ZEBRA LIFE

ZERO EMISSION BIOCHEMICAL AND RENEWABLE ADDITIVES

D5.1 MONITORING AND REPORTING PLAN

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ZEBRA-LIFE MONITORING AND REPORTING PLAN

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EXECUTIVE SUMMARY

The target of this reporting and monitoring plan is to define the strategy to measure the impact of the Project actions and define the monitoring guidelines.

For this, this document starts by introducing the project's objectives and the reporting exigencies.

It follows by first describing the project's context and influence scope and secondly describing the different environmental and socio-economics project's effects. In here, a review of the project impacts pathways is portrayed, and based on them, the corresponding key performance indicators are presented together with their matching targets. This section also includes the different activities that will be completed for the impact evaluation such as the pilot plant mass and energy balance study, the Life Cycle Assessment, the socio-economic assessment or wiliness to pay study among others.

To finalize, some considerations in regard to the methodology for data collection and corresponding assessment are listed as for example the sources of information, the partners' roles and responsibilities, effective communication methods and cautions in regard to data privacy issues.

It is worth to say that the document here presented is the first version of the impact reporting and monitoring plan and will be continuously updated to consider and adapt its content to the project progress and ongoing activities.

1. APPROACH TO ZEBRA MONITORING AND REPORTING PLAN

The primary goal of the ZEBRA-LIFE project is to develop sustainable lignin-derived additives for the cosmetic, food, rubber, fuel, and lubricant, and polymer sectors to safeguard and enhance the climate and marine ecosystems.

To achieve this goal, the project will demonstrate the operation of an innovative technology for the chemical depolymerization and fractionation of technical kraft lignin from black liquor (waste stream produced in the paper sector) into bio-aromatics with antioxidant activity and UV filtering properties, which will be validated for the formulation of various end products such as sunscreen lotions, rubber components, food, lubricants and fuel in a relevant, pre-commercial environment. Moreover, one of the bio-aromatics that will be developed has the potential to substitute the use of fossil fuels due to the high combustion properties. Its usage as renewable fuel will be tested as replacement to the use of natural gas or fuel oil in the lime kiln in the pulp and paper manufacturing process.

Through the completion of these objectives, ZEBRA-LIFE will have an impact both during and after the project (after 5 years), including both environmental and socio-economic impacts.

Therefore, the main goal of the D5.1 "Reporting and monitoring plan" is to develop a methodology to monitor and evaluate these project impacts through quantitative measurements during the project's operation period.

1.1. OBJECTIVES

The Reporting and Monitoring plan's aim is to create and execute impact assessment measures and requirements that will lead to consensus on a set of guiding principles that will apply to the environmental, societal, and economic scrutiny of the planned development. The impact assessment (IA) will determine whether the ZEBRA-LIFE project's actions will have the intended effect. The method entails identifying and characterizing the most probable consequences of the planned actions (impact prediction/forecasting), as well as assessing the environmental, social, and economic significance of those consequences (impact evaluation).

1.2. REPORTING REQUIREMENTS

A list of Deliverables for WP5 is shown in Table 1, followed by the relevant Milestones (Table 2).

Table 1. List of Work Package 5 deliverables

NO.	DELIVERABLE NAME	DELIVERY DATE	LEAD
D5.1	Monitoring and reporting plan	M6	INVENIAM
D5.2	Reporting extracts of project data from the LIFE KPI webtool	M9, M42	INVENIAM
D5.3	Techno economic assessment and Environmental Life Cycle Assessment	M48	CENER

Table 2. List of Work Package 5 milestones

NO.	MILESTONE NAME	DELIVERY DATE	LEAD	MEANS OF VERIFICATION
M14	KPI reporting	M48	INVENIAM	LCA, ESG

2. IMPACT ASSESSMENT

The assessment of short to long-term actions brought about by the development of the project under consideration is known as impact assessment (IA). It is a structured method for considering the implications of the planned actions – particularly improved performance - while the plans are still subject to modification. Rather than tasks or deliverables, IA concentrates on change and pathways to change. It entails describing actions and possible effects, as well as establishing the type of the impact, its anticipated magnitude, and the receptors sensitivity. Furthermore, it examines the possibility of project impacts combining with other impacts connected with current or scheduled task and activities, as well as the possibility of the project impacts extending across national boundaries.

To do so, the quantification and evaluation of those impacts is fundamental to assess the possible effects of the planned activities. The Impact Assessment methodology will consider influence magnitude as well as receptor sensitivity. To allow the quantification of this influence, the Key Performance Indicators (KPIs), which describe how well a project is meeting its goals, will play an important part in this process. The KPIs will be used to track the effectiveness of actions being an essential management instrument for tracking success, making evidence-based decisions, and developing future strategies.

So then, given the nature of ZEBRA-LIFE project, this Impact Assessment section is divided in 2 main sub-categories to differentiate and evaluate separately the environmental and the socio-economic impacts. For each of the sub-sections, first the potential project's pathways for impact will be identified in order to evaluate the project base line, or in other words, to determine the status quo of the project's context. Then, and based on this evaluation, a set of KPI's and corresponding targets will be defined.

2.1. CONTEXT

To properly assess the impact, it is important to first underline which is the scope of the project to properly perform the corresponding calculations.

The ZEBRA-LIFE solution will allow the valorisation of the kraft lignin contained in the black liquors from the pulp and paper industry to produce 2 types of products with high added value:

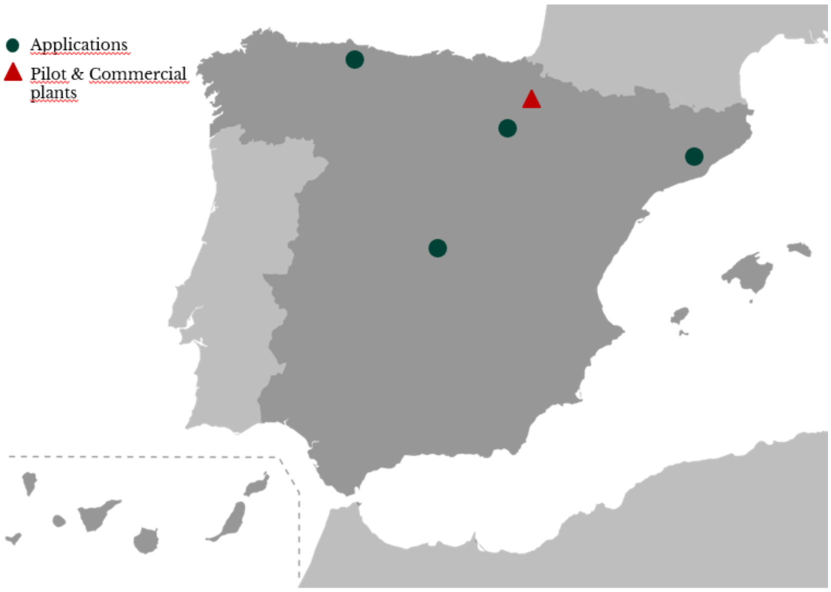
a) ZEBRA LMW (Low Molecular Weight): bio-aromatic additives with antioxidant and UV filters properties that can be used in many applications such as cosmetics, food, fuels, lubricants, and rubber.
b) ZEBRA MMW (Medium Molecular Weight): a second product also with antioxidant properties that will be tested by the rubber industry. In addition, given that, due to its high net calorific value, this product can also be used in the paper and pulp industry as a renewable energy source in the lime kiln.

Because of the different projects impacts that the above products can bring along the project duration and 5 years after its finalization, 3 different contexts have been defined.

CONTEXT 1: SPAIN

The above-mentioned products will be firstly formulated, then produced at pilot scale in the pilot plant constructed at CENER facilities (Aoiz, Navarra, Spain), and finally tested by the different applications to prove their suitability to substitute synthetic additives. All these activities will be completed in different Spanish locations as show in the figure 1 below (Asturias, Catalonia, La Rioja, Madrid, and Navarra). In addition, the use and consumption of the final products reformulated with the ZEBRA-LIFE additives are expected to be used at national level not only on the application areas but all over the country, therefore it will be difficult to annotate a smaller scale than the national one to calculate the impact as the complexity to obtain data would raise considerably. Therefore, for some of the KPI defined below on this document, they will be considered to have an impact at national level.

