Switching Mediterranean Consumers to Mediterranean Sustainable Healthy Dietary Patterns

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History of changes

Version	Author	Date	Comments
0.1	CNTA	03.10.2022	1st draft
0.2	EURECAT	06.10.2022	2nd draft
1.0	ENCO	10.10.2022	Quality assessment and final version

Table 1: History of changes

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Abbreviations and Acronyms

Abbreviation / Acronym	Description
CE	Circular economy
CO_2	Carbon dioxide
EC	European Commission
EPD	Environmental product declarations
EMAS	Eco management and audit scheme
EU	European Union
FP	Food product
GHG	Greenhouse gas
IPP	Integrated product policy
LCA	Life cycle analysis
LT	Long term
MT	Medium term
PET	Polyethylene terephthalate
PRIMA	Partnership for research and innovation in the Mediterranean area
ST	Short term
SWOT	Strengths, Weaknesses, Opportunities and Threats

Table 2: Abbreviation and Acronyms

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1. Executive Summary

The growing awareness regarding environmental sustainability has fully reached business reality and food production currently is facing two crucial questions:

- How damaging is the industry for the ecosystem? It generates more than a third of all greenhouse gas emissions globally, and uses substantial and rising amounts of environmental resources, including land, water and nitrogen- and phosphorus-containing fertilisers. There is therefore an urgent need to drastically reduce these environmental impacts.
- How sustainable is the current velocity at which the resources are being consumed, for both the future of the industry and the future of our planet (nature and human population)? The Food and Agriculture Organisation (FAO) estimates that farmers will have to produce 70% more food by 2050 to meet the needs of the world's expected 9-billion-strong population. However, at the same time expansion of agricultural land should be limited as a way of safeguarding the environment.

So, forthcoming actions include the transformation for sustainability in food and agriculture systems

Eco-design is used as a tool in the manufacturing for improving the sustainability of food products by integrating environmental aspects into the design stage. This deliverable aims to serve as an Eco-design guide for the agri-food industries. This guide focuses on the possible improvements to be implemented by the agri-food sector to optimize the Eco-design of its products. In this way, companies will be better prepared to adapt its activity to the new ecomodulation measures. Its realization has been led by CNTA but also with the participation of EURECAT.

Firstly, Section 1 introduces the concept of Eco-design and the benefits and opportunities of implementing Eco-design in companies are reviewed. Second, an overview of circular economy and its relationship with Eco-design is presented (Section 2) as well as its legal framework (Section 3). In following section (Section 4) the focus is on the Eco-design methodology to present the different steps to implement it (project preparation, environmental impact analysis, definition of Eco-design strategies and the final prototype design).

What follows in the next chapters is intended to be implemented in the food prototypes development (at laboratory and pre-industrial scale up) conducted by companies involved in WP2 of SWITCHtoHEALTHY project: Delafruit, Kocahan and Chocorica. Therefore, this guide is a living document to be amended and adjusted (at the end of workpackage 2) in accordance with future experience, strategies implemented and environmental results analysis of these interventions, will be included in this document as an Annex.

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2. Introduction

Since the purpose of the current document is to disseminate the knowledge of the project regarding Eco-design methodology and to reach the food industry on the most effective way, it has been created in a user-friendly document (attached as Annex I to the present report).

Through communication activities, the guide of Food Eco-design methodology aims to improve overall general awareness about this issue, training food industry to implement the Eco-design strategies hereof presented.

3. Annex I

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Food eco-design methodology guide

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OCTOBER 2022

CNTA

RESEARCH & TECHNOLOGY
FOR THE COMPETITIVENESS
OF THE FOOD INDUSTRY

collaborate:

eurecat

Guide undertaken in the framework of *SWITCHtoHEALTHY* project

SWITCHtoHEALTHY

Financed by

PRIMA
PARTNERSHIP FOR RESEARCH AND INNOVATION
IN THE MEDITERRANEAN AREA

The PRIMA programme is supported under Horizon 2020 the European Union's Framework Programme for Research and Innovation

EXECUTIVE SUMMARY

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1

Introduction

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1.1 What is Eco-design?

Eco-design is an approach to include environmental considerations in the food product (FP) development processes (Schäfer & Löwer, 2021), taking preventive measures with the objective of reducing the environmental impact over their life cycle. Food products' life cycle include: production (e.g. agriculture), manufacturing, distribution, retail, consumption and end of life (e.g. waste management) (*Figure 1*).

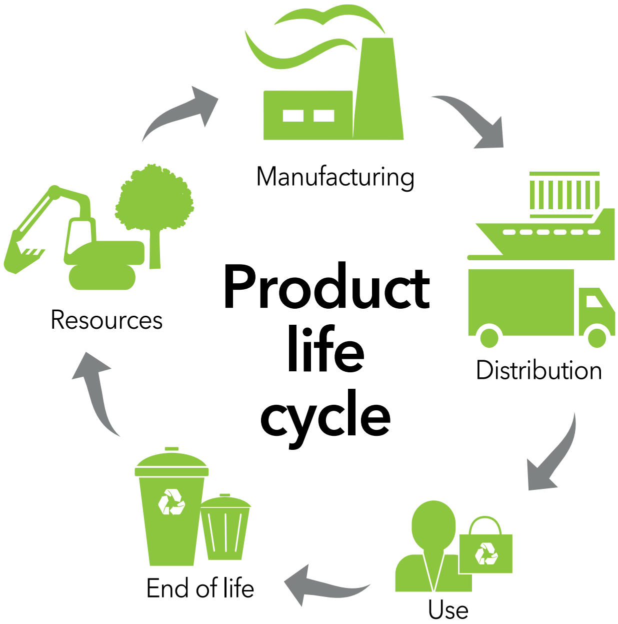

Figure 1. Product life cycle

For most FPs, agriculture is the most significant contributor to the overall environmental impact of the FP in its life cycle (Baldwin, 2009). Nevertheless, sustainability assessments must be carried out in all life-cycle stages of the FP (Anton & McLaren, 2017).

The cost and environmental impact attributed to the sale and consumption of any food product are associated to the type of manufactured product, its raw materials, the type and design of the packaging used, the required manufacturing processes for its production, the distribution and commercialization, and the consumer's use, among others. Therefore, the total cost and the global impact are accumulated throughout the whole agri-food chain and should be accounted for in an integrated way.

Eco-design represent a business opportunity, considering environmental factor as an additional factor to those that have traditionally been taken into account, such as, cost, safety and quality (*Figure 2*).

It has been estimated that around 80% of the environmental impact of a product is determined during the design phase. Therefore, every choice made in the designing stage has consequences.

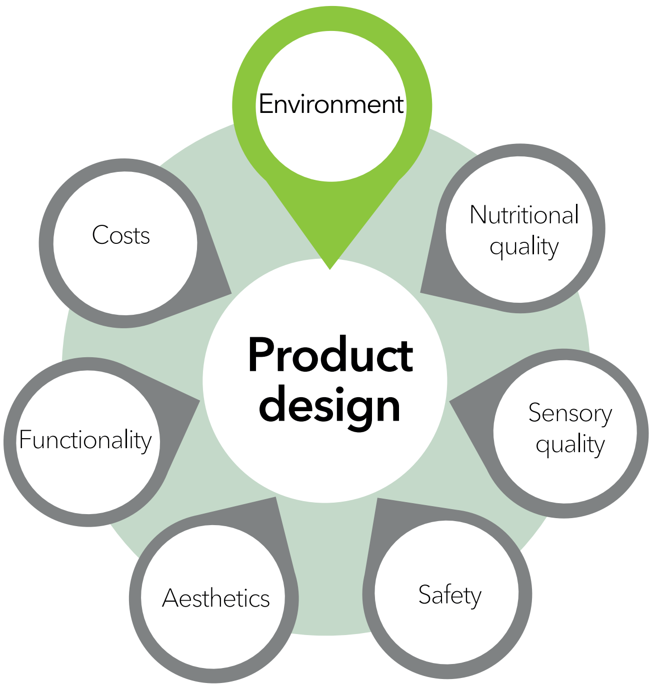

Figure 2. Aspects to consider in Eco-design

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1.2 Eco-design principles

There are 10 core environmental considerations of Eco-design:

- **01** Use of materials with less environmental impact
- **02** Use fewer materials overall in the manufacture of products
- **03** Use fewer resources during the manufacturing process
- **04** Producing less pollution and waste
- **05** Reduction of the environmental impacts of distributing products
- **06** Ensuring that products use fewer resources when they are used by end customers
- **07** Ensuring that products cause less waste and pollution when in use
- **08** Optimization of the function of products and ensuring the most suitable service life
- **09** Making reuse and recycling easier
- **10** Reduction of the environmental impact of disposal

1.3 Company benefits of Eco-design

It has been estimated that nearly 80% of the economic costs of products are defined during product design (Cooper & Chew, 1996). Similarly, it is also surmised that around 80% of the environmental impact of a product is determined at the design phase (DG Enterprise & Industry and DG Energy - European Commission, 2014; McAloone & Bey, 2009). Because of this, there is a lot of potential to reduce environmental and economic costs, and consequently improve sustainability performance, by proactively assessing the products before they are produced, rather than using a reactive approach to minimize impacts of a product already designed (García-García *et al.*, 2021). It would therefore be especially useful to undertake such sustainability assessments in the first stages of the development of new products.

