Recommendations for improved material efficiency in three Portuguese economic sectors: **Construction, Textiles, and Furniture**

THREE ROADS TO CIRCULAR ECONOMY: REDUCE, REUSE, RECYCLE (3R2CE)

March 2023

This project is funded by the European Union via the Structural Reform Support Programme and implemented by CLEAN in collaboration with its experts, in cooperation with the European Commission.

Acknowledgements

This report is the result of a collaboration with the Portuguese EPA (Agência Portuguesa do Ambiente, APA) and valuable feedback from the Institute that regulates Construction Activity, Real Estate and Public Procurement (Instituto dos Mercados Públicos, do Imobiliário e da Construção, IMPIC) and Portuguese Agency for Competitiveness and Innovation (Agência para a Competitividade e Inovação, IAPMEI).

CLEAN and Norion Consult would like to thank the Portuguese Governmental Entities, APA, IAPMEI and IMPIC, for their engagement during the preparation of the final draft of 'Recommendations for improved material efficiency in three Portuguese economic sectors', and the Policy Officer of the Directorate-General for Structural Reform Support (DG REFORM), Ms Leticia Lopez Joya, for continued overview and guidance.

The Authors would like to thank all stakeholders who participated in interviews and meetings between 2021-2023 to produce this report. This report has been prepared under the guidance of Bjørn Bauer, Director and Partner at Norion Consult, and Amalie Olsen, Environmental Consultant at Norion Consult, who drafted the content of this report. Analytical support has been given by 3Drivers, and inputs and direction from Maria Dominquez, the project coordinator at Clean.

Executive summary

Portugal has requested support from the Structural Reform Support Service (SRSS) of the European Commission under Regulation (EU) 2017/825 on the establishment of the Structural Reform Support Programme ("SRSP Regulation"). The Commission has analysed the request in accordance with the criteria and principles referred to in Article 5 of the SRSP Regulation, following which the Commission has agreed to provide technical support to Portugal in the area of institutional, administrative and growth-sustaining structural reforms, with the objective to:

- to support the national authorities in enhancing their capacity to formulate, develop and implement reform policies and strategies and in pursuing an integrated approach ensuring consistency between goals and means across sectors;
- to support the efforts of national authorities to define and implement appropriate processes and methodologies by taking into account good practices and lessons learned by other countries in addressing similar situations.

The project 'Reduce – Reuse – Recycle: Three Roads To a Circular Economy – 3R2CE' has had the aim of developing and presenting strategies for three key areas of the circular economy. For each of the three key areas, a report has been developed. The report 'Recommendations for improved material efficiency in three economic sectors' are the first of three roads to a circular economy, focusing on material efficiency to increase circularity.

This report includes an assessment of the State of Play of material efficiency in Portugal, determining comparability with other EU Member States with similar Domestic Material Consumption and Resource Productivity; an assessment of best practices for material efficiency in Portugal and comparable EU Member States; and an assessment of stakeholder identified barriers to material efficiency in Portugal.

The report contributes to an increased understanding of relevant areas of intervention in Portugal, focusing on improvement potential in a regulatory, economic, cultural and technical context. Addressing the identified challenges will require a collaborative effort among the Portuguese Governmental entities, the private sector and citizens.

Financing for this project has been made available as part of the Work Programme for the year 2020 for the Structural Reform Support Programme under Regulation (EU) 2017/825 as amended by Regulation (EU) 2018/1671.

Technical terms and abbreviations

TERM/ABBREVIATION	DEFINITION[1,2,3]
MATERIAL	The term material comprises raw materials such as minerals or biomass and materials processed by humans by psychical or chemical processes. Products and materials processed by humans are distinguished based on whether the materials are further processed – products can be considered 'finished', and there is no need for further processing[4].
PREVENTION	According to the Waste Framework Directive, prevention refers to measures taken before a substance, material or product has become waste that reduce a) the quantity of waste, including the re-use of products or the extension of the life span of products; b) the adverse impacts of the generated waste on the environment and human health; or c) the content of hazardous substances in materials and products.
RESOURCE PRODUCTIVITY	Resource productivity (RP) is a measure of the total amount of materials used by an economy, often measured as Domestic Material Consumption (DMC) in relation to Gross Domestic Product (GDP). RP provides insight into whether decoupling of natural resources and economic growth are taken place. In the EU, RP is expressed by the amount of GDP generated per unit of direct material consumed[5].
MATERIAL EFFICIENCY	Material efficiency from an industry perspective refers to actions to reduce the materials input in production (and substitute harmful materials) while maintaining the number of manufactured products. Material efficiency involves the pursuit of technical strategies, business models, consumer preferences, and policy instruments that can maintain existing levels of services with significantly less material input or through the substitution of materials with lower impact materials. Material efficiency is not a fixed state but a relative term of progress (much like sustainable development). Material efficiency is improved when waste generation and/or material-related environmental impact associated with the provision of a given service is reduced.
DMI & DMC	Domestic Material Input (DMI) and Domestic Material Consumption (DMC) are commonly used as indicators for material consumption in each economy annually. DMC measures the total amount of materials consumed in an economy per year. DMI measures the direct input of materials for use, including the domestic extraction and the import of materials. DMI and DMC are restricted to the consumption of economically valued materials while not accounting for unused materials from domestic extraction or indirect flows from imports and exports[6].
QL & QN	Abbreviations for qualitative (QL) and quantitative (Qn)
MOC	Abbreviation for Management of Change

TABLE NO 01: OVERVIEW OF TERMS AND ABBREVIATIONS UTILISED IN THE REPORT

[1] EC (2021a): EU Construction and Demolition Waste Protocol and Guidelines.
[2] EC (2021b): Level(s) Indicator 2.1.
[3] EC (2021c): Level(s) Indicator 2.2.
[4] EC (2013a): Material-efficiency Ecodesign Report and Module to the Methodology for the Ecodesign of Energy-related Products (MEErP).
[5] Eurostat (2016): Glossary: Resource productivity.
[6] EC (2013a): Material-efficiency Ecodesign Report and Module to the Methodology for the Ecodesign of Energy-related Products (MEErP).

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1 Introduction

Since the industrial revolution, materials have been processed in an industry operating mainly as an open, linear system, transforming resources into products that are eventually discarded. However, an expanding population living on finite resources risks consuming all available resources. Because of growing demand, access to materials affects all nations' present and future well-being. Materials production and processing dramatically impact the environment, including land use patterns, water use, undesirable air, water, and land emissions, and the consumption of other significant environmental resources[7]. Therefore, the EU introduced the 'Resource-efficient Europe' flagship initiative, intending to increase resource productivity (RP) by ensuring the increased economic performance of the EU Member States while reducing pressure on natural resources[8]. RP varies between countries by a factor of about 14 within the EU, reflecting the influence of the types of industrial production and material resources available in the countries and the economy's structure. The comparative understanding of resource efficiency in the EU Member States shows how countries with service-based economies tend to have higher RP than economies with a higher proportion go heavy industry, as service industries often have a lower demand for material inputs[9]. This report will assess Portugal's resource and material efficiency, addressing options to improve economic performance while reducing the pressure on natural resources.

Changes in how materials are viewed, processed and utilised significantly impact the realisation of the Circular Economy (CE). Improving resource and material efficiency refers to reducing material input in the production of functional products and further reducing waste in the production phase. To achieve material efficiency from a producing industrial perspective, raw material input and production waste must be reduced while maintaining the material or product output level. In quantifiable terms, material efficiency is the ratio between material input per benefit derived (e.g. economic goods, services provided, social gains, etc.). Material efficiency can be addressed by substituting non-renewable materials with renewable, recycled, or secondary raw materials 9, reducing inefficient use of non-renewables. The European Commission emphasises CE and resource efficiency as a significant strategic opportunity to capture value in the industry, improve productivity, drive down costs, increase efficiency and effectiveness, and boost competitiveness. Therefore, material efficiency constitutes an opportunity to realise benefits from both an economic and environmental perspective. Material efficiency is a crucial element within the CE and resource efficiency, reducing quantities of industrial waste, recouping a large portion of the original material value, and assisting manufacturing industries in moving up the waste hierarchy. From a macro perspective, material efficiency can reduce pressures on virgin raw material flows, carbon emissions, and total energy consumption[10,11,12].

The urgency of increasing material efficiency aligns with the targets set in the amended Waste Framework Directive (WFD) 13, identifying measures relevant for the EU Member States. Standards in the WFD relevant for material efficiency include 1) ensuring the security of supply of raw materials of high importance to the EU economy and high risk; 2) promoting the reuse of products that are the primary sources of critical raw materials to prevent these materials from becoming

[7] Bansard & Schröder (2021): The Sustainable Use of Natural Resources: The Governance Challenge.
[8] EC (2011): Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions – Roadmap to a Resource Efficient Europe.
[9] EEA (2018): Briefing – Resource efficiency.
[10] Cordella et al. (2020a): Guidance for the Assessment of Material Efficiency: Application to Smartphones.
[11] EC (n.d.a): Resource efficiency and recycling.
[12] Mathieux (2021): Resource Efficiency = Energy Efficiency + Material Efficiency.

waste. The EU Member States are expected to ensure the best possible management of waste containing significant quantities of critical raw materials, considering the economic and technological feasibility and the environmental and health benefits[13]. Resource efficiency is further addressed in the 8th Environment Action Programme (8th EAP), which includes objectives to improve resource efficiency to accelerate the green transition by 2030. Resource efficiency is among six interlinked priority objectives of the 8th EAP, whereunder an acceleration of the transition to a "*non-toxic circular economy, where growth is regenerative, resources are used efficiently and sustainable, and the waste hierarchy is applied*"[14]. This priority objective will be the underlying focus of this study of how material efficiency can be improved in Portugal. As the basis of the investigation, three Portuguese economic sectors have been selected by the Portuguese Environmental Agency (Agência Portuguesa do Ambiente, APA), namely the construction-, textiles- and furniture sectors, based on the potential of improving material efficiency.

This report is a part of the project **3R2CE – Three Roads to Circular Economy**. The project aims to impact critical areas that contribute to moving towards a circular economy in Portugal, Reduce, Reuse and Recycle by strengthening material efficiency, exploring options for improved waste management, and assessing urban waste infrastructure capacities. **3R2CE** consist of three work packages evaluating options to Reduce, Reuse and Recycle waste products in Portugal:

WP1 - Recommendations for improved material efficiency in three Portuguese economic sectors

WP2.1 - Recommendations for Improved Waste Management: Baseline study for Preparation for Reuse and Increased Recycling of Textiles, Bulky waste, Hazardous Household Waste and C&D Waste

WP2.2 - Recommendations for Improved Waste Management: Assessing Waste Management Infrastructure

This work package, WP1, will result in a deeper understanding of the state of play of the Portuguese material efficiency landscape to identify opportunities and barriers and provide a draft strategy for improved material efficiency across the three selected economic sectors. In this work package, material efficiency is limited to production processes and the value chain from subcomponents and products until the products are ready for retail. The report should be considered a continuation of the work done in the preceding work done in Strategy Document, '*The Current and Future use of Secondary Raw Materials in Portugal*', which focused on cascading secondary resources from one Portuguese industry to another. Therefore, to avoid overlap, only internal recycling and reuse in production are considered within the scope of this report. The explanation provided in the above box will serve as the definition of material efficiency in this project. Thus, material efficiency in this definition focuses on limiting the use of raw materials and the waste management approaches related to producing materials, products, and buildings[15].

[13] EP (2018a): Directive (EU) 2018/851 of the European Parliament and of the Council of 30 May 2018 amending Directive 2008/98/EC on waste.
[14] EP (2022): Decision (EU) 2022/591 of the European Parliament and of the Council of 6 April 2022 on a General Union Environment Action Programme to 2030.
[15] Mathieux (2021): Resource Efficiency = Energy Efficiency + Material Efficiency.

1.1 Defining Material Efficiency

Material efficiency from an industry perspective refers to actions to reduce the materials input in production (and substitute harmful materials) while maintaining the number of manufactured products. Material efficiency involves the pursuit of technical strategies, business models, consumer preferences, and policy instruments that can maintain existing levels of services with significantly less material input or through the substitution of materials with lower impact materials[16,17].

In 2016, the European Environment Agency, EEA, published a comprehensive mapping of national policies, instruments, and targets within material efficiency in EU member states. The EEA found that climate change and material efficiency policies often appeared largely disconnected in practice[18]. Although attention to material efficiency historically has been routine, in recent decades, it has been overshadowed by a focus on energy efficiency within many policy and research activities[19,20]. Material efficiency is now increasingly gaining focus[21,22.] It is comprehended in combination with energy efficiency within the overall concept of 'resource efficiency'[23], which is a crucial term appearing in EU initiatives such as 'The Resource Efficiency Roadmap' from 2011, 'Closing the loop – an EU action plan for the Circular Economy' from 2015 and the updated 'New Circular Economy Action Plan for a cleaner and more competitive Europe' from 2020. In other words, material efficiency, and thus the scope of this report, is limited to physical material consumption, not energy consumption. Furthermore, water efficiency is another category outside the scope of this report.

It has been criticised that *material efficiency* does not necessarily deviate from the assumption of a one-way, linear flow of materials, where raw materials are extracted from the environment, transformed into products, and finally disposed of. In contrast, material effectiveness aims not to minimise the cradle-to-grave flow of materials but to generate cyclical, cradle-to-cradle materials that enable them to maintain their status as resources and accumulate quality over time (upcycling)[24]. The JRC recommends that material efficiency be addressed in an integrated way by unified control of all aspects of production, from raw materials to the distribution of finished products. Further, JRC argues that a life cycle perspective should be considered, meaning that not just the use of a product or service should be considered, but also its related resource extraction, production, and waste management need to be considered in the assessment of material efficiency.

In Portugal, material efficiency is not directly defined in policy papers. However, the Portuguese strategy, Green Growth Commitment (GGC), addresses *resource efficiency* as a key idea behind its vision; "*Optimised resource management aimed at increasing productivity and maximising its use (e.g., reuse, recycling, energy efficiency) while reducing carbon intensity*". Thereby aspects of material efficiency are addressed indirectly by focusing on maximising the utilisation of material

[16] Allwood et al. (2011): Material efficiency: A white paper.
[17] Cordella et al. (2020b): Improving material efficiency in the life cycle of products: A Review of EU Ecolabel Criteria.
[18] EEA (2016a): Environmental and climate policy evaluation.
[19] JRC (2021): Raw Materials Information System (RMIS).
[20] Hernandez et al. (2018): Leveraging material efficiency as an energy and climate instrument for heavy industries in the EU.
[21] JRC (2022): Raw Materials Information System (RMIS).
[22] Hernandez et al. (2018): Leveraging material efficiency as an energy and climate instrument for heavy industries in the EU.
[23] Mathieux (2021): Resource Efficiency = Energy Efficiency + Material Efficiency.
[24] EMF (2013): Towards the circular economy – Opportunities for the consumer goods sector.

input. Furthermore, the GGC aims to "*help decouple economic growth from using resources, foster energy and material efficiency*"[25].

1.2 Methodology of the study

3R2CE: Recommendations for improved material efficiency in three Portuguese economic sectors, findings, conclusions and the draft strategy must be seen in the context of **3R2CE – Three Roads to Circular Economy** as a continuation of **The Current and Future use of Secondary Raw Materials in Portugal**. The two projects and the three work packages within **3R2CE – Three Roads to Circular Economy** are all interrelated, focusing on different aspects to improve the condition of the CE in Portugal. The interrelations of the projects and work packages are illustrated in the model below.

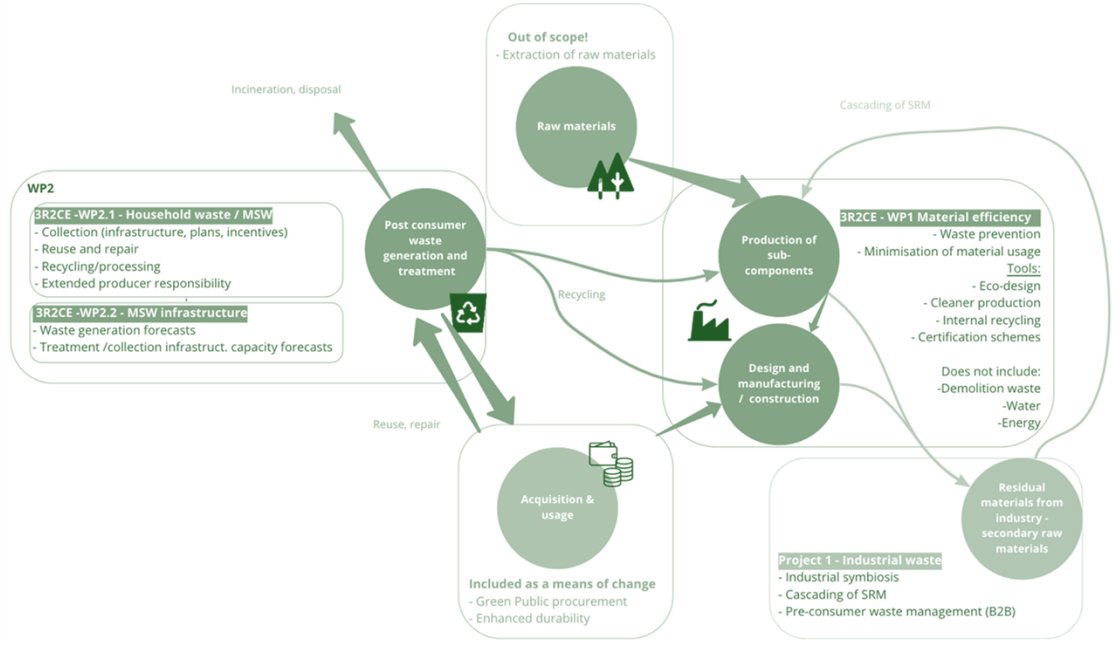


FIGURE 1 INTERRELATIONS BETWEEN WORK PACKAGES AND SCOPE OF REPORT

3R2CE: Recommendations for improved material efficiency in three Portuguese economic sectors will, through the focus on material efficiency, focus on the higher levels of the waste hierarchy of the WFD[26], hereunder especially waste prevention through increased utilisation of pre-consumer waste. As WP2.1 (*Recommendations for Improved Waste Management - Baseline study for Preparation for Reuse and Increased Recycling of Textiles, Bulky waste, Hazardous Household Waste and C&D Waste*) and WP2.2 (*Recommendations for Improved Waste Management - Assessing Waste Management Infrastructure*) covers the post-consumer waste through assessment of municipal waste in Portugal, post-consumer waste will not be included in the evaluation of material efficiency.

Continuation of *'The Current and Future use of Secondary Raw Materials in Portugal'*

Within the scope of this report, pre-consumer waste plays a significant role. Therefore, the findings and knowledge gained on Secondary Raw Material (SRM) from the project **The Current and Future**

[25] The Portuguese Ministry of Environment, Spatial Planning and Energy (2014): Green Growth Commitment.
[26] EP (2018a): Directive (EU) 2018/851 of the European Parliament and of the Council of 30 May 2018 amending Directive 2008/98/EC on waste.

use of Secondary Raw Materials in Portugal will provide some of the backgrounds for the following analyses, as SRM falls within the scope of pre-consumer waste. Conclusions and the draft strategy were based on more than 60 interviews with Portuguese industry and governance stakeholders, which provided the findings to map the current possibilities and barriers for increasing the utilisation of SRM in Portugal. The findings of the stakeholder interviews were validated through four workshops with almost 500 Portuguese stakeholders from across Portuguese economic sectors[27]. While the findings are not 1:1 transferable, many similarities in the topics, challenges, and opportunities can be found. Therefore, the understanding gained from this initial project serves as a starting point and validation for the interviews and findings identified throughout the project **3R2CE – Three Roads to Circular Economy** and the work package *3R2CE: Recommendations for improved material efficiency in three Portuguese economic sectors.*

1.2.1 Empirical foundation

This study's conclusions and draft strategy will be based on the knowledge gained through **The Current and Future use of Secondary Raw Materials in Portugal** and empirical data gathered in connection with **3R2CE:** *Recommendations for improved material efficiency in three Portuguese economic sectors.* The latter consists of a combination of findings from an extensive literature study, statistical data, interviews with Portuguese industry stakeholders from the construction-, textiles- and furniture sectors, and inputs from governmental entities.

An extensive literature study combined the systematic identification approach and the snowball method. The literature study included analysis of regulation and legislation by EU entities and EU Member States; academic literature; environmental reports and accounts done by businesses; Programmes, reports and accounts on material efficiency.

Statistical data was primarily derived from 'proxies' from Eurostat and databases by the EEA and data from the Eurobarometer. A review of the databases available on Eurostat and EEA with a focus on statistical data on material efficiency in the selected three sectors has revealed that none of these databases includes material efficiency at the sectorial level; this has been confirmed through consultation with administrators from EEA and Eurostat[28]. Several datasets provide proxies, allowing a better understanding of the material efficiency situation in the sectors, as accounted for in annex 1.

Twenty-nine interviews were conducted specifically for the WP1 assessment with Portuguese stakeholders within the construction-, textiles- and furniture sectors. Stakeholders included representatives from organisations, associations, and prominent industry players in the abovementioned sectors. The interviews provided a long list of initial findings, which were triangulated with one another. The triangulation was done both within the sectors and across sectors to identify if the same challenges were applied across sectors. The conclusive findings were then compared to the project's results, **The Current and Future use of Secondary Raw Materials in Portugal,** and the literature study, for further validation.

Governmental entities have been consulted for their expert knowledge throughout the empirical data collection, assessment of the state of play, and strategy development progress. APA played a signification role in the first stages of the project by providing the direction of the focus by selecting

[27] Bauer & Egebæk (2019) The Current and Future use of Secondary Raw Materials in Portugal.
[28] The EEA Enquiry Service, 2021 and the Eurostat User Support service, 2021.

relevant economic sectors. APA has further provided feedback on the assessment of the State of Play. The Portuguese Government Portal Administrative Modernization Agency (Instituto dos Mercados Públicos, do Imobiliário e da Construção, IMPIC) and Portuguese Agency for Competitiveness and Innovation (Agência para a Competitividade e Inovação, IAPMEI) later provided inputs and feedback for the State of Play and strategy development.

1.2.2 Assessment of material efficiency

Measuring and comparing material efficiency is complicated, and existing material efficiency indicators are limited[29]. Often material efficiency is measured as a cost or quality parameter rather than an environmental one, and manufacturing companies do not consider material efficiency as a central aspect of their business. Given the complexity and dynamics of resource utilisation and material transformation, measuring material efficiency becomes quite complex[30]. The following section will address methodologies to access material efficiency. The following section will identify relevant indicators and monitoring models that allow a comparison of the material efficiency of the three chosen sectors in Portugal. The methodologies will be applied in assessing material efficiency in Portugal, compared to estimations of material efficiency in EU27. This section will further provide a quick overview of some indicators monitoring material efficiency and some considerations for the context of the Portuguese sectors.

The material intensity of use (MIU) or **material input per service (MIPS)** was popular in academic studies from the 2000s and 2010s[31,32]. MIU measures the ratio of the mass of a given material over an economic output indicator such as gross domestic product (GDP). MIU is a simple indicator that, in some cases, can be misleading since, for instance, the weight of materials may not reflect their environmental degradation potential[33]. This indicator is seldom used today without clear system boundaries and considerations of the role of the studied material in society and its influence on economic development.

Material flow accounting (MFA) measures materials put in the given system. This method is recognised in Eurostat reports that use MFA indicators, GDP over Domestic Material Consumption (DMC), as metrics for monitoring resource efficiency in EU[34]. The standardised MFA framework classifies materials into four categories: fossil energy carriers, metal ores, biomass, and industrial and construction materials. DMC is calculated as the mass of all domestically extracted raw materials and harvested biomass plus the mass of imports minus the mass of exports[35]. A shortcoming of the MFA as a territory-based indicator is that it does not account for outsourced production.

Material footprint (MF) connects raw material extraction (at the input side) with the final use stage. Whereas DMC represents national material consumption, MF looks at the consumption of an individual, a population, a territory, or an activity—the indicator intents to capture materials extracted across regions. MF is closely related to Ecological Footprint (assessing space needed to

[29] Shahbazi et al. (2017): Material Efficiency Measurement: Empirical Investigation of Manufacturing Industry.
[30] Zhang et al. (2018). Measuring material efficiency: A review of the historical evolution of indicators, methodologies and findings.
[31] Cleveland & Ruth (2008): Indicators of Dematerialization and the Materials Intensity of Use.
[32] Wiesen et al. (2014): Calculating the Material Input per Service unit using the ecoinvent database.
[33] Cleveland & Ruth (2008): Indicators of Dematerialization and the Materials Intensity of Use.
[34] Eurostat (n.d.): Material Flows and Resource Productivity.
[35] Eurostat (2021c): Environmental accounts – establishing the link between the environment and the economy.

provide a resource, produce a product, and dispose of waste), Water Footprint, and Carbon Footprint[36].

Impact-oriented indicators expand the assessment to include resource extraction's impacts on the natural environment[37]. In contrast to inventory-based indicators, defined as the ratio between outputs and the inventoried flows of natural resources, industrial resources waste, or emissions, impact-oriented indicators reflect the balance between results and the environmental impacts of production flows. These may be expanded by considering resource scarcity and supply scarcity[38]. Life Cycle Assessment (LCA) databases are examples of impact-oriented indicators traditionally developed for product, service, or process applications. Related to the definition of material efficiency described in the previous section, it is clear that this method would provide the **most accurate metric** for measuring material efficiency. Unfortunately, this method is resource-dependent and requires large amounts of data[39]. Consequently, this methodology is only used at the product or business level, and results are seldom publicly available.

Other quantitative indicators can be extracted from waste productivity data (sales/tons of waste produced), hazardous waste treatment and percentage of transported waste shipped internationally[40], material intensity, waste recycling, waste/end products sent to energy recovery, waste sent to landfill (land use), human toxicity (hazardous waste), raw material consumption and waste treatment cost[41,42].

Questionnaires and interviews can add another layer of qualitative and quantitative information. This has also been the approach taken to measure material efficiency among companies, e.g. Flash Barometers developed by the European Commission[43]. The perception of material efficiency, knowledge, and honesty of the interview/questionnaire respondents limits this approach.

Few researchers have addressed material efficiency measurement and key performance indicators for material efficiency. Some methods, metrics, and indicators have been developed to monitor material efficiency on a broader basis. Still, each with its limitations and monitoring material efficiency with different indicators may lead to significantly different conclusions. For instance, a significant difference is whether the metric takes a production- or consumption-based perspective. Material efficiency may be expressed either in intensity form (the ratio between a material indicator and an economic indicator reflecting the amount of material input per unit of economic output) or productivity form (measuring the amount of economic output generated per unit of material input). Each methodology for assessing material efficiency has its downsides and represents simplifications of reality – or in other words: To truly study the material usage and efficiency of a sector, one needs more data than what is available under normal circumstances.

[36] Čuček et. al. (2015): Overview of environmental footprints.
[37] Peersman et al. (2016): When and how to develop an Impact-oriented Monitoring and Evaluation System.
[38] Fang & Heijungs (2015): Investigating the inventory and characterization aspects of footprinting methods: lessons for the classification and integration of footprints.
[39] Peersman et al. (2016): When and how to develop an Impact-oriented Monitoring and Evaluation System.
[40] Rahdari & Rostamy (2015): Designing a general set of sustainability indicators at the corporate level.
[41] Vermeulen et al. (2012): Sustainability assessment of industrial waste treatment processes: The case of automotive shredder residue.
[42] Shahbazi et al. (2017): Material Efficiency Measurement: Empirical Investigation of Manufacturing Industry.
[43] Gesis (n.d.): Flash Eurobarometer.

Therefore, a combination of the abovementioned approaches has been utilised to assess Portuguese material efficiency.

1.2.3 Assessment of Best Practices

The literature study provided an understanding of overall challenges and solutions to improve material efficiency in an EU and Portuguese context, accounted for in the State of Play (Cf. section 3)

Identifying the EU Member States that achieved the highest levels of resource efficiency in 2021 provided the basis for developing a long list of best practices for improving material efficiency. Utilising a systemic identification approach, the regulatory and legislative frameworks of the high-performing Member States concerning resource efficiency were assessed to identify policy measures supporting material efficiency within the construction-, textile- and furniture sectors. Businesses within the construction-, textile- and furniture sectors were then identified and assessed for best practices. While some material efficiency information is available, companies seldom address this subject directly. This challenged the identification of a sufficient number of best practices. Therefore, a broader mapping of best practices was initiated, including all EU Member States. This provided a long list of best practices within the economic sectors (Cf. Annex 2).

The EU Member States with the most similar resource efficiency to Portugal in 2021 were also identified to ensure that best practices were applicable and relevant in Portuguese. Utilising Eurostat data, the following six EU Member States were identified as the most comparable resource efficiency as Portugal in 2021:

- Lithuania 0.9349 euro/kilogram
- Hungary 1.0367 euro/kilogram
- Latvia 1.1986 euro/kilogram
- **Portugal 1.2116 euro/kilogram**
- Croatia 1.2578 euro/kilogram
- Finland 1.2977 euro/kilogram
- Cyprus 1.378 euro/kilogram[44]

The resource efficiency of EU27 and the six most similar to Portugal did not provide sufficient context to the industrial composition to develop selection criteria for the best practices applicable to Portugal. Therefore, the industrial composition was considered by identifying the EU Member States with the most similar material flow accounts by four categories; Biomass, metal ores; non-metallic minerals; and fossil energy materials/carriers. Utilising Eurostat, the following EU Member States were identified as the most comparable for each category in 2021 in thousand tonnes (TT):

BIOMASS[45]

- Greece 25107.835 TT
- Czechia 27086.789 TT
- Hungary 32023.174 TT

NON-METALLIC MINERALS[46]

- Hungary 97393.3 TT
- Finland 97557.246 TT
- Sweden 114141.115 TT

[44] Eurostat (2022a): Resource productivity ENV_AC_RP.
[45] Eurostat (2022b): Material flow accounts ENV_AC_MFA Biomass.
[46] Eurostat (2022c): Material flow accounts ENV_AC_MFA Non-metallic minerals.

- **Portugal 35019.729 TT**
- Ireland 38770.098 TT
- Austria 39961.213 TT
- Finland 40616.776 TT

- **Portugal 114995.022 TT**
- Spain 189995.528 TT
- Italy 259697.578 TT
- Poland 351786.531 TT

METAL ORES[47]

- Ireland 7079.427 TT
- Romania 8293.41 TT
- Austria 8432.64 TT
- **Portugal 9796.143 TT**
- Belgium 13062.436 TT
- Italy 16061.974 TT
- France 18682.693 TT

FOSSIL ENERGY MATERIALS/CARRIERS[48]

- Slovenia 6005.687 TT
- Estonia 8834.781 TT
- Slovakia 11154.564 TT
- **Portugal 11940.358 TT**
- Finland 13123.535 TT
- Ireland 13578.619 TT
- Sweden 15806.949 TT

By comparing the resource efficiency with the material flow account, it was possible to identify that Portugal has a similar material flow to some of the EU Member States with the highest resource efficiency (Ireland, France, Italy, Belgium, Spain, Austria[49]), and only shared similarities in material flow with Finland and Hungary from the list of Member States with similar resource efficiency development. Therefore, the long list of best practice cases where prioritised based on the order of the following EU Member States:

1) Ireland;
2) France;
3) Italy;
4) Belgium;
5) Spain;
6) Austria;
7) Finland; and
8) Hungary

A final selection of best practice examples (Cf. section 4) was selected based on the above prioritisation, literature study findings, and material efficiency assessment in Portugal.

1.2.4 Assessment of barriers and drivers

To identify barriers to improvements in material efficiency in Portugal, interviews were conducted with 29 relevant stakeholders from businesses, sector- and business associations, and governmental entities. Interview guides were based on the literature study and were conducted in

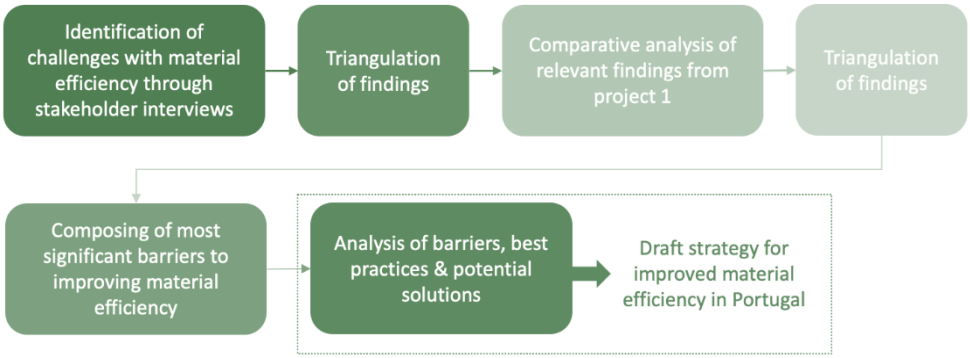


FIGURE 2 VALIDATION OF INTERVIEW DATA

[47] Eurostat (2022d): Material flow accounts ENV_AC_MFA Metal ores.
[48] Eurostat (2022e): Material flow accounts ENV_AC_MFA Fossil energy materials/carriers.
[49] Eurostat (2022a): Resource productivity ENV_AC_RP.

a semi-structured manner, ensuring that the overall focus was on material efficiency. The findings of the interviews went through multiple validation processes, as illustrated below:

The process was initiated by extracting findings from the 29 interviews. Findings were selected based on statements relevant to the overall improvement of CE practices with relevance to material efficiency. The relevance then sorted the findings to the construction-, textiles- and furniture sectors. Findings were triangulated, firstly with statements provided by other stakeholders within the same sector, then with statements provided by stakeholders within the two remaining sectors. Findings that stakeholder interviews could not validate were compared to the findings from the literature study. This resulted in a long list of either validated or seemingly invalid findings. This long list was compared to findings and derived barriers from project 1, **The Current and Future use of Secondary Raw Materials in Portugal**. If validation still was not possible, the finding was deemed invalid.
Based on the triangulation, findings deemed valid were then compared with other findings from the stakeholders of the same sector to identify overlapping statements that the same barrier could represent. Barriers were then developed based on the statements from the stakeholders of the three economic sectors. The barriers of the three economic sectors were compared to identify cross-sectorial barriers. The cross-sectorial barriers indicated challenges with Portugal's general conditions and non-sector-specific regulation.
The barriers analysis (Cf. section 5) comprised four barrier categories: regulatory-, cultural-, economic-, and technological barriers. The barrier categories ensure comparability with other relevant CE barriers, providing an understanding of solutions that can simultaneously assist with more than one challenge. The identified barriers were assessed based on the findings of the assessment of material efficiency (Cf. section 2), the literature study on options to improve material efficiency (Cf. section 2) and the assessment of best practices (Cf. section 4). This assessment identified possible solutions to the challenges faced in Portugal related to material efficiency.

1.2.5 Strategy development

Work package 1 - Recommendations for improved material efficiency in three Portuguese economic sectors were finalised with the development of a draft strategy based on the assessment findings presented in this report. The strategy was developed by combining the theory of Change (TOC) methodology with the Logical Framework Approach (LFA). The strategy development process was initiated by developing five possible orientations for the draft strategy, which representatives of APA, IAPMEI and IMPIC then evaluated. Their feedback developed a draft strategy for the three economic sectors, utilising TOC and LFA.

Theory of Change (TOC) is mainly used for designing and monitoring development interventions and as a framework for evaluations. A TOC of a project intervention describes the processes of change by outlining the causal pathways from outputs (goods and services delivered by the initiative) through direct outcomes (changes resulting from the use of outputs by critical stakeholders) through other 'intermediate states' towards impact, long term changes that deliver environmental benefits and improved human living conditions.

The identified changes are mapped as a set of interrelated pathways. Each pathway shows the required outcomes in a logical relationship concerning the others and chronological flow. The change processes between outcomes/intermediate states may require certain conditions to hold (assumptions[50] - conditions that are beyond the direct control of the initiative) or may be facilitated by supporting actions or conditions (drivers - where the initiative has a measure of control and can make a meaningful influence). A TOC reflects a negotiated understanding or interpretation of the strategic intervention logic – contextual and temporal. It should be regarded as dynamic - subject to modifications as contexts change over time. Figure 3 shows a simple linear generic TOC diagram with two main causal pathways. The reality is seldom so simple: there are often many more pathways, feedback loops etc.[51].

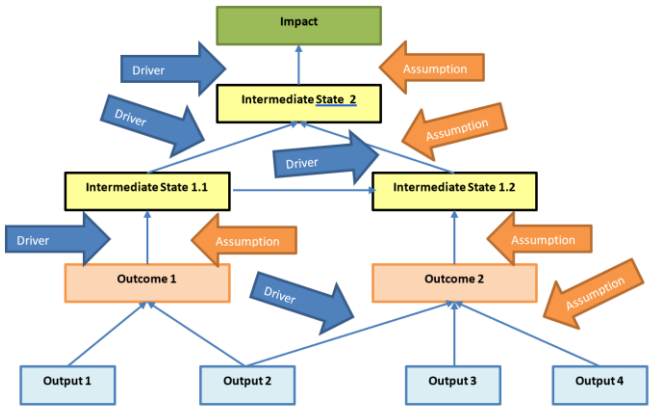


FIGURE 3 SIMPLE LINEAR GENERIC TOC DIAGRAM

The logical Framework Approach (LFA) is a methodology for planning projects and programs. The framework provides overview, structure and uniformity for the most relevant intervention selected by the proposers. The EC has required the LFA as part of its Project Cycle Management system since 1993. The overall structure is entirely in line with the TOC; however, the wording of the levels differs slightly:

- The overall objective, Development objective, or Goal: The broad development impact to which the project contributes – at a national or sectoral level (provides the link to the policy and/or sector programme context). In TOC: Impact.
- Project objective, Immediate objective, or Purpose: The development outcome at the end of the project – more specifically, the expected benefits to or change for the target group(s). In TOC: Outcome.
- Outputs or Results: The direct/tangible results (goods and services) that the project delivers and which are mainly under project management's control. In TOC: Output.
- Activities: The tasks (work programme) must be carried out to deliver the planned results (optional within the matrix). Typically not included in TOC.
- Input: The resources needed to carry out the project.
- Indicators define the performance standard to be reached.
- Means of verification specify how to measure indicators.
- Assumptions are events, conditions or decisions necessary for project success but largely or entirely beyond the control of project management.

