Eco-design Strategy

Designing products to be more sustainable

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[1] PU = Public
PP = Restricted to other programme participants (including the Commission Services)
RE = Restricted to a group specified by the consortium (including the Commission Services)
CO = Confidential, only for members of the consortium (including the Commission Services)

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Executive Summary

EU is moving towards a smart, digital and sustainable industry economy, setting decarbonisation and zero net emission targets by 2050. The European Green Deal offers a set of policies initiatives and measures to achieve climate neutrality. In addition, the New Industrial Strategy for Europe aims to strengthen SMEs and empower industry to apply the green transformation, while the updated Circular Economy Action plan, adopted in 2020, paves the way for circular economy.

INN-PRESSME aims at developing and implementing a sustainable OITB to support European companies to manufacture new market-ready products and goods from bio-based materials by feedstock conversion and support them to adopt a digital transition. INN-PRESSME gathers 16 pilot lines, organized in routes and processes for feedstock conversion (PLA, PHA, fibre-based, cellulose-based), together with other nanoadditives and nanofeatures, in packaging, energy/automotive, and consumer goods applications for making them more sustainable and greener, meeting the current specifications.

Eco-design considers environmental aspects at all stages of the product development process, striving for products which make the lowest possible environmental impact throughout the product life cycle. In the frame of circular economy and digitisation, providing guidance to companies to follow and apply eco-design strategies from the very early stages of product design would boost and enhance the transition from linear to circular production.

Thus, INN-PRESSME has incorporated in the implementation phase the development of an eco-design strategy to improve and ensure the sustainability of the INN-PRESSME products. At first, eco-design principles awareness, potential barriers, benefits, and business opportunities when implementing eco-design have been identified by partners and PL owners through dedicated surveys and questionnaires. The analysis of the results indicated critical parameters and highlighted the impact of eco-design principles on the benefits within the entire life cycle of INN-PRESSME products. Eco-design concepts will be balanced throughout the project duration with requirements of other crucial entities involved in the product (stakeholder requirements, quality, recyclability, health, and safety issues). The eco-design methodology will be updated/fine-tuned by using data from LCA/LCC studies and nanosafety and upgraded pilot line quality control activities for accurate representation of benefits and risks.

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1. Introduction

Great attention has been gained over the past few years to the circular economy concept as an approach to sustainable growth, however, today's global economy is still mainly based on a linear approach with the focus on the purchasing low-cost natural resources. Therefore, EU has tackled the challenge of shifting toward a productive circular economy with the creation of a series of directives, initiatives, and roadmaps but also the formation of the European Green Deal, in 2019, as a growth strategy with the aim of zero net emissions of greenhouse gases in 2050. Simultaneously, the updated version of EU Circular Economy Action Plan was released in 2020 with the objective of encouraging societal transformation towards a circular economy while the New Industrial Strategy for Europe aims to strengthen SMEs and empower industry to apply the green transformation. In addition, in March 2022, the Eco-design for Sustainable Products Regulation (ESPR) was proposed as a cornerstone approach for more environmentally sustainable and circular products. Through ESPR, it is achieved the establishment of a framework for eco-design requirements in specific product categories to enhance circularity, and improve the energy performance and environmental and sustainable aspects. The eco-design requirements will be regulated for the product durability, reparability, and refurbishment part of the resource efficiency, while enhancement of green labels and green procurement is involved in the green sourcing strategy. It will further be regulated for preventing and reducing the waste as part of the zero-waste strategy, it will minimize the greenhouse gas emissions by taking into account the climate neutrality and it will enhance synergy of diverse stakeholders and SMEs considering the industrial symbiosis. Those strategies and their best practises are included in this report and are described in chapter 5 as part of the literature review conducted.

In general, this preliminary report provides the general framework in which the eco-design strategy of INN-PRESSME solutions/products aims at improving their sustainability. The implementation of eco-designing in fiber-based materials of various applications targets to ensure sustainability of materials throughout the life cycle of bio-based solutions with respect of circular economy.

This report has been prepared in the framework of WP 8 'Sustainability Assessment' and Task 8.1: 'Designing products to be more sustainable (eco-design)' lasting from M1- M36 and led by IRES with involvement from AIMPLAS and OY Keskuslaboratorio –Centrallaboratorium AB (KCL).

2. What is Eco-design

Eco-design is a principle towards sustainability, considering the entire life cycle of a product, balancing out environmental aspects with other requirements, such as performance, cost, health and safety requirements. According to ISO 14006:2020, "*Ecodesign is defined as a systematic approach, which considers environmental aspects in design and development with the aim to reduce adverse environmental impacts throughout the life cycle of a product*". Other terminology includes Design for Environment (DfE), Environmentally Conscious Design (ECD).

As eco-design considers the whole life cycle of a product, eco-design strategies can be targeted in one or more life cycle stages.

Life Cycle Assessment (LCA) is a systematic tool that allows to identify the environmental loads of a product in its entire life cycle and assess their potential environmental impacts. The international standards ISO 14040 and ISO 14044 provide the general framework of LCA and

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the basic requirements to analyse the life cycle environmental sustainability of a product towards eco-design strategies. However, there are further standards and protocols that focus on specific aspects, such as the following:

- Eco-design standards (ISO 14006:2020), provide guidelines for assisting organizations in establishing, documenting, implementing, maintaining and continually improving their management of ecodesign as part of an environmental management system (EMS).
- BS EN IEC 62430:2019 provides specific guidance on how to incorporate Eco-design in design and development.
- EU directive 2009/125/EC, establishing a framework for the setting of ecodesign requirements for energy-related products.
- Carbon footprint of products and GHG emissions (e.g., ISO/TS 14067, GHG Protocol, PAS2050)
- Determination of Biobased/renewable content (e.g., EN 16785-1 /-2, ASTM 6866)
- Waste management and prevention (e.g., Roadmap to a Resource-Efficient Europe, ISO 14001:2015)

3. Eco-design step-based methodology

The aim of INN-PRESSME is to provide and advance beyond state-of-the-art supported by 2 main pillars:

a) upgraded pilot lines, and
b) beyond state-of the art materials through test cases.

Table 1 presents the Pilot lines upgrade targets clustered by INN-PRESSME general goals.

***Table 1** PLs identification per INN-PRESSME targets*

PLs for feedstock conversion to deliver specific raw materials	
1	Cellulose NanoFibrils,(CNFs), produced from ligno-cellulose feedstock
2	Cellulose NanoCrystals (CNCs), produced rom lignocellulosic material
3	PHA powder, produced from marine bacteria
4	Processing & modification of flax/hemp microfibres (MFs) without structural damage
5	PLAX dispersion, conversion from starch based lactic acid
PLs for formulation of raw materials to deliver bio-based material	
1	Functional (nano)cellulose-based inks and slurries
2	Graphene and carbon-based material
3	PLAX dispersion for coating applications
4	Bio-based nanocomposites.
PLs for the formulation, transformation, and processing (PROC) of bio-based materials	
1	Nano-enabled bio-based compounds with isofunctional properties
2	Bio-based lacquers with nanoparticles synthesis, roll2roll application plant.
3	Nano-functionalized bio-based foam
4	Continuous coating line for electrodes/electrolytes
5	Large surface S2S printing
6	Surface treatment with dispersion coatings

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7	Films nano-texturing by multi-nano layering co-extrusion and extrusion calendaring
8	Processing of nano-enabled bio-based materials by additive manufacturing technologies

Therefore, in this context, a step-based methodology (**Figure 1**) has been structured to support the development and implementation of eco-designing across the respective Pilot lines and products in the duration of task 8.1, involving:

1. Regulatory and literature research on eco-design (i.e. EU directives, research papers)
2. Development and distribution of dedicated surveys to identify barriers/benefits/business opportunities across the identified strategies, as well as environmental, cost and health aspects of PLs
3. Analysis of results to match upgrade of PLs with eco-design strategies/best practises.
4. Identification of eco-design scenarios that can be quantified
5. Assessment of eco-design scenarios vs. default PLs (LCA/LCC studies)
6. Implementation of Health & Safety assessments
7. Identify business opportunities
8. Preparation of INN-PRESSME eco-design strategy (D8.1), consolidating all information collected

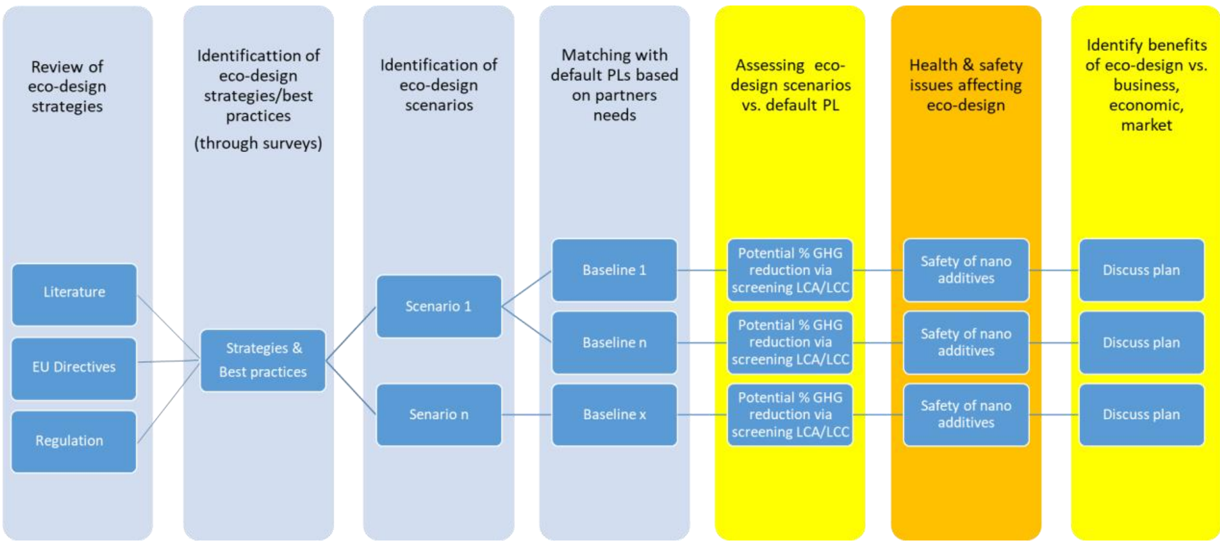

Figure 1 Eco-design step-approached methodology of INN-PRESSME

To explain in further detail, the first step is to review generic eco-design strategies as those found in literature (Figure 1). In step two, to identify and match the eco-design strategies and best practices to be followed by the PLs. The next step would be d on performance data and the INN-PRESSME PLs, a set of specific eco-design scenarios are identified. In the next step, match the matrix of eco-design scenarios (from Step 3) with default PLs based on the partner's needs. In step four, the performance of the eco-design scenarios versus the default PLs, in terms of potential – per cent % - emission reduction via screening Life Cycle Assessment (LCA) and Life Cycle Costing (LCC) tools will be assessed.

LCA is a standardized methodology that aims to assess across the supply chain the environmental performance of a product or a system. LCC is an economic tool that assesses across the supply again the economic performance of a product or a system.

Next step is where other requirements such as health and safety (i.e., Safety of nano additives) are taken into consideration and where the output from WP8 Task 8.4 (CEA) is integrated. Finally, based on recommendations deriving from prior steps, benefits from eco-designing

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including business, economic, environmental and market opportunities are identified with partners, as per Task 10.1.

4. Eco-design strategies and best practises

Based on the literature review conducted, as the first step of the eco-design methodology, five main strategies have been identified: Resource efficiency, Zero-waste, Climate neutrality, Green sourcing, and Industrial synergy, as presented in **Figure 2**. The mentioned strategies are already recognized by the partners in the surveys filled and, in this chapter, the literature review enhances the categorization of those strategies in regards to the eco-design.

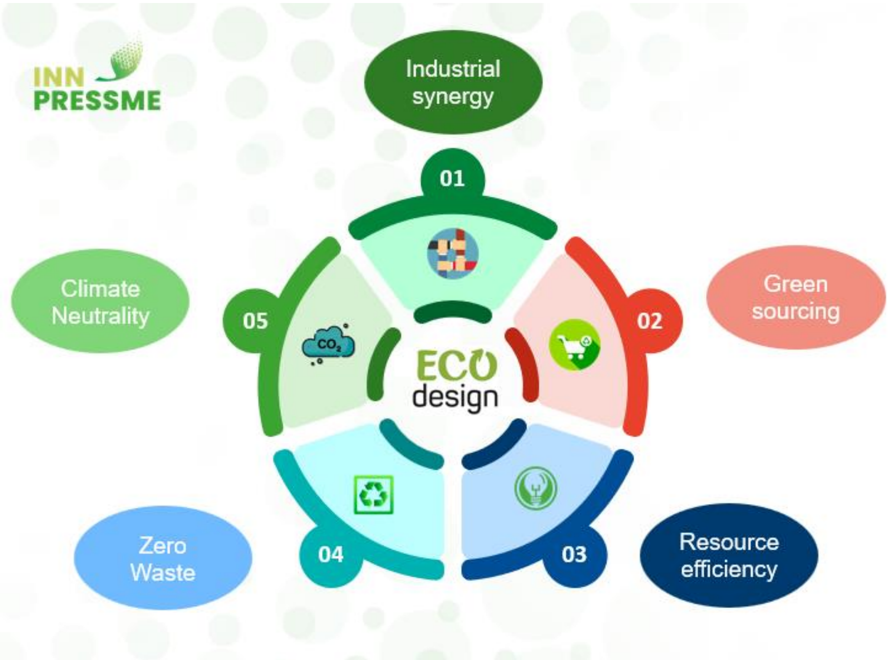

Figure 2 *Illustration of the 5 strategies identified in eco-design*

4.1. Resource efficiency

From the surveys conducted, it is shown that 26% of the partners recognize Resource efficiency as a strategy in their organizations. "Resource efficiency means using the Earth's limited resources in a sustainable manner while minimizing impacts on the environment" as defined in Europe's Roadmap "Towards a Circular Economy," 2020. Businesses and organizations are facing increasing costs for vital raw materials while their shortage and price volatility are having a detrimental effect on the economy[1]. Although the current economic system still advocates the inefficient use of resources by pricing below accurate costs, some active businesses have acknowledged the advantages of more productive use of resources. Supporting efficient use of resources should d assist businesses improve their competitiveness and profitability. It also aids in a sustainable recovery from the economic crisis and it can boost employment opportunities. Therefore, Resource efficiency typically starts by improving the efficiency of the production processes, however, it should be implemented across all

[1] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52011DC0571&from=EN

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departments of an entity/organization. In the following paragraphs, the identified best practices are described under the resource efficiency strategy.