In view of this, Eco-design have emerged to support the incorporation of sustainability principles during the design phase of new products or redesigning existing products (CPRAC 2012, Plouffe *et al*. 2011, García-García *et al.*, 2021).

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The potential benefits of using Eco-design include:

01 Reduction of environmental impacts, as the first and foremost benefit. The main environmental impacts influenced by Eco-design are water contamination, soil contamination, depletion of natural resources, greenhouse effect, ozone depletion, smog, acid rain, etc.

02 Reduction of (manufacturing and distribution) costs, by identifying inefficient processes that can be improved and new ways of food production.

03 Market differentiation and/or market share increase. Through Eco-design, a company can improve its corporative image or that of its product by projecting to their customers a "green" company image.

04 Innovation. The introduction of news aspects in the design methodology can provide new ideas about aesthetic, functionality and/or formulation, facilitating the creation of new market opportunities.

05 Compliance with environmental legal requirements. The requirements set by current regulations must be considered as a baseline to be improved. In this way, an attempt should be made to anticipate future legislative changes.

06 Meet customers' demand. Nowadays, customers are becoming more environmental- conscious and "greener" in their purchasing, reinforcing the need for companies to increase their commitments to responsible practices.

07 Improved functionality and quality of products and, therefore, higher added value of food products.

08 Access to Eco-labelling systems. This system identifies products that meet low environmental impact criteria and provides insight into the process to facilitate consumer decision-making.

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1.4 Barriers of Eco-design

Some possible difficulties that may arise during decision making and during implementation of Eco-design. These include:

- Lack of experts in environmental issues
- Difficulty to access information:
  - Dealing with aspects that the company is not used to.
  - There is a lack of trust from the suppliers to provide such information.
- Consumers' low level of understanding of eEco-design.
- Economic costs - and whether your clients or customers are prepared to pay for it.
- Difficulties to clearly demonstrate the benefits to buyers so that they choose your product.
- Risks of trying new materials and approaches.
- Low innovative character, which makes it difficult to implement such actions until there is no legislative requirement or by market demand.

1.5 Relevance of Eco-design in the food sector

Food industry sector have several peculiarities compared to other industrial sectors, such as, variability of the primary sector (agriculture, livestock and fisheries), a short shelf-life, high biodegradability, global chain of production, etc. These specific characteristics make necessary a highly differentiated process from usual design processes.

A food product such as yoghurt may not appear to be an evident target for Eco-design, but note that there are several different types of yoghurt, such as: organic versus conventional, yoghurt made from soy, yoghurt from cows in intensive livestock farming versus extensive farming or from cows with different diets, and yoghurts with different taste, fat content, packaging type, shelf life, bacteria culture, etc. Therefore, there is a broad range of possibilities that cover different stages of a product's life cycle from ingredient and products innovation (agriculture, production, etc.)

Additionally, the literature provides numerous examples of food packaging based on recycled materials, or made of materials that can be reused, recycled, or even consumed. Admittedly, improvements of packaging can deliver some benefits and may represent an important signal to consumers. But it is typically the food product inside the packaging that represents the largest impact potential (Angervall *et al.*, 2008). Food and packaging should therefore be analysed and optimised as an integrated unit, as part of Eco-design in the food sector.

2

Eco-design and circular economy

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The world faces the challenge of how food production can meet consumer's expectations of safety, nutrition, quality, price, environmental concerns and social issues. At the same time there are the challenges imposed by legislation, population dynamics, climate change, water scarcity, international trade, diminishing resources, etc. Therefore, a global food challenge is required for a more sustainable food production. The goal is no longer simply, since a broad range of aspects must be pursued simultaneously, such as, economic feasibility, compatibility with the environmental challenges, production of more food from the same area of land while reducing the environmental impacts (sustainable intensification), whilst providing high-quality products (Godfray *et al.*, 2010).

The Circular Economy is a system of exchange and production that, aims to increase the efficiency of resource use and decrease the impact on the environment (ADEME, 2014). Nowadays, 8.6% of the world's economy is defined as circular (www.circle-economy.com). The current goal is to move toward a circular, sustainable, and regenerative bioeconomy, which should consider direct and medium- and long-term factors that affect the environment.

Therefore, the practical relationship between the circular economy and Eco-design is acknowledge (Besch, 2005). In a circular economy, Eco-design is used to improve the environmental performance of the product. Implementing Eco-design principles is key to success for the circular economy, as shown in *Figure 3*.

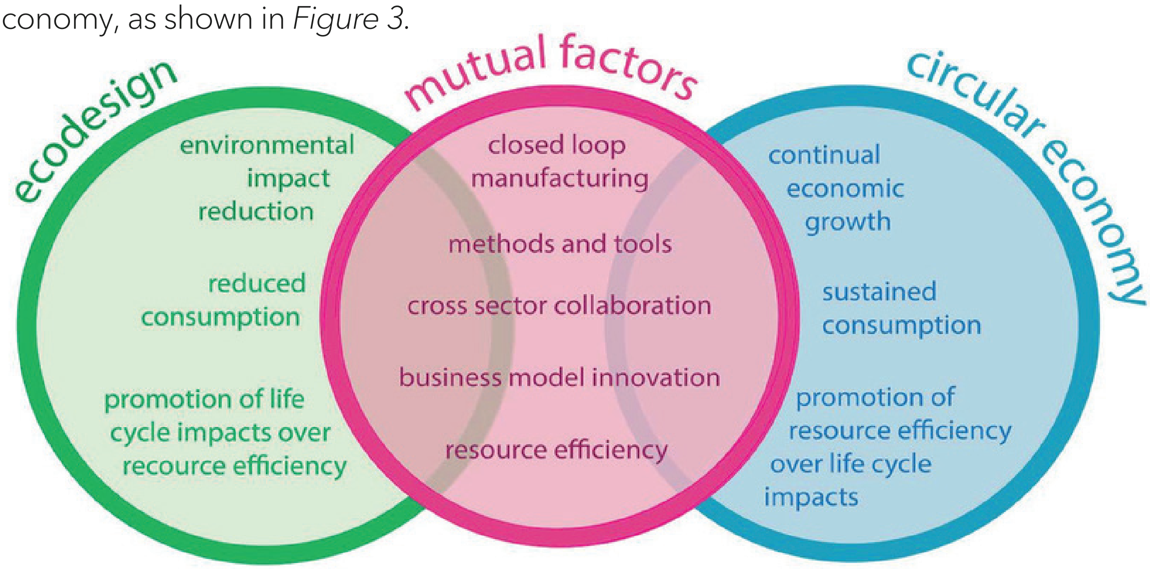

Figure 3. Relationship between ecodesign and circular economy (source: Prendeville *et al.*, 2014)

Sustainable business models of circular economy:

Nowadays, there is an active social demand to make the best and most profitable use of available resources, given the scarcity of raw materials and the global economic crisis. Added to this is the need to reduce the growing generation of waste and its polluting effects on the environment.

The agri-food sector, in recent years, has paid considerable attention to issues such as food safety, traceability of production, product quality, and respect for the environment. This has led manufacturing systems to move toward more sustainable approaches. Waste generation along

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the world supply chain in 2019 totalled, approximately, 1.3 billion tonnes (Food and agriculture organization, 2019) due to mismanagement of resources and processes (Proto *et al.*, 2008) and unsustainable consumer consumption patterns (Taghikhah *et al.*, 2019).

Corrado *et al.* (2018) found that current estimates of food loss and waste generation vary between 194 and 389 kg per person per year on a global scale and between 158 and 298 kg per person per year on a European scale. The authors suggested that more efforts are required to promote suitable strategies related to food loss and waste. Options for exploiting food waste (FW) include, for example, the extraction of high-value compounds, using it as animal feed, the production of biomaterials, and the generation of biofuels.

The improvement in sustainable solutions for food waste management is one of the main challenges for society. Girotto *et al.* (2015) provided an overview of the present discussion on the definitions of food waste, reduction strategies, and conversion technologies that have emerged from the concept of biorefinery. The paper highlights several solutions implemented in the management of food waste, such as donating edible fractions to social services or for the production of biofuels or biopolymers and providing food for nutrient recovery and carbon fixation by composting; less desirable options are incineration and landfilling. The identified solutions should be able to exploit the valuable resources represented by food waste to obtain social, economic, and environmental benefits.

The following pictures illustrate how circular business models prove to be a sound business strategy that facilitates access to new markets, drives innovative solutions and saves production costs.

Figure 4. Types of preserves manufactured under the brand im-perfect

Espigoladors is a Spanish organisation that valorises leftovers of fruits and vegetables production. It is a team of gleaners that go out into fields and collect imperfect or ugly pieces of fruits and vegetables which do not enter the commercial market due to their (un)aesthetic characteristics. Gleaned fresh products with the help of volunteers are donated to social organisations.

Moreover, part of these fresh products is used to manufacture different preserves like jams, creams and sauces (under the brand name es im-perfect). As well as providing the basis for delicious meals, Espigoladors are preventing waste, easing the impact of agriculture on the environment and providing employment for people at risk of social exclusion **(Espigoladors | We fight to stop food waste and losses)** (*Figure 4*).

Algan Composites and Càmara Arrosera Montsiá (cooperative storage and rice processing facilities from Spain), after ten years of research and development, have created Oryzite, a plastic substitute made from rice rusk. An enzimatic process, also coming from the rice plan, turns it into a powdered natural filler.

This transformation gives a second life to this agro product waste, since this material can be added to all kinds of thermoplastic compounds in different percentages (in some cases up to 85 %).