Figure 1. Project location



CONTEXT 2: NAVARRA

Also, the ZEBRA MMW product can be used as a renewable energy source. In the project, in one hand, the pilot plant that will be constructed at the CENER's owned Bioenergy and Biorefinery Centre in Aoiz (Navarra, Spain) will analyse the potential use of the ZEBRA MMW product as substitute of fossil fuels. On the other hand, the partner Smurfit Kappa, the pulp and paper industry representative, will be in charge to evaluate the substitution of fossil fuels in the lime kiln (used in the pulp and paper manufacturing process) by studying the technical and economic viability of constructing after the project end a ZEBRA-LIFE commercial plant in their plant in Sangüesa (Navarra, Spain). So then, it becomes easier to annotate the impact area as the use of renewable energy will only affect a specific region. Therefore, for some of the KPIs, the impact scope has been reduced to the region of Navarra.

CONTEXT 3: INDUSTRIAL PLAN LOCATION (TO BE DEFINED)

On the other hand, according to the expected exploitation strategy defined in the early stage of this project, Smurfit Kappa plans to introduce ZEBRA-LIFE technology in an existing industrial plant in Europe. This plant is still not identified so neither located as first the commercial viability need to be assessed. Based on this study, which is planned to start on a later stage of the project and based on the exploitation strategy defined jointly with the consortium members, the location for the industrial scale plant will be decided. Consequently, the project indicators will be calculated for the given area in a future version of this document.

2.2. ENVIRONMENTAL IMPACT

2.2.1. ENVIRONMENTAL IMPACT PATHWAYS

Based on the 2 different products that ZEBRA-LIFE project will produce, the expected benefits of the project are listed below.

- The ZEBRA-LIFE technology will enable paper mills to valorize their black liquor waste product in the form of two natural products LMW and ZEBRA MMW, to create a new circular value chain.
- ZEBRA-LIFE aims to generate high-value products from a waste product in the paper industry, thereby improving the sustainability of both the pulp and paper industry and of the end-user industries, where the ZEBRA-LIFE product will substitute current synthetic aromatic additives, as well as contributing to industrial symbiosis.
- ZEBRA-LIFE will produce high-value products with a large end-user market and will substantially reduce the environmental impact of the current synthetic additives' solutions.
- ZEBRA-LIFE technology has shown excellence performance: from an environmental point of view no metal or toxic catalyst is used and the energy demand is low since no high temperatures ($T > 250$ °C) or pressures are employed. Therefore, this is in line with economic and environmental evaluation of the overall process. Besides the process can be integrated in the current pulp mill process since no additional chemicals are employed and downstream technologies after lignin conversion do not consume chemicals.
- Compared to other lignin conversion and separation technologies CO_2 emissions calculated by LCA in the production process are reduced by 50%. This is mainly achieved by the low energy demand of the process during lignin conversion with lower temperatures and pressures[1].

[1] Lettner M, Solt P, Rößiger B, Pufky-Heinrich D, Jääskeläinen A-S, Schwarzbauer P, et al. From Wood to Resin—Identifying Sustainability Levers through Hotspotting Lignin Valorisation Pathways. Sustainability 2018;10.

Therefore, it is expecting ZEBRA-LIFE to reduce the environmental impact of synthetic aromatic additives both in its production and use phase, compared to the baseline.

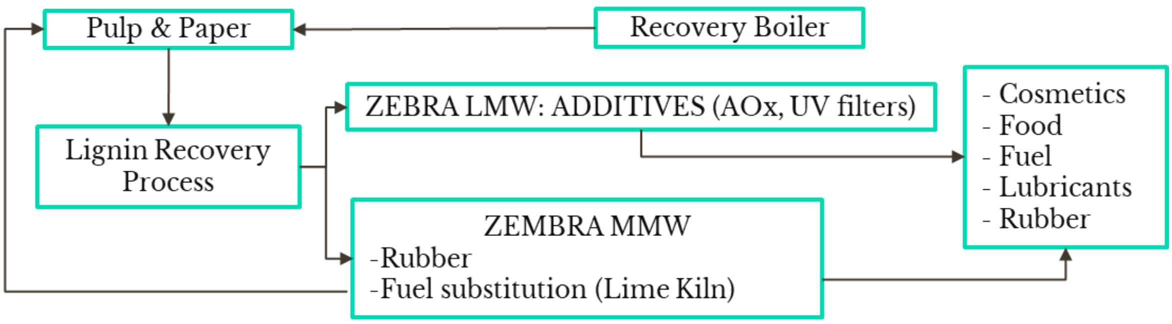
PRODUCTION

The ZEBRA-LIFE additives will be avoiding the utilization of fossil fuel derived products, and instead, will be creating a circular process that will be valorizing black liquor. In this case, ZEBRA technology does not utilize any catalysts and will avoid at least the use of 0.05 kg of metal-catalyst per kg of lignin. In addition, the production process operates at a much lower pressure and temperature, reducing the environmental impact in regard to the energy required.

USE

It is expected the ZEBRA-LIFE additives to have a lower impact on human health and toxicity in biodiversity compared to synthetic additives. However, the consortium cannot yet quantify this impact because toxicology tests have not been yet performed. BHT for example, has low solubility and thermic stability, which makes it highly degradable and produces transformation products that also pose environmental and health problems. CENER has seen that the ZEBRA-LIFE products are thermally more stable and should reduce the adverse effects due to the reduced migration rate. Human impact and toxicity comparison with synthetic additives will be evaluated during the project implementation through the execution of some trials.

Figure 2. ZEBRA-LIFE value chain



So then, in order to evaluate the potential environmental impact and given the circular value chain offered by ZEBRA-LIFE, it has been considered that the 3 main pathways for impact are the following:

- Avoiding the combustion of black liquor in a recovery boiler (biogenic emissions) in the Pulp and Paper production process thanks to the new circular value chain created.
- Avoiding the production of fossil-based additives in different market sectors (cosmetics, food products, fuels and lubricants and polymer industry) thanks to LMW product.
- Renewable energy production to substitute natural gas in the kiln in the paper and pulp industry thanks to MMW product.

2.2.2. ENVIRONMENTAL INDICATORS DEFINITION (KPI)

According to the environmental pathways identified previously, the project will contribute to the following indicators:

- Green House Gas (GHG) emissions
- Renewable energy generation

GHG EMISSIONS

This indicator's purpose is to measure the project's net mitigation effect, which is the decrease in the carbon footprint of the project's demonstration activities in units of CO2-eq. It denotes the entire net quantity of CO_2 eq saved per year. Nevertheless, it should also be provided the decrease of CO_2 eq normalized per unit of project product as an explanatory aspect.

The "net" element is because the decreases in greenhouse gas (GHG) emissions on-site frequently result in GHG emissions elsewhere. In the case of ZEBRA-LIFE, when determining the overall net quantity, it will also be considered the amount of CO2-eq produced elsewhere, for example in case of energy generation or EOL management.

The trend between the start, end and beyond values should be negative (it is expected that the start value will be higher than the end value to demonstrate a decrease in the emissions both in the per unit assessment and in the total net CO_2 eq emissions). It is also expected that the beyond value will be lower than the end value to demonstrate a further reduction 5 years after the project end.

In this case, the productivity-related indicator will be referenced to two different scenarios:

- Targeted total amount of fossil-based additives to be replaced by 2040, which aim is to substitute 38% of the total synthetic phenolic additives market. Considering the different market growth for the different application, the aim is to substitute 72.700 t of synthetic antioxidants. Therefore, the unit considered will be t CO2-eq/ t of replaced additive.
- Energy generation by substituting natural gas by 308.000 t in of ZEBRA MMW in 2040 equivalent to 2.162 GWh/year (where the PCI is 7,021 kWh/kg). Therefore, the unit considered will be t CO2-eq/ GWh of substituted natural gas energy.

RENEWABLE ENERGY

This indicator tracks how the project contributes to the net increase in the quantity of primary energy generated from renewable sources. The indicator is intended to provide statistics related to the EU's clean energy package (CEP), particularly the Renewable Energy Directive, which is a component of the CEP.