Recognized best practices of Resource efficiency

Table 2 *Recognized best practices of resource efficiency*

Resource efficiency	
Best practices	**Recognition of partners**
Productivity	44%
Recyclability	26%
Energy efficiency	15%
Remanufacturing	4%
Longevity of products	7%
Non-toxic raw materials	4%

Several circular economy strategies have been comprised to support sustainable products. However, the focus of the research is mainly on the recycling, recovering and final disposal and limited strategies refer to the lifespan extension including reusing, repairing, remanufacturing, and repurposing[2]. A longer lifespan of products can provide advantages both to consumers and businesses under a circular economy concept. The **longevity of materials** can be enhanced with sustainable material usage, in which the potential measures should consider the materials which are used and the way that can keep their value. Additionally, the conservation of the expertise to maintain and repair the products is a potential road for the expansion of their lifetime. Highly determining is additionally, the economic value that a consumer receives from the utility of a product rather than the product itself. A longer-use product needs fewer resources which implies less environmental impacts. However, this cannot lead to a general rule for all products since there are cases where extended use can cause higher impacts than replacing it[3]. The proposed solution for the specific concern can provide the environmental lifetime indicator which shows the environmental performance of an achieved lifetime in comparison with the optimal taking into consideration changes in impact over time as well as different replacement scenarios. Regarding the second-best practice identified, the definition of **Remanufacturing** given by the EU is "The process of returning a used product to at least its original performance with a warranty that is equivalent to or better than that of the newly manufactured product while from a customer viewpoint, can be considered the same as a new product."[4] Remanufacturing is considered as one of the most vital components of a circular economy which assists in exploiting economic, environmental and social advantages by prolonging the value of the materials and their end-of-life and use. Another practice under the Resource efficiency strategy is **Productivity** which is the most popular option selected by the partners (44%) and it is used by the European Commission as a proxy for resource efficiency since resource productivity measures the quantity of economic output produced using a certain amount of material resources. **Energy efficiency** is one of the key components of strategies to tackle climate change and to improve the security of energy supply as well as resource efficiency. Increasing energy efficiency involves using a reduced quantity of energy to generate the same or improved product, process, or service and a considerable 15% of the partners recognized energy efficiency as a good practice of

[2] https://www.sciencedirect.com/science/article/abs/pii/S0921344920302056

[3] https://www.europarl.europa.eu/RegData/etudes/STUD/2020/648767/IPOL_STU(2020)648767_EN.pdf

[4] https://www.remanufacturing.eu/about-remanufacturing.php

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Resource efficiency strategy. Lastly, **Recycling** is another necessary parameter in a circular economy, however, it should be considered when there are not any other options such as reuse, remanufacturing or repairing.

4.2. Zero waste

Moving to the next strategy, it is observed that 6 out of 16 of the partners include Zero waste strategy in their organizations. Zero waste is about designing waste, considering the toxics and inefficiencies associated with it, out of the system. In a zero-waste system, the value of materials and products is kept within the community where they are used repeatedly. Any technology that cannot allow for material recovery should be considered as unacceptable and phased out. Whilst waste management aims at turning waste into resources, zero waste is about keeping resources from becoming waste. According to the Zero Waste International Alliance, 2018, the definition of Zero Waste strategy is "The conservation of all resources by means of responsible production, consumption, reuse, and recovery of products, packaging, and materials without burning and with no discharges to land, water, or air that threaten the environment or human health." In the next paragraph the identified best practices of the above-mentioned strategy are analysed.

Best practices identified in Zero waste strategy

Table 3 *Recognized best practices of zero waste strategy*

Zero Waste	
Best practices	**Recognition of partners**
Green packaging	27%
Recyclability	27%
Circular waste management	18%
Remanufacturing	9%
Sufficiency	9%
Raw material reduction	5%
None	5%
Reusability	0%

It is important to clarify in this stage that some of the best practices identified are part of more than one strategy. For example, Recyclability and Remanufacturing are not only considered in the Zero-waste strategy but also in Resource efficiency. This fact is based on the multi-applicability of those practices in more than one strategy. Therefore, those practices are not analysed below. In the literature is observed that a new paradigm of **Sufficiency** is emerging and gaining interest in industrial sustainability to close the loop of a circular economy's actual implementation. This means that the term "Efficiency" in industrial sustainability is connected to" supply-side" or production-focused, with the aim of moderating production inputs of materials, energy, and labour. In contrast, the concept of "Sufficiency" in industrial sustainability as primarily demand-side or consumption-focused, aimed at restraining end-user consumption by encouraging consumers to make do with less[5]. This approach needs further research and observation to successfully be part of current business policies since other more crucial parameters (e.g., shifting from linear to a circular economy, reducing waste) should be considered. Continuing with the **Reusability,** which is critical for a more sustainable circular economy where the products are circulated and thus, the waste is reduced. For the reuse of resources to be successful, it requires to be considered throughout the entire design process.

[5] https://www.sciencedirect.com/science/article/pii/S2210422415300137

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As the e uncertainty around waste streams, there is no formalized approach around reuse during the design process and a comprehensive circular waste management plan is required. Waste management should be redirected to more circular options by enhancing reduction, recycling remanufacturing but also reusing techniques, which consider the waste as resources and be based on cross-disciplinary eco-economic collaboration. The last identified practice under the Zero waste strategy is the **Green packaging**, in which EU stated “A move to more sustainable packaging requires thinking about the entire lifecycle of a product and its packaging, so that the whole system can be circular by design. Companies that facilitate this can stay ahead of tightening regulation, improve their growth prospects, and reduce their environmental footprint”. Therefore, it is essential to pro-actively design and estimate the needs and usage of packaging to actively contribute to a circular economy and enhance eco-design principles.

4.3. Climate neutrality

The climate neutrality strategy, which 14% of the partners selected as part of their organizational strategy, plays a determining role to eco-design principles. The Intergovernmental Panel on Climate Change (IPCC) gave a definition of climate neutrality as the “concept of a state in which human activities result in no net effect on the climate system”, which means that anthropogenic emissions of GHGs are compensated by anthropogenic removals (carbon credits are analysed in the below section) over a certain period[6]. Further, some companies go beyond “net neutral” targets and claim to be climate positive or carbon negative, by which they imply their operations can reach more GHG removals than emissions. Recently, a growing number of organizations have set goals considering the reduction of their GHG emissions by providing climate neutral products and services[7]. *However, significant is to mention that there are barriers to the actual implementation in the business world due to a lack of consistently applied definitions. The targets set and the relative strategies are not clearly defined while the value chain is limited regarding the emission sources covered by the targets. Moreover, the role of offsetting where companies purchase carbon credits and count them towards their own targets, has also a significant imbalance. Furthermore, reaching GHG footprint to zero is not feasible for many organizations and entities since there are unavoidable emissions from numerous sources which cannot be eliminated, especially in chemical processes with by-products. Measures to remove or store those emissions can be a solution in these cases.*

Identified Best practices in Climate neutrality strategy

Table 4 *Recognized best practices of climate neutrality strategy*

Climate Neutrality	
Best practices	**Recognition of partners**
GHG footprint estimation	16%
Green/ renewable energy	16%
Carbon credits	16%
Green transportation	10%
Renewable feedstock	5%
Locality	0%
None	37%

[6] https://www.ipcc.ch/site/assets/uploads/sites/2/2019/06/SR15_Full_Report_High_Res.pdf
[7] https://epub.wupperinst.org/frontdoor/deliver/index/docId/7868/file/ZI20_Climate_Neutrality.pdf