[50] Note that assumptions are not just a negatively formulated risk; they should be expressed as a contributing condition that needs to hold for a change process.
[51] Figure and terminology adapted from the UN (2019): Evaluation Guideline.

STATE OF PLAY

This chapter will address the current (2021-2023) state of material efficiency in Portugal compared with EU27. Options to improve material efficiency will be assessed based on market, transnational and EU policy instruments. Best practices to improve material efficiency will be included for the construction and demolition, textile, and furniture sectors to inspire measures to increase material efficiency. At last, barriers and enablers for material efficiency have been derived from Portuguese sector stakeholders, and literature has been assessed, providing indications of pathways to improve material efficiency in Portugal.

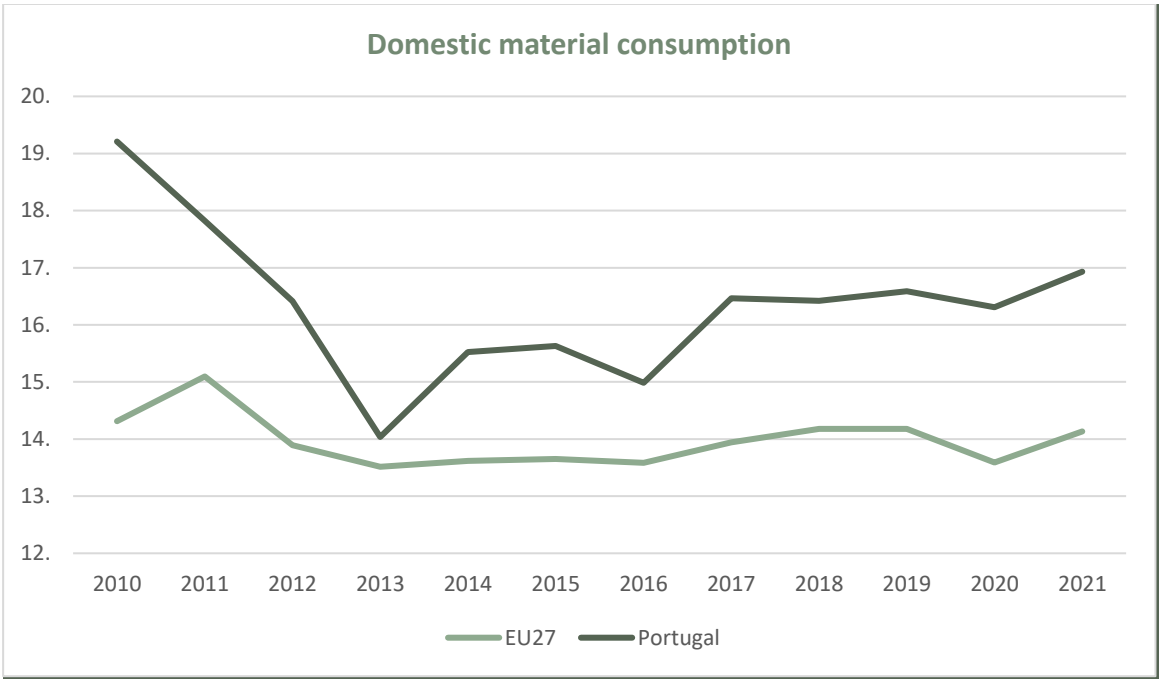
2 Account of material efficiency

Resource and material efficiency vary significantly among the EU Member States, depending on various factors. Countries with service-based economies tend to have a higher resource- and material productivity than economies with a high proportion of heavy industry since service industries typically have a lower demand for material input[52]. Measurements of material productivity are possible at the national level based on national input/output statistics; it is much more challenging to measure and evaluate material efficiency at the sector or business level[53]. Many manufacturing companies miss material efficiency key performance indicators (KPIs), mainly since productivity, quality, cost, and delivery are generally considered more important than sustainability KPIs to running the business and fulfilling customer needs. Among sustainability measurements, material efficiency has a lower priority at manufacturing companies. It is not considered as crucial as other sustainability aspects, such as energy efficiency, energy consumption, or CO_2 reduction, mainly due to existing legislation and regulations.

2.1 Economy-wide material flow assessment

To ensure proper grounds to analyse material efficiency among the selected Portuguese sectors, the overall economy in Portugal is compared to the EU average through the MFA method (material flow accounting). When investigating Eurostat data on RP, it is clear that Portugal has relatively low material productivity compared to EU27, as Portuguese RP (1,2 €/kg) was just under half the EU average in 2021 (2,3 €/kg)[54]. According to INE, RP dropped by 1,6% in 2021 compared to 2020, following an increase in DMC higher than the real GDP growth. Decoupling of material consumption from economic growth has only occurred consistently during the years following the last financial crisis[55]. This illustrates the general need for material efficiency initiatives in Portugal and provides a context for the study. Graph No. 1 shows the overall domestic material consumption of materials per capita. This includes fossil energy carriers, metal ores, biomass, and industrial and construction materials. DMC is calculated as the annual quantity of raw materials extracted from the domestic territory, plus all physical imports minus all physical exports. It cannot be used as a direct indicator of material efficiency, as it more likely reflects the consumption patterns related to wealth. However, it is still included here as a proxy since it adds to the complete picture.

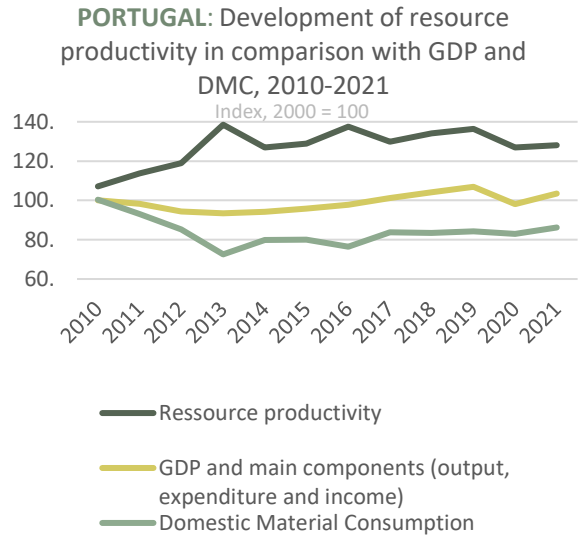
[52] EEA (2018): Briefing - Resource efficiency.
[53] Shahbazi et al. (2017): Material Efficiency Measurement: Empirical Investigation of Manufacturing Industry.
[54] Eurostat (2022a): Resource productivity, ENV_AC_RP.
[55] INE (2022): Productivity associated with the use of materials decreased by 1.6% in 2021.

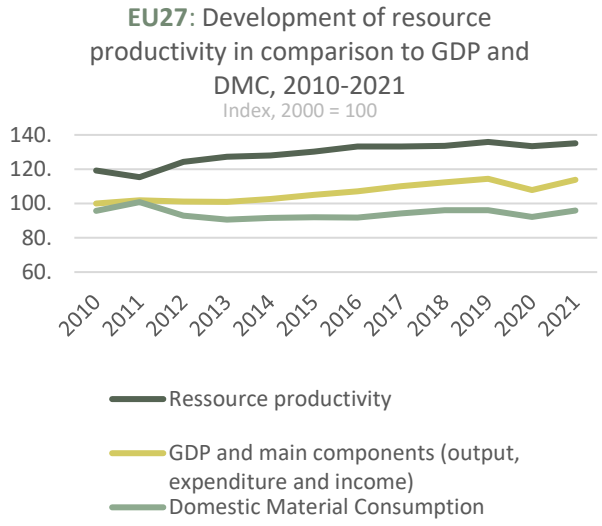


GRAPH NO 01. DOMESTIC MATERIAL CONSUMPTION PER CAPITA AS A PROXY FOR EFFICIENCY. DATA CODE: ENV_AC_MFA

Graph No. 1 shows reductions of the DMC for both EU27 and Portugal in the period of 2010-2021. The Portuguese DMC has decreased significantly, based on the reference year. However, the Portuguese DMC is still significantly higher than the EU27. The relatively higher DMC can be due to regional economic specialisation, as regional economic specialisation often strongly impacts DMC per capita, illustrated by the unbalanced distribution of environmental burdens across the EU. This unbalance can also be identified nationally, exemplified by Southern Portugal tending to concentrate on material-intensive sectors. However, regions like Andalusia in Spain diverge from the tendency seen in Southern Portugal, as material-intensive sectors present a low material consumption per capita[56]. This comparison is fascinating due to the similar consumption of non-metallic minerals in Spain and Portugal, providing an overall understanding of the industrial composition (Cf. section 1.2.3). However, on this note is important to highlight that the DMC does not account for the use of upstream extraction and processing stages and further does not reflect relocation or outsourcing of material-intensive activities. To supplement the understanding derived from the DMC statistics, the following two graphs will provide an overview of the relation between the parallel improvements in the EU average and Portugal's resource efficiency by illustrating resource efficiency as the effect of GDP and total DMC. Resource efficiency comprehends material and energy efficiency (Cf. section 1).

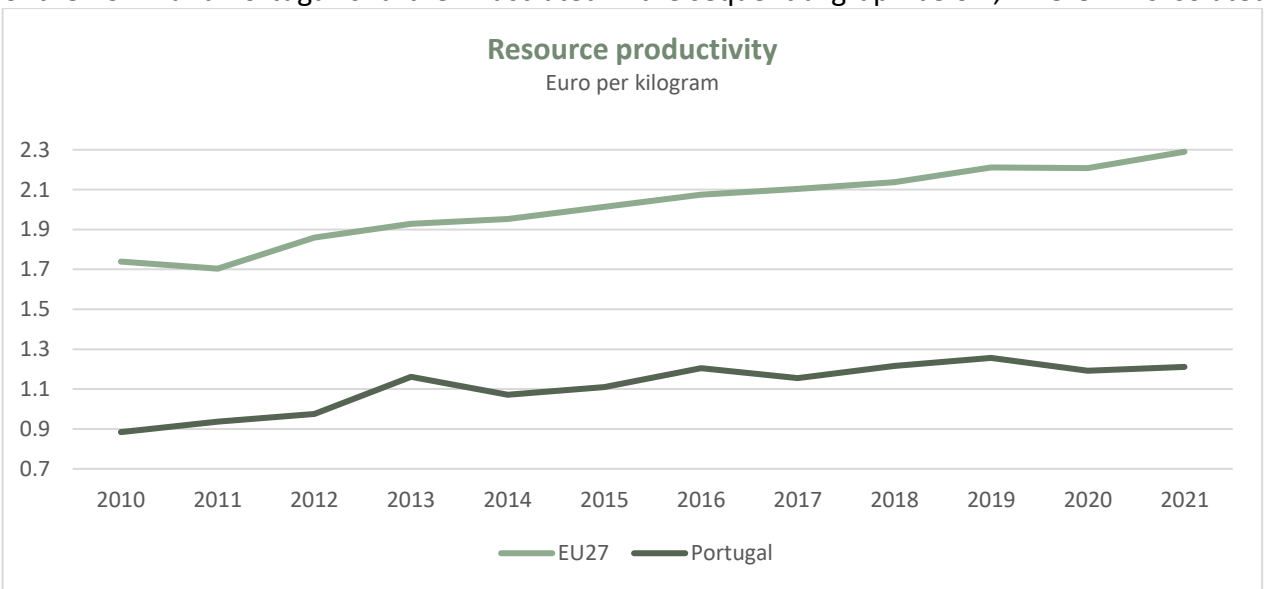
[56] Bianchi (2020): Monitoring domestic material consumption at the subnational level – Enabling the territorial perspective.





Graph NO. 02 ILLUSTRATES RP IN EU27 (LEFT) AND PORTUGAL (RIGHT) ON AN ECONOMY-WIDE BASIS AS AN EFFECT OF GDP ON DMC. SOURCE: EUROSTAT (ONLINE DATA CODE: NAMA_10_GDP; ENV_AC_MFA; ENV_AC_RP) (NOTE: GDP REFERENCE YEAR 2010.)

The graphs illustrate that the relative development in RP as the effect of DMC and GDP is similar in Portugal compared to the EU average. Utilising the index 2000 = 100 unit of measure provides an understanding of the overall significant improvements of RP in Portugal since 2000. The graphs further illustrate a stabilisation of RP in Portugal in the last few years, while the EU average has continued to grow steadily. Although the relative development in Portugal and EU27 is similar, shifting the unit of measure from Index 2000 = 100 to Euro per kilogram provides a significantly different picture of resource efficiency in Portugal compared with EU27. In this regard, Portugal is still significantly below (half) the EU average when comparing RP in absolute terms. A comparison of the EU 27 and Portugal is further illustrated in the sequential graph below, where RP is isolated.



GRAPH NO 03 COMPARES RP PER CAPITA IN PORTUGAL AND EU27 (INCLUDING ENERGY) ON AN ECONOMY-WIDE BASIS. SOURCE: (ONLINE DATA CODE: NAMA_10_GDP; ENV_AC_MFA; ENV_AC_RP) (NOTE: GDP REFERENCE YEAR 2015.)

The Eurostat [ENV_AC_RP] dataset provides ratios of gross domestic product (GDP) over domestic material consumption (DMC). RP, measured as GDP divided by domestic material consumption (DMC), monitors the relationship between what an economy produces and the physical materials it uses. Hence, it depicts an aggregate measure of an economy's material efficiency. This is typically

a macroeconomic concept. DMC indicates the total amount of material consumed domestically by resident units. DMC of a given country's national economy is calculated as direct material input minus physical exports: *DMC = DMI – EXP*[57]. While the two first graphs show the interrelation between GPD, DMC, and RP in Portugal and EU27 sequentially, the third graph juxtaposes RP in Portugal and EU27 on the same graph. The third graph (NO.03) shows that although Portugal gradually improves yearly, the country is still well below the European average regarding RP.

Comparing the RP, DMC (based on MFA) and GDP of Portugal with EU27 data provide a general understanding of the state of play of material efficiency in Portugal. However, an additional analysis was conducted, comparing Portuguese material efficiency with EU Member State with similar material flows (Cf. section 1.2.3) in the four categories: Biomass, metal ores, non-metallic minerals, and fossil energy materials/carriers. This analysis is the foundation for selecting best practice cases for improving Portuguese material efficiency. Table No. 1 below provides a comparative overview of the Resource Productivity (RP), Domestic Material Consumption (DMC), Material Footprint (MF), Circular Material Use Rate (CMUR), and the Recycling Rate of Municipal Waste (RRMW) of Portugal and eight EU Member States with similar MFA to Portugal.

2020	**RP** (€/kg)	**DMC** (Tonnes/capita)	**MF** (Tonnes/capita)	**CMUR** (%)	**RRMW** (%)
EU27	2,2072	13,587	13,654	11,7	49,2
IRELAND	3,3335	22,437	10,758	1,7	40,8
FRANCE	3,333	10,259	10,901	19,2	41,7
ITALY	3,6121	7,718	9,846	20,6	51,4
BELGIUM	3,0457	12,996	13,049	21,5	51,4
SPAIN	2,6412	8,968	9,922	9,3	40,5
AUSTRIA	2,2262	19,108	21,267	10,8	62,3
PORTUGAL	**1,1916**	**16,306**	**17,097**	**2,3**	**26,8**
FINLAND	1,3012	33,075	33,617	5,9	42,2
HUNGARY	0,9825	14,348	14,741	5,2	32,0

TABLE NO 01 COMPARISON OF PORTUGUESE RESOURCE PRODUCTIVITY, DOMESTIC MATERIAL CONSUMPTION, MATERIAL FOOTPRINT CIRCULAR MATERIAL USE RATE AND MUNICIPAL WASTE RECYCLING RATE, WITH EU27 AND EIGHT EU MEMBER STATES. SOURCE: (ONLINE DATA CODE: ENV_AC_RP; ENV_AC_MFA; ENV_AC_RME; SDG_12_41; & SDG_11_60). THE TABLE IS BASED ON 2020 DATA, AS 2021 DATA WAS NOT PROCESSED FOR ALL CATEGORIES.

Among the EU Member States included in the table above, Ireland (in biomass; metal ores; fossil energy materials/carriers) and Finland (in biomass, Non-metallic minerals; fossil energy materials/carriers) have the most similar MFA to Portugal (Cf. section 1.2.3). Significant differences can be identified for RP, DMC, and MF by comparing the data from the three countries. At the same time, Portugal and Finland have relatively similar data on RP and an approximate balance between the DMC and MF. Ireland is among the EU Member States with the highest RP, likely affected by the relation between DMC and MF, as the latter is almost half the DMC. When comparing the EU Member States performing greater than EU27 regarding resource efficiency (Ireland; France; Italy;

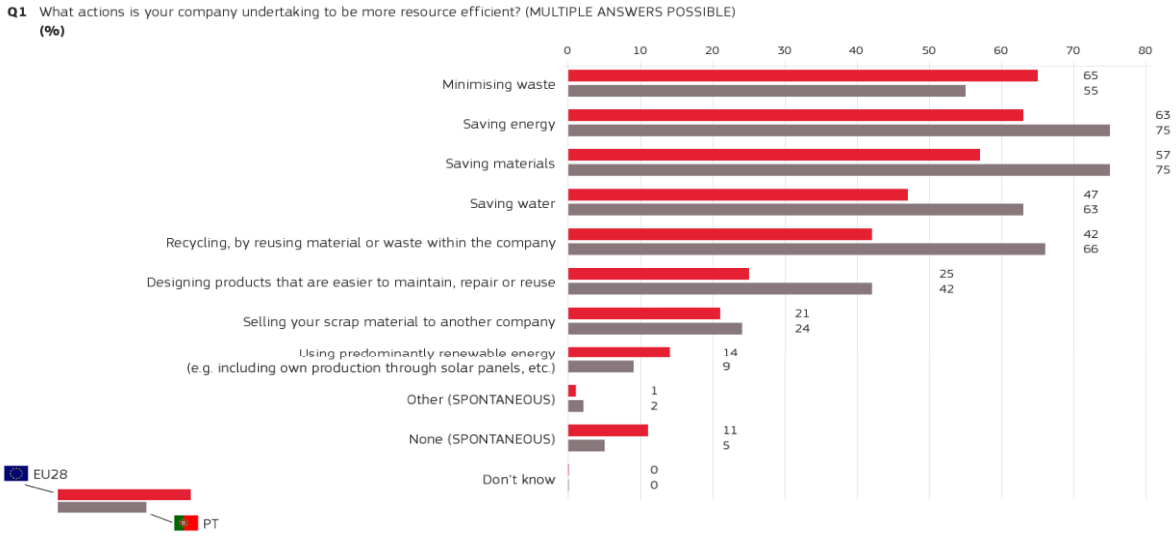
[57] Eurostat (2021b): Material Flow Account (env_ac_mfa).

Belgium; Spain; and Austria), all countries perform significantly better than Portugal regarding CMUR, excluding Ireland. CMUR is approximated by the amount of waste recycled in domestic recovery plants minus the imported waste destined for recovery plus exported waste destined for recovery abroad. Therefore, a higher CMUR value indicates that more SRM substitutes for primary raw materials, thus a reduction in the environmental impacts from extracting primary material and increasing **material efficiency**. The Portuguese CMUR shows potential for improvements in the uptake of SRM among Portuguese industry actors. However, this requires the availability and valorisation of SRM, which can be facilitated through increased collection and treatment of municipal and industrial waste streams. The needed improvement of municipal waste streams, indicated by the recycling rate of municipal waste in Portugal, will be addressed in work package 2.1 and work package 2.2 of the project **3R2CE – Three Roads to Circular Economy.** The following sections of this report will address options to increase the uptake of SRM in an industrial context to increase material efficiency in Portugal.

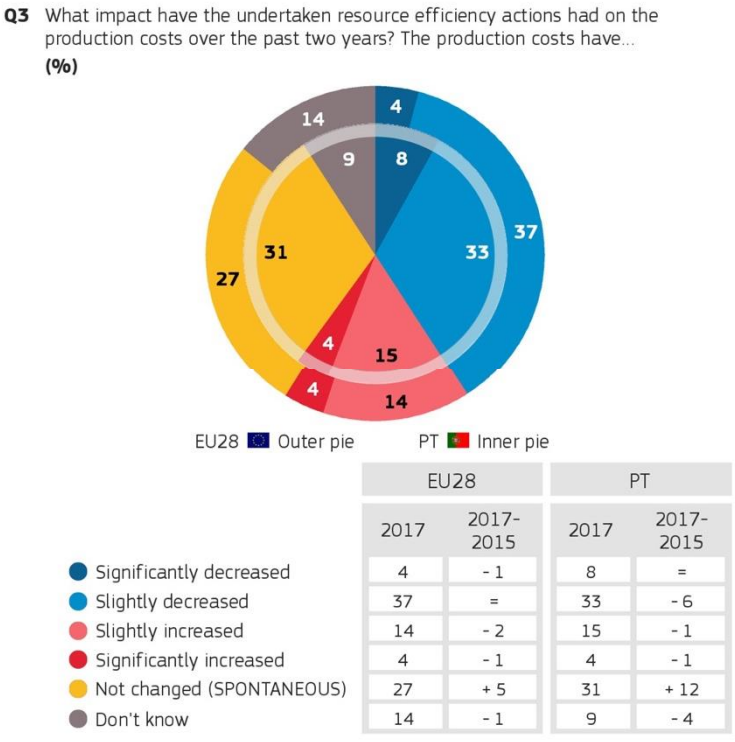
2.2 Material efficiency in SMEs

The assessment of material efficiency in Portugal would have been ideal if data in the categories processed in the previous section was available on a subnational or sector level. This, unfortunately, is not the case. DMC and other related economic and environmental monitoring methods have significant data constraints. The lack of regional, local and sectoral data is arguably one of the most critical barriers to conducting representative metabolism studies, despite the importance of developing regulations and policies to facilitate improvements, e.g., material efficiency[58]. While quantitative data on regional, local and sectorial CMUR is unavailable for Portugal, some qualitative data is available on resource efficiency among SMEs in Portugal. In September 2018, the European Commission published the Flash Eurobarometer on SMEs, Resource Efficiency and Green Markets, which provided statistics from 499 Portuguese interviews and 12.902 European interviews with SMEs[59]. The interviews were conducted via telephone and based on a multiple-answer questionnaire. Some results from the Flash Eurobarometer no. 456 are included here, as they provide critical supplementary insights into the state of the art concerning material efficiency in Portugal. Note that the definition of material efficiency in the questionnaire differs from the definition and scope in this report as it includes energy and water efficiency and cascading resources from one company to another.

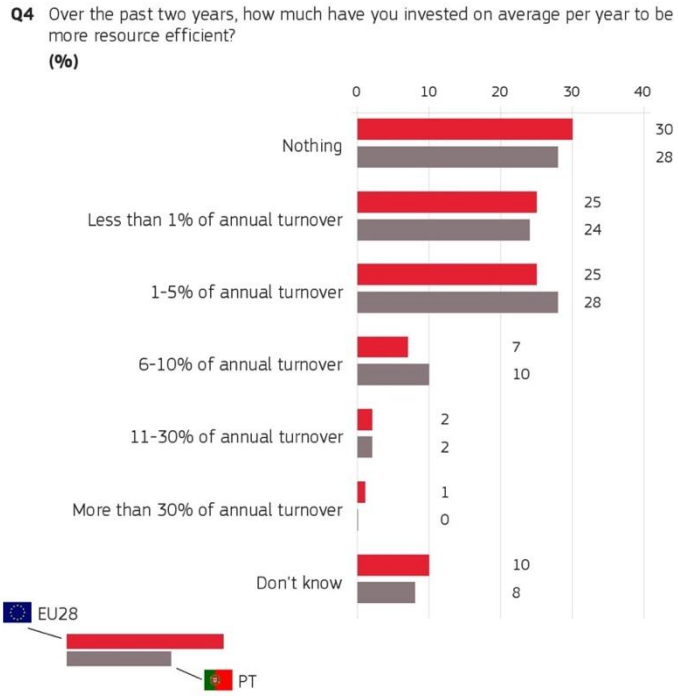
[58] Bianchi (2020): Monitoring domestic material consumption at the subnational level – Enabling the territorial perspective.
[59] EU (2018): Eurobarometer – SMEs, resource efficiency and green markets.



GRAPH NO. 04. Q1, ACTIONS WITHIN SMES[60].



	EU28		PT	
	2017	2017-2015	2017	2017-2015
Significantly decreased	4	- 1	8	=
Slightly decreased	37	=	33	- 6
Slightly increased	14	- 2	15	- 1
Significantly increased	4	- 1	4	- 1
Not changed (SPONTANEOUS)	27	+ 5	31	+ 12
Don't know	14	- 1	9	- 4

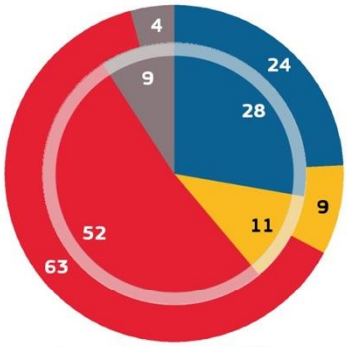


GRAPH NO. 05. Q3 AND Q4 IMPACT ON PRODUCTION COST[61].

[60] EU (2018): Eurobarometer – SMEs, resource efficiency and green markets.
[61] EU (2018): Eurobarometer – SMEs, resource efficiency and green markets.

The EU Flash Eurobarometer no. 456 provides some crucial pieces of information: First of all, it illustrates very clearly, that the state of SMEs, including the types of actions and investments for the improvement of resource efficiency (as well as the perceived potential enablers for further action), are very similar in Portugal and EU overall[62]. This enables a more straightforward translation of EU best practices to the Portuguese economy. Secondly, the statistics indicate that the SMEs in Portugal are highly competitive with EU28 average SMEs[63]. When it comes to taking actions towards resource efficiency, Portuguese SMEs have a significantly higher percentage of companies claiming to have taken measures towards material productivity: For instance, 75% of companies in Portugal had taken steps towards saving materials (compared to 57% of EU28 average), 66 % did internal recycling/reuse (compared with 42 % of EU average), and 42% designed products for easy maintenance (compared with 25% of EU28 average). 11% of the SMEs in Portugal (compared with 9% in EU28) plan to offer green products or services in the next two years[64]. Of course, understanding such actions may be biased, but this also applies to other EU countries. With this perspective, the starting position for some of the measures assessed in the Eurobarometer might differentiate between the EU member states, exemplified by, e.g. landfill costs, which are low in Portugal compared to many other member states. Therefore there might be a greater incentive to reduce waste production already in the member states with high landfill costs.

Q9 Does your company offer green products or services? **(%)**



	EU28		PT	
	2017	2017-2015	2017	2017-2015
Yes	24	- 2	28	+ 2
No but you are planning to do so in the next 2 years	9	+ 2	11	- 1
No and you are not planning to do so	63	+ 3	52	+ 11
Don't know	4	- 3	9	- 12

GRAPH NO. 06. Q4, GREEN PRODUCTS OR SERVICES[45].

When comparing more objective factors such as investments (as % of annual turnover) in material efficiency, Portugal seems to be more in balance with the EU average, with only minor fluctuations. These results indicate that the lower performance of the Portuguese economy in terms of material efficiency (as seen in previous economy-wide statistics) is not the result of lacking investments or engagement from SMEs. A bonus insight derived from the Flash Eurobarometer is that most SMEs report slightly reduced production costs over the last two years resulting from resource efficiency actions (33% in Portugal and 37% in the EU) [65].

2.3 Discussions of resource- and material efficiency in Portugal

A country's industrial and economic composition undoubtedly significantly affects material efficiency. This is illustrated by Italy, which has a relatively high per capita income attained with a

[62] EU (2018): Eurobarometer – SMEs, resource efficiency and green markets.
[63] EU (2018): Eurobarometer – SMEs, resource efficiency and green markets.
[64] EU (2018): Eurobarometer – SMEs, resource efficiency and green markets.
[65] EU (2018): Eurobarometer – SMEs, resource efficiency and green markets.

comparatively low level of resource consumption. However, countries like Finland and Estonia show high levels of resource use and low RP. This is primarily due to the amount of raw material processing and export in Finland and Estonia[66]. The type of materials, and their place in the value chain, significantly affect the relationship between resource use and RP. The industrial fabric and outputs of the industries' impact on material efficiency were illustrated by the impactions on the resource productivity at the EU economy as a whole when construction activities in 2008-2013. In 2008, the construction sector was responsible for more than one-third of total material use in the EU but contributed only 6.3% of its total economic output. Therefore, the construction sector in the EU had relatively low resource productivity in 2008 compared to the economy as a whole. In 2013, the European construction sector had shrunk significantly but preserved an approximately similar economic output, leading to an increase in resource productivity of the whole economy. However, the European construction sector contributed to the rise in non-metallic minerals post-2013, decreasing the EU resource productivity acceleration[67].

A further cause of the underlying increase in the EU resource productivity is the gradual shift towards a service economy. The service sector is considered a high contributor to a material-efficient economy due to an assumed reduced material input compared to the economic output. Therefore, the service sector is generally considered less material intensive than the manufacturing and construction industries[68]. However, a large service industry does not necessarily constitute a great resource- and material efficiency, as illustrated by Portugal's comparably low RP and relatively high share (64,75%) of the service sector related to Portugal's GDP[69]. While this tendency can be explained concerning resource efficiency by potentially high utilisation of fossil fuel products in the service sector, the lack of connection between the high share of service industries in Portugal and RP can be derived from the relation between capital productivity, resource productivity, and labour productivity. OECD reports that Portuguese firms generally have a low level of productivity compared to other OECD countries, stemming from generally low labour productivity, particularly in the manufacturing sector. The ratio between labour productivity in Portuguese firms and the OECD benchmark is substantially larger for small firms, as the average labour productivity level in large Portuguese manufacturing firms amounts to about 55% of the OECD benchmark countries, Portuguese micro-firms only achieve about 25% of the labour productivity level compared with the OECD benchmark countries. In the Portuguese service sectors, the gap between OECD benchmark countries and Portugal is most significant, with medium-sized firms[70]. The substantial productivity disadvantage of the smallest companies in Portugal will likely impede scaling up the Portuguese economy. This is supported by comparing start-ups and young companies in Portugal and OECD benchmark countries, as Portuguese start-ups tend to be slower. This is problematic for economy-wide resource- and material efficiency, as employment is concentrated in micro firms and SMEs in Portugal[71].

An aspect that can further influence the low CMUR in Portugal can be related to the share of rural areas, decrease in technological development and inefficiencies related to low levels of management. An overarching research study of DMC in the EU indicates that Portuguese regions, of which most are considered predominantly rural, have an increased technological gap concerning the European meta frontier, most significantly in the Northern regions of Portugal[72]. The increasing

[66] Bianchi (2020): Monitoring domestic material consumption at subnational level – enabling the territorial perspective.
[67] EEA (2018): Briefing - Resource efficiency.
[68] EEA (2018): Briefing - Resource efficiency.
[69] Statista (2022): Portugal: Share of economic sectors in gross domestic product (GDP) from 2011 to 2021.
[70] OECD (2019): Insights on Productivity and Business Dynamics – Portugal: Productivity.
[71] OECD (2019): Insights on Productivity and Business Dynamics – Portugal: Productivity.
[72] Bianchi (2020): Monitoring domestic material consumption at the subnational level – Enabling the territorial perspective.

technology gap could be related to lower capital intensity, meaning that there are fewer technologies and tools, be they digital or mechanical available to workers to increase labour productivity and overall efficiency. However, there is not necessarily a causal connection between lower capital intensity and increased productivity, as increased productivity also can be brought on by flexible, productive industries, abundant and cheap labour, and a shift in factors of production from less productive sectors to more productive sectors[73].

From a policy perspective, Portugal is among the few EU Member States adopting resource productivity targets beyond 2020[74]. Since the 2000s, regulatory support for increased resource productivity has been implemented through extensive legislations reforms, promoting and enhancing competition and market selections[75]. However, there is a continued need to improve the framework policies and intuitional efficiency to encourage productivity and thereby accelerate convergence in living standards. Recent OECD Product Market Regulation indicators show excessively high barriers in the services and network sectors due to suboptimal regulations for the service industries, reducing productivity growth and indirectly affecting downstream industries that use services as an intermediate input to production. Furthermore, the OECD Insolvency indicators show that the personal cost to failed entrepreneurs is more significant in Portugal than in most other OECD countries. Combined with a large number of SMEs and micro firms, business actors face significant risks and divert resources away from start-ups with innovation and growth potential, affecting the overall national resource- and material efficiency[76].
SMEs and micro firms might intend to invest in material efficiency, indicating that the lower performance of the Portuguese economy in terms of material efficiency (as seen in previous economy-wide statistics) is not the result of lacking investments or engagement from SMEs (Cf. section 2.2). However, this could be challenged by the Portuguese corporative tax system, which contains size-contingent provisions, such as the reduced statutory rates for small firms, incentivising them to cap their growth and thereby contribute to the GDP[77]. SMEs and micro firms operating within the service sectors are further challenged by being strictly regulated and represented by the same professional associations. Implementation of independent supervisory bodies could facilitate regulations that both are in the public interest and promotive of competition. Lastly, “zombie firms”, inefficient businesses in persistent financial difficulties surviving due to weak market selection, are present enough on the Portuguese market to affect the productivity statistics[78]. Ensuring good market conditions for new, innovative competitors to the zombie firms could further increase RP and material efficiency.

2.4 Summary

By describing some of the different approaches for measuring material efficiency, it becomes clear that the results depend highly on the methodology, each method has limitations, and high-accuracy results depend on comprehensive data. Therefore, the most valuable data is available on Eurostat to measure the total material efficiency for national sectors. This data indicates lower material efficiency in Portugal compared to the EU27 average and EU Member States performing well concerning RP and CMUR. However, the picture can be supplemented by qualitative data

[73] Correia (2022): Productivity in Portugal: magic ingredient or main course?
[74] EEA (2018): Briefing - Resource efficiency.
[75] OECD (2019): Insights on Productivity and Business Dynamics – Portugal: Productivity.
[76] OECD (2019): Insights on Productivity and Business Dynamics – Portugal: Productivity.
[77] OECD (2019): Insights on Productivity and Business Dynamics – Portugal: Productivity.
[78] OECD (2019): Insights on Productivity and Business Dynamics – Portugal: Productivity.

from the EC Flash Barometer questionnaires targeting all SMEs in Portugal. Here, Portuguese SMEs are highly competitive compared to the EU average when it comes to taking actions toward improving material efficiency.

3 Options for improving material efficiency

Efficiency can be described at the output level generated within a certain input level. Increased efficiency can therefore be achieved through a combination of the management of materials, and inputs, leading to higher productivity and enabling the creation of greater economic prosperity[79]. Material efficiency, therefore, also constitutes a pathway to minimise waste production and environmental impacts associated with the service or product being produced through the uptake of SRM and by-products. The current state of play of Portugal requires an emphasis on substantial improvements in education (increasing training in cutting-edge fields), attracting foreign investments (mainly through larger companies exposing the national economy to external competitiveness, bringing knowledge and capital into a low-capital economic fabric) and innovation (both in terms of efficiency procedures for products and services available at the market and an increase in innovative and less material-intensive business models)[80].

In practical terms, a range of theoretical concepts aims to contribute to achieving increased material efficiency. The theoretical concepts are connected to the sustainability agenda, demonstrating different perspectives or strategies for improving material efficiency. This section presents vital instruments and their influence on modern design, operations, business models, and environmental management in the targeted sectors[81].

3.1 Circular economy

Ecological systems have inspired the concept of the circular economy. It re-introduces closing-the-loop production patterns to increase resource usage efficiency, focusing on waste[82]. The term circular economy (CE) was introduced in the late 1970s and is the combination of several schools of thought, including “cradle to cradle”, “regenerative design”, “industrial ecology”,” biomimicry”,” natural capitalism”,” blue economy” among others. CE aims to decouple economic growth from resource constraints by maintaining material and resources in the economy for as long as possible, thus minimising waste and resource use. Over 100 definitions of CE have emerged[83], but a common understanding is to achieve economic prosperity and environmental quality through a combination of reducing, reusing, and recycling (the three R’s) activities. More recently, the three ‘Rs are expanded to ten Rs, providing a more detailed picture of circular economy strategies: Refuse, Rethink, Reduce, Reuse, Repair, Refurbish, Remanufacture, Repurpose, Recycle and Recover.[84]

In production processes, circularity can be achieved by measures such as

- Maintaining the quality and value of the raw materials used;

[79] Correia (2022): Productivity in Portugal: magic ingredient or main course?
[80] Correia (2022): Productivity in Portugal: magic ingredient or main course?
[81] Hens et al. (2018): On the evolution of “Cleaner Production” as a concept and a practice.
[82] Ghisellini et al. (2016): A review on circular economy: the expected transition to a balanced interplay of environmental and economic systems.
[83] Kirchherr et al. (2017): Conceptualizing the circular economy: An Analysis of 114 Definitions.
[84] Kirchherr et al. (2017): Conceptualizing the circular economy: An Analysis of 114 Definitions.

