NARRATE

Regenerative Resilient Smart Manufacturing Networks

D1.3 ENERGY EFFICIENCY & CIRCULARITY

2024/09/03

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D1.3 ENERGY EFFICIENCY & CIRCULARITY

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Abstract	This deliverable analyses current context and trends from the sustainability perspective. It performs a specific diagnosis on the 3 pilots to identify main environmental areas and requirements to be considered, also based on the analysis of sustainability scenarios and related decision processes. Corporate carbon footprint calculation is described (data and methodology) are specified and Industrial Symbiosis requirements are specified. Environmental management KPIs system is proposed.
Keywords	Energy efficiency; Circular Economy;

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STATEMENT ON MAINSTREAMING GENDER

The NARRATE consortium is committed to including gender and inter-chapterality as a transversal aspect in the project's activities. In line with EU guidelines and objectives, all partners – including the authors of this deliverable – recognise the importance of advancing gender analysis and sex-disaggregated data collection in the development of scientific research. Therefore, we commit to paying particular attention to including, monitoring, and periodically evaluating the participation of different genders in all activities developed within the project, including workshops, webinars and events but also surveys, interviews and research, in general. While applying a non-binary approach to data collection and promoting the participation of all genders in the activities, the partners will periodically reflect and inform about the limitations of their approach. Through an iterative learning process, they commit to plan and implement strategies that maximise the inclusion of more inter-chapteral perspectives in their activities.

DISCLAIMER

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ABBREVIATIONS

BAT	Best Available Techniques
CEAP	Circular Economy Action Plan
CoC	Chain of Custodian - Certification
CRDDD	Corporate Sustainability Due Diligence Directive
CSRD	Corporate Sustainability Reporting Directive
EC	European Commission
EFRAG	European Financial Reporting Advisor Group
EMAS	Environmental Management and Audit Scheme
EMS	Environmental Management System
EPR	Extended Producer Responsibility
ESG	Environmental and Social Governance
ESPR	Ecodesign for Sustainable Products Regulation
ESRS	European Sustainability Reporting Standards
EUDR	European Deforestation Regulation
FSC	Forest Stewardship Council
GAR	Green Asset Ratio
GHG	Green Houses Gases
GRI	Global Reporting Initiative
IMC	Intelligent Manufacturing Custodian
IPCC	Intergovernmental Panel on Climate Change
KPI	Key Performance Indicator
MaaS	Manufacturing As A Service
MED	Former acronym for partner MIC (MICUNA)
MSx	Milestone x
Mx	Month x
REACH	Regulation on the registration, evaluation, authorisation and restriction of chemicals

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RoHS	Restriction of Hazardous Substances
SFDR	Sustainable Financial Disclosure Regulation
SMART	Specific Measurable Achievable Relevant Timeframed
SUPD	Single-Use Plastics Directive
Tx.x	Task x.x
VOC	Volatile Organic Compound
WEEE	Waste Electrical and Electronics Equipment
WP	Work Package
WRI	World Resources Institute

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EXECUTIVE SUMMARY

The primary objective of this document is to identify and analyze the requirements necessary to evaluate process circularity, energy efficiency, carbon footprint, Industrial Symbiosis, and other sustainability aspects in the supply chain inside MaaS context. Environmental and circularity Key Performance Indicators (KPIs) are developed to select the best sourcing alternatives among the evaluated suppliers.

After the introduction and explanation of the methodology followed, the document begins at Chapter 3 with a contextual analysis of current sustainability trends, exploring European policies and market dynamics that influence sustainability supply chain requirements (corporate management and products).

Critical regulations such as the European Green Deal, the Ecodesign for Sustainable Products Regulation (ESPR), and various directives related to sustainability are addressed, including those focused on Due Diligence and Corporate sustainability reporting and or Waste Framework Directive that included references to extended producer responsibility, and Industrial Symbiosis.

Once the context is defined, in Chapter 4 a sustainability diagnosis is performed on the three pilots and conducted to identify main environmental aspects and leading into the identification of sustainability requirements. This diagnosis involves a detailed evaluation from the life cycle thinking perspective (ecodesign questionnaire) and from the corporate management perspective (annual process mass balance), with a focus on energy use, material efficiency, waste management, and the potential for Industrial Symbiosis.

Additionally, at Chapter 5, disruptive sustainability scenarios and related resilience actions that companies can adopt to address these challenges are explored considering following disruption risk origins: new stricter environmental regulation, changes in consumer preferences, supply chain break, resources scarcity and corporate social responsibility.

Considering previous analysis, Chapter 5 finishes with the prioritization of environmental targets to support sustainability along supply chains, and further chapters address the following targets:

Chapter 6 details data and methodology to calculate corporate carbon footprint.

Chapter 7 describes Industrial Symbiosis benefits, data and functionalities of Industrial Symbiosis platforms needed to find opportunities and assess their feasibility, provides some real examples.

Chapter 8 proposes environmental KPIs to monitor and improve performance at lead companies (to be used from the corporate and product perspective), as well some examples of selected KPIs according to different typologies in supplier selection (machinery, raw materials, electricity and transport).

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1. INTRODUCTION

1.1 DELIVERABLE PURPOSE

The purpose of this deliverable, D1.3 “Energy efficiency & circularity”, is to analyze the requirements for assessing processes circularity, energy efficiency, carbon footprint, Industrial Symbiosis and other sustainability aspects of the supply chain. The supply chain is defined from raw materials extraction till the product is put on the market. It is developed environmental and circularity KPIs in order to select the best procurement alternatives from the assessed suppliers when a disruption or external event occurs.

Based on a sustainability context and use case sustainability requirements, the potential disruption scenarios and decision process are analyzed in order to select the best procurement alternatives, providing environmental Information requested by customers such as corporate carbon footprint or environmental product declarations. Then, the needed environmental and circularity data and related Indicators are defined.

Finally, this deliverable aims at identifying requirements and digital solutions that can support companies with the environmental life cycle management, and to prevent, or be ready to consider sustainability aspects or consequences when a disruption occurs, as an input for NARRATE technical implementations.

1.2 TASKS, DELIVERABLES AND MILESTONES

This deliverable considers the inputs from D1.2 and provides a deeper vision from the environmental perspective. It goes beyond regarding requirements and the parameters affecting sustainability. which is also core of the milestone MS2, and strongly related to those performed in D1.1 Project Requirements, reaching an architectural (T1.4) and energy efficient model (T1.3) in NARRATE.
It should be noted that the main objective in task T1.3 and reported in this deliverable is O1.4 Identification of potential regarding environmental sustainability & circularity from WP1.

1.3 STRUCTURE OF THE DOCUMENT

This report aims at providing a clear structure of the contents related to the activities performed in task T1.3 " Energy Efficiency, Circularity & Environmental Sustainability". Therefore, from this introduction and the methodology explanation, the next chapter presents Context analysis from two perspectives, policies-regulations and market trends. Then, after the extraction of sustainability related requirements previously identified at D1.2., a deep sustainability diagnosis has been designed and applied to pilot companies. After this, sustainability-related disruptive scenarios and related resilience actions have been drafted.

From previous results, the sustainability related IMC requirements are defined. Finally, further development on critical sustainability requirements is presented: corporate carbon footprint, Industrial Symbiosis and environmental management systems.

2. METHODOLOGY

To achieve the previous goals, the first step is to present current European drivers (policies and regulations) and market trends in sustainability. This will establish potential future scenarios with higher environmental requirements for companies, beyond the current ones that companies can identify.

After extracting from the general analysis, the sustainability requirements identified at T1.2, a deeper analysis is needed. A sustainability diagnosis has been developed to identify the supply chain needs to

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assess energy efficiency, processes' circularity, carbon footprint and other sustainability aspects. It is based on life cycle management, from the ecodesign perspective and production process mass balance.

The diagnosis is developed with the use case companies in two steps:

1. The questionnaire on market context diagnosis and ecodesign strategies to support the further identification of:

- Requirements and possible disruptions that affect the supply chain from a sustainability perspective, with the focus on the environmental part.
- Feasible product ecodesign strategies to improve the environmental impact in relation to the use (maintenance, repairability, reconditioning or updating) and end of life of your products or those of your clients (if B2B), and that could affect to the current or future activities of the company and analyse possible disruption scenarios derived from them.

2. A productive annual mass balance, where companies are requested to identify and quantify the main production processes, and associated inputs (resources, raw materials and energy) and outputs (waste, wastewater and air emissions). The annual mass balance at the diagnosis has 3 objectives:

- To identify potential problems for companies to complete it, since any environmental management system or most environmental assessment tools require quantification of environmental aspects, to develop the required environmental information (eco-labelling type III, corporate or product carbon footprint, etc.).
- Combined with the questionnaire, the balance will be used to have an initial overview of production processes and their environmental aspects, and to establish a prioritization based on the amount of each of them.
- Finally, to identify potential outputs, within the use case companies, that can be considered resources for other companies to find Industrial Symbiosis opportunities.

From the perspective of the sustainability context (market demand, regulations) and the specific use case diagnosis, the sustainability requirements are specified. Then, the sustainability related risk and disruption scenarios are drafted, and the related decision processes and resilience actions are identified.

Considering the environmental information to be integrated into an environmental management system, data needed to be collected and associated key performance indicators (KPIs) are specified. Two specific requirements were previously identified, and they will be horizontally considered:

- Industrial Symbiosis functionalities for the supply chain scope are identified. Besides the potential of digital technologies for tracking, tracing and mapping of secondary resources across the supply chain to support for circularity through Industrial Symbiosis will be analysed horizontally.
- Carbon footprint calculation is one of the pre-identified requirements. Thus, the main standards, related greenhouse gases (GHG) classification of industrial sources will be studied, and the scope of the calculator will be defined. The good delivery transport factors contributing to the related the carbon footprint and data needed to calculate the related emission factor are also included.

Finally, environmental KPIs that each company should consider for their corporate or product environmental management, and specific KPIs to select different typologies of suppliers is proposed. The relationship with sustainability reporting can be graphically seen below.

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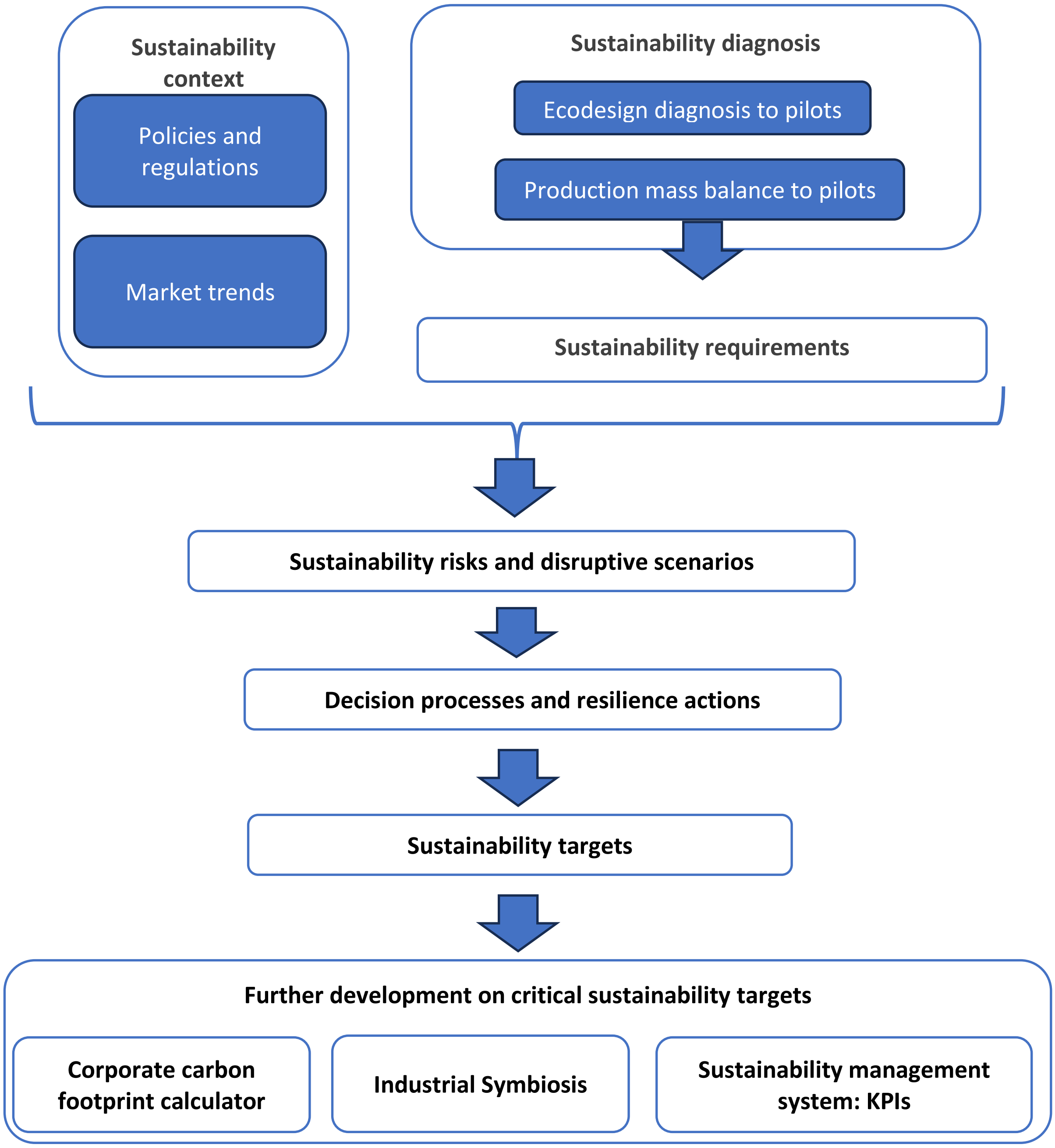

Figure 1: Methodology steps.

3. SUSTAINABILITY CONTEXT

The context of the companies determines most of the requirements affecting the sustainability of the supply chains that must or should be considered. These requirements may relate to technical and/or environmental properties, certifications or specific information flows. Supply chain disruptions and the assessment of related alternatives must consider sustainability issues and how the different changes may affect them.

To identify the key sustainability requirements affecting supply chains, the context is analysed from two linked perspectives: European regulations and market trends. Obviously, mandatory requirements in one sector or for certain companies, such as large ones, can generate a market trend in others.

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The diagram shown in Fig 2. summarises graphically the most relevant regulations and requirements found (in orange blocks) and those referred to market (blue blocks). The requirements are classified according to whether they are more related to products or if they mainly affect to companies, and in consequence they are considered from the corporate management.

Nevertheless, it should be noted that any corporate management of manufacturing industries, is only one phase of the product life cycle and should be considered as such from the product design stage. Consequently, these two boxes are connected by a discontinuous arrow, resulting in a global interdependence.

The large number of existing regulations does not allow to detail all of them. In some cases, only the main thematic regulation is shown and in others where there is not a unique law, such in the case of Ecodesign. most of the relevant regulations are surrounded by a discontinuous line representing the whole group.

All these regulations and market trends are presented in the following chapters and are linked to the requirements that affect the supply chain. These requirements, have the potential to generate major supply chain disruptions, especially if are new to companies or the market, or, on the other hand, if a supply chain disruption occurs, they should be considered when assessing alternatives.

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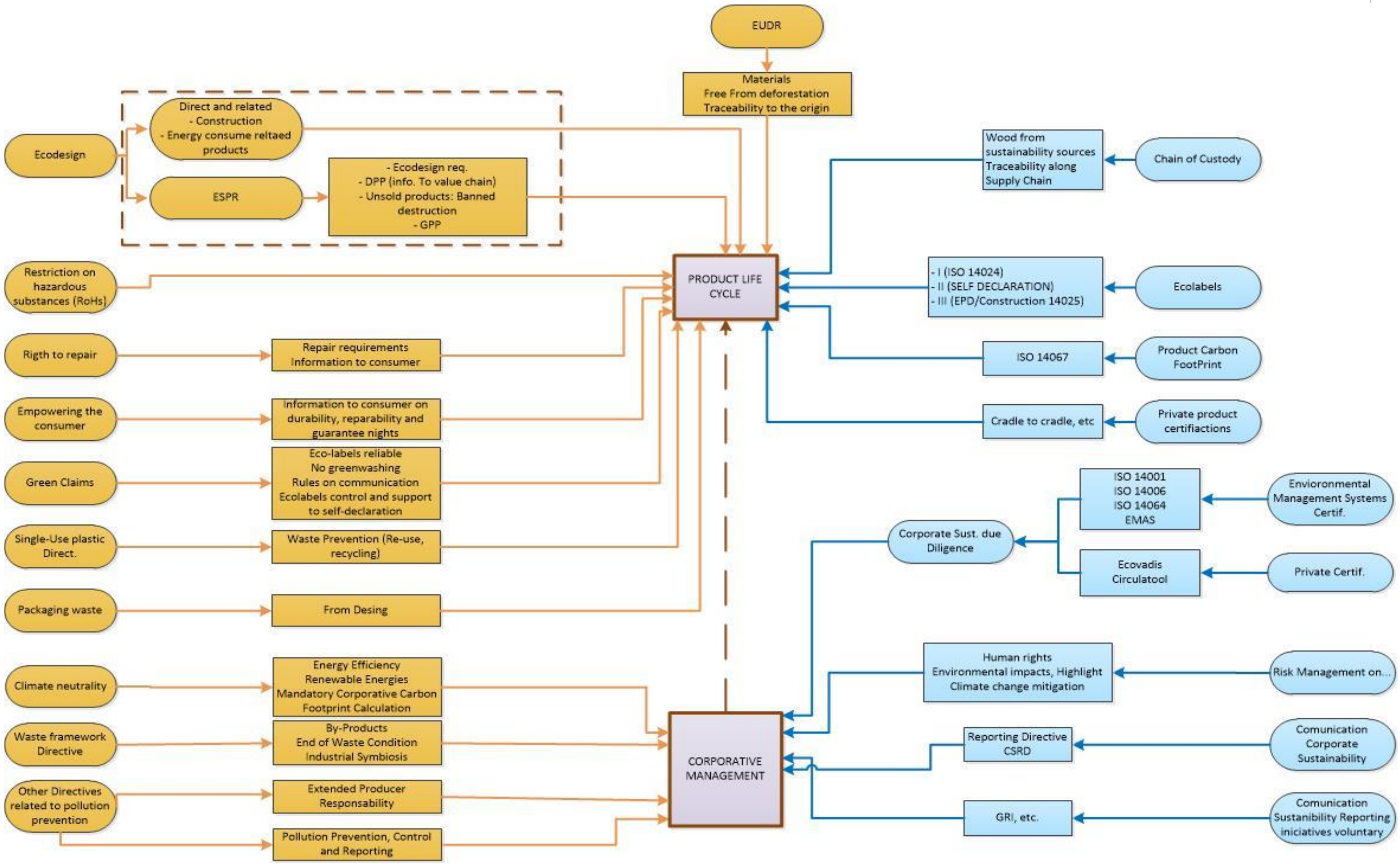

Figure 2: Context analysis: sustainability requirements derived from regulations and market trends (source: AIDIMME).

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3.1 EUROPEAN POLICIES AND REGULATIONS

The different European policies, regulations and procedures that are considered in NARRATE are:

- The European Green Deal
- The regulation to sustainable products
- The right to repair
- Plastics and packaging in the context of the European Green Deal
- The climate change and carbon footprint
- The Industrial Symbiosis
- The Extended Producer Responsibility (EPR)
- The Corporate-Sustainability-Due-Diligence Directive (CSDDD)
- The Corporate Sustainability Reporting Directive (CSRD)
- The European Deforestation Regulation (EUDR)
- REACH Regulation on the registration, evaluation, authorization and restriction of chemicals
- RoHS Restriction of Hazardous Substances in Electric and Electronic Devices Directive
- Other regulations: substances of concern

3.1.1 The European Green Deal

In December 2019, the EC published the Communication introducing the European Green DealL, which is the commitment of Europe to act on climate change and environmental-related challenges (1). It is a growth strategy that aims to transform the EU into a fair and prosperous society, with a modern, resource-efficient and competitive economy where zero net emissions of greenhouse gases will be achieved by 2050 and where economic growth will be decoupled from resource use.

It also aims to protect, conserve and enhance the EU's natural capital, and protect the health and well-being of citizens from environment-related risks and impacts. At the same time, this transition must be fair and inclusive.

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The Fig. 3 illustrates the various elements of the Green Deal.

Figure 3: The European Green Deal (communication from the Commission).

Several new regulatory initiatives and instruments support the Green Deal's objective of sustainable consumption. On the supply side, the Ecodesign for Sustainable Products regulation aims to prevent environmental impacts from the product design stage, incorporating the Digital Product Passport to provide necessary information along the value chain. Strategies include product reparability, supported specifically by the proposed Right to Repair Directive (2). On the demand side, the proposal for a Directive on Empowering Consumers for the Green Transition (3) helps consumers make informed purchasing decisions,

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strengthening the demand for repair services in the after-sales phase. This is complemented by the initiative on Substantiating Green Claims, supports the green transition through consumers purchasing choices and stops companies from making misleading claims about environmental merits of their products and services. Together, these initiatives cover the entire product lifecycle, complementing and reinforcing each other. In consequence, resilient and sustainable supply chains are key to achieving the goals they set.

3.1.2 Regulation to sustainable products

The Ecodesign for Sustainable Products Regulation (ESPR), which entered into force on 18 July 2024, is the cornerstone of the European Commission's strategy to promote environmentally sustainable and circular products (4). This regulation aims to enhance the sustainability of products placed on the EU market, focusing on their entire lifecycle from production to disposal (excluding certain items like food and feed as defined in Regulation 178/2002).

Replacing the Ecodesign Directive 2009/125/EC, the ESPR is a pivotal part of the 2020 Circular Economy Action Plan (CEAP) contributing to the EU's environmental and climate goals (5). Key objectives include doubling the circularity rate in material use and achieving energy efficiency targets by 2030. The regulation aims to improve the circularity, energy performance and overall environmental sustainability of products. It represents a significant step towards a more sustainable future, but its implementation and fulfilment will generate a huge number of potential disruptions in current supply chains.

The priority groups for the first working plan have been set in advance (unless there is a good reason to change them): iron and steel, aluminium, textiles (garments and footwear), furniture (including mattresses), tyres, detergents, paints, lubricants, chemicals, energy-related products (including new measures and reviews of existing ones) and ICT products, and other electronics. The first working Plan is expected to be published in the second half of 2025. Other remarkable new measures contained in the ESPR are:

- Rules to Address the Destruction of Unsold Consumer Products.
- Green Public Procurement criteria for EU authorities, potentially boosting demand for sustainable products.
- Digital Product Passport: that stores relevant information to support product sustainability, circularity, and legal compliance.

Integrating the ESPR into supply chains necessitates resilient and sustainable practices, as companies must adapt to new regulations without compromising operational stability. By focusing on the lifecycle of products, businesses can create supply chains that are more adaptive, circular, and energy-efficient, ensuring long-term sustainability and minimizing disruptions.

3.1.3 Right to repair: new consumer rights for easy and attractive repairs

The 'Right to Repair' proposal, part of the New Consumer Agenda and the CEAP, was announced on March 22, 2023. With this proposal the EC aims to make repairing an easy and attractive option for consumers. It tackles obstacles that discourage consumers to repair due to inconvenience, lack of transparency or difficult access to repair services. It therefore encourages repair as a more sustainable consumption choice (2).

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The proposal will ensure that more products are repaired under the legal guarantee, and that consumers have easier and cheaper options to repair products that are technically repairable after the legal guarantee has expired or when the good no longer works because of wear and tear.

The proposal introduces a new 'right to repair' for consumers, both within and beyond the legal guarantee:

- Within the legal guarantee, sellers will be required to offer repair except when it is more expensive than replacement.
- Beyond the legal guarantee, a new set of rights and tools will be available to consumers to make 'repair' an easy and accessible option. This will ensure that consumers always have someone to turn to when they want their products repaired, as well as will encourage manufacturers to develop more sustainable business models.
- Annex II contains the list of Union legal acts laying down reparability requirements, which includes Welding equipment according to Commission Regulation (EU) 2019/17846. In such regulation, the ecodesign requirements stablished in Annex II are:
  - Energy efficiency requirements on power source efficiency and idle state power consumption.
  - Resource efficiency requirements (spare parts, repair and maintenance information, etc.)
  - Information requirements.

The 'Right to Repair' proposal strengthens supply chain resilience and sustainability by promoting repair over replacement, reducing waste, and extending product lifecycles. This encourages circular economy practices and drives innovation in durable, repairable products, in line with sustainable consumption goals.

3.1.4 Plastics and packaging in the context of the European Green Deal

A key component of the Green Deal is the Circular Economy Action Plan (CEAP), which aims to redesign the way products are made and used, ensuring they last longer and are easier to reuse, repair, and recycle. This plan specifically targets plastic packaging, with the goal that all plastic packaging on the EU market will be reusable or recyclable in an economically viable manner by 2030. Additionally, the CEAP includes measures to tackle microplastics and increase the uptake of recycled plastics, setting requirements for recycled content in products to drive demand for recycled materials.

The new packaging waste regulations play a significant role in the Green Deal and aim to improve the sustainability of packaging through increased recycling targets and measures to reduce packaging waste. These regulations encourage the use of reusable packaging solutions and set specific recycling targets for all packaging materials, with a particular focus on plastic packaging.

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The impact of these regulations on businesses is profound. Companies are encouraged to innovate and invest in research and development to create sustainable packaging solutions. Supply chains will need to adapt to comply with new regulations and to incorporate more sustainable materials. While these changes may entail initial costs, they also offer significant opportunities for market growth and sustainability leadership. European companies that adapt quickly and effectively can gain a competitive advantage in the global market for sustainable products and packaging.

Despite the clear benefits, there are challenges to implementing these ambitious plans. Businesses face the cost of compliance and the need for technological advances in recycling and waste management. Ensuring consistent compliance across EU Member States and industries is also a challenge. However, the opportunities presented by the Green Deal, including market expansion and environmental benefits, far outweigh these challenges.

The CEAP enhances supply chain sustainability by requiring companies to innovate in sustainable packaging and recycling. Adapting to these regulations, while challenging, offers long-term environmental benefits and competitive advantages in the global market.

3.1.5 Climate change and carbon footprint

In the context of the European Union, the "Roadmap for Moving to a Low Carbon Economy in 2050" was approved in 2011 (6) and in 2019 emerged the European Green Deal. Following the launch of the European Green Deal, frameworks and strategies were established outlining specific actions and objectives in the fight against climate change.

Subsequently, the European Green Deal also led to the approval of the "Climate and Energy Framework for 2030" (7) (adopted in 2020, setting specific targets for the period 2021-2030) and the "European Climate Adaptation Strategy" (adopted in 2021). This ecosystem of plans and programs led to the approval of legislation such as the Regulation 2021/1119 (8) establishing the framework for achieving climate neutrality (also called "European Climate Law", which sets out a binding objective of climate neutrality in the Union by 2050 in pursuit of the long-term temperature goal set out in the Paris Agreement), or the CBAM (Carbon Border Adjustment Mechanism) established by the Regulation (EU) 2023/956 (9), which aims to put a fair price on the carbon emitted during the production of carbon intensive goods that are entering the EU, and to encourage cleaner industrial production in non-EU countries.

In accordance with the European Union's legislative framework, Member States have also had to establish national and regional action plans to achieve the objectives set. In Spain, for example, the Climate Change and Energy Transition Law (Law 7/2021, of May 20th, 2021) was approved (10). This law also led to the approval of the National Integrated Energy and Climate Plan (PNIEC) for 2021, which sets out the path to achieve national objectives in line with European strategies (11). Furthermore, Law 7/2021 already requires companies with more than 500 employees to calculate their carbon footprint (understood as a valuable tool for corporate management and minimizing the company's carbon footprint).

Derived national and regional policies and regulations are also encouraging SMEs to calculate and register their carbon footprint.

This multifaceted approach highlights the necessity of coordinated policies and the active participation of all sectors to achieve a sustainable, low-carbon future. However, the development of tools that enable companies to integrate the carbon footprint as a KPI in their daily management (at least in a simplified

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form initially) is essential. This serves as a starting point for the widespread adoption and normalization of the carbon footprint as a key consideration in the daily company operations.

The European Green Deal and related regulations require companies to measure and reduce their carbon footprint to combat climate change. These measures drive sustainability in supply chains and promote cleaner production practices.

3.1.6 Industrial Symbiosis

Industrial Symbiosis is an innovative approach to environmental management and the circular economy that promotes collaboration between different industries to optimize the use of resources and minimize environmental impact. This concept is based on the idea that waste or byproducts from one company can be used as raw materials by another, creating a closed cycle of materials and energy.

When establishing Industrial Symbiosis strategies, it is important to understand the applicable waste management legislation in advance. Directive 2008/98/EC on waste management (well known as the Waste Framework Directive) established a legal framework with the focus on the waste generation and prevention policies (12) as shown in Fig. 4, and explained below:

1. **Prevention**, which includes measures across all phases of a product's life cycle to minimize waste, environmental and health impacts, and reduce harmful substances, while promoting reuse and extending product lifespan.
2. **Preparation for reuse**, which is the recovery operation that includes the inspection, cleaning or repair of products or product components that have become waste, so that they can be reused without any other further transformation.
3. **Recycling**, which refers to processes that convert waste materials back into products or substances, excluding energy recovery and the use of materials as fuel or landfill.
4. **Recovery**, which refers to operations where waste is repurposed to replace other materials for a specific function, either within a facility or in the wider economy.
5. **Elimination** is any operation that is not valuation.