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The baseline to reach climate-neutral targets is to calculate the **climate footprint** which provides a baseline for the reductions that have to be achieved. Indeed, the partners recognized GHG footprint estimation as one of the practices (16%) under the climate neutrality strategy. The emissions are categorized based on scopes as defined by the GHG Protocol Accounting and Reporting Standard[8], to create a complete inventory of the GHG emissions taking into account the chosen organizational boundaries. The EU has provided strategies also to decarbonize the transport sector by providing clean and sustainable mobility with reduced GHG emissions, air pollution and noise. It is estimated that transportation in businesses counts for one-fifth of the total emissions[9]. **Green transportation** is a novel concept which targets to be a convenient, safe, efficient, and low-pollution urban transportation system in alliance with the climate-neutral principles. One significant parameter in transportation is the location of the entity, its suppliers, and customers. This parameter was not recognized by the partners in the survey by having 0% in **locality** option at the survey relative question. Energy consumption and efficiency cannot be excluded from the climate-neutral strategy. It is estimated that purchasing 100% truly renewable electricity is one of the most efficient paths to reducing the carbon footprint. Investing a company in the purchasing of **renewable energy**, if not possible to install in-site a renewable energy system, means that carbon offset providers pump electricity into the grid from a renewable source or contribute with offsets based on the carbon-based consumption of the company. The certification scheme is especially useful since it can ensure the quantity, quality, and type of the green power[10]. However, as mentioned there are some unavoidable emissions and thus, a different approach requires. The creation and implementation of climate protection measures inside and outside their value chain can highly contribute to their climate targets. Those measures contain practices such as offsetting the emissions with **carbon credits**. Through offsetting, the entity can count **carbon credits** produced outside of its value chain. As it is defined by the Carbon Offset Guide "A carbon offset refers to a reduction in GHG emissions – or an increase in carbon storage (e.g., through land restoration or the planting of trees) – that is used to compensate for emissions that occur elsewhere. This drives the conclusion that carbon credits and offsetting play a complementary role in the climate strategy and value chain[11,12] and quality requirements are necessary. A variety of tools and guides are available to assist in making appropriate choices. Essential is to mention at this point that the highest percentage of the partners (37%), have not recognized any of the above practices as part of their strategy. This shows the novelty of the Climate-neutral strategy and further attention needs to be given.

4.4. Green sourcing

A green sourcing strategy, which is the most preferable strategy selected by the partners (31%), provides guidance to businesses when acquiring materials, supplies and services and selecting such products based on their impact on the environment and human health. It can apply to both products obtained to operate the business internally as well as for producing the

8 https://ghgprotocol.org/sites/default/files/standards/ghg-protocol-revised.pdf
9 https://thedocs.worldbank.org/en/doc/236681571411019437-0090022019/original/GreenMobilityGlobalRoadmapofAction.pdf
10 https://www.sciencedirect.com/science/article/abs/pii/S0301421504002423?via%3Dihub
11 Broekhoff, D., Gillenwater, M., Colbert-Sangree, T., & Cage, P. (2019). Securing Climate Benefit: A Guide to Using Carbon Offsets. 60. http://www.offsetguide.org/wpcontent/uploads/2020/03/Carbon-Offset-Guide_3122020.pdf
12 CCQI. (2021). The Carbon Credit Quality Initiative—About. Carbon Credit Quality Initiative. https://carboncreditquality.org

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goods and services of the business itself. The best practices identified through literature review together with the assistance of the partners are presented below.

Best practices identified in Industrial Synergy

Table 5 *Recognized best practices of green sourcing strategy*

Green Sourcing	
Best practices	**Recognition of partners**
Recycled and bio-based materials	61%
Safe and sustain by design	17%
LCA screening	13%
Green procurement	9%
Ecolabel	0%

Based on the nature of the project which the main objective is to introduce more sustainable products in the market by upscaling nano-enabled bio-based materials, the practice with the highest recognition is the usage of **recycled and bio-based materials** with 61%. Important practice also is considered, the **safe and sustain by design**. The European Green Deal, the updated Action Plan for a Circular Economy, the new European Industrial Strategy and the Chemicals Strategy for Sustainability launched in October 2020 plans to reach a sustainable, and inclusive European Union's economy. These require that any new material or product should be not only functional and cost-effective but also safe and sustainable to ensure compliance with regulation and acceptance by consumers. Especially, nano-enabled but also bio-based materials and products could enable such a green growth[13].
Green procurement stems from pollution prevention principles and activities. Also known as green or environmental purchasing, green procurement compares price, technology, quality and the environmental impact of the product, service, or contract. In a broad sense, it can be said that green procurement means purchasing environmentally friendly products and services that cause minimal adverse environmental impacts. Despite the zero recognition of the **ecolabels** by the participants of the survey as good practice under the Green sourcing strategy, those play a key role in eco-design. Ecolabels as having been defined, are environmental certifications given to products, services and buildings which have minimal negative environmental impact compared with other products or services. These can enhance green procurement and thus, developers and consumers to decide on products with harmless specifications[14]. Finally, partners acknowledge the necessity of **LCA screenings** which are useful for an organization to evaluate the environmental footprint of its products. Screening is used to identify opportunities for environmental impact reduction within the value chain and serves to obtain environmental knowledge about a product and thus support eco-design.

4.5. Industrial synergy

Industrial synergy includes activities in which two or more industrial units create mutually beneficial affairs taking into consideration the geographical proximity by sharing of activities, utility, and by-products to add value, reduce costs and improve the environment. PL owners identified the value of this strategy with 12% in their organizations. In Industrial Synergy, one entity adopts productive use of a material stream that is considered as waste or by-product by

[13] https://www.sciencedirect.com/science/article/pii/S2452074821000069
[14] https://www.ihs.nl/en/media/2017-11-greenlabels

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another unit. The keys to industrial symbiosis are collaboration and the synergistic possibilities offered by geographic proximity[15]. Those cases of symbiotic cooperation include the shared utilization of specific equipment or facilities and the pooling of resources as is suggested by European roadmaps and Ellen MacArthur foundation papers[16,17]. For the industrial entities, the benefit stands in economic advantages, while at the same time it creates environmental advantages. The main best practices found in literature review and are enhanced by the recognition of the partners are summarized below.

Identified Best practices in Industrial Synergy

Table 6 *Recognized best practices of industrial synergy strategy*

Industrial Synergy	
Best practices	**Recognition of partners**
Joined technical innovation	39%
Synergy in technological parks	26%
Circular business models	18%
Waste/ energy valorisation	13%
Smart regulation	4%

An **Eco-Industrial Park** is defined as a gathering of manufacturing and service entities installed together in an area where the enterprises involved **combine their knowledge** and capabilities, explore advanced environmental, economic, and social appearance through collaboration in directing environmental issues, such as pollution **reduction and conservation of water, energy, and raw materials**. This collaboration provides collective advantage for the involved enterprises, greater than the total of the individual benefits that each entity could reach by its optimization and efficiency.

Such characteristics are activities of exchange of by-products / waste or network of companies which proceed such exchanges, gathering of recycling enterprises with the usage of environmentally friendly technologies. Additionally, implementation of industrial synergy brings huge potentiality to activate instruments and **favourable regulations** that support practically sustainable development[18]. Industrial Synergy relies on the approaches of industrial ecology where the goal is the net production for environmental protection and is a plan of implementing the circular economy, with the aim of eliminating wastes and "closing the loop" of product cycles by improving recycling and re-use, eco design and waste prevention methods.[19] Therefore, the development of **circular business models** is a significant step to drive the sustainability of the business network through the circular strategies.

[15] https://www.annualreviews.org/doi/pdf/10.1146/annurev.energy.25.1.313
[16] https://www.aquafil.com/assets/uploads/ellen-macarthur-foundation.pdf
[17] https://www.sciencedirect.com/science/article/pii/S0306261921010813#b0015
[18] https://sustainabledevelopment.un.org/content/documents/635486-Kusch-Industrial%20symbiosis_powerful%20mechanisms%20for%20sustainable%20use%20of%20environmental%20resources.pdf
[19] http://ec.europa.eu/environment/circular-economy. Last retrieved 10-3-2016

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5. Surveys

Questionnaires and surveys are essential tools, used for collecting information and data to be further processed and analysed for a specific objective. Within the objectives of Task 8.1 and in the general scope of the WP8 - Sustainability Assessment, two surveys were developed by IRES and distributed to the consortium and to PL owners. The main goal is: a) to initially perform a qualitative assessment on eco-design, identify main barriers and benefits, and b) final, to incorporate all partner's insights towards an eco-design strategy for developing sustainable products.