Water is not used as a resource in the manufacturing process and 16 kg of material are obtained for every kw used. It allows to reduce energy consumption and reduce CO_2 emissions (carbon footprint) as well as each kg of Oryzite replaces 1 of plastic.

Oryzite uses the least resources and produces the least waste **(Oryzite | a redefined material)** *(Figure 5)*.

Figure 5. Examples of the new sustainable material made from rice

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3

Legal framework

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The issues of agri-food industry by-products and the resulting generation of waste have pushed the European Union (EU) to promote a zero-waste economy by 2025, attracting the interest of researchers, regulators, industry, and consumers. The initiative promoted in December 2019 by the European Commission (EC, 2020) for a **Green Deal** aims to make the climate challenge and the ecological transition an opportunity for a new development model, providing the EU with the opportunity to play a leadership role at the global level. The Green Deal constitutes an important framework for accelerating the transition to a CE, moving toward a more sustainable bio-economy (Hamam *et al.*, 2021). The European Green Deal will transform the EU into a modern, resource-efficient and competitive economy, ensuring:

- No net emissions of greenhouse gases by 2050
- Economic growth decoupled from resource use
- No person and no place left behind

The **Farm to Fork Strategy** is the heart of the Green Deal. It addresses comprehensively the challenges of sustainable food systems. The strategy lists four main requirements:

1. Ensuring that the food chain, covering food production, transport, distribution, marketing and consumption, has a neutral or positive environmental impact.
2. Helping to mitigate climate change and adapting to its impacts.
3. Ensuring food security, nutrition and public health, making sure that everyone has access to sufficient, nutritious, sustainable food that upholds high standards of safety and quality, while meeting dietary needs and food preferences.
4. Preserving the affordability of food, while generating fairer economic returns in the supply chain, so that ultimately the most sustainable food also becomes the most affordable.
5. As the production of commodities can have negative environmental and social impacts in the countries where they are produced, the Strategy recognises that the efforts to tighten sustainability requirements in the EU food system should be accompanied by policies that help raise standards globally, in order to avoid the externalisation and export of unsustainable practices.

Therefore, the Strategy announced that the EU will support the global transition to sustainable consumption and production of agri-food systems, as one of the priority areas of action, in line with its objectives and the **Sustainable Development Goals.**

Eco-design is of vital importance in European environmental policies, as it is demonstrated by the European strategy for "Sustainable Development Goals" of 2009.

In this context, movements towards new business, production and management models have accelerated both in the practical and/or operational sphere and in the regulatory framework. Eco-design methodology aims to design and redesign food products lowering the impact of themselves in all the supply chain.

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Following there is a summary of the basic legal framework/initiatives/actions existing in Europe:

- Directive (EU) 2019/904 on the reduction of the impact of certain plastic products on the environment (Single-use plastics Directive).
- Directive (EU) 2018/851, amending Directive 2008/98/EC on waste (Waste Framework Directive, WFD, consolidated version to July 2018) to prevent and reduce the negative impacts caused by the generation and management of waste and to improve resource efficiency.
- On April 9, 2022, Spain published Law 7/2022 on waste and contaminated soil for a circular economy, which directs competent authorities to adopt measures to prevent the generation of waste by promoting and supporting sustainable and circular production and consumption models.
- Integrated product policy (IPP). It is a European Union level initiative, focused on the product development and design phase. IPP aims to tackle the stage at which man of the environmental burdens of products are determined (Charter *et al.* 2001).
- Environmental product declarations (EPD), in accordance with International Standard ISO 14025, is a document which transparently communicates the environmental performance or impact of any product or material.
- Proposal for establishing a framework for setting Eco-design requirements for sustainable products and repealing Directive 2009/125/EC (Directorate-General for Environment, Brussels 2022).
- Eco management and Audit scheme (EMAS), is a management instrument developed by the European Commission for companies and other organisations to evaluate, report, and improve their environmental performance. EMAS is open to every type of organisation eager to improve its environmental performance.
- Green Public Procurement is a voluntary tool for Europe's public authorities that favours products and services that respect the environment.
- Action plans: effective use of resources, Eco innovation, sustainable consumption and production and circular economy.

4

Steps of Eco-design implementation

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STEPS OF ECO-DESIGN IMPLEMENTATION

- **STEP 1 – PROJECT PREPARATION**
  - Work Team
  - Food product selection
  - Motivating factors identification
- **STEP 2 – FOOD PRODUCT ENVIRONMENTAL IMPACT ANALYSIS**
  - Critical aspects identification (process, materials...)
  - Environmental aspects analysis (MET, eco-indicators)
- **STEP 3 – ECO-DESIGN STRATEGIES**
  - Strategies for improvement
  - Selection of strategies
- **STEP 4 – FOOD PROTOTYPE CONCEPT DEVELOPMENTS**
  - Requirements identification
  - New concepts generation
  - Concept selection
- **STEP 5 – PROTOTYPE VALIDATION**
  - Laboratory scale
  - Pilot scale
  - Industrial scale
- **STEP 6 – MEDIUM AND LONG TERM ACTION PLANS**
  - Improvement measures plan
  - Monitoring
- **STEP 7 – ACTION PLAN RESULTS EVALUATION**
  - Environmental results analysis
  - Motivating factors compliance assessing

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STEP 1
Project preparation

Eco-design methodology is commonly perceived as a tough and complex way to develop new products (bringing a new product to market or redesigning an existing food product), despite the fact that this is a general perception, it offers huge potential benefits if it is correctly applied (Crul and Dhiel, 2007).

Certain points to take into consideration are:

POINTS TO TAKE INTO CONSIDERATION

- Realistic selection of purposes
- Good integration between environmental and design considerations
- Focusing the design on product life cycle (LCA), considering the consequences of food product redesign
- Quality and actual information about the food product production
- Using Eco-design tools and strategies for food product redesign
- Proposing lower environmental impact options for actual material and production systems

1.1 WORK TEAM

Just as projects are carried out by people, food Eco-design projects are conducted by the different people from all the departments in the company, the success of this kind of projects depends on a good coordination between the people who is involved. The main characteristics of the team are:

- **Small and well organised teams:** the group must be operational; therefore, it should not be composed of too many people. One of the team members (preferably the product development manager) will be responsible of directing and coordinating the stages of the project.
- **Decision making capacity:** need of including the Company's management.
- **Multidisciplinary team:** wide vision of the project (from quality requirements to sales vision).

The main participants of a complete Eco-design team are:

- **Company management:** the key role of this participant is to boost this initiative, to validate the chosen food product and to evaluate the Eco-design result.
- **Project coordinator:** is the core of the project and its contributions are: control of the project, provide communications meetings between all the members and choice of the Eco-design tools with the environmental specialist.
- **Production department:** this member should advise about the consequences of the redesigned product in the production procedure (mainly environmental and technical feasibility).
- **Product development department / R&D&i department:** its role has deep impact in long term decisions, it should be open minded to changes looking for new perspectives.
- **Environmental department:** this participant should provide the team project with Eco-design tools (BREFs and MTDs) and methodology, its task is to coordinate the environmental vision of the project with the company strategy.
- **Quality department:** they inform about the aspects related to the existing regulations on the food product.
- **Marketing or sales department:** contribution with the customer and market preferences for designing new food products and redesigning existing food products.
- **Purchasing department:** this member complements the contribution of the marketing/ sales department to the project. Besides, it contributes with new lower environmental impact materials from suppliers.
- **External advisor:** its contribution will be determined by the project coordinator and the environmental department.

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1.2 FOOD PRODUCT SELECTION

The selection of which food product might be the most appropriate for applying Eco-design methodology is based on several criteria:

- The food product must have enough degrees of freedom to allow a modification hereof.
- Preferably, the selected food product must be affected the most by the Eco-design motivating factors of the company. Furthermore, this selection should be aligned with the expected goals previously defined.
- If it is the first time in introducing the Eco-design criteria it would be advisable to start by a food product which allow easy modifications to foster fast and motivation results.
- New product based on Eco-design.

1.3 MOTIVATING FACTORS IDENTIFICATION

After a SWOT analysis emerge motivating factors that could boost the application of Eco-design methodology. Those can be divided into:

- **EXTERNAL MOTIVATING FACTORS:** opportunities and threats of the SWOT analysis
- **INTERNAL MOTIVATING FACTORS:** strengths and weaknesses of the SWOT analysis

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1.3.1 EXTERNAL MOTIVATING FACTORS

EXTERNAL MOTIVATING FACTORS

Administration	Market	Competitors	Sectoral organisations
Legislation and regulation	Demand by customers	Environment as differentiating element	Motivation, support, demand

Social Environment → Environmental awareness

Administration

The European Union is developing environmental guidelines aiming to focus on the "responsibility of the manufacturer". In addition, many countries are developing their own legislation.

Market

Increasingly, public opinion is more aware about the environmental impact of the food products they consume, likewise industrial customers have increased their influence in companies in comparison with final customers.

For this reason, environmental characterization, besides ecological labels, are two of the main stimuli which can contribute to include Eco-design methodology in the design of new food products.

Competitors

Environmental characteristics are being used by the most important companies of the world with the aim of employing them as a marketing claim, therefore Eco-design methodology can provide this specialization.

Social environment

Many sectorial organizations motivate companies to include environmental aspects in their processes and food products, eco-design methodology could be an answer to this demand.