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Figure 4: Waste Hierarchy (European Commision).

Subsequently, Directive (EU) 2018/851 of the European Parliament and the Council, of May 30, 2018, introduced a series of modifications to Directive 2008/98/EC on waste, contemplating sustainable use of resources and Industrial Symbiosis. Indicating to this end that Member States must take appropriate measures to facilitate the recognition, as a by-product, if the harmonized conditions at Union level are met. In this sense, Industrial Symbiosis would be within the highest level of the waste hierarchy, preventing its production, and reintroducing resources into the productive sector.

Although it is necessary to consider legal obligations regarding the reuse of by-products (or production waste) in the production process, Industrial Symbiosis is an option to consider when looking for alternatives that represent a viable solution to manage possible disruptions in the supply chain.

Industrial Symbiosis optimizes resource use by repurposing waste between industries, aligning with EU waste directives. This approach enhances supply chain sustainability and resilience.

3.1.7 Extended Producer Responsibility (EPR)

The Waste Framework Directive sets the basic concepts and definitions related to waste management, including definitions of waste, recycling and recovery (12). The Directive also introduces the "polluter pays principle" and the "extended producer responsibility".

EPR is an environmental approach that places significant responsibility on manufacturers and producers for the entire lifecycle of their products, particularly for take-back, recycling, and final disposal. The primary goal of EPR is to reduce the environmental impacts of products by making producers responsible for the costs associated with the waste management of their products. Key objectives of EPR are:

- Waste Reduction: Encourage producers to design products that generate less waste.
- Resource Efficiency: Promote the use of fewer raw materials and greater recycling and reuse.

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- Cost Allocation: Shift the financial burden of waste management from taxpayers and municipalities to producers.

It is crucial to consider EPR obligations when managing supply chains, given their importance in administrative management of customs requirements for imports or exports. Extended Producer Responsibility (EPR) shifts waste management costs to producers, encouraging waste reduction and resource efficiency. This approach is crucial for supply chains management, as it affects customs requirements for imports and exports.

3.1.8 Corporate-Sustainability-Due-Diligence Directive (CSDDD)

On 23rd February 2022, the EU Commission proposed the Corporate Sustainability Due Diligence Directive (CSDDD), that has been recently approved and will entry into force 25th July 2024 (13). Member States will have two years to transpose the Directive into national law. One year later, the rules will start to apply to companies, with a gradual phase-in between 3 and 5 years after entry into force.

The aim of this Directive is to foster sustainable and responsible corporate conduct in companies' operations and across their global value chains. The new rules will ensure that covered companies identify and address the adverse human rights and environmental impacts of their activities inside and outside Europe.

This Directive establishes a Corporate Due Diligence Duty. The core elements of this duty are identifying and addressing potential and actual adverse human rights and environmental impacts in the company's own operations, their subsidiaries and, where related to their value chain(s), those of their business partners (for example, suppliers, sales, transport, distribution, storage, and waste-management).

In addition, the Directive sets out an obligation for large companies to adopt and put into effect, through best efforts, a transition plan for climate change mitigation aligned with the 2050 climate neutrality objective of the Paris Agreement as well as intermediate targets under the European Climate Law.

Companies may need to implement new or update their current risk management program to better manage the risks related to environmental and human rights issues. These procedures tend to take time. Therefore, companies should start as soon as possible to determine whether the business may fall within the scope. Review the company's risk assessment to identify where the wider business operations might be impacted. Make sure to look across the entire value chain/chain of activities, including the subsidiaries.

This applies to large EU limited liability companies and partnerships companies and even large non–EU companies. The Directive contains provisions to facilitate compliance and limit the burden on companies, both in scope and in the value chain.

Micro companies and SMEs are not covered by the proposed rules. However, the Directive provides supporting and protective measures for SMEs, which could be indirectly affected as business partners in value chains.

In conclusion, the Corporate Sustainability Due Diligence Directive (CSDDD) aims to enhance corporate responsibility by requiring companies to address human rights and environmental impacts across their value chains. It will necessitate updates to risk management programs and transition plans for climate goals, with a focus on large companies.

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3.1.9 Corporate Sustainability Reporting Directive (CSRD)

EU law requires all large companies and all listed companies (except listed micro-enterprises) to disclose information on what they see as the risks and opportunities arising from social and environmental issues, and on the impact of their activities on people and the environment. This helps investors, civil society organizations, consumers and other stakeholders to evaluate the sustainability performance of the companies, as part of Green Deal Europe.

The CSRD entered into force January 2023 (14). It modernizes and strengthens the rules concerning the social and environmental information that companies must report. A broader set of large companies, as well as listed SMEs, will now be required to report on sustainability. The first companies will have to apply the new rules for the first time in the 2024 financial year, for reports published in 2025.

Reporting costs for companies will be reduced in the medium to long term by harmonizing the information to be provided. Companies subject to the CSRD will have to report according to European Sustainability Reporting Standards (ESRS). The standards are developed in a draft form by the EFRAG (European Financial Reporting Advisory Group). The first set of ESRS was published in the Official Journal on 22 December 2023 under the form of a delegated regulation. They are tailored to EU policies, while building on and contributing to international standardization initiatives. The CSRD also requires assurance on the sustainability information that companies report and will provide for the digital taxonomy of sustainability information.

The CSRD strengthens supply chain resilience by requiring large and listed companies to report detailed social and environmental impacts. Standardizing this reporting through ESRS enhances transparency and helps companies better manage risks and sustainability across their supply chains.

3.1.10 European Deforestation Regulation (EUDR)

EUDR aims to prevent the importation and sale of products in the EU that contribute to deforestation and forest degradation (15). The regulation comes into effect in January 2025 and has significant implications for the furniture industry. The EUDR requires companies to ensure that products placed on the EU market are not linked to deforestation, illegal logging, or forest degradation. Companies must conduct thorough Due Diligence to verify the legality and sustainability of their supply chains.

Furniture manufacturers and importers must establish robust Due Diligence systems to trace the origin of their wood products and ensure they are legally and sustainably sourced. The companies must maintain transparency in their supply chains and provide documentation to demonstrate compliance with the EUDR. The Due Diligence system must include a risk assessment and mitigation plan for each covered material purchased. Non-compliance may lead to significant penalties, loss of market access, and damage to brand reputation.

In consequence, companies must implement thorough Due Diligence systems, maintain transparency, and provide documentation on the sustainability of their supply chains, thereby enhancing both resilience and sustainability. Therefore, companies will need to proactively assess and mitigate the risks associated with their supply chains.

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3.1.11 Other regulations: substances of concern.

There are many other regulations that manufacturers need to consider when designing and managing their supply chains. These regulations include both horizontal and product´s specific requirements or restrictions. Most of the regulations are related to substances of concern. In this chapter we can mention REACH and RoHS. REACH is a horizontal regulation on hazardous substances that affects all sectors, and RoHS is one of the best well known for specific products (Electric and Electronic Devices) and affects one of our pilot demonstrators.

The Regulation on the Registration, Evaluation, Authorisation and restriction of CHemicals (REACH) is the main EU law to protect human health and the environment from the risks that can be posed by chemicals. The REACH Regulation (EC 1907/2006) entered into force in 2007 and has since evolved to reflect advances in knowledge about various chemicals and their properties (16).

This is done through better and earlier identification of the intrinsic properties of chemicals and through measures such as phasing out or restricting substances of very high concern. REACH also aims to promote innovation and the competitiveness of the EU chemicals industry.

REACH places responsibility on industry to manage the risks from chemicals and to provide safety information on the substances. To that end, manufacturers and importers are required to gather information on the properties of their chemicals and to register that information in a central database in the European Chemicals Agency (ECHA). The Agency is the central point in the REACH system: it manages the databases necessary to operate the system, coordinates the in-depth evaluation of the information provided on chemicals and runs a public database where consumers and professionals can find hazard information.

REACH ensures supply chain resilience and sustainability by requiring companies to manage chemical risks and provide safety information. By requiring registration and evaluation of chemicals, it promotes safer practices and innovation while protecting human health and the environment, which must be considered when managing supply chain disruptions.

Restriction of Hazardous Substances in Electric and Electronic Devices Directive (RoHS) (Amendment proposed in December 2023) Directive aims to prevent the risks posed to human health and the environment related to the management of electronic and electrical waste (17).

It does this by restricting the use of certain hazardous substances in EEE that can be replaced by safer alternatives. These restricted substances include heavy metals, flame retardants or plasticizers. The RoHS Directive currently restricts the use of ten substances: lead, cadmium, mercury, hexavalent chromium, polybrominated biphenyls (PBB) and polybrominated diphenyl ethers (PBDE), bis(2-ethylhexyl) phthalate (DEHP), butyl benzyl phthalate (BBP), dibutyl phthalate (DBP) and diisobutyl phthalate (DIBP).

The Directive promotes the recyclability of EEE, as EEE and its components, when become waste, contain hazardous substances. At the same time, it ensures a level playing field for manufacturers and importers of EEE in the European market. By limiting toxic substances and promoting recyclability, it improves the sustainability of the supply chain and ensures fair competition in the EU market. This must be considered when enhancing the resilience of the supply chain.

3.2 MARKET TRENDS

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This chapter aims to highlight the relevance of market trends in sustainability that affect how companies consider customers commitment to these social and environmental values, by communicating their commitment (green claims).

In the same way as regulatory requirements, market requirements can apply to companies (corporate management) or to their products. In order to demonstrate this commitment, companies need to obtain the environmental information, ensure that they have the supporting documental evidence to make these green claims or even to obtain certain environmental certifications.

This may affect part or all the supply chain, and in the event of a disruption, the documents and purchasing environmental criteria for raw materials from alternative suppliers, subcontracted activities, etc. must continue to preserve the validity of these green claims.

However, to highlight the importance of environmental communication to consumers, there are two important Directives proposed that focus on this issue and have therefore been included in this chapter, instead of the previous one:

- Directive on Empowering Consumers for the Green Transition (18)
- Proposal Directive on green claims, aimed to fight against greenwashing. Specifically, this Directive will have a great impact on supply chain due to the required independent verification based on evidences that should be collected in most cases along the supply chain (19).

3.2.1 Empowering the consumer for the Green Transition

The new Directive on Empowering Consumers for the Green Transition will ensure that consumers are better informed at the point of sale about the durability and repairability of goods and about their legal rights under guarantee. It will also strengthen consumer protection rules against greenwashing and early obsolescence practices. It will make EU horizontal consumer legislation better suited to the green transition and will support the changes in consumer behaviour needed to achieve the climate and environmental objectives of the European Green Deal.

The proposal was announced in the New Consumer Agenda (20) and the CEAP (5). By September 2025, the Commission shall specify the harmonised label on commercial guarantees of durability offered by producers and of the harmonised notice on the legal guarantee. Member States will then have until March 2026 to transpose the Directive that will apply from September 2026.

3.2.2 Proposal on the Directive on Green Claims

A Commission study from 2020 highlighted that 53.3% of examined environmental claims in the EU were found to be vague, misleading or unfounded and 40% were unsubstantiated (21). The absence of common rules for companies making voluntary green claims leads to 'greenwashing' and creates unloyal competence against genuinely sustainable companies.

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The Green Claims directive (19) aims to fight against greenwashing and misleading environmental claims, giving consumers greater clarity, confidence and better information to help them choose environmentally friendly products and services. Companies will also benefit, as those who make a genuine effort to improve the environmental sustainability of their products will be more easily recognized and rewarded by consumers and will be able to boost their sales.

Besides the stablished minimum rules for how companies must communicate and substantiate their green claims about their products or services, such claims will need to be independently verified and supported by scientific evidence. As part of the scientific analysis, companies will identify the environmental impacts that are relevant to their product, as well as identifying any possible trade-offs, to give a complete and accurate picture.

It covers all voluntary claims about the environmental impacts, aspects or performance of a product, service or the trader itself. However, it excludes claims that are covered by existing or forthcoming EU rules, such as the EU Ecolabel or the DPP, as regulated claims are considered reliable.

There are currently at least 230 different labels and there is evidence that this leads to consumer confusion and distrust. As well as setting general rules for ecolabels, the proposal will also regulate environmental labels: new public labelling schemes will not be allowed, unless they are developed at EU level, and any new private schemes will have to be more environmentally ambitious than existing schemes and will need to be pre-approved to be allowed.

The proposal for a Green Claims Directive is now awaiting approval by the European Parliament and the Council.

3.2.3 Market awareness

Energy efficiency and circularity are commonly and widely recognized by the European and global market under the disciplines of environmental and sustainability management. Consumers with their expectations and the European Community with the last directives and guidelines previously explained, are conditioning the market and triggering many interesting changes related to sustainability, affecting the supply chains as a whole. Keeping the requirements along the supply chain to be able to communicate these messages even in case of disruptions is important to conserve consumer confidence and to comply with new Green Claims Directive.

Here are a few examples that illustrate the relevance and current effort of companies to communicate the environmental benefits of their offer to consumers, in order to be chosen over their competitors.

Table 1 Upcycling and recycling initiatives.

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 Ecoalf: Project “Upcycling the Oceans”. Marine waste as raw material. (22)	The goal was to create the first generation of fashion products made from recycled materials with the same quality, design, and technical properties as the best non-recycled products. Once collected, the marine waste is sent to recycling plants where a continuous filament is produced that meets the purity conditions required by Ecoalf. The resulting thread is used to produce fabrics with the same quality and design as top-of-the-range non-recycled materials, and is used to make various types of textile and footwear products: coats, T-shirts, bags, sneakers... being this the company main activity.
SAICA - Natur Cycle Plus - Recycling of low-density polyethylene. “Sustainable solutions for paper and corrugated cardboard packaging and their subsequent recovery”. (23)	The project involves the production, through various controlled processes, of a high-performance granulate (plastic material obtained from recycled materials, usually in the form of pellets), capable of replacing virgin granulate (derived from petroleum) and with a high degree of processability to create flexible packaging solutions.
 Lehigh Technologies (24)	The company processes use tires and other rubber waste, resulting in micronized rubber powder, which can be reused to produce tires, plastic, asphalt, and construction material.

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 ENERKEM (25)	It is a Canadian company that uses waste to fuel cars. The non-recyclable waste contains carbon. *Enerkem's* tool extracts this carbon and converts it first into gases, and then into methanol and ethanol. These two components can be used in thousands of everyday products. In this way, the Canadian city of Edmonton reuses 90% of its waste.

Table 2 Substitution of plastics by renewable materials

 CanCollar (26)	*CanCollar* is a product of WestRock, a global company that offers sustainable differentiated packaging solutions to its customers. To reduce the environmental impact of its products, Coca-Cola decided to change the packaging of its cans. It replaced the plastic ring carriers and film with cardboard, increasing the use of recycled materials and reducing the use of unnecessary virgin plastics.
Cannuccella Eco Design Product NO PLASTIC STRAWS (27) 	The straws are made with a recipe that combines durum wheat semolina and water with a special process that allows to obtain an ecological straw that is a perfect replacement of plastic straws. *Cannuccella* rise from the ground and come back to the ground leaving no traces, but feeding the life: a cradle-to-cradle model.

Table 3 Design for recycling initiatives

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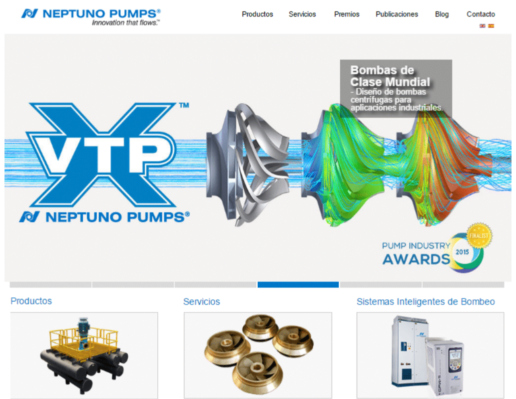
 RecyclableBlade	Siemens Gamesa has designed *RecyclableBlade*, the world’s first wind turbine blade that can be recycled at the end of its life cycle, and ready for commercial use in the offshore wind industry. This technology allows blade's components to be separated at the end of their life and the materials recycled for new applications.
 Neptuno Pumps, Chilean company specializing in propulsion pumps made from recyclable material.	The company designs its equipment to be easily disassembled, so that most of the critical and expensive parts can be reused and recycled, reducing the cost of remanufacturing and ensuring that the pumps are robust enough to withstand multiple use cycles. This has enabled the company to offer products at 60% - 70% of their original price, with the same warranty as new products.

Table 4 Functional economy business models

 Drivy: Rent out your vehicle when you're not using it. (30)	This model allows you to rent out your vehicle when you're not using it and has become the largest car-sharing service in Europe, with 2 million users and over 50,000 cars in six countries. Its app allows drivers to find a car near their home, unlock it with their smartphone, and start driving. It uses a daily rate, "not by the minute or by the hour." It helps to reduce traffic congestion in cities and free up streets from parked vehicles, making it possible to create more green areas, pedestrian zones, or bike lanes.

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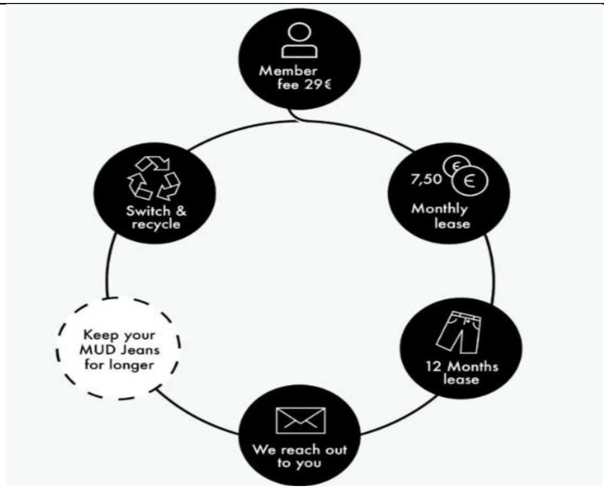 Mud Jeans, Rent eco-friendly cotton pants. (31)	Mud Jeans (a textile company known for making its denim garments ethically and from recycled material) launched a rental service for its garments, allowing users to rent them and ensuring their subsequent recycling.
 Circular economy Web Placement for refurbished tools (32)	At ADEO companies the circular economy makes sense, as demonstrated by the concrete examples: In Italy, tools from the Dexter range can be hired for 5 €/day in Leroy Merlin store in Milan, being the hammer drill the most popular since many buildings nearby are made of reinforced concrete. In France, Leroy Merlin in Blois offers a number of solutions, such as rental, repairs and also the sale of secondhand products. In Spain, items bought over the internet and returned in-store are recovered and sold as secondhand goods.

Table 5 Life span extension and second life

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CIRCULAR HUB (33)		To extend the lifespan of its products (thereby reducing their environmental impact), IKEA launched this initiative aimed at repairing and reselling its products once the original user decides to dispose of them.
Dynamic Pricing to encourage the consumption of products before expiring (34)		Wasteless, together with Finiper and Gruppo Amadori (…) launches in Italy the project at the Iper La Grande shop in Milano Portello: a price calculation and management system able to increase the profits of the shop, reducing waste and helping to manage perishable food stocks. Expiring Date could be introduced as part of Bar Coding and managed by distributor IT system to optimize selling of "products close to expiring" and reduce waste.
Circular economy Web placement for used industrial equipment or furnishings (35)		Equipment or furnishings that no longer have a use in a kitchen or restaurant can be uploaded to the portal by Camst group employees and find a new life in other kitchens or restaurants in our company, thus avoiding being turned into surplus for disposal.

Table 6 Environmental information to facilitate green purchasing

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Visual indicator that's easy to identify and understand multiple environmental parameter (36)	Home Index by ADEO Launched in 2022 at Leroy Merlin France, Home Index marks a major first in the home improvement sector. Home Index makes it possible to mark a product from A (the best score) to E (the lowest) depending on its environmental and social performance.

Previous tables include different examples of circular economy initiatives at the market, and we can identify several typologies of circular economy initiatives that different companies have communicated to the society, not only to their customers.

The first and second types are related to the implementation of recycling processes to obtain a recycled material that can be used in several applications or the substitution of plastic elements with alternative materials that are considered more sustainable.

In those cases, market and even regulatory drivers, cause disruptions in the supply of raw materials, such as materials shortage and the resulting high price volatility. Besides, the change in the production process coming from the use of different materials or the resulting element can derive in unexpected performance of the final products, resulting in disruptions at the distribution or use phase, that will affect the supply chain. Quality control of raw materials and production processes is particularly relevant when considering recycled materials, since the starting waste used (and even more so when if they are post-consumer wastes) can have a great diversity of properties and contaminants due to their diversity and variability over time. Disruptions on their supply, returning for example by reverting to virgin plastic, may result in the payment of taxes and changes to reporting requirements that should be considered.

On the other hand, strategies based on life span extension may generate new needs for companies such as additional services after the products are put on the market such as repair services (by the manufacturer or partners), create dismantling protocols to be shared with waste managers, specific collection systems, etc. Also, second life business models can experiment disruptions due to strong fluctuations in stocks and workload, or specific parts scarcity, depending on the number of returned products/parts (to be checked, reconditioned and put again on market) and the demand of reconditioned/remanufactured products.

New business models based on the economy of functionality or servitization (pay-per-use and not for product ownership), depend strongly on fluctuations in demand, and picks of demand may require researching companies to subcontract this excess without affecting the quality of the service offered.

Finally, and very relevant due to the new regulations coming into force in brief, any environmental information given to the consumer must be in a near future supported and verified based on documental evidence. This implies to check thar any change along the supply chain (for example by subcontracting activities or change of raw material supplier) does not change the key parameters affecting the green claim provided, and we can demonstrate them.

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3.2.4 ISO standard role

To better understand the sustainability in the current market context, the knowledge of the changes along the last decades should be considered, guided by the international standards.

Environmental Management System (EMS) requirements are defined by ISO 14001 (37), first issued in 1996 with the purpose of providing a certification scheme for those companies that want to minimize negative impacts on the environment, comply with applicable laws, regulations or other environmental requirements and ensure continual improvement of the above. A few years earlier, the European Commission had launched its EMAS scheme with the same purpose. These standards have been developed and applied using a risk management and PDCA approach, and their ultimate purpose is to demonstrate the capability of the company to properly manage risks and environmental impacts and are not related to products as such.

More oriented to the B2B market, environmental management certifications and corporate sustainability corporate reporting play an important role boosting the improvement of the sustainability management and its communication. Their scope is corporate management and affect positively the reputation of those companies in the market.

The need to assess and communicate the products environmental sustainability to enable clients and consumers in the position to do responsible choices, comes late with ISO 14020-14025 (38). Some years earlier, the European Commission had launched its Ecolabel scheme (according to ISO 14024) where testing and quality control are promoted to improve transparent communication and consumer market trust on products with best environmental performance (39).

Certified environmental product declarations (according to ISO 14025, Type III ecolabelling programmes) are increasingly requested. Figure 5 shows the evolution of these product declarations in the construction sector, which is one of the most demanding sectors for these environmental reports, based on the results of Life Cycle Assessment (LCA) studies.

LCA is a well- known methodology to assess the product impact “cradle to grave” or “cradle to cradle” where applicable, and it is also supported by ISO standards (ISO 14040, ISO 14044). This methodology gives a clear figure of the impact of each product and can be used to assess potential changes, to compare alternative products or to assess the results of a proper ecodesign process. Consumer ecolabels such Type I (certified ecolabels according to ISO 14021 distinguishing products with predefined environmental properties) and Type II (environmental self-declarations according to ISO 14024) also have a standardisation support.

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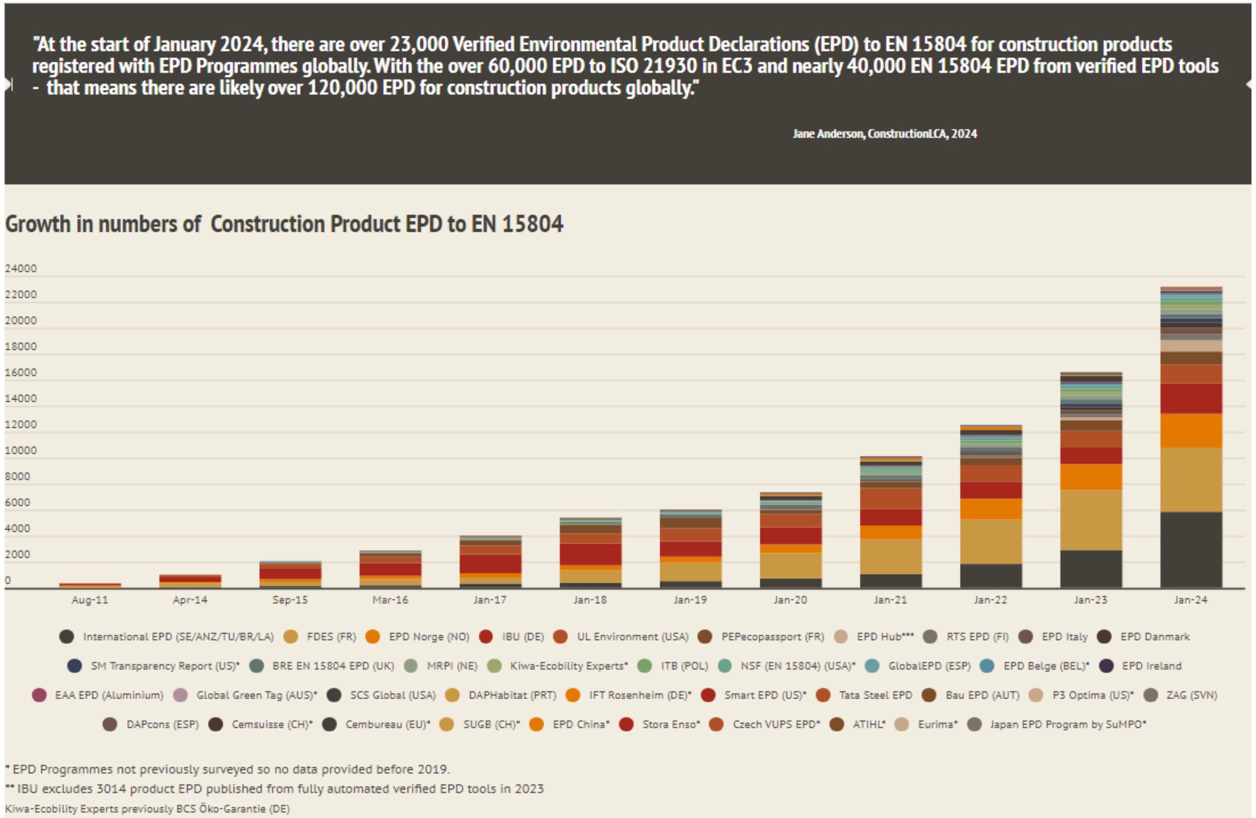

Figure 5: Evolution of construction products´s EPD published. (eco-platform).

Considering ISO standards and certification of corporate management systems, it is relevant to highlight that in February 2024 ISO has introduced an additional and mandatory requirement in ISO 14001 for the context analysis, where "The organization shall determine whether climate change is a relevant issue". This is a clear demonstration of how ISO standards are updated considering environmental as critical factor for each organization.

More popular is ISO 14064 that was designed as guidance for quantification and reporting of greenhouse gas emissions and removals (40). This standard helps any kind of organization to calculate and communicate its global environmental impact in terms of total carbon dioxide emissions. The advantage of this scheme is its flexibility and the ability to compare organizations even if they have different products and services.

In 2023, ISO finally issued a new standard (ISO 14068) which provides principles, requirements, and guidance for achieving and demonstrating carbon neutrality (41). It focuses on quantifying, reducing, and offsetting carbon footprints, using a hierarchical approach prioritizing direct and indirect GHG emission

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reductions and removal enhancements within the value chain over offsetting. This standard is essential for entities committed to carbon neutrality, supporting sustainable development and transition to low GHG emission activities. It ensures that carbon neutrality efforts are true, fair, scientifically valid, and transparently communicated.

The reason why ISO Standards have been considered to analyze the market context is because of the strong role of international standards in business-to-business relationship management and also due to their international application. The promotion and training role that technical regulations can provide for many companies in all countries of the world should also be noted. When they come market requirements, not having the related ecolabel (for products) or environmental management certification (corporate management) can result in significant disruptions to the supply chain.

3.2.5 Certifications of source traceability for materials

The relevance of sustainable sourcing materials is clearly stablished. But from the origin to the consumer, the material is transformed several times and the confidence in certified traceability systems is the only way to ensure the consumer the origin of responsible obtained materials at the final product they are buying. One of most important of those systems in the market, affecting wooden and derived products, are the Chain of Custody Certifications (CoC).

CoC is a critical component in ensuring that products, particularly those derived from forests, are sourced responsibly and sustainably. CoC certification tracks the journey of raw materials from their origin in the forest, through the supply chain, to the final product sold to consumers. Here are the key certifications relevant to the furniture industry:

- Forest Stewardship Council (FSC).
- Programme for the Endorsement of Forest Certification (PEFC).

Furniture manufacturers using wood certified by CoC must follow strict tracking protocols to ensure compliance, which can improve their reputation and appeal in sustainability-focused markets. Any supply chain disruption deriving into the need for an alternative supplier of those materials must be checked and their documentation controlled to ensure the fulfilment of CoC systems. On the other hand, those certification schemes can prohibit the use of wood coming from specific origins (such as war scenarios), generating in turn supply chain disruptions.