The 1st survey consisted of 18 questions, distributed on M6 and was divided into three segments:

- Business information
- State of the art situation on eco-design
- Future perspectives on eco-design

Surveys' success depends upon the information and feedback received from all actors involved. INN-PRESSME responses in the 1st survey was limited, however, essential insights and valuable information have been identified. The information provided was anonymous and considered confidential. The results were aggregated and individual actors could not be identifiable. Initial results of the 1st survey were presented in M6 Consortium meeting and discussion followed among partners providing any necessary explanations and clarification upon the main findings.

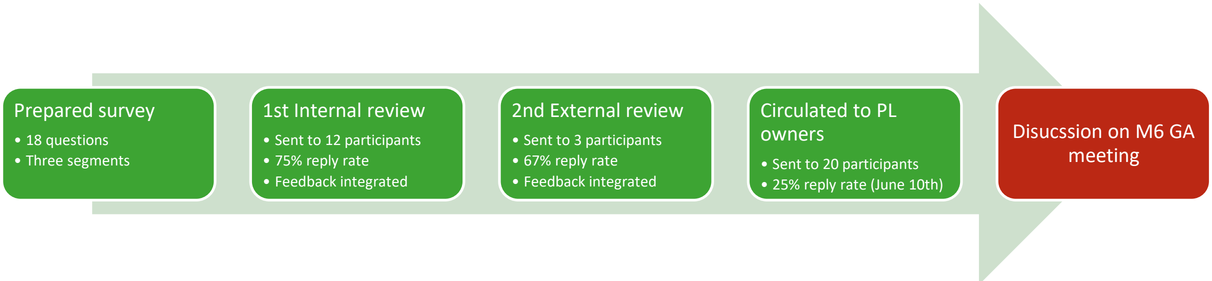

Figure 3 *Timeline of the 1st survey distribution and assessment*

The 2nd survey contains 22 questions and was shared among partners (pilot owners) on M14-M15. The survey is divided into three segments:

- General questions considering general information for the pilots and their organizations
- Specific questions related to the eco-design knowledge of the partners
- Eco-design strategies and good practices implemented.

The responses provided were anonymous and confidential. Initial discussions with partners were organized for clarification, if needed, regarding the given answers.

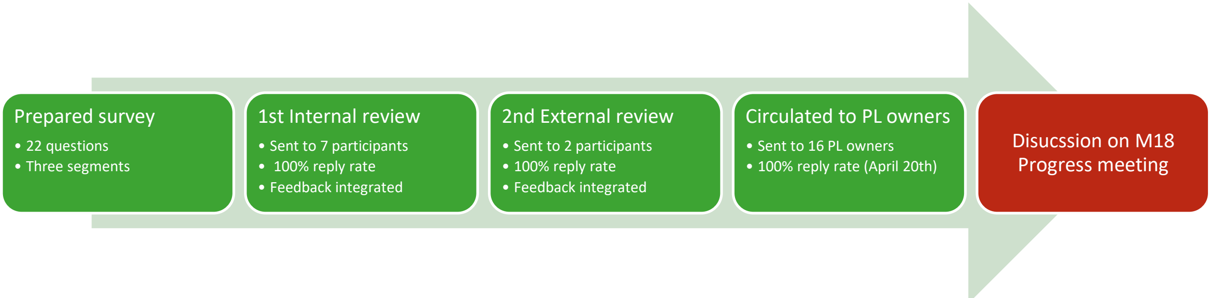

Figure 4 *Timeline of the 2nd survey distribution and assessment*

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5.1. 1st Eco-design survey results

Responses rate was limited in the first survey as only 25% out of 20 participants sent, provided their replies. Simple statistical analysis was applied to further process the results. According to the three thematic segments of the survey's questions, the following insights have been obtained from this first survey.

Business information

Initial questions (Questions 1-8) reflect general business information (type of organisation, product/process categories, clientele, experience in eco-design and related projects) and request the extent of familiarity with eco-design. The purpose of these questions was to retrieve information on partners' type of activities and identify their awareness on implementing eco-designing.

SoA of partner on eco-design

Following questions (Questions 9-13) focus on the state of the art of partners on eco-design. Identifying current state-of-art situation on eco-design would give a first impression of partners' awareness and thus, the identification of the main barriers and opportunities can be described.

Future perspective on eco-design

A final set of questions (Questions 14-18) indicates the future perspective of the partners on eco-design. This means that information regarding the employment actions of eco-design integration, targets set and mechanisms used is gathered and further assessed through this section of this first survey.

Results analysis highlighted the diverse levels of engagement with eco-design amongst participants, identifying engagement as opportunity and aligning expectation as the respective challenge. The importance of expertise to eco-design was reflected in responses and the main benefits identified include economic, new business opportunities and improved satisfaction by product-related environmental performance. Partners' responses on the main barriers preventing companies/organization from eco-designing was the increase of cost compared to conventional production (economic barriers), limited usability compared to traditional design and lack of knowledge or tools to implement eco-design.
Therefore, even though the responses' rate was low, essential information was derived. Focus when developing the eco-design strategy for PL owners and INN-PRESSME should be on:

- economic aspects,
- know-how,
- availability/awareness of eco-design tools
- engagement in management structure of organizations
- new business opportunities
- improved satisfaction on product-related environmental performance.