- Reducing complexity and number of processing steps;
- Designing products that can be reused/recycled in the future;
- Maximising service life through repair friendliness;
- Increasing intensity of use (through, e.g. diverse use options);
- Ensure adaptability and flexibility of usage;
- Minimise extraction and consumption of finite resources and the production of waste[85].

3.2 Cleaner production

Cleaner production (CP) initially emerged to make industries aware of their associated negative environmental externalities during the first decades after the Second World War. The concept was directed to businesses, industry, and services and developed by UNEP during the preparations for the Rio Conference (United Nations Environmental Program) in 1991 as "*the continuous application of an integrated preventive environmental strategy to processes, products, and services to increase efficiency and reduce risks to humans and the environment"*[86]. During the 1970s, environmental problems caused by industry were dealt with through pollution abatement and treatment of emissions and effluents, mainly through end-of-pipe solutions. In the mid-70s, the concept of low and non-waste technologies emerged, and now pollution prevention rather than pollution treatment has come into focus.

The term CP has been in everyday use since 1989. Since the original definition of CP, UNEP, the European Commission, and several researchers have reviewed and offered alternative explanations of CP, among other things, by introducing the life cycle perspective and including all three pillars of sustainability; economic, social, and environmental. Also, gradually, more attention has been given to resource efficiency[87]. In 2017, the European Commission reviewed the concept and emphasised that CP is also about producing durable products suitable for recovery and recycling within the circular economy[88].

3.3 Eco-design

Whereas Cleaner Production and Circular Economy serve as generic terms for economic, technological, and policy guidelines, eco-design provides more hands-on methodologies for improving material efficiency. Eco-design is more specific to environmental performance than the two above-mentioned; in the same way, CSR focuses more on the social aspects of sustainability.

Eco-design is the integration of environmental conditions into design and product development which is where the most significant environmental impact from a product is determined: it has been estimated that up to 80% of a product's environmental impact is already specified in the

[85] DGNB (n.d.): Circular Economy.
[86] UN (1992): Agenda 21 - United Nations Conference on Environment & Development – Rio de Janerio, Brazil, 3 to 14 June 1992.
[87] UNEP (2001): Implementation Guidelines for Facilitating Organizations.
[88] EC (n.d.b): Annex 2 – Review of Cleaner Production.

design phase[89]. There are many methodologies and tools for eco-design, including Design for Environment (DfE[90]), Eco-design (ISO 14062), Design for sustainability[91], and Eco-innovation[92].

Traditional design criteria are functionality, quality, price, safety, and user-friendliness. Eco-design includes environmental considerations early in the design process before too many other fundamental decisions are taken through strategies to reduce negative externalities during the product's life cycle[93].

Some benefits of eco-design include improved environmental performance and designs, marked position, and reduced risks and costs associated with legislative compliance. Eco-design principles relevant to material efficiency include, but are not limited to:

- Reduce the material content of products and services;
- Reduce the spread of harmful substances through products;
- Increase the proportion of recycled materials in the product;
- Optimise product durability;
- Integrate environmental features into products;
- Signal the product's environmental properties through the physical design;
- Optimise product performance;
- Construct the life cycle first and then the actual product[94].

The EU Ecodesign directive has set out minimum mandatory requirements for energy efficiency and product-specific requirements to help prevent the creation of barriers to trade while improving product quality and environmental protection[95]. Harmonised standards would complement this. The Ecodesign directive applies to energy-related products. However, there are plans to widen the scope of the Ecodesign directive to other product groups and make it applicable to "the broadest possible range of products" [96]. Prioritised product groups are defined in the Circular Economy Action Plan and include textiles, furniture, electronics, and ICT[97].

3.4 Certification schemes

Certificates and Ecolabels are used to certify the environmental sustainability of products, including material efficiency. Ecolabel certifications are voluntary and can be performed by private or public entities. The goal is to promote environmentally friendly products and provide transparency to the end user. The European Ecolabel, issued by the European Union and defined through Regulation (EC) No 66/2010, is one of the most recognised ecolabels in Europe. It can be rewarded to products

[89] EC (2020a): The New Circular Economy Action Plan - For a cleaner and more competitive Europe.
[90] U.S. EPA (2002): DfE Fact Sheets.
[91] UNEP (2006): Designing for Sustainability - A Practical Approach for Developing Economies.
[92] EC (2013b): Eco-Innovation – the key to Europe's future competitiveness.
[93] Rossi et al. (2016): Review of ecodesign Methods and tools – Barriers and strategies for an effective implementation in industrial companies.
[94] Danish EPA (2008): MIljøforbedringer gennem produktudvikling.
[95] EC (2021d): Sustainable Product Policy and ecodesign.
[96] EC (2021d): Sustainable Product Policy and ecodesign.
[97] EC (2020a): Circular Economy Action Plan – For a cleaner and more competitive Europe.

that fulfil specific environmental criteria, proving limited use of substances harmful to health and the environment.

Many of the criteria set up in the EU Ecolabel cover material efficiency aspects. Product requirements stretch across the whole lifecycle, including supply and use of raw materials, reuse and recycling, and waste management. All product groups included in the EU Ecolabel have some criteria related to material efficiency; however, the requirements vary between product groups[98]. For some product groups, the material efficiency criteria are typically weighted towards the production phase, while measures are more angled towards the end-of-life stage for other product groups.

MATERIAL EFFICIENCY ASPECTS IN EU ECOLABEL REQUIREMENTS[99]	
CATEGORY	REQUIREMENTS
Product material use	Light weighting Eco-design Raw material sourcing
Manufacturing process	Efficiency in material use Manufacturing waste minimisation
Durability	Endurance Reliability Extended guarantee Use and maintenance information
Repairability	Availability of spare parts Repair information Product design Ease of disassembly
Reusability	Availability of spare parts Properties regarding data transfer and deletion Reuse information
Recyclability	Product design Ease of dismantling Material content and labelling Availability of product information on, for example, hazardous substances
Recycled content	Minimum content of recycled materials
Take-back systems	Provision of take-back systems for certain products

[98] Cordella et al. (2020): Improving material efficiency in the life cycle of products: A Review of EU Ecolabel Criteria.
[99] EC (2022a): EU Ecolabel – Translated User Manuals Part A: General Information.

TABLE NO 02: MATERIAL EFFICIENCY ASPECTS IN EU ECOLABEL REQUIREMENTS

Other environmental certifications and labels also address material efficiency and include different aspects in their certification requirements. These labels are typically either international, national or sectoral. Examples include Ecologo[100] and Nature Plus[101] (international), The Nordic Swan[102] and The Blue Angel[103] (national), and Energy Star[104] (sectoral).

For the construction sector, several certification schemes have been developed around the ISO standards and based upon individual measurements using the LCA approach. These certification schemes provide indicators and benchmarks related to, among other things, material efficiency. Third-party private companies often provide these and are developers' quality assurance and sustainability guidelines. Some of the most widespread sustainability certification schemes are the American LEED[105], the British BREEAM[106], the German DGNB[107], and the French HQE[108]. Some other certification schemes and rating tools include Miljobyggnad[109], VERDE[110], Green Key[111], and WELL[112].

3.5 Longlist of industry tools and methods

Theoretical approaches have been identified based on an extensive literature study of industry approaches currently utilised to increase material efficiency in industries inside and outside the EU. The following longlist provides an overview of tools and methods relevant to increase material efficiency at an industry level:

STRATEGIES

- Measuring efficiency (ABC analysis, input-output analysis, environmental accounting, material flow cost accounting, value stream analysis);
- Environmental management systems;
- Certification schemes;
- Business model configurations, combining products and services (Product Service Systems).

INITIATIVES

- Material choice/material substitution;
- Lightweight design;
- Mission match and safety;
- Miniaturization Production-oriented product design;

[100] UL Solutions (n.d.): Ecologo Certification Program.
[101] natureplus Institute (n.d.): natureplus eco-label.
[102] Nordic Ecolabelling (n.d.a): Sets of criteria.
[103] Blue Angel (n.d.a) Basic Award Criteria.
[104] Energy Star (n.d.): Energy Star Impacts.
[105] USGBC (n.d.) LEED rating system.
[106] Bre (n.d.) BREEAM.
[107] DGNB (n.d.): Neuigkeiten.
[108] Saint-Gobain (n.d.): HQE International.
[109] Green Building Council Sweden (n.d.): Miljöbyggnad.
[110] GBCe (n.d.) Verde Certificate.
[111] Green Key (n.d.): Find bæredygtige steder.
[112] WELL (n.d.): WELL Certification.

- Use-oriented product design;
- Extension of a technical lifetime;
- Extension of product service life;
- Product service systems (dematerialisation);
- Cascading use of products;
- Reparability;
- Recycling-oriented product design;
- Adding instructions on user behaviour to the manual;
- Resource-efficient packaging design;
- Manufacturing process selection and optimisation;
- Equipment dimensioning;
- Minimisation of machining volume;
- Substitution of auxiliary materials and operating supplies;
- Dry machining and minimum quantity lubrication;
- Minimisation of planned loss;
- Minimisation of planned scrap;
- Avoidance of losses due to rework;
- Release of losses due to disposal of finished products;
- Avoidance of losses due to dumping of purchased materials;
- Avoidance of losses due to improper storage or obsolescence;
- Efficient building infrastructure;
- Efficient building envelope;
- Efficient cleaning;
- Manufacturing-process-related recirculation;
- Cascading use of auxiliary materials and operating supplies;
- Complete and unambiguous product documentation;
- Detailed task descriptions and structured shift handovers;
- Employee qualification/ employee potential[113].

3.6 Longlist of regulatory instruments

Based on an extensive literature study of governance approaches currently utilised to increase material efficiency by EU member states, nations outside of the EU, and theoretical approaches, have been identified. The following longlist provides an overview of governance measures with relevance when developing strategies to increase material efficiency:

GOVERNANCE

- Partnerships with the private sector and other stakeholders;

[113] Schmidt et al. (2019): 100 Pioneers in Efficient Resource Management: Best practice cases from producing companies.

- Mainstreaming resource efficiency in public policy;
- Promoting investment in resource-efficient infrastructure;
- Job skills for the transition to a resource-efficient economy;
- Effective governance for resource efficiency;
- Strengthening policy development and evaluation through better data and analysis[114].

REGULATORY INSTRUMENTS

- Bans & restrictions (product restrictions, restrictions on mining of certain materials, restrictions on landfill);
- Take-back requirements;
- Standards (LCA-based standards, standards for durability, performance standards, standards for recycled materials);
- Extended producer responsibility.

PUBLIC FINANCIAL SUPPORT

- Taxes (tax breaks);
- Grants (grants for R&D, grants for the purchase of eco-labelled products or services, grants for research on recycling);
- Soft loans (for SMEs);
- Green Public Procurement (GPP);
- Industrial symbioses.

ENVIRONMENTAL LABELLING AND INFORMATION SCHEMES

- Information schemes (good practice dissemination, advisory services for SMEs);
- Labelling and certification schemes;
- Platforms to match the supply of and demand for secondary raw materials;
- Information on dismantling products.

ECONOMIC INSTRUMENTS

- Taxes on virgin materials;
- Advance disposal fees;
- Product taxes or charges;
- Deposit refund schemes;
- Pay-as-you-throw pricing for waste collection systems;
- Landfill and incineration taxes;
- Tradable landfill permits;
- Quotas.

[114] OECD (2016): Policy Guidance on Resource Efficiency.

3.7 Note on the rebound effect

The EU has forecasted that under certain conditions, resource productivity can be increased by 14% in 2030, compared to resource productivity in 2014. If specific policies promoting the transition to CE are implemented effectively, resource productivity could be increased by 30% in 2030, enabling job creation and GDP growth. European industries recognise the potential, and it is estimated that material inputs can be reduced by 17-24% by 2030. The better use of resources represents an overall potential savings of € 630 billion per year for the European manufacturing industry[115]. However, the rebound effect can challenge the emission reductions related to a reduced material input.

The rebound effect is grounded in reinforcing the relationship between resource efficiency and resource use, or in this case, material efficiency and material use, stipulated by efficiency changes met with behavioural and systemic responses. The rebound effect is typically described as the per cent of materials saved offsets once additional materials are used[116]. The rebound effect occurs, e.g. when efficiency improvement reduces prices, stimulating an increased demand and offsetting some of the environmental benefits that would have been realised due to the reduced material or energy input[117,118]. While only a few in-depth studies have been done on the rebound effect of material efficiency strategy implementation[119,120,121], there are indications that 77% of emissions in material efficiency scenarios are offset by economy-wide rebound effects, compared to 7% in energy efficiency scenarios. These findings show that emissions remain relatively unconstrained, and the material efficiency that is particularly good at enabling growth is also likely to allow the superlative rebound effects[122]. Underlying value structure along supply chains does facilitate rebound effects, as downstream efficiency improvements saving embodied emissions involve more significant monetary savings per unit greenhouse gas emission avoided[123]. The relation between material efficiency and the rebound effect reflects the balance of potentially increased earnings based on reduced production costs, increased financial availability for consumers, and the potential environmental effects of increased material efficiency. However, the rebound effect can be countered by regulatory framework conditions that influence pricing, consumption of virgin materials, etc. However, conclusions based on these findings depend on the macroeconomic model. Macroeconomic models[124], and the scope of the assessment of rebound effects, is a debated area with significant effects on the outcome of assessments. There is a general disagreement on the magnitude and scope of rebound effect assessments, as estimates range from moderate offsetting environmental gains to complete elimination, depending on the boundaries and methods adapted[125].

[115] EEA (2018): Briefing - Resource efficiency.
[116] Vivanco et al. (2018): Roadmap to Rebound: How to Address Rebound Effects from Resource Efficiency Policy.
[117] Skelton et al. (2020): Comparing energy and material efficiency rebound effects: an exploration of scenarios in the GEM-E3 macroeconomic model.
[118] Vivanco et al. (2018): Roadmap to Rebound: How to Address Rebound Effects from Resource Efficiency Policy.
[119] Skelton et al. (2020): Comparing energy and material efficiency rebound effects: exploring scenarios in the GEM-E3 macroeconomic model.
[120] Hertwich et al. (2019): Material efficiency strategies to reducing greenhouse gas emissions associated with buildings, vehicles and electronics – a review.
[121] Allwood et al. (2011): Material efficiency: A white paper.
[122] Skelton et al. (2020): Comparing energy and material efficiency rebound effects: an exploration of scenarios in the GEM-E3 macroeconomic model.
[123] Skelton et al. (2020): Comparing energy and material efficiency rebound effects: an exploration of scenarios in the GEM-E3 macroeconomic model.
[124] Skelton et al. (2020): Comparing energy and material efficiency rebound effects: an exploration of scenarios in the GEM-E3 macroeconomic model.
[125] Vivanco et al. (2018): Roadmap to Rebound: How to Address Rebound Effects from Resource Efficiency Policy.

Potential rebound effects of material efficiency strategies are very dependent on the sector assessed. For electronics, there is evidence that price reductions lead to increased demand, and hence material efficiency may also result in a rebound effect. Opposite, material costs are relatively small for, e.g. construction; therefore, material efficiency initiative alone is unlikely to result in a strong rebound effect. Moreover, the purchasing power of consumers changes continuously, as other factors affect demand, and therefore correlated rebound effects are challenging to determine[126].

3.8 Summary

Circular Economy and Cleaner production constitute the underlying theoretical grounds for material efficiency, emphasising the need to maintain the quality and value of raw materials, the durability of products, ensure adaptability, designing products suitable for reuse or recycling, among others. Further, Eco-design and relevant certification schemes are presented to conceptualise a practical approach to address material efficiency. Since the material usage and immediate environmental impact of a product are determined in the design phase, Eco-design provides the tools to reduce material content, increase the proportion of recycled materials, optimise durability, optimise product performance, and so forth. Multiple certification schemes and Ecolabels include material efficiency aspects, why these can be utilised both to provide indicators and benchmarks for industrial material efficiency and as an informative tool to create awareness, guidance, and transparency for consumers.

4 European best practices applicable to Portugal

In 2016, only three EU Member States, Austria, Finland and Germany, and two sub-national regions, Flanders and Scotland, had adopted dedicated strategies for resource efficiency. More EU Member States have incorporated resource productivity concepts into other strategies and policies, hereunder waste, energy, and industrial development or national reform programmes. The national effort for material and resource productivity within the EU is often based on a mixture of economic and environmental considerations, often aiming to increase competitiveness and secure access to raw materials. Several EU Member states have, or are developing, national raw material strategies and national resource productivity targets. However, policies and targets for reducing overall material use are far less common than those aiming at increasing resource productivity[127].

The following chapter supplements the previous theoretical chapters with practical examples from the EU Member States with similar DMC as Portugal and Portugal. The assessment of best practices will further be supplemented with best practices examples from EU Member States that have achieved a significant and efficient improvement of their RP, such as Ireland, which achieved a 140% increase in RP between 2000-2017[128]. The chapter focuses on best practices within the industry. For each sector, both industry examples and policy examples are included.

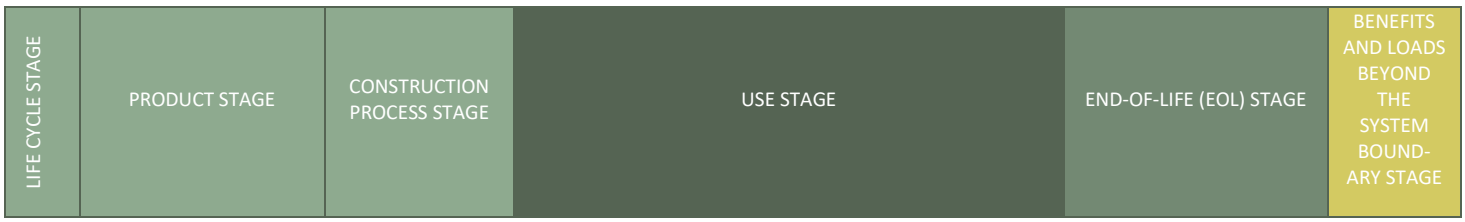
[126] Worrell et al. (2016): The Role of Material Efficiency in Environmental Stewardship.
[127] EEA (2018): Briefing - Resource efficiency.
[128] EEA (2018): Briefing - Resource efficiency.

4.1 Best practices of the construction sector

The construction sector provides essential services for a country's infrastructure and fulfils the basic functions of giving the psychical conditions for housing, industry, and businesses. However, resource- and material demand are driven by population growth, a continuous increase in floor space per capita, and higher thermal comfort requirements. UNEP estimates that more than 60 % of greenhouse gas emissions from construction activities of residential buildings stem from materials and that half of those emissions were associated with an expansion of floor space. In contrast, the other half served to maintain or replace existing floor space[129]. Taking a whole life cycle perspective that includes all life stages of a building, the construction sector is responsible for half of all extracted materials and one-third of all waste generation[130]. There is significant potential for more effective and efficient use of natural resources and the mitigation of the environmental impacts on the planet if the sector's material usage and waste management are improved, e.g., substituting materials such as reinforced concrete and masonry with wood and plant-based materials. Using sustainability-sourced wood alone could reduce 1 to 2 % of expected building life-cycle emissions[131]. The following section will investigate the best practices supporting improvements in material efficiency in the construction sector.

4.1.1 Private initiatives for improvement of material efficiency

Energy optimisation and efficiency in construction have been a prioritised focus in regulation and policies throughout the past decade. However, the focus on material consumption, substitution, efficiency etc., has been neglected. Assessment and mitigation scenarios often ignore material- and construction-related emissions and the interactions between the two. Each construction goes through many phases, and the definition of material efficiency and the following methods for improving material efficiency depends mainly on which life cycle stage is referred to. A construction project includes 17 subphases within five overall life cycle stages. The life cycle stages include the stage of the product (A1-A3), the construction and process stage (A4-A5), the use stage (B1-B7), the end-of-life (EOL) stage (C1-C4), and finally the benefits and loads beyond the system boundary stage (D).



[129] UNEP (2020): Resource Efficiency and Climate Change – Material Efficiency Strategies for a Low-Carbon Future.
[130] EC (n.d.c): Level(s) - European framework for sustainable buildings.
[131] UNEP (2020): Resource Efficiency and Climate Change – Material Efficiency Strategies for a Low-Carbon Future.

Processes	Raw material supply	Transport	Manufacturing	Transport	Construction-installation process	Use	Maintenance	Repair	Replacement	Refurbishment	Operational energy use	Operational water use	Deconstruction/demolition	Transport	Waste processing	Disposal	Reuse, recovery, and recycling potential
	A1	A2	A3	A4	A5	B1	B2	B3	B4	B5	B6	B7	C1	C2	C3	C4	D

TABLE 03 LIFE CYCLE STAGES AS DEFINED IN THE EUROPEAN STANDARD EN 15978:2011. AREAS IN DARK GREY ARE OUT OF SCOPE IN THIS REPORT.

Raw materials are extracted and transported in the product stage, and building materials are manufactured. This stage is mainly regulated by the European Construction Products Regulation (CPR)[132], laying down harmonised rules for marketing construction products. In the EU, non-metallic minerals are mainly used as construction materials and account for almost half of all materials used by weight. Products made from non-metallic minerals can often be recycled and reused as SRM. However, recycled materials have had minimal uptake compared to raw material demands for non-metallic minerals. The contribution of recycled materials to the overall demand is highest for metal ores. However, metal ores only account for a small share of the total use of materials by weight[133].

The following construction process stage includes the transportation of materials and the construction and installation process. Material usage in stages A1-A5 is efficient if 1) the materials are extracted, processed, ordered, transported, stored, and handled with generating the least amount of waste; 2) the building design matches the dimensions of the material that are available in the market; and 3) the residuals and packages are reduced, recovered, or recycled[134]. One could add that these steps are essential, but only after selecting the materials with the most negligible environmental impact that can still provide the needed service – as argued in the eco-design principles.

The use stage includes the use of the building, maintenance, repair, refurbishment, operational energy, and operational water usage. Our definition of material efficiency tells us that efficiency is achieved when existing services are performed using fewer materials or materials with less negative environmental impact. Since buildings are often demolished due to changing needs rather than expired qualities, there are substantial efforts in this phase that can prevent unnecessary waste of value and embodied environmental impacts in materials and overall improve the material efficiency in the building's lifetime by simply expanding the lifetime of the materials used in construction. The most significant environmental impact of constructing a building relates to its structure and facade and if there are substantial environmental benefits in extending the useful life of especially these elements. Thus, the definition of material efficiency is expanded to be a functional unit that includes time as a variable. The International Energy Agency (IEA) has identified ways to make building designs more adaptable. These efforts include:

[132] EC (n.d.d): Construction Products Regulation (CPR).

[133] EP (2018b): Material use in the European Union – Towards a circular approach.

[134] Tafazzoli (2016): A Method to Measure Material-Use Efficiency in Construction Projects.

- efficient use of space (better utilisation of space as occupier needs for space increase)
- increased longevity of buildings and components (extension of the total lifetime of a building that reflects the design life of components)[135].

Although the effect of such actions can only be measured in the use stage (out of scope in this report), the implantation is made in the previous product and construction process stage. Similarly, designing for deconstruction and disassembly are strategies in the EoL stage for prolonging the lifetime of building components and, thus, strategies for increasing material efficiency. However, the strategy must already be implemented in the product and construction stage.

The European Construction Industry Federation (FIEC) has addressed the goals related to the construction sector in the new Circular Economic Action Plan (CEAP2). One of the challenges under the current regulation is the distribution of responsibility in the recovery of materials for increased recycling. Industry actors have yet to be directly involved in the targets developed, challenging the ownership of improving recycling activities among industry actors. Further, they ask for a balance in the market between supply and demand for SRM. There still needs to be more demand for SRM in the construction industry, partly due to the high prices of SRM. The industry welcomes SRM, but concerns about quality and high prices constitute a barrier to the uptake of SRM. Therefore, FIEC recommends harmonised standards, digital passports, tagging and watermarks to ensure quality, non-contamination, and competitive pricing. At last, they address the need for End-of-Waste Criteria at an EU level to facilitate an increase in the reuse of materials across EU internal borders, ensuring equalised accessibility[136].

RECYCLED AGGREGATES (FR)	Aggregates are the second most used resource in the construction sector. VINCI, a French company, recycles these aggregates to be reused. They work after a Circular Economy principle to reduce their waste and promote the recycling of construction waste and less use of virgin materials. The company uses its Granulat+ facilities to retrieve, sort, and recycle construction waste – there are 130 certified facilities in France in total. The retrieval of the waste is done by local short-supply loops to reduce transportation as much as possible. The Granulat+ facilities can recycle 100% of concrete and asphalt waste and create new secondary raw materials and recover more than 8 million aggregates per year[137]. VINCI is aiming to reduce their Scope 1 and Scope 2 emissions by 40% by 2030 compared to 2018, and Scope 3 emissions by 20% compared to 2019. In terms of Circular Economy, they also focus on improving their design and production processes, having as low an impact on natural environments as possible, optimise water consumption, and achieving a zero net loss on biodiversity[138].

4.1.2 Certification & standards

The following section will provide an overview of certification schemes and standards that can support the improvement of material efficiency in the construction sector.

DGNB (Deutsche Gesellschaft für Nachhaltiges Bauen) uses a lifecycle perspective on buildings and uses 49 environmental, economic, and social criteria to give a final sustainability score to a building. This results in a grade ranging from bronze to platinum. Material efficiency plays a relatively minor role compared to the other indicators: the score is given to material usage, and soil balance only

[135] Russel & Moffatt (2001): Assessing Buildings for Adaptability – Annex 31 – Energy-Related Environmental Impacts of Buildings.
[136] FIEC (2020): FIEC position paper on the new Circular Economy Action Plan.
[137] VINCI (2022a): Recycled aggregates: the circular economy supplying the construction sector.
[138] VINCI (2022b): Forging a sustainable World.

weighs 1,8 % in the final score. This score is based on how significantly a share of the materials is recycled, locally sourced, and certified, how much soil from the construction will be recycled, and how hazardous soils are managed. One could argue that this score is mainly related to stage A1, stage C3 and stage D (out of scope), except certified building components, stage A3[139].

Similarly, **BREEAM** (BRE Environmental Assessment Method) provides an environmental score ranging from 'pass' to 'outstanding'. There are 40 sustainability criteria within five core technical categories; governance; land use and ecology; resources and energy; social and economic wellbeing; and transport and movement; plus, a sixth category called 'Innovation'. Within the resource and energy assessment issue, one finds the criterion 'resource efficiency' and 'low impact materials' addressing material efficiency, weighing 2,7% in the final rating. The score for each criterion is awarded where the development designs and plans meet the performance levels defined for the particular issue[140]. Within the first criterion, resource efficiency, there are no mandatory standards. Credits are given based on the following background check marks:

- A waste audit (using an appropriate protocol) that references an existing waste management plan is conducted on building sites with existing facilities and infrastructure to maximise the recovery rate.
- Concerning the waste management plan, excavated wastes that will be generated are estimated. It is assessed how to maximise its onsite reuse and alternately maximation the recovery of materials (high-grade applications only - backfill excluded).
- The design team has embedded resource efficiency within the overall scheme design, explicitly referring to best practice guidance principles for Designing out Waste.
- A waste management plan or strategy has been completed to estimate all CDW.
- Landscape design is informed by and references the waste management plan to consider existing SRM on site.
- Building designs refer to best practice guidance principles for Designing out Waste principles and are informed by the waste management strategy or plan.
- Where the site is divided into individual plots and developed independently, the developer has provided a written commitment to reduce and recover waste during construction, supported by contractual agreements with the main contractor or waste management contractor.
- The developer has provided a written commitment that an agreement will be in place at the start of construction to divert non-hazardous CDW from landfill[141].

LEED (Leadership in Energy and Environmental Design) has different schemes that can be applied to other kinds of projects, including BD+C (Building Design and Construction) for construction and shell in new constructions and major renovations, ID+C (Interior Design and Construction) for commercial interiors, and O+M (Building Operations and Maintenance) for existing buildings. LEED also has individual schemes for developing whole neighbourhoods, cities, and communities. In

[139] DGNB (n.d.): Circular Economy.
[140] BREEAM (2017): BREEAM Communities – Technical Manual SD202 – 1.2: 2012.
[141] BREEAM (2017): BREEAM Communities – Technical Manual SD202 – 1.2: 2012.

LEED version 4, the new construction category has 77 criteria, 12 of which are mandatory[142]. Some criteria related to material efficiency for new constructions include:

- Storage and Collection of Recyclables;
- Planning of construction and Demolition Waste Management;
- Building Life-Cycle Impact Reduction;
- Building Product Disclosure and Optimization - Environmental Product Declarations;
- Building Product Disclosure and Optimization - Sourcing of Raw Materials;
- Building Product Disclosure and Optimization - Material Ingredients;
- Construction and Demolition Waste Management[143].

Regarding certification schemes, approximately 125 building projects have been BREEAM certified in Portugal, while 81 have been LEED certified[144]. Often, certification tools are applied by the Green Building Council present in the country, including the abovementioned certifications. Unfortunately, a Green Building Council in Portugal has not been established[145].

MEMBER STATE PERFORMANCE

According to the EU Eco-Innovation Index 2021, Finland has been categorised as an eco-innovation leader. The country's performance has continued to improve, scoring above the EU27 average on three parameters: eco-innovation inputs, eco-innovation outputs and socio-economic outcomes[146]. Finland has dramatically improved resource and energy efficiency, driven by widespread acceptance and usage of Building Information Modelling (BIM)[147]. BIM has been established as a common practice in larger infrastructural and small residential construction projects. The swift implementation of BIM as a standard practice has been supported by Finnish Universities, offering master's and degrees in BIM technologies. However, the common use of BIM, Finnish building control, is still predominantly based on paper documents and 2D drawings[148]. While Finland shows excellent improvements, there is room for increasing resource efficiency in the construction sector. The country still scores below the EU27 average on two Eco-Innovation Index indicators: eco-innovation activities and resource efficiency outcomes[149].

Italy has achieved a strong performance rate concerning resource-efficiency outcomes, and the country's performance on eco-innovation activities, eco-innovation outputs and socioeconomic outcomes was also above the EU27 average[150]. The high performances are related to eco-labelling, waste management, bioeconomy, and green industry. Italy has one of the highest levels of eco-labels and EMAS in the EU region. However, there are still challenges with low R&D investments and regional disparity in legislative procedures and performance[151]. Italy has adopted a progressive strategy for the uptake of BIM, facilitated through the approval and publication of UNI 11337 and the 'BIM Decree', DM 560/2017[152]. BIM has been adapted gradually by making the modelling

[142] U.S. Green Building Council (2016): Checklist: LEED v4 for Building Design and Construction.
[143] U.S. Green Building Council (2016): Checklist: LEED v4 for Building Design and Construction.
[144] GBIG (2021): Portugal.
[145] World Green Building Council (n.d.a): Global Directory of Green Building Councils.
[146] EC (2021e): The Eco-Innovation Scoreboard and The Eco-Innovation Index.
[147] EIB Investment Survey 2020: Finland Overview.
[148] Aecbusiness (2018): How BIM is Revolutionizing Building Control in Finland.
[149] EC (2021f): European Construction Sector Observatory – Country profile Finland, October 2021.
[150] EC (n.d.e): European Eco-Innovation Scoreboard 2019 Profile – Italy.
[151] EC (n.d.e): European Eco-Innovation Scoreboard 2019 - Italy.
[152] BIM Community (2018a): The use of BIM in Italy will be mandatory for public procurement by 2019.

method mandatory for all construction projects, firstly required for € 100 million construction projects. € 50 million for construction projects in 2020, € 15 million for construction projects in 2021, € 5,2 million in 2022, and by January 2023, BIM are required for all construction projects amounting to € 1 million[153]. Italy has further implemented requirements for cross-border service providers wanting to carry out activities in Italy, as the service providers are subject to mandatory certification schemes. The Certificate of Undeclared Work (CUW) functions as a tool to demonstrate that construction companies have complied with tax and social obligations. The CUW has to be submitted with the application for a building permit[154].

Spain has the strongest performance in eco-innovation activities, scoring significantly above the EU27 average. However, the country scores below the EU27 average concerning eco-innovation outputs, socioeconomic outcomes, and resource efficiency outcomes[155]. In recent years, Spain has promoted sustainable and digitalised construction, resulting in a slightly more innovative construction sector. Around 20% of construction firms have used drones, 18% have implemented augmented or virtual reality, and 10% have used 3D printing[156]. Spain transposed the EU Directive 2014/24/EU in 2017 (Ley 9/2017), ensuring encouragement to use BIM in construction projects financed by EU public funds. The law came into force in 2018, enabling contracting authorities for all public construction tenders in Spain to require BIM or similar tools[157]. The Spanish Government further implemented an inter-ministerial commission to adapt the BIM methodology in Public Procurement in 2018. The non-profit association, BuildingSMART, aims to promote efficiency in the construction sector through the utilisation of open standards of interoperability based on BIM to reduce costs and time and increase the quality of construction projects[158]. BuildingSMART comprises various construction stakeholders, including promoters, investors, developers, manufacturers, and universities[159].

Portugal has increased its Eco-Innovation performance over the past few years and is currently ranked 12th among the EU Member States, primarily due to improvements in digital competencies[160]. Through projects such as SUDOKET and CircularBuild, an increased focus has been set on growth, technological leadership, reuse of waste, and enhancing research innovation and development in innovative buildings[161]. Portugal has not yet reached the maturity level of other developed countries concerning the implementation of BIM. Existing public procurement laws favour procurement processes based on the fragmentation of different steps rather than a cooperative approach needed to utilise digitisation tools in construction. There is a lack of incentives for implementing alternative solutions, thereby preventing enterprises from investing in innovation. Despite lacking an official central government supporting BIM, the Technical Committee for BIM Standardisation (VT197-BIM) has been created to develop standardisation procedures for informational classification systems, information modelling, guidelines, and processes throughout the lifecycle of construction projects[162].

[153] EC (2021g): European Construction Sector Observatory – Country profile Italy, September 2021.
[154] EC (2021g): European Construction Sector Observatory – Country profile Italy, September 2021.
[155] EC (n.d.f): Eco-Innovation Scoreboard 2021.
[156] European Investment Bank (2020): Spain Overview – EIB Investment Survey.
[157] BIM Community (2018b): The implementation of BIM in Spain: Past, Present and Future.
[158] buildingSMART (n.d.): buildingSMART Spain.
[159] EC (2021h): European Construction Sector Observatory – Country profile Spain, January 2022.
[160] EC (n.d.e): European Eco-Innovation Scoreboard 2019 - Portugal.
[161] EC (2021i): European Construction Sector Observatory – Country profile Portugal, October 2021.
[162] BIM Plus (2016): BIM around the world: Construction 4.0 in Portugal

4.1.3 Regulation & policies for improvement of material efficiency

Several European policy initiatives target the construction sector to achieve the overall objectives within the European Green deal[163], including the Renovation Wave[164], the New European Bauhaus[165], the new Construction Product Regulation (CPR), and Level(s)[166]. Here, we will only describe Level(s) and the new CPR as an international framework before presenting a few examples of national legislation to increase material efficiency in construction. Not that some examples will include initiatives and indicators that go beyond the scope of the definition of material efficiency presented in this report.

The European framework: Level(s) offer an alternative to the private certification systems; the European Commission has recently introduced a non-voluntary framework for sustainable building; Level(s). Level(s) is the new framework for sustainable buildings the European Commission provides. Based on existing standards, Level(s) provides a new approach to assess and report on the sustainability performance of buildings, throughout their life cycles, through 16 sustainability indicators. Four indicators focus on resource efficiency and circular material lifecycles[167]. These are:

- Bill of quantities, materials, and lifespans;
- Construction and demolition waste;
- Design for adaptability and renovation;
- Design for deconstruction.

Level(s) is meant to support companies in measuring their performance and providing them support and resources for initiatives to improve their environmental performance. As such, there are no benchmarks or ratings like those in certification schemes – and the assessment is no more informative than the chosen scope of the study. Level(s) aims to provide a common language for sustainability across the value chain of C&D and Member States. The framework also introduces a whole lifecycle perspective which (as the only EU regulation) covers all stages of building projects, including embodied environmental impacts in building materials and end-of-life-cycle practices[168].

The indicator 2.1 Bill of quantities is the foundation for environmental assessments, providing insights into the amounts and lifespans of building materials used in a construction project. Indicator 2.2. Construction and demolition waste offers the methodology for measuring waste and systematically planning optimal waste management. Indicator 2.3 provides metrics and principles for prolonging the service life, especially building facades and shells associated with the most critical environmental impacts. And finally, indicator 2.4 provides best practice principles and a rating tool for assessing the easiness with which materials can be separated at the end of a building's lifecycle without compromising on their usefulness for future applications[169].

Construction Products Regulation (CPR) provides a common technical language to assess the performance of construction products, ensuring reliable information is available to professionals, public authorities and consumers. The CPR lays down harmonised rules for marketing construction products in the EU, enabling comparing the performance of products from different

[163] EC (n.d.g): A European Green Deal.
[164] EC (2020b): The renovation wave: doubling the renovation rate to cut emissions, boost recovery and reduce energy poverty.
[165] EC (2021j): New European Bauhaus: Commission launches design phase.
[166] EC (n.d.c): Level(s) - European framework for sustainable buildings.
[167] EC (n.d.c): Level(s) - European framework for sustainable buildings.
[168] EC (n.d.c): Level(s) - European framework for sustainable buildings.
[169] EC (n.d.c): Level(s) - European framework for sustainable buildings.

manufacturers in different countries[170]. The Harmonised European Standards on construction products provide a technical basis to assess the construction performance, enabling manufacturers to draw up the Declaration of Performance as defined in the CPR and affix the CE marking. Regulatory authorities in EU countries are tasked with the definition of requirements. The supporting testing standards provided in the CRP include the following:

- Resistance to fire, reaction to fire, external fire performance, noise absorption;
- Construction products in contact with drinking water;
- Release of dangerous substances into indoor air, soil and (ground)water[171].