3.2.6 Supplier qualification.

To support the use of both, EMS and Environmental Labels, several brands and supply chain leaders have adopted a qualification and audit system expanding the environmental requirements to suppliers. Suppliers' qualification, which was originally performed internally, is now supported by private third party's whit specific tools designed to cover several disciplines and to consider also best practices: Chain of Custody certification or ECOVADIS is an example of this approach.

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ECOVADIS, based in Paris in 2007 has grown to become the world's largest and most trusted provider of business sustainability ratings, creating a global network of more than 130,000 rated companies (42). Each organization could assess itself following a rating/scorecards methodology principles of Sustainability/CSR are evaluated confidentially through documented and proof declaration considering environmental, labour and human rights, ethics and sustainable procurement.

3.3 CONCLUSIONS FROM SUSTAINABILITY CONTEXT

Sustainability is an important vector by companies to consider. Most of the changes and pressures come from new policies and regulations derived from CEAPs (first published in 2015) and more recently by the European Green Deal.

There is an important strategy affecting manufacturing industries focused on sustainable production and consumption. Main representative regulation is the ESPR, connecting the ecodesign with the Digital Product Passport (DPP). We must highlight the huge effort the EC is making at the use stage of the products. DPP is a communication tool, reinforced by other two new proposed directives focused on empowering consumers by communicating in a reliable way environmental properties of the products. Together with the Right to Repair proposal, they form a strong pack to reinforce consumers.

Also, market trends are reflecting the regulatory pressure asking for more environmental certifications to grant the products and services they consume are more sustainable. In this sense, the control of green claims is very important since the explosion of private "green" labels and affirmations without clear or reliable support are generating more confusion in the consumer, and a certain lack of confidence due to the greenwashing. On the contrary, regulated labels such as the energy label for home appliance, ICT products, industrial machinery or tyres, have demonstrate their great usefulness to consumers at the purchase of those goods.

4. SUSTAINABILITY DIAGNOSIS

This chapter develops an environmental sustainability diagnosis methodology to identify in more detail main environmental aspects for companies, the actions they have already implemented and the potential ones to improve their environmental performance and to prioritize them.

The diagnosis is applied to the different pilots, and results are analysed to extract horizontal conclusions and sustainability requirements, that together with the context (regulatory and market), are the base to next chapter, to define sustainability disruptive scenarios and related potential associated decisions and resilience actions.

4.1 SUSTAINABILITY DIAGNOSIS DESIGN

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The design of the diagnosis is based on considering the current context from the 3 pilots, which is totally different, to identify the requirements on sustainability issues, that would allow the companies to be more resilient in case of potential disruptions.

The diagnosis is divided in two parts, a questionnaire (see template in ap1.1 Ecodesign questionnaire template) considering the context of companies and their communication strategy along the supply chain (from providers to customers) and a second part structured according to the different ecodesign strategies along the life cycle of their products. Ecodesign perspective have been selected due to the explained relevance of new ESPR regulations and because from the life cycle thinking perspective, all the stages, included the most traditional corporate management (production), are considered in a clear structured way.

In this second part, they are asked in which areas they have yet work and what they do, and where they can see a higher potential to improve. Mainly from the potential ecodesign actions the requirements are specified.

Ecodesign strategies considered are summarise in the following way:

- Raw Materials (including packaging)
  - Green purchasing policy and related management system
  - Recycled materials
  - Renewable materials
  - Materials with low embodied energy
  - Non-use or reduction of hazardous substances
  - Due diligence system (to know the origin of specific materials and avoid non allowed)
  - Product and packaging weight reduction: (avoid superfluous components, use light materials, optimize design of parts …)
  - Ecolabelled/certified materials
- Raw materials supply
  - Distance from providers (raw material manufacturer)
  - Environmental certifications from provider management
  - Other environmental practices from provider
- Productive process
  - Energy: control and reduce energy demand

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    - Energy: use of renewable energy
    - Water: reduction of water demand
    - Material efficiency: reduction of non-hazardous waste generated
    - Material efficiency: reduction of hazardous waste generated
    - Wastewater: reduction of effluents volume, reduce specific contaminants
    - Emissions: reduce specific contaminant emissions (VOC, etc.)
    - Waste management: increase recycling rates by contracting proper waste managers
    - Potential to internal recovery/valorization of raw materials
    - Find secondary resources providers
    - Find secondary resources customers
- Efficient distribution
    - Low consume-GHG emission vehicles
    - Load efficiency (delivery unit design compacted, max number of deliveries by trip)
    - Routes optimization to reduce distance travelled
- Use
    - Functional optimization (customer based- design thinking)
    - High energy efficient product (if applies)
- Use life extension
    - High durability (free extra guarantee)
    - Easy cleaning/maintenance
    - Modular structure (adaptability to changing requirements)
    - Technical upgradability (additional service)
    - Easy to repair

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- Availability of replacement parts over the legal period (10 years after the product is no longer manufactured)
- Maintenance or repair as a service (predictive maintenance by IoT, available professional partner near customers,)
- Product as a service: renting, pay per use business model

o End of life

- Remanufacturing: recovering old products from customers to manufacture new ones from them (or from non-sold ones). Potential connection with servitization/upgradability services
- Design for easy dis/reassembly
- Hazardous components and critical material content is informed, and their recovery is facilitated from design
- Easy material separation of recyclable materials
- Avoid multi-materials (non-easy to recycle)
- Feasible energy valorization of non-recyclable materials

Besides the questionnaire, a *process diagnosis table* has been developed to assess the capacity of companies to identify and quantify their input and output, and which problems they find to achieve this information from their internal systems. The table has mainly 3 chapters (process, inputs and outputs), and pilots were requested to identify to each process (grouping unitary operation as they consider significant) the related inputs and outputs of materials, energy sources (electricity from different origins, fuels) and outputs of each type of waste, wastewater and atmospheric emissions. Then they were requested to quantify them indicating the amount and used units (preferably in kg).

Input flows were classified as main raw material or auxiliary materials (not part of final product, such as cleaning solvents, etc.). And to identify if the source was external or internal, representing thus, an internal valorization. Regarding output flows, quantification is hard except in waste, which is one of the major interests in NARRATE, because relates to potential Industrial Symbiosis actions. For this reason, regarding this typology of output, additional information such a description of its condition and pictures and current final treatment were requested.

The ability to collect this information in an accurate and easy way is essential to any environmental management system. To develop any environmental information or an improvement action plan, first, environmental aspects should be quantified and assessed to identify significant ones and further it is needed to control them to check their positive evolution. Regarding products, the environmental information of manufacturing processes is also used to ecodesign process, to develop requested information from customers such Environmental Product Declarations (EPD) or Product Environmental Footprint (PEF).

The quantification would also support on priorate input and output flows and to identify potential Industrial Symbiosis interests.

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4.2 SUSTAINABILITY DIAGNOSIS RESULTS

The resulting ecodesign questionnaire template and diagnosis answers to both parts (questionnaire and mass balance) from each pilot are presented in Appendix 1. Sustainability diagnosis results.

In this chapter the results are presented and conclusions discussed with companies to have a better understanding of the context and their relevance, and some answers were recalculated or reformulated in a proper way, and additional inputs from the interviews are included in following diagnosis results.

4.2.1 Pilot #1 - Furniture industry - MEDWOOD

In this chapter, the conclusions regarding the ecodesign questionnaire and diagnosis from MEDWOOD are presented (see complete answers in ap1.2 MEDWOOD Ecodesign questionnaire and in ap1.3 MEDWOOD Process diagnos). MED produces furniture for children as well as child support pieces, leading the Spanish market and positioned in the fourth place as largest children furniture manufacturer at European Level.

MEDWOOD (MED) has transform its business model from MICUNA recently, and even they currently do not design because they do not own the products they manufacture, they have the staff from the technical office to make product development. Besides, the associated company MICUNA FAMILY BRANDS (retailer from the familiar holding, keeping the trademark "MICUNA") is their main customer, indeed makes the product design and MED manufactures, but as well they have other customers in furniture arena. MED manages a wide variety of suppliers making a big challenge to have a proper reaction when a disruption occurs becoming competitive in the market.

Main environmental aspects considered in their products are the sustainable origin of the wooden materials, certified with PEFC; the use of water-based coatings, and the design of high-quality products that are evolutive and multifunctional. Those are the requirements transferred to their provider, because they come from market. Provider proximity is appreciated, and this comes more from their historical evolution (second generation of a familiar company), but most important selection criteria is quality-price relationship.

Quality is the main distinctive aspect from MED products, but the others (sustainable materials and evolutive multifunctional furniture), are also well communicated and appreciated by the market and use to be requirements from specific clients (mainly big retailers). Main communication channels are web and social media. The PEFC certification can be considered an ecolabel, and the other information a self-declaration. PEFC certification must be checked in each delivery note and invoice from providers and must be properly included in each delivery note /invoice to customers (as part of the chain of custody certification system).

Recycled content is still not considered. Their products are mainly made with solid wood (renewable materials and certified from sustainable origin), but it would be interesting to know this parameter regarding wooden panels used. They are also working to reduce and eliminate plastics in packaging elements.

Regarding hazardous substances, this criterion is considered in paints (used in the process) and textiles (only to distribute), and the fulfilment of the criteria must be requested to suppliers. Having certifications on this are much more appreciated than self-declarations.

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In addition, MED, with the support of AID, developed their Sustainability Report (2022) according to GRI standards, at the end of 2023, and all the relevant information on environmental KPIs and their improvement strategy had to be collected and reported. This was a challenging task as the data was not aggregated or even quantified in the required units.

One of most disrupting novelties to the wooden sector is referred to the regulation EUDR, that will entry in force in January 2025 and will forbid to put on the market any wooden material or product (it affects also other raw materials) generating deforestation, so they will have to have a Due Diligence Declaration (DDD), containing between others, the geo-localization of the forest. The DDD will have to be verified in any purchase on material and generated to any sell of product though the software developed by the EC.

Reducing the weight of products is currently considered, since it reduces transport incidences (products with higher weight present more transport problems) and its cost in raw materials. On the other hand, reducing packaging materials reduces Ecoembes taxes.

The main barriers to applying ecodesign in a more formal way, would be the excessive cost of resources (time) and the lack of environmental assessment tools, which is closely related to the second barrier, the lack of specific information on environmental indicators. The main potential benefits of having this information and tools are to improve the environmental management of their processes and to increase knowledge of the environmental aspects and impacts of their products throughout their life cycle.

Ecodesign certification according to ISO 14006 is still not demanded and would require a big additional effort. In a near future (3-5 years), the ESPR regulation will affect furniture, since is one of the priority product groups. The related Delegated Act will establish ecodesign requirement and will be mandatory Digital Product Passport for Furniture to set furniture products in the market.

To boost ecodesign, the collaboration is based on a more agile communication from suppliers (environmental data) and better understanding of this information from customers.

Regarding the productive process, the main priority is energy. Not only the demand but also its origin. An energy management system based on monitoring has been installed. MED has installed solar panels and a software measuring in real time the energy generated from them and consumed one at the production process. Despite having limited information (only global consumption data for the entire ship is available), meters have been installed on each line, to study where the highest consumption comes from, and if it is possible to avoid them without affecting the production. Even they have adapted their working hours to the solar light, to maximize the energy consumed from auto-generated renewable source.

Energy is also the main parameter affecting their corporate carbon footprint (scope 1 and 2). Its calculation is currently optional and can be registered voluntarily at the environmental ministry register (43), but it is expected to be mandatory from 2025 (10).

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Figure 6: Energy data managed at MEDWOOD.

Water is not relevant since they do not use it in industrial processes.

Material efficiency is around 75%. 90% of their wooden raw materials are solid wood, from which 23% is generated as a waste from mechanizing parts. But all this material is energy valorized at the biomass furnace to dry coated pieces. This is not possible with the waste from MDF (30% of the raw material processed), because of their glue content, and they are managed as non-hazardous waste. In any case MDF represents only the remaining 10% of wooden materials.

As drying process depends on climatic conditions, according to the season, they can have an excess of this material (summer), or they can have a lack of it (winter). In punctual situations, they adapted the production plan to satisfy the demand of furnace to the drying process. In this case to make Industrial Symbiosis with biomass providers can be interesting.

The other non-hazardous waste they have is cardboard from raw materials packaging mainly. All hazardous waste is generated at the finishing process (painting).

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Waste generated are 64% non-hazardous and 36% hazardous ones. From non-hazardous ones, the biomass from solid wood represents 80% and it is internally recovered at the furnace. The cardboard is recycled by the waste manager.

Alternatives to some hazardous ones can be studied, such as the big containers of paints, to be recovered by the paint provider.

MEDWOOD is not considering the distribution from the environmental perspective, since it is not part of their processes. They consider it a low priority, and the potential actions would depend on synergies and benefits with other areas or future requirements.

At the use phase, as already mentioned, the functional optimization from customer needs, that evolves with the child's grow are fully considered, together with high quality standards, that are part of their market distinctive. Evolutive furniture implies a high modularity and upgradability and thus, a design for easy disassembly and reassembly.

Remanufacturing is a strategy not feasible at the moment. They just do it with transport incidences from customers (reconditioning damaged products). Material separation is not a big deal for waste managers, and at the moment, they also do not put an additional effort into considering other end of life strategies.

4.2.2 Pilot #2 - Printing Network-as-a-Service - AIDIMME

In this chapter, the conclusions regarding the ecodesign questionnaire and diagnosis from AIDIMME are presented (see complete answers in

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ap1.4 AIDIMME Ecodesign/environmental diagnosis and ap1.5 AIDIMME Process diagnosis). AIDIMME (a private and non-profit organization) is the research institute for metal, wood, furniture, packaging, and construction technology, what also covers additive manufacturing technologies (research and services to companies), which are the focus of the proposed pilot.

AIDIMME´s additive printing service, does not always carry out the design of the parts produced, but nevertheless the same specific design rules must be applied to each technology, and they check the design brought by the customer.

Even though they do not apply ful ecodesign, they take into account certain aspects with a strong relationship with the final environmental impact of the parts.

Especially when they develop the design, it is optimised in terms of weight of material and volume of the pieces. This is because the cost is very related to those parameters, both in terms of time for processing and in raw materials consumed. But not only in cost, those aspects are probably the most important in the environmental impact generated.

In addition, some additive printing technologies require support structures generated with the same raw material during the process. At a later stage they are separated from the parts and become waste. Those structures are avoided or minimized during the design phase. The supportg structures are critical as they account for approximately 10-15% of the additional material, process energy and a potential risk of part quality.

Increasing ecodesign considerations can be considered as an over cost during design time or raw material, despite the potential to be more efficient in production or reducing waste management cost. Besides there is the lack of specific information on environmental indicators. This would increase the knowledge on environmental aspects and impacts along the life cycle of their products allowing them to improve, but the market is not yet mature enough and does not appreciate the environmental improvement or the information related to those additive printed parts. Most appreciated by customers are pre-sales ad-hoc technical service to optimize the results to our customers, (quality price, technical feasibility), short delivery time and the technical expertise that allows AID to perform very complex developments that cannot be addressed by others.

As a result, no environmental comparison of the improved part design is carried out and communicated to customers.

This closed loop would be broken if the improvements would be highlighted in terms of economic and environmental benefits to customers as part of a self-declaration included in the final report of each project or even through direct contact with the customer. Besides, due to the special activity of AID as a research center, the environmental benefits of additive manufacturing can be explored and then exploited through research projects.

To do this, the technologies should be considered from a more global perspective and information on raw materials from each provider, and the process itself should be collected. As additive manufacturing is an icon of the decentralized manufacturing, the potential advantages of transport avoidance should be also studied to each customer, offering more quantitative data on the environmental advantages of those technologies.

Regarding current information or requirements to providers, only the safety data sheets of materials are requested to prevent harmful substances into our wastewater from some of our finishing processes. It is difficult to ask for more requirements because the materials are very specific (high purity rates), and the market offer is very limited and the main criterion is quality-price relationship.

Either way, first there should be analyzed which are the main environmental aspects to be requested and secondly, we should map the current providers and additional alternatives with better environmental properties. This green procurement criteria establishment is considered a medium priority action, but between the different parameters to control, at list the energy embodied (very related to the carbon

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footprint of raw materials) is considered as a high priority, but there is no current information from providers. Other aspects such as recycled content or its origin from renewable sources are considered only interesting (medium priority). In the case of recycled content, it could be technically feasible for polymer printers, but certain properties should be ensured. Technical, economic and logistical requirements for secondary materials should be established. The distance to the supplier is not taken into account, unless long distances increase the risks associated with lead times or customs. In this sense, synergies could be found with the environmental benefits of local suppliers.

Finally, regarding the raw materials, the packaging is not optimized at all (in contrast to the product). It would be interesting a study on this potential optimization, although it will be difficult to standardize it because each production batch is completely different. Finding providers of packaging to be reused would be an alternative, but with low priority.

As far as the production process, no specific measure is carried out. Energy demand is considered the most important environmental aspect, and they would like to be able to calculate the energy demand of each specific process. This will facilitate besides the carbon footprint calculation to be offered to each customer. Secondly, the origin of this energy can be also relevant.

The other environmental aspect to be considered is the use of auxiliary raw materials. They are not quantified and controlled, and staff should be aware of making responsible use of gloves, alcohol, paper. This would also support the reduction of part of the related non-hazardous waste produced.

On the contrary, associated with the strong effort on raw material optimisation, the internal recovery of raw materials has a high priority and is currently applicated. Metal and polymer powders are recycled internally by mixing them with fresh powder to maintain technical properties. So, there is a maximum percentage allowed, and usually are generated more than the amounts that can be reintroduced. The percentage of recycled material admitted is a general recommendation from the machine provider. In fact, this percentage depends on several production parameters that affect the technical degradation of the raw material that is not fussed (the recoverable material). Usually, the maximum % of pieces manufactured can be 10% of the volume available at the machine. The quantity of pieces, the height (number of layers) etc., are some of those parameters. Therefore, improving this practice would require developing algorithms to correlate those parameters and the technical experimentation of the real degradation to adjustment the % of material that can be recycled. Probably this would require classifying recovered dust into several internal categories according to the quality or degradation of the material.

It would be also interesting (medium priority) to find customers to this secondary material in excess and to the supporting structures or damaged parts from additive manufacturing processes.

Regarding water demand and related wastewater, it is not significant in those processes, and atmospheric emissions are below the legal limits and their improvement would depend on technological advances in machinery used. So, they are not considered relevant.

Distribution efficiency it is not considered from the environmental perspective and would only be interesting if its contribution to the total product carbon footprint was significant, and this information is appreciated by the customer.

At use stage, as the product it is only a part for other final products, the only but most important consideration at the design phase is the functional optimization (customer based- design thinking), since their added value regarding competitors Is their excellence based on customer specifications/needs. When designing for additive manufacturing, one of the requirements that is assessed is the working conditions of the part, if it is assembled to other parts, etc. This affects positively the life use extension, by adjusting the part design to fulfil the use in specific working conditions (humidity or extreme temperatures) or mechanical performance. In this sense, communication with customers before design and after (marketing) is crucial.

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Other strategies such as ease of cleaning/maintenance, modularity (adaptability to changing needs), technical upgradeability (additional service), ease of repair or even availability of spare parts over the legal period do not apply directly to the part manufactured by AID, but to the final product. In this sense, the influence of AID is very limited. The main contribution can be the ability to produce new parts on demand to repair broken ones in the main product, whether the original was previously manufactured by AID or not. To do this, they should document traceability to be able to replicate the part with the original requirements.

Regarding recycling potential, the parts manufactured are usually mono-material and polymer-based parts do no use halogenated materials like PVC, but they do not control if there is any other limitation and in lats instance, it depends mostly on the final product, so it is not a priority to AIDIMME, they only can assess during design to their customers to improve separability of those parts.

When they have tried to quantify the annual inputs and outputs from the different additive manufacturing processes or equipment, there are two main differences regarding raw materials: plastics and metals. There have been found several Industrial Symbiosis potential improvements in this pilot related to the waste generated. With this focus the waste generated is analyzed deeper than in the other pilots.

We can find following conclusions:

- Energy comes fully from electricity from the network. The amount has been estimated by calculation, based on the number of jobs performed last year and the average duration and the power of the machine. This will not allow the energy demand calculation of one specific part, but an analogue calculation based on the specific duration and number of parts by batch would be possible.
- The quantification of most of the equipment consumables is made in units (according to the purchases). This is because those waste from Additive manufacturing department is not specifically segregated from other AIDIMME´s waste if they are compatible.
- In the framework of NARRATE, Industrial Symbiosis could be considered as a resource in case of disruptions that may arise in the value chain. In addition to knowing the potential of symbiosis in terms of environmental sustainability and circularity.
- To understand the potential of pilot 2 in the field of Industrial Symbiosis, the different processes that can be carried out through environmental diagnosis have been analysed, quantitatively identifying the inputs and outputs of the processes carried out. With the diagnosis carried out, the inputs/outputs that could be potential and interesting in relation to Industrial Symbiosis have been detected.
- From the different technologies available at AIDIMME, it is necessary to distinguish those technologies that manufacture metal parts and those that manufacture plastic parts. Regarding the resources available for the manufacture of plastic parts, we highlight the use of polyamide type powder as raw material and although the process is similar and residual plastic powder is generated, the latter has less potential as a resource than the use of metal powder.

The following *Table 5* and *Table 6* summarise the potential resources that could be analysed for their interest in the implementation of Industrial Symbiosis models between companies for this pilot. More detailed information on waste generated, with relevant pictures needed to further explore Industrial Symbiosis are available at the ap1.5 AIDIMME Process diagnosis.

Table 5 Potential Industrial Symbiosis flows from metal additive manufacturing

METAL ADDITIVE MANUFACTURING TECHNOLOGY	INPUTS	OUTPUTS	POTENTIAL RESOURCES
METAL ADDITIVE MANUFACTURING	Electricity		
	Powder	Powder and Support structures	**Powder and Support structures**
	Coater blade	Damaged coater blade	

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	Argon	Air emissions	
SIEVING MACHINE	Electricity		
SIEVING MACHINE	Powder	Powder	**Powder**
CURING OVEN	Electricity		
FINAL PRODUCT DISTRIBUTION	Packaging material		**Packing material**
RECEPTION OF RAW MATERIALS		Plastics bottles	**Plastics bottles**
MAINTENANCE		Bulbs with tungsten filament	
METAL ADDITIVE MANUFACTURING		Non-conforming manufactured parts	**Non-conforming manufactured parts**

Table 6 Potential Industrial Symbiosis flows from plastic additive manufacturing

PLASTIC ADDITIVE MANUFACTURING TECHNOLOGY	INPUTS	OUTPUTS	POTENTIAL RESOURCES
PLASTIC ADDITIVE MANUFACTURING TECHNOLOGY	Electricity		
	Powder	Powder and Support structures	Powder and Support structures
	Coater blade	Damaged coater blade	
	Argon	Air emissions	
POST PROCESING UNIT	Electricity		
POST PROCESSING UNIT	Powder	Powder	Powder
DYEING MACHINE	Electricity		
FINAL PRODUCT DISTRIBUTION	Packing material		Packing material
RECEPTION OF RAW MATERIALS		Drunks	Plastics drunks

4.2.3 Pilot #3 - Semiconductor industry - BUDATEC

In this chapter, the conclusions regarding the ecodesign questionnaire and diagnosis from BUDATEC are presented (see complete answers in ap1.6 BUDATEC Ecodesign questionnaire and ap1.7 BUDATEC Process diagnosis). BUDATEC GmbH is a plant manufacturer for the semiconductor and solar industry and based in Berlin. The main business areas are thermal systems as well as products and solutions for electronic manufacturing. The focus is on vacuum soldering systems and systems for sintering semiconductor chips. The product range extends from small batch systems to fully automated production systems.

BUDATEC designs its products and includes the design for second life usage/ refurbished usage as one main ecodesign strategy for the easy replacement of parts. Vacuum soldering systems are technologically complex products.

Customer loyalty is based on product quality-price relationship and communication. Customization service is one strategy that shows a high potential, followed by the energy efficiency of products.

To extend the use life of the products, the software updates and hardware/spare parts supported for 10 years (legal requirement). All the strategies associated with lifespan extension are priority: reliability, easy cleaning/maintenance, modular structure, technical upgradability and easy reparability. They are included in all design guidelines. Partly according to VDI/VDE standard.

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They prevent unauthorized resale of the machine and the need for maintenance by contract with BUDATEC. Service points in US, Singapur incl. spare parts to reduce distance to customer for repair and maintenance.

Besides, they consider product as a service as part of their business model, since machines can be rented by hour. This strategy is initiated but can be a potential grow.

Directly connected with their design for second life, they perform remanufacturing as an important circular economy strategy to the company, thanks to design for disassembly previously applied. An attempt is made to recover all materials after the machines' life cycle. In this sense, is very important for BUDATEC to find customers for the refurbished machines and parts.

The establishment of green purchasing criteria is in progress and planned for a period of 3 years but is not priority. Regarding raw materials we can mention also the use of recycled aluminum, and the reduction of hazardous substances, when possible, like the lead-free solder material. Find more providers of recycled aluminum, plastics, steel and maybe copper can be considered low priority.

Additionally, they pay great attention to regionality, also regarding delivery reliability.

No other environmental information, such as carbon footprint, is requested because it is not required by regulations or the market. Anyway, Alcoa, their provider has sustainability information and a product line on more sustainable aluminums, representing the high interest of the industry in those environmental issues:

- Eco-Lum: primary aluminum with a carbon footprint that is 3 times better than the industry average. EcoLum™ primary aluminum is produced with less than 4.0 metric tons of CO_2e for every ton of metal, including both direct and indirect (Scope 1 and Scope 2) emissions from mining, refining, smelting and casting.
- EcoDura™ contains at least 50% recycled content, conserving significant amounts of energy and reducing the environmental impacts associated with producing virgin aluminum.

This kind of suppliers can efficiently support BUDATEC to improve their own corporate and product carbon footprint (when considering scope 3), and to fulfil ecodesign targets.

Besides, aluminum and iron materials are the two first intermediate materials that will be affected by the ESPR regulation and the related Digital Product Passport. This means that not only the material suppliers, but also their customers, as BUDATEC, will have to adapt to this new regulation. It is expected that, as energy consuming products, ESPR also will affect directly BUDATEC´s products.

Current requested requirements to their providers are the origin and processing of wood as packaging material for worldwide shipping and the use of aluminum.

Besides, there are certain materials that should have a due diligent document to avoid conflictive sources. There are internal work instructions, and the documents received are filed in a defined manner so that they can be presented on request.

Regarding the productive process, energy is important. They have complete energy recording on the machines and evaluation resulting in an intelligent control of energy systems. They also have installed of solar cells and purchase electric cars.

Material efficiency would reduce non-hazardous waste generated, specially metal parts, by means of design decisions for manufacturing. This is partially implemented but still can be improved. Generated waste are mostly recycled by external waste managers. Besides the metal savings from the productive process, there are significant amounts of packaging from providers.

Products weight is reduced by supporting designers and reduction of weight of milled parts e.g. The other high priority strategy is related to packaging weight reduction. There is no need for expensive shipping

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material thanks to logistical coordination of self-collection/direct shipping by the manufacturer. No need for logistics companies.

Routes optimization to reduce distance travelled are made especially when coordinating service assignments for customers (several assignments on one route) and to increase the load efficiency. One action being implemented is the use of electric vehicles for the service.

Main barriers to additional ecodesign implementation are the lack of specific information on environmental indicator and related environmental assessment tools. Lack of information from supply chain, together with the over costs associated to additional tasks in ecodesign, are considered just as partial barriers.

On the other hand, their current customers are not appreciating their environmental improvements beyond the energy efficiency of the machines, but BUDATEC considers it can be an interesting opportunity to the near future to access to new markets where there are valuated environmental improvements on products, besides the potential economic savings deriving from a higher efficiency. They inform environmental improvements of their products by self-declarations, so this should increase the awareness of their customers.

To improve ecodesign application, there would be helpful to have specification lists and templates, already tested in other sectors.

4.3 GENERAL CONCLUSIONS ON SUSTAINABILITY DIAGNOSIS

4.3.1 Results from pilots' Sustainability Diagnosis

Customer demands and new regulations are the main drivers of companies' environmental improvement. Current market demand on environmental issues is focused in most cases on materials used, sustainable and legal origin. Specially at MEDWOOD pilot, the specific requirements are directly applied (chain of custody to ensure the sustainable origin of wood, and additionally the control of harmful substances and use of water-based paints). This last requirement is motivated not only by environmental regulations, but for the specific market they cover (children's products). Other ecodesign strategies applied to products design are derived from their strategy to be more competitive (reliability and evolutive furniture), because those characteristics are very appreciated by their customers.

At BUDATEC, life span extension is also considered from design, by improving reparability. But this easy to disassembly and reassembly design, standardisation of components etc, would allow them to develop a new remanufacturing business model they have start to explore.

When products are energy consuming during their use phase, the energy efficiency is the most relevant parameter, besides quality and durability (reliability plus reparability).

Besides material/components certifications, one of most demanded data from companies and products is the carbon footprint. Here we can find synergies between market pressure and coming regulative requirements. Regulatory demands on carbon footprint are limited mostly to scope 1 and 2 because they are more simply to calculate. Scope 3 implies a huge complexity and databases not easily available except for expert LCA practitioners. Anyway, this is increasingly demanded by the market, specially at construction sector, and by law in France, where the building carbon footprint is limited. The selection of construction products based on this limitation has increase the demand of specific providers with this calculated data.