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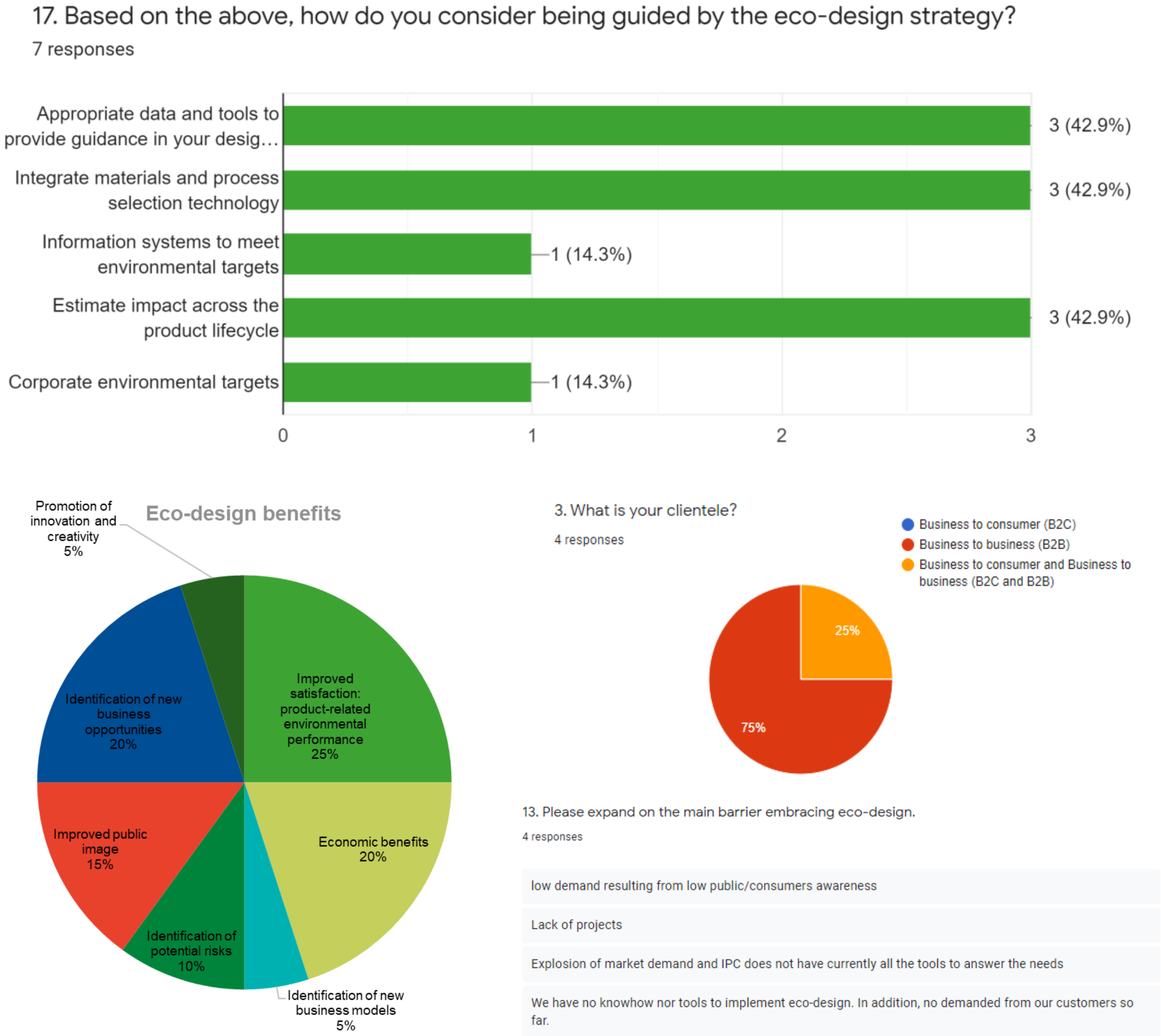

Figure 5 *Initial results from statistical analysis of 1st Survey responses*

5.2. 2nd Eco-design survey results

The 2nd questionnaire on eco-design had a higher rate of success in responses with at least one answer per PL and the outcomes concluded have essential value. Some of the partners provided more than one answer per PL which enhance the reliability and the preciseness of the findings. After the preparation of the survey, the draft was sent to the IRES, Sustainability team with a 100% response while feedback was integrated, as 1st internal review. During the 2nd internal review, the survey was sent to the WP8 leader and Project coordinator and was approved to be shared among the partners. Simple statistical analysis was used for the processing of the results. Based on the three segments of the survey the first findings are described below.

General questions

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In this segment, general questions regarding the pilot owners were gathered by collecting information about the type of the organization, the PL category, and the location of the major clients that they have. Questions were formulated to have an overview and categorise the pilot owners profiles and their participation in the relative PL. Responses showed that 56% of the pilot owners clients' are European based, while 19% and 25% are locally and internationally based respectively (**Figure 6**). This result can provide information about the **locality of the pilot line** and thus the **transportation needs** occurred per pilot line.

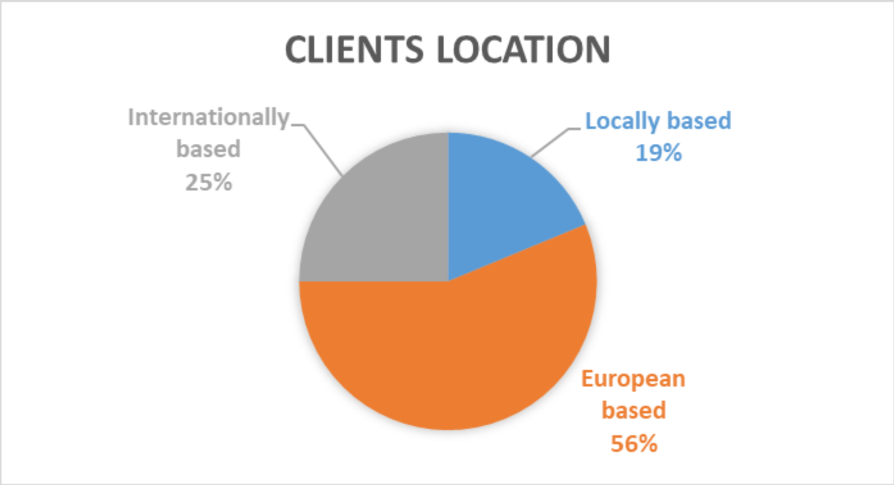

Figure 6 *Partners' clients location based on the 2nd survey*

<u>**Dedicated/specific questions on PLs**</u>

Specific questions (Questions 4-13) were provided to the pilot owners which covered information regarding their co-products and/or by-products, potential economic benefits of their exploitation and potential barriers for non-exploitation, their waste management approach, potential additional market targeting after the upgrade of the PL, their LCA awareness and potential implementation or other environmental tool methodologies and finally, the recognized benefits and barriers of eco-design implementation.

Most of the PL owners (81%) do not have any co- or by-products and they do not have any economic benefits by exploiting their by-products, co-products. Additionally, the main barrier identified for non-exploitation of those is their low-cost value (22%) and low quality (22%) respectively (**Figure 7**). Lack of business plan and lack of the customer interest are also other further reasons for not exploitation (11% and 6%, relatively). For many of the participants (39%) this question was not applicable.

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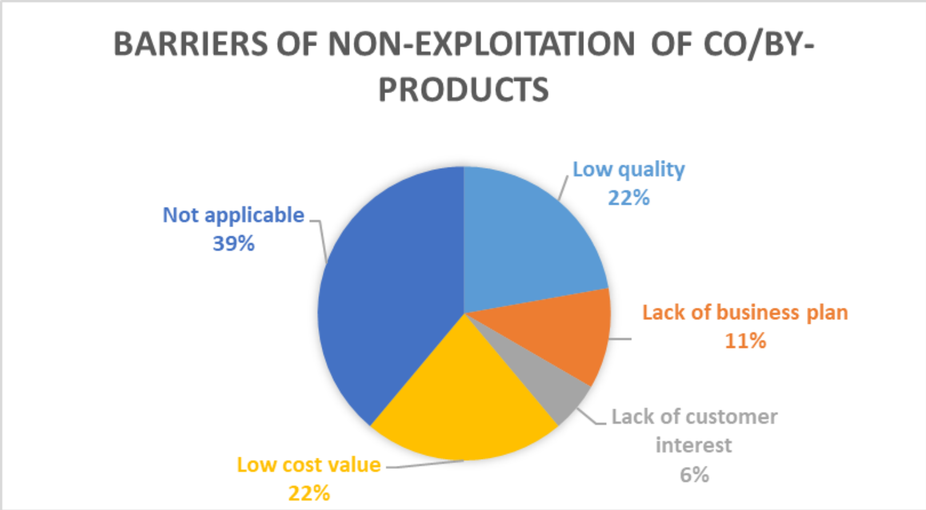

Figure 7 Barriers identified of non-exploitation of co/by-products based on the 2nd survey

Concerning the waste management (**Figure 8**), the majority has a third-party collaboration for the collection and recycling of their waste (75%). Moreover, 13% of the partners incinerate their waste and only 4% recycles their waste at on-site facilities. An 8% is equally divided to the usage of the wastewater treatment plant as the main waste management approach and landfilling. This result is highly significant for the formulation of the eco-design strategy as indicates that the last preferable option regarding waste management, landfilling, is avoided.