Expected benefits from the harmonised standards for the construction sector are, among others, a standard assessment method for construction products and a single European scheme for declaring product performance, enabling an equalised playing field for constructors and consumers.

Products not covered by the harmonised standards can be subjected to requirements by EU Member State authorities. Technical national standards for products not covered by the CPR can still be implemented but shall respect the limits imposed by the CPR. With the harmonised standards, quality or private markets covering the same characteristics as the CPR will no longer be allowed and can only be attested using CE marking[172].

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In **Austria,** the construction regulations fall under the nine Austrian regions, the *Länder*. While there has been a significant focus on energy optimisation in recent years[173], the new Austrian Government formed in 2020 proposed significant changes to existing construction and real estate laws, whereunder proposed laws for construction and renovation subsidies state that public subsidies only will be granted if the construction project is built in an environmentally friendly manner. These changes are expected to promote refurbishment and increase the value of 'ecological' buildings[174]. The Austrian Sustainable Building Council (ÖGNI) was founded in 2009, and the role of the non-governmental organisation is to establish sustainability in the construction and real estate sectors[175]. The objectives of ÖGNI are to demonstrate the added value of building certification and to establish resource-saving buildings with high economic and social efficiency.

ÖGNI has partnered with the German DGNB (German Sustainable Building Council), whose certification system was adopted and adapted to Austria in 2009[176]. The Austrian Recycling Building Material Ordinance was published in 2015 and revised in 2016. The main objective of this ordinance was to promote the recycling of construction and demolition waste by ensuring high-quality waste generation during related activities. The purpose was to contribute to increasing material efficiency and the CE. The ordinance particularly applies to the production and use of recycled materials. The ordinance sets out requirements. Environmental benefits achieved through the ordinance were resource efficiency, reduced landfill volume compared to the variant with less recycling, and

[170] EC (n.d.d): Construction Product Regulation (CPR).
[171] EC (n.d.h) Harmonised standards.
[172] EC (n.d.i): FAQ Construction Products Regulation (CPR).
[173] EC (2021k): European Construction Sector Observatory – Country profile Austria, November 2021.
[174] International Bar Association (n.d.): Austria: new government promotes green building.
[175] World Green Building Council (n.d.b): Austrian Sustainable Building Council.
[176] World Green Building Council (n.d.c) Buildings & Energy Brochure.

increased reused waste volume. Economic benefits were high-quality waste from construction and demolition activities to enhance the recycling of such waste—approximately 8,6 million. Tonnes of recycled building materials were produced in Austria in 2019[177]. The Austrian government actively assist SMEs in their internationalisation through various programmes. Financial support to SMEs and start-ups has been provided since 2013, focused on innovation and technology, value chains and digitalisation[178].

In **France**, 2018," *The Plan for Natural Resources*"[179] was implemented following the Energy Transition for Green Growth Act. Here, the objective is to identify the strategic resources needed for the French economy and to identify policy actions. The plan offered several strategic directions relating to material efficiency. Regarding construction, the program pointed towards increased support and aid for R&D within circular economic transitions, especially incorporating recycled biomaterials into the building. Most action points of this plan were operationalised in Roadmap for Circular Economy. The Roadmap for the Circular Economy[180], published in 2018, and the Law on the Fight against Waste and the Circular Economy[181], adopted in 2020, address material efficiency through better manufacturing (Ecodesign and use of recycled materials), optimised consumption (increase in rates of reuse and repair, lengthening of product lifespans), optimised waste management (better sorting of waste, growth of recycling and recovery) and better mobilisation of stakeholders[182]. Some objectives and actions identified in the roadmap with relevance for material efficiency within construction include:

- Setting sorting and recycling targets during demolitions and the construction phase;
- studying the possibilities of extended producer responsibility for building waste;
- Conduct an in-depth review of the current regulatory procedure for pre-demolition waste assessments to adapt assessment/inventory processes to reuse and recover building materials. This includes:
  1) extending the scope of operations covered in major building renovation works;
  2) digitising the process and promoting the use of open data to promote the emergence of digital applications that can be used to create a link between the supply and demand for reusable materials;
  3) strengthening the skills of those involved in carrying out assessments; and
  4) raising awareness and training prime contractors;
- Developing technical guides to acknowledge the performance of reused and recycled materials;
- Disseminating and explaining regulations applicable to stakeholders utilising secondary raw materials – mainly excavated earth and materials from major construction projects.

In **Finland**, the state-owned company Motiva were initiated in 1993 with a focus on energy conservation, offering advice for the promotion of material efficiency in public procurement and providing information on the use of recycled materials in infrastructure construction as well as offering tools for the improvement of material efficiency. In 2012, the Ministry of the Environment appointed a working group to assess the potential of material efficiency in real estate and construction. One objective was to create a framework for realising the objectives outlined in the

[177] Interreg Europe (2021a): Austrian Recycling Building Materials Ordinance.
[178] EC (2021l): Austria – SME Fact Sheet 2021.
[179] The French Republic (2018): Économie circulaire - Plan ressources pour la France 2018.
[180] EU (n.d.): Circular Economy roadmap of France: 50 measures for a 100% circular economy.
[181] Boring (2020): France: New Anti-waste Law Adopted.
[182] EC (2020c): Integrated National Energy and Climate Plan for France.

EU Waste Framework Directive. The working group highlighted some of the issues in Finland's construction sector. Alongside this, another working group dedicated to construction issued procedural recommendations in 2013. Published in 2014 and updated in 2017, the material efficiency programme; "Sustainable growth through material efficiency – national program"[183] is a strategy dedicated specifically to material efficiency. Here, eight measures were proposed, including creating a consortium within resource efficiency to allocate EU LIFE funding to material efficiency projects. One of the four target areas in Finland's waste plan from 2018, "From Recycling to a Circular Economy – National Waste Plan to 2023",[184] is construction. In the waste legislation and environmental protection legislation, requirements for material efficiency can be found. For instance, there is a separate collection obligation and recycling targets for certain types of waste, as well as waste taxes limiting landfill.
Finland also aims to be a front-runner in a life-cycle-driven circular economy. Finland has initiated the "Strategic Programme of Prime Minister Juha Sipilä's Government 29 May 2015"[185] and the consecutive roadmap to a circular economy: "Leading the cycle – Finnish roadmap to a circular economy 2016-2025"[186] establishing the direction for the country towards a circular economy. Here, several policy actions and project-based initiatives are presented. For addressing material efficiency within construction, a few can be highlighted:

- Promoting the use of natural abundance materials (wood) in construction.
- Promoting the use of secondary raw materials, including waste act interpretation and streamlining the environmental permit procedure.
- Including eco-design requirements in product design, construction, and material development

In **Portugal**, the Circular Agreement with the Construction Industry was signed in 2021[187]. The protocol aimed to develop various training actions and thematic workshops to support companies transitioning to the new regulation of Construction and Demolition Waste. The agreement's purpose is to further contribute to the greater incorporation of recycled materials in public and private work contracts and encourage circularity in construction. Companies and Public Administration entities will be supported to increase competencies to promote the decarbonisation and efficient use of resources to achieve Portuguese carbon neutrality by 2050[188]. The protocol includes actors from:

- The Portuguese Environment Agency (APA);
- the Business Confederation of Portugal (CIP);
- the Portuguese Confederation of Construction and Real Estate CPCI);
- the Association of Civil Construction and Public Works Industries (AICCOPN);
- the Association of Construction Companies and Public Works and Services (AECOPS);
- the Portuguese Construction Technology Platform (PTPC);

[183] The Finnish Ministry of Employment and the Economy (2014): Sustainable growth through material efficiency - working group proposal for a National material efficiency programme.
[184] The Finnish Ministry of the Environment (2018): From Recycling to a Circular Economy - National Waste Plan to 2023.
[185] The Finnish Prime Minister's Office (2015): Finland, a land of solutions.
[186] SITRA (2016): Leading the cycle - Finnish road map to a circular economy 2016-2025.
[187] BuiltColab (2021): Signing of the Protocol Circular Agreement with the Construction Industry takes place on October 11th.
[188] Feedback from competent Portuguese Governmental entity in the area of the economy with attributions in the industry.

- the Public Markets, Real Estate and Construction Institute (IMPIC); and
- the Association BUILT COLAB - Collaborative Laboratory for the Future Built Environment)[189].

The Portuguese Government will be supported in future decision-making on circular construction through the Action Plan for Circularity in Construction. The action plan includes objectives on increased durability of constructions, promoting reuse or recycling of construction materials, efficient product design of construction materials, and enabling reuse of SRM[190].
Shortly, IMPIC intends to develop a certification scheme for construction companies facilitating compliance with environmental requirements and publish information on public procurement in Portugal on the BASE Portal, namely on compliance with the incorporation of 10% recycled materials or materials containing recycled materials in new buildings. The Laboratório Nacional de Engenharia Civil (LNEC) also intends to create a legal obligation to carry out pre-demolition audits[191].

4.2 Best practices of the textile sector

The textile and clothing industry is the second most polluting industry worldwide[192]. Producing textiles also requires high amounts of energy, chemicals, and water, e.g. cotton production. Within the lifecycle of garments, about 80% of their climate impact and 92% of the toxicity impact stems from the production phase, highlighting the environmental opportunities for improvements associated with this phase[193,194]. When looking at the global textile sector, there is also a significant need to increase material efficiency. International research shows an enormous waste of resources within the textile industry. Globally, it is estimated that as much as 12 % of all fibres are discarded at the factories, and 25 % of all clothes produced end up unsold (moreover, less than 1 % of all products within the industry are recycled)[195,196]. The global consumption of clothes is estimated to rise continuously and triple by 2050, reaching 160 million tonnes of clothes consumed every year[197].

The Portuguese textile sector is vital to the country's economy, representing 10% of the national exports - 5.328 million euros. In employing over 138.00 people, the textile industry accounts for more than 19 % of the people employed in the manufacturing industry and almost 3 % of the country's total workforce[198, 199].

4.2.1 Private initiatives for improvement of material efficiency

According to Euratex, the textile sector and clothing industry had a recorded turnover of € 165 billion in 2019, accumulated by 160.000 companies, of which the majority are SMEs. The textile sector accounts for 4.7 % of all employment in the EU and over 2 % of the added value in total

[189] Feedback from competent Portuguese Governmental entity in the area of the economy with attributions in the industry.
[190] BuiltColab (n.d.a): O Plano de Ação.
[191] Feedback from competent Portuguese Governmental entity in the area of the economy with attributions in the industry.
[192] The Danish Ministry of Environment and Food (2016): Best Practice Examples of Circular Business Models.
[193] Morlet et al. (2017): A New Textiles Economy – Redesigning Fashion's Future.
[194] We Are Spindye (n.d.a): Supreme Colors – Low Impact – Radical Transparency.
[195] Amed et al. (2021): The State of Fashion 2021.
[196] Textile Exchange (2021): Preferred Fiber & Materials – Market Report 2021.
[197] Morlet et al. (2017): A New Textiles Economy – Redesigning Fashion's Future.
[198] Associação Têxtil e Vestuário de Portugal (n.d.): Estatísticas.
[199] Statista (2021): Employment in Portugal 2022.

manufacturing in the EU. The textile and clothing industry also has a noticeable effect on the environment. The Joint Research Centre estimates that textile consumption accounts for 4 to 6 % of the EU's environmental footprint[200].

Private companies and public authorities are increasingly seeking the potential regarding the economic, social, environmental, and climate benefits of a circular textile system[201]. While there is a need to address social barriers and consumption patterns to improve the clothing industry's overarching environmental impact, material efficiency improvements should also be addressed in the manufacturing process of the textile industry. The production of raw materials is responsible for much of the total environmental impact of the textile and clothing industry, as sustainable fibres only account for 5 % of global fibre production[202].

Portugal is the 30th largest exporter and the 18th largest importer of cotton in the world[203]. Producing raw cotton materials requires extensive land, water, fertilisers, and pesticides. Cotton is challenging from a pre-consumer material efficiency perspective, as it is challenging to recycle cotton into a virgin-like quality[204].
Besides cotton, Portugal is the 21st most prominent exporter of and 40th largest importer of polyester fibres in the world[205]. Polyester fibres have a lower water footprint than cotton and can technically be recycled into virgin-like fibres. However, 99% of all recycled polyester is not made from SRM or used clothing but from plastic bottles. While water consumption is lower and recycling is possible, polyester is a fossil-based fibre, contributing to the release of microplastics into the environment, responsible for around 8 % of European microplastics released to oceans. The textile industry is currently experimenting with bio-based polyester, made from by-products of agriculture and the food processing industry[206].
While it is unclear how much Manmade cellulosic (MMCs) textiles are exported or imported to Portugal, the Portuguese textile industry has included MMCs in manufacturing to some extent. Cellulose is mainly made from the dissolved wood pulp of trees. However, there are some challenges with sustainably sourced cellulose. Therefore, industry actors are investigating innovative sources of cellulose, such as leaves[207]. In Portugal, the ongoing Fiber4Fiber project is investigating the options of developing an optimised dissolving pulp from the Portuguese Eucalyptus globulus trees, enabling the production of the MMCs Lyocell and Viscose[208]. MMCs open up the possibility of a textile industry facilitating improved cross-sectoral material efficiency. The MMCs' textile fibres can be made from the by-products of foresting, wood, and paper production.

Innovation and technological advancements in the textile production field are a continued focus of the textile industry, potentially contributing to higher material efficiency through technology development and implementation. There are several recommended ways to reduce the environmental impact of the processing and manufacturing phase[209] hereunder:

[200] EP (2022): Textiles and the environment.
[201] EEA (2019): Briefing - Textiles in Europe's Circular Economy.
[202] EP (2022): Textiles and the environment.
[203] OEC (n.d.a): Cotton in Portugal.
[204] EP (2022): Textiles and the environment.
[205] OEC (n.d.b): Woven fabric polyester staple fibres in Portugal.
[206] EP (2022): Textiles and the environment.
[207] EP (2022): Textiles and the environment.
[208] Centi (2020): Fiber4Fiber.
[209] EP (2022): Textiles and the environment.

- Reduced chemical input in the production of intermediate products through substitution with enzymes;
- The utilisation of dye controllers and dyeing machinery that require less water and entails water recycling;
- The utilisation of CO_2 as a dying medium instead of water;
- Integral knitting, producing whole garments without sewing and cut-offs, reducing waste generation[210].

Industry actors also experiment with different cut-offs, garments with no or fewer seams, and bonding or glueing instead of sewing[211]. Some industry actors even experiment with 3D printing to increase the efficiency of production[212]. Members of the European Parliament want to promote a new culture of reuse and recycling and suggest that digital technology could be used to obtain a sustainable market through common databases and product passports, making it possible to track products and their paths along the entire value chain[213]. This approach to changing production and consumption patterns would promote information exchange between producers and consumers, enabling more effective market surveillance.

PRE-CONSUMER (FR)	WETURN is a French company that recycles pre-consumer textile waste, textile overstock, and IP-protected textiles. It was founded by Sophie Pignères in 2020, and the company recently received the *Global Recycled Standard* certification (January 2022)[214]. The company recycles natural fabrics, cotton, wool, and cashmere, and handles the pick-up of the textile waste and intermediate storage. The recycled materials are traceable and fully European-based, and the company can provide material certifications and environmental impact measurements. WETURN has a tag for partners using their recycled material, MT®, representing recycling, transparency, and sustainability in the European Circular Economy, and they can also scan a QR-code that will display the full journey of the textile[215].

4.2.2 Certification & standards

A wide range of certification schemes targets intermediate textile products and clothing. Certification in the clothing sector is mainly driven by strategic factors such as marketing considerations and information considering the sustainability aspects of the provided product. Certification schemes can strengthen the competitive position of clothing companies but are also known to raise consumers' awareness of sustainable textile production measures and the apparel supply chain in general[216]. The following section will highlight some of the most relevant textile certification schemes and standards for improving material efficiency in the textile sector.

The EU Ecolabel is a voluntary certification programme covering a wide range of products and services, including intermediate textile products and clothing. The certification scheme was established in 1992, recognised across Europe and worldwide as an ecolabel certifying textile

[210] EP (2022): Textiles and the environment.
[211] EP (2022): Textiles and the environment.
[212] We Are Spindye (n.d.a): Supreme Colors – Low Impact – Radical Transparency.
[213] EP (2020): How to promote sustainable consumption.
[214] WETURN (2022a): Our purpose.
[215] WETURN (2022b): MT® Quality, recycled material.
[216] Oelze et al. (2020): Motivating Factors for Implementing Apparel Certification Schemes – A Sustainable Supply Chain Management Perspective.

products with a guaranteed, independently verified low environmental impact[217]. The EU Ecolabel establishes ecological criteria guaranteeing limited use of substances harmful to human health and the environment, reduction in water and air pollution, and criteria for an extended lifetime of clothing, entailing criteria for resistance to shrinking during washing and drying, and colour resistance to perspiration, washing wet and dry rubbing and light exposure[218]. More than 80.000 goods and services have been awarded the EU Ecolabel, and more than 2.000 licenses have been awarded across Europe[219]. The majority of product and service certifications are awarded in Spain (21%), Italy (14%), Germany (12%) and France (11%). Portugal ranks no. Six EU Member States have the most awarded product and service certifications. The most EU Ecolabel licenses are awarded in Italy (16%), Germany (16%), Spain (15%) and France (15%). Portugal ranks no. Fourteen of the EU Member States with the most awarded licences. Among the products awarded by the EU Ecolabel, textiles are the third largest[220].

The OEKO-TEX Association were established in 1992 by the Hohenstein Research Institute and the Austrian Textile Research Institute, like the EU Ecolabel certification programme. Later the Textile Testing Institute (Testex) joined the association[221]. In 2021/2022, more than 36.000 certificates and labels were issued[222]. The OEKO-TEX Association specifically targets the textile value chain and offers a range of certification standards, including:

- OEKO-TEX® STANDARD 100 and the OEKO-TEX® LEATHER STANDARD labels are awarded to products that have been scientifically tested for the presence of harmful substances to human health;
- OEKO-TEX® MADE IN GREEN labels are awarded to textile products that are manufactured at socially responsible workplaces;
- OEKO-TEX® STeP certification and the DETOX TO ZERO analysis sets the highest standards for social and environmental aspects of textile and leather production; and
- OEKO-TEX® ECO PASSPORT standard is awarded to textiles, where chemicals and treatments have been tested and analysed against strict criteria for a lower environmental impact[223].

The OEKO-TEX Association further offers a Responsible Business management tool to meet supply chain due diligence requirements in the textile and leather industry. The tool support companies in preventing and mitigating existing and potential negative impacts of business operations within their internal activities, supply chains and broader business relations[224]. In 2022, OEKO-TEX launched the Impact Calculator, a tool for facilities to measure production's carbon and water footprint through screening LCAs[225].

The Global Recycled Standard (GRS) addresses input material verification, the chain of custody, environmental principles, social requirements, and the labelling of textile products made from recycled materials. The GRS aims to be a full-product standard for recycled material content,

[217] EC (n.d.j): EU Ecolabel.
[218] EP (2022): Textiles and the environment.
[219] EC (n.d.): EU Ecolabel.
[220] EC (2022b): EU Ecolabel facts and figures.
[221] OEKO-TEX (n.d.a): The OEKO-TEX® story.
[222] OEKO-TEX (2022): Annual Report 2021/2022.
[223] OEKO-TEX (n.d.b): Make decisions which protect our planet.
[224] OEKO-TEX (n.d.c): OEKO-TEX® RESPONSIBLE BUSINESS.
[225] OEKO-TEX (2022): Annual Report 2021/2022.

balancing rigour and practicality for the textile industry and consumers[226]. SCS Global Services offers GRS certification, as well as recycled claim standard certification and recycled content certification, as one of the few companies addressing recycled materials[227].

The 'Bra Miljöval' was developed by the Swedish Society for Nature Conservation (SSNC) and translates to 'Good Environmental Choice'. The idea behind the label is to guide the consumer toward good environmental choices, as the name suggests. The label sets criteria for the use of harmful chemicals, purification of wastewater, ethical and social requirements, and packing requirements, thereby applying to most of the value chain, from production to the finished product[228].

The Ecolabels mentioned above and standards are only a small selection of certification schemes for textile products and services. **The Nordic Swan Ecolabel**, established by the Nordic Council of Ministers in 1989, is a voluntary ecolabelling scheme for the Nordic countries targeting multiple product groups[229]. The **Blue Angel**, established by the German Federal Minister of the Interior in 1872, is a voluntary marked-based ecolabelling scheme targeting multiple product groups[230]. While the Nordic Swan Ecolabel and the Blue Angel certification schemes include some aspects of material efficiency in their criteria, they mainly focus on criteria related to the quality and durability of the products certified.

The international NGO ECoS (Environmental Coalition on Standards) argues that eco-design requirements for textiles are a crucial step towards stopping fast fashion and promoting material efficiency and circularity within the textile industry. However, through analysis of the current environmental tools for the textile industry, ECoS argues that schemes for certification of sustainable textiles will not be able to transform the current linear fast fashion model into a circular model without additional action. According to ECoS, a significant obstacle certification schemes cannot overcome increased reuse and repair[231]. These challenges must be overcome through regulation, consumer awareness campaigns, and economic incentive structures. Furthermore, certification schemes have limited reference to recycled content and content of natural fibres, often not addressing chemical additives and material composition and seldom addressing microplastic from synthetic fibres[232].

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Italy is the leading contributor to the textile and clothing industry in the EU. 22 % of the total employment of the EU textile sector is in Italy. Furthermore, 36 % of the total turnover and 27 % of the total textile export stems from the Italian textile and clothing industry[233]. The high turnover of textile products made in Italy can be explained by the high-end textiles produced in Italy. In Italy, the textile and clothing industry is considered one of the key economic sectors, mainly comprised of SMEs in industrial districts. These districts serve a vital function for the SMEs' economic viability, as the independent SMEs all are located in a limited geographical area and historically linked by the same production purpose. The directs enable close value chain collaborations, as companies

[226] MCL Global (n.d.): Global Recycled Standard.
[227] SCS Global (n.d.) Global Recycled Standard.
[228] Bra Miljöval (2021): Om Bra Miljöval.
[229] Nordic Ecolabelling (n.d.b): The official ecolabel for the Nordic countries.
[230] Blue Angel (n.d.b): Ecolabel with history.
[231] ECoS (2021): Ecodesign requirements for textiles are a crucial step towards stopping fast fashion.
[232] ECoS (2021): Ecodesign requirements for textiles are a crucial step towards stopping fast fashion.
[233] Euratex (2022): Facts & key figures 2022 of the European textile and clothing industry.

specialised in specific activities (spinning, warping, weaving, dyeing or finishing) are in close quarters with the following processing steps of the textile production. The SMEs in these textile districts show great economic results, often above the industry average[234].
Modernisation and technical advancements have been the focus of the Italian textile industry over the past years. Industry 4.0 has been widely implemented due to a policy prepared by the Italian Government, incentivising investments in functional and technological transformations in the textile industry. Research and innovation related to the textile industry of Italy have mainly been focused on the uptake of by-products, e.g. by utilising orange peels for fibre production, the revival of traditional material, such as linen or hemp, and fabrics that can be used as alternatives to artificial fibres[235]. The technological development of the Italian textile industry reflects a significant focus on innovation and material efficiency due to investments in modernisation and research in available SRMs and by-products.

France excels in fundamental research of textiles and material development and mechanical recycling[236]. However, the French clothing industry has been reduced significantly over the past decade, and the remaining activity consists mainly of industrial customers placing orders with foreign subcontractors[237]. Despite the significant reductions, the French textile industry is still among the major contributors to the textile and clothing industry in the EU. 6 % of the total employment of the EU textile sector is located in France. 9 % of the total turnover, and 11 % of the total textile export stems from the Italian textile and clothing industry[238].
French textile production is mainly organised around textile groups with 250 or more employees, and the textile groups are often multinational. These groups specialise in producing luxury items, e.g. leather goods or high-added-value textiles, such as technical textiles used in the aeronautics and automotive sectors[239].
The French textile industry has overcome the sector's struggles through a renewal of historical SMEs into technical textiles and the development of new fibres, such as biobased fibres and intelligent fibres capturing energy or collecting physiological data. The French state has supported the textile sector for the past ten years by establishing textile competitiveness clusters and financing nearly 60 R&D projects. The R&D projects have ensured that the French textile sector has the newest knowledge and technology available, providing the opportunity to develop and implement recyclable and bio-based fibres[240].

Spain has a long-standing history with textiles, and the textile and clothing industry is regarded as one of the main economic sectors of Spain. The textile sector in Spain shows similar structural characteristics to the European industry, such as productive specialisation, geographic agglomeration, a large share of SMEs and uneven development[241]. Spain is among the essential contributors to the EU industry as a whole, as 6 % of the total employment in the EU textile sector is in Spain. Spain is responsible for 7 % of the total EU turnover and 11 % of the textile export in the EU[242].
Most Spanish textile sectors in Catalonia (24%) and the Valencian Community (18,5%). The

[234] ITMA (2023): The Italian Textile Industry – A Key Economic Sector.
[235] ITMA (2023): The Italian Textile Industry – A Key Economic Sector.
[236] Gras & Eliot (2019): Innovation and sustainability in French Fashion Tech outlook and opportunities. The Dutch Ministry of Foreign Affairs.
[237] Insee (2018): The French textile industry: globalised production, expect for luxury products and technical textiles.
[238] Euratex (2022): Facts & key figures 2022 of the European textile and clothing industry.
[239] Insee (2018): The French textile industry: globalised production, expect for luxury products and technical textiles.
[240] EPO (n.d.): Trade Opportunities in France.
[241] Puig et al. (2022): Coronavirus versus the textile industry: cluster lessons for future challenges. Fashion and Textiles, Vol. 9.
[242] Euratex (2022): Facts & key figures 2022 of the European textile and clothing industry.

Valencian textile industry differs from the rest of the Spanish textile sector, as the industry is concentrated in the Valencian Textile Cluster (VTC). The cluster consists of 880 companies, mainly focused on producing the Home-technical textile subsector. The cluster formation of the Valencian textile industry has enabled a high level of resilience, competitiveness and a model for industrial organisation and symbiosis, outlining the efficiency achieved by the cluster[243]. A range of related or supporting sectors is located in Valencia, Alicante, Alcoi and Ontinyent. Textile machinery repair shops, the chemical industry, import-export service companies, etc., are located near the VTC. Studies of the VCT have shown that the industrial setup provides three main effects: 1) increased entrepreneurial activity, 2) improved efficiency rates, and 3) facilitation of innovation processes. The clustering positively affects generating business and the dynamic knowledge generation growth and development for participating companies, attracting new companies and industry actors. The clustering facilitates trust, information diffusion and cost savings, all contributing to the resilience of the industrial model[244].

Portugal's textile sector is considered a traditional sector and is one of the oldest industries of Portugal[245]. The textile industry has been under a restructuring phase following intense pressure created by competing cheap labour economies, a change in the economic paradigm, the fast-paced transformation of consumer preference and the evolution of technology. Advantages sprung from the industrial restructuring, increasing dynamic and competitive behaviour among industry actors, increased know-how, moderate salary costs compared to European standards, growing international recognition of production, investment in technological modernisation and growing development of a quality culture, providing added value[246].

The aforementioned best practices country examples (Italy, Spain and France) have all been a part of an EU group of countries engaged on the task force to reduce energy consumption in the textile sector, further accompanied by Portugal, Germany and the UK (pre-Brexit). Unlike the other members of the task force, Portugal has shown fewer improvements over the years. This is, among others, because the Portuguese textile sector still consists of many small facilities that function with equipment with very low efficiency and due to lacking reporting of material input and overall resource consumption. Further, the Portuguese textile industry depends on resource import for material input[247]. The Portuguese textile sector employs 9% of the total EU textile sector employment (a larger share than both Spain and France) but only 5% of the total turnover and 2% of the total export of the EU (a smaller share than both Spain and France) [248]. While the Portuguese textile sector primarily consists of SMEs, cluster collaboration like the VTC is less prominent in Portugal. The Portuguese textile SMEs are in an overly competitive state in the domestic market with low-profit margins. However, the Portuguese textile SMEs are challenged in internationalisation processes, mainly due to low financial resources, challenging investments and challenges with management and means of communication related to language barriers and cultural differences[249].

[243] Puig et al. (2022): Coronavirus versus the textile industry: cluster lessons for future challenges.
[244] Puig et al. (2022): Coronavirus versus the textile industry: cluster lessons for future challenges.
[245] Galvão et al. (2021): Motivation and Barriers for the Sustainable Internationalization of the Portuguese Textile Sector.
[246] Araújo et al. (2019): The Quality Management Systems as a Driver of Organizational Culture: An Empirical Study of the Portuguese Textile Industry.
[247] Costa et al. (2019): Ecological Footprint as a sustainability indicator to analyze energy consumption in a Portuguese textile facility.
[248] Euratex (2022): Facts & key figures 2022 of the European textile and clothing industry.
[249] Galvão et al. (2021): Motivation and Barriers for the Sustainable Internationalization of the Portuguese Textile Sector.

4.2.3 Regulation & policies for improvement of material efficiency

Several examples of policies support higher material efficiency in the textile sector. This includes regulations and other political instruments directed towards GPP, support of innovation and collaboration, economic incentives for consumers and producers, mainstreaming across regions, and promoting sustainable trade[250, 251].

The Ecodesign Directive 2009/125/EC[252] has been revised and adapted the Sustainable product policy as a part of the circular economy package in 2022 to assist in achieving the Green Deal objectives of lower resource consumption and less environmental impact[253]. Under the legal framework, almost all products produced or sold in the EU have to align with technical sustainability standards. The new Ecodesign for Sustainable Products Regulation builds on the Ecodesign Directive, covering a more comprehensive range of requirements, including:

- Product durability, reusability, upgradeability, and reparability;
- Presence of substances that inhibits circularity;
- Energy and resource efficiency;
- Recycled content;
- Remanufacturing and recycling;
- Carbon and environmental footprints;
- Information requirements, including a Digital Product Passport (DPP)[254].

Creating a DPP to an electronic register within the adopted proposal is expected to increase transparency and efficiency in information transfers. The DPP enables the processing and sharing of product-related information among supply chain businesses, authorities, and consumers[255]. Particularly relevant for the textile sector, the new Ecodesign for Sustainable Products Regulation prohibits the destruction of unsold consumer products[256], a practice the textile sector is known for[257]. The prohibition of destroying unsold products will enable the Member States to facilitate increased availability of pre-consumer reusable and recyclable materials. Facilitated networks and industrial symbiosis can further support the uptake of these material types as input to production.

Through **The New Sustainable Product Framework,** the EU promotes the transition towards a circular economy by delivering the policies and measures announced in the Circular Economy Action Plan (CEAP). With the initiative 'Toward an EU Product Policy Framework contributing to the Circular Economy', the EU Commission aims to address the many products in use today that are not designed or produced with circularity in mind. According to the CEAP, several product groups, including textiles, are currently not covered by EU policies regarding their high circularity potential[258]. The European Commission also identified textiles as a 'priority product category for the circular economy in response to the fact that textiles are the fourth highest-pressure category

[250] Ecopreneur (2019): Circular Economy Update – Overview of Circular Economy in Europe.
[251] Bauer et al. (2017): Pre-Study: Indicators on Circular Economy in the Nordic Countries.
[252] EC (2009): Ecodesign and Energy Labelling – Directive 2009/125/EC and Regulation (EU) 2017/1369.
[253] EC (n.d.k): Sustainable product policy & ecodesign.
[254] EC (2022c): Making sustainable products the norm in Europe.
[255] EC (2022d): Proposal for a Regulation of the European Parliament and of the Council establishing a framework for setting ecodesign requirements for sustainable products and repealing Directive 2009/125/EC. COM(2022) 142 Final.
[256] EC (2022d): Proposal for a Regulation of the European Parliament and of the Council establishing a framework for setting ecodesign requirements for sustainable products and repealing Directive 2009/125/EC. COM(2022) 142 Final.
[257] Elia (2020): Fashion's Destruction of Unsold Goods: Responsible Solutions for an Environmentally Conscious Future.
[258] EC (2019a): Toward an EU Product Policy Framework contributing to the Circular Economy.

for using primary raw materials and water[259,260]. The strategy also aims to strengthen industrial competitiveness and innovation within the textile sector, thereby boosting the EU market for sustainable, circular textiles and clothing. Applying the New Sustainable Product Framework includes:

- Developing eco-design measures, such as the minimum threshold for recycled material content, ensures that textile products are fit for circularity.
- Ensuring the uptake of secondary raw textile materials.
- Tackling the presence of hazardous chemicals in the preparation and colouring phase.
- Empowering businesses and private consumers to choose sustainable textiles, e.g. by labelling measures, and ensuring easy access to reuse and repair services[261].

The new framework aims for EU member states to achieve high levels of separate textiles waste collection by 2025 by boosting textile sorting, preparation for reuse and recycling through innovation. Bettering the business and regulatory environment for sustainable and circular textiles in the EU will be achieved by providing incentives and support to:

- Product-as-service models
- Circular materials and production processes
- Internal cooperation for increased transparency[262].

The effects of the strategy will be strengthened by encouraging the implementation of applications in the textile sector and by enabling regulatory measures for the EU member states, such as Extended Producer Responsibility (EPR) systems[263].

The EU Strategy for Sustainable and Circular Textiles was adopted in 2022, implementing commitments made under the European Green Deal, the New Circular Economy Action Plan (CEAP2) and the Industrial Strategy to create a greener, more competitive, and more modern textile sector, with greater resistance to global shocks and value chain obstructions. The strategy proposes actions for the entire lifecycle of textile products that support the upholding of ecosystems and increase the green and digital transitions of the textile sector. The strategy addresses how textiles are designed and consumed, among others, through technological solutions and innovative business models[264]. The key actions of the Strategy for Sustainable and Circular Textiles, with relevance for material efficiency improvements, include:

- Mandatory performance requirements for environmental sustainability of textile products, from 2024;
- Disclosure of the number of discarded products by large enterprises and their subsequent treatment, including measures on banning the destruction of unsold textiles from 2024;
- Revision of the EU Ecolabel criteria for textiles and footwear from 2024;
- Initiative to address the unintentional release of microplastics from textile products by 2022;
- Enforcing the Corporate Sustainability Due Diligence Directive in the textile sector as of 2023;

[259] EC (2019b): Commission Staff Working Document – Sustainable Products in a Circular Economy – Towards an EU Product Policy Framework contributing to the Circular Economy.
[260] EC (n.d.l): Strategy for textiles.
[261] EC (n.d.l): Strategy for textiles.
[262] EC (n.d.l): Strategy for textiles.
[263] EC (n.d.l): Strategy for textiles.
[264] EC (2022e): Questions and Answers on EU Strategy for Sustainable and Circular Textiles.

- Extended Producer Responsibility requirements for textiles with eco-modulation of fees and measures to promote the waste hierarchy for textile waste by 2023;
- Launch of the Transition Pathway for the Textile Ecosystem from 2022;
- Guidance on supporting uptake and partnerships for the CE between social enterprises and other actors, including the textile sector, from 2022;
- Guidance on CE business models featuring the textile sector from 2024;
- Horizon Europe calls on support R&D in textiles from 2021-2027;
- Adoption of common industrial technology roadmap on circularity from 2022;
- Criteria for circular manufacturing of apparel under the Taxonomy Regulation from 2022[265].

MEMBER STATE PERFORMANCE

Belgium is well known for the textile waste management system in the region of Flanders. A selective collection of textile waste has been obliged for companies (and households) through the VLAREMA regulations and the Implementation Plan for Household Waste and Comparable Industrial Waste[266]. With the latest revision of VLAREMA, sustainable management of material cycles was addressed by implementing the 'Material Decree' principles. The 'Material Decree' stipulates that waste operators are obliged by law to detect and record sorting errors, meaning that companies that send in residual waste with a lot or too many recyclable materials, the company will be notified and targeted inspections can be done by the authorities. The purpose is to decrease the amount of mixed industrial waste[267]. Non-conformity with the requirements of separate waste management will be recorded in register[268], enabling a continuous outlook on reducing mixed waste.
The Flemish Waste Agency has started round table discussions, focused on calculations of local and global impacts of circular strategies of the textile sector, to gain new understandings and inputs for new policies to support a decrease of the regional material footprint by 30% by 2030, by closing resource loops and dematerialisation[269].

France is addressing the clothing and textile sector's material efficiency through their Extended Producer Responsibility (EPR) regulation. France is the only EU member state with a functioning mandatory EPR system for textiles with established taxation corresponding to this legislation[270, 271]. The EPR policy for textiles was first introduced in January 2007 in France through the *Article L541-10-3 of the Code de l'Environnement*[272]. Since its implementation, everyone developing, manufacturing, distributing, processing, selling or importing clothing and textiles to the French market is held responsible for the recycling and proper disposal of their products[273, 274]. The approach taken by the French authorities puts the responsibility of promoting and contributing to the prevention and management of waste into the hands of the sector. Actors within the textile

[265] EC (2022f): Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions – EU Strategy for Sustainable and Circular Textiles. COM (2022) 141 Final.
[266] Interreg Europe (2021b): Focusing on steps towards sustainable textiles.
[267] Fostplus (2021): Changes in Vlarema 8 are intended to reduce the proportion of recyclable material in industrial residual waste.
[268] IMOG (n.d.): Vlareme.
[269] Interreg Europe (2021b): Focusing on steps towards sustainable textiles.
[270] Watson et al. (2014): EPR systems and new business models - Reuse and recycling of textiles in the Nordic Region.
[271] The Danish Ministry of Environment and Food (2016): Best Practice Examples of Circular Business Models.
[272] Bukhari et al. (2018): Developing a national programme for textiles and clothing recovery.
[273] Bukhari et al. (2018): Developing a national programme for textiles and clothing recovery.
[274] The French Republic (n.d.): Code de l'environnement.

industry will receive economic bonuses or penalties per their compliance with the environmental performance criteria. These criteria include:

- the quantity of material used;
- the incorporation of recycled material;
- the use of sustainably managed renewable resources;
- possibilities to repair and reuse;
- recyclability, advertising;
- and promoting the sustainable purposes of products and the absence of ecotoxic and dangerous substances[275].