Recently MEDWOOD has developed their first sustainability report, and the environmental indicators to be reported supposed a challenge because the effort of collecting annual data and process it into KPI related to production values.

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New EU regulations are pushing companies to be more conscious and communicative to their customers. Ecodesign and Digital Product Passport will gradually force companies to put sustainable products on the market, and this pressure will be transferred along the whole supply chain.

In case the ecodesign or ecolabelling process is required by customers or regulations, both materials and supply transport plus annual productive data must be processed to be allocated to unitary products. Some product certifications require a traceability system, and this will be reinforced by all the upcoming Due Diligence regulations (CSDDD, EUDR).

The establishment of an environmental management system supporting the environmental data collection from the supply chain in a more automated way would roughly support this kind of reporting and thus the transparency through the value chain.

Besides, the KPI system will move companies not only to inform their customers and positioning their products regarding green procurement but will boost them to design accurate improvement action plan and compare year by year to control their positive evolution by supporting decision taking both on their supply chain and also their internal processes.

Internally, when considering the production processes, energy is a decisive factor, also because of the increasing price of energy. In two of the pilots, there are solar panels installed at the roof of their facilities for self-consume, and thus reduce the electricity demand from the network. At Budatec, they are also improving the purchase of their vehicles substituting fuel by electric ones. This will reduce their corporate carbon footprint, but they are not able to calculate the environmental benefit achieved by their investment.

AIDIMME pilot is different from the others since they are not a full manufacturing company but mainly a research technological center, and the pilot it is focused only in one part of the company. Additive manufacturing is a new set of technologies that can bring a great potential in manufacturing as a service, with identified technological advantages in material efficiency and flexible and delocalized production.

Their main competitive advantage is their technological excellence, but till this moment they are not able to offer environmental quantitative information to support potential environmental benefits that can boost even more those technologies into the market. To compare additive manufacturing technologies with traditional technologies, main environmental data from their providers should also be included in the comparison. Delocalized production would also need the support of a transport carbon footprint calculator to demonstrate the benefits of this technology.

Main environmental factors to be considered, which are directly linked to economic factors are energy demand and material efficiency (not only considering the raw material used, but also some equipment consumables).

As the raw materials used are comparatively expensive because of the specificity of their technical properties (purity, etc.), the waste generated can offer opportunities for valorisation at higher economic incomes through Industrial Symbiosis.

4.3.2. Sustainability Requirements

Considering the prioritization of requirements of the user stories already performed, sustainability diagnosis contributes to set the focus on the core environmental issues, explaining their environmental relevance supported by the context analysis from chapter 3, and classifying them according to the life cycle stages affecting the supply chain: raw materials, production and transport processes (supply and distribution). Also, those aspects related directly to final products are considered (mostly certifications or related environmental information).

The three pilots are fully different, but making an abstraction analysis we can determine following common requirements (supported by the context analysis), to assess energy efficiency, processes

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circularity, carbon footprint and other sustainability aspects inside MaaS context, looking to find the best supplier alternatives (for equipment suppliers, raw materials suppliers, logistics, etc.) when a disruption occurs. The best supplier alternatives will be those which can influence positively in corporate management and products environmental performance.

- Raw materials: Environmental information from suppliers about supplied raw materials/services or about their corporate management, and related documentation demonstrating specific environmental requirements fulfilment it is needed to be managed to ensure the compliment of regulatory and market requirements. This includes links to necessary legal or customer requirements.

  Verified sustainability information from supplier and own organisation can consider the recycled content of materials, origin of renewable materials, carbon footprint or even environmental product declaration, company certifications, etc.). In some specific cases (such in wooden materials), availability of traceability of materials from origin is a critical criterion to comply with Due Diligence requirements.
  Then it should be performed an automatic evaluation of certification of product parts and materials and notification function (i.e. warning for non-certified parts).

- Productive processes: Environmental performance of production processes affects not only the corporate sustainability KPI for reporting, but also the products itself, since production it is a life cycle phase.

  In case of any disruption affecting the environmental performance, corrective actions should be implemented, or in case of requiring a subcontracting, the environmental performance of subcontracted activity must be controlled and integrated into the remaining productive process for further treatment.
  Specifically, to waste reduction targets, it is needed to manage the inventory of waste materials generated and finding potential Industrial Symbiosis options (companies near me to use our waste as a raw material). This can require the connection with a local platform on Industrial Symbiosis.
  Management and analysis of historical data regarding quality can be also applied to environmental data, to environmental KPIs calculation, control and reduction targets establishment, that can be oriented to solar energy improvement, waste reduction and corporate carbon footprint, etc.
  In consequence, it is required to create simulations of production (and transport) processes finding the best alternatives for supply chain alternatives with the Digital Twin-related technologies and the IMC. This implies to have the possibility to calculate the energy demand and related product carbon footprint and another environmental information, considering energy demand, raw materials used (type and amount), depending on the specific production batch, process efficiency, for each supplier´s alternative possibility.

- Transport: Data collection and management is needed to calculate and reduce transport carbon footprint (corporate or for a specific product) and can be integrated with other data from transportation partners to select them. So, the analysis of contracted and alternative transportation partners information and suggestions for new ones based on transport carbon footprint calculation, scenario analysis and reduction alternatives, is required.

- Products: Product´s environmental information to be provided to customers can represent a competitive advantage in most cases or even a mandatory requirement. This is coming directly from raw materials or by combining it with additional environmental production data (track and trace) is needed to obtain certifications (PEFC certification, recycled content, product carbon footprint, etc.) or for ecodesign. Specific calculation of distribution´s carbon footprint to each customer can represent a competitive advantage. This requires track and trace, external and internal data collection and calculations (allocations) from suppliers and production (coming from the environmental assessment system) to final products. Improvement or satisfactory reaction when a disruption occurs requires proposal simulations supported by the IMC.

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In this part there are specific requirements for the IMC and the AI platform to take into account that will help the several user profiles at the companies dealing with the aspects of corporate or product life cycle sustainability in the MaaS context. As the focus of the platform is the implementation of resilient supply chains, the sustainability requirements diagnosed from the beforehand stated analysis of the pilot partners are only a small part of a big set of functional requirements. The requirements regarding sustainability and environment that were stated through the user stories from the pilot partners themselves were already mentioned before.

The following requirements are a result of the presented environmental diagnosis. Some of the already gathered requirements in D1.1 can be used to support in sustainability aspects. Others need an extension to new KPIs and aspects, but the main functionality is already represented. Only a few of the user stories based on sustainability diagnosis are completely new in comparison of the existing ones.

The sustainability diagnosis was performed by interviews to pilot companies, but no user stories were created. To be able to Integrate the new formed requirements into the already existing set of requirements from D1.1, the method was performed similar, according to specific user ´s profiles (design engineer, supply chain manager, managing director, capacity manager, quality manager and environmental manager) and user stories. Following the same methodology as in D1.1, from those user stories, up to three requirements were elicited and accomplished with operational information and possible limitations regarding the implementation.

ID	1	
Identification (role):		Design engineer
Functional Requirements:		
S1.1	Design support to collect, manage and environmentally asses product life cycle for alternative designs.	
S1.2	Suggestions for substitution to more sustainable parts and materials, reduce waste and used material (also in terms of packaging and use phase)	
S1.3	Provide product environmental information and indicators to be use in ecolabelling	
User story:	As a design engineer I would like to get support in ecodesigning our products.	
Operational:		Limitations:
Integration of already existing software ad-ons.		Product Environmental Assessment tools such as LCA requires software complex to use or if they are semiquantitative and simpler they should be designed to each product typology

Figure 7: User Story for support in sustainability #1.

Figure 7 focuses on a design engineer's need for ecodesign support. The functional requirements include product life cycle assessment and suggestions for reducing waste and use of more sustainable materials and technologies (renewable, non-hazardous substances…), elaborate servitization proposals or functional optimisation of products, etc.). Assistance in designing products with lower environmental impact plus supporting in the elaboration of ecolabels (at least self-declarations) is emphasized, with a need for integrating existing software addons.

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ID	2	
Identification (role):		Design engineer
Functional Requirements:		
S2.1	Tracking of lifetime of parts and products on customer side	
S2.2	Analysis of transmitted information	
S2.3	Assistance in construction for critical parts	
User story:	As a design engineer I would like to improve the lifetime of our products.	
Operational:		Limitations:
Proposed solutions should help with substituting parts that cause early product failure or change design to work without those parts.		Necessity for information from customer.

Figure 8: User Story for support in sustainability #2.

The content in Figure 8 describes a design engineer's focus on extending product lifespan. Functional requirements include tracking part lifetimes, analysing information, and constructing critical parts. The user story details the need for improving product longevity, emphasizing substitution of early-failing parts.

ID	3	
Identification (role):		Supply chain manager
Functional Requirements:		
S3.1	Connection to supplier for data transmission	
S3.2	Data management system	
S3.3	Analysis algorithms regarding sustainability	
User story:	As a supply chain manager, I would like to have transparency over my suppliers for sustainability KPIs.	
Operational:		Limitations:
A reasonable data structure should be implemented to get enough data for sustainability analysis, but also not to overwhelm suppliers.		Necessity for information from supplier.

Figure 9: User Story for support in sustainability #3.

Figure 9 addresses a supply chain manager's need for supplier transparency regarding sustainability KPIs. It includes data transmission, management, and sustainability analysis criteria and related algorithms conforming the green purchasing strategy of the company (such as environmental certifications, proximity, criteria on sustainable materials, potential Industrial Symbiosis opportunities etc.). The narrative underscores the importance of a structured data system that balances data volume and supplier burden.

ID	4	
Identification (role):		Managing director
Functional Requirements:		
S4.1	Interface or dashboard for KPIs	
S4.2	Calculation systematics for KPIs	
S4.3	Get and process sustainability relevant data	
User story:	As a managing director, I would like to have an overview of KPIs regarding sustainability.	
Operational:		Limitations:
Figure out which KPIs are relevant for the company to have a clean dashboard.		Keep the data accurate and clean.

Figure 10: User Story for support in sustainability #4.

A managing director's (also environmental manager directly) requirement for KPI dashboards related to sustainability is the focus in the following users story showed in Figure 10. Key aspects involve KPI

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interfaces and data processing. It shows the necessity of clear, relevant KPIs and maintaining accurate data for effective dashboard use. This dashboard is connected to requirement ID1 from the design engineer, since all the data and related KPI should be coherent for both, corporate and product assessment.

ID	5	
Identification (role):		Managing director
Functional Requirements:		
S5.1	System for managing and checking of documents	
S5.2	Automatic checking of validity and actuality of documents	
S5.3	Notification for deviations	
User story:	As a managing director, I would like to have assistance in managing relevant certificates and documents for sustainability.	
Operational:		Limitations:
Documents such as such as safety data sheets and environmental certificates.		Diversity in formats to provide the required data from suppliers, and need of human interpretation in some cases.

Figure 11: User Story for support in sustainability #5.

The managing director's need for managing sustainability-related documents is highlighted in Figure 11. This can involve document management, automated checks, and notifications for deviations. Effective handling of certificates and environmental documents is crucial. This also affects purchase manager as the direct contact person with suppliers, to explain and request the related information or documents.

ID	6	
Identification (role):		Supply chain manager
Functional Requirements:		
S6.1	Get and process transportation data	
S6.2	Scenario analysis regarding different transportation options	
User story:	As a supply chain manager, I would like to have an analysis support for decision making for the location and transport options (such as type of vehicles) of suppliers.	
Operational:		Limitations:
Analysis regarding different sustainability KPIs that can be connected to transportation.		Get data from transportation providers.

Figure 12: User Story for support in sustainability #6.

Figure 12 outlines a supply chain manager's need for transportation data analysis. Important components include data processing and scenario analysis for transportation options affecting transport carbon footprint. The goal is a decision support in supplier selection based on sustainability KPIs (distance, vehicles, transport practices, etc.).

ID	7	
Identification (role):		Capacity manager
Functional Requirements:		
S7.1	Analysis of historical and current use data	
S7.2	AI support for optimizing warehouse, equipment utilization and order management	
User story:	As a capacity manager, I would like to have an optimized usage of equipment and resources.	
Operational:		Limitations:
Analysis regarding different sustainability KPIs that can be connected to equipment and resource usage.		Get real time and historical data.

Figure 13: User Story for support in sustainability #7.

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The focus of the requirements in Figure 13 is on a capacity manager's need for optimized resource utilization. This requires analysing usage data and AI support for equipment and order management. It would be also interesting support to identify Industrial Symbiosis opportunities or even potential re-manufacturing processes (recovered products and parts that can be reintroduced in the productive process). It emphasizes improving resource use efficiency with real-time and historical data analysis.

ID	8	
Identification (role):		Managing director
Functional Requirements:		
S8.1	Analysis of historical and current energy use data	
S3.2	AI support for optimizing utilization of energy consuming machines	
S8.3	AI support for investing in and using self-sufficient energy sources such as solar panels	
User story:	As a managing director, I would like to optimize the energy and water usage in my company.	
Operational:		Limitations:
Analysis regarding different sustainability KPIs that can be connected to energy and water consumption.		Get real time and historical data.

Figure 14: User Story for support in sustainability #8.

A managing director's aim to optimize energy (and water if relevant) usage is detailed Figure 14. Included are analysing energy data and AI support for energy-efficient investments. Optimizing utility consumption through relevant KPI analysis such the carbon footprint, is a primary goal.

ID	9	
Identification (role):		Managing director
Functional Requirements:		
S9.1	Automated checklists	
S9.2	Automated audits	
S9.3	Transferring to suppliers	
User story:	As a managing director, I would like to check that all my activities are complied with regulations.	
Operational:		Limitations:
This includes the management of certificates and evidence of environmental and social standards.		

Figure 15: User Story for support in sustainability #9.

Figure 15 covers a managing director's need to ensure regulatory compliance. Key features include automated checklists, audits, and supplier communication to make maintaining compliance effective through management of environmental and social standards.

ID	10	
Identification (role):		Quality manager
Functional Requirements:		
S10.1	Risk management system	
S10.2	Assistance function for recognition of violations in terms of environmental and social standards	
S10.3	Proposals of appropriate mitigation strategies	
User story:	As a quality manager, I would like to be aware of the risks regarding sustainability.	
Operational:		Limitations:
This needs the management of certificates and evidence of environmental and social standards.		

Figure 16: User Story for support in sustainability #10.

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To get an entailed risk management system, Figure 16 shows the importance of managing certificates and maintaining compliance is a major focus. The system should include violation recognition, and mitigation strategies to give the quality manager awareness of risks.

ID	11	
Identification (role):		Quality manager
Functional Requirements:		
S11.1	System for automated web search	
S11.2	Comparison of existing and new regulations and standards	
S11.3	Notification system for changes	
User story:	As a sustainability or director manager, I would like to be aware of new regulations and standards.	
Operational:		Limitations:
This needs the management of certificates and evidence of environmental and social standards.		Evaluation of relevant terms in standards and regulations

Figure 17: User Story for support in sustainability #11.

A sustainability or director manager's requirement to stay updated on new regulations and standards is highlighted in Figure 17. This would also affect quality manager and design engineers regarding product requirements (which is connected to ID1 on ecodesign). This includes automated web search, regulation comparison, and notification systems. Keeping abreast of regulatory changes is of utmost importance.

ID	12	
Identification (role):		Environmental manager
Functional Requirements:		
S12.1	Suggestions for customers or recyclers for the production waste types	
S12.2	Suggestions for suppliers for recycled materials used in production	
User story:	As an environmental manager, I would like to get assistance with finding industrial symbiosis opportunities: buying and purchasing recycled material or finding customers for production waste to be considered as by-products.	
Operational:		Limitations:
		Material and supply conditions need to be evaluated before advance in administrative authorizations.

Figure 18: User Story for support in sustainability #12.

To increase the use and distribution of recycled material or underused resources, Industrial Symbiosis possibilities are of great interest. Figure 18 shows the requirements from an environmental manager to improve inside and outside the company resources efficient use (not only materials) and get suggestions about both potential customers and suppliers.

4.4 SUSTAINABILITY DIAGNOSIS CONCLUSIONS.

We can conclude that existing and new regulations and market trends are pushing companies to collect environmental information from their supply chain, including certifications and traceability systems to be transferred from raw materials to final products. Also, their own activities (not only productive processes) are subject to demonstrate their commitment with the environment (very focused on climate change) and sustainability (including social values). Collected data from their supply chain and their own productive processes must be collected and transformed in comparable KPI to be used both in ecodesign process and ecolabelling (DPP, environmental product declarations, etc.).

When facing traditional disruptions, or those coming from the new sustainability context requirements (that will break current supply chains because they will deeply transform the way of communicating and

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working between companies), data and KPI will be needed to be collected and properly processed in short timings to support market and regulatory communication demands, and on the other hand taking supported decisions to improve both the communicated environmental results and the internal efficiency processes, to be more competitive.

Attending the context analysis (regulations and market), the identification of main sustainability issues when addressing resilience in supply chain and their prioritization at the 3 pilots, the most important and horizontal targets are:

- To calculate the corporate carbon footprint (direct emissions, energy indirect emissions and transport emissions), as a first step to increase the scope to the whole value chain and to calculate product carbon footprint.
- To boost waste reduction and raw material efficiency (enlarge use of underused resources) by means of finding opportunities of Industrial Symbiosis.
- And finally, to dispose of environmental indicators (KPIs) to corporate/product design decision taking, incorporating sustainability criteria.

To respond to these needs, chapters 6, 7 and 8 of this document have been developed.

5. SUSTAINABILITY-RELATED DISRUPTIVE SCENARIOS AND RESILIENCE ACTIONS

In the context of modern industrial operations, sustainability-related scenarios refer to potential events or conditions that could significantly impact a company's productivity. These scenarios often arise from environmental, social, and economic factors, and they can disrupt supply chains, manufacturing processes, and market dynamics. The increasing focus on sustainability and regulatory compliance means that companies must be prepared to navigate these disruptions effectively.

The following information outlines the importance of recognizing and addressing sustainability-related risks and disruptive scenarios. Then main decision processes involving resilience actions are identified. There are highlighted specific points for each of the three pilots in NARRATE.

5.1 STRICTER ENVIRONMENTAL REGULATIONS

Stricter environmental regulations are increasingly being implemented worldwide to combat climate change, reduce pollution, and promote sustainable practices. These regulations can significantly impact industries by imposing new requirements on production processes, material use, emissions, and waste management. Understanding and adapting to these regulations is crucial for businesses to remain compliant, avoid penalties, and maintain their market position.

Businesses need to establish robust systems to stay informed and compliant with new sustainability regulations. This proactive approach not only ensures compliance but also positions businesses as leaders in sustainability, which can enhance their reputation and competitive edge. Businesses must stay informed about the evolving regulatory landscape and ensure their products meet legal requirements and related sustainability information is provided (DPP, Due Diligence Declaration, etc.), to avoid penalties and market access issues.

Risks and initiating events plus the disruptive scenario are detailed in the different tables below:

Table 7 Risk and initiating events

Risk origin: changes in regulations	Initiating event:	Disruptive scenario

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	noncompliance of legal requirements*	
EUDR: Due Diligence on free from deforestation materials CSDD: Due Diligence Systems to risk assessment and mitigation on human rights and environmental impacts ESPR and previous related legislation on energy related products, construction, etc.: ecodesign requirements/ DPP Specific product legislation limiting the content on substances of concern in specific products Extended Producer Responsibility: financial and/or operational responsibility for a product to include the management of the post-consumer stage European Climate Law	Administrative requirement (new or more demanding), for example: • New register (EUDR Due Diligence document) • Register and incorporation into an EPR scheme (in packaging, textile, furniture, or other products regulated) • Information providing (DPP, etc.) • Energy efficiency, carbon footprint calculation	• Economic sanctions • Not allowance to put products in the market (or even product recall) and consequently damage to brand reputation and breach of contract with clients. • Lack of trained personnel. • Lack of information to mandatory reporting: the management system of the company cannot satisfy the requirements (collect, manage and generate needed reports/evidence). • Need of product redesign. • Need of incorporating new materials and/or technologies. • Need of payment taxes and reporting obligations to the EPR schemes (usually national) operating at markets where we sell our products. • New documental requirements derived from regulations (EPR schemes identification, Due Diligence declaration, etc.)
Specific environmental legislations affecting pollution from industries (Waste framework directive, and other environmental liability and other pollution prevention regulations)	• Emissions, discharge of wastewater with parameters out of limits. • Waste management requirements • Accidents with damage to environment (explosion, leak, etc.)	Environmental damages (potential or generated) can derive into: • Mandatory financial security • Economic sanctions or obligation to repair the caused damage. • Changes in facilities (equipment, warehouses…) • Incorporation of new technologies • If the environmental potential damage to the environment requires, the paralysis of the productive activity. Besides, the non-compliant with environmental legislation can deal into loose of contracts with customers.

To prevent these disruptive scenarios, organizations must systematically assess regulatory impacts, integrate sustainability goals into strategic planning, innovate technologies and processes, engage stakeholders, manage supply chains responsibly, allocate finances strategically, and continuously monitor and improve performance.

Table 8 Decision process and resilience actions

Decision Process	Resilience Actions
Regulatory Impact Assessment	• Understand new regulations and their requirements.
	• Conduct impact analysis on business operations.
Strategic Planning and Goal Setting	• Set SMART sustainability goals aligned with regulations.
	• Integrate sustainability goals into business strategy: regarding processes (environmental management systems) and products (ecodesign)
	• Train new skills and improve the awareness of your staff. Generate efficient protocols.

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Monitoring, Reporting, and Continuous Improvement	• Implement systems to monitor compliance and measure sustainability progress.
	• Foster a culture of continuous improvement through regular performance reviews and corrective actions.
Supply Chain Management	• Collaborate with suppliers: Work closely with suppliers to ensure they also comply with sustainability standards and practices.
	• Diversify supply chain to mitigate risks and ensure sustainable material supply.
	• Collect environmental information from your suppliers (materials, distances, carbon footprint, etc.) and trace the properties to calculate environmental indicators for the final products.
	• Companies must stablish severe controls on provider documentation related to the materials requirements fulfilment and then and reliable traceability systems (internal and along the supply chain).
Technology and Process Innovation	• Optimize processes to reduce energy demand, emissions, conserve resources, and minimize waste.
	• Research and invest in clean technologies (e.g., equipment upgrades, renewable energy), monitoring systems (sensors or manual)
Financial Planning and Investment	• Allocate budget for clean technologies, process improvements, and compliance initiatives.
	• Explore funding opportunities (grants, subsidies, green financing).

ESPR and related regulations will enforce affected companies to design products according to specific requirements on materials, process efficiency, use efficiency, durability, and aptitude to reparability, re-use or recycling and to provide the requested environmental information (public and maybe physically and online supported) to consumers and other relevant agents of the value chain).

Ecodesign is reinforced by EUDR and CSDD to make companies to develop due Diligence Systems to ensure legal and sustainable origin of certain materials, and their traceability to consumer. For example, EUDR requires to develop Due diligence Systems to risk assessment and mitigation of buying materials generating deforestation. Transparency on origin (geo-localization) and tracking along the supply chain by means of legal documentation is required.

Also, restrictions on hazardous substances (e.g., heavy metals, certain chemicals) implies this kind of control on supplier documentation (declarations or accreditations) and even can lead to research for alternative materials and processes, such as recycled or rapidly renewable resources and reduce the use of content on substances of concern (for example in metal parts finishing). To find feasible procurement alternatives to incorporate new materials or substitute suppliers, they must comply with regulations and be transparent.

European Climate Law will push companies to improve their energy efficiency optimising their processes and investing in energy-efficient technologies. It also promotes the use of renewable energy, electric-cars, etc. than can result in technology implementation (solar panels) or vehicles supply changes and facilities modifications (charge points, etc.).

Waste Framework Directive and requirements on Extended Producer Responsibility (EPR) enforce stricter waste disposal (resulting in more expensive waste management and landfilling taxes) and promote recycling practices, according to circular economy principles. In consequence, companies should implement prevention strategies affecting material efficiency (mainly prioritizing hazardous waste reduction) and will have to apply administrative procedures to achieve alternatives to waste condition: by-product or end of waste condition, booting Industrial Symbiosis. When applicable (current scope will expand to new product groups), companies are required to participate in Extended Producer

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Responsibility schemes or take-back programs for products and packaging, paying taxes by each product put on the related market.

Restrictions on industrial emissions (greenhouse gas (GHG) emissions, or specific pollutants such as sulphur dioxide (SO2), nitrogen oxides (NOx), and volatile organic compounds (VOCs) or heavy metals, etc.) might require to companies to adopt cleaner technologies (such as identified Best Available Technologies-BAT), to substitute materials generating those emissions (like water based paints in furniture sector to reduce VOCs emissions) , or to implement emission control and treatment systems.

Limits on water usage and effluent discharge regulations can impact industrial processes, requiring more efficient water management (control on process demand and water aptitude to use) till the efficiency of wastewater treatment systems, prior to the final discharge to sewage system.

Supply chain management is critical to face all the regulatory changes that are influencing market conditions and relationships between companies, forcing to deep collaboration and supplier's diversification, and strong control on relevant information flows and supporting documentation. Challenge consists of most of this information was usually considered in most cases sensitive information, or it is new information not currently available and has to be develop.

Following paragraphs underline for each pilot industry some potential disruptive scenarios and potential resilience actions derived from new regulative requirements to become resilient in selecting better alternatives in any outsourced process, or to incorporate a new material into the product:

At furniture sector we can highlight the impact coming from the Delegate Act derived from the ESPR regulation, since it is one of the priority product groups considered, affecting the design of products, not only regarding use phase (durability, upgradability or re-usability), but also the material selection from sustainable sources (specially for wooden materials EUDR compliant). At production, main characteristic restriction can be COV emissions. Also, the mandatory inclusion on EPR schemes will affect companies at design stage and financially.

In consequence, those disruptive scenarios will be addressed mainly by ecodesign processes and supply chain control regarding wooden material traceability from sustainable sources (legal + free of deforestation), and reduction of substances of concern. Besides material selection, at the design phase, reducing the weight of furniture and durability (reliability + reparability) will be considered with the same or even higher relevance than furniture end of life (improving remanufacturing or recyclability). Both kind of strategies support furniture waste prevention and they are reinforced by obligations on Extended Producer Responsibility (EPR) (prevention by and).

In 3D printing industry impurities or substances of concern has to be controlled by documental control from provider at these advance technologies, and regarding emissions metals and other particulates emission treatment technologies are implemented (mainly filters) and analytical controls should be made to ensure all the emissions are under authorized limits and any operative disruption affecting emissions will be prevented, or detected and corrected.

Optimising waste management to boost plastics and metals recycling, is aligned with regulations (unused materials, support structures, and failed prints) and would suppose an economic saving for companies.

In the electric and electronic equipment (EEE) industry, the Restriction of Hazardous Substances (RoHS) Directive, restricts the use of certain hazardous materials such as lead, mercury, cadmium, and certain brominated flame retardants in electrical and electronic equipment. Companies need to trace the origin of materials used and verify compliance with RoHS to avoid further disruptions when products are put on the market. Compliance drives innovation in materials science, encouraging the development of lead-free soldering techniques and alternative materials that meet regulatory standards.

Legislation such as the Dodd-Frank Act in the United States requires companies to disclose the use of conflict minerals (e.g., tin, tantalum, tungsten, gold) sourced from conflict-affected regions. Conflict Minerals Reporting Requirements requires from manufacturers to conduct Due Diligence to identify and

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mitigate the use of conflict minerals in their supply chains. Compliance promotes ethical sourcing practices and transparency, enhancing corporate social responsibility and mitigating reputational risks.

The Waste Electrical and Electronic Equipment (WEEE) Directive mandates the collection, recycling, and proper disposal of waste electrical and electronic equipment. Manufacturers are required to establish take-back schemes or collaborate with recycling firms to manage end-of-life products and electronic waste.

Electrical and electronic equipment, and specifically welding equipment are subject to ecodesign requirements, including the energy efficiency, to reduce energy consumption and greenhouse gas emissions, fostering product innovation.

Companies should emphasise the following strategies in their ecodesign process and facilitate the relevant information in order to avoid non-compliance with these regulations: design for durability, design for efficient use and design to facilitate the remanufacturing and recycling of these products.

5.2 CHANGES IN CONSUMER PREFERENCES

Consumers are increasingly demanding more sustainable and transparent products. This shift in consumer preferences is driven by heightened awareness of environmental issues, social responsibility, and the long-term impact of purchasing decisions. As a result, consumers are favouring brands that demonstrate a clear commitment to sustainability and ethical practices.

The requirements stablished by the customers beyond the legal requirements, or even the Green Public Procurement lays on demonstrating the fulfillment or providing specific qualitative and/or quantitative information, and even additional services (repair service or spare parts).

There are also several considerations regarding product use: reparability (logistics and spare parts, international repair services, etc.), or product labelling energy efficiency or other consume parameters, etc.).

Finally other considerations can be related to information (instructions) to be provided to customers or downstream specific agents: maintenance, assembly and disassembly, repair diagnosis and operations, reusability, and end of life valorization (substances of concern, recyclable materials, etc.)