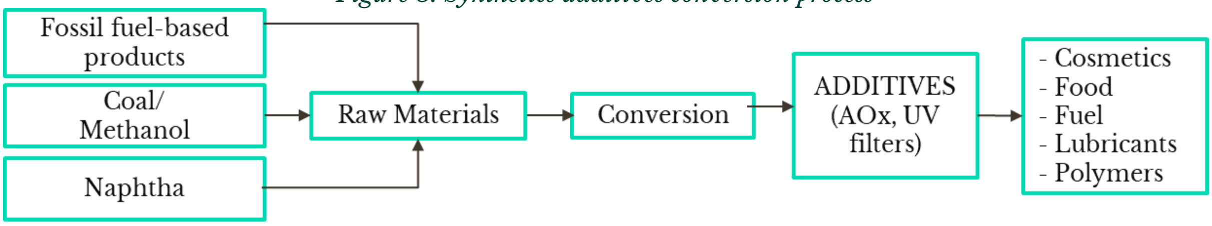
Throughout the project, it will be shown the projected output of primary energy from green sources for all kinds of renewable energy sources. The term "primary energy" alludes to the quantity of energy that can be conserved by using renewable sources instead of fossil fuels.

2.2.3. CLIMATE BASELINE

The climate baseline defines the starting point of the ZEBRA-LIFE project to quantify its impacts. It defines the environmental situation based on the existing context. For that, it will be key to understand and identify the current situation in regard to the 3 main pathways for impact identified previously which, given the existing data, are mainly related to the GHG emission avoidance.

SYNTHETICS ADDITIVE'S PRODUCTION

Figure 3. Synthetics additives conversion process



The fossil-based synthetic phenolic antioxidants (SPAs) are a family of high-efficiency, lipophilic, and excellent antioxidants, which are a component of many types of foods, cosmetics, fuels, lubricants and rubber. The main SPAs utilized are butylhydroxyanisole (BHA), dibutyl hydroxytoluene (BHT), tert-butyl hydroquinone (TBHQ), gallate antioxidants, i.e.,propyl- (Pg), octyl- (Og), lauryl- (Dg). The most widely used SPA is BHT, which has been added to various foods and more than 1700 cosmetics, in a concentration of up to 0.5%[2]. BHT is often used in combination with BHA due to its low cost and low thermal stability[3]. BHT can be converted into a variety of transformation products (TPs) in the natural environment and organisms, which can also have a negative effect[4].

Some researchers have detected BHT in indoor dust, surface water, groundwater, domestic sewage, and soil, in a concentration range from one part per trillion (ppt) to parts per million (ppm)[5]. These SPAs are taken up from food, water, air, indoor dust, and their widespread use has led to their presence in various environmental matrices (e.g., oil products, urban dust, water, soil, and sediment) and biological samples (e.g., marine mollusks, human serum, and urine)[6]. The in vitro and in vivo toxicities of SPAs were also proved. For example, BHA has an obvious estrogen effect, which has a great impact on the reproductive development, also exhibiting teratogenic and carcinogenic effects at high concentrations[7]. Pg has testicular toxicity, inducing male infertility

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[2] Liu and Mabury, 2018
[3] Ling, 2000
[4] Liu and Mabury, 2020
[5] Fries and Püttmann, 2004; Nilsson et al., 2005; Rodil et al., 2010; Hernández et al., 2012; Weschler et al., 2014
[6] Butte et al., 2001; Soliman et al., 2007; Gao et al., 2011; Liu et al., 2015a, 2017a; Wang et al., 2016, 2018a; Liu and Mabury, 2018
[7] Grice, 1988; Kahl and Kappus, 1993; Jobling et al., 1995; Yang et al., 2018a

through mitochondrial dysfunction and disruption of calcium homeostasis[8]. TBHQ is the main metabolite of BHA, and it also has a certain estrogen effect, influencing the sex formation of zebrafish[9]. BHT and its transformation products have endocrine disrupting effects, being a typical tumor promoter and carcinogen[10]. Therefore, synthetic phenolic antioxidants have been attracting much attention regarding their toxicity and environmental health risks. Therefore, they pose an environmental impact both during their production and use stages.

To quantify the environmental impact of the additives production, the impact calculation of the BHT production has been performed since it is the most widespread used additive in the targeted applications. No literature has been found regarding the environmental impact of the production of BHT, and its production process has not been found in the Ecoinvent database. Since the product was not present in the database, a similar material or proxy was used. Different compounds were studied in order to take a reference emission factor for BHT.

- Para-cresol is a precursor of BHT. Its impact was not found in Ecoinvent or any available literature, therefore orto-cresol was used, assuming similar production routes[11]. According to Ecoinvent database, the emission factor of orto-cresol's production is 4,8 kg CO2-eq/kg.
- Ethyl Benzene: similar compound of BHT precursor.[12,13] According to Ecoinvent database, the emission factor of its production is 2,2 kg CO2-eq/kg.
- 2,6-di-tert-butylphenol: its derivates are used as antioxidant and UV stabilizers for hydrocarbon-based products. According to Ecoinvent database, the emission factor of its production is 3,7 kg CO2-eq/kg.

Orto-cresol was selected as a reference for the impact of BHT production, considering that has the highest resemblance in their environmental impacts to para-cresol, which is a precursor of BHT. Para-cresol can be used both as a precursor to produce BHT and to produce UV filters, therefore, it can be used as a baseline for all the target applications that are being considered. The processes that contribute to the o-cresol's production impact are mainly benzene production, propylene production, and energy/electricity consumption.

Given the difficulty to obtain the SPAs production quantity in Spain[14], it has been estimated that in the project start value (baseline scenario) 32.495 t have

[8] Ham et al., 2019
[9] Yang et al., 2018a
[10] Umemura et al., 2006
[11] https://www.osti.gov/servlets/purl/5351924
[12] https://pubchem.ncbi.nlm.nih.gov/compound/Ethylbenzene#section=Use-and-Manufacturing
[13] https://pubchem.ncbi.nlm.nih.gov/compound/isobutylene
[14] Total production amounts are available for Europe but it has not been possible to obtain specific production data for Spain, instead a end-use consumption approximation has been calculated.

been used in Spain in the different application in 2022. This value is obtained by calculating the total amount of end-products (cosmetics, food, fuels, lubricants, and rubber) and considering the additive proportion in each of the product's formulation. Therefore, once obtained the total amount of additives, the resulting value is multiplied by the ortocresol's emission factor introduced before to finally obtain the corresponding emission factor. According to this estimation, in Spain, a total amount of 155.976t of CO_2-eq were emitted in 2022 due to the production of fossil-based synthetic phenolic antioxidants. The calculation can be examined in the table below.

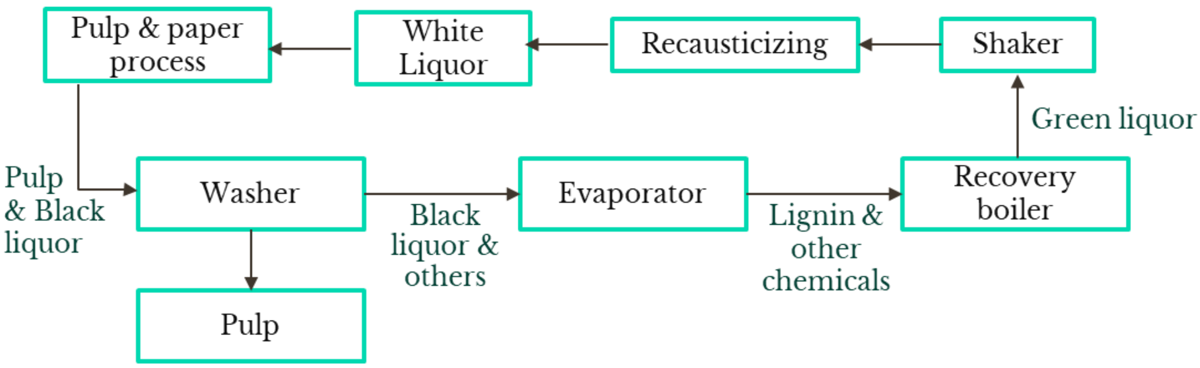
Table 3. Synthetic additive's GHG emissions calculation