In February 2020, France extended the producer liability to additional products and tightened it for the existing product groups[276] with *Article L541-10-1 under law n ° 2021-1104 of August 22.*
The entities of the French textile market can accomplish their legal obligation either by setting up an individual take-back programme[277], which needs to be approved by the French Government or by collectively setting up a state-approved eco-organisation[278], also known as Producer Responsibility Organisation (PRO)[279]. Eco-organizations are approved for a maximum period of six years by the Minister responsible for the environment. They must create stakeholder committees consisting of producers, representatives of local authorities competent in waste management and environmental proception associations, consumer protection associations, and waste prevention and management operators [280]. Some researchers argue that the collective scheme (PRO) does not offer enough incentives for promoting waste prevention and green product design[281]. It does, however, make it possible to hold the waste collection and treatment up to a more uniform standard and to ensure the traceability of the waste[282].

Hungary has been struggling with low resource efficiency, to some extent, due to the low price of landfilling. This serves as a barrier for companies to pursue more resource-efficient options and engage in industrial symbiosis networks. However, Hungary has successfully introduced a facilitated network nationally under the National Industrial Symbiosis Programme (NISP)[283].
Further, focusing on public-private partnerships and funding streams, including EU programmes such as LIFE+, has provided short-term positive outcomes. Programmes in Hungary have primarily been developed with the help of EU funding on a project basis, but the programmes have been implemented at a regional level. While long-standing networks, such as Northern Ireland Industrial Symbiosis, provide evidence that long-standing facilitation structures enable continuous positive outcomes, shorter-term initiatives, such as networks in Hungary, achieved outcomes. Still, they found it challenging to compete with the low costs of landfilling[284]. Hungary is an example of the barriers that can occur when progressive regulatory frameworks do not support public-private

[275] The French Republic (n.d.): Code de l'environnement.
[276] Deger (2020): Reform of extended producer responsibility in France.
[277] Bukhari et al. (2018): Developing a national programme for textiles and clothing recovery.
[278] The French Republic (n.d.) Code de l'environnement.
[279] Bukhari et al. (2018): Developing a national programme for textiles and clothing recovery.
[280] The French Republic (n.d.) Code de l'environnement.
[281] Bukhari et al. (2018): Developing a national programme for textiles and clothing recovery.
[282] The French Republic (n.d.) Code de l'environnement.
[283] Domenech et al. (2018): Cooperation fostering industrial symbiosis: market potential, good practice and policy actions. European Commission, the Publication Office of the European Union.
[284] Domenech et al. (2018): Cooperation fostering industrial symbiosis: market potential, good practice and policy actions. European Commission, the Publication Office of the European Union.

collaborative efforts.

Hungary performs very well in data collection on waste and material flow. Hungary has developed a sound monitoring system for waste generation and treatment and has collected good-quality data since the establishment of the Waste Management Information System (HIR) in 2004. The HIR is based on the European Waste Catalogue and receives around 25 000 data entries annually. Before the implementation of HIR, the Hungarian waste management data were generally of poor quality, with estimates often complemented by sporadically collected data. Material flows are monitored and analysed based on the 2001 Eurostat methodical guidelines aligned with OECD methodology for material flows and indicators. Since 2007, the Hungarian Central Statistical Office (HCSO) has published annual nationally aggregated material flow accounts for governmental publications such as the Indicators of Sustainable Development[285].

Portugal has prioritised working towards harmonising procedures and processes in the textile industry with the European Union and ISO environmental standards and implementing Corporate Social Responsibility (CSP)[286]. Three incentive systems are in place in Portugal, affecting the improvements of material efficiency, which are highly relevant for the Portuguese textile sector:

- SI I&DT – An incentive system for technology research and development in companies;
- SI Inovação – An innovation incentive system to promote innovation in businesses that support the progression of the Portuguese value chains;
- SI Qualificação PME – incentive system for the qualification and internationalisation of SMEs, aiming to promote the competitiveness of SMEs and increase productivity[287].

CITEVE provides technical and innovative support to the textile industry, as well as the furniture sector, a private non-profit technological centre, joined the inter-regional EU programme RESET to improve CSP compliance in the textile sector[288]. The RESET project has initiated sustainable networks of innovation, partnerships and cooperation, which has led to an increase in textile SMEs participating in R&D activities. Under the POCI – COMPETE 2020 Operational Programme, the main objectives for the Portuguese textile industry have been to increase business investments in R&D, increase economic incentive activities in knowledge and value creation, strengthen networks and partnership through enhanced clustering to improve efficiency and competitiveness; and increase business investments in innovative activities[289].

4.3 Best practices from the furniture sector

The European furniture industry has a good reputation due to its creative capacity for new designs and responsiveness to new demands. The industry is further recognised for its ability to combine new technologies and innovation with cultural heritage and styles[290]. Approximately 10 million tons of furniture is consumed within the EU each year[291]. According to a European Environmental Bureau (EEB) study, increased material efficiency through refurbishment and remanufacturing

[285] OECD (2018): Waste, material management and circular economy. OECD Environmental Performance Reviews – Hungary, 2018.
[286] Dugal (2021): An Overview To The Portugal Textile Industry: A Strong Industry Known For Its Craftmanship and Quality.
[287] Compete (n.d.): Incentivos às Empresas.
[288] CITEVE (n.d.): Sobre o CITEVE.
[289] CITEVE (2020): RESET – Interreg Europe. RESearch Centres of Excellence in the Textile Sector.
[290] EC (n.d.m): Furniture industry.
[291] EEB (2017): Circular economy opportunities in the furniture sector.

could save between six million and fourteen million tons of annual municipal furniture waste in the EU[292].

While the furniture sector employs around 1 million workers in 130.000 companies, the furniture sector was severely challenged by recent crises, resulting in reduced numbers of companies, jobs, and turnover. Challenges with competition from countries with low production and labour costs, the ageing European workforce and difficulties in attracting workers may lead to disruptions in the persistence of the annual turnover of around € 96 billion and the maintenance of skilled workers and craftsmanship in the furniture industry. Further, the European furniture industry faces duties on imports of raw materials and tariffs on the export of finished products and higher operational costs due to environmental, sustainability and technical standards[293]. Still, the European furniture sector remains the second largest furniture manufacturing region, with Germany, Italy and Poland as the central exporting countries[294].

The significant challenges cannot be overcome by material efficiency efforts alone. However, an increased focus on the recirculation of SRM and by-products from the furniture industry and the construction and textile sectors could assist in the challenges with duties on material imports and achievement of environmental, sustainability and technical standards.

4.3.1 Private initiatives for improvement of material efficiency

The European furniture sector has changed significantly and has achieved a more export-oriented and resilient focus through restructuring, technological advances, and business model innovations, resulting in increased quality, innovation, and better design[295]. Sub-segments of the European furniture sector are affected differently in the material import balance, affecting the resilience and the opportunities for improvements of the sub-segments' material efficiency. Kitchen and office furniture are sub-segments with relatively low import penetration due to standards, specialised orders, and installation. Mattresses also represent a sub-segment with low import penetration, partly due to sizes and standards varying considerably across countries (also within the EU) and due to the costs of long-distance transport. Sub-segments of the European furniture industry that continuously increase imports include upholstered furniture, mainly due to high labour costs in the EU. The furniture sub-segment is classified as ‘other’. The ‘other’ sub-segment accounts for 50% of EU production and consists of bedroom furniture, dining and living room furniture, unupholstered seats, occasional furniture, bathroom furniture, outdoor furniture, and furniture parts. The ‘other’ sub-segment has a high import penetration due to using materials that cannot be produced sufficiently in the EU, like bamboo[296].

The European furniture sector faces a range of economic, regulatory, and environmental challenges, hereunder growth in emerging markets, improved logistics (reducing the costs of the import-heavy sub-segments), declined tariffs on foreign trade, increased demand for low-cost items in the internal market, and increased raw material, labour, and energy costs in the EU. The growing pressure for cheaper, low-end furniture products challenges European furniture manufacturing trends, as high-end furniture manufacturing dominates in the EU. Competitors from low-cost countries, therefore, have a crucial advantage, as expenses related to commitments and obligations from labour laws and environmental standards do not affect the production costs in

[292] EEB (2017): Circular economy opportunities in the furniture sector.

[293] EC (n.d.m): Furniture industry.

[294] Morder Intelligence (n.d.): Europe Furniture Market – Growth, Trends, COVID-19, Impact, and Forecast (2023-2028).

[295] EC (n.d.m): Furniture industry.

[296] Renda et al (2014): The EU Furniture Market Situation and a Possible Furniture Products Initiative – Final report. Ref. Areas(2014)3842167.

the same manner as within the EU[297]. Regarding material efficiency and pre-consumer waste, the EEB recognise limited information on the EoL treatment of furniture. Assuming waste generation reflects a similar pattern to consumption, waste arising from commercial sources, including pre-consumer waste and SRM, can be assumed to contribute 18% of total furniture waste generation across sector[298]. The waste from commercial sources can be expected to reflect the furniture composition on the market.

According to the EEB, one of the European furniture industry's biggest challenges is the consumer demand for sustainable products. Currently, information on consumer preference is sparse, and the availability of spare parts is lacking, hindering a prolonged lifespan of the furniture. Furthermore, the demand for second-hand furniture is low among European consumers in general, partly due to the low-price difference between new and second-hand furniture, coupled with poor awareness of the availability and benefits of sustainable furniture options and stigmas related to second-hand furniture[299]. The European Furniture Industry Confederation (EFIC), representing more than 70% of the total turnover of the furniture industry in Europe[300], emphasises the importance of improving consumer awareness in the transition toward a circular economy. The EFIC argues that the best guidance for consumers is an EU-level information scheme since too many tools providing information to consumers would be counterproductive and lead to confusion[301]. Material passports have been adopted in other sectors to assess the reusability or recyclability of products and, thereby, whether or not the product is designed for disassembly. Research findings from one of the Resource Efficient Business Model (REBus) pilot projects highlighted the potential benefits of implementing material passports in the furniture sector. The relevance of supporting value retention of raw materials across the value chain was identified[302]. The possibility of implementing product passports for the furniture industry on multiple occasions has been welcomed by EFIC since this could provide the lacking information to consumers as well as a standardisation of the information given[303,304]. The European Commission addresses investment, research, access to new markets and synergies as the main opportunities for the sector[305].

[297] EEB (2017): Circular economy opportunities in the furniture sector.
[298] EEB (2017): Circular economy opportunities in the furniture sector.
[299] EEB (2017): Circular economy opportunities in the furniture sector.
[300] EFIC (n.d.): About us.
[301] EFIC (2020a): The Furniture Sector and Circular Economy 2.0.
[302] EEB (2017): Circular economy opportunities in the furniture sector.
[303] EFIC (2020a): The Furniture Sector and Circular Economy 2.0.
[304] EFIC (2020b): Annual Report 2020.
[305] EC (n.d.m): Furniture industry.

FURNITURE WITH PRODUCT PASSPORTS (NL)

Arco is a 4th generation Dutch furniture manufacturer specialising in tables and chairs. They brand their products on durability and quality, claiming to design their tables to last for generations. Arco also designs their products for refurbishing and offers restoration and/or upgrading of existing products, in an attempt to reuse as many components as possible[1]. The company uptakes primary raw materials, such as wood, from local and certified sources.

The business model of Arco is interesting when it comes to the implementation of their 'Product Eco Passport' on all products. This product passport includes information on the materials used to produce the table, indicated by weight, certificates of the wood used, information on packing and logistics, and what Arco calls 'sustainable features[1]. These features give the consumer information on:

- The possibility of getting the product repaired by Arco
- If the wood used is locally sourced
- Country of origin
- The possibility of getting the product refurbished
- The possibility of recycling the product
- The so-called Arco duramas, where the core of the table tops is produced of less scarce wood species
- The possibility of getting the product specifically tailored to the wants and needs of the consumer[1].

Arcos solution is an example of, how similar product passports for the furniture industry could be formulated. Some elements are still lacking in Arco's Product Eco Passport, such as the source of components besides wood[1], however, Arco gives the consumer a much greater possibility to engage in conscious furniture consumption and exemplifies the possibilities in assisting the consumers in making sustainable decisions.

4.3.2 Certification & standards

As with the textile industry, eco-design and eco-labelling are seen as the targeted requirements and criteria that can lead to the most significant environmental benefits within the furniture industry. Several ecolabels have been developed with criteria for furniture[306]. Ecolabels such as the EU Ecolabel or the Nordic Swan promote material efficiency in the furniture industry, similar to the textile industry.

Examples of **EU Ecolabel** criteria that should be fulfilled to achieve the label include restrictions on using hazardous substances, design, instructions for disassembly to ensure proper recycling, and product information, such as material usage[307]. The EU Ecolabel formerly had a restrictive material content threshold (≥90% wood/wood-based material and ≤3% of any other product) but revised the restrictions after consulting with furniture stakeholders, clarifying that only a few furniture products contain more than 90% wood. A JRC Technical Report done on the topic of EU Ecolabeling of furniture recommended that restrictions for minimum and maximum threshold content are to be removed but that meaningful ecological criterion were set for other materials than wood, as wood generally is considered to have e better environmental profile, provided that the wood originates from certified sustainable sources[308]. The Commission Decision (EU) 2022/1229 recognise that the EU Ecolabel criteria for bed mattresses, furniture and wood-, cork- and bamboo-

[306] Parikka-Alhola (2008): Promoting environmentally sound furniture by green public procurement.

[307] EC (2016b): Commission decision 2016/1332 of 28 July 2016 establishing the ecological criteria for the award of the EU Ecolabel for furniture.

[308] Donatello et al. (2017): Revision of EU Ecolabel criteria for furniture products. JRC Science for Policy Report, Final Technical Report. The European Commission.

based floor covering are to be revised in line with the New Circular Economy Action Plan (CEAP2) for a cleaner and more competitive Europe and related forthcoming legislative initiatives[309].

The Nordic Swan Ecolabel also includes restrictions for hazardous substance content in a product, design for disassembly and product information, the availability of spare parts, and a set warranty period[310]. There are currently 62 companies that have achieved the Nordic Swan Ecolabel, and these have applied the label on 2145 of their products[311].

The Swedish ecolabel **Möbelfakta**, has taken a different approach to ecolabelling, setting up a reference system for furniture quality determination with regards to either the European standards (EN-standard) or ISO standards. This system is developed to assist designers, buyers, architects, and other actors related to the furniture industry in assessing the most critical qualities in furniture products. Möbelfakta is always provided with an Environmental Product Declaration (EPD), which includes data about environmental policies, pollution emissions, waste materials from the manufacturing process, raw materials or SRM used through material specification, the waste-handling process of the waste associated with the specific product and environmentally classified materials or chemicals[312]. The in-depth focus on systemising the environmental impacts of furniture production promotes the material efficiency for the endorsed bands and the awareness of the production process and effects for the consumers, making it easier to make environmentally sound purchases.

The Forest Stewardship Council (FSC) certification scheme certifies timber for various products, including construction, fashion, fibre, furniture, natural rubber, paper, and packaging. Consumers have become very aware of sustainably sourced wood, as illustrated by GlobeScan Global Consumer Research done in 2021, as 84% of the consulted consumers expect companies to sell wood and paper products that do not cause deforestation, and 77% recognise the FSC label prefer FSC-certified over non-certified products[313]. Three Ecolabels can be awarded to the furniture value chain:

- The Forest Management Certification can be awarded to organisations managing forest operations in a socially, environmentally, and economically responsible way.
- The Chain of Custody Certification can be awarded to companies involved in the processing or transforming of FSC-certified products, including manufacturing, repackaging, or relabelling.
- FSC Trademark Promotional Licence can be obtained by traders of finished products labelled as FSC from an FSC-certified company[314].

Labels can be provided for products entirely or partially made of materials from FSC-certified forests. In the context of material efficiency, the FSC Recycled label can be obtained if a product is made of 100 % recycled materials. This reduces the pressure to harvest more trees and increases the longevity of wood-based materials[315].

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[309] Commission Decision (EU) 2022/1229 of 11 July 2022 amending Decisions 2014/312/EU, 2014/391/EU, 2014/763/EU, (EU 2016/1332 and (EU) 2017/176 as regards the period of validity of the EU Ecolabel criteria and the related assessment and verification requirements (notified under document C(2022)4739). Document 32022D1229.

[310] Svanen (2021): Remissammanställning för - Utemöbler, lek- och parkutrustning.

[311] Svanen (2021): Remissammanställning för - Utemöbler, lek- och parkutrustning.

[312] Parikka-Alhola (2008): Promoting environmentally sound furniture by green public procurement.

[313] GlobeScan (2021): 2021 Global Consumer Research Reveals Escalating Concerns about Climate Change and Threats to Forest Biodiversity.

[314] FSC (n.d.a): The Value of FSC® for Furniture.

[315] FSC (n.d.b): What's in a label?

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In **Ireland**, several initiatives have been implemented to support furniture manufacturers in improving material efficiency. Under the government-supported 'Environmental Initiatives in Indigenous Industry', a Sector Specific Best Practice Guide for the furniture manufacturing industry was provided. The best practice guide considers a wide range of areas to improve the environmental impact of furniture production in Ireland, many with material efficiency relevance, including:

- Choice of raw materials;
- Reducing finished goods damage rate;
- Process control;
- Maintenance procedures;
- Waste handling;
- Types of cutting machines; and
- Product Design[316].

Most of the furniture manufacturers in Ireland are SMEs. Funding and tax reductions for start-ups and SMEs are available, among others, for digital and technology implementations and R&D projects[317]. Networking between companies, Government agencies, academic researchers, representative bodies and consultants across sectors is facilitated by the Lean Business Ireland Community, supporting networking opportunities for lean production[318].

The Federal Ministry Republic of **Austria** has developed the Austrian Ecolabel, much in line with the EU Ecolabel. A range of guidance documents, events, and education efforts to support the adaptation of both the Austrian Ecolabel, the EU Ecolabel and EMAS[319]. For the furniture sector, a detailed guide has been developed, entailing health and environment criteria, emissions limits, the fitness of use, production criteria and an overview of normative standards (including relevant ISO standards), acts and other regulations (both Austrian and EU regulation) with relevance for the obtaining of the Austrian Ecolabel. Among the production criteria, the Austrian Ecolabel requires that application present a waste management concept on the completeness of company-level waste management plans[320]. Concerning durability, at least one of the following 'desirable criteria' must be fulfilled:

- Repair and maintenance service;
- Spare parts guarantee for wearing parts of a least ten years and service phone for customers; or
- Establishment of a take-back system[321]

[316] Enterprise Ireland (n.d.): Sector Specific Best Practice Guide – Furniture Manufacture.
[317] The Government of Ireland (2019): Overview of Government Supports for Indigenous Business.
[318] Lean Business Ireland (n.d.): About us.
[319] The Federal Ministry Republic of Austria (n.d.): Welcome to the "Green World" of the Austrian Ecolabel.
[320] Österreichisches Umweltzeichen (2015): Austrian Ecolabel Guideline UZ 06 – Furniture – Version 8.0 1 January 2015.
[321] Österreichisches Umweltzeichen (2015): Austrian Ecolabel Guideline UZ 06 – Furniture – Version 8.0 1 January 2015.

All of the above could increase material efficiency in furniture production, as waste production will likely be reduced for all three options. Further, they incentivise the production of durable products and efficient use of materials through prolonged product lifespan[322].

Belgium initiated the participation of the Sustech project for wood, textiles and furniture manufacturers as a step in the realisation of the Green Action Plan for SMEs of the EU Commission. The project was realised by the project partners Fedustria, Centexbel and WOOD.BE[323], supporting participating businesses to move forward with the following:

- Dematerialisation;
- Sustainable material selection;
- Design for recycling, reassembly, and modularity; and
- Product life extension[324].

The project has been lauded as a model for accelerating the transition towards resource efficiency within the furniture sector[325].

In **Portugal**, efforts have been made to support SMEs with CE transitions through the Vale Economia Circular, Circular Economy Vouchers. The Circular Economy vouchers apply to SME in general, and are therefore relevant not only for the furniture sector but also e.g. the textile sector. The purpose of the Vale Economic Circular was to provide Portuguese companies with a diagnosis leading to a definition of an action plan for implementing management and growth models aligning with the national and international CE strategies and commitments assumed by Portugal. The vouchers have allowed Portuguese companies and industries to improve their management and growth performance by adapting CE business plans[326], and introducing Environmental Management Systems (ISO 14001) and Energy Management Systems (ISO 5001)[327]. The vouchers have facilitated an increased transition to a more circular national industrial fabric, supporting actions that contribute to good practices in eco-design, eco-efficiency, eco-innovation and industrial symbiosis. The Vale Economia Circular has improved Portuguese performance in terms of efficiency in using resources, new processes, new products, and new business models[328].

4.3.3 Regulation & policies for the improvement of material efficiency

Existing EU policies affect various aspects of furniture, such as safety (General Product Safety Directive), chemical content (REACH), and recycling (Waste Framework Directive). However, no specific legislation exists for furniture from a Circular Economy perspective [329]. In both the 'Circular Economy Package of the EC' and the 'New Circular Economy Action Plan for a Cleaner and More Competitive Europe' furniture is mentioned as a priority group, with no further specification yet[330], making it reasonable to assume that the furniture will be included in future regulations[331].

[322] Österreichisches Umweltzeichen (2015): Austrian Ecolabel Guideline UZ 06 – Furniture – Version 8.0 1 January 2015.
[323] EEB (2017): Circular economy opportunities in the furniture sector.
[324] EEB (2017): Circular economy opportunities in the furniture sector.
[325] EEB (2017): Circular economy opportunities in the furniture sector.
[326] Henriques et al. (2022): Policies and Strategic Incentives for Circular Economy and Industrial Symbiosis in Portugal: A Future Perspective.
[327] NERSANT (n.d.): Vale Economia Circular.
[328] NERSANT (n.d.): Vale Economia Circular.
[329] EC (2019b): Commission Staff Working Document – Sustainable Products in a Circular Economy – Towards an EU Product Policy Framework contributing to the Circular Economy.
[330] Sawyer (2020): Skills and safety needs in a circular furniture sector.
[331] Interreg Europe (2021c): Make sustainable products the norm in the EU.

A report from the European Commission[332] indicates that the market and consumers would welcome the furniture industry's inclusion in the **Circular Action Plan for Europe**. Respondents to a public consultation showed that 43% considered the EU policy instrument coverage of sustainable design and production of furniture inadequate, and 54% believed that the current framework could not provide consumers with needed information on sustainable consumption and proper waste handling. Stakeholders from the European furniture industry are also interested in developing EU policy tools to pursue a more circular furniture design, considering the life cycle of furnishing products. Workshops facilitated by the European Commission showed that stakeholders from the furniture industry are calling for the harmonised application of EPR across the EU, including rules on fee modulation since EPR is considered a good instrument in this context[333]. Furthermore, stakeholders from the furniture industry described that reparability could be improved by better disassembly options and encouraging circular public procurement is also called for[334].

As described in former sections, **The Eco-design Directive** 2009/125/EC[335] was revised and adapted to the Sustainable product policy under the circular economy package in 2022[336]. Under the new Ecodesign for Sustainable Products Regulation, the requirements below apply to furniture in the same manner as to textiles:

- Product durability, reusability, upgradeability, and reparability;
- Presence of substances that inhibits circularity;
- Energy and resource efficiency;
- Recycled content;
- Remanufacturing and recycling;
- Carbon and environmental footprints;
- Information requirements, including a Digital Product Passport (DPP)[337].

Furniture is covered as a priority product category through the Commission's preliminary assessment, disseminated in the communication 'Making Sustainable Products the Norm in Europe'[338]. Requirements for furniture could be further detailed by including the suggestions of The Nordic Council of Ministers for Ecodesign requirements for furniture[339]; these are:

- Fitness for use: Furniture should be regarded as fit for use if they comply with the current standards (for safety, durability, strength etc.).
- Extended mandatory warranty: The warranty period should be raised above EU requirements and communicated to the buyer.
- Provision of spare parts: Spare parts must be available from the producer for a minimum period after product delivery.
- Design for disassembly: Disassembly instructions should be provided by the manufacturer.

[332] EC (2019b): Commission Staff Working Document – Sustainable Products in a Circular Economy – Towards an EU Product Policy Framework contributing to the Circular Economy.
[333] EC (2019b): Commission Staff Working Document – Sustainable Products in a Circular Economy – Towards an EU Product Policy Framework contributing to the Circular Economy.
[334] EC (2019b): Commission Staff Working Document – Sustainable Products in a Circular Economy – Towards an EU Product Policy Framework contributing to the Circular Economy.
[335] EC (2009): Ecodesign and Energy Labelling – Directive 2009/125/EC and Regulation (EU) 2017/1369.
[336] EC (n.d.k): Sustainable product policy & ecodesign.
[337] EC (2022c): Making sustainable products the norm in Europe.
[338] EC (2022c): Making sustainable products the norm in Europe.
[339] Bauer et al. (2018): Potential Ecodesign Requirements for Textiles and Furniture.

- Packaging materials: Packaging materials must be reusable or recyclable.

Enhancing the eco-design approach in the furniture industry, using, e.g. life-cycle analysis as a foundation, can address the selection of materials and product lifetime and ensure that furniture is recyclable and reusable. However, the life-cycle analysis is often costly and not assessable to all industry actors. Therefore, incentive structures can be needed to push forward eco-design implementation. Incentives to increase eco-design can be internal or external from an industry perspective. Internal incentives are considered a prerequisite for change in the realised operations of a business. The internal incentives include increased cost-effectiveness, material and energy efficiency, value creation, staff motivation, company image (e.g. sustainable), and environmental responsibility. External drivers include changes in regulation, customer demand or competitors' actions[340].

Green Public Procurement (GPP) is a promising tool for fostering more environmentally sound products, especially furniture[341]. Establishing procurement criteria for furniture bought through public entities can push the sector to include eco-design principles and improved material efficiency[342]. Purchasing under a fixed set of standards within institutions and municipalities significantly increases the demand for material-efficient products. Procurement requirements can be set up within several categories that support the reduction of material consumption and waste production within the sector, including, for example:

- Warranty Requirements;
- Durability requirements;
- Repairability/recyclability requirements;
- Requirements regarding the content of hazardous chemicals.

The EU has established a considerable number of GPP criteria. Regarding furniture, there are 17 core criteria and 28 somewhat overlapping criteria that can be applied voluntarily by the member states. The requirements are formulated to be integrated into tender documents if deemed appropriate by the individual authority[343]. The core criteria are suitable for usage by any contracting authority across member states. They are designed to be used with minimum additional verification efforts or cost increases and to address the critical environmental impacts. The comprehensive criteria are aimed at those who wish to access the best environmental products on the market[344]. The current core GPP criteria for furniture are as follows:

PROCUREMENT OF FURNITURE REFURBISHMENT SERVICES FOR EXISTING FURNITURE[345]	
Technical Specification	Refurbishment requirement
Technical Specification	Durable upholstery covering
Technical Specification	Blowing agents
Technical Specification	Refurbished furniture product warranty
Award Criteria	Extended warranty periods
PROCUREMENT OF NEW FURNITURE ITEMS	
Technical Specification	Sourcing of legal timber
Technical Specification	Formaldehyde emissions from wood-based panels
Technical Specification	REACH Candidate List substance reporting

[340] Horn et al. (2023): Promoting ecodesign implementation: The role and development areas of national policy.
[341] Horn et al. (2023): Promoting ecodesign implementation: The role and development areas of national policy.
[342] EEB (2017): Circular economy opportunities in the furniture sector.
[343] EC (2018b): EU Green Public Procurement criteria for Furniture.
[344] EP (2017): Green Public Procurement and the EU Action Plan for the Circular Economy.
[345] EC (2018b): EU Green Public Procurement criteria for Furniture.

Technical Specification	Blowing agents
Technical Specification	Fitness for use
Technical Specification	Design for disassembly and repair
Technical Specification	Product warranty and spare parts
Award Criteria	Formaldehyde emissions rates that comply with 65% of the E1 threshold limits
Award Criteria	Plastic marking
Award Criteria	Extended warranty periods
PROCUREMENT OF FURNITURE END-OF-LIFE SERVICES	
Technical Specification	Collection and reuse of existing furniture stock
Award Criteria	Improvement in the re-use targets

TABLE NO 04 CORE GPP CRITERIA FOR FURNITURE

All core criteria seen above are categorised as 'same for core and comprehensive', meaning that the standards are identical for both levels of ambition, with some requirements differentiating in verifying the requirements. Besides the requirements stated above, the current comprehensive standards for furniture are as follows[346]:

PROCUREMENT OF FURNITURE REFURBISHMENT SERVICES FOR EXISTING FURNITURE	
Award Criteria	Low chemical residue upholstery coverings
Award Criteria	Low chemical residue padding materials
Award Criteria	Low emission padding materials - Low emission latex padding materials - Low emission polyurethane foam padding materials - Other low emission foam padding materials
PROCUREMENT OF NEW FURNITURE ITEMS	
Technical Specification	Coating mixture restrictions
Technical Specification	Restrictions for metals
Technical Specification	REACH Candidate List substance restrictions
Technical Specification	Durable upholstery coverings
Award Criteria	Low chemical residue upholstery coverings
Award Criteria	Low VOC emission furniture
Award Criteria	Low chemical residue padding materials
Award Criteria	Low emission padding materials - Low emission latex foam padding materials - Low emission polyurethane foam padding materials - Other low emission foam padding materials

TABLE NO 05 COMPREHENSIVE GPP CRITERIA FOR FURNITURE

As seen with the GPP criteria, setting standards for a service instead of an actual product is possible. For example, an office company typically needs each employee's desk and chair. Instead of buying these products, the company may lease such a service for five years. This may result in more flexibility for the office company because of less up-front investments while simultaneously providing incitements for the leasing company to provide durable and material-efficient products: Since the company has a stable income through the lease, they no longer need to maximise sales of new products, through fast fashion initiatives or programmed obsolescence etc. And the longer the products last, the longer they can provide the service without making further investments.

EEB describes how new furniture can often be brought as cheaply as refurbished ones and that the new products usually will have a more extended warranty. This weakens the economic incentives

[346] EC (2018b): EU Green Public Procurement criteria for Furniture.

to buy refurbished or repaired furniture, restricting the growth of a material-efficient furniture sector[347].

Financial incentives targeting different areas of the supply chain can be used to promote material efficiency within the furniture. Producers and manufacturers can be targeted through tax reductions if the furniture they produce is designed for repair or recycling or when it comprises a specific part of reused or recycled materials. Tax breaks can be introduced to promote the reparation and refurbishment of furniture and purchase products manufactured from reused or recycled materials. According to EEB, strong arguments suggest that reducing relevant taxes can encourage key actors to consider more sustainable product procurement options, making a market of repaired and remanufactured furniture more prominent[348].

Several studies have shown that, in general, the effectiveness of reduced VAT rates in promoting social and environmental objectives depends on the pass-through and price elasticity of demand for the goods or services subject to the reduced VAT rate. The European Parliamentary Research Service argues that the effectiveness of a reduced VAT rate for environmentally friendly products depends on the extent to which consumers are willing to switch from non-sustainable to sustainable products in response to price changes. However, implementing reduced VAT rates for environmental purposes is limited, so empirical evidence of the effects of reduced VAT rates is scarce[349].

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Ireland has, in connection with the Irish Government's policy of decentralisation of Government Departments, introduced several new offices outside Dublin. This significantly increased public sector furniture procurement under the Furniture Division of the Office of Public Works (OPW). The OPW has had an increased focus on the sustainability of its furniture, ensuring that all products purchased conform to all EU and international environmental standards and directives. The OPW has commissioned an independent accredited test consultancy to perform environmental impact assessments on its furniture specification, resulting in additional points for contractors demonstrating that their goods and processes are environmentally preferable. Contractors are now required to demonstrate compliance with OPW's timber sustainability requirements, hereunder that all wood used must come from legal and sustainable sources[350]. Under Contract Performance Clauses, contractors must employ sound environmental practices on site concerning:

- Waste reduction;
- Waste recovery;
- Minimisation of packaging;
- Use of recoverable packaging materials;
- Control of environmental emissions; and
- Efficient use of materials and transport[351].

The Furniture Division has not experienced an increase in costs as a result of its sustainability-oriented GPP policies. Costs were reduced for the procurement done under the Furniture Division

[347] EEB (2017): Circular Economy Opportunities in the Furniture Sector.
[348] EEB (2017): Circular Economy Opportunities in the Furniture Sector.
[349] EP (2021): VAT gap, reduced VAT rates and their impacts on compliance costs for businesses and consumers.
[350] EC (n.d.n): Ireland Makes Sustainable Furniture Purchasing Work – GPP in practice.
[351] EC (n.d.n): Ireland Makes Sustainable Furniture Purchasing Work – GPP in practice.

and for suppliers. The suppliers have, overall, reacted well to the 'carrot rather than stick' approach, as specific proposals seeking ways in which the environmental impacts of furniture supply can be reduced have been encouraged progressively. Today, the OPW accepts several existing commercial certification systems for verification of purposes, hereunder Canadian Standards Association (CSA), FSC, Programme for Endorsement of Forest Certification (PEFC), and the Sustainable Forestry Initiative (SFI)[352].

In **France**, as with textiles, furniture that has reached its end-of-life stage is managed under the same Extended Producer Responsibility (EPR) regulation in France[353]. The furniture waste scheme was a part of the latest generation of schemes (2012) under the French EPR regulation. The scheme covers both household and professional furniture waste, and behind the scheme is the intention to generate over 300 million Euros per year that should be allocated to help develop furniture reuse and recycling, help create jobs and industrial structure activities around furniture waste management[354]. As with the regulation of the French textile industry, actors in the furniture industry receive bonuses or penalties following compliance with environmental performance criteria[355,356]. In 2013, 80M € was collected from furniture producers, retailers and importers through levies to finance the domestic scheme and cover the cost of collection, logistics, infrastructure and R&D into new markets. By 2015, 850 thousand tonnes of domestic furniture were collected, achieving an 86% recovery rate and a 55% recycling rate[357]. By 2016, the French EPR scheme initiated the support of eco-design furniture by creating Eco Modulation Criteria and rewarding new furniture manufacturers that met these criteria with a 20% fee reduction[358]. The requirements have been kept simple to ensure that the implementation did not become burdensome to administrators. By 2017, France exceeded its goal of 45%[359] of the EPR regulation, with 80% of waste furniture reused or recycled[360].

Italy introduced new public procurement minimum environmental criteria in 2022 for the supply, rental service, and service for extending the useful life of interior furnishings, published under Official Gazette No. 184[361]. The minimum environmental criteria are an annex to the Ministerial Decree of June 23, 2022, No. 254, whereunder the new criteria replace those in force since 2017. The new criteria for interior furnishing regulate the following:

- Supply of new interior furnishings;
- Rental service for interior furnishings;
- Service for extending the useful life of interior furniture or repairing and reusing furniture that allows extended lifespan[362].

[352] EC (n.d.n): Ireland Makes Sustainable Furniture Purchasing Work – GPP in practice.
[353] EEB (2017): Circular Economy Opportunities in the Furniture Sector.
[354] The French Ministry of Environment (2014): 20 years of EPR in France: achievements, lessons learned and challenges ahead.
[355] The French Republic (n.d.): Code de l'environnemente.
[356] EEB (2017): Circular Economy Opportunities in the Furniture Sector.
[357] EEB (2017): Circular Economy Opportunities in the Furniture Sector.
[358] EEB (2017): Circular Economy Opportunities in the Furniture Sector.
[359] EEB (2017): Circular Economy Opportunities in the Furniture Sector.
[360] Veolia (n.d.): 400,000 metric tons of urban furniture recovered and recycled.
[361] Gazzetta Ufficiale (2022): Gazzetta Ufficiale della Repubblica Italiana.
[362] UL Solutions (2022): New CAM (Minimal Environmental Criteria) Interior Furniture – Regulatory update.

The new minimum environmental criteria promote eco-design of furniture using renewable or recycled materials, modularity enabling partial replacement, and a Nondestructive disassembly allowing recovery of parts to be used as spare parts or recycling of materials[363].

In **Portugal**, public furniture procurement is regulated under the framework agreements signed by the Government Shared Service Entity (ESPAP), which has applied the National Strategy for Ecological Procurement criteria, ENCPE 2020[364]. Circular Public Procurement (CPP) is one of the critical priorities of the National Action Plan for a Circular Economy in Portugal, showing high governance level interest and ongoing efforts from the central purchasing organisations to develop a framework and criteria that promote ambitious circularity. With CPP as an emerging field, the comparability between GPP and SPP (Sustainable Public Procurement) is still discussed in academics[365]. While there is an awareness of the concept of CE among stakeholders in Public Sector Organisations (PSOs), public procurers of PSOs are expressing constraints in choosing from environmental or sustainable criteria predefined by the Portuguese Central Public Administration (PCPA). This illustrates that innovation in Portuguese public procurement towards circularity and the diffusion of CPP in PSOs are impacted by top-down dynamics and leadership styles. As a result, high energy efficiency is the main selection criteria utilised by procurers in PSOs (approximately 56% address energy efficiency as the determining selection criterion), while procurement practices supporting material efficiency, such as procurement of reused and remanufactured products, are only prioritised as the determining selection criterion in approximately 36% and 22% of procurement cases. Further, there is an understanding among public procurers in PSOs that second-hand purchasing is not possible nor undertaken yet in the PCPA. However, this contradicts the procurement of reused and remanufactured products, illustrating that the criterion for reused and remanufactured products is promoted for PSOs but is not as widely used in practice as other criteria[366].