The risk of non-compliance with market requirements can result into disruptive the following scenarios:

Table 9 Risk of non-compliance

<table>
<tr><th>Risk origin</th><th>Initiating event:
New market requirements
(final user or B2B customer)</th><th>Disruptive Scenario</th></tr>
<tr><td rowspan="3">Consumer empowerment, including Green Procurement (Public or Corporate)</td><td>Product or material certifications or self-declarations regarding:
Origin of materials from responsible sources, non-content on substances of concern, etc.</td><td rowspan="3">New market requirements may deal in the need of:
o Products or even business model redesign, including new services.
o Changes in installations
o Collecting information and to make complex calculations in a record time, or event to contract specific services (LCA and EPD studies, certifications, etc.)
o Provide instructions, product labeling…</td></tr>
<tr><td>Certified ecolabel Type I or type III (EPD)</td></tr>
<tr><td>Environmental management system certification (ISO or private accreditation)</td></tr>
</table>

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	Sustainability reporting (non-financial) or to agree on environmental and social audits performed by the customer or their representants.	NOTE: If requirements are previously communicated and included in the contract with the customer, this can generate a loose of competitiveness and sales if we cannot satisfy them, but also an unexpected effort of time and cost. If we realize on those requirements after the signature of the contract, or if they are demanded after and we do not prepare our contract against additional requirements, this can generate a disruption.
	Product durability (reliability + reparability)	
	Product use efficiency parameters	
	Use and maintenance instructions	
	Requested information and collaboration with other professional agents (repair services, waste managers, Admin).	

Companies must adapt to these changing demands to maintain their market share, enhance brand loyalty, and meet consumer expectations. Responding to changes in consumer preferences requires organizations to apply reliance actions such as: to conduct market research, innovate products, align marketing strategies with sustainability, optimize supply chains, engage with customers and partners, train employees, and track performance metrics.

Table 10 Decision process and resilience actions

Decision Process	Resilience Actions
Market Research and Trend Analysis	○ Conduct regular market research to understand evolving consumer preferences towards sustainability. ○ Analyse trends in consumer behaviour and demands related to sustainable products/services.
Product Development and Innovation	○ Develop or reformulate products/services to meet sustainable standards and preferences. ○ Innovate in circular business models to improve product lifecycle sustainability ○ Implement environmental management systems (according to ISO 14001 or ISO 14006, etc.) to systematically collect and manage environmental information and achieve improvement goals.
Marketing and Branding Strategy	○ Develop reliable green claims, including ecolabels ○ Incorporate sustainability into brand messaging and values. ○ Educate consumers about the sustainability benefits of products/services.
Supply Chain Optimization	○ Evaluate suppliers for sustainability practices and compliance. ○ Collaborate with sustainable suppliers and prioritize them.
Customer Engagement and Feedback	○ Engage customers through surveys, feedback channels, and focus groups. ○ Actively listen to consumer preferences and integrate feedback into product/service offerings. ○ Monitor consumer sentiment and behaviour changes related to sustainability.
Partnership and Collaboration	○ Partner with NGOs, sustainability organizations, or industry alliances. ○ Collaborate with peers and competitors on sustainability initiatives and industry standards. ○ Collaborate with other value chain agents to implement circular business models.

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Employee Training and Engagement	○ Educate employees on sustainability practices and consumer trends. ○ Foster a culture of sustainability within the organization to align with consumer expectations.
Metrics and Performance Tracking	○ Establish metrics to measure the environmental impact of products/services. ○ Continuously improve products/services based on feedback and performance data.

Product improvement from the sustainability perspective is the key factor to satisfy (B2B or individual) customers' requirements. Doing this, would need to also evolve current business models into more circular ones, that requires to involve on this strategy the whole supply chain. Certifications will add additional confidence to customers on the green claims provided.

5.3 SUPPLY CHAIN

Supply chain disruptions due to external events are a major challenge for all industries. Climate change and its consequences, other natural disasters and even human driven events like (accidents like Suez channel, wars, explosion at Beirut port, etc.) can severely disrupt supply chains, affecting the availability and cost of raw materials. These disruptions can result in significant operational challenges, including material shortages, increased production costs, and delays in production and product delivery.

Table 11 Break of supply chain and possible scenarios provoked

Risk origin	Initiating event:	Disruptive Scenario
Break of supply chain	• Natural disaster • Accidents • Providers/customers in war conflict areas • Material from restricted places	• Production stop • Need for alternative suppliers • Need to change raw materials • Need for technology change • Non-compliance with delivery deadlines • Product loss • Increase in production costs

Companies must implement strategies to mitigate these risks and ensure supply chain resilience by anticipating and preparing for these disruptions to minimize their impact on operations and maintain business continuity.

To manage supply chain disruptions, businesses must conduct risk assessments and scenario planning concluding in robust contingency plans, diversify suppliers, build collaborative relationships, leverage technology and analytics for real-time monitoring, fostering agility in decision processes and flexible manufacturing, to continually improve their resilience. The following actions outlined provide a roadmap for businesses to effectively navigate and mitigate the impacts of supply chain disruptions effectively.

Table 12 Roadmap to mitigate impacts of supply chain disruptions

Decision Process	Resilience Actions
Risk Assessment and Scenario Planning	• Conduct thorough risk assessments to identify potential supply chain vulnerabilities. • Develop contingency plans for various disruption scenarios (e.g., natural disasters, geopolitical events).
Supplier Diversification and Redundancy	• Diversify supplier base to reduce dependency on single sources. • Establish redundancy plans for critical supplies to ensure continuity during disruptions.
Collaborative Relationships	• Foster collaborative relationships with key suppliers and partners. • Maintain open communication channels to swiftly address issues and find solutions.

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Technology and Data Analytics	• Implement supply chain visibility tools for real-time tracking. • Utilize predictive analytics to anticipate disruptions and optimize inventory management.
Agility and Flexibility	• Build agile processes that can quickly adapt to changing circumstances. • Establish flexible logistics strategies to reroute and expedite deliveries during disruptions.
Continuous Improvement and Adaptation	• Conduct post-disruption reviews to identify lessons learned and improve resilience. • Continuously update and refine supply chain strategies based on evolving risks and market conditions.

The following paragraphs underline for each NARRATE´s pilot industry the main issues regarding supply chain disruptions:

The furniture industry has a higher dependency on renewable resources natural disasters events such as extreme weather, fires, plagues, etc., that can disrupt the productivity or timing of harvesting wood, especially when furniture manufacturers are heavily reliant on specific regions for high-quality timber.

Natural fibres such as cotton and wool used in upholstery can be also affected by external events (animal illness or pests) breaking the supply chain or making them temporarily scarce, affecting delivery times or prices, prompting a shift to synthetic fibres or recycled materials.

3D printing industry often relies on specialized suppliers for specific polymers and resins and technologies generates a great dependency on them and does not allow the diversification of supply chain. Any disruption can cause significant production bottlenecks with significant delays in production timelines and delivery schedules, impacting customer satisfaction.

The EEE industry relies on a highly intricate and global supply chain, and they can be very dependent on high tech components and shortages of critical raw materials. Disruptions in one part of the world can have a cascading effect, leading to delays in strategic components manufacturing and assembly, causing significant delays in the production and delivery.

In all the three pilot cases, supply disruption may be prevented by implementing the same resilience action in order to reduce high dependencies: to diversify the suppliers. This can be done by looking for in the market alternative suppliers of the same raw materials and even advancing in research of alternative materials, testing them (suppliers and materials) to know in advance the specific potential problems or working conditions in case of supply chain disruption and having to substitute the original ones.

5.4 RESOURCE SCARCITY

Growing demand and overexploitation of natural resources are leading to the scarcity of essential raw materials for production. This scenario poses significant challenges for industries as they face increased costs, the need to find sustainable alternatives, and reduced production capacity. Dependency on scarce resources generates higher vulnerability at supply change and they can be easily broken.

Table 13 Scenarios provoked by scarcity of resources

Risk origin	Initiating event:	Disruptive Scenario
Resource scarcity	• Overexploitation of renewable natural resources (non-sustainable management avoiding natural regeneration) • Increasing demand • Critical raw materials (scarce yet without demand intervention)	• Need of higher stocks of critical raw material • Increase of raw material prices • Need for new suppliers • Need of products redesign • Need for alternative materials or recycled ones and related processing technologies.

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Companies must adopt strategies to mitigate the impact of those disruptions and ensure sustainable resource management. Following strategies outlined, provide recommendations for businesses to navigate resource scarcity effectively and sustain their operations in the long term.

Table 14 Roadmap to mitigate impacts of scarcity of resources

Decision Process	Resilience Actions
Resource Assessment and Inventory	• Conduct comprehensive assessments to identify critical resources and their availability. • Develop inventory management strategies to optimize resource use and reduce waste.
Alternative Sourcing and Innovation	• Explore alternative sourcing options (e.g., sustainable materials, recycled inputs). • Invest in research and development to innovate products/processes that reduce scarce resource´s dependency.
Efficiency and Conservation Measures	• Implement efficiency measures to reduce resource consumption • Adopt conservation practices to extend the lifecycle of resources and minimize waste.
Collaboration and Supply Chain Integration	• Collaborate with suppliers and partners to ensure responsible sourcing practices. • Integrate sustainability criteria into supplier selection and procurement processes.
Circular Economy Practices	• Adopt circular economy principles to promote resource reuse, recycling, and regeneration. • Design products for disassembly and material recovery to minimize resource depletion.
Regulatory Compliance and Advocacy	• Stay informed about regulatory requirements related to critical raw materials and corporate sustainable Due Diligence requirements. • Advocate for policies that support sustainable resource use and conservation efforts.

The following paragraphs underline for each NARRATE´s pilot industry the main issues regarding resource scarcity.

In the furniture industry, the overexploitation of hardwood forests like oak, mahogany, and teak can generate important damage to biodiversity and lead to shortages, driving up costs and limiting availability. This scarcity forces furniture manufacturers to seek alternative suppliers for wood species or alternative materials like bamboo or reclaimed wood.

The 3D printing industry relies on materials like specialty resins and high purity powder metals like titanium and aluminium, or even certain consumables such as tungsten filaments, coming from a very few numbers of suppliers, that can become scarce due to supply chain issues and increased demand. This scarcity can impede production and innovation.

3D printing companies need to innovate with biodegradable and recycled filaments, such as bio-based PLA and recycled PET, which may require new R&D investments and adjustments to additive manufacturing technologies, and to optimise the material efficiency in metal powders processing, and their valorisation of current non-usable powders coming as waste from the processes to other applications less demanding.

In the EEE, essential materials like silicon, gallium, and rare earth elements (e.g., neodymium) are critical for electric and electronic equipment production and are becoming increasingly scarce due to high demand and limited supply. Resource scarcity can slow down the production of advanced chips and components, affecting technological progress and the ability to meet market demand and lead to higher procurement costs.

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The industry must invest in the development of alternative materials such as graphene and compound semiconductors (e.g., gallium nitride) and enhance recycling techniques for existing materials.

5.5 CORPORATE SOCIAL RESPONSIBILITY

Increased public and media pressure on corporate social responsibility (CSR) practices is compelling companies to address issues such as labour conditions, community impact, and ethical practices. This scrutiny arises from a growing awareness among consumers, investors, and other stakeholders about the importance of CSR in business operations.

Table 15 Scenarios provoked by the increase of awareness

Risk origin	Initiating event:	Disruptive Scenario
Increase of awareness of stakeholders	• New CSR requirements in public procurement • Lack of non financial reporting (mandatory for certain companies) • Companies with suppliers or facilities in countries with lower environmental or social legal requirements. • Lack of transparency or traceability along the supply chain (origin or raw materials, content of substances of concern, etc)	• Sanctions (in case of mandatory reporting or illegal situations) • Loose of reputation • Need for alternative social responsible suppliers • Need for develop/implementing Due Diligence systems. • Need of documentation revision from suppliers. • Need for generating additional trace and tracking documentation • Need for new personal or provide them new skills.

The emphasis on CSR affects industries differently, requiring tailored strategies to demonstrate transparency, accountability, and a commitment to sustainable and ethical practices to maintain their reputation and competitive edge.

Enhancing CSR initiatives requires engaging stakeholders, developing comprehensive strategies aligned with organizational values, managing ethical supply chains, promoting environmental sustainability, supporting social impact programs, ensuring transparency in reporting, and fostering employee engagement. Including CSR in companies management will contribute to avoid disruptive scenarios described above.

Table 16 CSR and its support to avoid disruptive scenarios

Decision Process	Resilience Actions
Stakeholder Engagement and Alignment	• Identify key stakeholders (e.g., employees, communities, investors). • Engage stakeholders to understand expectations and priorities for CSR initiatives.
CSR Strategy Development	• Develop a comprehensive CSR strategy aligned with organizational values and stakeholder expectations. • Set clear goals and metrics to measure the impact of CSR efforts.
Ethical Supply Chain Management	• Establish ethical sourcing policies and supplier codes of conduct. • Monitor and audit suppliers to ensure compliance with ethical standards.
Environmental Sustainability Initiatives	• Implement sustainable practices to reduce environmental impact (e.g., energy efficiency, waste reduction). • Set targets for reducing carbon footprint and resource consumption.
Social Impact Programs	• Support social initiatives such as community development projects and education programs. • Partner with NGOs and local organizations to maximize social impact.

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Transparency and Reporting	• Communicate CSR activities and performance transparently to stakeholders. • Publish CSR reports that highlight achievements, challenges, and future goals.
Employee Engagement and Volunteering	• Encourage employee involvement in CSR activities through volunteering and skill-based initiatives. • Foster a culture of corporate citizenship and social responsibility.

The following paragraphs underline for each pilot industry the main risks and related resilience actions regarding CSR:

In the furniture industry, he harvesting of timber for furniture production can lead to deforestation, which is a primary driver of biodiversity loss. Deforestation destroys habitats, leading to the decline or extinction of numerous plant and animal species. Logging operations can fragment habitats, isolating species populations and disrupting ecosystems, it also can lead to soil erosion, reduced soil fertility, and water pollution.

Furniture manufacturers face significant risks if involved in non-sustainable or unethical practices such as illegal logging 8generating deforestation), use of toxic chemicals, or poor labour conditions. Public exposure can severely damage their brand reputation.

Thus, companies must ensure transparency and accountability in sourcing materials, particularly wood, by compliant the EUDR regulation and plus obtaining chain of custody certifications such as FSC or PEFC.

In the 3D printing and EEE industry, from the social perspective, based on minerals such as tantalum, tin, tungsten, and gold (often referred to as conflict minerals), they must ensure that they are sourced ethically to avoid financing armed conflict and human rights abuses.

Large-scale mining projects can lead to the displacement of local communities, forcing people to relocate and disrupting their lives and livelihoods. Addressing labour conditions in global supply chains, particularly in countries with less stringent labour laws, to ensure fair wages and safe working environments is essential.

From the environmental perspective, mining operations often lead to the destruction of ecosystems and contribute to soil erosion and degradation, rendering the land barren and unproductive for agriculture or other uses post-mining. The removal of vegetation and topsoil, deforestation, and habitat destruction are common practices that severely disrupt local biodiversity and ecosystems. Then, the extraction process frequently involves the use of toxic chemicals such as cyanide and mercury, which can leach into water bodies. This pollution contaminates drinking water sources and harms aquatic life. Finally, the supply chain of virgin minerals is characterised for being very energy demanding.

Ensuring that manufacturing processes minimize environmental impact through energy efficiency, waste reduction, and pollution control is critical for maintaining stakeholder trust. In consequence, industries must address the environmental footprint of materials used, reduce energy demand, and promote recycling. since most of their materials used (plastics and mainly metals) are technically recyclable. In the case of 3D printing metals, their special requirements on purity might can be appreciated to achieve better economic incomes by Industrial Symbiosis options compared to them from current their management as common metallic parts.

All alternatives to find appropriate suppliers while maintaining social responsibility is crucial to be able to replace or substitute suppliers by building a reliable smart manufacturing network.

5.6. SUSTAINABILITY TARGETS PRIORITIZATION IN MaaS CONTEXT

The context analysis developed at Chapter 3, plus the sustainability diagnosis performed to pilots at chapter 4, have led to the establishment of a set of sustainability requirements for the IMC. Most of them support the prioritized sustainability targets also defined at the end of that chapter.

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At Chapter 5 the main risk origin (stricter environmental regulation, changes in consumer preferences, supply chain break, resources scarcity and corporate social responsibility) that can generate disruptive scenarios potentially affecting supply chain sustainability are discussed. Then, to each typology of risk the disruptive scenario proposal of potential resilience actions is proposed related different areas of process decision.

By combining all the previous information, we can conclude that existing and new regulations and market trends are the most relevant drivers to be considered from the sustainability perspective, while the others are not so horizontal or can generate more punctual disruptions in a MaaS context. Anyway, a resilient supply chain considering the requirements to satisfy new regulations and market demands, will be well prepared to face the others by adding the supply chain diversification, which involves the possibility of selecting alternative suppliers considering environmental criteria and KPIs.

Analysed disruptive scenarios are pushing companies to collect environmental information from their supply chain, including certifications and traceability systems to ensure complying with regulatory and market requirements, including to be used at ecodesign processes by selecting best environmental alternatives, and to be managed to be transferred from raw materials to final products. Also, their own activities (not only productive processes) are subject to demonstrate their commitment with the environment (very focused on climate change) and sustainability (including social values). Collected data from their supply chain and their own productive processes must be collected and transformed in comparable KPI to be used both in ecodesign process and ecolabelling (DPP, environmental product declarations, etc.).

When facing traditional disruptions, or those coming from the new sustainability context requirements (that will break current supply chains because they will deeply transform the way of communicating and working between companies), data and KPI will be needed to be collected and properly processed in short timings to support market and regulatory communication demands, and on the other hand taking supported decisions to improve both the communicated environmental results and the internal efficiency processes, to be more competitive.

Attending the context analysis (regulations and market), the identification of main sustainability issues and their prioritization at the 3 pilots, there should be underlined:

- Regarding energy efficiency and carbon footprint:

  New climate change regulations, and also fossil fuels scarcity are motivating not only stricter CO2eq emissions control and limitations, but also price fluctuations deeply affecting supply chains generating disruptions. Resilience actions imply to improve energy demand (amount consumed) and its origin (preferably from self-production or external renewable sources) in order to calculate and reduce the corporate carbon footprint (direct emissions, energy indirect emissions and transport emissions), as a first step to increase the scope to the whole value chain and to calculate product carbon footprint.

- Regarding circularity of processes by Industrial Symbiosis:

  To boost waste reduction and raw material efficiency (enlarge use of underused resources) by means of finding opportunities of Industrial Symbiosis. This can be positive when supply chain breaks and secondary resources can be considered as an alternative, or when there is need the subcontracting of specific activities (for example, other specialised companies can be more efficient than the lead company) or when sharing underused resources or services in a service manufacturing network context. All those possibilities can improve the supply chain sustainability performance.

- Regarding to assess and improve supply chain sustainability:

  Companies need to dispose of an environmental KPIs system to incorporate sustainability criteria from a holistic life cycle perspective (energy efficiency and carbon footprint, processes circularity and other sustainability aspects) into corporate/product decision making, especially when assessing

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alternative suppliers when a supply chain disruption occurs. In this sense, there following interlinked needs:

- a corporate environmental management KPIs system leading with the sustainability performance of the leading company,
- understanding the environmental influence of supplier´s performance into the lead company´s one,
- and to identify most adequate KPIs to be used in each supplier selection. It is not possible to define a fix environmental KPI system for supplier selection, since each supplier would have different specific influence and priorities. For example, electricity supplier or equipment supplier, and even each of the different materials suppliers are related to different requirements.

To respond to these needs, Chapter 6, 7 and 8 of this deliverable have been developed.

6. CORPORATE CARBON FOOTPRINT

The objective of this chapter is to provide a detailed and comprehensive understanding of the key elements related to the calculation of greenhouse gas (GHG) emissions within the framework of climate change and the specific legal framework, as well as the methodology and tools that will be developed and used for this purpose within the project.

Climate Change can be defined as the set of changes in the Earth's climate as a result of the increase in the average planetary temperature caused by the emission of greenhouse gases due to human activity. Its environmental, social, economic, and cultural impacts—both present and future—are indisputable across all scenarios defined by the IPCC . This is why, in recent years, the actions of various international actors (states, organizations, etc.) have accelerated in terms of implementing agreements, establishing plans and strategies, and approving legislative frameworks. All these efforts are aimed at mitigating climate change (focusing on the transition to a low-carbon global economy) and adapting to its inevitable consequences (urban restructuring, bioclimatic construction, access to potable water, etc.).

Companies must, not only understand the relevance and obligation of complying with climate change regulations, but also consider carbon footprint when assessing its supply chains resilience and sustainability. In the context of MaaS, potential disruptions in supply chain can affect final corporate or product carbon footprint. In consequence, alternative supplying options' carbon footprint must be assessed in a rapid, simple and transparent way.

In summary, this chapter aims to provide a complete framework for the calculation of GHG emissions, ensuring compliance with applicable regulations and precision in the quantification of emissions generated by different activities, with a particular emphasis on the transportation of raw materials and goods.

6.1 CARBON FOOTPRINT CALCULATION: TECHNICAL DESCRIPTION

The carbon footprint is a measure representing the total amount of greenhouse gases (GHGs) emitted directly or indirectly by an individual, organization, event, or product throughout its life cycle. These gases are commonly expressed in terms of carbon dioxide equivalent (CO_2e) to facilitate comparison and analysis. The carbon footprint encompasses various sources of emissions, such as energy consumption, transportation, industrial processes, and waste management, among others. It is a tool of great interest for companies, since it provides indicators and information of great relevance for environmental management and continuous improvement.

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Two of the most widely internationally used standards for calculating the corporate carbon footprint are the GHG Protocol and ISO 14064. Below, both methodologies will be defined and the classifications of the different sources of greenhouse gas emissions will be compared. This includes a comparative table of the different types of emissions sources (including a detailed description of each type of source) and their correspondence between both standards.

The GHG Protocol was developed by the World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD). The GHG Protocol provides a comprehensive framework for measuring and managing GHG emissions and is divided into two main standards. The *Corporate Standard* is designed to help companies account for and report their GHG emissions. It focuses on all direct and indirect emissions, classifying them into three scopes:

- Scope 1: Direct emissions from sources that are owned or controlled by the company.
- Scope 2: Indirect emissions from the generation of purchased electricity consumed by the company.
- Scope 3: All other indirect emissions that occur in the company's value chain.

On the other hand, the ISO 14064 standard (40) is part of the ISO 14000 family of standards, which focus on environmental management. Specifically, ISO 14064 is divided into three parts and provides detailed guidance for the quantification and verification of GHG emissions:

- ISO 14064-1: Specifies the principles and requirements at the organizational level for designing, developing, managing, and reporting GHG inventories.
- ISO 14064-2: Focuses on the principles and requirements for the quantification, monitoring, and reporting of specific projects aimed at reducing GHG emissions.
- ISO 14064-3: Provides guidance for the validation and verification of GHG assertions.
- ISO 14064 standard classifies emissions only in two categories: direct and indirect. However, even though the main classification provided by ISO 14064 is the one already shown, all sources can be also classified in six different subcategories:
- Category 1: direct GHG emissions and removals.
- Category 2: indirect GHG emissions from purchased energy.
- Category 3**:** indirect GHG emissions from transportation.
- Category 4: indirect GHG emissions from products used (raw materials).
- Category 5: indirect GHG emissions associated with the use of the organization's products.
- Category 6: indirect GHG emissions from other sources.

In the following table, a comparison between GHG Protocol classification and ISO 14064 classification is shown:

Table 17 GHG protocol classification and ISO 14064 classification

GHG Protocol	ISO 14064	ISO 14064 (subcategories)	Description
Scope 1	Direct emissions	Category 1	Direct GHG emissions and removals.
Scope 2	Indirect emissions	Category 2	Indirect GHG emissions from purchased energy.
Scope 3		Category 3	Indirect GHG emissions from transportation.
		Category 4	Indirect GHG emissions from products used (raw materials).
		Category 5	Indirect GHG emissions associated with the use of the organization's products.

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		Category 6	Indirect GHG emissions from other sources.

The scope chosen for the development of the calculator within the NARRATE project (which will be described in the next subchapter) will exclude GHG Protocol Scope 3, except for indirect GHG emissions from transportation (ISO 14064 category 3). It must be noted that the main objective of the project, regarding GHG emissions, is to offer companies a tool that helps them calculate their carbon footprint in a semi-automated way. Considering the wide variety of GHG emission sources included in Scope 3, it is extremely difficult from a technical perspective to automate carbon footprint calculations in that regard. However, due to the significance of goods and raw materials transportation in value chains (as well as the availability of reliable data, as will be described in chapter 2.5), it has been decided to include this source in the tool.

6.2 CARBON FOOTPRINT CALCULATION: CALCULATOR DESCRIPTION

The NARRATE project involves, among other things, the development of a "calculator" that allows for the simple calculation of direct emissions (and indirect emissions corresponding to the transport of goods) at a corporate level. The objective of this subchapter is, therefore, to describe the design of the calculator that will be used to calculate emissions, detailing the fields and parameters that must be completed. This design is crucial to ensure that users can enter the necessary data accurately and effectively.

The calculator will be developed using a spreadsheet, making it accessible to any company that wishes to use it. The primary goal is to enable companies to obtain both aggregated and disaggregated data on their carbon footprint, expressed in tons of CO2 equivalent, by entering easily obtainable data (such as fuel consumption, energy consumption, kilometers travelled during logistical operations, etc.). The results will be an input for the IMC for analysing the best alternatives in supply chain possibilities.

The calculator (spreadsheet) will consist of six sheets:

- General information: This sheet will allow the company to enter data identifying the year of the carbon footprint calculation, the scope (location or locations to be included), and the results of previous carbon footprint calculations (to facilitate easy tracking of the carbon footprint).
- Emission factors: This locked sheet will provide transparent access to the emission factors applied in the carbon footprint calculation.
- Direct emissions: This sheet will calculate the carbon footprint associated with the energy consumption (both stationary and mobile) directly controlled by the company, as well as any emissions from potential refrigerant gas leaks.
- Indirect emissions from electricity importation: By entering the country of operation and the annual energy consumption (in MWh), the company can determine the carbon footprint associated with its electricity consumption.
- Indirect Emissions from Transportation: This sheet will allow the company to determine the carbon footprint from transportation not under its operational control by entering the type of vehicle and the total mileage for each vehicle type during the study year.
- Results: This sheet will provide an overview of the carbon footprint, both aggregated and disaggregated, as well as a comparison with previous calculations (if provided).

6.3 EMISSION FACTORS (SCOPE 1 AND 2)

As mentioned before; in order to calculate the carbon footprint associated with the different sources of greenhouse gas emissions, it is necessary to have "emission factors" obtained from reliable sources (public or highly referenced) or calculated from transparent and technically correct manner.

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Public emission factors, extracted from official sources of the corresponding ministry, corresponding to direct emissions (or indirect emissions correspondent to "scope 2") will be used in the calculator. This will ensure transparency and standardization of data used in emissions calculations.

6.4 EMISSION FACTORS CALCULATION IN GOODS TRANSPORTATION

In reference to "scope 3", as previously justified, only those emissions linked to the transport of raw materials and/or merchandise will be considered. In this case, emission factors must be developed. Therefore, the method for calculating specific emission factors for the transport of goods will be developed and explained below.

6.4.1 Input data to consider: transport factors affecting CO2 eq emission.

Considering the logistics and transport factors, greenhouse gas emissions are calculated according to the internationally recognized Greenhouse Gas Protocol Corporate Standard and in accordance with the requirements of the European Emissions Trading System (EU ETS), the ISO 14083 and the ISO 14064 (40) standards. The logistics and transport provider leg also follows the accounting methodology of the Global Logistics Emission Council (GLEC). Greenhouse gas emissions must reflect the full lifecycle of the fuels and energy used and be reported as well-to-wheel emissions (sum of well-to-tank and tank-to-wheel, vehicle and energy process) as shown in Fig. 19 below.

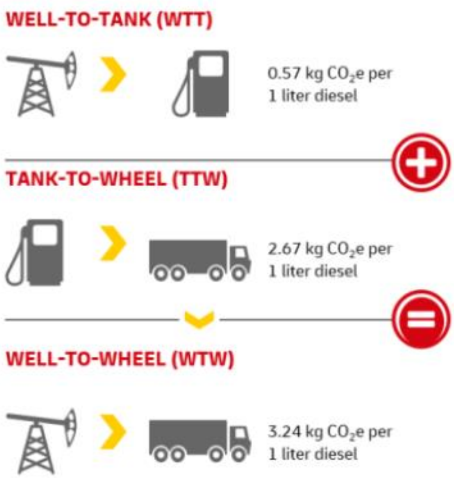

Figure 19: Different fuels and energy lifecycle.

Considering this and the European standard EN 16258 , emissions should be presented as follows:

- CO2e Tank-to-Wheel (TtW): Carbon dioxide emissions and other greenhouse gases that occur during the combustion of fuel or the use of other energy sources.
- CO2e Well-to-Wheel (WtW) Carbon dioxide emissions and other greenhouse gases arising from the production of fuel or other energy carriers as well as carbon dioxide emissions and other greenhouse gases arising from the combustion of fuel or the use of other energy sources.
- MJ Tank-to-Wheel (TtW) Megajoule; consumption during energy use.
- MJ Well-to-Wheel (WtW): Megajoules consumption during use and energy consumption that arises as a result of the use of energy sources (upstream).

For “scope 3” emissions, we will consider the staged method framework that project logistic partner DHL has developed. It uses primary data where available from their large cooperation partners, and model-

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based calculations based on operational data, such as shipments' weights, distances and types of vehicles and fuels; for residual categories models based on economic parameters may be applied.