APPLICATION	PRODUCT	END PRODUCT SALES VOLUME IN 2022 (T)	% USED	TOTAL ADDITIVES USED (t)	ADDITIVE CO2 EMISSIONS RATE	t CO_2-eq YEAR 2022
Rubber and polymers	Rubber	857.148[15]	0,30	2.571	4,8	12.342
Food	Chorizo[16]	100.000	0,05	5.000	4,8	24.000
	Burguer meat[17]	40.400	0,045	1.818	4,8	8.726
	Cookies[18]	487.000	0,01	4.870	4,8	23.376
Comestics[19]	Cosmetic Antioxidant	118.000	1,50	1.770	4,8	8.496
	Cosmetic Preservant	550.000	1,00	5.500	4,8	26.400
	Sunscream UV filter	10.400	10,00	1.040	4,8	4.992
Fuels and lubricants	Lubricants[20]	339.000	0,45	1.526	4,8	7.322
	Fuels[21]	28.000.000	0,03	8.400	4,8	40.320
TOTAL				**32.495**		**155.976**

[15] Consorcio Nacional de Industriales del Caucho. Asamblea general del 01/12/2022
[16] ANICE, Consorcio del Chorizon Español
[17] ANICE, Alimarket, Kantar
[18] Produlce 2022
[19] CEFIC, AEIC, EFFCI
[20] ASELUBE, STRATAS
[21] STRATAS, EUROSTAT

PULP AND PAPER INDUSTRY

Figure 4. Pulp and paper lignin recovery process



BLACK LIQUOR COMBUSTION IN RECOVERY BOILER

Despite its high energy consumption, the pulp and paper industry is one of the least CO_2 intensive industrial sectors in Europe and worldwide. This is due to the large utilization of biomass as a primary energy source, which is considered as carbon-neutral by the Intergovernmental Panel on Climate Change (IPCC). In 2015, 57.7 % of total fuel consumption in the Confederation of European Paper Industries (CEPI) member countries originated from biomass, natural gas (33,2%), coal (3,1%), fuel oil (1,5%) and other type of fuel (2,3%)[22].

Nevertheless, the process releases significant amounts of CO_2 into the atmosphere. The last statistics published by CEPI indicates that in 2022 108,1 Mt of wood were consumed in Europe to produce cellulose pulp. According to statistics from the total wood pulp (35.9 Mtn) kraft pulp represents 70% (25,13 Mt). Considering a production ratio cellulose-lignin of 2:1 about 12,6 Mt of lignin are burnt as black liquors in the recovery boilers of the pulp mills in Europe annually. Only 1 Mt of lignin is recovered from the black liquors worldwide, about the half is recovered in Europe[23]. Since combusting kraft lignin releases all the lignin carbon content to atmosphere and considering lignin carbon content is about 60%, CO_2 emissions by black liquors combustion in pulp mills can be estimated in 27.5 CO_2 Mt/year. Considering the Spanish Pulp and Paper industry represented in 2022 4.9% of the totals Europe's market, this represents 1.35Mt/year. However, these emissions are considered biogenic and are therefore neglected from the baseline calculation.

Hence, lignin combustion is not the most sustainable use of lignin in long-term. Lignin applications and lignin upgrading to bioproducts such as higher value chemicals will further improve the overall environmental impact and provide a higher profit.

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[22] Final-Key-Statistics-2019.pdf (cepi.org)

[23] Zevallos Torres LA, et al. Lignin as a potential source of high-added value compounds: A review. J Clean Prod 2020;263:121499. https://doi.org/https://doi.org/10.1016/j.jclepro.2020.121499

NATURAL GAS COMBUSTION IN KILN

In the baseline scenario, Smurfit Kappa, the Pulp and Paper industry representant in the consortium, has an energy requirement from fossil fuels of 120.000.000 MJ per year only in their plant in Sangüesa, using natural gas as energy source, and knowing that the emission factor for natural gas combustion is 0,182 kg CO_2/kWh natural gas[24,25], this supposes 6.067 t of CO_2-eq emissions every year.

On the other hand, the baseline scenario for the renewable energy generation is 0 GWh/y, since it is a new value chain and there is currently no renewable energy production in the pulp and paper industry.

CLIMATE BASELINE SUMMARY

Table 4. ZEBRA-LIFE GHG emission baseline

IMPACT PATHWAY	GHG EMISSION (t CO_2-eq/year)
Additives production	155.976
Black liquor combustion	-
Natural gas combustion in kiln	6.067
TOTAL	**162.043**

Table 5: ZEBRA-LIFE renewable energy baseline

IMPACT PATHWAY	RENEWABLE ENERGY GENERATED (GWh/y)
Fossil fuel substitution in kiln	0
TOTAL	**0**

2.2.4. ZEBRA-LIFE OUTCOMES QUANTIFICATION

As introduced in section 2.2.1, the environmental impact of the ZEBRA-LIFE project will be based on the 3 following pathways.

- Avoiding the combustion of black liquor in a recovery boiler by creating new sustainable and circular bio-additives (LMW and MMW).
- Avoiding the production and utilisation of fossil-based additives.
- Avoiding the combustion of fossil-fuels by generating renewable energy production using the MMW product.

[24] https://energia.gob.es/desarrollo/EficienciaEnergetica/RITE/Reconocidos/Reconocidos/Otros%20documentos/Factores_emision_CO2.pdf
[25] https://www.miteco.gob.es/es/cambio-climatico/temas/mitigacion-politicas-y-medidas/factoresemision_tcm30-479095.pdf

In order to properly quantify the project's impacts and corresponding definition of the key performance indicators, here below is described the calculation performed to estimate ZEBRA-LIFE outcomes along the project duration and 5 years after its finalization.

LIGNIN RECOVERY AND PRODUCTION OF ZEBRA-LIFE PRODUCTS

The ZEBRA-LIFE project will be reducing the GHG emissions creating a new circular process where, instead of combusting, the black liquor can be valorised for a higher value application.

For the LIFE project, the consortium will produce lignin recovering it from the black liquor out of the pulp and paper industry. The biogenic GHG emission avoidance will only be evident once the paper and pulp industries implement the ZEBRA technology in their plants (commercial or industrial scale) and use the lignin recovered from black liquor to produce the additives. This is because during the project duration the black liquor from the pulp and paper consortium partner in Spain (Smurfit Kappa) will not be transformed directly into lignin, as the current process does not count with the required extraction equipment. To cope this, the transformation of black liquor into lignin will be subcontracted to an external company located in Sweden.

Once the ZEBRA-LIFE process is proven at higher scale and its application in the targeted applications is proven, then the paper and pulp industry, in this case Smurfit Kappa, will have an incentive to implement the technology in additional plants and avoiding the combustion of the black liquor.

In regard to the production of additives, it is assumed the impact of the ZEBRA-LIFE products LMW and MMW will be minimal. No fossil fuel products will be utilised for its production as there will be no use of catalysts.

Different LCA have shown the importance of the production parameters in the overall production impact. For example, they found catalyst selection was a deterministic factor affecting the sustainability of the lignin-based products, as well as continuous production process, which has been proved to be more efficient than batch processes. Among the experimental parameters evaluated, it was determined that the greatest environmental benefits occurred using short reaction times, lower temperatures, and non-toxic catalysts. The energy necessary to maintain operational conditions at higher temperatures (>250 °C) and/or for longer periods negated any yield benefits and the type of catalyst accounted for carcinogenic and ecotoxicity impacts by ~ 80 and 90% respectively[26]. Other studies have shown that special attention should be paid to the high amounts of energy needed for the required valorisation technologies (250-350 °C and high pressures 150–300 bar). This issue should not only be

[26] Isola C, Sieverding HL, Numan-Al-Mobin AM, Rajappagowda R, Boakye EA, Raynie DE, et al. Vanillin derived from lignin liquefaction: a sustainability evaluation. Int J Life Cycle Assess 2018;23:1761–72. https://doi.org/10.1007/s11367-017-1401-0

considered because of the related environmental aspects, but it might also be of great interest when discussing the economic feasibility of using lignin.

In the case of ZEBRA-LIFE, the process is done at much lower pressure and temperature, and the energy used for heat and power will be produced from renewable sources (biomass). Therefore, only the electricity consumption of the process could be emitting CO_2 emissions which accounts for the 1.5% of the total cost of the process. Nevertheless, the electricity contract will contemplate origin certificate to ensure that renewable energy is consumed. In consequence, the emissions due to the electricity consumption can be neglected.