Suppliers: technological innovations

The emergence of new technologies which are more careful with environmental aspects helps to carry out better Eco-design implementations.

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1.3.2 INTERNAL MOTIVATING FACTORS

INTERNAL FACTORS

Product quality	Corporate image	Cost reduction	Innovation	Motivation
Improving quality	Eco-labels	Production, consumption	New concepts	Improving health and safety of employees at work

Product quality

The constant search for quality in products is a priority task for all companies. Eco-design application leads to rise the functionality, reliability, durability, and others.

Corporate image

Through Eco-design, the environmental quality of the food product can be widespread within ecological labels, green marketing, etc.

Costs reduction

This result could be expressed:

- Immediately with food product improvements through changes in the production process, lowering the carbon footprint, water consumption, etc.
- Long term with company changes such as optimization of resources consumption and minimize wastes volume

Innovation

Eco-design introduces new concepts of innovation through an environmental point of view, this could bring new opportunities to generate new food products.

Employees and managing motivation

Environmental conscience might be promoted in a company by management through Eco-design projects, moreover, it could help to increase the work healthy and safety.

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STEP 2
Food product environmental impact analysis

There are several important concepts for the environmental improvement of a product. These important concepts are life cycle, product system, functional unit, environmental aspect of a product, environmental impact of a product and impact transfer.

- **LIFE CYCLE:** the life cycle is the set of stages of a product, from the extraction and processing of raw materials, production, marketing, transport, use and maintenance, to the final management when the product reaches the end of its shelf life. The sum of all inputs of matter and energy and outputs of waste and emissions constitutes the environmental impact of the product.
- **PRODUCT SYSTEM:** a product system is the set of unitary processes connected in terms of matter and energy through elemental flows and product flows, which perform one or more defined functions. It serves as a model for the life cycle of a product.
- **FUNCTIONAL UNIT:** the functional unit is the reference unit used to measure the performance of the inputs and outputs of the product system. Its objective is to be the reference for all the inputs and outputs of the system under study. It allows us to assess and compare objectively all the impacts generated.
- **ENVIRONMENTAL ASPECTS OF A PRODUCT:** the environmental aspects of a product are those elements of the product that can interact with the environment. As the product is an element that possesses these elements (and not the activity of the company), in the study of these aspects it is necessary to analyse the entire life cycle of the product. The products can generate the following environmental aspects:

  - Material consumption
  - Water consumption
  - Energy consumption
  - Use of toxic substances
  - Atmospheric emissions
  - Liquid spills
  - Waste
  - Soil contamination
  - Noise
  - Smells

- **ENVIRONMENTAL IMPACT OF A PRODUCT:** the environmental impact of a product is any change in the environment as consequence of the different environmental aspects of the product. The objective of the identification of the environmental aspects of a product is to minimize its negative environmental impacts. Some of the environmental impacts, generated by the products, are depletion of natural resources and ozone layer, greenhouse effect, photochemical smog, water contamination, soil contamination, acid rain, etc.

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Food production is responsible for one-quarter of the world's greenhouse gas (GHG) emissions, as shown in a large meta-analysis of food system impact studies performed by Poore & Nemecek's (2018). As shown in *Figure 6,* livestock and fisheries (which include animals raised for meat, dairy, eggs and seafood production) account for 31% of food emissions. Crop production accounts for 27% of food emissions which result mainly from agricultural production (release of nitrous oxide from the application of fertilizers, methane emissions from rice production, or carbon dioxide (CO_2) from agricultural machinery are some examples). Land use accounts for 24% of food emissions, including the sum of land use change, savannah burning and organic soil cultivation. Finally, supply chains (which include food processing from the farm into final products, transport, packaging and retail) account for 18% of food emissions. Whilst supply chain emissions may seem high, it's essential for reducing emissions by preventing food waste during the supply chain.

Thus, reducing emissions from food production must be one of the greatest challenges in the coming decades. An approach where producers monitor their own impacts by considering the complete life cycle of the product (see section 2.2), flexibly meet environmental targets by choosing from multiple practices, and communicate their impacts to consumers should be encouraged.

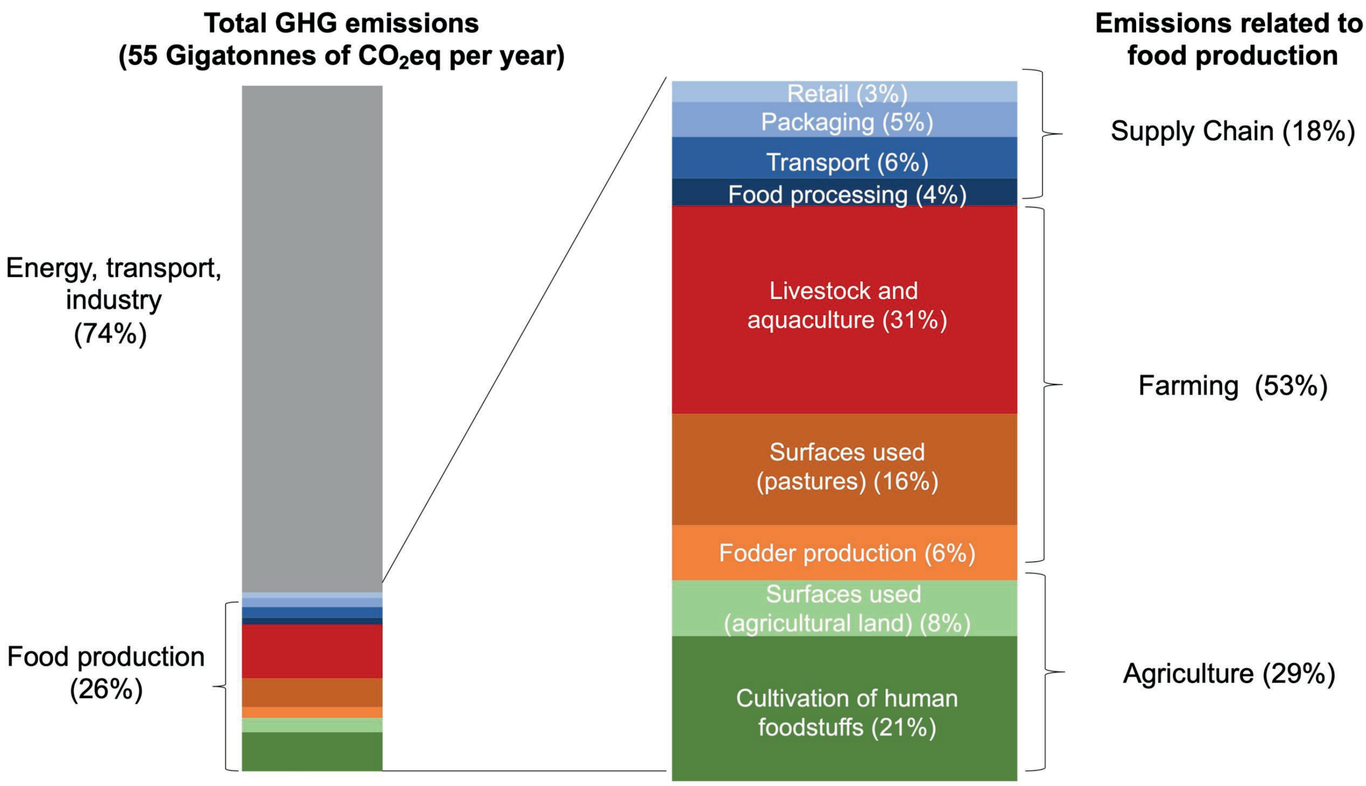

Figure 6. Contribution of the food sector to the annual production of greenhouse gases (GHG). Adapted from Ritchie and Roser (2020)

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Dietary choices and environmental impact

There is rightly a growing awareness that consumers diet and food choices have a significant impact on the carbon footprint. Food's carbon footprint involves the greenhouse gas (GHG) emissions produced by growing, rearing, farming, processing, transporting, storing, cooking, and disposing of the food. CO_2 is the most important GHG, but not the only one. Agriculture is a substantial source of the greenhouse gases methane and nitrous oxide. The GHG emissions from food production usually are expressed in kilograms of carbon dioxide equivalents ($KgCO_2eq$), which takes into account not just CO_2 but all greenhouse gases.

Overall, animal-based foods tend to have a higher footprint than plant-based. For instance, producing a Kg of beef emits 60 $KgCO_2eq$, while peas production emits just 1 $KgCO_2eq$ per Kg (*Figure 7*).