4.4 Summary

This chapter accounts for the current state of play for the construction, textile, and furniture sectors, including best practices and examples of certification schemes and policies.

Relevant to the Construction sector, the European Construction Product Regulation (CPR) sets harmonised standards for manufacturing and marketing building materials in the EU. Furthermore, the European Commission has introduced the non-voluntary framework, Level(s), as an alternative to private certification schemes. Level(s) provides a new approach to assess and report on the sustainable performance of buildings based on existing standards. Of private certification schemes, DGNB, BREEAM, and LEED are highlighted. Among others, the legislative setup in Finland has been highlighted due to the national material efficiency program, which is a strategy dedicated specifically to material efficiency. Here, eight measures were proposed, including creating a consortium within resource efficiency to allocate EU LIFE funding to material efficiency projects.

Regarding the textile sector, the European Commission has acknowledged textiles as a priority product category for Circular Economy. However, the EU currently does not cover specific policies

[363] UL Solutions (2022): New CAM (Minimal Environmental Criteria) Interior Furniture – Regulatory update.
[364] APA (2019): ENCPE 2020.
[365] Klein et al. (2022): A survey of Circular Economy initiatives in Portuguese central public sector organisations: National outlook for implementation.
[366] Klein et al. (2022): A survey of Circular Economy initiatives in Portuguese central public sector organisations: National outlook for implementation.

for the industry. Textiles are expected to be included in the New Sustainable Product Framework to achieve a better regulatory environment for sustainable and circular textiles in the EU. Furthermore, the European Commission is currently assessing the feasibility of widening the scope of the Eco-design directive to cover more categories, such as textiles. The EU Ecolabel, Nordic Swan Ecolabel, Blue Angel, OEKO-TEX, GRS and Bra Miljöval are highlighted private certification schemes. Among others, the legislative setup in France has been highlighted due to the successful implementation of EPR regulation. The textile industry actors of France receive bonuses or penalties for their compliance with the criteria, which include the quantity of material used, the incorporation of recycled material, possibilities to repair and reuse, recyclability etc.

Like the textile sector, the European Commission has acknowledged furniture as a priority product category for CE but does not cover industry-specific policies. However, the EU has established many GPP criteria relevant to the furniture sector that member states can apply voluntarily. Furthermore, the European Commission is currently assessing the feasibility of widening the scope of the Eco-design directive to cover more categories, such as furniture. As with textiles, the European Commission also evaluates the feasibility of including furniture in the Eco-design directive. The EU Ecolabel, the Nordic Swan Ecolabel, TOC and Möbelfakta have been highlighted in private certification schemes. Among others, the legislative setup of Sweden has been highlighted due to criteria for sustainable Public Procurement of furniture. This legislative setup ensures that organisations within the Swedish public sector drive development to a more sustainable furniture sector by demanding socially and environmentally sustainable products and services.

5 Barriers and enablers for Portuguese material efficiency

Before strategy recommendations can be developed to improve material efficiency in the selected Portuguese sectors, it is crucial to identify the challenges the policy initiatives seek to address. The following section will utilise the PESTEL analysis is presented to systematically analyse Political, Economic, Social, Technological, Environmental and Legal factors that impact the uptake of material efficiency in Portugal. However, due to the available data and the scope of the project, a limited version (PEST) will be utilised. The environmental and legal aspects of the PESTEL analysis will be included where possible. While a PEST analysis is commonly used to assess all positive and negative factors that have an impact, we focus on those that might provide barriers to material efficiency since drivers and best-practice examples are covered in detail in section 4 of this report. The analysis includes general findings on barriers to material efficiency, as well as country-specific barriers for Portugal whenever available. The barriers have been identified through a literature review and consultation with Portuguese industry stakeholders.

5.1.1 Political barriers & enablers to material efficiency improvements

Public authorities are vital in providing the regulatory framework and setting incentives to increase material efficiency in different policy areas such as energy, waste and industry[367]. This includes regulation in productive industries, as well as increasing the material efficiency of existing goods, such as extending the life of buildings[368]. General Portuguese barriers to CE implementations related to material efficiency include regulatory-related bureaucracy and associated costs and delays of action; Improvement of the capacity of the states and agencies to address innovation;

[367] EPRS (2018): Material use in the European Union – Towards a circular approach.
[368] IRP (2020). Resource Efficiency and Climate Change: Material Efficiency Strategies for a Low-Carbun Future.

uncoordinated decisions and lack of common ground between CE policies; collaboration between companies; citizen participation; competencies of actors of state bodies responsible for developing and implementing policies; application of fiscal instrument increasing the competitiveness of circular business models[369].

In the Portuguese regulatory framework, material efficiency is mentioned in the Green Growth Commitment, but the current legislative system does not require industries to increase their material efficiency[370]. This means there is no standard or monitoring system to measure progress towards material efficiency. Across all sectors investigated in this project, there is a general understanding that the Portuguese Ministries are working towards CE through the implementation of legislation and action plans. However, the industry actors perceive the legislative and regulatory efforts towards CE as uncoordinated and unbacked by the Central Government of Portugal[371]. While the PSOs illustrate an understanding of CE[372], the private sector representatives worry that they will have the entire burden of implementing CE efforts[373], illustrating the need for increased dissemination and detailed guidance for the economic sectors of Portugal.

For the **construction sector**, general targets for recycling and recovery of raw materials exist; however, these targets include, e.g. options for backfilling demolition waste. Similarly, public procurement criteria for construction require 10% of recycled materials. However, price still counts for 60-70% of the procurement criteria, indicating that economic factors outweigh environmental considerations and that circularity needs to be incorporated further[374]. Industry representatives from the Portuguese construction sector have expressed that the main barriers to improved material efficiency in a regulatory context are:

- Absence of construction-specific action plans;
- Lack of publicly available monitoring methodology for material efficiency;
- Low inclusion of industries in environmental legislative development;
- Incoherence in waste management plans and public procurement criteria for reused and recycled materials;
- Low focus on industrial symbiosis in CE action plans;
- Complexity and ambiguity of legislative framework;
- Dilatory processes of licensing;
- Excessive requirements for licensing from different governmental bodies;
- Rigid waste classification systems[375].

Most of the barriers identified refer to incoherence or challenges with understanding the connections between legislative requirements in the regulatory framework. The interviewed stakeholders express a desire to be more involved in the policy development processes, which could be facilitated through increased public-private partnerships (Cf. section 3.6) or strengthening the focus on and the accessibility of the already existing partnerships. The disorientation about the regulatory framework indicates that it could be beneficial for increased compliance and inclinations

[369] EEA (2022): Circular economy country profile – Portugal.
[370] Some legislative acts indirectly address material efficiency, which is extensively elaborated in Project 1.
[371] Multiple interview findings, cross-sectorial.
[372] Klein et al. (2022): A survey of Circular Economy initiatives in Portuguese central public sector organisations: National outlook for implementation.
[373] Multiple interview findings, cross-sectorial.
[374] Bauer & Egebæk (2019) The Current and Future use of Secondary Raw Materials in Portugal.
[375] Findings from interviews with Portuguese construction industry actors.

to improved business practices. The regulatory framework, both for CE and resources efficiency, was streamlined, ensuring effective governance for resource efficiency of the Portuguese construction sector (Cf. section 3.6). The industry actors further request concrete actions towards industrial symbiosis and publicly available monitoring methodology to transition towards CE and material efficiency. The current regulatory setup and approach are creating uncertainty for them on how to move forward and what to prioritise[376].

Legislative challenges are experienced in the Portuguese adaptation of the ever-changing EU legislation for the **textile sector**. One of the major legislative obstacles is related to the uptake of SRM and by-products from internal and external processes. There are currently limits to the inclusion of industrial waste, such as off-cuts from licensed firms, in the production processes. This hinders a realised closed material loop, as manufacturing companies cannot simply use their production waste unless it is declared 'sub-products' or 'intermediate products'[377]. Industry representatives from the Portuguese textile sector have expressed that the main barriers to improved material efficiency in a regulatory context are:

- Low inclusion of industries in environmental legislative development;
- Incoherence in waste management plans and public procurement criteria for reused and recycled materials;
- Inadequate CE objectives and goals;
- Dissonance between CE objectives and goals and the achievement of these;
- Lack of regulatory intervention on international companies for Ecodesign;
- Low focus on industrial symbiosis in CE action plans[378].

There are many overlaps of the regulatory barriers experienced by the construction and textile industry stakeholders. The desire to be more involved in the policy development processes and the disorientation about the regulatory framework could, in the same manner as the construction stakeholders, benefit from increased or strengthened public-private partnerships, a streamlining of CE and resource efficiency policies, and actions towards industrial symbiosis (Cf. section 3.6). Particularly for the regulatory barriers identified for the textile industry stakeholders are the challenges faced by competition with international companies. There is an understanding that competition distorts requirements for Ecodesign, which might be the case with some international companies. However, with most European-based international companies, the requirements for Ecodesign will be similar to those in Portugal. Investigation of equal competitive ground and communication of these efforts could assure the Portuguese companies on this topic.

For the **furniture sector**, regulatory barriers specific to the foresting industries have been discussed extensively due to the large wood material input in the industry. Forest is a recently approved Portuguese Recovery and Resilience Plan (RRP) topic. Derived from this, the unclarity of the regulatory framework for the foresting industries can be expected to be resolved through the dissemination effort of the RRP. Industry representatives from the Portuguese furniture sector have expressed that the main barriers to improved material efficiency in a regulatory context are:

- Complexity and ambiguity of legislative framework;
- Low efficiency of legislation due to perceived lack of inclusion of industry actors;

[376] Associação Smart Waste Portugal (2021): Circular Buildings – Guideline for creating Circular Material Passports.
[377] Isaac (2018): Restitching the Common Thread – The Potential of Closed Loop Recycling in the Textile and Clothing Industry for Regional and Entrepreneurial Resilience in Northern Portugal.
[378] Findings from interviews with Portuguese textile industry actors.

- Unclear governmental responsibilities of efficient use of wood and material sourcing;
- Low coherence between legislative targets and the state of play[379].

Barriers identified across the three Portuguese economic sectors show strong indications that the Portuguese industry actors could benefit from increased or strengthened public-private partnerships and a streamlining of CE and resource efficiency policies (Cf. section 3.6). There seems to be e general confusion about the regulatory setup of CE actions and material efficiency efforts, challenging efficient implementation and compliance with the current legislation. Transparent dissemination to industry actors on governmental responsibilities and which agencies are responsible for what could enable industry actors to address the proper authorities in doubt of their legislative duties, reducing the confusion of the regulatory framework.

5.1.2 Economic barriers to material efficiency improvements

While rising costs of raw materials increasingly provide financial incentives for material efficiency, companies continue to face economic barriers which can prevent them from adopting circular production methods and investing in material efficiency. Despite rising prices for raw materials due to delivery shortages, recycled materials remain higher in price in most cases because market prices do not reflect most negative externalities on the environment. In Portugal, there are indications that market prices do not capture costs from waste production sufficiently, as EPR schemes are still being implemented in some sectors and due to the high utilisation of landfilling[380]. At the same time, virgin materials are still cheaper than labour in Europe, meaning that reducing material input and waste production is not (yet) incentivised by market mechanisms alone, and users/customers are often unwilling to pay the extra cost[381]. Even though consumers tend to have a positive attitude towards products made from recycled materials, they are often reluctant to buy them due to perceived barriers. Products made from recycled materials can be perceived as products of lower quality, associated with a higher risk of low performance, and hence doubts whether a product is worth the money[382]. This further challenge the industrial uptake of SRMs and by-products for the three economic sectors accessed.

As illustrated in the Flash Eurobarometer from 2018, most Portuguese SMEs that have invested in material efficiency also report decreased production costs, reaping economic benefits from their investments. However, knowledge of the environmental, economic and social benefits of adopting material efficiency measures is still limited and continues to be a barrier[383]. This is also the case within public institutions in Portugal, where there is not yet a broad sense understanding of what actions support the circular economy development most efficiently, making it difficult to develop a deeper understanding of more specific concepts such as material efficiency[384]. Therefore, the economic benefits of improved material efficiency are not fully achieved.

There is a shortage of high-quality SRMs and by-products for the **construction sector** because waste regulation is not adequately enforced, and waste is sometimes dumped illegally in nature, as documented for CDW[385]. This indicates that SRMs and by-products are not considered a

[379] Findings from interviews with Portuguese furniture industry actors.
[380] EC (n.d.o): Portugal.
[381] Santos et al. (2019): Social life cycle analysis as a tool for sustainable management of illegal waste dumping in municipal services.
[382] Polyportis et al. (2022): Consumer acceptance of products made from recycled materials: A scoping review.
[383] Associação Smart Waste Portugal (2021): Circular Buildings – Guideline for creating Circular Material Passports.
[384] Findings from interview with governmental representative.
[385] Santos et al. (2019): Social life cycle analysis as a tool for sustainable management of illegal waste dumping in municipal services.

resource, hindering a market for these products. Industry representatives from the Portuguese construction sector have expressed that the main barriers to improved material efficiency in an economic context are:

- Low valorisation or monetary benefits of utilising by-products and SRM;
- Low awareness of financing opportunities;
- Low market readiness for reused and recycled materials;
- Low incentive through taxation frameworks or VAT;
- Poor infrastructure for recycling and reuse;
- Inadequate inspection rates and monitoring;
- Low incitement to implement CE practices;
- Low consumer incentive to pay increased prices for sustainable goods and services;
- Inefficient incentive structures for circular design[386].

The economic barriers to the construction sector for improved material efficiency refer to two major themes: the availability of circular material input and the incentive to introduce circular practices in the production and construction. To increase the valorisation of SRMs and by-products, an efficient and accessible market must be available to the industry actors. Waste management regulation can increase the accessibility of non-virgin materials and will, in the long term, affect the cost-effectiveness of including circular materials in the production process. Concrete instruments to include the regulatory framework for waste management include landfill and incineration taxes and deposit refund schemes. Robust instruments to facilitate the increased uptake of SRMs and by-products include (enforced) GPP requirements, promoting investments in resource-efficient infrastructure, and support for developing industrial symbiosis (Cf. section 3.6). Economic instruments to increase the incentive to implement circular practices includes taxes on virgin materials, tax breaks, and grants for eco-labelling (Cf. section 3.6).

The **textile sector** in Portugal has a strong international reputation, but a large amount of SMEs in the sector means an overloaded domestic market. Differentiation from the construction sector, there is a need for increased internationalisation. Internationalisation can be achieved by supporting the sector in overcoming economic barriers to material efficiency, adding to the good reputation and, thereby, the international competitiveness of the Portuguese textile sector. Industry representatives from the Portuguese textile sector have expressed that the main barriers to improved material efficiency in an economic context are:

- Low awareness of financing opportunities;
- Low incentive through taxation frameworks or VAT;
- High expenses of recycling, it is cheaper to landfill waste materials;
- High internal competitiveness;
- Low willingness to take risks among public entities;
- Problem avoidance among public entities;
- Inadequate inspection rates and monitoring, potential unfair competition;
- Poor infrastructure for recycling and reuse;
- Inadequate monitoring of SMEs;

[386] Findings from interviews with Portuguese construction industry actors.

- Low incitement to implement CE practices;
- Inefficient incentive structures for CE practices[387].

Similar to the economic barriers for the construction sector, there is a perceived low incentive for CE practices and challenges with the availability of SRMs and by-products of high quality. Therefore, the Portuguese textile sector could also benefit from implementing landfill and incineration taxes, deposit refund schemes, (enforced) GPP requirements, support for developing industrial symbiosis, taxes on virgin materials, tax breaks, promoting investments in resource-efficient infrastructure, and grants for eco-labelling (Cf. section 3.6). Further, the consulted textile sector stakeholders, and to a lesser extent, the construction sector stakeholders, expresses a perception that inceptions are not systematic and equalised, creating potential competitive distortions. An increased focus on performance standards (Cf. section 3.6) and particular dissemination of inspection practices, ensuring industry stakeholders of equal treatment.

For the **furniture sector**, very few economic barriers were identified. The furniture sector stakeholders seem to be most affected by monitoring efforts, illustrated by the industry by the main barriers experienced to improved material efficiency in an economic context, which are:

- Low monitoring efforts by governmental entities in material extraction processes;
- Inadequate inspection rates and monitoring[388].

To accommodate the barriers related to monitoring the material extraction and furniture production processes, increased implementation of standards, such as LCA-based standards, standards for durability, performance standards, and standards for recycled materials (Cf. section 3.6), could be beneficial for both steps in the value chain. Increased dissemination of monitoring and inspection efforts could reassure furniture sector actors that the examination efforts are equally distributed and therefore do not have a competition-distorting effect.

5.1.3 Social barriers to improved material efficiency

Portuguese companies generally have a relatively low level of labour productivity compared to other OECD countries. Labour productivity is particularly low in the manufacturing sector and within micro-firms, which only achieve ca. 25% of labour productivity compared with OECD benchmark countries. Portuguese start-ups tend to grow slower compared to other OECD countries[389]. Since most employment in Portugal is concentrated in SMEs, low labour productivity might negatively influence the Portuguese economy's wider resource- and material efficiency. While the relationship between labour productivity and resource efficiency depends on the specific context and sector, it has been found that low labour productivity might lead to increased waste due to errors of workers and inefficient work processes, reduced innovation due to a lack of resources for research and development, and reduced investment in sustainable practices due to a focus on short-term problems instead of long-term development[390,391]. The challenges with labour productivity are also related to the perceived low coordination between public and private actors, as the economic sectors do not experience the needed support to increase efficiency in multiple parameters. While there are many ideas and initiatives to increase circularity, there is not enough cohesion between them, and they lack a shared perspective on the overall direction. The

[387] Findings from interviews with Portuguese textile industry actors.
[388] Findings from interviews with Portuguese furniture industry actors.
[389] OECD (2019): Insights on Productivity and Business Dynamics – Portugal: Productivity.
[390] EEA (2019b): Resource efficiency and the circular economy in Europe 2019 – even more from less
[391] OECD (2020): Labour market consequences of a transition to a circular economy: A review paper – environment working paper N°162.

targets developed by the public authorities are considered unrealistic by industry actors, who do not feel prepared to reach them[392]. This aligns with the overall criticism of cross-sectorial business organisations that the Portuguese government does not integrate companies well when formulating new environmental legislation, resulting in implementation problems[393].

The **construction sector** experience challenges with a low social acceptance of recycled materials, also identified as a barrier to circularity in general to the Portuguese construction sector in Circularidade na Construção[394]. This is a general challenge for the construction sector across Europe, mainly due to concerns about safety and human health. However, the most prominent barriers identified through consultations with Portuguese construction stakeholders are related to the dissemination efforts of governmental entities. Industry representatives from the Portuguese construction sector have expressed that the main barriers to improved material efficiency in a social context are:

- Inadequate guidance for complying with environmental legislation;
- Time-consuming bureaucratic processes;
- Inefficient communication between governmental bodies with overlapping responsibilities;
- Low facilitation of innovation in public procurement;
- Perceived low enthusiasm for CE practices at a governance level;
- Conservatism in the sector, hindering CE innovation;
- Inadequate education on material efficiency and recycling methods among contractors;
- Poor barrier mediation between industry actors and governmental bodies;
- Low perceived strategic ownership from Governmental entities;
- Dilatory dissemination of development pathways for action plans;
- Low or inadequate dissemination of best practices;
- Unclear timelines for CE improvement activities[395].

There is a general perception among the construction industry stakeholders that there is poor communication between governmental bodies responsible for CE action plans and legislation, resulting in the understanding that there is a lack of ownership of CE strategies. This leads to an understanding that the actions taken towards CE are not a priority in Portugal, strengthening conservative, linear approaches in the industry. A combination of soft and hard policy instruments could be beneficial to increase the understanding of urgency and prioritisation among governmental bodies. Relevant instruments include coordinated information schemes (good practice dissemination and advisory services for SMEs), strengthening policy development and evaluation through better data and analysis, (enforced) GPP, Bans & restrictions (product restrictions, restrictions on mining of certain materials, restrictions on landfill) and increased EPR scheme implementation (Cf. section 3.6).

For the **textile sector**, many of the same challenges to the construction sector apply in regard to the perceived dissemination and governmental ownership of CE efforts and action plans. While dissemination of best practices is perceived as plentiful among textile sector stakeholders, industry actors have expressed that they appear uncoordinated and inapplicable to the Portuguese textile

[392] Findings from an interview with a national governmental entity
[393] Findings from interview with cross-sectorial business associations
[394] Builtcolab (n.d.b): Circularidade na Construção.
[395] Findings from interviews with Portuguese construction industry actors.

industry. The following barriers were identified as the main barriers to improved material efficiency in a social context among industry representatives from the Portuguese textile sector:

- Governmental entities facilitate many CE dissemination forums, but they have low applicability;
- Time-consuming bureaucratic processes;
- Low coordination between governmental entities;
- Consumer pressure is only disseminated to distributors and not producers;
- Poor barrier mediation between industry actors and governmental bodies;
- Inadequate guidance for complying with environmental legislation;
- Inadequate dissemination of CE principles;
- Unclear timelines for CE improvement activities;
- Low dissemination of waste management practices to citizens;
- Low dissemination of targets to industry actors[396].

In addition to the challenges and options addressed for the construction sector, which also apply to the textile sector in improving material efficiency, consulted stakeholders of the textile industry also expressed challenges with disseminating CE activities to citizens. To increase the understanding of the citizens' role in increasing material efficiency for the textile industry, informational campaigns, modulated product taxes, and support for labelling and certification schemes could assist the industry in improvements to the material efficiency of their value chains (Cf. section 3.6). A unique barrier for the textile industry identified in the investigation is the perception of low dissemination of targets to industry actors. Dissemination efforts must be increased to ensure proper legislative compliance. The increased dissemination efforts could be facilitated through already established public-private partnerships for the sector (Cf. section 3.6).

For the **furniture sector**, some of the challenges identified for the construction and textile sectors are also perceived as prominent. This mostly regards the dissemination of CE activities and strategies and the perceived lack of ownership of CE strategies for essential input materials for the industry. Industry representatives from the Portuguese furniture sector have expressed that the main barriers to improved material efficiency in a social context are:

- Governmental entities facilitate many CE dissemination forums, but they have low applicability;
- Low perceived strategic ownership from Governmental entities on essential materials such as wood;
- Low perceived ownership of CE tasks and actions among public actors;
- Low understanding from public entities on the challenges of industry actors;
- Challenged communication with some governmental agencies;
- Unclear timelines for CE improvement activities;
- CE action plan is perceived more as a CE knowledge dissemination report rather than a regulatory framework;
- Dilatory dissemination of development pathways for action plans;

[396] Findings from interviews with Portuguese textile industry actors.

- Perceived low enthusiasm for CE practices at a governance level[397].

Similar to the industry stakeholders of the textile industry, the furniture industry stakeholders experience high availability of best practice examples. However, the best practices disseminated are not perceived as applicable to the Portuguese industry. The furniture industry stakeholders experience challenges in communication with governmental entities and public authorities, indicating that there is a need for improvements in the public-private partnerships for the furniture sector. Informational schemes provided information on the proper communication challenges, and relevant governmental entities could further facilitate a decrease in the perceived communication barrier. Additionally, advisory services for SMEs with limited resources to seek out information could be beneficial for the improvement of material efficiency efforts of the furniture sector (Cf. section 3.6).

5.1.4 Technical barriers to improved material efficiency

The technology gap of Portugal, compared with other EU Member States, can pose a challenge for improving material efficiency[398] across the three economic sectors. While increased efforts have been made to close the technology gap, the uptake of new technologies and materials is often perceived as a risk by stakeholders. In the construction sector, for example, niche solutions are perceived as an economic or safety risk rather than an opportunity to enhance the environmental impact. Therefore, actors prefer to comply with minimum standards, especially in sectors where investments are high, and errors may lead to increased economic losses and potential lawsuits. This is particularly the case when there is a lack of best practices and pilot projects demonstrating the feasibility of implementing alternative materials or production processes.
Consequently, companies balance the expected environmental, social, and economic outcomes and often prioritise short-term benefits over long-term planning[399]. This may lead to missed opportunities for innovation and product improvements, lower competitiveness, and more negative environmental and health impacts. In this context, the challenged communication with institutions or regulatory authorities can hinder innovation if companies hesitate to seek advice from inspectors and consult them on implementing new processes or using new materials. The approximated avoidance behaviour may also hinder the registration of mistakes. In the short run, this might benefit the companies, as undetected, e.g. waste production, is not a major challenge with current monitoring and inspection rates. However, in the long run, it will likely cause negative economic (both on a business and a market level), health and environmental effects.

For the **construction sector**, one of the major technical setbacks for improvements in material efficiency is the implementation of Building Information Modeling (BIM), where Portugal lacks behind other countries due to a lack of support from the central government. The Technical Committee for BIM Standardization was created to develop standardisation procedures across all stages of construction processes, inter alia, to improve the selection of construction materials to reduce waste with the help of digital tools. While the existing Portuguese public procurement process is split across different steps, implementing alternative solutions requires a more holistic and cooperative approach so that contractors invest in innovative production materials and processes[400]. While BIM is not required in Portuguese construction practices, LNEC, Instituto Técnico Universitário de Lisboa, and Universidade do Minho are working on introducing the

[397] Findings from interviews with Portuguese furniture industry actors.
[398] Bianchi (2020): Monitoring domestic material consumption at subnational level – enabling the territorial perspective.
[399] Adams et al. (2017): Circular economy in construction: current awareness, challenges and enablers.
[400] EC (2020d): ECSO Country Factsheet Portugal.

standard with the Portuguese context in mind[401]. Industry representatives from the Portuguese construction sector have expressed that the main barriers to improved material efficiency in a technical context are:

- Few alternatives to landfill at EoL of products;
- Low dissemination of indicators;
- Low availability of industry data for benchmarking;
- Low efforts to increase modular construction[402].

The construction sector stakeholders address that there are still very few alternatives to landfill at the EoL of construction materials. While this challenge is reinforced by the political, economic, and social barriers identified for improved material efficiency for the construction sector, enforcement of the waste hierarchy through infrastructural improvements, increased on-site inspections and monitoring efforts. Increased dissemination of indicators for material efficiency are essential to reduce the perception that landfill is the only option. Further, monitoring efforts by public authorities, either by investigating the validity of self-reporting or by increasing on-site inspections, could facilitate the data collection of waste management practices. This data could be utilised to overcome the barrier of the low availability of industry data for benchmarking (Cf. section 3.6).

For the **textile sector**, there are similar challenges to the construction sector in regard to industry data for benchmarking and the dissemination of indicators. Unlike the construction sector stakeholders, the textile sector stakeholders emphasised challenges with public procurement processes, despite the swift transition of production during the COVID-19 outbreak, where the Portuguese textile sector supplied the public sector with urgently needed equipment[403]. Industry representatives from the Portuguese textile sector have expressed that the main barriers to improved material efficiency in a technical context are:

- Low understanding of sustainable materials and products in public procurement;
- The mindset of public procurers is too 'business as usual;
- Profitability is a higher priority than material efficiency;
- Low facilitation of innovation in public procurement;
- Perceived unavailability of technology;
- Lack of comparative overview of available technology and BAT;
- Low availability of industry data for benchmarking;
- Low dissemination of indicators;
- Few alternatives to landfill at EoL of products[404].

A significant challenge for improved material efficiency in the Portuguese textile sector is the perception that new technology is unavailable. Over the past years, the Best Available Technology (BAT) for the textile industry has significantly improved options to include SRMs and by-products. However, this can explain the need for a comparative overview of available technology; efforts to provide this to the industry stakeholders are already in progress[405]. Public procurement and the perception that the low facilitation of innovation and a business-as-usual approach in the context of material efficiency could be due to the need for increased education of public procures. CE and

[401] Findings from interviews with Portuguese construction industry actors.
[402] Findings from interviews with Portuguese construction industry actors.
[403] ISPO (2020): Portugal's Textile Industry Supports Fight Against Coronavirus.
[404] Findings from interviews with Portuguese textile industry actors.
[405] Findings from interviews with Portuguese textile industry associations.

material efficiency can be challenging to keep an overview of. Therefore, clear guidance material and prioritisation of procurement criteria are needed (Cf. section 3.6). Based on the perception of the textile industry stakeholders, guidance and clearer criteria for textile procurement could assist in the improvement of the material efficiency of the sector.

Only one barrier to improved material efficiency in a technical context was identified for the **furniture sector**. This barrier referred to the perception of low dissemination of indicators and benchmarks[406]. This barrier has been expressed across all investigated sectors, indicating a general challenge in communicating indicators and benchmarks. While the challenge is that indicators and benchmarks are disseminated, the communicative approach does not reach the relevant stakeholder efficiently. An increased focus on the communicative efforts of private-public partnerships, ensuring specialised dissemination of indicators and benchmarks, can decrease the perceived barrier (Cf. section 3.6).

5.2 Summary

The consulted stakeholders from the three Portuguese economic sectors have extensive overlaps in the perceived barriers to material efficiency improvements. Many barriers are related to regulatory and legislative dissemination and the interaction with governmental entities. There seems to be e general confusion about the regulatory setup of CE actions and material efficiency efforts, challenging efficient implementation and compliance with the current legislation. Priorities, targets and activities of CE action plans are often unclear for the sector stakeholders. There is a general perception that governmental entities do not take sufficient ownership of the activities towards CE. Clear dissemination to industry actors on governmental responsibilities and which agencies are responsible for what could enable industry actors to address the proper authorities in doubt of their legislative duties, reducing the confusion of the regulatory framework.
The industry actors further request concrete actions towards industrial symbiosis and publicly available monitoring methodology for the transition towards CE and material efficiency, as the current regulatory setup and approach are creating uncertainty challenges faced by competition with international companies. Further, the industry actors are looking for more public-private partnerships for assistance in CE transitions. Still, they desire concrete indicators and benchmarks to develop strategies and monitor improvements.
There is a perceived low incentive for CE practices and challenges with the availability of SRMs and by-products of high quality. Investigations of options to implement landfill and incineration taxes, deposit refund schemes, (enforced) GPP requirements, support for developing industrial symbiosis, taxes on virgin materials, tax breaks, promoting investments in resource-efficient infrastructure, and grants for eco-labelling will be beneficial for the material efficiency of the Portuguese industries. Additionally, infrastructural improvements, increased inspections and monitoring efforts, and increased dissemination of indicators for material efficiency are essential to reduce the perception that landfill is the only option. Further, monitoring efforts by public authorities, either by investigating the validity of self-reporting or by increasing inspections, could facilitate the data collection of waste management practices. This data could be utilised to overcome the barrier of the low availability of industry data for benchmarking.

[406] Findings from interviews with Portuguese textile industry actors.

6 Strategy development

The investigations of material efficiency in Portugal have revealed that material efficiency is lacking behind in Portugal compared to the EU average in the sectors covered by the project: Construction, furniture and textiles. The investigation of material efficiency in Portugal has revealed general challenges with the composition of the Portuguese private sector due to many SMEs in the assessed sectors with low capital opportunities and high internal competition in the Portuguese market. The investigation has further identified challenges with the valorisation of SRM and by-products, low customer acceptance of SRM and by-products, labour productivity, low internationalisation of companies, and dissonance between requirements and practices. The investigations and the many consultations with Portuguese companies, business sector representatives, and researchers have at the same time documented that Portuguese businesses, generally speaking, are not very familiar with circular economy principles and have only, to a limited extent, introduced circular business models bringing economic gains and resource benefits to both the individual companies and the country as a whole.

The consultations have revealed that both the business sector and the relevant public authorities are ready to commence the stroll towards a circular economy. However, many barriers hinder the widespread adoption of circular approaches, and the business sector does not possess the necessary knowledge, experience or tools to overcome these barriers. Cross-sectorial barriers identified that significantly affect material efficiency are mostly related to the perception of low coordination of CE efforts between the public and the private sector, low monitoring and reinforcement efforts, inefficient incentive structures, and a lack of indicators and benchmarks (cf. section 5). The public sector must take the lead and support the business sector in realising the significant benefits of the circular economy.

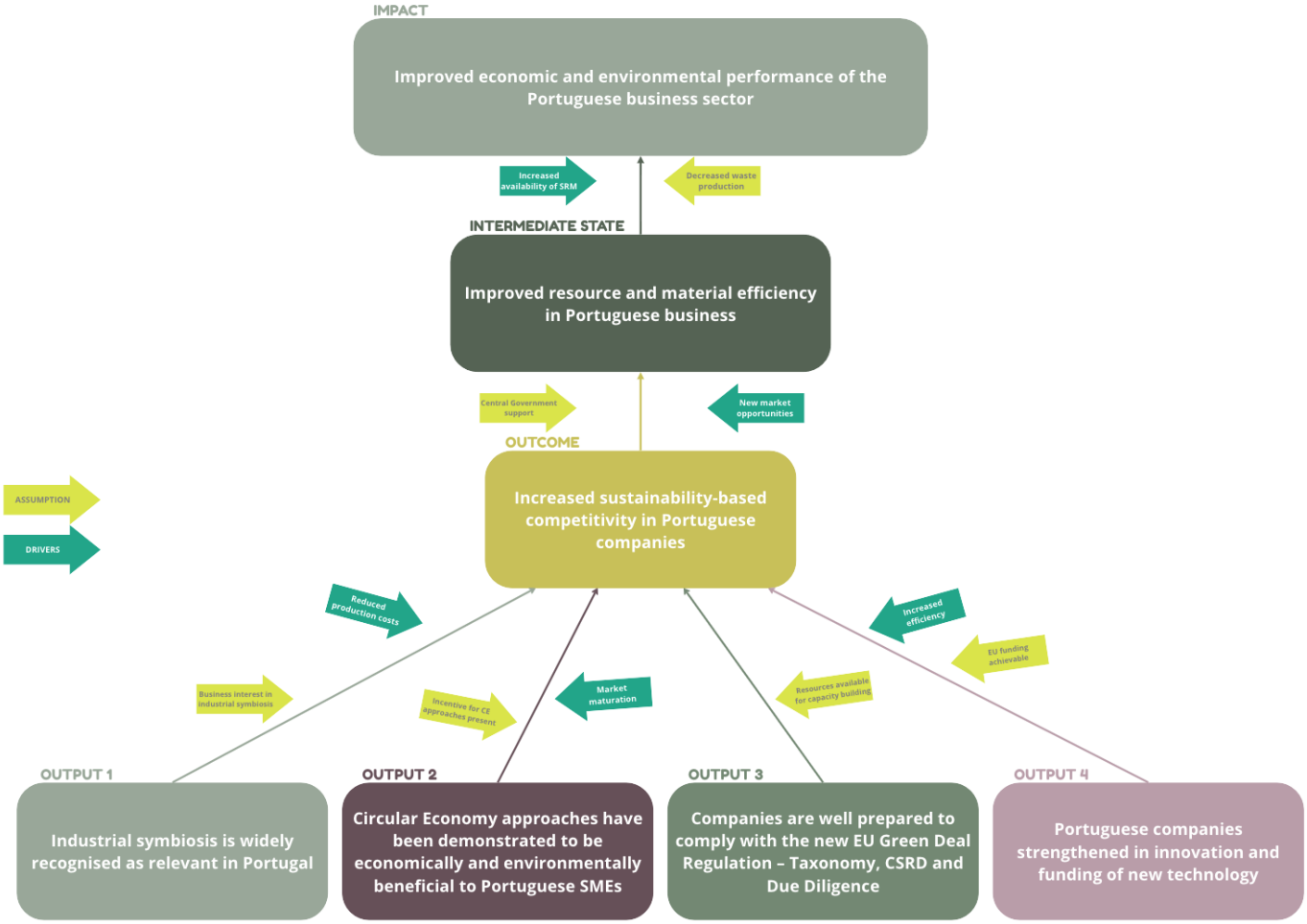
Based on the assessment of the state of play, best practices, and identified barriers (cf. section 2-5), the five simplified strategic themes to improve material efficiency in Portugal were presented to IAPMEI, IMPIC and APA. The themes were as follows:

- Demonstration of CE approaches as economically and environmentally beneficial;
- The EU Ecolabel and Portuguese SPP criteria;
- Compliance with the new EU Green Deal regulation; and
- Constraining the Portuguese technology gap;

The Governmental entities evaluated a series of potential strategy goals based on the themes under the strategic approaches for a comprehensive circular strategy to increase competitiveness in the Portuguese business sectors. They provided feedback on relevance based on their expert knowledge. The feedback enabled the development of strategic goals that can address some of the challenges related to improved material efficiency in Portugal, with relevance for the current and

future regulatory framework in Portugal. The strategic goals, which best reflect the current state of Portugal, are illustrated in the TOC model below:

FIGURE 4 TOC DIAGRAM OF STRATEGIC APPROACHES TO ACHIEVE MATERIAL EFFICIENCY



As figure 4 illustrates, four outputs were developed based on the most relevant themes. Based on the analysis of the state of play, best practices and Portuguese barriers to material efficiency (cf. section 2-5), it is assessed that the four outputs can lead to an increased sustainability-based competitivity in Portuguese companies, positively affecting material and resource productivity. The outputs can thereby condition an improved economic and environmental performance of the Portuguese business sector.

