LIFE Biorefformed

LAYMAN'S REPORT

Implementing a Mediterranean biorefinery to boost forest management through the production of value-added products (LIFE 19 ENV/ES/000544)

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More information

01 THE LIFE BIOREFFORMED PROJECT

Introduction

Spain accounts for 21% of the total Mediterranean forest areas, and in Catalunya, where this project has been developed, they cover up to 43% of its territory. In the last years, these forest areas have been growing due to rural depopulation and lack of economic profitability, leading to a lack of forest management. This fact has resulted in an increase of fire risk and a worse adaptation to climate change, threatening ecosystem functioning and associated biodiversity. Additionally, these types of forests are characterized by difficult orography, which makes their management a difficult task with low productivity and high costs. On the other side, European plans and policies encourage the shift towards bioeconomy and a more circular economy, demanding the development of new and sustainable biofuels and bioproducts.

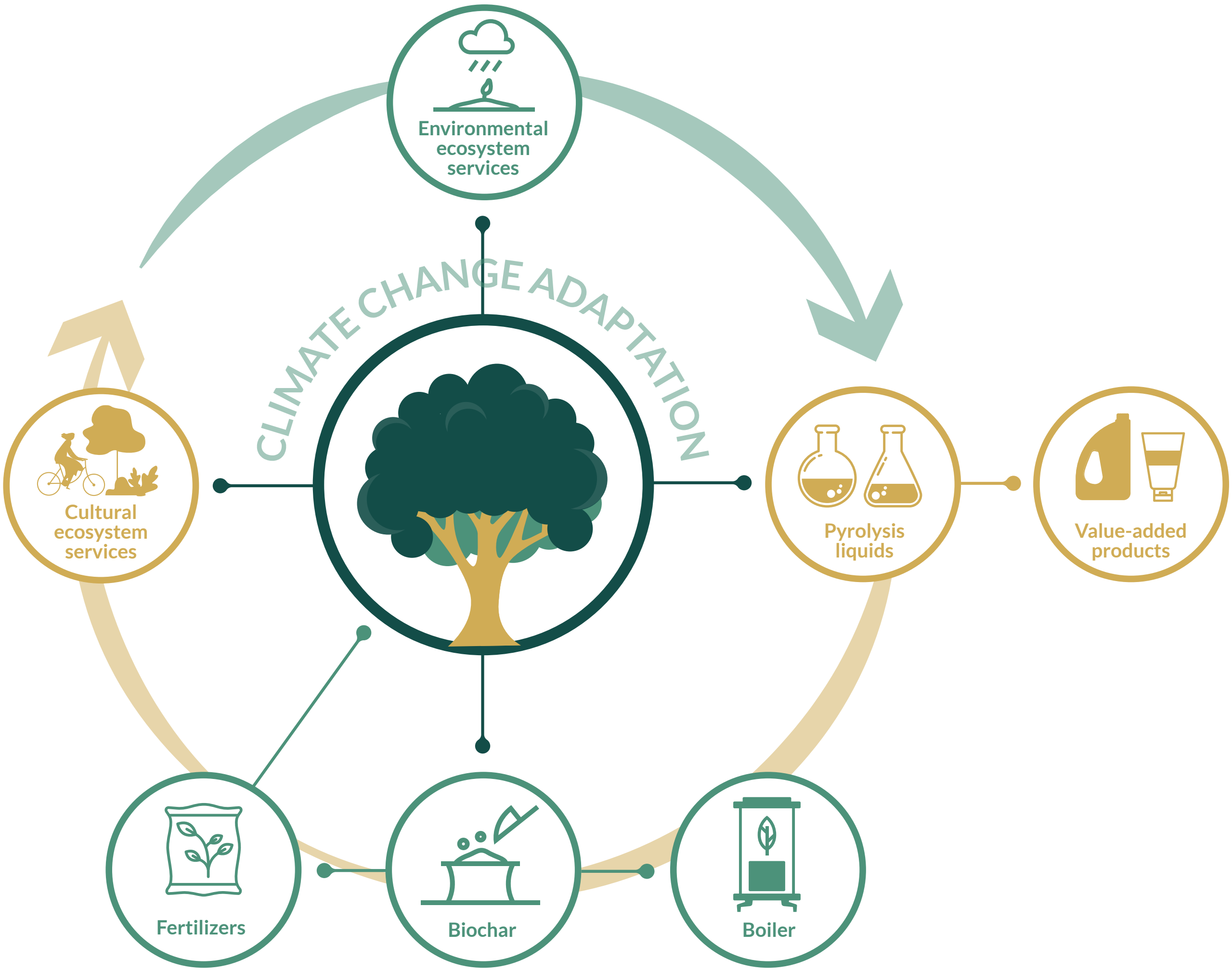
General objective

The main objective of the project has been to boost the sustainable management of Mediterranean forests through a biorefinery plant that uses pyrolysis to produce renewable chemicals and biofuels from forest biomass.