Emissions reports aim at providing customers with specific emissions reports with high data quality that reflect the network of vehicles used. The calculation method to be used for this is based on the transport work (tkm) together with specific emissions factors (e.g. CO2/tkm) with the application of relevant load factors for allocating CO2 emissions. Freight and operational data from internal proprietary Transport Management Systems (TMS) may be used as well as official sources as a basis for emissions calculations. Variables will be measured, reported by subcontractors (if possible) or estimated from own or external reliable data. The CO2 and MJ values Include the entire domestic transport from collection to delivery per product, including the emissions and energy use linked to the handling of goods at the warehouses. The values include CO_2 emissions, other greenhouse gases, upstream emissions (Well to Wheel) for fuels and electricity.

The calculation method for emissions, which forms the basis for customer emissions report, must be regularly verified by external third part.

The calculation is based on the product distance and the weight of the shipment that the customer paid for. There is a distribution of the actual total transport work as well as the distribution of vehicle types of technology and fuels used within the framework of the purchased product. Emissions are calculated for each individual shipment and then summarized to show total emissions for customers' total freight for the current reporting period. The weight of the shipment is based on the taxable weight; the shipment actual weight in kg, (or if the shipment is bulky, the volume of the goods converted to kg (volume weight)).

The product distance is stated in km for each shipment then multiplied by freight-bearing weight, which generates the current transport work.

6.4.2 Summary of real data provided

The data shown in the following tables have been collected from real scenarios, and will be used to calculate the carbon footprint linked to transportation.

Table 18: Figures used for emissions calculations

Categories of values	Default values	Transport operator fleet value	Transport operator speciffic value	Specific measured value
Fuel consumption (l/km)		See Table 21	See Table 21	
Distance (km)				Production Data DHL
Fuel consumption (l/tonne)		See Table 22	See Table 22	
Taxable weight (kg)	See Table 19	See Table 19		
Loading capacity				Production Data DHL
Distribution vehicle type			See Table 23	

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DHL domestic terminal		Energy data regarding DHL terminal		

Load factors and fuel consumption

There is no established definition for the industry for the degree of load factors. Calculating load factors for transports is complex as goods can be registered by both actual weight and volume weight. DHL's calculation tool is based partly on Network for Transport Measures (NMT) estimated load factors for different vehicle types and partly on measured load factors in the network (see table 18). In this data, empty runs for network transports are considered.

Table 19: type of truck and load factor

Vehicle type based on total weight	Load factor (%)
3.5 tons	20
14 tons	40
28 tons	73.4
40 tons	73.4

Table 20: Types of truck and payload capacity

Vehicle type based on total weight	Payload capacity (tons)
3.5 tons	0.7
14 tons	5.6
28 tons	20.6
40 tons	29.4

Table 21: Types of trucks and fuel consumption

Type of vehicle	Fuel consumption (l/km)
3.5 tons	0.124
14 tons	0.274
28 tons	0.340
40 tons	0.361

Table 22: Types of truck and fuel consumption per transport work

Type of truck	Fuel consumption (l/tonkm)
3.5 tons	1.77
14 tons	0.486
28 tons	0.166
40 tons	0.126

Table 23: Share transport work per type of truck in percent (Data for Spain)

Type of truck	Current share of transport work per truck type
3.5 tons	3%
14 tons	12%
28 tons	19%
40 tons	66%

Table 24: Fuels and their corresponding emission values

Type of fuel	MJ/l(wtw)	MJ/l(ttw)	WTW (g CO_2-eq/liter)	TTW (g CO_2-eq/liter)

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Diesel	45	36	3140-3194	2370-2950
Ethanol	52	50	438	0
RME	69	33	995	0
HVO 30 Diesel	48	35	2557-2623	1653-1912
HVO 40 Diesel	48	35	2000	1450
HVO 50 Diesel	48	35	1820	1271
HVO 100 Diesel	44	36	360-765	0
CBG	49	36	427	0
CNG	49	36	2402	i.u
LBG	50	36	442-769	0
LNG	50	36	3420-4500	i.u

Considering Spanish current fleet, diesel heavy vehicles still represent the largest segment with 94.4%. CNG portion is <4%, while LNG represents <o.5%. HVO fuels are still regulation pending in Spain.

7. INDUSTRIAL SYMBIOSIS

Industrial Symbiosis, within the industrial circular economy, enables to manage efficiently their resources and demonstrating that collaboration between different companies can lead to innovative and beneficial solutions for all participants and for the environment.

Considering symbiosis in supply chain resilience is essential because it enables the creation of interconnected systems where resources, byproducts, and waste are efficiently exchanged between industries. This not only reduces dependency on raw materials but also enhances the adaptability of the supply chain in times of disruption. By fostering collaborative networks, companies can quickly identify alternative sources and solutions, ensuring continuous operations and reducing environmental impact, thereby creating a more sustainable and robust supply chain.

The implementation of Industrial Symbiosis as an effective way to improve the resilience and sustainability of supply chains involves the use of specific digital solutions, given the specificity of the type of interaction between the companies involved in the synergies to be developed. They will be explained throughout this chapter.

7.1 THE BENEFITS AND CHALLENGES OF APPLYING INDUSTRIAL SYMBIOSIS IN NARRATE

In summary, the implementation of Industrial Symbiosis may face challenges, such as the need for coordinated planning, initial investment in infrastructure, and the creation of regulatory frameworks that facilitate collaboration between companies. However, the potential benefits, both economic and environmental, make this model an attractive strategy to promote industrial sustainability.

The study and implementation of Industrial Symbiosis actions generates a series of benefits and opportunities such as:

- Environmental benefits: By sharing resources and by-products between companies, Industrial Symbiosis minimizes the generation of waste and the emission of pollutants. Industrial Symbiosis promotes resource optimization, resulting in more efficient use of materials and energy.

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- Economic benefits: Industrial symbiotic relationships can imply an increase in efficiency in the use of energy and materials (which means a reduction in expenses for companies). In addition, it can mean savings in waste management, logistics, use of energy and other resources, etc.
- Social benefits: Industrial Symbiosis synergies can lead to job creation and alternative sources of employment and/or benefits. Furthermore, environmental or economic improvements imply direct and indirect benefits for society.
- Innovation and collaboration: Cooperation between companies from different sectors promotes technological innovation and the development of new sustainable solutions, which may be necessary both for the implementation of technologically complex symbiosis projects, and for the development of new tools that facilitate and promote Industrial Symbiosis networks.

Despite the numerous benefits of implementing Industrial Symbiosis, it is not free of barriers that make its implementation difficult.

The European Union, in a study published in 2015 that analyzed Industrial Symbiosis and its potential in waste streams of different types, defined the following difficulties in the implementation or popularization of Industrial Symbiosis in the European industrial ecosystem:

- Barriers in coordination between companies.
- A potentially low economic value of waste and by-product streams compared to substitute products and virgin materials.
- Relatively high transportation costs, dispersed production centers and inadequate economies of scale.

On the other hand, the diagnostic study published in 2021 within the framework of the Industrial Symbiosis Observatory of the Valencian Community (OSICV) revealed that, for Valencian companies, the main impediments to the implementation of Industrial Symbiosis are both administrative barriers (such as procedures, their slowness, etc.) and the absence, in their opinion, of policies to encourage it (such as aid, tax benefits, etc.). On the other hand, they also considered that there is still a lack of a positive attitude from the market or consumers towards Industrial Symbiosis or the companies that practice it, which could establish preferences based on the implementation of actions linked to it although this could mean an increase of prices, for example.

However, and despite the difficulties that the implementation of Industrial Symbiosis synergies between companies seems to entail, its promotion and implementation brings with it a series of opportunities both for companies and for the industrial areas in which they are located.

To overcome these barriers, it is important to have in industrial areas an agent that facilitates Industrial Symbiosis, which energizes relationships between nearby companies and encourages their cooperation, as well as the exchange of resources. These business environments in which coordination is encouraged between the companies that comprise them are, in addition, ideal for the implementation of symbiotic relationships linked to storage capacities or logistics management (whether raw materials or commodity). On the other hand, they allow innovation in energy efficiency and decarbonization (through, for example, the creation of energy communities).

The development of government policies and financial support for the implementation of Industrial Symbiosis projects is also necessary. Governments can play a critical role in establishing policies and programs that encourage the adoption of Industrial Symbiosis practices. Tax incentives and financing can motivate companies to participate in these initiatives. Government support is crucial for the long-term success of Industrial Symbiosis projects. Furthermore, digital platforms and other technological tools play an essential role in identifying and facilitating opportunities for Industrial Symbiosis. These platforms allow the exchange of relevant information and data between companies. Chapter 9 shows more information about the use of these information exchange platforms.

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Taking into account the objective of the project, Industrial Symbiosis could be considered as a resource in case of interruptions that may arise in the value chain. This is why, within the framework of this project, its role will be analyzed in each of the pilots defined as a possible alternative in the event of disruption, in addition to knowing their potential in terms of environmental sustainability and circularity.

7.2 TYPOLOGIES OF INDUSTRIAL SYMBIOSIS ACTIONS.

The term Industrial Symbiosis is inspired by biological symbiosis, where different organisms interact in a mutually beneficial relationship. Similarly, in an industrial context, companies from different sectors integrate to share resources such as water, energy, materials and waste, generating economic and environmental benefits. This type of collaboration would not only reduce operating and raw material costs, but also reduces waste generation and potential emissions such as greenhouse gases.

One of the most emblematic examples of Industrial Symbiosis is the case of Kalundborg, Denmark, where several companies, including a power plant, a refinery, a gypsum factory and a fish farm, have developed a resource exchange network. In this industrial ecosystem, steam and hot water from the power plant are used in the refinery and gypsum factory, while waste gas from the refinery is used for energy production. In addition, sludge from gypsum production is converted into fertilizer for local agriculture.

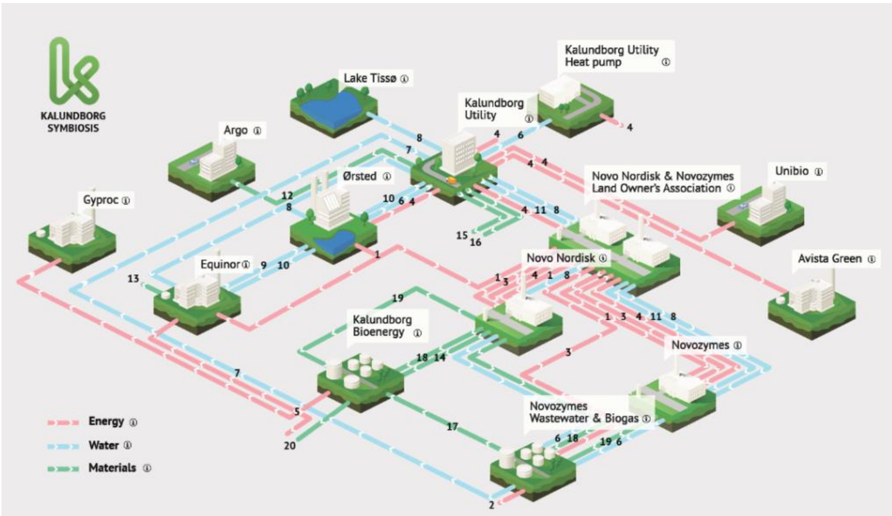

Figure 20: Resources flows in kalundborg (denmark) industrial area (Kalundborg symbiosis).

Taking into account the definition of Industrial Symbiosis, we can distinguish the following types of Industrial Symbiosis actions which, according to Ruiz-Puente (2012), are:

- Symbiosis of mutuality: It corresponds to different opportunities that may arise in the use or shared use of common services, facilities or infrastructures by the participating companies. (For example, energy supply or waste management, cooperation on topics of common interests such as emergency planning, training or sustainable planning, logistics and transport).
- Substitution symbiosis: These opportunities imply that residual flows from one company become input flows into another. (For example, exchange of byproducts, waste, residual heat, etc.) In this way, the useful life of raw materials is optimized.
- Genesis symbiosis: These opportunities are related to the creation of a new activity to satisfy the need for reuse of any flow or company.

7.3 DATA NECESSARY FOR THE DEVELOPMENT OF INDUSTRIAL SYMBIOSIS ACTIONS

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The implementation of Industrial Symbiosis actions is usually framed within the company's sustainability strategy, so the participation and support of management is essential.

To systematize the process of study and analysis of possible Industrial Symbiosis actions, the following stages can be followed:

Stage 1. Identification of underutilized resources. Analysis of input and output flows.

It corresponds to determining which are the underutilized resources that are generated in the different production processes of the company, analyzing the input and output flows to each of them. It is important to have a broad vision and not limit ourselves only to the materials that are involved in the manufacturing process, but to take into account what is also involved in one way or another in the process, such as the packaging of raw materials that could perfectly be used by other companies or even by other departments. Furthermore, within the underutilized resources, aspects such as experience, knowledge, logistics, spaces, water and energy must also be considered. Aspects that may not be used in their entirety and that may be interesting to share with other companies.

Underutilized resources can be generated continuously or sporadically. This can affect when establishing different collaborations with other companies in the long term. Although in both cases the Industrial Symbiosis actions carried out are beneficial, since both contribute to maintaining resources for longer within the production cycle, extending their useful life.

Stage 2: supply and demand for underutilized resources

Once underutilized resources are identified, companies must assess their needs. To facilitate the detection of synergies, the following actions can be carried out:

- Participate in synergy detection dynamics, such as matchmaking workshops.
- Use computer platforms specialized in detecting synergies.
- Attend meetings and inter-business meetings focused on the search for business opportunities and promotion of Industrial Symbiosis.
- Matching workshops are especially valuable, since they allow direct interaction between the company's technicians, generating a motivating effect in the search for synergies. However, its scope is more limited compared to the use of computing platforms.

To facilitate the collection of information after this reflection, it is recommended that companies complete supply and demand templates. These templates should include:

Offer templates: Resources that a company can offer, such as surplus raw materials, packaging, empty warehouses, reverse logistics, etc.

Demand templates: Resources that companies need, such as raw materials, storage space, experience, transportation, etc.

The templates must specify the quantity of the resource (kg, m^2, L, etc.) and whether its production or demand is continuous or discontinuous. Furthermore, it is crucial to indicate the place where the resource is generated or required, since transportation is a critical factor in determining the viability of Industrial Symbiosis actions.

There are several web platforms designed to facilitate symbiotic exchanges, offering a much greater reach than matchmaking workshops and other similar activities. An example of this is the SIMBYLAY platform, developed by AIDIMME, within the framework of a project funded with regional funds and free to use for companies.

Stage 3: Establishment of Synergies

Once the supply and demand templates are completed, synergies can be identified.

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If the process is carried out in person, such as in a matching workshop or similar activities, each participating company presents the underutilized resources it has or needs. This allows us to identify synergies with other companies. It is important to note that this is only a first contact, where initial interest is expressed. Subsequently, it will be necessary to organize meetings between interested companies to evaluate the viability of carrying out the Industrial Symbiosis action.

After entering offers, the platform itself should suggest matches and alerts companies about possible synergies. Subsequently, the companies must contact each other, being able to use the same platform for this purpose, with the aim of materializing Industrial Symbiosis actions.

7.4 INDUSTRIAL SYMBIOSIS WEB PLATFORMS

In this subchapter several examples of Industrial Symbiosis platforms are introduced.

7.4.1 Simbylay

Since 2017, AIDIMME has been working to publicize Industrial Symbiosis as a key tool of the circular economy, which allows underutilized resources to spend more time in productive use. In this sense and within a project funded with European Regional Development Funds. AIDIMME developed an Industrial Symbiosis web platform that automatically allows Industrial Symbiosis synergies to be established between companies that are registered.

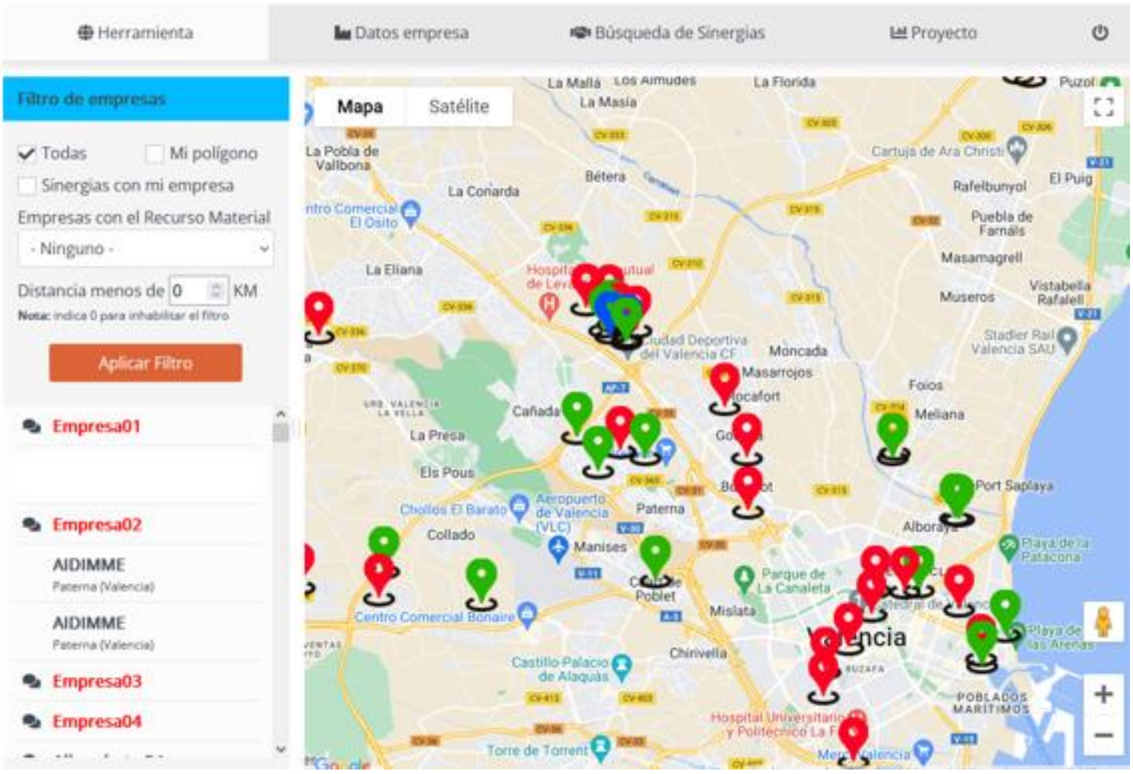

Figure 21: Simbylay main interface (AIDIMME).

Simbylay platform is a web platform designed so that users can register their offers and demands for underutilized resources and subsequently the application automatically links offers with demands. The sequence of steps to follow to use the web platform is:

1. Register as a company

2. Create offers and demands for underutilized resources

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3. Search for synergies between companies. To search for synergies, an automatic search engine for synergies between companies is activated, resulting in a proposal for synergies with other registered companies. With this information, each company will be able to select the synergies that are of interest and subsequently carry out a feasibility analysis. To search for synergies, the web platform has a series of functionalities such as filters related to:

- distance
- the type of underutilized resource
- companies located in the same industrial area

4. Contact with the company. To establish collaboration, the tool has tools to establish contact with other Simbylay user companies.

7.4.2 Other tools

- RECIRCULAR.NET: They have a digital recovery platform where you can sell a company's resources (waste, sub-products, production remains, material in stock) so that another company can give them a second life. They also inform about the different options for reusing and recycling their resources and facilitate contact with other companies that are potential consumers.

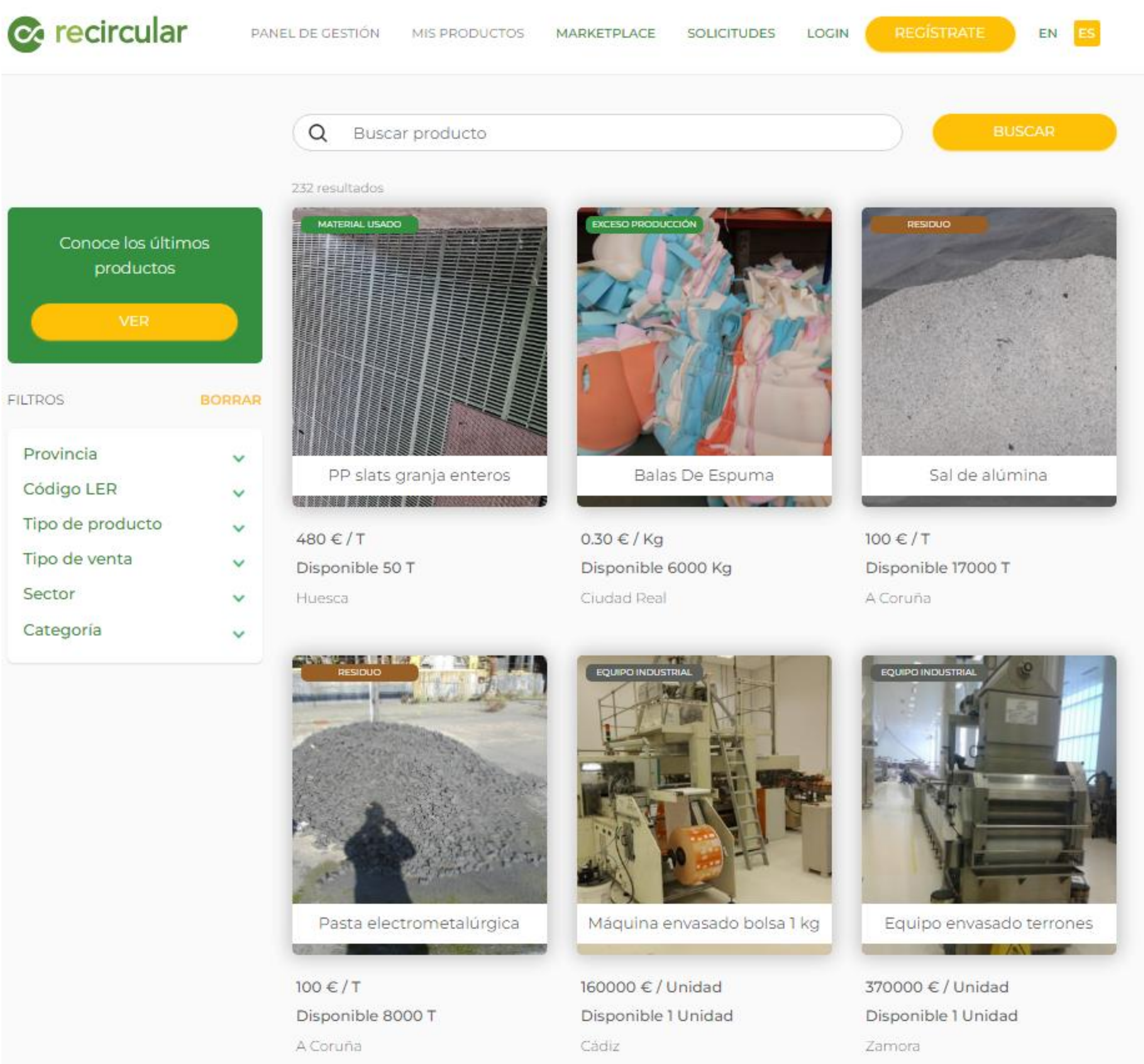

Figure 22: Recircular.net

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- OSICV.ES. The Industrial Symbiosis Observatory of the Valencian Community, (OSICV), is an initiative of ivace (valencian institute of business competitiveness) for the promotion and development of Industrial Symbiosis solutions among valencian companies, which can serve as inspiration to companies, by giving to learn examples of Industrial Symbiosis and ways to put them into practice in their context. The objectives of the observatory are the following:
    - Promote the concepts of circular economy and Industrial Symbiosis as business tools.
    - Ensure that the results of related initiatives and projects are communicated and disseminated to a wide range of local/regional actors.
    - Understand and exchange good local practices derived from said initiatives/projects, as well as the barriers or problems encountered.
    - Support synergies and demonstrative elements.
    - Propose a single and coordinated action plan in the medium term, monitoring the initiatives that are launched.

7.5 ANALYSIS OF THE VIABILITY OF INDUSTRIAL SYMBIOSIS PROJECTS

The existence of barriers to the development of Industrial Symbiosis actions implies the need to carry out an analysis of the viability of Industrial Symbiosis actions. It is advisable to review the following aspects prior to carrying out the action:

- Legislative-environmental factor. The new Industrial Symbiosis initiative must comply with those regulatory aspects that apply to it, and its environmental impact must not be greater than the non-development of the Industrial Symbiosis action.
- Technical factor. The technical effort that the company must make when launching the initiative must be evaluated, such as the existence of adequate technology and availability of it, adequate training, etc.
- Market factor. It corresponds to the analysis of the market that is the object of the Industrial Symbiosis initiative, where the demand from the market must be analyzed, if it is the right time, etc.
- Economic factor. An analysis should be carried out on the expenses associated with the start-up of the project, estimate the expected income and analyze the return on the investment to be made, to analyze the economic viability of the initiative.

8. ENVIRONMENTAL DATA AND KPIs

The purpose of this chapter is to identify environmental data that can be considered and adopted by the NARRATE project as “indicators” of energy efficiency & circularity by the Intelligent Manufacturing Custodian. In any case, it must be considered that environmental data and KPIs can be complex and diverse due to several approaches, contest and moreover due to the specific product and process. According to this, it is highly recommended to adapt them to each organization and its supply chain, resulting in a specific and different set of data and indicators.

8.1 NARRATE SUSTAINABILITY KPIS

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Indicators are key for management and performance improvement. To paraphrase the well-known quote from William Thomson, Lord Kelvin: "What is not measured, cannot be improved". In that sense, ISO 14031 standard ("Environmental performance evaluation") focuses on environmental indicators as a way to compare past and present performance, in order to develop new objectives and plans aimed at the improvement. As the standard points out, this management process must be based in a "P-D-C-A model" (this is, a "Plan-Do-Check-Act" model). Indicators, consequently, need to be able to offer the information needed to establish the new objectives, monitor them and evaluate the efficiency of the actions developed.

To reach this objective, the selection of environmental indicators, must follow few basic criteria:

- Must be measurable, relevant, representative and easy to be calculated
- Must be comparable and available by all potential users of IMC
- Compatible with the purpose of NARRATE.

An additional criterion to be considered is related to the European regulations specifically designed to support and guide corporate communication: Corporate Sustainability Reporting Directive and Corporate Sustainability Due Diligence Directive.

The sustainability of each supply chain, including the NARRATE pilots, can be measured and described by a broad set of specific indicators and managed by considering different strategies or disciplines. This entails the risk of not being able to compare different case histories and not being able to study or set up tools capable of analysing potential changes due to choices or external events, including disruptive ones. Applying the general criteria described above is expected to drastically reduce the datasets required for the IMC, to avoid the risk of having a lack of information and the risk of having detailed but unmanageable information that is not meaningful in the overall project context.

The following table considers a restricted list of indicators to by applied to the entire supply chain and to each organization inside it, able to give a high-level measure of sustainability and environmental impacts. These indicators can be applied and adapted to mostly any company that wished to do so. The raw data needed for each indicator will be useful from both a corporate management perspective and a product ecodesign management perspective (production stage). Therefore, it should be considered that data entry to be used from both perspectives, offering useful information to users without duplicating data entry processes. To allocate the corporate information into specific product´s one, it should be able to be defined company´s specific allocation rules.

The table 25 aims to collect a proposal of a complete list of KPIs, but the application to each specific company would need an adaptation and selection of main KPIs depending on their activities.