To further elaborate on the strategic approach determined in the TOC model, the LFA was applied to the strategic goals illustrated in figure 4. Based on the LFA, activities to support the outputs were developed based on the findings of the state of play, best practices and Portuguese barriers to material efficiency (cf. section 2-5). The LogFrame includes indicators, means of control and assumptions, as illustrated in the following table:

PROJECT ELEMENT	INDICATOR	MEANS OF CONTROL	ASSUMPTIONS

LONG-TERM GOAL Improved economic and environmental performance of the Portuguese business sector	Circular economy is on the agenda in Portuguese companies	• Response from the business sector/survey	Businesses adopt circular business models and practices
PROJECT GOAL Increased sustainability-based competitivity in Portuguese companies	The business sector experiences increased competitiveness	• Response from the business sector.	Circular economy shows economic and environmental gains for businesses
OUTPUTS 1. Industrial symbiosis is widely recognised as relevant in Portugal; 2. Circular Economy approaches have been demonstrated to be economically and environmentally beneficial to Portuguese SMEs; 3. Companies are well prepared to comply with the new EU Green Deal Regulation – Taxonomy, CSRD and Due Diligence; 4. Portuguese companies strengthened in innovation and funding of new technology.	• By end of 2026, the industrial know-how about industrial symbiosis will have doubled; • By end of 2026, more than ten Portuguese CE approaches have been demonstrated; • By end of 2026, more than 200 Portuguese companies have been capacitated to comply with the Green Deal Regulation; • By end of 2026, more than 200 Portuguese companies have been capacitated in innovation and funding	• Response from the business sector/survey • Company interviews, case study report • MoC reports • Technology investments statistics	Willingness among SMEs and larger enterprises to transition to circular approaches; support from the Portuguese Central Government; economic viability of outputs
ACTIVITIES			
1. **Industrial symbiosis is widely recognised as relevant in Portugal.** 1.a – Mapping of waste materials of relevance and industrial symbiosis screening of high-potential industries. 1.b – Development of tools and training programmes for regional and national organisations supporting increased industrial symbiosis. 1.c – Development of a strategy for value chain collaboration, industrial symbiosis, and industrial symbiosis networking. 1.d – Support to implementation of regional pilot projects for forming industrial symbiosis and developing national best practice approaches. 1.e – Preparation for LIFE and HORIZON applications for Portuguese companies pursuing industrial symbiosis.			Business interest in industrial symbiosis, circular approaches, EU funding, technology development
2. **Circular Economy approaches have been demonstrated to be economically and environmentally beneficial to Portuguese SMEs.** 2.a – Development of guidance for implementing circular economy in SMEs, ensuring economic viability and environmental benefits. 2.b – Train-the-trainer capacity building of local IAMPEI and IMPIC entities in subjects related to circular business models. 2.c – Development of a national knowledge-sharing platform and local knowledge-sharing activities. 2.d – Preparation of LIFE or HORIZON applications for companies pursuing circular solutions.			.
3. **Companies are well prepared to. Comply with the new EU Green Deal Regulation – Taxonomy, CSRD and Due Diligence.** 3.a – Review of upcoming Green Deal requirements to companies, assessment of the potential impact on Portuguese companies and sectors. 3.b – Identification of sectors especially prone to be impacted by the Green Deal regulation – establishment of cooperation forums with the sector organisations. 3.c – Development of strategy, training courses, tools and templates to support companies in complying with the Green Deal regulation. 3.d – Train-the-trainer courses for IAPMEI and IMPIC representatives, country and municipal business office staff, etc.			
4. **Portuguese companies strengthened in innovation and funding of new technology.** 4.a – Development of SME guidance to apply EU funding to implement the best technology available; training of business representatives 4.b – Assessment of options to increase technology uptake through national funding programmes and regulatory reforms. 4.c – Preparation of LIFE or HORIZON applications for companies pursuing technological development. 4.d – Development of a strategy to increase R&D projects enhancing Portuguese technology implementation and export. 4.e – Dissemination of best practices, lessons learned and benefits of technology implementation.			
RESOURCES Funding, staff, equipment and software, time, knowledge and information (Ql), statistics (Qn), space, infrastructure, communication/information channels, (possibly translators).			

TABEL NO 6 LOGFRAME OF STRATEGIC APPROACHES TO ACHIEVE MATERIAL EFFICIENCY

The following section will provide a background for the suggested project goal and supporting activities that have been evaluated to be relevant in the achievement of the overarching development objective:

Improved economic and environmental performance
of the Portuguese business sector

To ensure that the development objective is possible within the Portuguese regulatory framework, a superficial policy analysis was conducted during the strategy development process. The development objective and supporting activities have been evaluated to align with a range of Portuguese macro-level policy instruments, including:

- National Program for the Territorial Planning Policy (PNPOT);
- National Energy and Climate Plan 2030 (PNEC 2030);
- Roadmap for Carbon Neutrality 2050;
- Action Plan for the Circular Economy in Portugal (PAEC);
- PERSU 2030[407];

The macro-level policy instruments mainly respond to three areas of interest: promoting the circular economy, waste management, energy efficiency and carbon neutrality. The PNPOT explicitly establishes the promotion of regional and urban metabolism efficiency through increasing industrial symbiosis, promoting synergies of territorialised production[408].

OUTPUT 1: Industrial symbiosis is widely recognised as relevant in Portugal

The key objectives of Industrial Symbiosis (IS) are exchanging materials, energy and water between two or more companies, often within a limited geographical area. A network of more than two industrial actors interconnected through a symbiotic exchange of more than one resource is classified as an IS. IS can facilitate a reduction in pre-consumer waste, primary raw material input, waste disposal costs, and costs of material inputs through the exchange or sale of by-products and SRM. When companies collaborate in an IS network, the local industries achieve better resilience to external and internal developments, competitive advantages, and faster innovation. IS often requires some extent of facilitation through government-supported programmes and/or a facilitation organisation. A facilitation organisation contributes to the technical set-up of IS by conducting research and testing and obtaining funding for developing symbiotic exchanges. Further, facilitating organisations contributes to establishing mutual trust, connection and familiarity between the companies and innovation structures[409].

1	SUPPORTING ACTIVITIES
1.a	Mapping of waste materials of relevance and industrial symbiosis screening of high-potential industries
1.b	Development of tools and training programmes for regional and national organisations supporting increased industrial symbiosis
1.c	Development of a strategy for value chain collaboration, industrial symbiosis, and industrial symbiosis networking
1.d	Support to implementation of regional pilot projects for forming industrial symbiosis and developing national best practice approaches

[407] Henriques et al. (2022): Symbiosis in Portugal: A Future Perspective.
[408] Henriques et al. (2022): Symbiosis in Portugal: A Future Perspective.
[409] Lasthein et al. (2021): Guide for industrial symbiosis facilitators.

1.e	Preparation for LIFE and HORIZON applications for Portuguese companies pursuing industrial symbiosis

OUTPUT 2: Circular Economy approaches have been demonstrated to be economically and environmentally beneficial to Portuguese SMEs

Dissemination and demonstration of best practice approaches, innovative business models, and BAT for SMEs can be more challenging than with large enterprises due to limited resources (both monetary and timewise) and niche specialisation. Specialised guidance is often needed, and many depend on increasing their network to increase market accessibility. Continued activities to support the understanding and demonstration of beneficial circular economy approaches for Portuguese SMEs are essential to improving the overall national efficiency due to the high share of SMEs in the Portuguese market. The following supporting activities aim to train public sector representatives in the development of guidelines specialised to the Portuguese SME market, ensuring that best practice approaches presented are of relevance for the industry actors and that there is a capacity to assist SMEs in the implementation of best practices and circular business models and ensure that the Portuguese SMEs has the ability and incentive to share knowledge and lessons learned with each other. The latter can be facilitated through national knowledge-sharing conferences facilitated by Governmental entities such as IAMPEI and IMPIC, ensuring that SMEs are current on the newest policy initiatives, support programmes and offers.

2	SUPPORTING ACTIVITIES
2.a	Development of guidance for implementing circular economy in SMEs, ensuring economic viability and environmental benefits
2.b	Train-the-trainer capacity building of local IAMPEI and IMPIC entities in subjects related to circular business models
2.c	Development of a national knowledge-sharing platform and local knowledge-sharing activities
2.d	Preparation of LIFE or HORIZON applications for companies pursuing circular solutions

OUTPUT 3: Companies are well prepared to comply with the new EU Green Deal Regulation – Taxonomy, CSRD and Due Diligence

The EU has formulated its intentions[410] to increase transparency around sustainability performance and reporting in the corporate sector with new regulations, namely the Corporate Sustainability Reporting Directive (CSRD, the EU Taxonomy Regulation and the EU Corporate Sustainability Due Diligence Directive[411]. The soon-to-come implementation of this new regulation will put new requirements on Portuguese companies – initially larger companies, but later also on SMEs. Conglomerates with dedicated ESG/CSR departments may be able to comply with the new rules already from 2024. Still, many companies will experience huge challenges in perceiving and complying with the requirements.

This part of the project aims to train public sector representatives in the most important new regulations and to develop tools, templates and methodologies enabling Portuguese companies to not only comply with the regulation but also to gain from an improved ESG (Environment – Social – Governance) performance.

3	SUPPORTING ACTIVITIES
3.a	Review of upcoming Green Deal requirements to companies, assessment of the potential impact on Portuguese companies and sectors

[410] EC (n.d.g.): A European Green Deal.
[411] EC (n.d.p): Sustainable finance.

3.b	Identification of sectors especially prone to be impacted by the Green Deal regulation – establishment of cooperation forums with the sector organisations
3.c	Development of strategy, training courses, tools and templates to support companies in complying with the Green Deal regulation
3.d	Train-the-trainer courses for IAPMEI and IMPIC representatives, country and municipal business office staff, etc.

OUTPUT 4: Portuguese companies strengthened in innovation and funding of new technology

There is a growing consensus in the academic literature that digital technologies can offer a wide range of potential for implementing CE strategies in companies. Digital technologies are considered a critical enabler for CE transitions, particularly in collecting, managing, aggregating, and exchanging product data. Digital technologies facilitate the improvement of the availability and quality of data necessary for sustainability-based decision-making on a process and product level. Increased digitalisation can further foster inter- and intra-organisational collaboration and knowledge sharing[412]. While digitalisation and implementation of the best available technologies (BAT) are a focus in Portuguese Governance, the technology gaps significantly affect the Portuguese material efficiency[413] and the ability to implement CE strategies on a company level efficiently.

4	SUPPORTING ACTIVITIES
3.a	Development of SME guidance to apply EU funding to implement the best technology available; training of business representatives
3.b	Assessment of options to increase technology uptake through national funding programmes and regulatory reforms
3.c	Preparation of LIFE or HORIZON applications for companies pursuing technological development
3.d	Development of a strategy to increase R&D projects enhancing Portuguese technology implementation and export
3.e	Dissemination of best practices, lessons learned and benefits of technology implementation

[412] Schöggl et al. (2023): Implementation of digital technologies for a circular economy and sustainability management in the manufacturing sector.
[413] Bianchi (2020): Monitoring domestic material consumption at a subnational level – Enabling the territorial perspective.

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Annex 1 – Eurostat datasets informing on material efficiency

The following section is an overview of some potentially useful Eurostat datasets which may be used in combination with serving as proxies for estimating material efficiency in the Portuguese sectors:

OVERALL EFFICIENCY (NOT SECTOR SPECIFIC):

- The Eurostat dataset [env_ac_rp] provides nationally aggregated insight into the national resource productivity calculated by gross domestic product (GDP) over domestic material consumption (DMC). [ENV_AC_MFA] shows domestic material consumption (DMC) isolated, and [NAMA_10_GDP] shows the gross domestic product (GDP) isolated.
- The Eurostat dataset [SDG_12_41] on Circular material use rate measures the percentage of material recovered and fed back into the economy in the national overall material use. The dataset combines DMC data and data on waste recycling in recovery plants minus imported waste destined for recovery plus exported waste destined for recovery abroad.

WASTE PRODUCTION:

- The Eurostat dataset [ENV_WASGEN] shows waste generation by waste category, hazardousness and NACE Rev. 2 activity. This dataset provides insights on
    - annual total waste from construction (code F)
    - annual total waste from the manufacture of textiles, wearing apparel, leather and related products (code C13-C15)
    - annual total waste from the manufacture of furniture; jewellery, musical instruments, and toys; repair and installation of machinery and equipment (code C31-C33)
    - all above as total in kilograms per capita - hazardous or non-hazardous or distributed on different waste categories
    - The distribution of different waste categories within the total waste from each NACE Rev. 2 activity.
- The Eurostat dataset [TEN00106] shows total waste generation by economic activity. Relevant economic activities relevant for this study is code F, construction.
- [t2020_rt100] shows the generation of waste excluding major mineral waste (Kilograms per capita)
- [T2020_RT110] shows the landfill rate of waste excluding major mineral wastes (%)
- [t2020_rt120] shows the recycling rate of municipal waste.

WASTE MANAGEMENT AND RECOVERY:

- The Eurostat dataset [CEI_WM040] shows the recovery rate from construction and demolition waste[414].
- The Eurostat dataset [env_wastrt] provides insights on how waste is treated in different waste management systems by waste category, hazardousness and waste management operations. The waste categories include wood wastes [W075], textile wastes [W076], mineral wastes from construction and demolition [W121], as well as for instance glass wastes [W071] and Metal wastes (ferrous or non-ferrous) [W061 and W062].
- [t2020_rt130] shows the recycling rate of e-waste (%)

VALUE ADDED BY EACH SECTOR:

- The Eurostat [NAMA_10_A64] on national accounts aggregates by industry (up to NACE A*64) provides insights in the annual value added by each industry, including [C13-C15] Manufacture of textiles, wearing apparel, leather and related products, [C31_C32] Manufacture of furniture; other manufacturing, and [F] Construction.
- The Eurostat [NAMA_10_NFA_ST] Cross-classification of fixed assets by industry and by asset (stocks) provides insights in the fixed assets in industries, including [C13-C15] Manufacture of textiles, wearing apparel, leather and related products, [C31_C32] Manufacture of furniture; other manufacturing, and [F] Construction

OTHER DATASET

- [t2020_rl110] shows the domestic material consumption per capita (tonnes pr capita).
- [t2020_rd100] shows the productivity of artificial land (Million PPS per square km).
- [t2020_rd110] shows built-up areas (square km).
- [t2020_rd220] shows the water exploitation index (%).
- [t2020_rd210] shows the water productivity (EUR pr m3).
- [t2020_rk100] shows the daily calorie supply per capita – total (Kilocalories)
- [t2020_rt200] shows the Eco-innovation index (Index (EU=100)). In this particular case, Eurostat is not the producer of these data, but only re-publishes them from a combination of secondary sources.

[414] Note: The cei_wm040 from Eurostat informs us that the recovery rate (preparation for re-use, recycling and other material recovery, including backfilling operations using non-hazardous CDW to substitute other materials) of total construction and demolition waste in Portugal is 93% compared to 88% in EU 27, 2018. The high recovery rate of CDW in Portugal is mainly achieved by using recovered waste for practices such as backfilling and low-grade recovery applications, reducing the potential to move towards truly circular waste management. Also, there are indications of a discrepancy between the construction waste quantities registered and the actual quantities: When comparing the total waste generated from the construction sector in EU and Portugal, measured in kilograms per capita, there is a factor 13 difference (136 kg/cap in Portugal and 1870 kg/cap in EU27 average for 2018[414]). The reported quantities on Eurostat represents only 9% of the EU27 average. This gap is unlikely caused solely by less produced waste, but is more likely the effect of unregistered waste, which is consistent with the cultural issues described in the previous section. According to Eurostat, the generation of mineral waste from construction and demolition sector in Portugal has increased from 1.033.000 tonnes in 2012 to 1.560.000 tonnes in 2018. Correlated to the EU27 per capita data, the Portuguese amounts could be as high as 6 million tonnes/year.

- [t2020_rd300] shows the greenhouse gas emissions per capita (Tonnes of CO2 equivalent per capita)
- [t2020_rd310] shows the energy productivity (EUR per kg of oil equivalent)
- [t2020_rd320] shows the energy dependence (%)
- [t2020_rd330] shows the share of renewable energy in gross final energy consumption (%)
- [t2020_rk330] shows Average carbon dioxide emissions per km from new passenger cars (Gram of CO2/km). In this case, Eurostat is not the producer of these data but only re-publishes them from EEA.

7.1 Potential indicators

Indicator 1: Use of materials per person as an effect of DMC over the total population.

This method also appears in the EEA study, More from Less – material efficiency in Europe[415] and the Resource Efficiency Scoreboard[416]. It uses the dataset [t2020_rl110], where DMC is calculated per capita. This gives a rough picture of the average national material consumption – which can be used as a proxy for efficiency. However, it is most likely more related to wealth than efficiency measures.

Indicator 2: Economy-wide material flow accounting using DMC over GDP

The existing Eurostat datasets enable the Economy-wide material flow accounting, showing *resource productivity* as the effect of *GDP over DMC*. This method includes non-material consumption, such as energy usage, and is only a proxy for material efficiency. Furthermore, it cannot be isolated to the sectorial level, only the national level. However, this indicator provides an initial overview of the state in Portugal compared to the EU. See Section 3.1, "*The Portuguese economy compared to EU average (EW-MFA)*". This method is also used in the EEA study, More from Less – material efficiency in Europe and the Resource Efficiency Scoreboard.

Indicator 3: Use of materials per waste unit (DMC/total waste)

The existing Eurostat datasets enables the Economy-wide material flow accounting, showing material efficiency as the effect of DMC (material consumption) over total waste from all economic activities.

This would visualise total waste production from all economic activates as an effect of domestic material consumption from all economic activities. While it would only be a proxy, a higher DMC pr. Waste output would indicate better material utilisation pr. Unit material. Of course, this doesn't consider the quality of such unit. Simultaneously, the indicator would consider countries with low performing waste registration systems as material efficient, since not all waste is considered. In the case of Portugal, where there are indications that not all waste is registered, this could very well turn out to be the case.

[415] EEA (2016b): More from less – material resource efficiency in Europe – 2015 overview of policies, instruments and targets in 32 – Country profile Portugal.
[416] Eurostat (2021b): REIs.

Indicator 4: Sector specific material flow accounting using total waste over national accounts aggregates by industry

As a proxy for materials efficiency, we can calculate annual total waste from specific sectors as an effect of value added by the same sector. This allows us to zoom in on the specific sectors, because these data are available on industry level, categorised by type of economy activity (NACE codes) in Eurostat datasets. Total waste can be found in [ENV_WASGEN] using NACE code F, code C13-C15 and code C31-C33 while national accounts aggregated by industry can be found on [NAMA_10_A64] using the same NACE codes. By extracting value added (gross) by each sector and divide it by total waste produced in the three sectors, we get an indicator of value pr. waste produced, which can be a proxy for service provided pr. material input. In comparison with the economy wide indicator, this proxy is more relevant for the scope of study, since it zooms in on our selected industries. However, the results are highly dependent on which kind of product is produced, and thus lacks in comparability; some types of products are by nature more worth than others, even though the service they provide may be less essential. For instance, if we compare an expensive handbag with a pair of trousers, the indicator might not truly reflect material efficiency in the production process, but to some degree also the product types most common in the nation. As mentioned in the section above, there the waste registers might not be very robust, and likewise the indicator.

Indicator 5: Sector specific material flow accounting using Gross value added over direct entry of materials.

Replication of methodology in “Contributos para a Elaboração de uma Estratégia para o Uso Eficiente dos Recursos – Proposta de Relatório Final” for 2000-2020, Portugal compared to EU27 average.

Other relevant datasets to be used to evaluate the state of the art in Portugal compared to EU;

The Eurostat dataset [t2020_rd210] (water productivity in EUR pr m3). Since textiles has a huge impact on water consumption, this indicator is interesting. It is not sector specific, and thus cannot be isolated from other industries. Unfortunately, the dataset does not contain any available data from Portugal. The same goes for the Water exploitation index, Productivity of artificial land and Built-up areas.

Comments to the indicators above from the perspective of RACER:

A clear advantage to using EUROSTAT data is that it scores high on acceptability and easiness within the RACER criteria (relevance, acceptability, credibility, easiness, robustness). However, what they have in common is that most Eurostat data only allows for economy wide assessments, instead of sectorial assessment. A few datasets such as WASGEN and NAMA_10_64 have data available for groups of NACE codes, which can represent the sectors. However, it must be noted that even the NACE activities are grouped as follows: [C13-C15] “Manufacture of textiles, wearing apparel, leather and related products” and [C31_C32] “Manufacture of furniture; jewellery, musical instruments, toys; repair and installation of machinery and equipment”. [F] Construction is the only NACE activity that is not aggregated on those EUROSTAT databases.
These issues reduce the relevance for the scope of the study. Each methodology has some weaknesses, and for the indicator using waste statistics, a key weakness is the robustness of the data available: Unfortunately, there are indications that waste in Portugal is not registered consistently and that the datasets are biased.

Annex 2 – Longlist of best practice examples

PRIVATE INITIATIVES FOR MATERIAL EFFICIENCY IN THE CONSTRUCTION SECTOR	
VERKSBYEN (NO)	Frederikstad, Norway, began building a new green neighbourhood in 2019 to become Norway's most innovative housing project. Verksbyen will become home to 5000 people within the next ten years due to a collaboration between Arca Nova Bolig, project owner, and Metsä Wood, material provider[417]. The neighbourhood will consist of five five-story apartment buildings of sustainably sourced wood. The load-bearing structure in the first three floors consists of wall elements prefabricated by MetsäWood. In addition, wooden beams have been glued and screwed on the outside of the parts to stiffen and stabilise the construction. There is a traditional timber frame construction reinforced with CLT plates on the two top floors. Steel plates and parts, such as bolts, screws and glued rods, are still utilised in the building. However, the amount of steel used is predominantly reduced[418]. Increasing the use of wood brings several improvements to material efficiency. One of the inherent material properties of wood is an excellent weight-to-strength ratio and high strength qualities. Wood is so light that buildings can be constructed with less sturdy foundations, requiring less piling, construction materials and time[419]. MetsäWood have optimised the construction chain regarding material efficiency, e.g. by utilising sawdust and other by-products and by prefabricating modular building components reducing waste in production and on-site[420]. Furthermore, all wooden pieces used in Verksbyen are designed to be reused or recycled. The beams produced by MetsäWood are specially designed to be recycled into prefabricated intermediate floor and wall elements[421].
THE MAISON DE I´LLE DE FRANCE (FR)	Located in the Cité Universitaire de Paris, the Maison de I'lle de France is the first eco-campus constructed in the French capital. Using the RT 2005 methodology, the greenhouse gas emissions have been assessed to be impressive -5.9 kWhep/m2.an. In the design phase of the campus, eco-design played a part in deciding which materials to utilise. The facades of the eco-campus consist of light elements joining the concrete slab noses. Wood is used for the primary structure due to the material's renewability. Insulation and rain cover of the building are provided by compressed wood fibre panels comprised of upcycled by-products from local sawmills. Further, a cellulose wadding obtained from paper recycling was placed between the plaster facings, improving the isolation of the building. The bathrooms of the student residence were prefabricated to limit construction waste, reduce construction time, and facilitate the maintenance in the operating phase[422].
MODULAR CONSTRUCTION (JP)	In construction, material usage on-site is often dependent on the experience of the tradesman, whereas a pre-fabricated, modular component is produced in a factory, often with high level of precision and the opportunity to better minimize and reuse waste. Prefabrication enables easier reparation, rebuilding and rearranging of buildings[423]. Sekisui is a worldwide multifaceted company originated in Japan, specialising in plastics, urban infrastructure and environmental products, housing and pharmaceutical sciences[424]. Sekisui utilises modular construction methods, using factories to build steel framed and wooden modular housing[425]. Their factory systems in Japan are based on zero emission principles, where 100% of all waste and litter is recycled internally, and they are currently working on achieving the same standard of recycle in their factories around the world. 80% of houses build by Sekisui are prebuild

[417] MetsäWood (n.d.a): Verksbyen – sustainable neighbourhood.
[418] MetsäWood (n.d.a): Verksbyen – sustainable neighbourhood.
[419] MetsäWood (n.d.b): Sustainable building and resource efficiency with wood.
[420] MetsäWood (n.d.b): Sustainable building and resource efficiency with wood.
[421] MetsäWood (n.d.a): Verksbyen – sustainable neighbourhood.
[422] Lalsinque (2017): House of Ile de France.
[423] O'Brien (2011): Resource-efficient construction: A systemic approach to sustainable construction.
[424] Sekisui (2021): Corporate Profile, 2021.
[425] Sekisui (n.d.a): Housing Company.

	in the factories before on-site construction begins. To reduce on-site waste, the company have implemented principles of reduce – reuse – recycle, by introducing fractional recovery, simple packaging and turning cardboard boxes into containers. To ensure an upkeep of the waste recycling standards, waste is precisely classified by material in the factory, and their material recycling system processes and reuses waste for other products as a secondary raw material without combustion[426]. Furthermore, the houses are built to have a high durability performance, with the probability of small repairs needed every 30 years, and the houses are built to be earthquake and wind resistant as well as fire retardant, thereby adapting their housing to the local risks in Japan[427, 428, 429].
THE CORK HOUSE (UK)	The Cork House is a new, radically simple form of plant-based construction[430]. Built on an island on the Thames, the house's monolithic walls and corbelled roofs are made almost entirely from solid load-bearing cork [431 432]. The house is based on a self-build construction kit, conceived as a kit-of-parts, expanded cork blocks, and engineered timber components are prefabricated off-site and assembled by hand without mortar or glue[433]. In the design phase of the Cork House, the focus was on solid, simple, and sustainable, resulting in a robust life-cycle approach, from material extraction to end-of-life[434]. The expanded cork is a pure bio-material made of waste and by-products from the cork forest industry[435]. The compelling ecological origin of the expanded cork mirrored at the opposite end of the building's life cycle. The construction system is dry-jointed so that all 1,268 blocks of cork can be reclaimed at the end-of-building-life for reuse, recycling, or decomposition in the biosphere. The house was designed for disassembly, with cork as the primary building material. The house was considered carbon-negative at completion[436].
STEEL & AGGREGATE RECYCLING (IT)	Beltrame Group is an Italian construction recycling company originating in 1896. They recycle steel scraps from steel production to use in construction, shipyard, and excavators[437]. Steel is a favorable recycling agent as it can be recycled indefinitely. The steel scraps are melted, and lime, coal, and ferroalloys are added to obtain the right composition. Lastly, it is rolled to give the steel shape[438]. The company has developed a Scope 1+2+3 report for all stages of production and works after five sustainability pillars. These pillars are to improve the security of their workers, energy consumption i.e., increasing the use of renewable energy, and reducing water consumption, CO_2 emissions, and production waste. The company aims to reduce its total emissions by 40% in 2023 compared to 2015[439]. Beltrame Group has a focus on Circular Economy. The company also recycles aggregates to reduce the use of natural resources as well as production waste. The recycled aggregates can be used in road production and concrete[440]. The company is certified by several standards and systems (also internationally)[441].

[426] Sekisui (n.d.b): Zero Emission.
[427] Sekisui (n.d.c): Durability performance.
[428] Sekisui (n.d.d): Earthquake resistance.
[429] Sekisui (n.d.e): Wind-resistant and fire-retardant performance.
[430] Howland (n.d.): Matthew Barnett Howland.
[431] CSK Architects (n.d.): The Cork House.
[432] Howland (n.d.): Matthew Barnett Howland.
[433] CSK Architects (n.d.): The Cork House.
[434] Howland (n.d.): Matthew Barnett Howland.
[435] Riba Architecture (n.d.): Cork House.
[436] Howland (n.d.): Matthew Barnett Howland.
[437] Beltrame Group (n.d.): Chalibria. We promise a better quality of urban life.
[438] Beltrame Group (n.d.b): Production process.
[439] Beltrame Group (n.d.c): The pillars.
[440] Beltrame Group (n.d.d): BELTRECO aggregate.
[441] Beltrame Group (n.d.e): Certifications.

100% BY-PRODUCT CONCRETE (BE)	URBCON is a Belgium project led by the City of Ghent and Ghent University in Belgium. The project is based on reducing the use of raw materials and CO_2 emissions in the construction sector. The objective of the project is to produce 100% by-product (aggregate) concrete and low-clinker cement. Metallic slags and incineration ashes are examples of by-products used for making more sustainable concrete[442]. URBCON has 13 partners from 5 countries[443] participating in various projects and the testing of these. URBCON also intends to develop a wide network with the construction industry and by-product providers, and a "Strategic Technology Transfer Plan" which – among other factors – includes Life Cycle Assessments (LCAs). The municipality of Rotterdam has started a project with URBCON to replace an old, wooden pedestrian bridge with URBCON's sustainable concrete to encourage Rotterdam's goal of being climate-neutral by 2050. The project started in 2019[444].
RECYCLED STEEL BY-PRODUCTS (BE)	Aperam is a large Belgium company that recycles steel. They have six production facilities in Belgium, Brazil, and France with the goal of becoming a zero-waste company. In 2021 they shipped 1.82 million tonnes of recycled steel. As of 2020, Aperam's products contain a minimum of 80% recycled steel scraps and 25% recycled input material i.e., nitrogen. The company recycles 94% of its own waste and by-products from production and aims to reduce it by more than 3% by 2030[445]. The dust emission residue is sent to an external company for recycling, and the company has ambitions for improving its dust emissions beyond the Belgian legislation. In 2015 it has been reduced by 15% and by 2030, Aperam aims to reduce it by a further 70%[446]. In general, the company has a low energy level consumption and uses a low-carbon energy mix for the melting facilitates consisting of 39% renewable charcoal biomass. It owns a 100.000 ha FSC® certified forest in Brazil to produce charcoal for its production instead of fossil fuel coal. In 2020 the company reached a 35% reduction in carbon footprint since 2007 – they aim to be carbon neutral in 2050. Windmills and solar panels have been installed in various facilities which are expected to lower the carbon footprint[447]. Water is essential in steel production and in 2020, 95.3% of Aperam's water consumption was from closed circuits. The 2030 aim is to reduce water consumption by 40% compared to 2015[448]. Aperam is the first stainless steel company to be certified by ResponsibleSteel™[449].
SUSTAINABLE RESEARCH (BE)	VITO is an independent Flemish research organisation. They work with different partners to create more sustainability, provide counsel on relevant challenges, and to make their own research more sustainable. The company works with a Circular Economical perspective, with a goal "to accelerate the transition to a sustainable world"[450]. In the construction sector, VITO develops building materials from bottom ash and construction waste to get more out of the waste streams and costs and promote sustainable innovations in a field of major waste production. VITO has worked with cases such as: Developing two separation techniques for recycling bottom ash and removing metals therein – the technique produces hydrogen which is an

[442] URBCON (n.d.): Project Summary.
[443] URBCON (n.d.): URBCON – By-product for sustainable concrete in the urban environment.
[444] Gemeente Rotterdam (n.d.): URBCON.
[445] Aperam (n.d.a): Waste & Recycling.
[446] Aperam (n.d.b): Dust & Air Emissions.
[447] Aperam (n.d.c): CO2 & Energy.
[448] Aperam (n.d.d): Water.
[449] Aperam (n.d.e): ResponsibleSteel™.
[450] VITO (n.d.a): Vision on technology for a better world.

	energy source; Recycling cellular concrete and reducing the sulphate in the concrete, which is highly pollutant, by 90%; Investigation in usage of dredge spoil filter cakes as a cement replacement[451].
100% RECYCLED STEEL PRODUCTS (ES)	Sidenor is a Spanish company that manufactures a wide arrange of steel from scraps – 100% of their produce is exclusively made of scraps. They also have facilities in Germany, France, Italy, and the UK and handle around 900.000 tons of scrap per year which equals a production of over 1 million tons of steel[452]. They work from a Circular Economy perspective and aim to reach 95% of waste recovery by 2030, reduce 55% of GHG emissions by 2025, and be carbon-neutral by 2050 – since 2005 they have reduced their GHG emissions by 48%[453]. They also focus on the design of their products for future recycling, the overall efficiency of the production process, and creating jobs. Carbon and ferro must be used in the production, and Sidenor aims to find sustainable options[454]. Water is essential in steel production, and to improve the use of it, Sidenor reuse their water – in some of the facilities, the reuse of water is over 95%. The air emissions are purified, and the by-product is reused as a secondary raw material in the zinc industry. There is a focus on renewable energy, and the company aims to use 50% renewable energy in the next 10 years[455]. They are certified by ISO:14040, ISO:14044, and ISO:14025[456]. Sidenor recycles their steel by-products to aggregates which can be used for asphalt, road-construction, sewers, industrial area fills, secondary raw material in cement, and precast concrete products. The company also led the 5RefrACT program to maximise the use of materials in steel production[457]. Transparency is encouraged and a Greenhouse Gas (GHG) report was published in 2021. Sidenor aims to reduce 55% of their emissions in Scope 1+2 by 2025 compared to 2005 and to be climate neutral in 2050[458].
SLAG-BASED BY-PRODUCTS (FI)	Outokumpu is a company located in Finland originating in 1910 – in the 2000s they solely began working with stainless steel. Their aim is to reduce landfill waste and increase the sale of materials as by-products. The company's target is zero-waste stainless steel production. One of the biggest wastes from steel production is slag. Outokumpu collects the waste-slag to retrieve metals for reuse as secondary raw materials in its melt shops. The company also develops slag-based by-products used as aggregate in road construction. Dust is also a big waste and is collected by a dust-filtering system installed in their facilities. 99% of dust is collected in the filters. Metals are extracted from the collected dust and recycled in a facility in Sweden. Outokumpu also has facilities in the UK where the metal recovery is done on-site. Circular Economy is of focus by the company, especially their waste streams. 65% of waste and by-material are kept in the company's production cycle and the remaining is sent to licensed treatment facilities or landfill sites[459]. Outokumpu has several requirements for its chain suppliers such as sustainability, traceability, and quality[460].

[451] VITO (n.d.b): Construction & demolition waste.
[452] Sidenor (n.d.a): Recycling.
[453] Sidenor (n.d.b): Environment.
[454] Sidenor (n.d.c): Circular Economy.
[455] Sidenor (n.d.d): Efficient use of Resources.
[456] Sidenor (n.d.e): Sustainable Steel.
[457] Sidenor (n.d.f): Water Reuse and Recovery.
[458] Sidenor (n.d.g): Climate Change.
[459] Outokumpu (n.d.): Waste and by-products.
[460] Outokumpu (2022): Suppliers information.

RAW MATERIALS RECYCLE (FI)	Syklo is a Finnish company with the goal of increasing "the recycling rate of resources and raw materials by directing waste towards recovery and reuse and by refining waste into new materials and products"[461]. They focus on two systems: Closing construction material cycles and utilizing bio-streams. The recovered and recycled waste (constriction and municipal) is used as materials in the industrial sector, or as fuel. The company also retrieves and recycles wood for industrial reuse and manufactures Solid Recovered Fuel if the waste is unrecyclable. Syklo also recovers ashes to use as fertilization in forests and earthworks and is exploring the use of ashes as a replacement for cement[462]. Circular Economy is a priority for the company and more investments in that regard will be made in the future.
ECO-CEMENT (IE)	Ecocem is a cement producer originating in 2003 in Ireland, Dublin. The Irish company develops eco-cement by use of the Best Available Technology (BAT) with a 16 times lower carbon footprint compared to other cement producers in Ireland[463]. The company works with a focus on environmental performance, sustainability and quality, and health and safety[464]. Ecocern produces three different types of eco-cement: Ecocem GGBS, Ecocem Cement (CEM III/A), and Ecocem Superfine. Ecocem GGBS is an upcycled alternative to traditional cement which will increase the technical performance of the application and has an improved appearance. The mix of Ecocem GGBS consists of ground granulated blastfurnace slag, which is an iron manufactory by-product, and Portland cement[465]. Ecocem Cement (CEM III/A) is the company's special formula consisting of a mix of traditional cement and a minimum of 50% ground granulated blastfurnace slag. Due to its strength, durability, and low heat properties, the cement is particularly good for marine, agricultural, and chemically aggressive environments. It is also ideal for deep pour foundations, i.e., wind farms, and architectural components due to its white and smooth finish. The cement is also EN 197-1 certified[466]. Ecocem Superfine is ground granulated blastfurnace slag in powder form. It is a finer grade than what is used in the cement mixes and is specially used as an additive in binders, all dry-mortar applications, Ultra High Perfomance Concrete, and precast concrete. The finer grade improves the finish of the concrete and can reduce the need for pigment. Due to a lower pH and Cr(VI) content, the Superfine powder is a safe additive to building material formulations[467].
POLICIES FOR IMPROVING MATERIAL EFFICIENCY WITHIN CONSTRUCTION IN EU	
BELGIUM	Regionally, Belgium has launched multiple initiatives for eco-innovation. In the region of Wallonia several projects focus on sustainability in a variety of sectors one of them being the construction sector. GreenWin is a company in Wallonia with a particular focus on eco-innovation in green chemistry and sustainable materials[468]. Projects in the region of Brussels share the same ambitions including a focus on the waste management sector[469]. The Centre for Excellence in Sustainable Construction (CESC) is also based in Brussels and is run by the Belgian Building Research Institute (BBRI), a private research centre whose foundation was supported by the National Federation of Belgian Building Contractors. The CESC is indispensable in research and innovation in the construction sector. The aim is to support construction companies by applying new technologies and promoting sustainable buildings and renovation techniques. For road construction, the Belgian Road Research Centre acts similarly[470].

[461] Syklo (2022a): About us.
[462] Syklo (2022b): Services and products.
[463] EC (2021m): European Construction Sector Observatory – Country Profile Ireland.
[464] Ecocem (2023a): About us.
[465] Ecocem (2023b): Ecocem GGBS.
[466] Ecocem (2023c): Ecocem cement (CEM III/A).
[467] Edocem (2023d): Ecocem Superfine.
[468] EC (2021n): European Construction Sector Observatory – Country Profile Belgium.
[469] EC (2021n): European Construction Sector Observatory – Country Profile Belgium.
[470] EC (2021n): European Construction Sector Observatory – Country Profile Belgium.