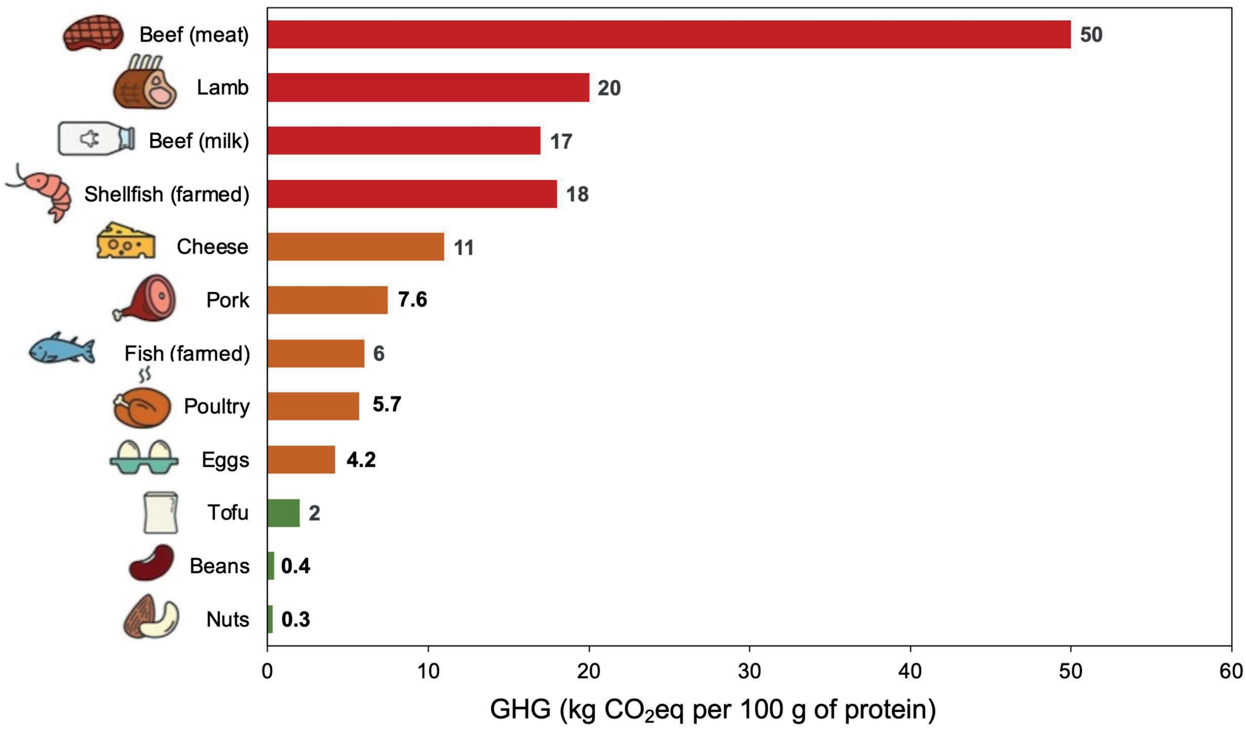

Figure 7. Comparison of GHG levels generated during the production of different protein sources. Based on Poore and Nemecek (2018), as modified by Eikenberry (2018).

Most GHG emissions results from land use change and from processes at the farm stage accounting for more than 80% of the footprint for most foods. Transport and the rest of the processes in the supply chain once the food left the farm represent a small share of emissions.

It is noteworthy that the impacts of the lowest-impact animal products typically exceed those from vegetable substitutes. Recent evidence suggests that the reduction in the consumption of meats, sweets, and drinks, in combination with increases in vegetables, cereals and legumes, as well as following diets with no red meat or vegetarian diets (without meat or fish), have considerably lower impacts (Walker *et al.*, 2018; Sandström *et al.*, 2018). It reinforces the importance of dietary change to mitigate food environmental impact.

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- **IMPACT TRANSFER:** in the process of environmental improvement of a product, it is important to consider that a modification in the design of the product (with the objective of reducing the environmental impact of a specific environmental aspect) can generate another new environmental aspect in that same stage or at a different stage of the life cycle. This is what is called impact transfer and the best way to prevent it from occurring is to assess the consequences that the design modifications have at all stages of the life cycle.

2.1 CRITICAL ENVIRONMENTAL ASPECTS IDENTIFICATION OF A PRODUCT

One of the first issues to develop the Eco-design task is the identification and evaluation of the environmental aspects of the products. For that, it is necessary to:

- Identify the environmental aspects of all stages of the product life cycle.
- Prioritize environmental aspects throughout the life cycle and avoid transferring impacts from one stage to another.
- Knowing the priority or significant environmental aspects of a product, include its improvement among the main motivating factors that the company has when the design of a product is modified: legislation, customer requirements, sectoral pressures, innovation needs, etc.

The environmental aspects of a product can be classified in the groups:

- Aspects that can be managed and controlled directly by the company (for example, those derived from the production process).
- Aspects in which the company has not a direct control, but can influence its management (for example, the characteristics of raw materials supplied by the supplier).
- Aspects in which the company has not any management capacity (for example, requirements set by the client, such as the origin of the energy used).

The environmental aspects of a product can be grouped in **material aspects, transport aspects** and **usage aspects,** which basically include all types of environmental aspects of the product life cycle.

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2.1.1 ENVIRONMENTAL ASPECTS OF A PACKAGING MATERIALS

The aspects of materials collect information about the use of a specific material, depending on its characteristics (weight, toxicity), place from it is transported, process for its transformation and destination-effect on the environment that its disposal can have at the end of its life cycle. This allows comparing some materials with their alternatives and choosing those that generate less environmental impact.

The material aspects are constituted by all the components of the product, packaging and auxiliary materials used throughout all the stages of the product's life cycle and depend on the characteristics of the materials, their production processes, waste generated, and energy consumed, places of origin and kilometres.

2.1.2 ENVIRONMENTAL ASPECTS OF TRANSPORT

The transport aspects consider all the transport of the final product once manufactured, for its distribution and sale.

For that, it is necessary to consider:

- The effective distance of transport routes.
- The means of transport used.
- The quantity of products sent in each transport (the use or efficiency of each transport action).
- All destinations to which the products are sent, the percentage of products sent to each destination, the average kilometres and the means of transport used.

2.1.3 ENVIRONMENTAL ASPECTS OF USAGE

The usage aspects are generated by the consumables or energy that the product uses for its operation throughout its shelf life, its quantities, the processes for obtaining the consumables and waste generated, energy consumption and final disposal of these consumables.

In order to identify these characteristics of the usage aspects, the shelf life of the product is previously identified, which serves as the basis for calculation. It is necessary to identify:

- The amount of each consumable or energy
- The production processes and the energy of the production process to obtain them
- The waste generated
- The origin and the kilometres associated to its transport
- Destination of the waste throughout the shelf life of the product

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2.2 ENVIRONMENTAL ASPECTS ANALYSIS

During the development of a new product, the environmental analysis of its potential impacts is an essential part of the application of the Eco-design. This analysis has two main objectives:

1. Get the overview of the main environmental aspects of the product throughout its life cycle.
2. Identify the environmental priorities that will be addressed during the Eco-design process.

The environmental analysis should be carried out considering the complete life cycle of the product and including all the elements that are part of its system by using different tools. Although all methods are aimed to accomplishing these objectives, the selection of the most suitable tool for a specific case depends, among other things, on the objectives of the analysis, the complexity of the product, economic cost, time consumption and the availability of quality information.

The three methods considered most interesting by IHOBE (2000) are briefly discussed below.

1. MET (materials, energy, toxic emissions) matrix
2. Evaluation with Eco-indicators
3. Life cycle analysis

2.2.1 MET (materials, energy, toxic emissions) matrix

The MET matrix is a qualitative or semi-qualitative method used to obtain a global view of the inputs and outputs at each stage of the product life cycle. It also provides a first indication of the aspects for which additional information is needed.

The MET matrix encompasses:

M	E	T
use of materials in each stage of the life cycle. It refers to all inputs (consumption) in each stage of the life cycle. This provides a view of the important inputs due to their greater quantity, toxicity or because they are scarce materials.	**energy use.** It refers to the impact of processes and transport at each stage of the life cycle (mainly those that consume a lot of energy). This provides a view of the processes or transports with the greatest impact in the product's life cycle.	**toxic emissions (all outputs: emissions, discharges or toxic waste).** It refers to all the outputs produced in the process. This gives an idea of the most important outputs due to their toxicity.

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These aspects are included in the MET matrix in a simplified way and organised according to the stages of the life cycle of the product. The systematic organization of the relevant environmental information related to the product makes it possible to identify the strong and weak points from the environmental point of view.

The basic structure of the MET matrix is shown in the following table (IHOBE, 2000):

	MATERIALS	ENERGY	TOXIC EMISSIONS
Obtaining and consumption of materials and components	All materials and components necessary for the manufacture of the product	Consumption of the necessary energy to obtain the materials. Energy consumed in the transformation of materials. Energy consumption in the transport of purchased materials to the factory	Toxic waste generated in obtaining and transforming materials
Production	Auxiliary materials and substances used in the production	Energy consumption in manufacturing processes	Toxic waste produced in the factory. Material scraps
Distribution	Containers and packaging Auxiliary elements	Energy consumption in packaging Transport from the factory to the final distributors	Combustion residues produced during transport Packaging waste
Waste management	Consumption of raw and auxiliary materials for waste treatment	Energy used in waste management Energy consumed during transportation	Toxic waste generated by the product Spilled materials Materials recycling Combustion residues

When is MET matrix recommended?

- When starting to work on Eco-design, since it facilitates the understanding of the entire process and the importance of optimizing each environmental aspect.
- When you have the support of an Eco-design expert or environmental consultant.
- To collect data before using the eco-indicators or a life cycle analysis software tool.
- When a global vision of environmental priorities without much precision is needed.
- When there are no relevant eco-indicators for the materials or processes of the product.

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2.2.2 Evaluation with eco-indicators

The eco-indicator is an easy-to-use quantitative tool for product designers. It is more precise than the MET matrix to prioritize the main environmental aspects of the product in its life cycle. It is quantitative because the prioritization is based on numerical calculations.