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Table 25: Environmental KPIs

Environmental indicators	Description	KPI for Corporate data management	KPI for Product ecodesign data management
Raw Materials			
Amount consumed	Amount of raw materials used during production, including losses and possible defective entries.	kg/production unit	kg/product
Source	Sustainability of the raw materials source: recycled materials, renewable materials, CMR, hazardous substances.	% (regarding the total of raw materials)	% (mean included in every product)
Carbon footprint	Amount of CO2eq emissions during the base year	tCO2eq/production unit	tCO2eq/product
Transport linked to the supply chain	Distance linked to the raw materials purchased.	tkm/production unit	tkm/product
Packaging	Sustainability linked to the packaging obtained: recycled content, recyclability, etc.	% (regarding the total of pakaging)	
Energy			
Amount consumed	MWh consumed during the base year	MWh/production unit	MWh/product
Source	Country electric pool	% of each source	
Fuel/gas consumption			
Type	Kind of fuel/gas consumed	-	-
Amount consumed	Amount consumed during the base year	L or m3/production unit	L or m3/product
Water			
Amount consumed	Amount consumed during the base year	m3/production unit	m3/product
Discharges			
Amount	Amount discharged during the base year	m3/production unit	m3/product
Pollutants concentration	Concentration regulation of pollutants in the discharges.	Have the concentration limits been met? YES/NO	
Waste			

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Environmental indicators	Description	KPI for Corporate data management	KPI for Product ecodesign data management
Classification	Kind of waste generated: hazardous or non-hazardous	% (regarding the total of waste)	
Amount	Amount of waste (hazardous and/or non-hazardous) generated during the base year	kg/production unit	kg/product
Final treatment	Type of final treatment applied to the generated waste (recycling, different kind of valorization, landfill)	% (regarding the total of waste)	
Product distribution			
Load efficiency	Average % of load in containers or other means used for distribution	% (regarding the total of the distribution)	
Vehicle type	km traveled for the distribution of the product according to the type of vehicle, considering: medium (road, rail, air, sea), cargo and, in the case of road transport, EURO classification of the vehicle.	km/production unit	km/product
Product use phase			
Reliability	Expected lifespan until the product first failure		Years
Maintenance	Ease of the products to be taken care to expand their lifespan by the user.		Existence of supporting technical service, updating and preventive maintenance services instructions
Reparability	Possibility for the products to be repaired after a failure, by the user or qualified staff.		Existence of local repair services, availability of spare parts (years)
Product end of life			
Remanufacture	% of the product parts that can be dismantled and returned to the production lines.		%
Recyclability	% of the product's weight that is potentially recycled		%
Final disposal	% of the product's weight ending in different final disposal options (incineration or landfill)		% (for each waste treatment)

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While the previous KPI table attempts to cover the needs of any company's sustainability assessment, when considering specific supplier selection, it is important to first understand how these KPIs affect the lead company's sustainability performance. Then it is possible to select the most relevant KPIs to be used in supplier selection. The following non-exhaustive list provides relevant examples:

Table 26: Most relevant KPIs in supplier selection

Supplier	KPIs to selection
Electricity supplier	• CO_2eq emission factor Other interesting data: electric mix
Machinery supplier	• Material efficiency: kg of key input material by unit of process • Energy efficiency: kwh demand by unit of process (derives from power and productivity) • Durability (guaranty years), reparability (existence of local repair services, availability of spare parts (years), supporting technical service and updating, preventive maintenance services, etc.
Material supplier (strongly dependant on each material)	• Avoidance or restriction on certain substances: ○ Paints: % of VOCs, absence of heavy metals ○ Wooden materials: limitations on formaldehyde emissions ○ Metals: chromium free coverings ○ Etc. • Origin: ○ Recycled content (%) ○ Renewable sources (Yes/no or %) ○ Sustainable origin certification (CoC, non war areas, etc.) • Recyclability potential (easy, difficult, non feasible) • Material unitary carbon footprint: kg CO_2eq/kg material
Process subcontractor (strongly dependant on the process to be subcontracted)	• Avoidance or restriction on use of certain substances (similar to raw materials) • Material efficiency: kg of key input material by unit of process • Process´s unitary carbon footprint: kg CO_2eq by unit of process Alternatively it can be used energy demand (kwh) and origin of this energy or the CO_2eq emission factor of main energy source, which considers fewer inputs than the corporate carbon footprint of the subcontracted company. • Distance to our facility and transport data (see below)
Transport supplier	• Typology and average CO2eq emission factor of vehicles • Average load capacity and load efficiency

8.2 SUSTAINABILITY REPORTING INDICATORS

The discussion on Environmental Indicators must also consider the recent European Directive related to Sustainability Reporting and Sustainability Due Diligence. This new directive emphasizes the importance of providing investors and stakeholders with the necessary information to support decisions regarding financial programs. This need for information extends to banks, insurance institutions, investors, and public administration decisions.

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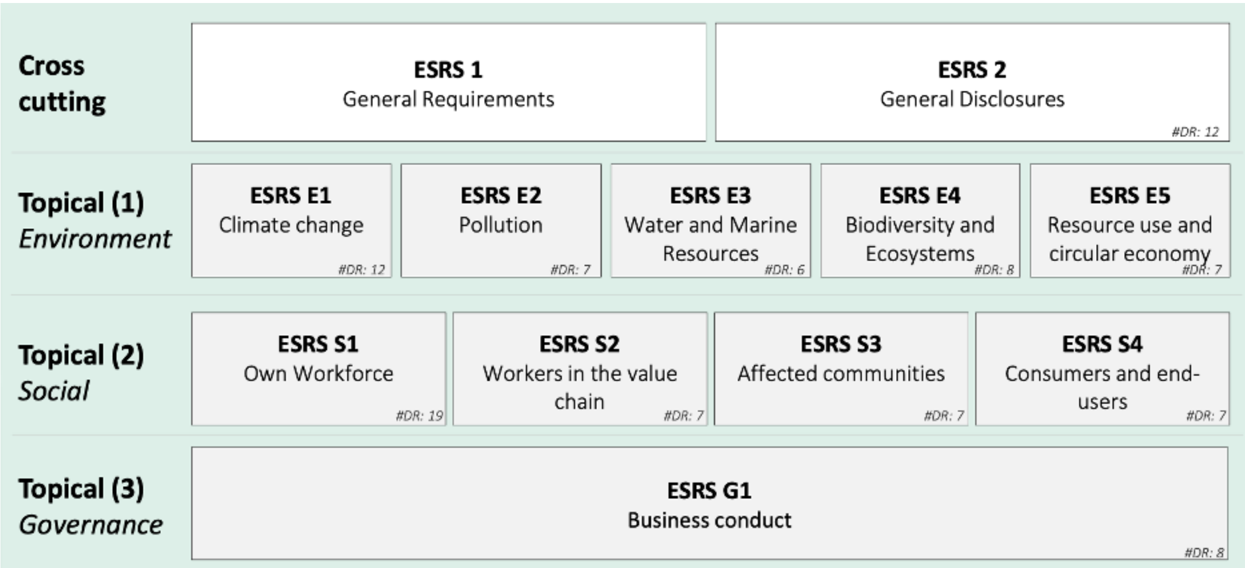
Non-financial reporting, while not mandatory for small and medium-sized enterprises (SMEs), represents a valuable exercise in transparency towards their stakeholders. SMEs can engage in this through sustainability reports, which can be guided by various standards. The Global Reporting Initiative (GRI), the principles of the Economy for the Common Good, or the previously referred Corporate Sustainability Reporting Directive (CSRD) all offer frameworks for creating these reports.

The CSRD was developed by EFRAG (the European Financial Reporting Advisory Group), which was appointed as a technical advisor to the European Commission for developing draft sustainability reporting standards under the referred Directive. Additionally, EFRAG was tasked with developing a proposal for voluntary sustainability reporting standards applicable to SMEs not covered by the CSRD.

Although these areas of decision-making are not directly within the scope of the NARRATE project, it is essential to recognize that inadequate sustainability reporting can have a disruptive effect on the supply chain. The following figure represents the organization of the European Sustainability Reporting Standards (ESRS) and the integration scheme between different disciplines and application fields.



9. CONCLUSIONS

This deliverable provides an analysis of the requirements for assessing circularity, energy efficiency, carbon footprint, Industrial Symbiosis and other sustainability aspects of the supply chain from raw materials extraction till the product on the market defining environmental and circularity KPIs , in order the IMC and AI platform could select the best circularity and energy efficiency options as well as the best procurement alternatives from a pool of assessed suppliers.

The document highlights the growing importance of incorporating sustainability into all aspects of the supply chain due to emerging European regulations and market trends. These changes necessitate the integration of new requirements across the supply chain, particularly in terms of identifying potential risks and disruptive scenarios. As these requirements reshape relationships and information flows between companies within the supply chain, they also demand greater attention to other risk factors, such as raw material scarcity. This underscores the need to select alternative suppliers based on sustainability criteria and key KPIs, thereby enhancing overall supply chain resilience.

A methodology for diagnosing environmental sustainability has been introduced and applied to assess the key environmental aspects, including those common across the three pilot partners. This approach involves a comprehensive questionnaire that addresses current and potential improvement actions, as well as an analysis of the production process mass balance. The methodology seeks to identify key

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environmental aspects, explore opportunities for Industrial Symbiosis, and assess the partners' capacity for effective data collection. The findings highlight the critical need for companies to implement robust environmental and circularity KPIs, underpinned by thorough and consistent data collection.

The next steps involve a review of these findings by the technical partners, which will be considered for the development of the IMC and AI platforms within the MaaS context. Additionally, the pilot partners will need to test the proposed environmental KPIs in real-world scenarios as part of WP5.

Furthermore, it will be essential to critically evaluate and refine the resilience strategies proposed in this deliverable response to potential disruptive scenarios. These strategies should be continuously updated based on emerging market trends and regulatory changes to ensure they remain relevant and effective. Close relationship with the technical WPs is absolutely necessary. The formalization of use cases will provide a clearer understanding of user expectations and how the IMC and the platform is designed to meet them.

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APPENDIX 1. SUSTAINABILITY DIAGNOSIS RESULTS

AP1.1 ECODESIGN QUESTIONNAIRE TEMPLATE

ECODESIGN/ENVIRONMENTAL DIAGNOSIS.

Context situation on ecodesign implementation.

1. Do you design your products? ☐ Yes ☐ No ☐ Occasionally

   If yes, ¿do you consider during design any environmental aspects along the life cycle of the product (ecodesing)? ☐ Yes ☐ No
   Why?

2. Please, indicate both barriers and potential benefits of implementing ecodesign at your company and priorise them from 1 (very relevant) to 5 (not relevant):

Barriers		Potential benefits	
Lack of internal knowledge on how to do it		Improvement on enviromental management	
Lack of specific information from supply chain		Improvement of knowledge related to environmental properties of our products and our raw materials	
Lack of specific information on environmental indicators			
Lack of environmental assessment tools		Overview of the main environmental aspects /impacts along the life cycle of our products	
Over costs (design, raw materials, etc.)		Potential increase of economic incomes (for example higher manufacturing efficiency, waste management cost reduction, higher product sale price, etc.)	
There is no positive valuation from our customers		Our current market considers positively the company public image or our products	
		Potential access to new markets where there are valuated environmental improvements on products	
Other:		Other:	

3. After improving environmentally your products/processes, do you perform any product environmental assessment to verify it? ☐ Yes ☐No
   If yes, which type of assessment?
   ☐ Qualitative (fulfilment of requirements from customer)
   ☐ Quantitative, based on environmental aspects like internal indicators (% recycled content, etc)
   ☐ Quantitative, based on environmental impacts (LCA or carbon footprint)
4. Which collaboration would you need from other agents in your value chain to implement potential environmental improvements along the life cycle of your products/services?

5. Certification of the Ecodesign management system (ISO 14006). Do you consider it would be beneficial to obtain this certification to your company? Why?

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Context situation on environmental communication

6. ¿Which is the element of your offer most appreciated by your customers (product quality, price, post-sale services, etc.)?
   Which environmental issue would they appreciate (if any)?

7. Do you communicate the environmental improvements of your product/services to your clients? ☐ Yes ☐ No

Not directly. We communicate the service of design for additive manufacturing of customer's parts as an economic advantage not environmental even they are strongly related.

Why?

If yes

☐ It is a legal requirement
☐ It is a common market requirement
☐ It is a requirement from one/some specific customers (not usual).
☐ It is not a market requirement but a competitive advantage.

If no

☐ It is not appreciated by the market.
☐ I do not know how to do it.
☐ I do not have any environmental improvement to communicate.

8. How do/would you communicate the environmental info on your product/services? Ecolabelling type:

☐ Certified ecolabel
☐ Self-declaration
☐ Environmental Product Declaration based on LCA

Communication channel: Direct contact with the customer, part of final report.

9. Are you asking for any environmental requirement to your providers (certified wood, absence of harmful substances, etc.)?
   ☐ Yes ☐ No If yes indicate:

We consider the safety data sheet of the materials to avoid harmful substances into our waste water from some of our finishing processes

10. Are you asking for environmental information to your providers carbon footprint, recycled content, etc.)?
    ☐ Yes ☐ No If yes indicate:

11. If you answered yes to any of the two previous questions: how are stablished the requirements or information requested to your providers? (transfer of customer requirement, legal requirement, internal process).
12. ¿Do you have a km 0 policy regarding your providers? How relevant it is versus other aspects (price, delivery time, quality, etc.)?.

☐ Yes ☐ No

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Indicate which environmental improvements you have yet implement (Done) or would like to implement (Potential), briefly explaining them specifically to your use case in column "Detail"

Life cycle stage	Relevance to your product/ process	Done (D) Potential (P)	Detail	Requirements to implementation
Raw Materials (including packaging)				
Green purchasing policy and related management system				
Recycled materials				
Renewable materials				
Materials with low embodied energy				
Non use or reduction of hazardous substances				
Due diligence system (to know the origin of specific materials and avoid non allowed)				
Product and packaging weight reduction: (avoid superfluous components, use light materials, optimize design of parts …)				
Ecolabelled/certified materials				
Raw materials supply				
Distance from providers (raw material manufacturer)				
Environmental certifications from provider management				
Other environmental practices from provider				
Productive process				
Energy: control and reduce energy demand				
Energy: use of renewable energy				
Water: reduction of water demand				
Material efficiency: auxiliary raw materials reduction				
Material efficiency: reduction of non hazardous waste generated				
Material efficiency: reduction of hazardous waste generated				
Wastewater: reduction of effluents volume, reduce specific contaminants				
Emissions: reduce specific contaminants emissions (VOC, etc)				
Waste management: increase recycling rates by contracting proper waste managers				
Potential to internal recovery/valorization of raw materials				

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Find secondary resources providers				
Find secondary resources customers				
Efficient distribution				
Low consume-GHG emission vehicles				
Load efficiency (delivery unit design compacted, max number of deliveries by trip)				
Routes optimisation to reduce distance travelled				
Use				
Functional optimisation (customer based- design thinking)				
High energy efficient product (if applies)				
Use life extension				
High durability (free extra guarantee)				
Easy cleaning/maintenance				
Modular structure (adaptability to changing requirements)				
Technical upgradability (additional service)				
Easy to repair				
Availability of replacement parts over the legal period (10 years after the product is no longer manufactured)				
Maintenance or repair as a service (predictive maintenance by IoT, available professional partner near customers,)				
Product as a service: renting, pay per use business model				
End of life				
Remanufacturing: recovering old products from customers to manufacture new ones from them (or from non-sold ones). Potential connexion with servitization/upgradability services				
Design for easy dis/reassembly				
Hazardous components and critical material content is informed and their recovery is facilitated from design				
Easy material separation of recyclable materials				
Avoid multi-materials (non easy to recycle)				
Feasible energy valorisation of non recyclable materials				

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AP1.2 MEDWOOD ECODESIGN QUESTIONNAIRE

Context situation on ecodesign implementation.

1. Do you design your products? ☐ Yes ☒ No

   *MEDWOOD does not design.

   Micuna Familiy yes.

   If yes, ¿do you consider during design any environmental aspects along the life cycle of the product (ecodesig)? ☒ Yes ☐ No

   Why? Market appreciates quality products evolutive and multifunctional, and also PECF certified.

2. Please, indicate both barriers and potential benefits of implementing ecodesign at your company and priorise them from 1 (very relevant) to 5 (not relevant):

<table>
<tr><th colspan="2">Barriers</th><th colspan="2">Potential benefits</th></tr>
<tr><td>Lack of internal knowledge on how to do it</td><td>5</td><td>Improvement on enviromental management</td><td>1</td></tr>
<tr><td>Lack of specific information from supply chain</td><td>4</td><td rowspan="2">Improvement of knowledge related to environmental properties of our products and our raw materials</td><td>2</td></tr>
<tr><td>Lack of specific information on environmental indicators</td><td>2</td><td></td></tr>
<tr><td>Lack of environmental assessment tools</td><td>1</td><td>Overview of the main environmental aspects /impacts along the life cycle of our products</td><td>2</td></tr>
<tr><td>Over costs (design, raw materials, etc.)</td><td>1</td><td>Potential increase of economic incomes (for example higher manufacturing efficiency, waste management cost reduction, higher product sale price, etc.)</td><td>4</td></tr>
<tr><td rowspan="2">There is no positive valuation from our customers</td><td>3</td><td>Our current market considers positively the company public image or our products</td><td>2</td></tr>
<tr><td></td><td>Potential access to new markets where there are valuated environmental improvements on products</td><td>2</td></tr>
<tr><td>Other:</td><td></td><td>Other:</td><td></td></tr>
</table>

3. After improving environmentally your products/processes, do you perform any product environmental assessment to verify it? ☐ Yes ☒ No

   If yes, which type of assessment?

   ☐ Qualitative (fulfilment of requirements from customer)

   ☐ Quantitative, based on environmental aspects like internal indicators (% recycled content, etc)

   ☐ Quantitative, based on environmental impacts (LCA or carbon footprint)

4. Which collaboration would you need from other agents in your value chain to implement potential environmental improvements along the life cycle of your products/services? More agile environmental communication from my providers, better understanding of environmental issues from customers.

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5. Certification of the Ecodesign management system (ISO 14006). Do you consider it would be beneficial to obtain this certification to your company? Why? No, because or current market does not demand and it requires a big management effort.

Context situation on environmental communication

6. ¿Which is the element of your offer most appreciated by your customers (product quality, price, post-sale services, etc.)? Quality

   Which environmental issue would they appreciate (if any)? Certified wood, water based paints and evolutive products.

7. Do you communicate the environmental improvements of your product/services to your clients? ☒ Yes ☐ No

   Why?

   ☐ It is a legal requirement
   ☒ It is a common market requirement
   ☐ It is a requirement from one/some specific customers (not usual).
   ☐ It is not a market requirement but a competitive advantage.
   ☐ It is not appreciated by the market.
   ☐ I do not know how to do it.
   ☐ I do not have any environmental improvement to communicate.

8. How do/would you communicate the environmental info on your product/services? Ecolabelling type:

   ☐ Certified ecolabel
   ☒ Self-declaration
   ☐ Environmental Product Declaration based on LCA

   Communication chanel: web and social media.

9. Are you asking for any environmental requirement to your providers (certified wood, absence of harmful substances, etc.)?
   ☒ Yes ☐ No If yes indicate: certified wood, absence of harmful substances in paints, textiles...

10. Are you asking for environmental information to your providers carbon footprint, recycled content, etc.)?
    ☐ Yes ☒ No If yes indicate:

11. If you answered yes to any of the two previous questions: how are stablished the requirements or information requested to your providers? (transfer of customer requirement, legal requirement, internal process).Market requirements

12. ¿Do you have a km 0 policy regarding your providers? Yes.

    How relevant it is versus other aspects (price, delivery time, quality, etc.)?. Mos t important is quality and price.

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Indicate which environmental improvements you have yet implement (Done) or would like to implement (Potential), briefly explaining them specifically to your use case in column "Detail"

Life cycle stage	Relevance to your product/ process	Done (D) Potential (P)	Detail	Requirements to implementation (to be selected those that can be considered by NARRATE)
Raw Materials (including packaging)				
Green purchasing policy and related management system	H	D	Yes but limited: Reach for chemicals PEFC for wooden materials Waterbased paints	Establishment of clear criteria by material/component Information to providers on green procurement policy/requirements Collect and verify signed declaration (documentation) from provider (general requirement valid for all raw materials/service provider). Green purchasing scale system.
Recycled materials	M	P		Technical-economical-logistic requirements on secondary materials
Renevable materials	H	D	Non plastics in packaiging Mainly wooden products	Identification and declaration when doubt is feasible (plastics for example)
Materials with low embodied energy	Low	P		Info from data bases / specific from the provider
Non use or reduction of hazardous substances	High	D	Paints, textiles	
Due diligence system (to know the origin of specific materials and avoid non allowed)	Mandatory	In progress EUDR	Wooden materials	Verification document required when buying a component containing the material.
Product and packaging weight reduction: (avoid superfluous components, use light materials, optimize design of parts ...)	High	D	Reduction of transport incidences (product) and its cost in RM, and Ecoembes taxes	To know the composition and related weight of each component. Rationale of products weight vs functionality Indicator kg packaging/kg contained product
Ecolabelled/certified materials	High	D	PEFC	Documentation from provider
Raw materials supply				
Distance from providers (raw material manufacturer)	Medium	D	Proximity is valuated but not main criteria	Collect and consider data provider in green procurement

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Environmental certifications from provider management	Low	P	PEFC	Documentation collection, verification and periodically update (annual at least)
Other environmental practices from provider	Low	P		Collect related information to its assessment
Productive process (MEDWOOD)				
Energy: control and reduce energy demand	High	D	Energy demand software in real time	Environmental indicators: Definition, monitoring (at least periodically) and relating quantities to production. Environmental action plan with objectives and follow up.
Energy: use of renewable energy	High	D	Solar panels and production planning according solar energy	
Water: reduction of water demand	Low	P	Good practices at employees	
Material efficiency: reduction of non hazardous waste generated	Medium	D	Waste reduction plan	
Material efficiency: reduction of hazardous waste generated	Medium	D	Internal recycling of solid wood dust	
Wastewater: reduction of effluents volume, reduce specific contaminants	Low	P		
Emissions: reduce specific contaminants emissions (VOC, etc)	High (mandatory)	D	VOC, particles	
Waste management: increase recycling rates by contracting proper waste managers	Low	D	Asking management to sustainability reporting	Collection treatment information from waste managers and select them accordingly
Potential to internal recovery/valorization of raw materials	High	D	Biomass furnace	Adjustment of production generating the “waste” to be recovered to the needs of the output from the valorisation process
Find secondary resources providers	Medium	P	Biomass to the furnace in specific periods	Offer-demand connection platform Ensuring desired resource properties (humidity, quantity, price, etc.) Legal classification of the secondary resource as a by-product Distance (km)
Find secondary resources customers	Low	P	No potential resource to offer but dust from	

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			MDF and Particle board	
Efficient distribution				
Low consume-GHG emission vehicles	Low	P		Information on emission factors from logistic providers
Load efficiency (delivery unit design compacted, max number of deliveries by trip)	Low	P		Coordination between agreed delivery times/routes/load efficiency
Routes optimisation to reduce distance travelled	Low	P		
Use				
Functional optimisation (customer based- design thinking)	High	D	Evolutive products	Communication with customer before design and after (marketing)
High energy efficient product (if applies)	Non applies			Calculation of consume and communication to customer
Use life extension				
High durability (free extra guarantee)	High	D	High quality products. Aptitude to use standards Correct use	Info to customer (durability tests, guarantee)
Easy cleaning/maintenance	Low	P		Instructions, technical after-sales service.
Modular structure (adaptability to changing requirements)	High	D	Evolutive	Assessment during design, potential customer requirements on modularity/adaptability
Technical upgradability (additional service)	High	D	Evolutive	
Easy to repair	Medium	D	Change broken parts	Assessment during design
Availability of replacement parts over the legal period (10 years after the product is no longer manufactured)	Low	P	Only legal period	Stock management of replacement parts
Maintenance or repair as a service (predictive maintenance by IoT, available professional partner near customers,)	Low	P	No feasible by the moment to particular customers	Availability of replacement parts, connectivity of the product, repair centres alliance, maintenance and repair instructions, after-sales staff, etc.
Product as a service: renting, pay per use business model	Low			Track and trace of products (real life use parameters and disruptions)
End of life				
Remanufacturing: recovering old products from customers to manufacture new ones from them (or	Low	P/D	Not feasible by the moment.	Track and trace of product versions, bill of materials and exchangeability between models. Protocols to parts recovery, inspection, etc.

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from non sold ones). Potential connexion with servitization/upgradability services			Done with transport incidences from customer (reaconditioning damaged products)	
Design for easy dis/reassembly	High		Transformers are a key of they offer	Instructions to professionals
Hazardous components and critical material content is informed and their recovery is facilitated from design	Does not apply			Instructions to professionals
Easy material separation of recyclable materials	Low	D	No concient design	Assessment during design
Avoid multi-materials (non easy to recycle)	Low	D	Not very used (not consciente)	Assessment during design
Feasible energy valorisation of non recyclable materials	Low	P		Assessment during design

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AP1.3 MEDWOOD PROCESS DIAGNOSIS

Process/ operation	Inputs	nº	Input (Description)	Source	Amount	UNIT	Outputs	nº	Air emission, Wastewater, Waste type (description)	Amount	unit	Mana-gement	Final treatment
General	Electricity	1	Electricity	External (Commercial)	742.040	kwh	Air emission	1	Combustion emission from biomass furnace				
		1	Electricity from solar panels (self-consume)	Internal Recovery									
	Energy (fuel)	2	Biomass (wooden sawndust)	Internal Recovery	193.000	kg	Waste						
	Aux	3	Water	External (Commercial)	2.171	m3	wastewater	2	Similar to domestic wastewater (no industrial)				
Wood-working	In	4	Solid wood	External (Commercial)	849.687	kg	Waste	3	Sawndust from solid wood	193.000	kg	Internal Recovery	
	In	5	MDF boards	External (Commercial)	86.929	kg	Waste	4	sawndust from MDF panels	26.000	kg	Sent to waste manager	Recycling
Varnishing	In	6	Chemical products	External (Commercial)		kg	Hazardous waste	5	Paint dust from sanding	2.268	kg	Sent to waste manager	
	In	7	Sandpaper	External (Commercial)		kg		6	Paint remains in original container	1.097	kg		
	In	8	Filters	External (Commercial)		kg		7	Sludge from the pit	20.040	kg		
								8	Remains of paints (in grg and drum)	2.380	kg		
								9	Remains of pasty paints (in grg and can)	10.499	kg		
								10	Solid from paint booth	15.324	kg		
								11	Waters with paints	52.281	kg		
								12	Water-based paint sludge (pit cleaning)	4.317	kg		

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								13	Natural peld plastic containers	80	kg		
								14	Contaminated metal containers	11.107	kg		
								15	Contaminated plastic containers	1.225	kg		
								16	Contaminated solid	12.757	kg		
								17	Cardboard filters and sandpads	223	kg		
Packaging and shipping			Hardware	External (Commercial)		kg	Waste	18	Cardboard	21.103	kg	Sent to waste manager	
			Cardboard	External (Commercial)	54.088	kg							
			Plastic	External (Commercial)	5.619	kg							

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AP1.4 AIDIMME ECODESIGN/ENVIRONMENTAL DIAGNOSIS

Context situation on ecodesign implementation.

13. Do you design your products? ☐ Yes ☐ No ☒ Ocasionally

    If yes, ¿do you consider during design any environmental aspects along the life cycle of the product (ecodesig)? ☒ Yes ☐ No

    Why?

    Additive manufacturing production costs are strongly related to the part volume (weight) and its size. When designing for additive manufacturing, these variables are taken into account to reduce the amount of material to be used and to optimize the production times. This will have an impact on environmental indicators.

    In addition, some additive manufacturing technologies require support structures, which are auxiliary geometries attached to the part needed for its construction in a layer by layer manner. These structures are waste after the parts are detached. When designing for additive manufacturing, we have in mind the technology limitations to avoid support structures as much as possible.

    Support structures are critical as they suppose about 10-15% of added material, process energy and a potential risk of part quality.

14. Please, indicate both barriers and potential benefits of implementing ecodesign at your company and priorise them from 1 (very relevant) to 5 (not relevant):
15.

Barriers		Potential benefits	
Lack of internal knowledge on how to do it	4	Improvement on enviromental management	3
Lack of specific information from supply chain	3	Improvement of knowledge related to environmental properties of our products and our raw materials	2
Lack of specific information on environmental indicators	2		
Lack of environmental assessment tools	5	Overview of the main environmental aspects /impacts along the life cycle of our products	2
Over costs (design, raw materials, etc.)	1	Potential increase of economic incomes (for example higher manufacturing efficiency, waste management cost reduction, higher product sale price, etc.)	1
There is no positive valuation from our customers	1	Our current market considers positively the company public image or our products	5
		Potential access to new markets where there are valuated environmental improvements on products	4
Other:		Other:	

16. After improving environmentally your products/processes, do you perform any product environmental assessment to verify it? ☐ Yes ☒ No

    If yes, which type of assessment?

    ☐ Qualitative (fulfilment of requirements from customer)

    ☐ Quantitative, based on environmental aspects like internal indicators (% recycled content, etc)

    ☐ Quantitative, based on environmental impacts (LCA or carbon footprint)

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17. Which collaboration would you need from other agents in your value chain to implement potential environmental improvements along the life cycle of your products/services?
    - Machine and feedstock suppliers providing environmental information about their processes / materials.
    - Our customers by implementing design rules depending on the technology limitations and optimizing the part volume (weight).
    - Our customers should consider the environmental benefits of using additive manufacturing and the specific information we can provide them to transfer it as a competitive advantage to their clients.
    - It would be nice that our material providers recover the waste coming from support structures / aged material at a convenient price as by-product.

18. Certification of the Ecodesign management system (ISO 14006). Do you consider it would be beneficial to obtain this certification to your company? Why?
    For the time being we do not consider interesting since our market is not requesting this kind of certification or even ecodesigned products.

Context situation on environmental communication

19. Which is the element of your offer most appreciated by your customers (product quality, price, post-sale services, etc.)?
    - Pre sales Ad-hoc technical service to optimize the results to our customers, (quality price, technical feasibility).
    - Delivery time.
    - Very complex developments that others cannot address.

    Which environmental issue would they appreciate (if any)? Carbon footprint impact.

20. Do you communicate the environmental improvements of your product/services to your clients? ☐ Yes ☒ No
    Not directly. We communicate the service of design for additive manufacturing of customer's parts as an economic advantage not environmental even they are strongly related.

    Why?
    ☐ It is a legal requirement
    ☐ It is a common market requirement
    ☐ It is a requirement from one/some specific customers (not usual).
    ☐ It is not a market requirement but a competitive advantage.
    ☒ It is not appreciated by the market.
    ☐ I do not know how to do it.
    ☐ I do not have any environmental improvement to communicate.

21. How do/would you communicate the environmental info on your product/services? Ecolabelling type:
    ☐ Certified ecolabel
    ☒ Self-declaration
    ☐ Environmental Product Declaration based on LCA

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Communication channel: Direct contact with the customer, part of final report.

22. Are you asking for any environmental requirement to your providers (certified wood, absence of harmful substances, etc.)?
    ☒ Yes ☐ No If yes indicate:
    We consider the safety data sheet of the materials to avoid harmful substances into our waste water from some of our finishing processes

23. Are you asking for environmental information to your providers carbon footprint, recycled content, etc.)?
    ☐ Yes ☒ No If yes indicate:

24. If you answered yes to any of the two previous questions: how are stablished the requirements or information requested to your providers? (transfer of customer requirement, legal requirement, internal process).
    Legal requirements on wastewater discharge.

