland.

1. Complexity and low predictability of policy instruments;
2. Sewage sludge utilization and wastewater treatment; and
3. Lack of incentives for biogas in Finland.

5.3.1. Complexity and low predictability of policy instruments

The value chain utilizing bio-based side and waste streams has unique features as it includes several different stakeholders from primary producers to industry actors and energy users. Increasingly ambitious sustainability goals and environmental protection measures have led to constant changes in regulatory instruments at an increasing pace for the sector of bio industry. The constantly changing regulatory framework poses challenges to the sector's operators and hinders development. The policy recommendations below aim to bring recognition to the bureaucracy burden experienced by stakeholders working in the bio sector, farmers in particular. The recommendations are intended to encourage initiatives to stabilize and simplify the regulatory framework.

Barriers:

- The policy framework (regulation and investment support system) is so complex that it hinders the development and use of biobased waste streams (Vogiatzaki;Skourtanioti;& Valta, 2022). The ecosystem of biobased side and waste streams is regulated by several administrative sectors, leading to different interpretations of the same issue. Practitioners find it difficult to understand the regulatory framework as a whole, which slows down opportunities to develop new business models in the industry and scaling up of successful solutions which have already been proven.
- Uncertainty is also increased by the lack of predictability of policy instruments, both regulations and funding instruments. The biogas industry, for example, is heavily reliant on subsidies and biogas plants are long-term investments that require predictability of the environment in which they operate (Winquist;Rikkonen;& Varho, 2018). Prediction of factors affecting production (energy taxation, sustainability scheme requirements, guarantees of origin, etc.) and factors affecting demand (taxation, the distribution obligation and the like, emissions trading obligations, etc.). Such foresight is required not only on issues related to the own end product, but also on issues related to competing products that affect the price competitiveness of the own product (taxes and obligations on diesel, petrol, electricity, and mineral fertilizers, etc.). There are examples where political decisions have negatively impacted the economics of biorefineries in unexpected ways, for example through tax increases. Long-term decision-making is required for policies and regulations to encourage investment.
- At farm level, investing in equipment suitable for digestate and recycled fertilizers is an expensive and long-term investment. Uncertainty about the future of the biogas sector hinders investments and slows down development in primary production as well.
- Discontinuity of some funding forms and mechanisms. Distribution obligation for fuels as an example which has been reduced in Finland (Ministry of Economic Affairs and Employment of Finland, 2023).

- Farmers already have a burden of bureaucracy regarding financial support from the CAP, the procedures, rules, and reporting requirements linked to it have been considered too complicated, especially among other regulatory instruments.

Case studies:

1. Unpredictable policymaking regarding soil sampling requirements

As a part of the Decree of the Ministry of Agriculture and Forestry of Finland on fertilizer products (964/2023) new regulations were set to collect soil samples from agricultural land to which fertilizers containing human-based sewage sludge are to be applied. Soil samples are required from all fields of at least 0,5 hectare before application. The regulation came into force in October 2023 and required samples to be taken before the next growing season. The timetable was too fast to allow sampling of soil already partially frozen. The sector did not receive a clear response from official authorities, adding unnecessary confusion to an already complex issue.

In addition, the requirement for soil sampling resulted in higher costs for farms using sludge-based fertilizers. Payments for measurement of heavy metals from farmland is a big expense with estimated costs of up to €100 per hectare (average area of arable land per farm was 52 ha in Finland in 2022).

2. Investment aid for farms is not granted for equipment made from recycled materials

Farmers in Finland can receive investment aid from the Ministry of Agriculture and Forestry for new constructions or repairs that improve, for example, the state of the environment or animal welfare. The support is granted also for energy production investments, such as heating plants, solar panels, or biogas plants. Depending on the investment, the aid ranges from 30-50%.

This investment aid for farms in Finland does not allow investments in equipment made from recycled or reused components, such as repurposed batteries from electric vehicles (e.g., for storing solar energy for milking robots). Agricultural investment support can only be obtained for new equipment. The incentive does not promote the circular economy, as reused or recycled materials are not subsidized, even if they are of high quality and have a lower carbon footprint than conventional alternatives.