The eco-indicators are the result of a project whose objective was to assess the environmental impact that industrial activity exerts on the environment, focusing on the impact on the ecosystem, resources, and human health at a European level. Thus, impacts such as greenhouse effect, depletion of the ozone layer, acid rain, depletion of natural resources, decrease in biodiversity and smog were taken into account.

Eco-indicators are defined in the different impacts assessment methodologies used in life cycle analyses. The most common is to use software that incorporate different databases and various environmental impact assessment methodologies.

The value of the eco-indicator is a numerical value that expresses the environmental impact as a function of the amount or the volume of a material or process. These values are expressed in their own unit called millipoints (mPt) and they are not comparable with any other traditional unit of measurement. The complete list of eco-indicators '99 is available in the Annex 25 of the practical manual of Eco-design (IHOBE, 2000).

In order to apply the eco-indicators, the product life cycle is divided into three steps:

PRODUCTION: includes the necessary materials obtention and product manufacturing. Each aspect is listed separately (materials, processes, materials transport, waste disposal...) with its corresponding quantity (in the units established in the eco-indicator lists) and the corresponding eco-indicator, obtaining the product of both as a result.

USE: includes the product transport from the factory to the final distributors and consumers, the consumption of energy and consumables of the product throughout its shelf life and the packaging (material indicators).

WASTE: refers to the final destination of the product and its components once its shelf life has ended. Depending on the destination that is given to each part or to the whole, a different eco-indicator will correspond to it (recycling, landfill, incineration...).

Finally, results obtained in the three steps are added, obtaining a quantitative value of the impact of the product throughout its entire life cycle.

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WHEN IS ECO-INDICATOR TOOL RECOMMENDED?

- In combination with the MET matrix, when working on Eco-design for the first time. It helps to understand the calculations and their importance.
- When you want to prioritise the main environmental aspects of the product without having an external consultant and/or a software tool (it requires necessarily to have the corresponding data of relevant ecoindicators of product and/or processes).
- When you want to base the priorization on data (quantitatively).

2.2.3 Life cycle analysis (LCA)

Life cycle analysis (LCA) is an effective tool for companies since it provides them enough information to know the environmental impacts throughout the life cycle of the products that they sell.

Life cycle analysis is a powerful, systematic, and objective tool that can evaluate the environmental impact of products, including all stages of their life cycle and all potential impacts without geographical, functional or temporal limits. Life cycle analysis is a very interesting tool for the design of products (including containers and packaging), the improvement of processes and the planning of environmental strategies in the medium and long term.

WHEN IS A SOFTWARE TOOL RECOMMENDED?

- When the environmental prioritization is quantitative.
- When it is wanted to compare the environmental aspects of different alternatives of the same product.
- When excessively complex products are analysed (in which case the use of eco-indicators would require many operations) or formed by common subsystems to several products.
- When assessments of environmental aspects are to be carried out on a periodic way, since entering the data is more complicated, but once the calculations are made, they are much faster and safer.

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STEP 3
Eco-design strategies

In the previous step the groundwork about the main environmental aspects of the product has been laid. The objective of this step is to generate and prioritise ideas for improvement of the product. Throughout this process, all type of ideas for improvement will arise. Therefore, once they have all been obtained, there has to be a selection, analysis and priorisation, as the objective is to concentrate on the improvements which refer to principal environmental aspects or are aimed at the fulfilment of the Motivating Factors of the company to perform Eco-design. Some ideas for environmental improvement of the product will arise spontaneously. Nevertheless, they will not be the only possible ones. Therefore, for the generation of ideas it is recommended not to concentrate on the main environmental aspects, but it should be considered the various stages of the product life cycle.

It is therefore appropriate to hold a brainstorming session, including different departments of the company (management, environmental, technical, quality, and other departments) as each one has a different point of view, and this may give greater richness to the process and favour all relevant matters to be taken into account.

TIPS FOR RUNNING A BRAINSTORMING SESSION:

- Define the aim/scope.
- State all ideas.
- Welcome the unusual.
- No criticism is allowed.
- Say the first thing that comes into your head.
- Focus on quantity and not the quality of ideas.
- Combinations may be made with other ideas.
- The idea is of the group and not individual.

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3.1 STRATEGIES FOR IMPROVEMENT

There are various strategies into which all ideas for the environmental improvement of a product may be classified:

1. SELECTION OF LOW-IMPACT INGREDIENTS
Use of raw materials with reduced carbon footprint, that is ingredients with lower CO_2 emissions to atmosphere during their production. Take into account the pre-processing for the extraction and the pre-processing of raw materials.
Use of raw materials produced by employing more ecological production processes (e.g. using renewable energy, introducing water and energy saving systems, etc.). Intensive agriculture depends on machinery and synthetic products that are harmful to the environment and biodiversity but also require more energy to manufacture and apply than ecological or traditional systems.
Use of raw materials, classified as sustainable (e.g. labelled/certified materials of recognised certification process)
Use of raw materials in whose production good labor and agronomic practices are used, such as: 1. Low or non-toxic fertilizers/pesticides. Cropping systems, such as integrated pest control, allow high productivity, reducing the use of pesticide 2. Reducing land use by improving crop yields
Enhancing the efficiency of water by improving irrigation efficiency, selection of appropriate crops and cultivar, better planting methods, nutrient management, etc. • Precision agriculture: management approach that uses information technology to ensure that crops and soil receive exactly what they need
Use of raw materials from local providers (km 0 philosophy: act locally, think globally) because they contribute to minimise the resource consumption and emissions associated to their transport.
Use of raw materials that come from surplus or by-products from other food activities
Identification of new alternative protein sources more sustainable to be used as raw material
Use of recycled and recyclable materials

In many cases there will be alternatives of lower impact for the great majority of products that are developed.

EXAMPLES OF SPECIFIC ACTIONS:

FRUIT AND VEGETABLE BY-PRODUCTS	Among the raw materials of the food industry, fruits and vegetables are characterized by being the ones that generate the most waste. Fruit and vegetable by-products contain valuable substances such as sugars, organic acids, proteins, fibers, etc., which may be of interest in the food industry. They can be used as low-impact and sustainable ingredients with high added value.
APPLE SKIN EXTRACT (Huber, G.M., & Rupasinghe, H.P.V., 2009)	Apple processing results in peel, stem, seeds, and pulp being left as a waste product. **Apple skin** is a natural source of antioxidants and phenolic compound. Therefore, the addition of apple skin extract into foods with a high lipid content can protect against rancidity occasioned by lipid oxidation.
APPLE POMACE (Skinner RC et al., 2018; Antonic B *et al.*, 2020)	**Apple pomace**, which results from the residue of apple pulp in the production of juices, is being studied for extraction and isolation of health-benefiting nutrients, including minerals, dietary fiber, antioxidants, and ursolic acid, for use as purified food ingredients. 
(Sudha ML *et al.*, 2007)	**Dietary fibers extracted from apple pomace** have a potential use as a replacement for fat in baked foods such as cookies, wheat bread and cakes. Cakes prepared with 25% apple pomace wheat flour resulted in 14.2% total dietary fiber content compared with 0.47% for wheat flour, and increased polyphenols by 50%. Also, apple pomace has been used in the development of fiber-enriched yoghurt.
(Issar K 3, 2017)	Thus, reformulating food products by including apple pomace results in the improvement of the nutritional quality of the product with minimal differences in sensory attributes.

EDIBLE MUSHROOMS
(Kumar H *et al.*, 2021)

Many by-products (caps, stipes, spent mushroom substrate) are produced during mushroom production, which cause environmental pollution and increase industry management costs. The waste of mushroom has a potential nutritional and functional value.

The inclusion of **mushroom powder** in bakery products, such as bread, biscuits, pasta or breakfast cereals, substantially increases crude fibers, minerals, proteins and vitamins which improve the nutritional quality and functional properties.

Wheatshiitake noodles, cookies foortified with Calocybe indica or extruded snack with coproducts from chestnut mushroom are some real applications of mushroom by-products in the food industry.

ELAIA
(SPAIN)

Precise **monitoring of farms and olive groves with sensors**, drones and satellite images allows to choose the most suitable soils for olive farming, calculate the perfect timing for harvest or optimize the production.

Use of mathematical models to predict when and where there is a threat of pest in olive orchards.

Monitoring of the olive groves with satellite imagery allows to estimate production or to define optimal moments for fertilization.

Substitution of electricity (grid) and diesel (generators) for renewable energy.

THE UGLY COMPANY
(California, USA)

Prevention of food waste by **upcycling ugly food** and transforming it into healthy dried fruits with no preservatives and no added sugar. The Company helps out local California farmers reducing waste from nectarins, kiwis, cherries, peaches and apricots crops and adding value back to their farms.

FANCYPANTS BAKING, CO.
(USA)

Use of different **by-products in new cookies** recipes:

- Flour made from oat milk waste
- Okara flour: a tofu and soy by-product.
- Flour from coffee cherries (the fruity pulp surrounding coffee beans).

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2. REDUCTION OF PACKAGING MATERIALS
Light weighting, that is, reduction in weight by optimizing (minimizing): • The thickness and density of materials. • The quantity and diversity of materials and components. • The volume of materials. but, without compromising the food safety and functionality of the product.
Minimization or removal of those components that do not have an important function or do not increase its quality (e.g. removal of cardboard dividers, foam or layer pads)
Reduction of the presence of heavy metals (e.g. cadmium, mercury and lead) in packaging materials
Avoid product oversizing: optimization of the products quantity inside the package intended for consumption, based on consumer needs (small or large portions)
Reduction of packaging surface treatments. This action makes it possible to reduce the consumption of auxiliary materials (such as paints, inks, solvents, etc) which usually have a high environmental impact.
Design a geometry that enables a production in which the discarded material is minimum (elimination of technical gaps/empty spaces through the improvement of packaging machinery, redistribution of food product inside the container allowing an increase in its amount).