At the end of the project lifetime, assuming that the pilot plant could be running 8000 h per year during the implementation of the project, the plant will be producing:

- ZEBRA-LIFE LMW: 48t, that will be substituting the fossil/synthetics additives during the testing performed in the different application, avoiding the emission 230 t of CO_2-eq.
- ZEBRA-LIFE MMW: 56t, knowing that the PCI of the product is 7,021 kWh/kg, it will be producing 393.176 kWh that can substitute natural gas avoiding the emission of 72 t of CO_2-eq.

After the finalization of the ZEBRA-LIFE project, its impact lies in the future uptake of the results, as a process by the paper mills and as a product by users of aromatic additives.

As said previously, the project will act as an initial pilot plant. If successful, then the consortium plan to bring the technology to the market and upscale it to be replicable across Europe. According to the preliminary upscaling plan, it is envisioned to scale the production process from the ZEBRA-LIFE project at CENER facilities (20kg/h capacity, equivalent to 160 t/year) to an initial commercial plant (500 kg/h or 4,000 t/year) at Smurfit Kappa and then to deploy several commercial plants (5 t/h or 40,000 tonnes/year). The process can be implemented at any paper mill in any point across Europe. Nevertheless, the consortium plans to scale up, step by step after the project, to ensure that, when licensing the technology, all scale up issues are clarified. This time will also serve to create market demand for bio-aromatics, so that when the larger facilities come online, they will have sufficient demand.

After the finalisation of the ZEBRA-LIFE project, the pilot plant could be running 5 more years for R&D purposes (new formulations and applications). The corresponding impact will not be considered on the after projects calculation as, at the moment, the production capacity and usage of developed products is unclear.

In 2027, in case ZEBRA-LIFE's objectives are reached, a flagship plant will be built by Smurfit Kappa, which will be running for 4 years to prove the process at a bigger scale (500 kg/h) and rentability for the company. Later, in 2031, one industrial plant will be built by Smurfit Kappa in one of the company-group plants in Europe which will be producing at a scale of 2.500 kg/h (20.000

kg/year, with a maximum capacity of 40.000 t/year). Therefore, the scale-up plan and corresponding production schedule is presented in the table below.

Table 6. ZEBRA-LIFE products production strategy

		EOP	5 YEARS AFTER EOP				
		2026	2027	2028	2029	2030	2031
CENER Pilot plant (Navarra, Spain)	Pilot plant lignin consumption capacity (t/y)	160	-	-	-	-	-
	ZEBRA LMW (t)	48	-	-	-	-	-
	ZEBRA MMW (t)	56	-	-	-	-	-
SMURFIT KAPPA Commercial plant (Navarra, Spain)	Lignin consumption capacity (t/y)	-	4.000	4.000	4.000	4.000	4.000
	ZEBRA LMW (t)	-	1.200	1.200	1.200	1.200	1.200
	ZEBRA MMW (t)	-	1.400	1.400	1.400	1.400	1.400
SMURFIT KAPPA Industrial plant	Lignin consumption capacity (t/y)	-	-	-	-	-	20.000
	ZEBRA LMW (t)	-	-	-	-	-	6.000
	ZEBRA MMW (t)	-	-	-	-	-	7.000
TOTAL Per year	Lignin consumption capacity (t/y)	160	4.000	4.000	4.000	4.000	24.000
	ZEBRA LMW (t)	48	1.200	1.200	1.200	1.200	7.200
	ZEBRA MMW (t)	56	1.400	1.400	1.400	1.400	8.400
TOTAL (Accumulated data)	Lignin consumption capacity (t/y)	160	4.160	8.160	12.160	16.160	40.160
	ZEBRA LMW (t)	48	1.248	2.448	3.648	4.848	12.048
	ZEBRA MMW (t)	56	1.456	2.856	4.256	5.656	14.056

5 years after the finalization of the project there will be more than 160.000 tonnes of black liquor being utilised to recover more 40.000 t of lignin and

producing more than 12.000 t of LMW and 14.000 tonnes of MMW as the ZEBRA-LIFE products to be exported all over Europe.

2.2.5. KPI TARGETS

Here below are summarized the KPI targets according to the project contexts, impact pathways and indicators defined, and the ZEBRA-LIFE project outcomes quantified.

CONTEXT 1: SPAIN

Table 7. Environmental KPIs for context 1

KPI	UNITS	BASELINE	EOP	5 YEARS AFTER PROJECT END
Net GHG emissions due to additive production	t of CO2-eq /year	155.976	155.745	150.216
Normalized GHG emissions due to additive production	t of CO2-eq / t additive	2,15	2,14	2,07

CONTEXT 2: NAVARRA

Table 8. Environmental KPIs for context 2

KPI	UNITS	BASELINE	EOP	5 YEARS AFTER PROJECT END
Net GHG emissions due to avoidance of fossil fuel usage	t of CO2-eq /year	6.067	5.996	4.278
Normalized GHG emissions due to avoidance of fossil fuel usage	t of CO2-eq / GWh	2,81	2,77	1,98
Renewable energy generation	GWh/year	0	0,39	9,83

CONTEXT 3: INDUSTRIAL PLAN LOCATION (TO BE DEFINED)

In this case, given the fact that the plant location is still not identified, on the table 9 below is shown the reduction or increase potential.

Table 9. Environmental KPIs for context 3

KPI	UNITS	BASELINE	EOP	5 YEARS AFTER PROJECT END
GHG emissions reduction due to additive production	t of CO2-eq /year	-	-	28.800
GHG emissions reduction due to avoidance of fossil fuel usage	t of CO2-eq /year	-	-	8.945
Renewable energy generation	GWh/year	0	0	49,15

2.2.6. MASS AND ENERGY BALANCE OF THE PILOT PLANT MONITORING PROTOCOL

To analyze the technical and environmental performance and economic feasibility of the ZEBRA-LIFE technology, a Techno-Economic Assessment (TEA) and a Life Cycle Assessment (LCA) will be carried out. Both assessments are important tools for the evaluation of the ZEBRA-LIFE technology. They will help in the identification of the main challenges and impacts to be faced in the progress towards its future commercialization.

The first step in these assessments is to identify all input and output streams in the pilot plant in terms of mass and energy including: chemicals, auxiliaries and wastes generated in the process for the evaluation of the ZEBRA-LIFE technology. Therefore, the technology will be compared and/or integrated with the current baseline scenario in the Pulp and Paper industry from an economic and environmental perspective.

These assessments will include the calculation of performance indicators such as production cost and environmental impacts that, together with the pilot-scale data (TRL6), can be useful to take a decision of the industrial feasibility and the upscaling of the technology. A detailed flowsheet of the whole process including each unit will be prepared which will be used as the basis for monitoring and streams characterization. Process data will be collected afterwards from different production campaigns in WP4. All the info will be gathered in a template that will include the following data:

- Detailed process description.
- Process Flow Diagram (PFD).
- Plant capacity (kg/h, kg/d, l/h or other).
- Inlet/outlet streams information (name, flowrate, composition, etc.)
- Process conditions (T, P, etc.)
- Equipment list (tanks, reactors, pumps, filters, etc.).
- Utilities (steam, water, compressed air, power, etc.).

- Reactions involved (formulation, nature, parameters, yield, conversion, etc.).
- Other specific information (recycle streams, process control, etc.).

Process parameters and mass and energy balances will be optimized during WP4. The results will be a source of experimental data from the pilot plant at TRL6 which will provide an insight into process equipment design and will be beneficial for trouble-shooting and sensitivity analysis required for the future upscaling of ZEBRA-LIFE technology. Besides, experimental data collected will serve for the industrial scale simulation modelling. The pilot plant monitoring will also provide sufficient information to compare the proposed technology with other alternatives from an economic and environmental perspective.

2.2.7. LCA METHODOLOGY AND CONSIDERATIONS

The ISO 14040 standard is an international standard that sets out the principles and framework for conducting a life cycle assessment (LCA) of a product or service. The LCA aims to evaluate the environmental impact throughout its entire life cycle, from raw material extraction to final disposal.

To conduct an LCA based on ISO 14040 standards, the following steps should be followed:

- Definition of study objectives and scope: At this stage, the study objective is defined, and the scope of the study is established, i.e., what aspects of the life cycle will be analysed, what products or services will be evaluated, and what data will be used.
- Inventory analysis: At this stage, relevant information about the product or service life cycle is collected and organized, including energy consumption, greenhouse gas emissions, natural resource use, waste generation, and air, water, and soil pollution.
- Impact assessment: At this stage, the environmental impact of each stage of the life cycle is evaluated using mathematical models and specialized software tools.
- Interpretation of results: At this stage, the analysis of the results is performed, and conclusions and recommendations are made to improve the environmental performance of the product or service.