Recommendations:

1. The regulatory framework of the biobased industry needs to be stabilized. Cross-government decisions are needed to promote the use of biobased side and waste streams. Operators need certainty on sectoral policies for at least 15-year periods.
2. Biogas programs are needed at the national level, focusing on both biogas production and nutrient recycling. These could have a significant impact on the development of biogas projects and build confidence in the sector.
3. Agricultural investment support should also be granted for items produced from recycled or reused materials to enhance circular economy in all EU countries.
4. More resources are needed for counselling services to help understand the bureaucracy of the policy framework and to understand funding possibilities for investments. Support should be provided for creation of clusters to allow for economies of scale and co-investments.
5. To enhance circularity in agriculture, e.g., for biogas, comprehensive advisory services for farmers are crucial. More resources to advisory services are needed to promote the adoption of other sustainable farming practices as well.

5.3.2. Sewage sludge utilization and wastewater treatment

Sewage sludge contains high levels of nutrients that are currently underutilized. The potential as a raw material for agricultural fertilizers is considerable, but potential contaminants create controversy over the use of sewage sludge. Regulations have a clear impact on recovery, thus potential to encourage more efficient recovery of nutrients from sewage sludge. The following policy recommendations aim to bring recognition to the importance of sewage sludge as a nutrient rich resource. They also aim to increase support for both research and incentives for stakeholders.

Barriers:

- The Sewage Sludge Directive is partly outdated and does consider organic pollutants and micro-plastics. The discrepancy between the directive's requirements and the latest scientific evidence on the potential threat that these pollutants may pose to soils has led to an increase in the incineration of sewage sludge. This jeopardizes the recycling of sludge, which would be important not only to ensure nutrient cycling but also to add carbon to soils (Seleiman;Santanen;& Mäkelä, 2020).
- The Urban Waste-Water Treatment Directive encourages reuse of sewage sludge without giving any advice on how this should be done.
- Ways in which the harmful substances of sewage sludge affect soil in the long-term are not fully known, neither their impacts to all crop species as well as the whole food chain – and what are possible differences in different climatic conditions (Seleiman;Santanen;& Mäkelä, 2020) (Ylivainio, et al., 2020) (Bolesta;Glodniok;& Styszko, 2022).
- Investment costs for solutions that extract important nutrients; nitrogen or phosphorus or others from the wastewater are too high for municipalities to cover (Ministry of the Environment of Finland, 2023).
- Facilities and technology used in wastewater treatment plants vary significantly. Currently, there is room for improvement in nutrient recovery from wastewater treatment plants. Technological barriers to efficient and safe recovery of nutrients from wastewater or sludge should be taken into focus (Ministry of the Environment of Finland, 2023).

Case study: Contradictions in permitting the use of purified water from wastewater plants in agriculture between EU countries

The use of purified water from wastewater plants for irrigation is prohibited in agriculture in some EU member states, but not in all. Differences in the implementation of EU regulations can create inequalities between farmers and distrust towards the final products. This is particularly the case for certified products, such as certified organic products, which are perceived as high quality and safe.

Recommendations:

1. Enact a stricter Sewage Sludge Directive to encourage use of sludge as fertilizer. It could help to reassure people about the safety of the end product.
2. Ensure funding opportunities for long-term research on the effects of sludge-based fertilizers on different crop species and possible effects of sewage sludge on the soil in different climatic conditions.
3. Create incentives to support technological development for regional wastewater treatment plants seeking cost-efficient ways to recover nutrients.
4. Provide funding for projects accelerating the development and deployment of wastewater treatment technologies that effectively eliminate challenging contaminants and simultaneously recover valuable nutrients and secondary materials.
5. Create a clear regulatory framework for the efficient use of sewage sludge.
6. The Urban Wastewater Treatment Directive, which is due to be updated, needs to be developed in parallel with the Sewage Sludge Directive to avoid further regulatory complexity. For instance, to avoid double monitoring of microplastics, organic compounds or heavy metals.
7. Allocate resources to campaigns to raise awareness in society about ‘toilet etiquette’. Toilets should not be used to dispose of drugs or medicines, as this unnecessarily complicates the use of sewage sludge for fertilizer.

5.3.3. Lack of incentives for biogas in Finland

Increased biogas production enhances self-sufficiency in terms of energy, nutrients, and local economy while reducing emissions when the process is optimized (Luostarinen, et al., 2023). The biogas sector has developed in Finland in recent decades, and in recent years the use of (liquefied) biogas as a fuel for heavy transportation has increased. There are several biogas plant projects proceeding across the country, ranging from large industrial-scale investments to small farm-scale plants, and everything in between. Projects have been held back by concerns about profitability, and the status and future of biogas. Political decisions have a major impact on the development of the sector. Incentives for biogas must not be cut, and its role must be stabilized in the policy framework.