Specific objectives

- To determine the best combination in the forest management practices in terms of economic viability and conservation of ecosystems and biodiversity.
- To present innovative models of Mediterranean forest management and guidelines focused on conservation and adaptation to climate change to be transferred to forest policies and regulations.
- To monitor the ecosystem services of the forest demonstration areas and their corresponding adaptation to climate change, ensuring that the project contributes to the habitat and biodiversity conservation.
- To produce antioxidants, sugars, acids, biochar and fertilizers from different combinations of forest biomass.
- Disseminate the results of the project to the different parties involved in the value chain, both in the biorefinery and forestry sectors.
- To install a local biorefinery with a capacity of 100 kg of biomass/h for the continuous production of liquid and solid products.
- To present innovative models of Mediterranean forest management and guidelines focused on conservation and adaptation to climate change to be transferred to forest policies and regulations.

- To monitor the ecosystem services of the forest demonstration areas and their corresponding adaptation to climate change, ensuring that the project contributes to the habitat and biodiversity conservation.
- Disseminate the results of the project to the different parties involved in the value chain, both in the biorefinery and forestry sectors.
- To create a more sustainable local and rural economic activity by increasing its social benefits.



Biomass from adaptation and restoration actions of cork oak and Mediterranean pine forests

The LIFE BIOREFFORMED project has worked on **three priority forest typologies**:

1. **Young pine forests for post-fire Aleppo pine regeneration**: areas where natural regeneration after the fire has been successful but which have become excessively dense. If silvicultural treatments are not applied, growth stagnates and the phase of high vulnerability to new fires is prolonged. This can lead to the delay of pine nut production and compromise the future regeneration of trees in the event of a recurrent fire.