	The Belgian government intends to develop an "Employment-Environment-Renovation" alliance to encourage demand for renovation of existing buildings and develop skills in the renovation, sustainable construction, eco-construction, and natural insulation[471].
DENMARK	In Denmark, material efficiency is mainly addressed through waste management plans and a resource strategy. The waste management plans include "Denmark Without Waste: Recycle more – incinerate less"[472] from 2013 and its continuation "Denmark Without Waste II - A Waste Prevention Strategy"[473] from 2015. One of the five focus areas is construction, and 13 initiatives and associated indicators focus on optimising resource usage in this sector. The most relevant initiatives include; • Establishing partnerships for sustainable construction and reduction of waste. Focus on including the whole value chain, identifying barriers and standard solutions, financing demonstration projects, nudging campaigns and concrete actions. • Enhanced requirements for demolition of buildings and to the competencies within demolition companies, e.g. waste sorting and handling. • Development of a nonmandatory sustainability class for construction (mandatory from 2023) • Several analyses are dedicated to identifying solutions, barriers and economic feasibilities of reuse and recycling practices, including managing hazardous materials. The indicators for material efficiency in the construction sector include; • the number of buildings where building materials are screened before demolition. • The amount of CDW that is used for new purposes A strategy for Circular Economy[474] was adopted in 2018 that directly and indirectly influences construction. The Circular Economy plan includes 15 initiatives related to 6 overarching circular economy objectives. Most of these objectives are related to material efficiency within a building, such as supporting the circular economy through data, digitisation, design, and creating proper functioning markets for wasted and recycled raw materials. Objective six is directly focused on construction as it aims to increase the value of buildings. Likewise, several of the 15 initiatives seeking to reach these six objectives are expected to influence structure. From these 15 initiatives, it's worth mentioning the following: • developing a nonmandatory sustainability class • propagating selective demolition • promoting circular business development in small and medium-sized enterprises (SMEs) • setting up a single point of entry to the authorities for enterprises with circular business models • expanding the access to financing of circular business models • supporting digital circular options by commercial use of data and challenges • promoting circular procurement • increasing focus on the total cost of ownership in public procurement • creating a level playing field on the market for waste and recycled raw materials • establishing a fund for the handling of regulatory barriers to the circular economy Finally, a newly accepted strategy from February 2021[475] is dedicated to sustainable buildings. The strategy focuses mainly on CO_2 emissions from buildings, which relates to energy efficiency. However, material efficiency is also addressed through several initiatives, those primarily taking the form of waste reduction policies. • investigate where and why mistakes in construction arise, leading to loss of materials

[471] EC (2021n): European Construction Sector Observatory – Country Profile Belgium.
[472] The Danish Government (2013): Denmark without waste - Recycle more - incinerate less.
[473] The Danish Government (2015): Denmark without waste II - a waste prevention strategy.
[474] The Danish Government (2018): Strategi for cirkulær økonomi.
[475] The Danish Government et al. (2021): National Strategi for Bæredygtigt Byggeri.

	• examine sources of construction waste • build case studies of economically feasible sustainable buildings • explore options for lower requirements for parking facilities in new building projects and associated opportunities for condensation of building mass • explore possibilities for enhancing opportunities for the transportation of module constructions investigate whether there are potentials for more sustainable construction materials than those required through the eurocodes improve the availability of environmental data to support the adaptation of sustainable building materials
PRIVATE INITIATIVES FOR MATERIAL EFFICIENCY IN THE TEXTILE SECTOR	
RECLAIM TO WEAR (UK)	Reclaim to Wear was first introduced by 'From Somewhere'. The pioneering upcycling fashion label started in 1997 by Orsola de Castro and Filippo Ricci to design beautiful clothes made entirely from discarded materials and remnants, hereunder both pre-consumer waste such as designer surplus, production off-cuts, and post-consumer waste such as second-hand clothing etc.[476]. Reclaim to Wear offers upcycling design solutions to inspire shifts towards a less wasteful, more efficient future, where surplus fabrics and discarded clothes are transformed and redesigned to prolong their usage[477]. The company develops methods for reclaiming that can be taught to anyone, whether individuals, small designers, brands, manufacturers, educators, students or communities. They provide simple ideas and resources for longevity and elaborate sourcing and sorting systems. Further, Reclaim to Wear offers guidance in cutting and sewing techniques to recycling and reuse of materials at pre- and post-consumer efficiently. The knowledge sharing is done through exhibitions, facilitating workshops and lectures on design schools[478].
LOW IMPACT POST-CONSUMER RECYCLED POLYESTER (DE)	Advansa, a German textile fibre-producing company, has aimed to eliminate occupational waste hazards and environmental pollution while carefully using environmental resources. Environmental contributions include a recycling program that converts post-consumer SRM into high-quality polyester and measures and investments to reduce waste, water, and energy. Together with local recycling partners, Advansa further uses two million recycled bottles as SRM in producing their fibre products[479]. Advansa has several products rewarded with: • The EU Ecolabel • OEKO-TEX® certification • Global Recycled Standard certification • ISP 50001 energy certification[480]. Advansa has had independent Life Cycle Analyses done on their fibres in 2010 and 2015, confirming the low carbon footprint of Advansa products. The fibres used in Advansa products are made from recycled polyester, and there are several initiatives to reduce the environmental impacts of production phase[481]. Initiatives in the production phase are clearly showing in the reduction associated with their PET products in the period from 2010 to 2015 with: • 10% reduction in CO2 emissions • 4% reduction in land use (which was already low using 0.0026 ha. compared to cotton using 0,82 ha.)

[476] Reclaim to Wear (n.d.a): A Design Solution to an Environmental Challenge.
[477] Reclaim to Wear (n.d.a): A Design Solution to an Environmental Challenge.
[478] Reclaim to Wear (n.d.b): Collaborations.
[479] Advansa (n.d.a): Sustainable products.
[480] Advansa (n.d.a): Sustainable products.
[481] Advansa (n.d.b): Advanced Fibre Technology.

	• 20% reduction in water use[482] The fibres are mainly used in home textiles, including mattresses, furniture, duvets and pillows[483]. Furthermore, biodegradable plastics, with similar properties to PET, made of plant starch, are used for products for packing and medical and hygiene industries[484].
Utilisation of Deadstock (KH)	Tonlé has combined two approaches to their ground rules in the sustainable production of garments. Firstly 100% of a given textile used in the production must be used. No waste can come from the output. Secondly, their garments must come from reclaimed materials[485]. Tonlé's design team source their textiles from Phnom Penh, Cambodia, where pre-consumer textile waste from large garment factories is collected and resold. Materials used in Tonlé's garments are primarily cut-waste, but they utilise deadstock and textiles unfit for industrial production as well. Back at Tonlé's sewing workshop, markers and designers work together to create designs from larger pieces of reclaimed fabric. The small scraps left over from making those garments are cut and individually sewn into yarn. In the weaving process, Tonlé partners with Weaves of Cambodia, a weaving collective in Cambodia's Preah Vihear province. Weavers in this collective earn fair wages and work in a community-centric environment that supports their specific needs and talents. The yarn is then handwoven and knit into new pieces, creating their iconic twice-recycled fabric pieces. The twice-recycled thread is used to hand-knit and crochet sweaters, scarves, bags and home accents[486]. Tonlés collections are tied together using screen printing, incorporating accent colours and prints. Every design is hand-printed, using nontoxic water-based inks and natural dye paste inks. The natural dye does not rely on heavy metals like lead and copper to produce plant-based colours. Instead, the natural colouring is 100% non-toxic, and 80% of these dyes come from edible ingredients like soy milk and lemon[487]. Tonlé's patchwork technique takes inspiration from historical quilt designs and gives them a modern twist while ensuring that no scrap of fabric goes to waste in their workshops. The small amount of textile waste from making Tonlé's garments is mixed with used paper waste from their offices and pattern making, creating Tonlés own handmade paper. Tonle acknowledge that wasteful packaging is a huge contributor to environmental challenges facing this planet. That is why all Tonlé packaging is made from 100% recycled materials, and all hang tags and eco-friendly printing houses print promotional materials in recycled paper[488].
PLATFRM FOR SUSTAINABLE CHANGE IN THE FASHION INDUSTRY (DE)	PLATFRM was launched in December 2020 to change the fashion industry positively. The incentive for the digital sustainable fashion platform was to convince shoppers to support upcoming fashion brands with sustainable principles and ensure that these brands were transparent regarding methods and material[489]. PLATFRM tests the brands by evaluating them according to eight principles before providing them access to the digital platform: 1) Transparency: This principle addresses whether brands are open about their production processes (e.g. where the production is, who is involved and how everyone is involved, materials used etc.). 2) Materials: This principle addresses the sustainability of the materials used by the brands (i.e. recycled or upcycled old fabrics, innovative eco-fabrics or certified organic materials).

[482] Advansa (n.d.a): Sustainable products.
[483] Advansa (n.d.b): Advanced Fibre Technology.
[484] Advansa (n.d.a): Sustainable products.
[485] Tonlé (n.d.) What is Zero Waste Fashion?
[486] Tonlé (n.d.) What is Zero Waste Fashion?
[487] Tonlé (n.d.) What is Zero Waste Fashion?
[488] Tonlé (n.d.) What is Zero Waste Fashion?
[489] Platfrm (n.d.a): Our Story.

	3) Supply Chain: This principle addresses the efforts toward reducing negative externalities in the shipment of goods (e.g., eliminating plastic packaging, using multi-use packaging, using bike couriers or compensating for the carbon emitted by delivery). 4) Local: This principle address whether or not brands produce their goods in the same country as the brand is located, minimising carbon emissions and providing local jobs. 5) Community: This principle addresses whether a brand actively tries to improve the community around them (e.g. taking vulnerable groups in society into account). 6) Work: This principle addresses whether brands look after the working conditions and salaries of all people in the supply chain. 7) Purpose: This principle addresses whether brands use their reach to educate. 8) Upcoming: This principle address whether brands are still up and coming. PLATFRM only allows brands with less than six full-time employees to help sustainable brands grow to better the industry[490]. PLATFRM describes how the idea for the brands is to do business in line with all eight principles. However, very few can do this at the moment. Therefore, the premise for selling clothing via PLATFRM is to adhere to at least four principles. From there, PLATFRM actively supports the brands to reach all eight principles. The first three principles are similar to what could be found in a product passport related to materials used and promote material efficiency awareness and pressure on producers by material efficiency part of the branding. By including material efficiency in branding, producers are incentivised to reduce waste and utilise circular materials in the design, production and distribution phase[491].
INNOVATIVE COLOURING PROCESS (SE)	The Swedish company We aRe SpinDye (WRSD) works exclusively with recycled polyester made from post-consumer water bottles or wasted clothing, allowing a circular production method. Multiple fabrics are made from one single source of yarn, making the production methods especially resource efficient with almost no waste or by-products[492]. WRSD uses an innovative and unique colouring process which colours the yarn before spinning. This saves chemicals and water compared to dying the yarn after spinning. By melting the colour pigment and the recycled polyester mass together, WRSD achieves a homogenously coloured yarn without using water[493]. Throughout the production chain, this colouring and production method reduces; • The water usage by 75% • The chemical consumption by 90%. • The energy consumption by 30-40% • The CO_2 imprint by 30%[494] Products fabricated in this way also generally achieve higher colour fastness and enhanced garment performance, thereby prolonging the lifespan[495]. WRSD bases their work on LCA standards in cooperation with the independent research organisation RISE (Research Institutes of Sweden), and the production complies with the ISO Standard 14040-series[496].
RENTING, WASHING &	DFD (The United Steam Laundries) is one of largest textile service businesses within the Nordics, founded in Denmark in 1958. DFD offers sector specific solutions for washing and rental services of work wear and -textiles for five market-specialized divisions:

[490] Platfrm (n.d.b): PLATFRM's principles.
[491] Platfrm (n.d.b): PLATFRM's principles.
[492] We Are Spindye (n.d.b): Our coloring process.
[493] We Are Spindye (n.d.b): Our coloring process.
[494] We Are Spindye (n.d.c): Environmental impact.
[495] We Are Spindye (n.d.c): Environmental impact.
[496] We Are Spindye (n.d.d): We aRe SpinDye®-certificate.

	• Industry (Industries utilising tear-resistant work wear); • HoReCa (Hotels, Restaurants and Cafes); • Cleaning, food & cleanroom (the cleaning, food production and medicinal industries); • RECA (Restaurants and Catering in Copenhagen); and • Health & welfare (public entities such as hospitals and clinics) Work wear offered by DFD are designed for durability and reuse and can be both purchased or rented. Multiple renting and washing solutions are offered to all divisions, to ensure durability potentials of the work wear are reached. When the work wear reach the EoL states due to wear and tear, it is either upcycled to new work wear or downcycled to industrial articles such as stuffing for car seats. Downcycling is only an option if the textiles are heavily worn down. Currently, some of the textiles within the system of DFD are sent to incineration if they have been in contact with contaminants or have lost all fibre integrity. DFD has a goal to reach a complete zero waste system by 2025[497].
RECYCLED FABRIC FROM OLD FISHING NETS (IT)	Econyl® yarn is a type of nylon fabric produced from recycled fish nets, old carpets destined for landfill and pre-consumer waste. After the collection, the plastic-based waste types are sorted and cleaned to recover as much nylon as possible. However, in a radical regeneration and purification process, the SRM achieve the same purity and quality as virgin nylon. Consequentially, it is possible to process the ECONYL® regenerated nylon into yarn and polyester that can be utilised in the production of new textile products. When these new products reach their end of life, collecting and recycling materials is possible[498]. Through this production process, raw material extraction is reduced and substituted. The fabrics can be used for clothing, swimwear, and furniture. Another company, Aquafil, collaborates with an international network structured around recovering materials that have reached the end-of-use phase. The network is based on partnerships with institutions, organisations, private and public associations, and companies. Based on this network, Aquafil has established a take-back scheme by reviewing production textile scraps that go into the production of ECONYL® yarn. Furthermore, Aquafil collaborates with Napapijri with their Circular Series, where a take-back program is integrated with the opportunity to return ECONYL® products after two years to secure recycling of the regenerated nylon[499].
POLYESTER FROM CO_2 EMISSIONS (FR)	Fairbrics is a pilot project that is taking a different approach to dealing with textile waste. It originates in France and is expected that the company will have a demo plant before or in 2027. The developing technology captures CO_2 emissions from the industrial sector and treats the emissions with chemicals, so they become plastic pellets suitable for use as polyester fabric. The pellets are spun into yarn and the yarn is made into fabric. Polyester is ordinarily derived from petroleum or coal and then treated with two chemicals: Purified terephthalic acid (PTA) and monoethylene glycol (MEG). MEG has a harmonised classification by ECHA and is harmful if swallowed or by prolonged exposure[500]. The chemicals have no other classifications. Fairbrics treats the captured CO_2 through a chemical process – including the above-mentioned chemicals – by an innovative technology resulting in the plastic pellets. The process has less environmental impact than traditional polyester production, is ten times cheaper, and Fairbric's future goal is to be carbon negative[501]. The company has won several awards and is supported by the EU and its partners in the project[502].

[497] DFD (n.d.): Vores tilgang til CSR.
[498] Econyl (n.d.a): The process – Econyl.
[499] Econyl (n.d.b): Special Take Back Projects.
[500] ECHA (2023): Substance description.
[501] Fairbrics (n.d.a): Fairbrics technology.
[502] Fairbrics (n.d.b): News.

PRE- & POST-CONSUMER (IT)	Manteco is an Italian company with a big focus on sustainability, zero waste, and Circular Economy. The company originated in 1943 where it recycled second-hand military blankets. Today, Manteco recycles primarily wool and has several patented wool blends. Their main blend called Mwool® is a fully circular and zero-waste recycled wool. It consists of recycled industrial and pre- and post-consumer textile waste, does not contain dye or chemicals, and is biodegradable. It has received a Higg MSI score (Materials Sustainability Index), is GRS-certified (Global Recycled Standard), and has the first recycled wool yarn to get EPD (Environmental Product Declaration) certified. It has also received a certified LCA (Life Cycle Assessment) calculation[503]. Out of a wide range of fabrics, six fabrics are created with the company's Mwool®: Vita, BiBye®, Woolten® (mixed with Tencel™), Ansedonia, Naiffo, and Eco Washable[504]. Manteco does use virgin raw materials and synthetic fibres in the remaining fabrics (recycled synthetic fibres at the client's request). All the fabrics produced by Manteco undergo the company's "Msystem" production. This consists of 50+ partners that make up Manteco's supply chain. They are all located in Italy within a 10-mile radius with a focus on traceability, transparency[505], and certifications[506]. Manteco designs their fabric to be recycled in the future and has several zero waste projects: Project 43 to promote zero waste with manufacturers that use Manteco's products by recycling the manufacturers' offcuts; Project 53 to promote zero waste with manufacturers that use other suppliers than Manteco by recycling their offcuts; and Manteco's own Zero-Waste system where all the production scrap-waste is recycled back in their production chain. The company is also a member of the Ellen MacArthur Foundation and is partnered with the Monitor for Circular Fashion[507].
PRE- & POST-CONSUMER PLATFORM (IT)	Re.Verso™ is an Italian platform created by two companies; Green Line and Nuova Fratelli Boretti. The platform is designed to recycle pre- and post-consumer textile waste, specifically wool and cashmere, for use in new textile production. The platform also focuses on improving its production chain and reducing energy use, raw materials, and waste. Re.Verso™ is certified by the Global Recycled Standard. Apart from the two founding companies, there are three partners responsible for the recycling process. Green Line retrieves the textile waste, roughly sorts the fabric, and sanitises it. The textile waste comes from Italy and various European countries. Nuova Fratelli Boretti then sorts the textile again, more thoroughly, to prepare for recycling; this is done by fibre and color. Re.Verso™ does not re-dye most of its fabric but maintains as well as possible the colors that the textile waste comes in. The textile waste gets tested for chemical safety and fibre content when sorted. The textile is now transformed into high-quality fibres to be used in yarns, fabrics, and fashion accessories. This is respectively done by the company Filpucci, A. Stelloni by Mapel, and Antica valserchio[508, 509]. Re.Verso™ also offers a takeback system where the company collects partners' pre- and post-consumer textile waste to recycle it, so the partners can reuse the fabrics[510].
SUSTAINABLE TEXTILES (ES)	TEJIDOS ROYO is founded in Spain, in 1903, and has two production facilities in Valencia[511, 512]. They are a textile company specialising in spinning, weaving, and finishing i.e., dyeing. They use pre- and post-consumer textile waste for recycling. TEJIDOS ROYO has developed specific foam technologies for dyeing: DRY INDIGO® which eliminates water use by 100% and reduces energy use by 65% and chemical

[503] Manteco (2023a): MWool®.
[504] Manteco (2023b): Collection.
[505] Manteco (2023c): MSystem.
[506] Manteco (2023d): Our commitment towards responsible practices.
[507] Manteco (2023e): Our circular economy practices and projects.
[508] CFDA (n.d.): Re.Verso™.
[509] Re.Verso™ (2020a): Re.Verso™.
[510] Re.Verso™ (2020b): Takeback program.
[511] TEJIDOS ROYO (2018a): Creation of a socio-economic value.
[512] TEJIDOS ROYO (2018b): We manufacture in Spain.

	use by 89% and DRY BLACK®, which reduces water use by 99%, energy use by 72% and chemical use by 52%. The company has also developed an imitation leather finish on cotton fabrics and super stretch fabric[513]. The company is certified by Oeko-Tex Standard 100, STEP Certified by Oeko-Tex®, GRS and OCS by ICEA, and a member of Textile Exchange, BCI, SMETA, and AMFORI Audit Social Program (BSCI)[514].
PRE- AND POST-CONSUMER (ES)COTTON	Textil Santanderina is a Spanish company located in Cantabria originating in 1923. It recycles primarily pre-consumer textile waste and additionally post-consumer waste in 4 different manufacturing facilities[515]. Their object is to use less virgin cotton and thereby reduce water consumption from cotton farming and intensive land use as well as CO_2 emissions. The recycled textile waste will become part of a more sustainable loop and become a secondary raw material. Firstly, the textile waste in grinded and pulled apart into fibres. The fibres are carded repeatedly to be cleaned and mixed and is now a secondary raw material (SRM). The SRM cotton is now spun into yarn and lastly made into fabrics[516]. The yarn contains 50% recycled cotton[517]. Textil Santanderina is partnered with a variety of textile companies. SEATEX is a company producing textile fibre from sustainably grown seaweed in Icelandic waters and wood pulp. The fibre is called SeaCell™ and has several advantages, one of them being the minerals and vitamins in seaweed nourishing the skin of the wearer[518]. Other companies include Pure Indigo, a chemical-free denim, and ECODESK, a sustainable fabric finish i.e., fabric dyeing[519].
PRE- AND POST-CONSUMER (ES)	Vilarrasa is a Spanish textile recycling company with more than 50 years of experience, with four production centers located in the province of Girona[520]. The company is certified under *ISO:9001*, *Global Recycled Standard*, *BSI*, *Standard 100 by OEKO-TEX*, and *Better Cotton*. They also run all their production on 100% renewable energy. Vilarrasa recycles pre- and post-consumer textile waste, working with cotton, viscose, polyester, acrylic, polyamide, and more recently linen, hemp, and jute[521]. Cotton and polyester are the most widely recycled textiles. The company produces different yarn mixes depending on the product and the client, recycled and virgin, and for the best fibre quality, Vilarrasa has a big network of suppliers all over the world. They use their own shredding machinery and have separate manufacturing centers for colored and white fabric to avoid any cross-contamination. The fabrics are not dyed. RESPIN by Vilarrasa is a subdivision branch of Vilarrasa that exclusively recycles post-consumer textile waste[522].
PRE- AND POST-CONSUMER	Pure Waste is a Finnish textile company created in 2013 and located in Helsinki. They create textiles from recycled cotton and polyester from pre- and post-consumer waste. Their ambition is a radical shift in production and consumption habits, reducing over-production, creating long-term quality products, and providing full transparency of the company's actions. Pure Waste prioritises the Circular Economy aspect to promote resource efficiency, especially to reuse textile waste and create secondary raw

[513] TEJIDOS ROYO (2018c): Innovation r + d.
[514] TEJIDOS ROYO (2018d): Our commitment.
[515] Santanderina group (n.d.): Textil Santanderina.
[516] Textil Santanderina (n.d.a): Recycled cotton, naturally circular.
[517] Textil Santanderina (n.d.b): S360º A new circular textile cycle.
[518] Textil Santanderina (n.d.c): The natural power of vitamin-rich seaweed textiles.
[519] Textil Santanderina (n.d.d): A Prepared for Garment Dye solution fully made in Europe.
[520] Vilarrasa (2021): Circular economy.
[521] Vilarrasa (2023): Types of recycled raw material to make yarn.
[522] RESPIN by Vilarrasa (2021): We turn garment into high quality products.

	material (SRM). All the company's SRMs contain 99% recycled content, 60% cotton, and 40% polyester, and wherever possible, they reuse cardboard packaging and plastic bags[523]. The pre-consumer cotton waste is collected in India where it is also created. The polyester is from recycled post-consumer waste and plastic bottles. The fabric is not dyed, and no harmful chemicals are used in compliance with the European REACH legislation – and the excess fabric is used for special edition collections. The hang tags are made of recycled cardboard and since 2021, the product labels and size tags are now made of recycled polyester instead of virgin polyester. Pure Waste focuses on their employees' work environment, sustainable energy such as wind and solar power, biogas, and collecting rainwater for watering greens. They are certified by GRS, Sedex, and BSCI. Among other goals: By 2023, the company aims to compensate for its carbon footprint and build a model for the traceability of raw materials. All data and more are collected in their Sustainability Report from 2021[524].
POLICY INITIATIVES FOR MATERIAL EFFICIENCY IN THE TEXTILE SECTOR	
THE LEGISLATIVE SETUP IN DENMARK	In Denmark, material efficiency is mainly addressed through waste management plans[525]and as with the Construction and Demolition sector, the clothing and textile sector is one of five focus areas. The textile sector is described to some degree in "Denmark Without Waste: Recycle more – incinerate less"[526] from 2013, but the material efficiency is primarily addressed through its continuation "Denmark Without Waste II - A Waste Prevention Strategy"[527] from 2015. The overall goal related to material efficiency is to make it easier for the textile sector to reuse and recycle textiles. To achieve the comprehensive plan, eight initiatives are prioritised, where the most relevant for material efficiency are: • A government-funded partnership to prolong the life span of clothes by collaboration between all players in the clothing value chain, relevant authorities, and stakeholder organisations. The partnership aims to identify barriers and standard solutions and will focus on textile materials, including wool, cotton, and polyester. • The Danish Partnership for Chemicals in Textiles will work to reduce the use of chemicals of concern in textile production through knowledge-building and experience and best practice sharing to optimise recycling. • Developing a joint Nordic action plan for a sustainable and resource-efficient fashion and textile industry. This action plan outlines the political direction and specific actions to be made within the areas of sustainable production, chemicals, waste prevention, and management. The monitor the development, the Government uses two indicators: • Consumption of clothes and textiles, including second-hand clothes • Developments in the number of eco-labelled garments and textiles.
PRIVATE INITIATIVES FOR IMPROVING MATERIAL EFFICIENCY IN THE FURNITURE SECTOR	

[523] Pure Waste (2023): Actions, Please!.
[524] Pure Waste (2021): Sustainability Report.
[525] The Danish Ministry of Environment and Food (2016): Best Practice Examples of Circular Business Models.
[526] The Danish Government (2013): Denmark without waste - Recycle More - incinerate less.
[527] The Danish Government (2015): Denmark without waste II - a waste prevention strategy.

ECO-DESIGNED OFFICE CHAIR (US)	The Think office chair has been designed after eco-design principles by the company Steelcase. Steelcase has been working closely with eco-design networks to find additional improvement opportunities and suppliers who could provide appropriate recycling materials with the sought-out technical properties[528]. The Think ®chair is produced using up to 28% recycled material content[529] as pre-consumer recycled polyamide. The Think ® Chair is designed for long product life, e.g., by making parts replaceable and thereby designing for disassembly, and to ensure responsible end-of-use strategies, e.g., refurbishing, charitable donation, or recycling. The product is made in Europe, reducing transportation and a four-piece optimised 'Eco-smart' packaging solution has been designed to keep transport volumes to a minimum. The Think ® Chair was the first product in the world to be granted the Cradle to Cradle ® environmental certification[530] and has additionally achieved the following certifications[531]: Environmental Product Profile, NF Environnement, NF Office Excellence Certifié, Indoor Advantage Gold, and OekoTex 100 (for textiles used)[532]. Furthermore, Think® provides Environmental Product Declaration (EPD) for their products for transparency. The end-of-life stage has been considered in the design process: Easy disassembly has been a priority, and in the latest models, the manufacturers have decreased the number of parts to reduce complexity further and thereby make disassembly more manageable. Finally, the plastic parts are clearly labelled to make sorting easy and effective regarding recycling533. The chair is up to 95% recyclable[534].

[528] Steelcase (2015): The new Think ® Chair: A sustainable pioneer.
[529] Steelcase (n.d.a): Sustainability.
[530] Steelcase (2015): The new Think ® Chair: A sustainable pioneer.
[531] Steelcase (n.d.a): Sustainability.
[532] Steelcase (n.d.a): Sustainability.
[533] Steelcase (n.d.a): Sustainability.
[534] Steelcase (n.d.b): Office Chairs Think.

NON-TOXIC CIRCULAR FURNITURE (SE)	The company Green Furniture Concept makes furniture for public areas. Green Furniture Concept recognise the importance of considering the entire life-cycle of products, which is why the materials and chemicals used in their products are carefully selected. The approach to sustainability is rooted in four cornerstones: • Chemical Awareness • Design and Resources • Reforestation • Post Sales Responsibility[535] Chemical substances used in the company's furniture are free from eco-toxins and harmful substances, which have been achieved by collaborating with suppliers and environmental chemists to evaluate and continuously improve the chemical footprint[536]. They have certified their product with the Nordic Swan Ecolabel, which required several alterations in the production process[537]. The Nordic Swan Ecolabel is the bottom line for Green Furniture Concept's work[538]. The furniture is designed using renewable and recyclable materials, using the highest possible percentage of second-hand wood and other upcycled materials. By using hard wax oil to treat the wood instead of traditional wood varnish, the toxicity of the treated material decreases[539]. Furthermore, this approach to wood treatment makes it possible to repaint and fix any scratches instead of replacing complete parts. The products are designed to be disassembled individually to minimise waste and separate materials for recycling. Green Furniture Concept only uses virgin wood from certified sources that guarantee responsible forestry to ensure the sustainability of the virgin timber used in the furniture. Furthermore, they plant a tree for every product sold. Green Furniture Concept have introduced a By-Back system for their Nova C Series, meaning that they provide a 15-year warranty period. The benches can be collected free of charge and the customer is eligible for a refund of up to 30%. The returned products are either refurbished and sold again or disassembled and recycled. In addition, Green Furniture Concept offers a Seating-as-a-Service, giving the customer the option to lease their products instead of buying them[540].

[535] Green Furniture Concept (2020): Sustainability.
[536] Green Furniture Concept (2020): Sustainability.
[537] Furn360 (2017): Circular Economy in the Furniture Industry: Overview of Current Challenges and Competences Needs.
[538] Green Furniture Concept (2020): Sustainability.
[539] Furn360 (2017): Circular Economy in the Furniture Industry: Overview of Current Challenges and Competences Needs.
[540] Green Furniture Concept (2020): Sustainability.

THE NAVY CHAIR (US)	In 1944 Emeco emerged, producing the famous 1006 Navy Chair made from reclaimed aluminium, an assignment given to the company by the U.S. Government that could (and can) withstand water, salt, air and sailors. The Navy Chair is so durable that it has an estimated life cycle of 150 years, exceeding the U.S. Navy's specifications[541]. Since then, Emeco has continued developing its responsible approach to manufacturing processes and production. They utilise the best control technologies to reduce their environmental impact, recycling waste and used materials, eliminating external environmental influences and reducing their products' carbon footprint[542]. The latest sustainability action came in 2020 when Emeco started measuring and declaring the carbon footprint of their products[543]. From a pre-consumer material efficiency perspective, Emeco's collections in reclaimed wood polypropylene (WPP) are an innovation of particular interest. Emeco became aware of polypropylene, one of the most versatile plastics used for everything from car batteries to medical equipment. The production steams of polypropylene lead to cut-offs and waste, often so small and insignificant that it's swept into the trash. Emeco receives leftover bits that wind up on the floor at plastic factories and mix it with discarded wood and sawdust from lumber yards. Combining the pre-consumer polypropylene waste with pre-consumer wood waste particles creates ground for furniture that can meet the demands of high-use environments, including outdoor use[544].
IT-SYSTEM DECREASING CONSUMPTION (SE)	Office furniture belonging to companies is usually stored out of sight when not needed in the office, and therefore it is often forgotten when offices are refurnished. This affects not only the emission of CO_2 and material used regarding the production and transportation of new office furniture but also a drop in the quality and, therefore, the reusability of the furniture due to improper storage[545]. To counteract furniture waste in office settings, an office furniture supplier called RP has made an IT system available. The IT systems help Swedish companies keep track of their existing furniture in storage, while RP also offers to buy and resell/lease used office furniture[546]. An inventory of the companies' furniture is set up in the system, including specifics for the individual piece of furniture. The company has access to a complete furniture database when planning to refurnish or move office. The existing furniture can then be reused in its current state within the company, or it can be refurbished to match the new requirements of the workplace. All recycled furnishings sold or rented through RP comes with a three-year warranty and a service agreement if furniture needs repair or reconditioning[547]. This method curbs the need for procuring new furniture.
POLICIES FOR IMPROVING MATERIAL EFFICIENCY WITHIN FURNITURE	

[541] Emeco (n.d.a): Emeco + Alcoa and US Navy.
[542] Emeco (n.d.b): Environmental Statement.
[543] Emeco (n.d.c): Sustainability Report 2020.
[544] Emeco (n.d.d): Reclaimed wood polypropylene (WPP) - Discarded becomes distinctive.
[545] The Swedish National Agency for Public Procurement (2021): Mycket att spara på nytt tänk för möbler.
[546] RP (n.d.): Hållbar kontorinredning.
[547] RP (n.d.): Hållbar kontorinredning.

PROCURING CIRCULAR LEARNING ENVIRONMENTS	The municipality of Aalborg is the fourth largest city in Denmark, with 207.000 inhabitants. Aalborg has been committed to improving the sustainability of their municipality for two decades[548] and uses GPP principles to promote the reuse of furniture in schools. The municipality started by mapping the opportunities for a higher degree of circularity and found opportunities among the 50 schools in municipality[549]. During establishing a framework agreement for school furniture, the municipality decided to facilitate an inspiring learning environment that supports learners' needs while simultaneously strengthening the circular economy[550]. Aalborg municipality cooperated with the schools, Aalborg University, and the Government's initiative for GPP, such as the Danish 'Travel Team for Public Procurement'[551], among others, to design tenders appropriate for increasing reuse between the schools[552]. Environmental criteria were included as minimum requirements, such as the need to: • Provide a minimum of five-year lifespan guarantee on the lifetime of new furniture. • Provide a minimum two-year lifespan guarantee on the lifetime of refurbished parts of furniture. • Provide a minimum five-year lifespan guarantee on spare parts • Provide a service which informs schools, once a year during the warranty period, on relevant maintenance services available and advises for each product • Use of packaging made from only recycled materials, e.g. recycled plastics • Labelling of plastic parts above 50 grams for recycling • Ensure that at least 70% of wood used in the production of new furniture comes from sustainable sources[553]. Criteria were also set to the number of reused items and the quality of the items, with the best possible learning environment for the students in mind[554]. In recognition of the innovative approach to classroom design, the municipality of Aalborg won the IKA (Danish Association of Public Procurement) awards for Denmark's Best Call for Tender in 2017. In addition to the framework, the municipality's School Department is also setting up a surplus furniture register that can be utilised elsewhere for all schools and school-based leisure facilities. The log will contain information about all furniture in such a good condition that it can be reused in another establishment without refurbishment[555].
TAX REDUCTION FOR ROT WORK IN SWEDEN	In 2008, the Swedish Government introduced a tax relief on home repair services (ROT), encompassing repair and maintenance, including conversions and extension services. At the time, the aim wasn't to promote material efficiency. Instead, the objective is to reduce undeclared work by incentivising declared domestic work. Furthermore, the goal was to increase demand for domestic services and create employment opportunities, especially for those with low educational attainment, by reducing the price of domestic services through tax deductions[556]. The tax reduction amounts to 50% of the labour costs, up to a maximum threshold of approximately 11,850€. The tax reduction resulted in a decrease in undeclared work by about 10% between 2005-2011. Moreover, 6% of the buyers of ROT indicated that the work would not have been performed had it not been for the tax reduction[557]. It is further discussed in Sweden to introduce a tax deduction for rental goods, second-hand goods and repairs as an addition to the already existing tax incentives. The purpose of this proposal is to increase the length of usage of products and promote repairs[558], supporting a greater material efficiency regarding, e.g. furniture.

[548] EC (2018c): GPP – In practice, Iss. No. 79, March 2018.
[549] NBE (2017): Netværk for Bæredygtig Erhvervsudvikling NordDanmark.
[550] EC (2018c): GPP – In practice, Iss. No. 79, March 2018.
[551] EC (2018c): GPP – In practice, Iss. No. 79, March 2018.
[552] NBE (2017): Netværk for Bæredygtig Erhvervsudvikling NordDanmark.
[553] EC (2018c): GPP – In practice, Iss. No. 79, March 2018.
[554] NBE (2017): Netværk for Bæredygtig Erhvervsudvikling NordDanmark.
[555] EC (2018c): GPP – In practice, Iss. No. 79, March 2018.
[556] EPUW (2019): Tax relief for domestic service work (ROT and RUT).
[557] EuroFound (2013): Tax deductions for domestic service work, Sweden.
[558] EC (2017): Eco-innovation in Sweden.

STANDARDS FOR PUBLIC PROCUREMENT	In Sweden, no EPR schemes have been set up for the furniture industry. However, criteria for sustainable Public Procurement of furniture have been set up by the Swedish National Agency for Public Procurement[559]. The purpose of the implementation of standards for public procurement is to ensure that organisations within the Swedish public sector: • Drive developments to a more sustainable society by demanding socially and environmentally sustainable products and services; • And the opportunity to use suppliers' capacity for innovation to develop new sustainable solutions[560]. Organisations that must follow the procurement legislation primarily include[561]: • State or municipal agencies • Governing bodies in a municipality or region • Publicly managed bodies such as most municipal or some state-owned companies • Associations of one or more authorities, assemblies or publicly controlled bodies • Companies that conduct operations within the water, energy, transport or postal services with an exclusive right or a specific right[562] The criteria developed for public entities are designed so that they are ready for use by public entities. They are available in different categories, such as technical specifications, special contract terms, or award criteria. Technical specification criteria can be related to the material content of the furniture, such as the chemical contents of plastics or metals. Special contract terms may be associated with the availability of spare parts or sustainable supply chains. The same criteria can be set up as award criteria, where the criteria are not mandatory but where points are rewarded for documentation of the requirements in the procurement process. Each standard is connected to the Swedish National Environmental Goals and, in some cases, to SDG[563].

[559] The Swedish National Agency for Public Procurement (n.d.): About Public Procurement.
[560] The Swedish National Agency for Public Procurement (n.d.): About Public Procurement.
[561] The Swedish National Agency for Public Procurement (n.d.): About Public Procurement.
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