Barriers:

- Insufficiency of investment support which reduces the number of investments. Incentives are needed to ensure viability.
- Unpredictable changes in subsidies and other funding instruments and mechanisms. For example, reduced support for biogas plants (see case study below) and changes to the fuel distribution obligation, such as lowered obligation levels, changes to the scope of the distribution obligation (synthetic fuels, electricity, and as a new flexibility mechanism in the distribution obligation allowing emission reductions elsewhere in the effort sharing sector to be taken into account in meeting distributors' obligations) and future changes to the penalty payments.
- Small scale and early-stage biofuel production is more expensive than for fossil fuels, and the market development phase would need incentives. The markets for both renewable gases and recycled fertilizers are still developing, which increases the level of risk for investment.
- Difficulty of market-creation in the immature market, especially in rural areas.
- CAP doesn't significantly encourage the use of digestate / recycled fertilizers.
- Low project funding success rates for both investment and development projects. High workload for funding applications.

Case study: Lack of funds for biogas investments in Finland

In Finland, the funding possibilities for biogas investments are limited. Farms and farm cooperatives can receive funding from the Ministry of Agriculture and Forestry. However, the budget is limited. For instance, municipalities and companies owned by municipalities, such as wastewater treatment plants, can receive funding for their biogas investments from the Ministry of the Environment if their project also considers nutrient recycling. However, this support is ending, and the last application opportunities are in 2024.

The Ministry of Economic Affairs and Employment will continue to grant subsidies also for biogas investments. However, the budget for energy subsidies has decreased from €100 million last year to €14 million in 2024 (Ministry of Economic Affairs and Employment, 2024). Business Finland has the funding authority. Funding has been decided to be granted only for value-added biogas plant investments, such as plants using new technologies. Additional EU RRF funding has been available until 2022 but is now coming to an end.

Recommendations:

1. Update the biogas program published by Prime Minister Marin's government in 2020 and secure the continuation of the program.
2. Secure the continuation of investment subsidies for biogas plants.
3. Ensure funding opportunities for nutrient recycling research and innovation actions.
4. Increase the distribution obligation for transport fuels to promote demand for biogas.
5. Continue the subsidies for the procurement of gas-powered heavy transport vehicles to increase the demand for biogas.
6. Consolidate the role of biogas in emissions regulation for heavy vehicles and maritime transport in favour of biogas.

6 CONCLUSION

Understanding the evolving policy landscape across diverse disciplines is pivotal in driving the paradigm shift toward a circular economy. This shift is essential for creating a sustainable future where resources are reused, repurposed, and recycled, reducing the environmental footprint, and promoting economic growth. Responding to this pressing need, the primary objective of this deliverable is to comprehensively map the legislative and regulatory framework, identify its key drivers and barriers then conclude policy recommendation to foster circular plastics, batteries, and bio-based side and waste streams.

To achieve this objective, existing and upcoming European regulatory frameworks regarding the circular economy of the three targeted value chains are mapped in addition to the case studies of national policy implementation in Finland, Norway, and Estonia. This process involves identifying and analyzing various policy drivers and barriers. By examining the current legislative landscape, areas that facilitate or hinder progress toward a circular economy are pinpointed. These include lack of regulatory framework and harmonization, lack of standardized practices, design not for recycling, and the need for financial incentives and stakeholder cooperation across the value chain.

The insights gained from this mapping are further validated through stakeholder engagement. Involving stakeholders across the value chains in this process ensures that the perspectives and experiences of those directly affected by these policies are considered. Stakeholder validation is crucial for accurately identifying practical challenges and opportunities within the regulatory frameworks and for ensuring that the recommendations developed are both realistic and impactful.

Based on the desk research and stakeholder validation insights, eight policy recommendations for plastics, five for batteries and three for bio-based side waste streams value chains are formulated with the goal of fostering the transition to a circular economy. These recommendations focus on key strategies such as eco-design, material traceability, recycled content requirement, standardization and certification, financial incentives and fundings, stakeholder engagement and consumer awareness as presented in Table 15 below. By focusing on these areas, the policy recommendations aim to address the most significant challenges and leverage the greatest opportunities for advancing the circular economy. The end goal is to create a coherent and supportive policy environment that enables the sustainable management of resources across the entire lifecycle of products, from design and production to consumption and end-of-life management.