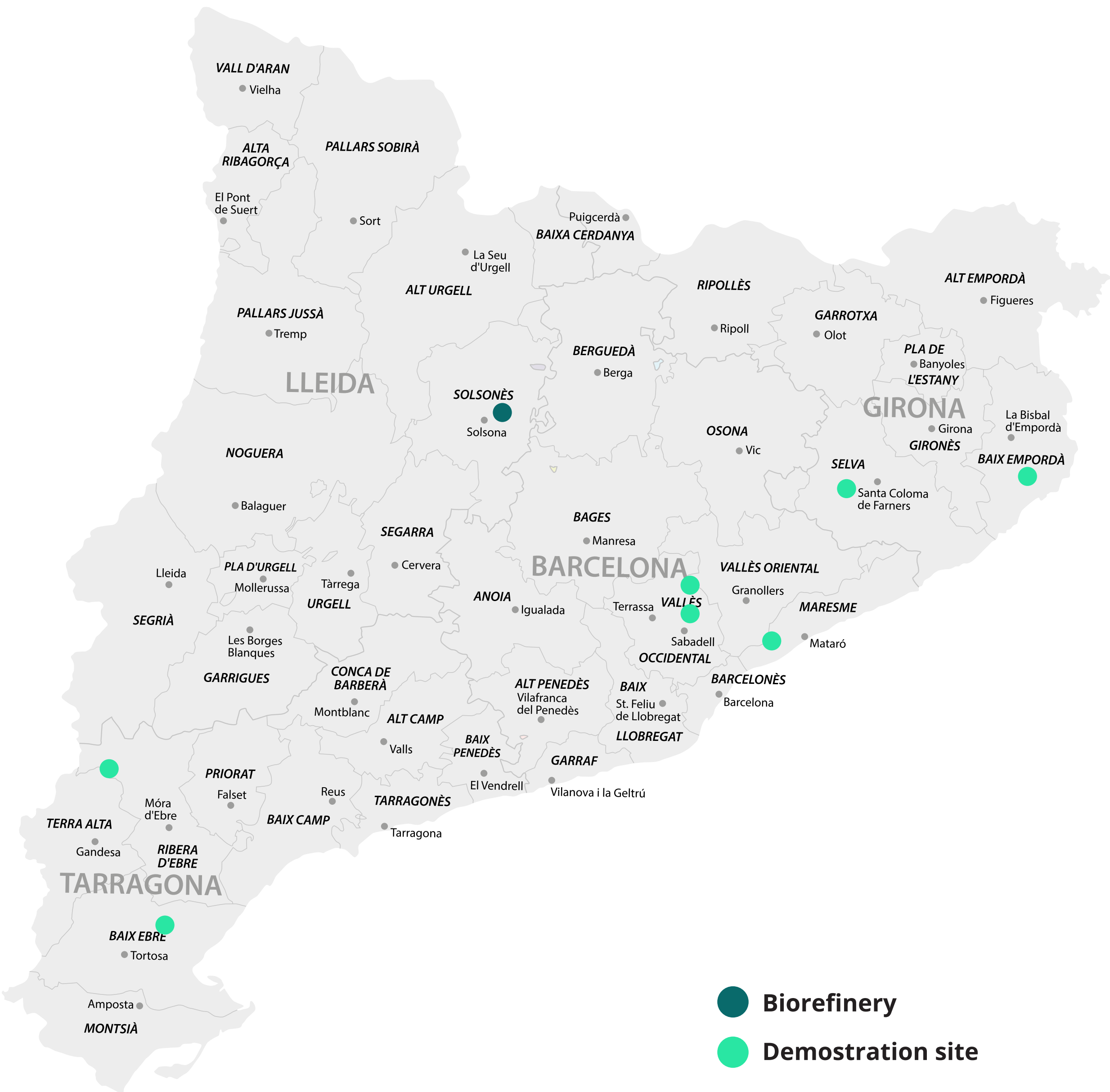
2. **Adult pine forests affected by a recent natural disturbance other than fire** (biotic or abiotic damage). The increase in aridity weakens vegetation and makes it more prone to pests and diseases and to suffer more adverse effects. This is especially relevant in dense pine forests or with an abundant undergrowth of oak trees. The effects are cyclical and with a degree and mortality that is difficult to predict. The disturbance itself, or the subsequent sanitary cuts, can generate unstructured masses that compromise their productive and ecological functions.

3. **Aged cork oaks with an excessive density of trees and symptoms of decay or cork oaks that are very vulnerable to droughts or fires** that must be adapted to new climatic conditions. It is considered that, currently, 2/3 of the Catalan cork oak forests in production are in areas that will be outside their ecological range by 2050.

The **species and types of biomasses** whose viability has been **tested in biorefinery processes** have been:

1. Young Aleppo pine (*Ph leaf* - *Pinus halepensis*): wood with thin bark, branches and leaves.
2. Aleppo pine (*Ph* - *Pinus halepensis*): wood with bark.
3. Stone pine (*Pp* - *Pinus pinea*): wood with bark.
4. Holm oak (*Qi* - *Quercus ilex*): wood with bark.
5. Cork oak (*Qs bark* - *Quercus suber*): wood with bark (hairy cork).
6. Chestnut (*Cs* - *Castanea sativa*): dead chestnut wood, with bark.
7. Heather (*Ea* - *Erica arborea*): wood, branches and leaves.
8. Strawberry tree *(Au* - *Arbutus unedo*): wood, branches and leaves.

Demonstrative forest stands:

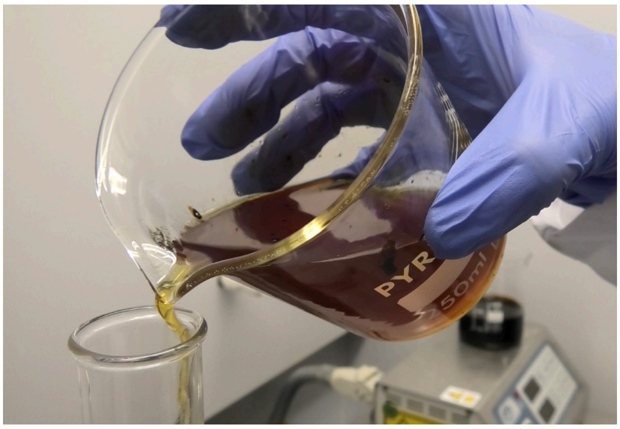


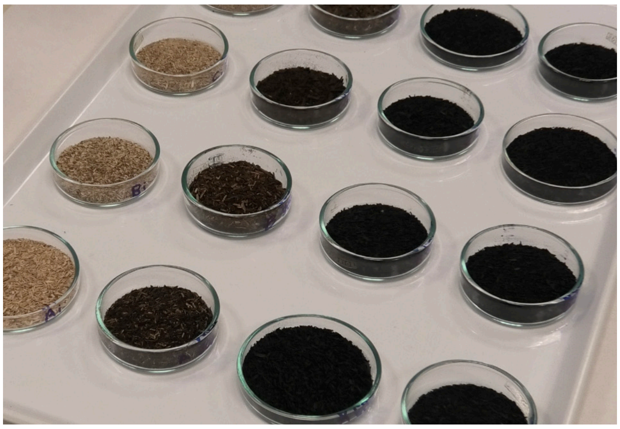
What products are obtained from the biorefinery?

In the biorefinery biomass is pyrolyzed at high temperatures and without access to oxygen, causing their thermal decomposition. Two majority fractions are obtained:

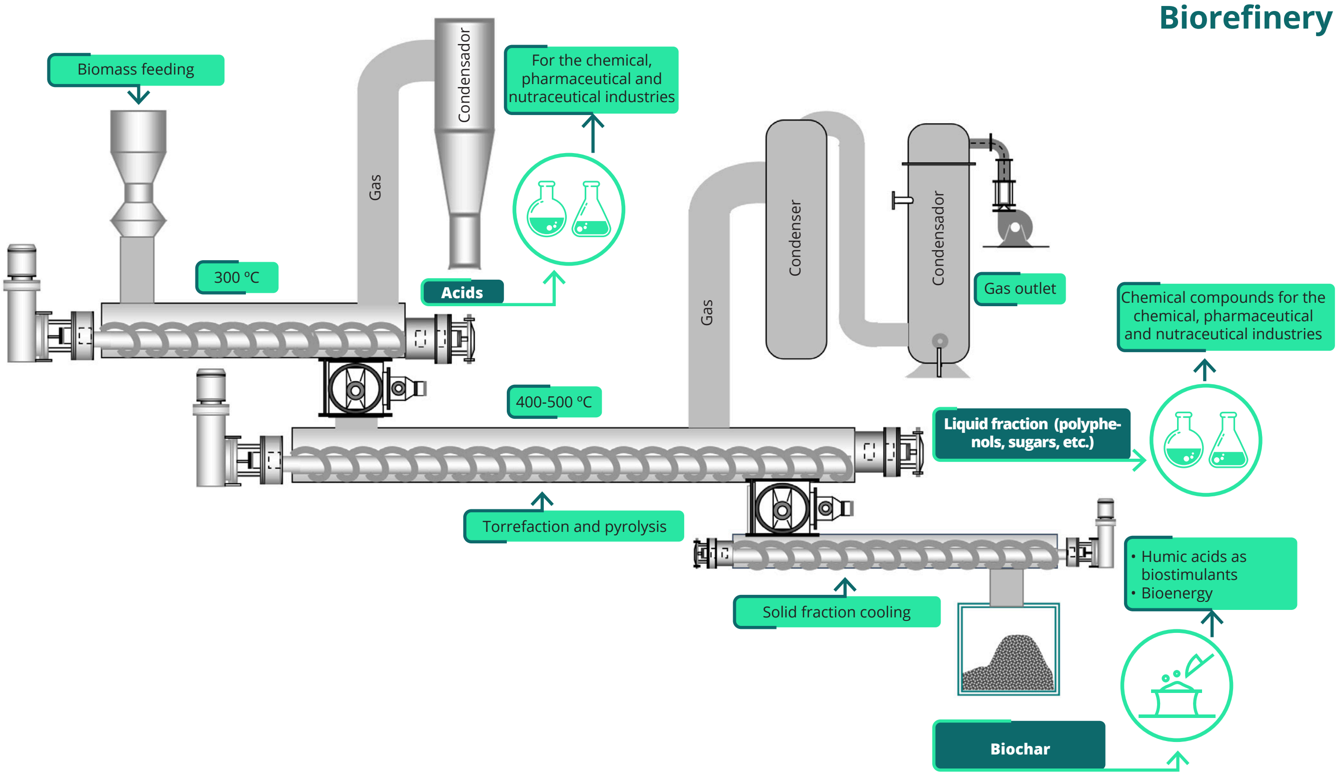
- **Liquid fraction** (*bio-oil*): From which a series of compounds of interest to the nutritional, food, cosmetic, pharmaceutical and chemical industries are extracted or synthesized, such as sugars, antioxidants (polyphenols), acids or phenolic resins.