Figure 8 Partners' waste management approach

In accordance with the question reflecting the potential targeting of new market segments, 81% of the partners replied the same market after upgrading their PL, while the remaining 19% referred that they will target larger companies for the same market and, additionally, they will address new projects based on low environmental impact polymers. This result gives an alternative perspective regarding the future of the PL upgrading with the inclusion of low environmental impact organizations and thus, the more circular and eco-design strategies.
A noticeable point of this survey were the responses received regarding LCA implementation and awareness. The large majority (62%) of the pilot owners implement for more than 2 years

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and 19% for 1-year LCA in their organization, while only 19% do not implement LCA or any other calculation method for their environmental footprint. This fact is essential regarding the knowledge and the implementation of LCA concept and the formation of an eco-design strategy considering the familiarity of the partners regarding environmental issues.

Lastly, regarding the benefits of implementing eco-design in their organizations, the following options are identified: Financial benefits (14%), Business opportunities (25%), Identification of potential risks (resource scarcity) (16%), Improved public image (27%) and Favourable regulations (18%), illustrated in **Figure 9**. Participants had the option to select more than one answers but the highest results are given based on the business opportunities and the improved public image.

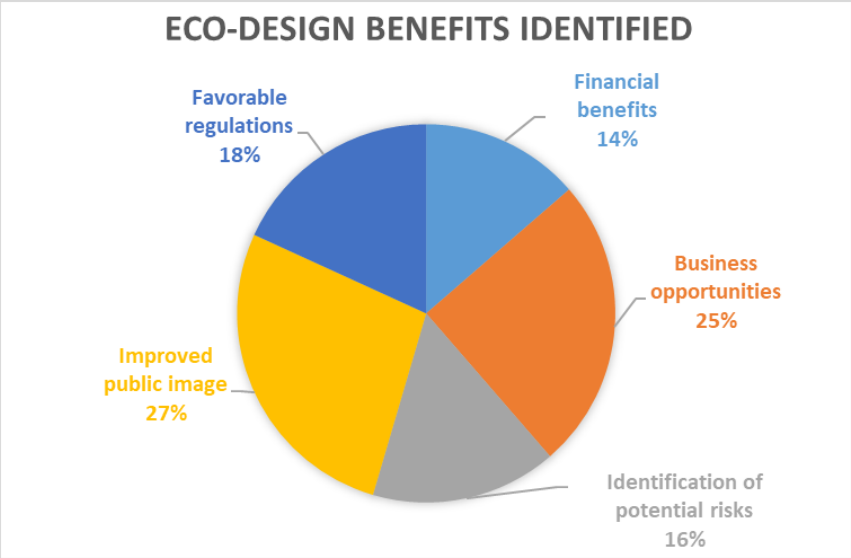

Figure 9 *Identified benefits of eco-design implementation*

The main barriers in implementing eco-design are the increased cost of implementation (27%), the lack of know-how (27%), market limitations (27%), followed by the lack of resources in top organization structure (13%) and low awareness of consumers (3%). Simultaneously, the participants had the freedom to choose more than one options and thus is occurred the variety of the percentages given. It is significant to further explore and assess the barriers given with the focus on the market limitation and the increased cost of implementation but also opportunities and strategies to close the gap of know-how inadequacy. Both challenges and opportunities identified, are further analysed in the next chapter.

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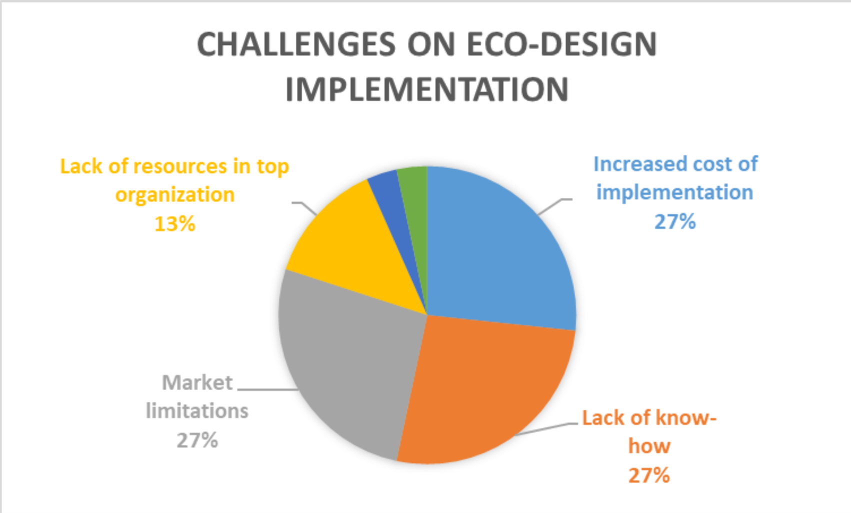

Figure 10 *Barriers recognized of eco-design implementation*

<u>**Eco-design and best practices implementation**</u>

In the 3rd segment, questions (Questions 14-22) on recognized eco-design strategies and their best practices were developed. Details about the inclusion of eco-design in PL owners' business policy, quantified reference estimation of PL upgrade targets, eco-design strategy implementation and relative identified best practices were further included as sub-questions. The purpose was to define the level of eco-design implementation and the relative practices of the partners, even if those are not recognized in their business policy. Interestingly, the vast majority of the partners already implement eco-design in their business policy (75%). Quantitative estimation targets of PL upgrades were able to be collected through dedicated options provided, as shown in **Figure 11**. Therefore, responses indicated the following percentages: reduce energy requirements 10-30% (2%), Decrease toxic waste 10-30% (8%), Increase productivity 20-40% (14%), Improve quality and properties 15-35% (23%), Improve reproducibility 20-40% (14%), Enhance green extraction more than 10% (2%), Reduce water requirement 15-40% (2%), Reduce cost more than 25% (4%), Process optimization more than 20% (21%), Accelerate time of entering the market 25-40% (2%) and finally, Improve product efficiency more than 20% (8%). It is significant to point out that most partners mentioned that the PL upgrades will improve the quality and the properties of their products while the majority stated that they will reach process optimization more than 20% faster after upgrading the PL.

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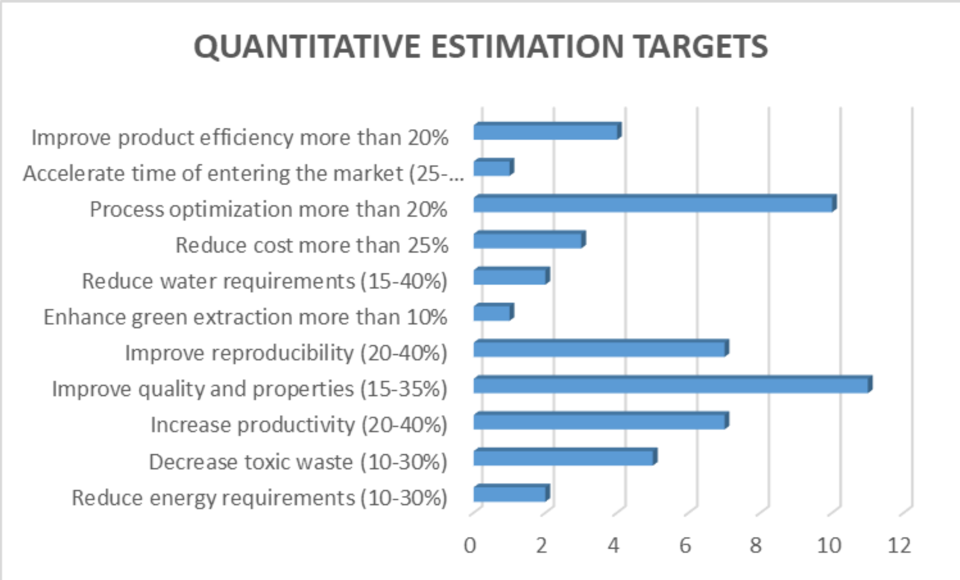

Figure 11 *Quantitative estimation of targets after the upgration of the PLs*

Partners were asked to select (one or more) the identified strategy based on literature review initially conducted that best describes the upgrade in their PL. At this stage, a brief definition of those strategies was given to assist the partners effectively choose the strategy that best describes their case. The first strategy referred to the Green Sourcing 31% with the partners' highest percentage of recognition, followed by the Resource efficiency (26%), the Climate neutrality (14%) and the Zero waste (17%). The least-matching strategy was the Industrial synergy with 12%.