In conclusion, the comprehensive regulatory analysis with stakeholder validation presented in this deliverable provides a robust foundation for developing effective policies that support the transition to a circular economy. Key regulatory frameworks have been addressed, policy drivers and barriers identified, and targeted recommendations formulated, paving the way toward a sustainable and circular future for plastics, batteries and bio-based side and waste streams.

Table 15. Policy recommendation strategies associated with the targeted value chains.

Strategies	Plastics	Batteries	Bio-based side and waste streams
Eco-design	**Eco-modulation for recyclability by design:** Incentivize producers to prioritize recyclability through EPR fees. **Design for recycling:** Encourage the design of plastic products that are efficient to recycle by using fewer additives and sustainable and simpler material combination.	**Eco-design of EV batteries:** Implement battery modular and circular design to enhance repurposing and recycling capability for second-life applications.	**Eco-design principles encouraging products made from bio-based materials**: enhance product recyclability and biodegradability.
Material traceability	**Digital product passport system**: Enable traceability of substances and materials in plastic products for better sorting and recycling. **Labelling system:** Provide information about the material composition and recyclability of plastic products.	**Battery Passport**: Facilitate the tracking of battery materials, components, state of heath and historical user data to enhance safety and efficiency for second life application.	**Labelling and tracking systems for bio-based materials**: Improve their management and end-of-life processing
Recycled content requirement	**Harmonize recycled content requirements with recyclate quality control**: Ensure the capability for safe and effective use of recycled materials in contact-sensitive products.	**Repurposing targets:** Recycled content requirement in new batteries drives recycling over repurposing, need to set targets for repurposing.	**Encourage the use of bio-based materials as alternative to fossil-based materials:** Promote the recyclability and bio-degradability of product.
Recylate quality and safety	**Quality management:** Establish stringent quality control measures and guidelines for plastic recyclates. **Advanced recycling processes**: Research to advance knowledge and adapt mechanical recycling complemented with chemical recycling to improve recyclate quality.	**Safety in installing and operation for BESS:** Implement guidelines for the safe installation and operation of Battery Energy Storage Systems. **Handling of incident:** Capacity building for building operators, maintenance staff, and firefighting crew**.**	**Safety protocols for bio-based fertilizers:** Ensure the safe use of sewage sludge and other bio-wastes recovery as fertiliser with stricter regulations and quality measures.
Standardization and certification	**Standardization of plastic types and plastic-derived products:** Create uniform standards for plastic types used in various applications and flexible standards for plastic-derived product based on feedstock composition. **End-of-waste criteria:** Comprehensive coverage of EoW criteria for diverse plastics, especially bio-based plastics**.**	**Standardization of battery design and safety assessment:** Develop standards for battery pack designs, Battery Management Systems (BMS), and risk assessment for installation of large BESS.	**Standardization for the production, utilization, and disposal of bio-based materials:** Develop standards and guidelines specific to bio-based materials such as sewage sludge to ensure their quality and environmental impact.
Financial incentives and fundings	**Investment for technology and infrastructure:** Provide funding for advanced recycling	**Subsidies for second-life application:** Offer financial incentives for installing	**Incentives for biogas production:** Establish stable funding and

	technologies and infrastructure improvements.	second life BESS such as covering a percentage of the cost related to the purchase and installation.	incentives for biogas facilities.
Stakeholder engagement	**Stakeholder collaboration:** Encourage collaboration between industry stakeholders, policymakers, and research institutions in standardisation and technological developments.	**Stakeholder cooperation:** Foster collaboration among battery manufacturers, recyclers, and regulators to enhance life cycle between 1st and 2nd life application of battery.	**Stakeholder engagement:** Promote stakeholder engagement to share initiatives and address challenges in bio-based materials management and recovery.
Consumer awareness	**Education programs:** Invest in consumer education to promote waste handling and sustainable choices.	**Public awareness campaigns:** Raise awareness about the benefits and safety of reused and recycled batteries.	**Policy advisory service to support farmers.** **Toilet etiquette awareness:** Toilets should not be used to dispose of drugs or medicines, as this unnecessarily complicates the use of sewage sludge for fertilizer.

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