- **Solid fraction** (*biochar):* Biochar can be used as a soil structuring agent for carbon sequestration and improved water retention or as a biofuel. From the solid fraction obtained at temperatures up to 300 ºC, humic and fulvic extracts can be obtained, which are used as biostimulants in agriculture.





Biorefinery



02 RESULTS

Process and final products

- Forest biomass has been transformed through the pyrolysis process and **biochar (solid)** and **bio-oil (liquid) have been obtained**, with different uses depending on their properties.

- It has been observed that the **optimal pyrolysis temperature** for producing bio-oils and for obtaining compounds of interest of higher quality and biochar, from forest biomass, **is 450º C**. On the other hand, to produce biostimulants from the solid fraction, of interest in agriculture, the optimal temperature has been 300º C.

- The **products obtained from bio-oil at 450º C** have been **antioxidant** compounds (polyphenols) (5 g per kg of biomass), **sugars** (10 g per kg of biomass), **acids** (25 g per kg of biomass) and **phenolic resins**. The final product with the highest added value is sugars, both in terms of the quantity obtained and the high market price.

- A comprehensive multi-objective extraction **and separation process based on** biorefinery techniques of **value-added compounds from bio-oil has been successfully developed, so that all the chemicals described can be obtained with the same process.**

- The **biochar** generated in this process has been shown to have no inhibitory effect on microbial activity in the soil, so it can be used as a **soil structuring agent** and with interest for **water retention**. This biochar can also be used as a **biofuel** with a lower calorific value range between 23 and 30 MJ/kg.

- The **biostimulants obtained from forest biomass torrefied at 300º C** are of **high quality** and similar to those obtained from plant compost.

Efficiency of the different types of forest biomass tested

- From the different types of forest biomass processed in the project, similar amounts of compounds of interest have been obtained. Therefore, it can be concluded that **there are no important differences between hardwood or softwood tree species, neither between these nor shrub species**.

- This suggests, on the one hand, the **feasibility of using all the forest species tested in this type of biorefinery**, and, on the other hand, the **possibility of mixing them and providing an outlet for biomass that is difficult to use alternatively**, such as i) scrub or small trees with bark and leaves from seedling or thinning, ii) hairy cork (wood and cork) from selection cuts in cork oak groves, or iii) mixed wood of different species and characteristics from post-disturbance actions that generate little volume of wood.

- Among the **tree species** studied, **pines** (especially Aleppo pine) have been the best for the production of antioxidant compounds (such as guaiacol, catechol, phenol and vanillin, among others). Chestnut and **cork oak** are the ones that have given the best results in the production of humic extracts as stimulants of soil microbial activity and plant growth. Shrub **species**, such as heather, have given many good results, especially in terms of the production of acids, such as acetic acid.

Table 1.1. Yields (g product/kg biomass) and potential use of the products obtained in the processing of biomass from the demonstration stands in the LIFE BIOREFFORMED biorefinery at a pyrolysis temperature of 400 ºC.

Fraction	Bioproducts	Biomass origin and yield of products obtained (g/kg biomass)							
		Pp	***Ph leaf***	***Ph***	***Qi***	***Au***	***Ea***	***Qs bark***	***Cs***
Liquid fraction (Bio-oil)	**Antioxidants** Phenol, catechol, vanillin, guaiacol, p-creosol, p-cresol	4.0	4.4	4.6	2.5	0.6	2.3	1.1	0.7
	Sugars Levoglucosan	6.9	8.3	9.5	5.9	2.9	9.6	2.7	5.9
	Acids Acetic acid, formic acid	16	21.1	17.6	19.8	11.9	25.6	17.6	11.5
	Aldehydes and ketones Hydroxyacetone, methyl cyclopentenolone, furfural, 5HMF	3.8	6.4	5.4	6.0	2.4	5.4	2.9	2.1
	Phenolic resins	3.33	2.38	1.43	2.01	1.67	2.01	1.34	2.33
Solid fraction (Biochar)	**Biostimulants** (g/100 mL) produced at 300 ºC	1.5	1.4	1.2	1.6	1.6	1.4	2.3	2.4
	Biochar (MJ/kg)	29.9	25.8	26.2	24.2	22.1	23.1	16.6	22.7

Table 1.2. Quality and market placement of the products obtained in LIFE BIOREFFORMED.