It is important to note that the ISO 14040 standard sets specific requirements for each stage, including data selection and modelling assumptions, verification and validation of results, and communication of findings to relevant stakeholders.

In addition, Simapro software and the Ecoinvent database will be used. On one hand, Simapro is a tool widely used for conducting life cycle assessment (LCA) and environmental performance analyses. It is designed to support the entire LCA process, from data collection and analysis to impact assessment and interpretation of results. Simapro includes a range of tools for inventory analysis, impact assessment, and sensitivity analysis, making it a powerful tool for LCA practitioners. Additionally, Simapro offers integration with the Ecoinvent database, a widely used source of life cycle inventory data for conducting LCAs. On the other hand, the Ecoinvent database contains comprehensive data on the environmental impacts of various processes, materials, and products across their entire life cycle. It includes data on energy use, greenhouse gas emissions, water use, and many other environmental factors and is frequently updated to ensure accuracy and relevance. With its comprehensive database and powerful tools, Simapro offers a robust solution for conducting accurate and reliable life cycle assessments.

2.2.8. PILOT PLANT ENVIRONMENTAL MANAGEMENT SYSTEM PLANT

The pilot plant environmental management system plan will be integrated within the BIO2C[27] environmental management system. The management system is ruled by the CENER's General Procedure "*6.1-01 Waste Management at BIO2C*" which is governed by the following national and regional laws:

- DECRETO FORAL 295/1996, de 29 de julio, por el que se establece el régimen simplificado de control en la recogida de pequeñas cantidades de residuos especiales.
- LEY 22/2011, de 28 de julio, de residuos y suelos contaminados.
- REAL DECRETO 679/2006, de 2 de junio, por el que se regula la gestión de los aceites industriales usados.
- REAL DECRETO 1481/2001, de 27 de diciembre, por el que se regula la eliminación mediante depósito en vertedero.
- REAL DECRETO 833/1988 – Ley básica de residuos tóxicos y peligrosos
- Ley 7/2022 de Economía Circular

Therefore, minor harm to the environment is expected as a consequence of CENER's contribution to the ZEBRA-LIFE project due to activities carried out either in the pilot plant or at laboratory scale. Any potential significant negative environmental impact will be previously assessed and, if necessary, an action plan displayed to reduce or minimize it.

The general principles that rule CENER activities are:

- Avoid any negative effect to fauna, flora, ground and surface water.
- Avoid and if not possible, reduce the generation of wastes.
- Maintain adequate cleanness and tidiness throughout the tasks.

[27] The BIO2C (Biorefinery and Bioenergy Center) is a semi-industrial pilot scale test facility owned by CENER, able to develop production processes for bioproducts, solid biofuels, advanced liquid or gaseous biofuels, as well as biorefinery concepts integrating different valorization routes. It will be the place where ZEBRA-LIFE pilot plant will be located.

Any solid or liquid waste generated on the process is managed according to local regulations, through a specialized and authorized waste management company when necessary. Additionally, any potential atmospheric emissions are below the limits established by local regulations due to the configuration of the installations. Environmental noise levels along the pilot plants are under local regulations established limits.

In case of accident or environmental incident both should be remedied, investigated and actions will be taken to avoid occurrence of any similar event according to our internal procedures.

2.3. SOCIO-ECONOMIC IMPACTS

2.3.1. ZEBRA-LIFE SOCIO-ECONOMIC IMPACTS PATHWAYS

Once the environmental analysis has been completed it would be possible to quantify the impact at socio-economical level.

During the project the substitution of additives derived from fossil origin can have significant impacts on social and economic levels. Synthetic additives are commonly used in various industries, including food, rubber, fuel, lubricants and cosmetics for their functional properties. However, as the world increasingly looks for sustainable alternatives to reduce dependence on fossil fuels and mitigate environmental concerns, the substitution of these additives with renewable or bio-based alternatives can result in both positive and negative social and economic impacts.

One of the key social impacts of substituting fossil fuel-derived additives with alternative options is the potential for creating new job opportunities. As the demand for renewable additives increases, there may be a need for skilled labor in the production, processing, and distribution of these additives. Resulting in the creation of new jobs in the renewable or bio-based additives industry, supporting local economies and providing employment opportunities for communities.

Moreover, developing and producing renewable additives may require infrastructure development, R&D activities, and pilot or demonstration facilities. This can result in their establishment in a specific work area, providing opportunities for economic development in this region, and potentially revitalizing rural or economically disadvantaged areas.

As renewable additives gain traction in the market, they may attract investments from various sources, such as private investors, venture capital firms, and public funding agencies. These investments can help accelerate the development and scaling up of renewable additives, driving innovation, and fostering economic growth in the sector.

As sustainability and environmental concerns gain prominence, projects focused on renewable additives may attract attention from stakeholders, policymakers, and the public. This can lead to increased website visits, visibility, and networking opportunities, which can facilitate knowledge sharing, collaborations, and synergies with other projects or initiatives, further driving social and economic impacts.

Factors such as regional economic conditions, local labor markets, regulatory frameworks, and stakeholder engagement can influence the outcomes of such substitutions. Additionally, there may be potential challenges and trade-offs, such as the need for additional investments in research and development, potential disruptions in existing supply chains, and the need for retraining or reskilling of workers in the transition process.

In conclusion, the substitution of fossil fuel-derived additives with renewable alternatives can have multi-faceted social and economic impacts. These can include creating new job opportunities, stimulating investments, driving innovation, fostering collaborations, and revitalizing project work areas. However, careful consideration of local contexts, stakeholder engagement, and appropriate policies and strategies is essential to ensure that the social and economic impacts are maximized and that the transition towards more sustainable additives is inclusive and beneficial to all stakeholders involved.

2.3.2. SOCIO-ECONOMIC ASSESSMENT

The ZEBRA-LIFE project will undergo a socio-economic assessment. As with any new technology, it is important to consider the impact it may have on the environment, as well as the social and economic implications of its implementation. To ensure that the ZEBRA-LIFE project is implemented in a responsible and sustainable way, an Environmental Social and Governance (ESG) study will be conducted. The ESG study will assess the social impacts of the technology, such as its effect on the communities affected by the project or the new jobs created.

One important economic indicator that will be followed up after the project is the Social Discount Rate (SDR, description can be found in the section 3.3.5). The aim of using the SDR is to evaluate the socio-economic impact of the project. The status of relevant impacts will be regularly monitored by the partner Inveniam, and at each General Assembly meeting where participants will check the status and decide on preventive or corrective actions if necessary. This action should enable the project to release key data allowing the stakeholders and decision-makers of the project to commit and invest in ZEBRA-LIFE plants.

The goal of this socio-economic assessment is to consolidate data and results obtained during the project to evaluate the awareness and acceptance of the benefits of the innovative product proposed by the project. Additionally, the evaluation will look at the potential direct or indirect employment growth, enhancement of other activities, impact on the citizen raising the profile of the area/region, the overall perception of the area or region, among others.

To achieve this goal, the collection and processing of information, including data and surveys, will be done at the plant, with desk-based analysis at Inveniam and other partners' offices. This approach is an efficient way to gather information collected is accurate and reliable.

This task is not planned to start until the second half of the project. Detailed description on the methodology of the Socio-Economic assessment will be provided on a later version of this document.

2.3.3. COST ANALYSIS OF THE ENTIRE INDUSTRIAL PROCESS

Based on the information provided in the business plan, the cost analysis of the product will be conducted by the partner Inveniam in conjunction with other partners. The cost analysis will take into account various factors, including the cost of the industrial process, the estimated costs of the components, as well as the costs of installation and maintenance.

The primary objective of this cost analysis is to identify ways to decrease the overall cost of the product. This will be achieved through careful evaluation of each cost component to determine where savings can be made. By reducing the cost of production, the ZEBRA-LIFE project hopes to make their products more attractive to customers and end-users.

One of the key benefits of reducing the cost of production is that it will enable the project to price their products more competitively. A lower price point will help to ensure that the product is well-received by the market and will increase the products' overall market penetration rate. Additionally, by making the product more affordable, the project will be able to attract a broader customer base, which will contribute to the project's long-term success.