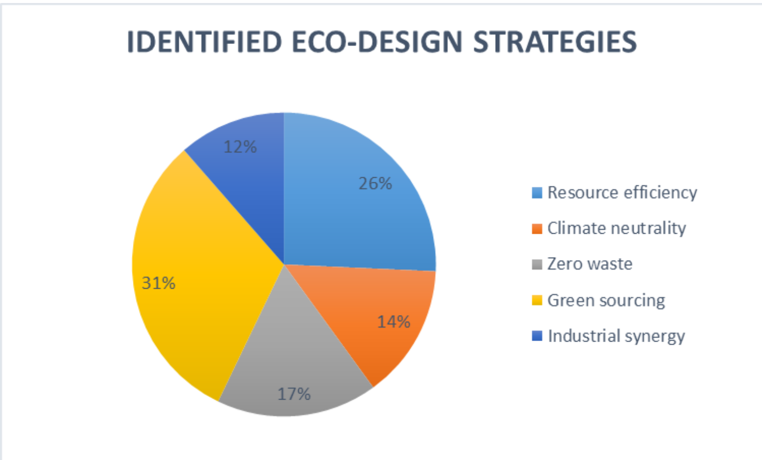

Figure 12 *Recognized eco-design strategies*

An open question for additional comments that partners wanted to share revealed that there is a need for the division of the eco-design strategy between business organizations and research institutes.

6. LCA, Recyclability and Eco-design

Life-cycle assessment is a standardised methodology by ISO 14040:2006 and ISO 14044:2006 that includes the compilation and evaluation of the input/output flows in a system

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and assesses the potential environmental impacts of a product throughout its life cycle. ISO 14040 describes the principles and the general framework for LCA, while ISO 14044 specifies the requirements and provides guidelines for conducting the LCA. Both technical reports are designed for the preparation, conduct, and critical review of life-cycle inventory analysis and provides guidance on the impact assessment and interpretation phases of LCA as well as on the nature and quality of data collected.
INN-PRESSME task 8.2 objective is to perform life cycle assessment on defined test cases to evaluate the potential environmental impacts from the upgrade of the PLs and its transformation. As a step in the methodology, the identified eco-design strategies are aligned with the targets set in each Pilot Line (**Table 7**). The quantified assessment results and the associated scenarios to eco-design, indicative ones are illustrated in **Table 8**, will provide deep and valuable information for the further development of the eco-design strategy.

Table 7 *Eco-design strategies aligned with targets identified in INN-PRESSME*

Targets	Strategies				
	Resource efficient	Climate neutral	Zero waste	Green sourcing	Industrial Synergy
Energy and resource efficiency	VTT, AIT	(X)	IWN	(X)	(X)
Reduce carbon and environmental footprint	(X)	RISE, POL, CID, GNA, CEA, IPC, FhG	(X)	(X)	(X)
Enable remanufacturing	FhG, VTT	(X)	(X)	(X)	(X)
Enable recycling	(X)	(X)	IPC	(X)	(X)
Increase biobased content	(X)	(X)	(X)	CID, CEA	(X)
Waste/energy/materials co-exploitation	(X)	(X)	(X)	(X)	RISE, GNA, PODO

Table 8 *Initial associated eco-design scenarios vs. Life Cycle assessment and business opportunities*

	Eco design scenarios	Resources	Life Cycle Stage	Business opportunity
1	Pursue alternative resources	Bio vs fossil	Design	Linear
2	Bio based content	Bio vs fossil	Design	Linear
3	Substitute virgin content	Fossil virgin vs fossil secondary	Design+EoL	Circular
4	Recycled based content	Fossil virgin vs fossil secondary	Design+EoL	Circular
5	Substitute virgin content	Fossil virgin vs bio virgin	Design+EoL	Linear
6	Substitute recycled content	Fossil recycled vs bio virgin	Design+EoL	Circular
7	Substitute recycled content	Fossil virgin vs bio recycled	Design+EoL	Biocircular
8	Substitute recycled content	Fossil recycled vs bio recycled	Design+EoL	Circular/Biocircular

7. Challenges and Highlights

Challenges

Regarding the findings through the surveys and the literature review, it is found that the most significant challenges for the implementation of eco-design in organizations are the market limitation, the increased cost of implementation and the lack of know-how of eco-design. Thus, below those challenges are summarized by analysing some of their essential aspects.

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- **Market limitations**
  - Not all stakeholders would be ready to engage completely with the eco-design strategies considering reasons such as legal framework, competition, hidden costs
  - Difficulties with the estimation of consumers' behaviour, future policy amendments on the manufacture and usage of eco-designed products can be found
  - Potential false interpretation and greenwashing of the strategies and results from different stakeholders.
- **Cost of implementation**
  - Costs in performing eco-design (personnel, man-hours, data collection) need to be assessed beforehand and should be included in the budget.
  - Economic and technical feasibilities in implementing eco-design strategies (selection of cost-intensive technologies, materials) can be uncertain
- **Lack of know how**
  - Members in the team involved in the eco-design strategy should be well informed in their expertise. Wrong estimation could put the production of new products and policymaking into risk
  - Eco-design approach is entirely subjective, however, the choice of the methodology should be justified with a scientific and technical background
  - Estimating future scenarios and technologies for the eco-designed products come with uncertainty

Opportunities

Accordingly, the opportunities of implementing eco-design in organizations are recognized by the partners. Those are the financial benefits, the improved public image, the favourable regulations, the business opportunities (new market) and below the main aspects of those are summarized.

- **Improved public image**
  - Advanced environmental performance assistance in increasing sales, share prices and brand value especially if environmental issues are addressed. Solid scientific evidence and the LCA assessments can be reported and thus relative green labels can be obtained.
  - Increasing interest in new models such as circular economy is evidence of the growing encouragement of producers to reduce waste and design more sustainable products. Customers expect to see business acting in a socially responsible manner.

- **Business opportunities**
  - Eco-design can also provide clear cost benefits and opening of new markets. By eco-designing during the design phase of a product, companies find that there are manufacturing costs such as materials and energy usage that can be reduced, as well as eliminating waste.
  - Assessing the risks associated with critical materials in an early stage can eliminate supply-chain disruptions by giving the opportunity to design without risky materials.
  - It is given the opportunity for innovation and thus new products.

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- **Favorable regulations**
    - Environmental legislation can be considered a significant driver for organizations to initiate eco-design activities. Through the implementation business can be financially benefited.

8. Future work

In M19-21 the Life Cycle Inventory (LCI) will be prepared and sent to the partners. Through the LCI, essential information and data are assessed and used for the LCA and LCC analysis. It is significant to clarify that the future work of LCA and LCC assessments, starting on M19, will have an effect on the final formation of the eco-design strategy. Therefore, modification is expected.

Further, a final survey is planned to be shared among the partners regarding the final information needed considering the eco-design strategy. Therefore, in M24 a capacity assessment survey will be asked to be filled by the partner

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