Always consider, if possible, "do the same with less".

EXAMPLES OF SPECIFIC ACTIONS:

Structural optimization and lighweight design of PET bottle based on ABAQUS (Hu Qingchun *et al.*, 2012)	The structure of PET bottle was optimize in order to increase the buckling load. Moreover, the plastic distribution of PET bottle was optimized in order to improve the PET material efficiency and reduce the weight of PET bottle.

GF HARVEST (GLUTEN FREE OATS) (USA)	Commercial launch of a sustainable to-go oatmeal bowls. The recyclable bowls are made from a collapsible cup, with a rigid outer carton and an inner liner. The packaging comes flat to save space. When the customer is ready to eat, they prop up the outer layer into a bowl and add hot water. The product comes with a wrapped paper spoon that is partially made from FSC certified paper and is recyclable wherever coffee cups are recyclable.

3. MORE EFFICIENT PRODUCTION TECHNOLOGIES

- Simplify the production process: reduction of number of operations and production steps.
- Use of more energy efficient processes (efficiency of refrigeration, lighting, heating, etc.) and use of low-energy consumption equipment (low energy pumps, compressed air, etc.).
- Minimization/optimization of thermal treatments (pasteurization, sterilization, etc) but always guaranteeing food safety.
- Minimization of energy consumption. Use of renewable energy sources that minimize the impact of greenhouse gases (GHG).
- Definition of good practices in the use of equipment (e.g. turn off machines when not in use, create a periodic maintenance plan, etc.).
- Minimization of water consumption.
- Water reuse practices, since food production requires of a large amount of water in their processed.
- Reduction of waste and wastages.
- Use of computer-aided process engineering tools. Although there is a major limitation due to the complexity of food products and their intrinsic properties.

To keep always in mind that we strive to minimise the environmental impact of our operations and to use cleaner technologies.

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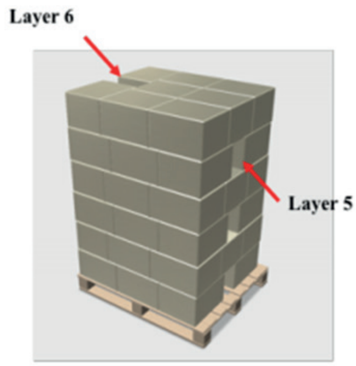
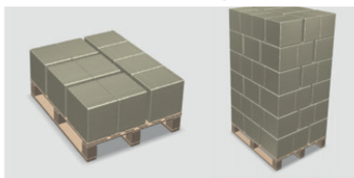
EXAMPLES OF SPECIFIC ACTIONS:

Florette (SPAIN)	Installation of technical equipment to improve the efficiency of washing/disinfection step of vegetables, reducing the use of water during processing.	Optimization of water consumption in several production lines, which enables water savings of 6% in each washing and represents a saving of 4% of total water consumption in the company.
Leygapack and Dow Chemical (France)	ADVANCES IN NEW PACKAGING SYSTEMS. The new technologies in barrier packaging also focus on improving the efficiency of processes, both in production and consumption. New packaging systems that allow us to: on-line integrated high-pressure treatments, development of packaging equipment in hygienic conditions, brick packaging with less environmental impact. Example of sustainable development: LeygaPACK is a new flexible packaging system that replaces the rigid container, which represents a cost saving of around 40-60% and in storage space.	

4. OPTIMIZATION OF DISTRIBUTION SYSTEMS
Optimization of the load for packaging and shipments. The goal is to minimize the empty space (stackable containers) and transport as many products as possible per load, which will reduce the number of shipments required.
Reduction of packaging volume, removing the spaces which are not necessary and for some products, increasing of the bulk density by concentration (coffee, juices, etc.)
Reduction of unnecessary packaging, layers and components
Distribution channels using transport systems of low impact and efficient (e.g. use of hybrid or natural gas-powered vehicles)
Use of alternative fuels (biodiesel, ethanol) rather than traditional petroleum fuels
Optimization of the road routes to be followed (in the delivery process)
Logistics that reduce the number of empty returns

Try to make all the transport efficient, from the supplier to the factory, and from this to the final customer.

EXAMPLES OF SPECIFIC ACTIONS:

An Oil Package Study aiming the Logistics Optimization on the Palletizing Capacity (Samed *et al.*, 2017)	The palletizing layout affects directly the company's costs and logistics efficiency, because with an optimal layout is possible to reduce the number of truck loading to meet the same demand. The reached results show a 25% pallet capacity increase, as well as a 25% reduction of the number of truck loading necessary to meet the demand.	 Actual palletizing layout  New pallet layout
Tesco (United Kingdom)	First storekeeper (Tesco) in the country to operate zero-emission electric trucks for deliveries (from theis distribution centres to city stores) with the same carry capacity as the conventional diesel trucks it is replacing.	It is expected to replace around 30,000 miles of diesel truck transport, saving around 23 tonnes of CO_2e annually.

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5. REDUCTION OF IMPACT DURING USE
Use of packaging for total use of the product
Make packaging sizes that match different consumer needs
Recommendations of package use to reduce waste
Product design without refrigeration needs
Package sealing use to maintain the product properties
Substitution of packaging materials with low environmental impact materials
Provide environmentally friendly recipes with the product

Consider whether the product has an impact during use (energy, waste, etc).

MERCADONA (SPAIN)	Mercadona has designed a new product for easy conservation, anned hake cready to eat without refrigeration needs	
CENTRAL LECHERA ASTURIANA (SPAIN)	The company has introduced added caps to the bricks to improve recycling process in plants and minimize recycling steps by the consumer. This action contributes to circular economy and is ahead of new Spanish regulation which will be applied on June 2024.	

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6. OPTIMIZATION/EXTENSION OF PRODUCT SHELF-LIFE
Use of active packaging to extend shelf life
Reduction of water activity
Reduction of pH (addition of citric and/or organic acids, pH regulators, etc)
Implementation of classification technics according to the expected shelf life
Conservation guidelines creation to extend the product shelf life
Develop new Eco-design products with extended shelf-life

Less food in the refuse bin, by minimizing food loses.

DANONE (France, Spain)	Transition of expiration date labelling to best before date mention. This action helps to reduce food waste supporting sustainability and environment awareness. At the end of 2021, 78% product portfolio in Spain had already change its labelling. Non-fermented products represent the other 22%, which maintains current labelling.

7. OPTIMIZATION OF PRODUCT END-OF-LIFE SYSTEM
Reusable and refillable packaging systems. The first unit is sold in a reusable packaging and following units are refill at home or on the go (through dispensing systems in stores or by buying refill pouches with improved packaging weight/product weight ratio, lighter and thinner materials).
Label the product/materials to facilitate the sort and recycling. Provide information about importance of correct disposal.
Use of easy recycling packaging (mono-material packaging, etc.). Laminates and composite packaging from multiple materials constitute one of the biggest hurdles to achieving recyclability.
Recyclability of packaging materials (compostability, biodegradability). Increase recycled content (Regulation requires increased recycled content for packaging, at least 30% recycled content by 2030).
Use of packaging which could be consumed as a product to reduce the cutlery washing.

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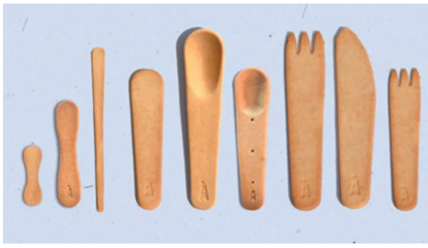
EXAMPLES OF SPECIFIC ACTIONS:

Voila (Spain) **Gloop** (Spain)	Edible cutlery: not only has an environmental impact (zero waste), but also improves the consumer's gastronomic experience (they are healthy and nutritious). Concept use&eat: it is a circular product that disappears at the time of consumption.	
Aquabona (Spain)	Commercial launch of a new environmentally responsible bottle "Compact", that uses 25% recycled PET (r-PET) which means a reduction in the CO_2 emitted into the atmosphere. Capacity of 2.5L and it is characterized by being easy to handle and adapted to the space of the refrigerator doors, it is stackable and does not roll.	
Soft Drink and Water Bottles Stajcer et al. (2001)	The study compared refillable plastic bottles, improved refillable bottles and single-use bottles. For virtually all impact areas, refillable bottles demonstrate a better environmental performance than single-use bottles, even when the single-use bottle uses 50% recycled material.	
Cardboard boxes for fruits & vegetables Levi et al. (2011)	Compared corrugated cardboard boxes with reusable plastic packaging systems to distribute fruit and vegetables. Environmental impacts are primarily dependent on the energy to make the materials and transport. Over transport distances of (one way) 1200 km, the single-use cardboard box was preferable.	
Müller (UK, Ireland)	The company has converted 75% of its cream volume to rPET. The pots are fully recyclable and embed 82% recycled material. This allows to remove 500 tones of virgin plastic from the dairy company's annual production of pots.	
THE COCA COLA COMPANY (USA)	The Company is increasing progressively the amount of recycled materials in its packaging: • 25% of plastic recycled in PET bottles, with the goal of reaching 50% by 2022. • 42% of recycled aluminium in cans. This action means an annual saving of 2.000 tons of virgin plastic, avoiding the emissions of 240 tones of CO_2 in Spain and Portugal.	 