In summary, the cost analysis that will be conducted by Inveniam and its partners is a critical component of the project's business plan. By reducing the cost of production and decreasing the price of the product, ZEBRA-LIFE expectation is to ensure the acceptance of its products by customers and end-users, while maximizing its market penetration rate.

Detailed methodology description for the cost analysis and wiliness to pay will be provided in a later version of this monitoring and reporting plan, as this task is not planned to start until the third year of the project.

2.3.4. SATISFACTION SURVEYS FROM END-USERS

The statement is discussing a plan to gather qualitative data about stakeholders' satisfaction with the pilot plant. To achieve this goal, the plan is to interview stakeholders who encounter the project, such as neighbors, clients, and workers. Additionally, satisfaction surveys will be conducted to collect and analyze feedback from end-users and managers during the monitoring period.

This approach is a great way to gather feedback on the effectiveness of the ZEBRA-LIFE project. By gathering qualitative data, researchers can get a deeper understanding of stakeholders' experiences and perspectives. Additionally, the use of satisfaction surveys can provide a structured approach to gathering feedback, which can help researchers identify common themes and trends in stakeholders' feedback.

However, it's important to keep in mind that qualitative data collection has some limitations. For example, the data collected may be subjective and influenced by stakeholders' individual biases and experiences. Additionally, qualitative data can be time-consuming to analyze, especially when dealing with large amounts of data. It is essential to ensure that the data is collected and analyzed systematically to avoid bias and ensure the results are accurate.

Overall, the plant to gather qualitative data about stakeholders' satisfaction with the ZEBRA-LIFE project is a useful approach to understating the program's effectiveness. By incorporating both interviews and satisfaction surveys, researchers can collect comprehensive data that can be used to inform future projects improvements.

2.3.5. SOCIO-ECONOMIC INDICATORS (KPI)

DEFINITION

PROJECT WORK AREA

The entire spatial extent of the work area in which the project's tangible activities take place is referred to as the project work area. It is the area of the undertaking where the budget is used to accomplish goals. This indicator should not be used to report on the effects.

For instance, in ZEBRA-LIFE project it has been considered that the project work area includes all the site plant area where the ZEBRA-LIFE pilot plant or the future commercial or industrial plants will be installed.

HUMANS IMPACTED BY THE PROJECT

This indicator counts the overall number of individuals affected by the initiative in the given setting. This KPI should declare and explain the sort of effect and individuals affected.

In ZEBRA-LIFE it has been considered two categories of impacted humans:

1. Direct employees derived from the development of new plants.
2. Reduction of CO2 emissions by removing fossil fuel power generation with renewable energy sources that consequently will affect all the population living close by to the pulp and paper industry.

WEBSITE VISITS

This is the total number of unique visits recorded by the project website that are clearly connected to ZEBRA project. It has been considered that the website activity (blog, newsletter, downloadable material) will no longer continue after the project finalization and therefore will not have an increasing trend, so considering the amount of the visits to be constant. The estimation on the number of unique visits has been done based on the possible project synergies with industries, other similar projects or possible final consumers.

NETWORKING AND SYNERGIES WITH PROJECTS

Under this KPI, ZEBRA will report on its networking with other European funded projects. It includes the quantity of projects/initiatives (not people) with which ZEBRA-LIFE will have interacted. The indicator will indicate the setting in which the networking occurred rather than the locations of the other initiatives.

NEW JOBS CREATED

These are all the Full Time Equivalent (FTE) new jobs generated during and after the project execution. The estimation for ZEBRA-LIFE corresponds to the workforce required to operate the additive production and their implementation in the corresponding applications.

SOCIAL DISCOUNT RATE

The SDR is a measure of the value that society places on future benefits and costs. It reflects the time preference of society, meaning how much people value benefits and costs that occur in the future compared to those that occur in the present.

REVENUE DURING OR AFTER PROJECT END, DUE TO PROJECT OUTCOMES

This KPI displays total profits generated by ZEBRA-LIFE project outcomes during or after the project's completion. It does not include any co-financing by project beneficiaries and/or co-financiers that will be part of the authorized project budget as income.

The revenues have been calculated considering an estimated price for the final product multiplied by the quantity produced of the final product.

CATALYTIC EFFECT - FINANCIAL - CUMULATIVE INVESTMENTS TRIGGERED, OR FINANCE ACCESSED.

In this indicator, it is possible to record extra money obtained or assets triggered by the ZEBRA-LIFE project that are matched with the goals of the LIFE project. Projects do not include co-financing from recipients or co-financiers in the project funding.

ASSUMPTIONS

Project work area: the area considered is the overall site plant where the lignin conversion process in high value additives will be built and installed.

Humans impacted by the project: the assumption consists in considering the new jobs created plus the people that lives around the pulp and paper plant, for which the CO_2 emissions are reduced thanks to the utilization of renewable energies.

Website visits: it has been estimated that since the official website launch approximately 1.500 person per year will visit the website. After 5 years from the end of the project the website will not be further updated even if it will remain operative, therefore, it has been estimated that the amount of the visits will remain constant.

New Jobs created: the consortium prevision for the employees needed to make the pilot plant working will be around 18 direct jobs. 5 years after the project end, one more plant, of bigger dimension, will be constructed and it has been estimated that other 59 employees will be needed for the correct functionality of the plant.

Networking and synergies with projects/initiatives: thanks to the website, social media posts and participation to public conferences it has been estimated that an amount of 3 project synergies will be possible to be reached every year. 5 years after the end of the project as the website will not be further improved it has been assumed that 1 project synergy per year would be possibly reached.

Revenue during or after project end, due to project outcomes: This KPI refers after the project end, once the ZEBRA-LIFE products could be commercialized, first at commercial and later at industrial scale. The ZEBRA-LIFE product costs assumptions for their commercialization after project end are:

- ZEBRA-LMW: between 3,7-4,9 €/kg
- ZEBRA-MMW: between 1,8-2,4 €/kg

Catalytic effect-financial-cumulative investments triggered, or finance accessed:

25M€ has been estimated to be needed for the completion of the flagship plant at the Smurfit Kappa facility, with an installed capacity of 4,000 t of lignin per year. While, for the first industrial plant with 44,000 t of lignin/year has been estimated that additional 85M€ are needed.

TARGETS

CONTEXT 1: SPAIN

Table 10. Socioeconomics KPIs for context 1

KPI	UNITS	START OF THE PROJECT	END OF THE PROJECT	5 YEARS AFTER THE END OF THE PROJECT
Website visits	Number of unique visits	0	6.000	13.500
New Jobs created	Number of people with a new job in the area	0	6	12
Networking and synergies with projects/initiatives	Number of project/initiatives	0	12	17
SDR	-	0	3,5	3,5

CONTEXT 2: NAVARRA

Table 11. Socioeconomics KPIs for context 2

KPI	UNITS	START OF THE PROJECT	END OF THE PROJECT	5 YEARS AFTER THE END OF THE PROJECT
Project work area	m2	0	32.000	32.000
Humans impacted by the project	Number of persons	0	12	620
New Jobs created	Number of people with a new job in the area	0	12	20
Revenue during or after project end, due to project outcomes	M€	0	0	7
Catalytic effect- financial- cumulative investments triggered, or finance accessed	M€	0	25	0

CONTEXT 3: INDUSTRIAL PLAN LOCATION (TO BE DEFINED)

Table 12. Socioeconomics KPIs for context 3

KPI	UNITS	START OF THE PROJECT	END OF THE PROJECT	5 YEARS AFTER THE END OF THE PROJECT
Project work area	ha, km2, m2	0	0	tbd
Humans impacted by the project	Number of persons	0	0	tbd
New Jobs created	Number of people with a new job in the area	0	0	30
Revenue during or after project end, due to project outcomes	M€	0	0	35
Catalytic effect- financial- cumulative investments triggered, or finance accessed	€	0	0	85M€

3. METHODOLOGY FOR DATA COLLECTION AND ASSESSMENT

In this section, ZEBRA partners will receive additional guidance and insights on various data sources and factors to consider when assessing the availability, sufficiency, and affordability of data. This guidance will assist them in identifying suitable data sources.