Fraction	Chemical Group	Quality obtained	Market
Liquid fraction (Bio-oil)	Antioxidants	100% purity *(Sum of all phenolic species)	Cosmetics, dermocosmetics, natural health ingredients and nutraceutical industries
	Phenolic resins	30% replacement	Adhesive for wood
	Sugars	44.5% purity	Chemical and food industries
	Acids	72.2% purity	Chemical industries
Solid fraction (Biochar)	Biostimulants	4.9 g of humic compound / 100mL	Agrochemical industries
	Biochar	HCV of 17.6 a 30.6 MJ/kg (per 400ºC biochar)	Bioenergy

Performance and impact of forest biomass extraction

- **The use of biomass in biorefineries can justify the partial extraction of biomass from adaptation/restoration treatments**, biomass that, on many occasions, is chopped up and left in the forest.

- **The bottlenecks of the use of biomass from adaptation/restoration actions are the low yields/ha** (the average yield in the demonstration stands has been 13 t/ha) **and the high extraction costs**, which are currently manual.

- **It is important that in the extraction of biomass for the biorefinery in adult forests, the crowns are left in the forest**, since the crown (branches and leaves) contains 60% of the nitrogen and potassium of the aerial part and up to 50% of the phosphorus, which is very difficult to recover naturally. **The extraction of biomass from regenerated Aleppo pine or scrub is done everywhere and the whole individual is extracted**, but the use is concentrated in accessible areas (strips on both sides of the paths), which at the stand scale **represents 10% of the total biomass** and contributes, at the same time, to the prevention of forest fires.

- After the forestry actions, the aerial carbon stock is, logically, lower due to the cutting and extraction of part of the biomass, but **the reduction in the CO_2 stock can only be counted as net CO_2 emissions if in the short term the material is used for biofuel**. A **CO_2 sink effect is expected** due to increased growth as a result of the treatment, but it is still imperceptible due to the short time that has elapsed.

- Forest management that is accompanied by the **enhancement of the historical socio-ecological heritage** (tangible and intangible) linked to that forest can promote the **Cultural Ecosystem Services** offered by forest estates. In this sense, actions such as the maintenance of oral expressions or traditional knowledge about the forest and its management promote the transmission of knowledge, which **is in turn a resilience strategy**.

Biorefinery performance and impact

- For the biorefinery to start to be profitable, it is necessary to feed 1-2 t of chips/hour, which means approximately 6,000 to 10,000 t of biomass per year. **The optimal scenario would be to make the biorefinery profitable with small plants, of less than 1 ton per hour**. This would also reduce the costs and impact of transport and open the door to the possibility of the plant being mobile, promoting a decentralized model.

- Within the operating costs of the biorefinery, **the highest cost is the purchase of biomass** (between 40% and 55%), followed by personnel and electricity costs and, finally, maintenance costs.

- Both to improve economic profitability and to reduce the environmental impact of the entire process, biomass extraction operations and its transport should be optimised, which means **strategically locating biorefineries in the territory** and **optimising pre-treatment operations** (storage and second chipping) and the load of product to be processed.

- **Seeking the production of bio-oil from biomass makes sense, from an environmental point of view.** The biorefinery, with a pyrolysis temperature of 400° C, has turned out to be a viable and sustainable alternative: the production of bio-oil, sugars and acids is **3.7 times less impactful than the combined production of the same products through industrial processes**. In terms of CO2eq emissions, **the overall impact is 0.5 kg CO2 eq/kg of biomass input for 1 kg of wet biomass processed in the pyrolysis plant**, with most associated with chipping, followed by forestry work, transport and pyrolysis process.

- Complementing the sale of the products generated with the **possibility of selling CO_2 credits, linked to the production of biochar** as a carbon sink, could contribute to improving the profitability of the biorefinery and its overall impact.

03 DISSEMINATION ACTIVITIES

The main tools used to publicise the project have been:

- Website, newsletters and the presence of the project in social media
- Information panels
- Explanatory leaflets
- Videos explaining the project
- Articles in dissemination publications and scientific journals
- Presence in the media
- Participation in conferences and other local events

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