Throughout this process it must be bear in mind the Motivating Factors analyses in Step 1, as they will help us to direct our work.

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3.2 SELECTION OF THE ECO-DESIGN STRATEGIES

Once the brainstorming session has ended, the selection of ideas will take place and in a subsequent phase, the ideas selected will be assessed in greater detail and prioritised.

Some of the criteria for prioritisation are technical feasibility, financial viability, expected benefits for the environment and positive response to the main Motivating Factors.

Each of these may be assessed, for example, according to the following criteria:

2	Very positive score/very feasible
1	Positive score/feasible
0	Neutral score
-1	Negative score / almost unfeasible
-2	Very negative score / completely unfeasible

Apart from the criteria indicated, each company may define new ones according to their own needs or give greater weight to some criteria rather than to others.

When all the selected measurements for improvement have been assessed, they are prioritised deciding whether each of these are applicable in principle in the short (ST), medium (MT) or long term (LT). This information will be included in the priorization column.

To this purpose it can be used following priorization matrix:

Strategy selected	Technical feasibility	Financial viability	Expected benefits for environment	Positive response to the main motivating factors	Priorization
1					ST/MT/LT
2					ST/MT/LT
3					ST/MT/LT

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STEP 4
Food concept prototype

Once the team have come up with the idea for the creation of a new food product or redesign of an existing one, it will be taken forward. The next step will be the conceptualization of the product, that is, to make a definition of the product itself.

Developing new food and beverage products is a complex process that requires knowledge of the ingredients, the formulation of foods, their processing techniques, their packaging, food legislation, aspects of food quality and safety and consumer demands and preferences from a sensorial perspective. A new product development or redesign process should follow next steps. Some of them could be ignored depending on the development requirements:

1. **Product general description (brief) (market data, product definition, needs to cover, target consumer, type of packaging, sustainability considerations, etc.).**
2. **Laboratory product development:**
   - Selection & characterization of raw materials: km 0, upcycling raw materials, by-products, etc.
   - Check specific raw materials/product/packaging regulations (quality and food safety aspects, local regulations, etc.).
   - Check specific raw materials/product/packaging requeriments (e.g. allergens, material barrier properties, etc.).
   - Formulation according to process and packaging requirements.
   - Laboratory prototipe characterization: physico-chemical, sensory and microbiological parameters.
   - Analysis of the nutritional profile & health claims.
   - Validation of laboratory prototype.
3. **Pilot/industrial scale development:**
   - Pilot/Industrial scale trials: formulation, elaboration process and packaging.
   - Product characterization: physico-chemical, sensory and microbiological parameters.
   - Shelf life study.
   - Validation of pilot prototype and flow chart.
4. **Product design specifications:**
   - Ingredients and additives: description, origin.
   - Formulation: physico-chemical, sensory & microbiological parameters.
   - Flow chart (including packaging process).
   - Environment and sustainability aspects.
   - Storage conditions.

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- Terms of consumption and method of preparation: ready to eat/ cooking requirements
- Expiration or best before date
- Labelling & claims according to countries regulation
- Other specific attributes of consumption

5. **Packaging specifications**
   - Format & net weight
   - Material definition and classification (recyclable, compostable)
   - Technical parameters (barrier properties, etc.)
6. **Marketing design specifications:**
   - Packaging
   - Promotion
   - Market channel
   - Price setting
7. **Environment: as a result of the Eco-design, it is needed to perform an evaluation of the most important environment aspects to evaluate the achievement of the objectives described on the brief.**
   - MET (materials, energy, toxic emissions) matrix
   - Evaluation with eco-indicators
   - Life cycle analysis
8. **Economic feasibility analysis:**
   - Production costs
   - Pricing
   - Marketing

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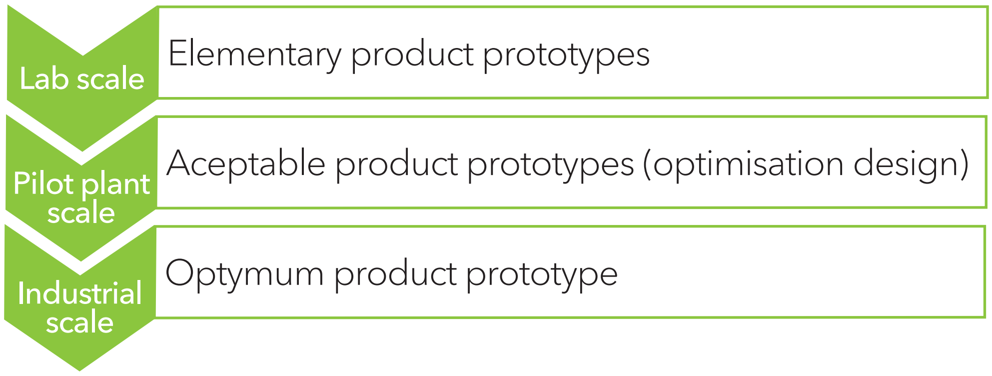
STEP 5
Prototype validation



Lab scale

The food prototype is an example of what the product will be like. The selected strategies are integrated and combined for obtaining a more environmentally friendly product with environmental aspects as added value. The prototypes are developed based on the product general description (briefing) and with their characterization can be defined the technical specifications.

Both technical testing and consumer testing of these product prototypes are carried out. The consumers are testing for acceptability and the technical tests are examining the chemical, microbiological, physical and sometimes the sensory properties of the products.

Pilot plant testing

Following establishment of prototype, the product is tested on a larger scale, called pilot plant scale. This is done to simulate commercial production and finalize product specification. This is important since some specifications may change as you scale up the operation. Pilot-scale testing allows you to make the necessary corrections before scaling up any further.

Sensory evaluation: This is done following pilot-scale testing in order to standardize the product. Until then, the pilot-scale process continues with the appropriate modifications until the desired specifications are met.

Consumer testing: consumers should be given an opportunity to taste the product and provide you with feedback. The feedback from the consumer testing will provide valuable information that can be used to modify the product to ensure that it satisfies their expectations. According to the feedback you may have to go all the way back to the drawing board to develop another prototype or you may just need to make further modifications at the pilot production step.

Industrial scale

This will involve scaling up the process to a commercial scale to produce products for the launch. The aim of the processing scale-up is to determine the optimum production process for product quality, product yield, process control and costs.

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STEP 6
Medium- and long-term action plans

Once the methodology is applied and the Eco-design tools are used, it is reached a set of improvement measures for medium and long term to be applied in the designed product. But if it is an innovative experience in the company and is not well organised the result could be unsuccessful.

To avoid this, an essential requirement is to establish an action plan in a product and company point of view:

- Product action plan guarantees not to forget interesting measures and to apply them
- Company action plan reaches to involve all the affected departments of the company in order to keep up with environmental product development

Besides, the general action plan in a company level will allow other benefits such as green marketing, quality and environmental requirements and others.

Product action plan for medium and long term

In this step is the moment to establish an action plan where all the selected and not yet implemented improvements measures must be defined.

Company Eco-design action plan

The same Eco-design methodology and tools previously used should be reviewed to get useful tools for the new products design. The steps to follow are:

1. Celebrate a meeting with all the departments involved in the product development to analyse the applied methodology and all the steps in the traditional product development.
2. After the analysis, establish an action plan with the changes in the development product plan.
3. Development and adaptation of the necessary tools.

It is highly recommended to implement in the company the knowledge obtained after the first Eco-design project. To this end the continuous improvement of products it is reached.

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STEP 7
Action plan results evaluation

The purpose of the evaluation of the Eco-design project is to verify if the motivating factors are achieved and to establish mechanisms to benefit from improvements. Besides the results from the Eco-design project, it can also provide:

- Staff formation, information, and motivation
- Include green marketing in the company marketing strategy
- Information to external groups such as company groups, social pressure groups, …

Eco-design project evaluation

There are many ways to evaluate an Eco-design project but there are some criteria to consider:

- Evaluate the improvements of the main environmental aspects, comparing the aspects of the new or redesigned product against the aspects of the baseline product. This evaluation should be carried out before the step 6 for immediate results and after the step 6 for medium and long-term results.
- Analise the impact of the environmental improvements in the motivating factors.
- Combine the environmental improvements and the motivating factors compliance and expressing them in an easy way to communicate

Practical application of the Eco-design project evaluation: green marketing

Some results of the Eco-design project which could be used as company objectives are:

- Evaluation and justification of the Eco-design project
- Guideline for future Eco-design projects in the company
- Personal motivation: using the company action plan for internalising the Eco-design methodology and use it in the departments of the company. Using the results as a dissemination plan in the company
- Green marketing: if the environmental is a key aspect of the company it can be used for integrating environmental improvements with marketing campaigns

Marketing campaigns usually start in parallel with distribution and selling steps, green marketing must influence in all the steps of the life cycle. Green marketing is not something simple because it has some basic principles:

- Keep the track of tendencies
- Take into account new stakeholders
- Integrate the "green" philosophy
- Be proactive, not only fulfil the mandatory

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- Spread the Eco-design to all the departments
- The company management has to be motivated with the Eco-design methodology
- Involve and motivate all the staff
- The Eco-design methodology is a continuous improvement
- Be accessible and transparent information to the public

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