When it comes to impact evaluation, there are two types of data that can be used: existing data and new data that needs to be collected by the ZEBRA-LIFE project. If the data has already been collected by someone else and can be used for impact evaluation, it is known as secondary data and can save considerable time and resources. On the other hand, if ZEBRA-LIFE partners collect the data themselves or through subcontractors, it is called primary data collection. The next section delves into more detail on the different types of secondary data and methods for primary data collection.

3.1. SOURCES OF IMPACT ASSESSMENT DATA

The data requirements for the measure/intervention level are currently unknown as the confirmation of the measures/interventions at each step has yet to be determined.

However, it is certain that the main objective of the measures/interventions in the ZEBRA-LIFE project is to develop sustainable lignin-derived additives for industries such as cosmetics, rubber, fuel, lubricants, and polymers. Therefore, the primary data collection process will need to be focused on these specific target products, and any secondary data that is available will only be useful if it pertains to these identified target products.

BASELINE

Bearing this in mind, the data collected will potentially come from a variety of secondary sources. These include:

- Scientific articles:
    1. Lignin as a potential source of high-added value compounds. This article explores the applications of lignin, a natural polymer, in various industries, such as food, biomedicine, cosmetics, and polymer composites.
    Zevallos Torres LA, Lorenci Woiciechowski A, de Andrade Tanobe VO, Karp SG, Guimarães Lorenci LC, Faulds C, et al. Lignin as a potential source of high-added value compounds: A review. J Clean Prod 2020;263:121499. https://doi.org/https://doi.org/10.1016/j.jclepro.2020.121499
    2. Current lignin production, applications, products and environmental impact.
    Bajwa DS, Pourhashem G, Ullah AH, Bajwa SG. A concise review of current lignin production, applications, products and their environmental impact. Ind Crops Prod 2019;139:111526. https://doi.org/https://doi.org/10.1016/j.indcrop.2019.111526.
    3. Lignin-based products need to meet technical requirements and be more sustainable than their fossil-based counterparts.

Lettner M, Solt P, Rößiger B, Pufky-Heinrich D, Jääskeläinen A-S, Schwarzbauer P, et al. From Wood to Resin—Identifying Sustainability Levers through Hotspotting Lignin Valorisation Pathways. Sustainability 2018;10. https://doi.org/10.3390/su10082745

4. Life Cycle Assessment of lignin extraction in a softwood kraft pulp mill.
   Culbertson C, Treasure T, Venditti R, Jameel H, Gonzalez R. Life Cycle Assessment of lignin extraction in a softwood kraft pulp mill. Nord Pulp Pap Res J 2016;31:30–40.
5. Synthetic Phenolic Antioxidants and Transformation Products in Human Sera from United Stated Donors.
   Liu and Mabury, 2018
6. Synthetic Phenolic Antioxidants: Environmental Occurrence, Fate, Human Exposure, and Toxicity.
   Liu and Mabury, 2020
7. Occurrence, toxicity and environmental health risks of synthetic phenolic antioxidants.
   Fries and Püttmann, 2004; Nilsson et al., 2005; Rodil et al., 2010; Hernández et al., 2012; Weschler et al., 2014

- National and European Clusters reports trough partners access:

1. Consorcio Nacional de Industriales del Caucho (National consortium of Rubber industries)
2. ANICE, Asociación Nacional de Industrias de la Carne de España
3. PODULCE, Asociación Española del Dulce
4. CEFIC, The European Chemical Industry Council
5. AEIC, Asociación Española de Investigación en Comunicación
6. EFFCI, The European Federation for Cosmetic Ingredients
7. ASELUB, Spanish Lubricants Association
8. STRATAS Advisors
9. Eurostats, European statistics to policy makers, businesses, researchers and the public at large

PROJECT IMPACT MONITORING

To truly measure the project impact, the consortium will consider a more comprehensive approach that looks at the entire lifecycle of the ZEBRA-LIFE products and their use in the different application. This will be achieving trough collection of primary data from the project's partners.

ENVIRONMENTAL IMPACT

This data will come primarily from CENER who will be developing the ZEBRA-LIFE production process. Data will cover the inputs and outputs of the process such as:

- Energy consumed and their sources.
- Raw materials
- Chemicals and other consumables used.
- Process efficiency
- Product efficiency
- Emissions
- Wastes
- Co-products
- Etc.

In addition, Smurfit Kappa will also contribute to define the antioxidant production process implementation into the pulp and paper manufacturing process such as:

- Lignin volume converted into high value products.
- Quantity of ZEBRA-LIFE products reintroduced into the process in form of renewable energy.

SOCIO-ECONOMIC IMPACT

The socio-economic primary data will come in one hand from the exploitation strategy and business plan that will be developed in collaboration with all project partners with special contribution from Smurfit Kappa, such as:

- Investments required for the construction of the commercial plant.
- Investments required for the construction of the industrial plant.
- Business model where the expenses and revenues plan will be outlined.

In the other hand, most of the data to assess the socio-economic impact will come from the different surveys that will be address to the project stakeholders to gather qualitative and quantitative information regarding to:

- Awareness and acceptance of the benefits of the ZEBRA-LIFE products
- Potential direct or indirect employment growth
- Enhancement of other activities
- Impact on the citizen raising the profile of the area/region
- Overall perception of the area or region
- Cost of the industrial process
- Estimated costs of the components
- Estimated costs of installation and maintenance
- Wiliness to pay
- Project's stakeholders satisfaction level

3.2. PARTNER'S ROLES AND RESPONSIBILITIES

Project partners are asked to support the monitoring and reporting activities with the collection and reporting of primary and secondary data. Here below are defined the different responsibilities according to the project's environmental and socio-economic monitoring activities defined on this document.

Table 13. Monitoring and reporting responsibilities

TYPE	ACTIVITY	DATA COLLECTION	DATA PROCESSING	DATA REPORTING
Environmental Impact	Base line calculation	All partners	INV	INV
	Mass and Energy balance of the pilot plant	CENER	CENER	CENER
	ZEBRA-LIFE products performance	CENER	INV/CENER	INV
	LCA	CENER	CENER	CENER
	KPI reporting	All partners	INV	INV
Socio-economic Impacts	Base line calculation	All partners	INV	INV
	Socio-economic Assessment	All partners	INV	INV
	Cost analysis of industrial plant	CENER/Smurfit Kappa	INV	INV
	Satisfaction surveys	All partners	INV	INV
	KPI reporting	All partners	INV	INV

3.3. EFFECTIVE COMMUNICATION OF PROJECTS IMPACTS

The monitoring and reporting plan is important to assess the project impacts to convince the corresponding value chain stakeholders on the adoption of the ZEBRA-LIFE circular solution in the national and international markets. Nevertheless, it is important to bear in mind that the monitoring of the project impacts is as important of its corresponding and effective communication.

Part of this plan has been outlined in the public deliverable "*D7.1 Communication and Reporting Plan*" developed under WP7 where the target audience, key communication messages and channels have been identified. The reader is invited to check the document for more details.

It is important to mention that due to the nature of this project, part of the project's impacts could not be communicated to the broad audience due to IP restrictions and confidentially issues. Dissemination of those results will be always reviewed by the consortium members before its release.

On the other hand, to help the European Commission and the LIFE-Programme to follow the project impacts across the European territory, 2 KPI reporting periods are scheduled to share the KPIs progress along the project duration through usage of the LIFE-KPI reporting platform.

- M9: Initial report, definition of baseline and targets to be achieved at the end of the projects and 5 years after project end
- M42: Report update according to project results.

3.4. DATA PRIVACY CONSIDERATIONS

The comprehensive data that will be gathered and analyzed, as outlined above, must be handled in accordance with all applicable data privacy regulations and practices, with particular attention to the General Data Protection Regulation (GDPR, EU2016/679), and in compliance with the ZEBRA-LIFE Data Management Plan (*D1.2 Management Handbook, risk management plan and data management plan*). A significant portion of the data collected as part of the impact evaluation activities may be classified as personal data, which is defined under the GDPR as "any information relating to an identified or identifiable natural person ("data subject").

When collecting or processing data that could potentially identify individuals on whom data is gathered (as either primary or secondary data as outlined earlier), these principles will be taken into account, particularly in relation to a specific activity or when combining data sets. Additionally, data privacy concerns will be taken into consideration broader ethical research requirements.