12. ¿Do you have a km 0 policy regarding your providers? ☐ Yes ☒ No
    How relevant it is versus other aspects (price, delivery time, quality, etc.)?.

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Indicate which environmental improvements you have yet implement (Done) or would like to implement (Potential), briefly explaining them specifically to your use case in column "Detail"

Life cycle stage	Relevance to your product/ process	Done (D) Potential (P)	Detail	Requirements to implementation (to be selected those that can be considered by NARRATE)
Raw Materials (including packaging)				
Green purchasing policy and related management system	Medium	P	First there should be analysed which are the main environmental aspects to be requested and secondly we should map the current providers and additional alternatives with better environmental properties. This is difficult because our materials are very specific and the market offer is very limited and the main criterion is quality-price relationship.	Establishment of clear criteria by material/component Information to providers on green procurement policy/requirements Collect and verify signed declaration (documentation) from provider (general requirement valid for all raw materials/service provider). Green purchasing scale system.
Recycled materials	Medium	P	Could be technically feasible for polymer printers, but certain properties should be ensured.	Technical-economical-logistic requirements on secondary materials
Renevable materials	Low	P	It could be interesting to explore possibilities.	Identification and declaration when doubt is feasible (plastics for example)
Materials with low embodied energy	High	P	Lack of information from providers.	Info from data bases / specific from the provider
Non use or reduction of hazardous substances	Low	P	It could be considered in certain sectors like automotive, the VOC emissions etc..	
Due diligence system (to know the origin of specific materials and avoid non allowed)	We do not know if there is any Due Diligence requirement		Indicate which materials.	Verification document required when buying a component containing the material.
Product and packaging weight reduction: (avoid superfluous components, use light materials, optimize design of parts …)	High	D	We optimize the product weight as much as possible as it is related to costs. However packaging is not optimized.	To know the composition and related weight of each component. Rationale of products weight vs functionality Indicator kg packaging/kg contained product
Ecolabelled/certified materials	Low			Documentation from provider

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Raw materials supply				
Distance from providers (raw material manufacturer)	High	P	Lead time, customs.	Collect and consider data provider in green procurement
Environmental certifications from provider management	Low	P	By the moment is not considered	Documentation collection, verification and periodically update (annual at least)
Other environmental practices from provider				Collect related information to its assessment
Productive process				
Energy: control and reduce energy demand	High	P	We would like to be able to calculate the energy demand of each specific process.	Environmental indicators: Definition, monitoring (at least periodically) and relating quantities to production. Environmental action plan with objectives and follow up.
Energy: use of renewable energy	Medium	P	It could be important if we calculate our corporate carbon footprint.	
Water: reduction of water demand	Low			
Material efficiency: auxiliary raw materials reduction	Medium	P	Make a responsible use of gloves, alcohol, paper.	
Material efficiency: reduction of non hazardous waste generated	Low	Partially done	Not evident ways to reduce them (auxiliary materials, packaging, etc) but the supporting structures that are yet optimised	
Material efficiency: reduction of hazardous waste generated	Low	P	Not easy ways to reduce them	
Wastewater: reduction of effluents volume, reduce specific contaminants	Low	P	We do not generate significative wastewater from our processes	
Emissions: reduce specific contaminants emissions (VOC, etc)	Low	P	We consider the legal limits in our emissions and by the moment any reduction depends on technology providers	
Waste management: increase recycling rates by contracting proper waste managers	Low	P		Collection treatment information from waste managers and select them accordingly
Potential to internal recovery/valorization of raw materials	High	D	Metal and polymer powders are recycled internally by mixing them with fresh powder to maintain technical properties.	Experimental test to develop algorithms to adjust the maximum percentage of recovered dust that each production process can accept.
Find secondary resources providers	Low	P	Only for packaging materials	Offer-demand connection platform

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Find secondary resources customers	Medium	P	Mainly for support structures / damaged parts from additive manufacturing processes.	Ensuring desired resource properties (humidity, quantity, price, etc.) Legal classification of the secondary resource as a by-product Distance (km)
Efficient distribution				
Low consume-GHG emission vehicles	Low	P	Only in case we develop the carbon footprint calculation and this results are relevant stage on it	Information on emission factors from logistic providers
Load efficiency (delivery unit design compacted, max number of deliveries by trip)				Coordination between agreed delivery times/routes/load efficiency
Routes optimisation to reduce distance travelled				
Use				
Functional optimisation (customer baseddesign thinking)	High	D	Business is based on customer specifications / needs.	Communication with customer before design and after (marketing)
High energy efficient product (if applies)	Low		Does not apply	Calculation of consume and communication to customer
Use life extension				
High durability (free extra guarantee)	Medium	D	According to customer requirements	Info to customer (durability tests, guarantee)
Easy cleaning/maintenance	Low		Not considered	Instructions, technical after-sales service.
Modular structure (adaptability to changing requirements)	Low		Does not apply to parts.	Assessment during design, potential customer requirements on modularity/adaptability
Technical upgradability (additional service)	Low			
Easy to repair			Does not apply to parts, but processes can improve the reparability of the final product by doing copies	Assessment during design Does not apply If a customer requires a new batch of parts for repairing the main product, we should have part and documentation traceability to be able to replicate the part with the original requirements.
Availability of replacement parts over the legal period (10 years after the product is no longer manufactured)			Does not apply	Stock management of replacement parts

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Maintenance or repair as a service (predictive maintenance by IoT, available professional partner near customers,)			Does not apply	Availability of replacement parts, connectivity of the product, repair centres alliance, maintenance and repair instructions, after-sales staff, etc.
Product as a service: renting, pay per use business model			Does not apply	Track and trace of products (real life use parameters and disruptions)
End of life				
Remanufacturing: recovering old products from customers to manufacture new ones from them (or from non sold ones). Potential connexion with servitization /upgradability services			Does not apply	Track and trace of product versions, bill of materials and exchangeability between models. Protocols to parts recovery, inspection, etc.
Design for easy dis/reassembly	High	D	When designing for additive manufacturing, one of the requirements that is assessed is the working conditions of the part, if it is assembled to other parts etc. In some occasions multiple parts are integrated in a single part to ease the assembly / disassembly.	Information about other connected parts / working conditions from customer.
Hazardous components and critical material content is informed and their recovery is facilitated from design			Does not apply	Instructions to professionals
Easy material separation of recyclable materials			Does not apply	Assessment during design
Avoid multi-materials (non easy to recycle)			We usually manufacture monomaterial parts.	Assessment during design
Feasible energy valorisation of non recyclable materials	Low	P	Polymer based parts we do no use halogenated materials like PVC but we do not control if there is any other limitation.	Assessment during design

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AP1.5 AIDIMME PROCESS DIAGNOSIS

	Process/ operation	Inputs	Input (Description)	Source*	Amount	UNIT	Outputs	Air emission, Wastewater, Waste type (description)	Amount	unit	Management	Final treatment
HP MJF	MJF-BUILD UNIT	Energy(electricity)	Electricity	Ext	42350	kWh						
		PA12 powder	PA12 powder (80µm)	Ext	1040	Kg	Waste	Residual PA12 powder that remain in the build unit / machine	5,5	Kg	Sent to waste manager	
		Printheads	Printheads deposte both detailing and fusing angents into the powder bed	Ext	4	Units	Waste	Empty printheads	4	Units	Sent to waste manager	Landfill
		Agent Cartridge (Detailing)	Agent Cartridges, Detailing agent is used to decrease the energy absorption of the PA12 and create a barrier surrounding the parts	Ext	5	Units	Waste	Detailing agent cartridges (empty)	5	Units	Sent to waste manager	Landfill
		Agent Cartridge (Fusing)	Agent Cartridges, fusing agent is used to increase the energy absorption of the PA12 Material. This agent is deposited in the part area	Ext	5	Units	Waste	Fusing agent cartridges (empty)	5	Units	Sent to waste manager	Landfill
		Cleaning roll	Cleaning roll is used to clean the printheads. They must be changed when excesive agents accumulate into it.	Ext	2	Units	Waste	Cleaning roll exhausted	2	Units	Sent to waste manager	Landfill
		Filters	Filters	Ext	6	Units	Waste	Filters with PA12 powder	6	Units	Sent to waste manager	Landfill
		Heating lamps	Heating lamps are used to apply the energy into the powder bed and therefore melt the PA12 powder. The machine has 22 heating lamps which should be changed when damaged.	Ext	4	Units	Waste	Molten lamps	4	Units	Sent to waste manager	Landfill

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	MJF - POSTPROCESSING UNIT	Electricity	Electricity	Ext	4004	kWh	Waste	PA12 overheat	208	kWh	Sent to waste manager	Landfill
		PA12 Powder	once the build job is finished, the build unit is managed in the postprocessing unit where the powder is collected.	Ext	1030	Kg	Waste	PA12 overheat	208	Kg	Sent to waste manager	Landfill
		Filters	Filters	Ext	4	Units	Waste	Filters with PA12 powder	4	Units	Sent to waste manager	Landfill
	DYEING MACHINE	Water	Water	Ext	1000	L	wastewater	water and dye	1100	L		
		dye	black dye is mixed with water giving as a result the media where the parts are dyed	Ext	200	L						
PG 250	PG250- BUILD UNIT	Energy(electricity)	Electricity	Ext	44160	kwh						
		Stainless steel powder	Stainless steel powders (15-45µm) used to produce parts	Ext	360	Kg	waste	stainless steel powder + support structures	92	Kg		
		Filters	the atmosphere of the chamber is filtered during the build job	Ext	4	Units	waste	clogged filters	4	Units	Sent to waste manager	Landfill
		Coater blade	Rubber coater blade used to deliver powder layers. It must be changed each build job	Ext	92	Units	waste	damaged coater	92	Units	Waste	Landfill
		deionized water	Water chiller requires deionized water mixed with dowcal to cool down the laser modules and the scanner	Int	10	L		no waste generated (water is refilled when needed)				
		Dowcal	Heat transfer fluid mixed with water to cool down both the laser modules and the scanning head.	Ext	5	L		no waste generated (water is refilled when needed)				
		ARGON	Argon is required to generate a inert atmosphere in the build chamber in order to protect the material from oxygen pick up	Ext	20	racks	air emissions	Air emissions when the machine is opened				
	SIEVING	Electricity	Energy consumption of the sieving machine while the powder is sieved	Ext	607	kWh						

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		Powder	powder must be sieved after each build job to collect fine and coarse powders out of the PSD of the material	Internal	84	Kg	waste	stainless steel powder + spattering collected in the sieving process	9,2	Kg		
	Drying o ven	Electricity	energy consumption of the drying oven	Ext	1546	kWh						
MELTIO ATILA	ATILA- BUILD UNIT	Stainless steel wire	stainless steel wire spools (1mm diameter)	Ext	523	Kg	waste	metal wire (stainless steel) that must be cut before and after any print	4,6	Kg		
		ARGON	Argon is required to generate a inert atmosphere in the build chamber in order to protect the material from oxygen pick up	Ext	32	racks	air emissions	Air emissions when the machine is opened				
		Electricity	electrical consumption	Ext	4180	kWh						
EBM	EBM-BUILD UNIT	Build plate	Ti64 build plates	Ext	65	Units						
		Electricity			31850	kWh						
		Pure copper	Pure copper powder used to manufacture parts	Ext	1000	Kg	waste	degradated ti64 powders (not usable anymore) (6,5kg) + support structures (65kg)		Kg	stored at AIDIMME	
		Ti64 powder	ti64 powder used to manufacture parts	Ext	600	Kg	waste	degradated ti64 powders (not usable anymore) (6,5kg) + support structures (65kg)	71,5	Kg	stored at AIDIMME	
		heat shields	stainless steel heat shield KIT (5 plates) assembled in the EBM chamber to retain heat in the Powder bed	Ext	163	Units	waste	metallized stainless steel heat shields that cannot be used anymore. Must be changed each 2 build jobs	163	units	sent to waste managger	
		Coater blade	Stainless steel rake kit (4 rakes) (powder delivery system)	Ext	87	Units	waste	rake system delivers powder each layer. The kit	87	Units	sent to waste manger	

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								must be changed each 2 build jobs				
		EB-Gun heat shield	EB Gun heat shield (1)	Ext	33	units	waste	eb gun heat shield. Must be changed each 2 build jobs	33	Units	sent to waste manger	
		Filament	EB filament (lasts 100hours and must be changed)	Ext	55	Units	waste		55	units	Currently this piece is not disposed. The lifespan of the filaments is about 100 hours but they are changed earlier to prevent a premature process failure, but this filaments can be used for expermental tests or shorter build jobs	
		Helium	helium is used to breake the chamber vacuum	Ext	2	bottles	air emissions	helium is flushed into the chamber once the build job is finished. Then the machine is open and the helium is released to the amosphere	2	bottle s		
		Pure copper	Fine particles are sieved in the PRS. Those particles are stored in a special cannister.		1200	kg	powder parciles	finer particles are rejected due to security protocols	38	Kg	Recovered by General electric (ARCAM)	
	PRS (Powder Recovery System)	Ti64 powder	Fine particles are sieved in the PRS. Those particles are stored in a special cannister.		500	kg	powder parciles	finer particles are rejected due to security protocols	20	Kg	Recovered by General electric (ARCAM)	
		Electricity	electricity to operate the PRS	Ext	55	kWh						

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LC MAGNA	LC MAGNA-BUILD UNIT	Protective film (VAT)	This film avoids the parts to get sticked to the VAT bottom base. As it is exposed to UV light the film is damaged each build job and therefore must be changed each 4 build jobs	Ext	36	Units	waste	damaged films that must be changed each 4 build jobs	36	Unit	sent to waste manager	
		Protective film (Screen)	Under the VAT film, the LED screen must be protected so	Ext	4	Units		scrached fils that must be changed each 3 months	4	Units	sent to waste manager	
		Resin (methacrylate based)	3D printing resin used to build parts in VPP LCD technologies	Ext	73,5	L	Waste	support structures + unrecyclable resin	24,8	L	sent to waste manager	
		Electricity	electrical consumption of the machine	Ext	2808,0	kWh						
	CLEANING UNIT	Cleaning liquid	Parts must be cleaned after the build job is finished. The entire platform is submerged into the cleaning unit which has a specific cleaning liquid provided by photocentric	Ext	160	L	waste		164,32	L		
		Electricity	electrical consumption of the cleaning unit	Ext	35	kWh						
	POSTCURING UNIT	Electricity	electrical consumption of the postcurin unit	Ext	691	kWh						
POSTPROCESSING (COMMON)	SAND BLAST ING MAC HINE	Corindon	Corindon media is used to sandblast the parts and remove the powder attached to the part surfaces and hollowings.	Ext	310	Kg	waste	Corindon + PA12 + Stainless steel + ti64 powder	494	Kg		
CNC (COMMON)	CNC	Electricity	metal parts must be machined to make them functional	Ext	50934	kWh						
		Build plate (ss316l) PG250	Plate where the parts are attached to.	Ext	92	Units	waste	machining chips ss316l	23	Kg	sent to waste manager	

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		Build plate (ti64) ebm	Plate where the parts are attached to.	Ext	65	Units	waste	machining ti64 chips	16,25	Kg	sent to waste manager	
		Build plate (ss316L) MELTIO	Plate where the parts are attached to.	Ext	95	Units	waste	machining chips ss316l	23,75	Kg	sent to waste manager	
		machining coolant + water	machining coolant (7%) mixed with water	Ext + int	180	L	waste	degradated water + oil mixture	180	L	Sent to waste manager	Recycling
		machining tools	machining tools to perform finishing operations	Ext	100	Units	waste	tool wear (tools that are not operating well anymore)	80	Unit	sent to waste manager	

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PLASTIC Additive Manufacturing

Most used resin is Polyamide (PA12) powder. Residual waste is generated in small quantities at the 3D printing machine (MJF-BUILD UNIT), with a material efficiency of 95% %, but is at the post processing, where it is generated the most part of this waste, around a 20%.

The other materials and related waste generated are packaging and auxiliary consumables. They have been quantified in units since there is not easy to know the mass and their composition. All of them are managed by an authorized waste manager and the final treatment is landfill.

- Printheads deposit both detailing and fusing agents into the powder bed
- Agent Cartridges, Detailing agent is used to decrease the energy absorption of the PA12 and create a barrier surrounding the parts
- Agent Cartridges, fusing agent is used to increase the energy absorption of the PA12 Material. This agent is deposited in the part area
- Cleaning roll is used to clean the printheads. They must be changed when excessive agents accumulate into it.
- Filters
- Heating lamps are used to apply the energy into the powder bed and therefore melt the PA12 powder. The machine has 22 heating lamps which should be changed when damaged.
- The PA12 and the damaged/defective PA12 printed parts are also managed by waste manger.

Figure 23 Residual printheads Resin waste: dust and failed parts.

The other used polymer is a methacrylate-based resin. There is consumed in small amounts (73,5 L/year) but the material efficiency is not high (loses in unrecyclable powder and structures are near 34%). Besides protective films used avoids the parts to get sticked to the VAT bottom base. Parts must be cleaned after the build job is finished. The entire platform is submerged into the cleaning unit which has a specific cleaning liquid provided by photocentric. So, there is generated other waste: used cleaning liquid, representing around the double volume than the consumed resin.

METAL Additive Manufacturing

There are 3 main metals used in AIDIMME: titanium, stainless steel and copper.

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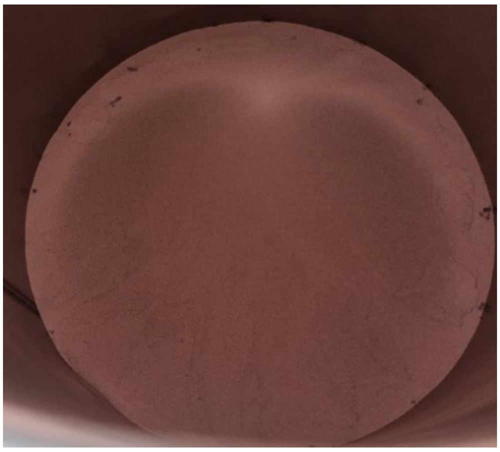
There are two equips working with stainless steel. One of them is feed with powder (360 kg/year), and the other is feed with filament (523 kg/year). The steel powder generated as waste in each process it is mostly recovered and reused in the following batch, since the material it is not degraded during the process. But there are loses of powder generated mainly in sieving operations after extracting the parts (15%), and the supporting structures (10%). In the case of the steel filament, there are material loses because a small fraction of the filament is cut and discarded each time the process starts, but the material efficiency is high because all the filament processed is transformed into a piece.

Argon is required to generate an inert atmosphere in the build chamber to protect the material from oxygen pick up. Also, some equipment consumables, such as rubber coater or clogged filters are generated.

The EBM process can work with titanium powder (Ti64) or pure copper powder. Its material efficiency is around 78%, generating degraded powder by an excess of oxygen, not usable in this process anymore and support structures or failed parts. Currently this material is storage at AIDIMME. Besides there is generated a fraction of fine particles that are recovered by the material provider (3% aprox.)



Copper waste: powder and failed parts

(left), and fines and supporting structures (right).

Figure 24: Copper waste: dust, failed parts and supporting structures.

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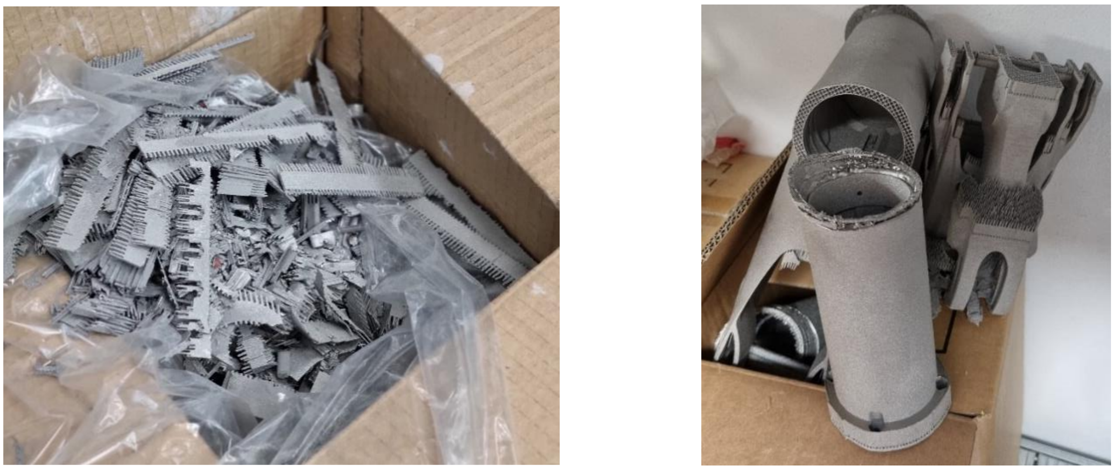

Figure 25: Titanium waste: supporting structures and failed parts.

There are equipment consumables such as stainless-steel heat shields and coater blade, resulting metalized with the fused raw material (copper or titanium) that has to be changed each 2 build jobs. They represent an important number of units, but their potential interest will depend on their weight. Also, some build plates (base to manufacture parts on them which is polished and reused several times).

On the other hand, there is a very expensive element, the EB filament made of tungsten. They are changed before their failure. The lifespan of the filaments is about 100 hours, but they are changed earlier to prevent a premature process failure, since if it breaks, the whole batch production has to be rejected. Currently this piece is not disposed, because those filaments can be used for experimental tests or shorter build jobs.

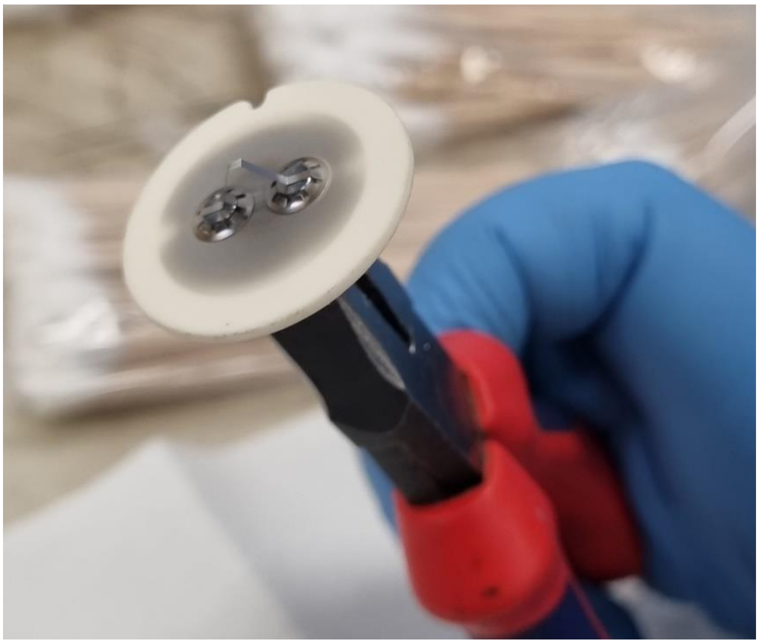

Figure 26: Tungsten filament.

Finally, there are some common equipment for post-processing manufactured parts, sandblasting and CNC, where different materials are processed and mixed waste chips are generated. Beside the abrasive material used (corindon) is the main waste generated, mixed with powder of different metals or polymers.

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Figure 27: Mixed metal dust.

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AP1.6 BUDATEC ECODESIGN QUESTIONNAIRE

Context situation on ecodesign implementation.

1. Do you design your products? ☒ Yes ☐ No

   If yes, ¿do you consider during design any environmental aspects along the life cycle of the product (ecodesig)? ☒ Yes ☐ No *If Yes, specific considerations during design must be indicated in the table at the second part of the questionnaire.
   Why? Designed for second life usage/ refurbished usage → easy replacement of parts
   Software updates and hardware/ spare parts are supported for 10 years
   Customer loyalty through quality
   Prevention of unauthorized resale of the machine and need of maintenance contract from budatec

2. Please, indicate both barriers and potential benefits of implementing ecodesign at your company and priorise them from 1 (very relevant) to 5 (not relevant):

Barriers		Potential benefits	
Lack of internal knowledge on how to do it	4	Improvement on environmental management	3
Lack of specific information from supply chain	3	Improvement of knowledge related to environmental properties of our products and our raw materials	5
Lack of specific information on environmental indicators	2		
Lack of environmental assessment tools	2	Overview of the main environmental aspects /impacts along the life cycle of our products	5
Over costs (design, raw materials, etc.)	3	Potential increase of economic incomes (for example higher manufacturing efficiency, waste management cost reduction, higher product sale price, etc.)	2
There is no positive valuation from our customers	4	Our current market considers positively the company public image or our products	5
		Potential access to new markets where there are valuated environmental improvements on products	2
Other:		Other:	

3. After improving environmentally your products/processes, do you perform any product environmental assessment to verify it? ☐ Yes ☒ No

   If yes, which type of assessment?
   ☐ Qualitative (fulfilment of requirements from customer)
   ☐ Quantitative, based on environmental aspects like internal indicators (% recycled content, etc)
   ☐ Quantitative, based on environmental impacts (LCA or carbon footprint)

4. Which collaboration would you need from other agents in your value chain to implement potential environmental improvements along the life cycle of your products/services? Specification lists and templates for your own procedure, which have already been tested in other system

5. Certification of the Ecodesign management system (ISO 14006). Do you consider it would be beneficial to obtain this certification to your company? Why? At this moment no, since that ISO is not well known in our markets and not requested by our customers.

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Context situation on environmental communication

6. ¿Which is the element of your offer most appreciated by your customers (product quality, price, post-sale services, etc.)?

Always the ratio of quality / price and communication.

Which environmental issue would they appreciate (if any)? Low energy demand of our products during use.

7. Do you communicate the environmental improvements of your product/services to your clients? ☒ Yes ☐ No

   If yes, indicate which ones:

   Why?

   - ☐ It is a legal requirement
   - ☐ It is a common market requirement
   - ☐ It is a requirement from one/some specific customers (not usual).
   - ☒ It is not a market requirement but a competitive advantage.
   - ☐ It is not appreciated by the market.
   - ☐ I do not know how to do it.
   - ☐ I do not have any environmental improvement to communicate.

8. How do/would you communicate the environmental info on your product/services? Ecolabelling type:

   - ☐ Certified ecolabel
   - ☒ Self-declaration
   - ☐ Environmental Product Declaration based on LCA

   Communication chanel: ……………………….

9. Are you asking for any environmental requirement to your providers (certified wood, absence of harmful substances, etc.)?

   ☒ Yes ☐ No   If yes indicate: Due diligence of certain materials/components (indicate in table below) and ….please complete if there is any other. The origin and processing of wood as packaging material for worldwide shipping. Usage of Aluminium

10. Are you asking for environmental information to your providers carbon footprint, recycled content, etc.)?

    ☐ Yes ☒ No   If yes indicate:

    Until now is not required

11. If you answered yes to any of the two previous questions: how are stablished the requirements or information requested to your providers? (transfer of customer requirement, legal requirement, internal process).

    - Due diligence: legal requirement

    there are internal work instructions and the documents received are filed in a defined manner so that they can be presented on request

12. ¿Do you have a km 0 policy regarding your providers? How relevant it is versus other aspects (price, delivery time, quality, etc.)?

    we pay great attention to regionality, also with regard to delivery reliability

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AP1.7 BUDATEC PROCESS DIAGNOSIS

Budatec has face some difficulties with the inputs and was not able to answer the diagnosis table partially. Some clarifications have been added.

Budatec manufactures welding machinery. Budatec has manufacturing and non-manufacturing processes. The manufacturing process is mainly assembly processes. 70% of the parts installed are purchased parts (we faced problems to obtain data from our suppliers). 30% of the parts used are our own turned and milled parts. Regarding raw materials, semi-finished products made of copper, aluminium and ferrous metal are produced here. Furthermore, coolants and lubricants as well as gases such as compressed air and energy/cooling water energy.

The main energy sources are electricity (coming from the network and the solar system on the roof with 20 KW of solar power), and natural gas. They use electricity from solar panels to supply part of it directly in production and store part of it in e-cars. They have 3 of them and charge them during the day on weekdays. They do not yet have a fixed storage system for electrical energy. In the production processes, 80% of the energy is used. 20% is for supporting processes such as office or communication.

Regarding outputs, wastewater for cooling can be equated with fresh water and they spill it to the sewer system. Atmospheric emissions: there is an exhaust air system for the emission of nitrogen, hydrogen and polluted production air.

Waste is mostly recyclable fractions from urban waste (paper, packaging and rest) and metal savings from drilling machine.

Inhouse waste concept. Paper / yellow point (plastic, recycle material from packaging) / rest waste

Waste from the milling machine.

Figure 28: Budatec waste: input/output.

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Waste inputs

General	Energy (electricity)	1	Electricity	External (Commercial)	28150	kwh
	Energy (electricity)	1	Electricity (solar panels)	Internal		
	Energy (fuel)	2	Natural gas	External (Commercial)	62020	kwh
	Aux	3	Water	External (Commercial)	131	m^3

Waste Outputs:

1	Waste (similar to household waste, non segregated)	External (Commercial)	2860	kg
2	Paper/cardboard	External (Commercial)	11700	kg
3	Recyclable materials (non hazardous segregated fractions: paper, packaging)	External (Commercial)	7800	kg
4	Copper shavings	Other external	452	kg
5	Aluminium shavings	Other external	1024	kg
6	Chips Mixed scrap	Other external	154	kg
7	Copper cable for shredding	Other external	63	kg

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