LAYMAN'S REPORT

LIFE 16 CCM/GR/000044 BIOMASS C+

Low-cost, carbon positive bioethanol production with innovative Green Floating Filters in multiple water bodies

1. What is LIFE Biomass C+?

LIFE Biomass C+ aims to demonstrate improvements in climate change mitigation strategies through the production of sustainable biofuel.

Life Biomass C+ consortium representatives

The project utilises existing and underused infrastructure and water resources (i.e. irrigation channels, ponds, lakes, river arms) to produce zero-input biomass with high starch content, which is then converted into bioethanol and eventually to biofuel.

Green floating filters recently placed in Spain

To achieve this, an innovative technology of Green Floating Filters (GFF) is proposed, by which aquatic macrophyte plants, like *Typha domingensis*, can be grown in multiple water bodies. That way, the project approaches biofuel production from a sustainable perspective, purifying water bodies and absorbing carbon from the atmosphere at the same time.

2. Project motivation

Despite the fact that awareness on climate crisis is increasing, CO_2 emissions keep rising.

CO_2 emissions reached a world record in 2021

Biofuels, such as bioethanol or biodiesel, present several advantages over fossil fuels as they generate fewer emissions. This constitutes them as an interesting source of energy in the times of climate crisis. However, biofuels can have serious disadvantages, as their production demands land use for energy crops (i.e wheat, corn) that often involves deforestation, resulting in biodiversity loss and soil degradation. Moreover, these crops compete with farmland, thus inhibiting food production and leading to an inevitable increase in food prices.

LIFE Biomass C+ addresses these challenges by proposing an innovative method to produce bioethanol from biomass cultivated in water bodies (*Typha domingensis*), which provides a carbon-positive energy balance. This approach has additional positive environmental impacts, such as improving water quality and local biodiversity, thanks to the filtering and decontaminating effect of the cattails' root system.

Furthermore, large-scale implementation of the methodology proposed by LIFE Biomass C+ could also provide an incentive to local economies by offering an alternative source of income from cattail cultivation.

Extensive monocultures for bioethanol production sometimes involve deforestation and other negative environmental impacts.

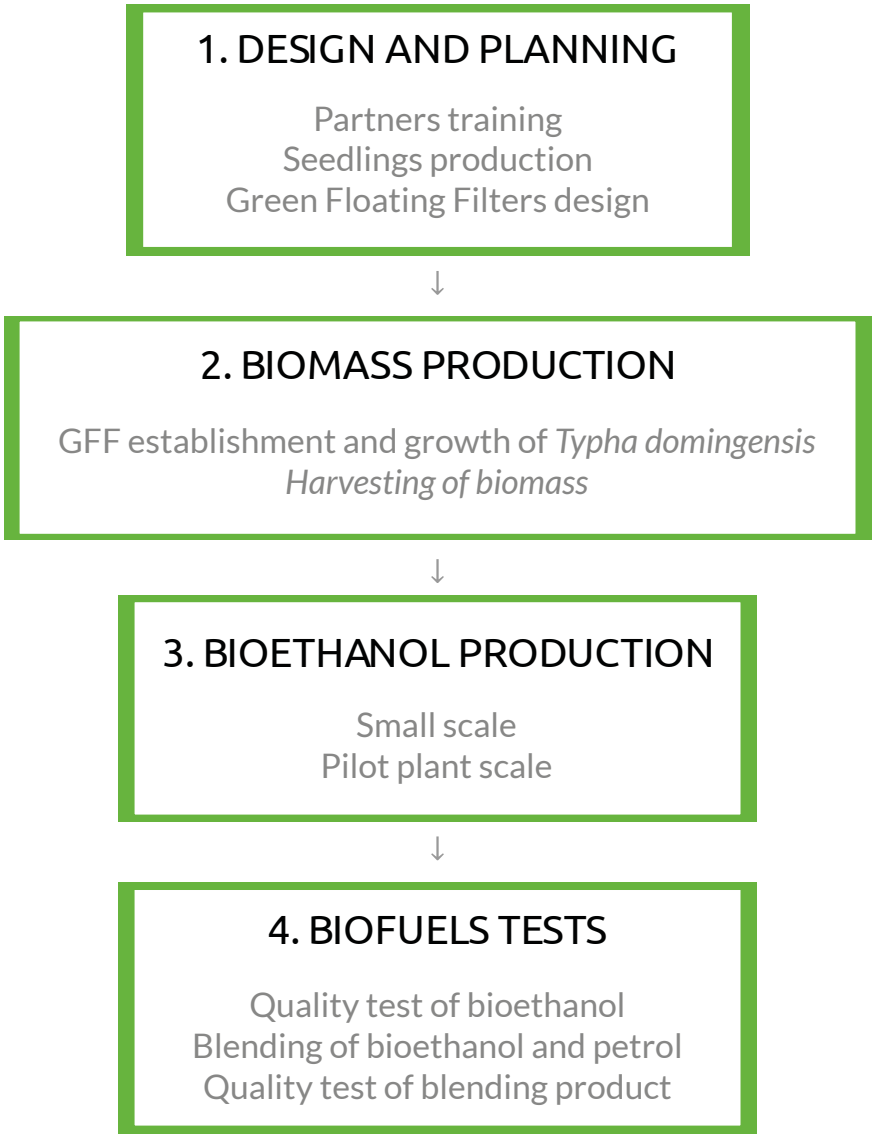
Competition for agricultural land increases food prices

Typha domingensis also has a purifying effect on the water in which it grows.

This approach also increases local biodiversity.

Biomass cultivation in underused water bodies represents a sustainable alternative to land use.

3. Project overview



The project was carried out in Spain and Greece by a consortium of five partners.

OBJETIVES:

1. Provide a carbon positive energy balance and other environmental co-benefits.

2. Develop a clean, dependable method to produce biofuel without utilising agricultural land.

3. Demonstrate the applicability of Biomass C+ on an industrial scale.

4. Demonstrate the potential and cost-effectiveness of this new, close-to-market concept.

4. How was the project carried out?

4.1 Design and planning

The first steps of the project were the design and planning of the cattails production, as well as the training of the rest of the partners. The partner involved in these first steps was the UPM whose main role has been the scientific coordination of activities related to the technology of Green Floating Filters (GFFs) based on cattails (*Typha domingensis*).

- **Training.** This includes partners' training that was carried out at the beginning of the project.

- **Seedlings production.** During the project, UPM produced about 68,000 seedlings of *Typha domingensis* for the establishment of GFFs in Spain. At the same time, more than 80,000 typha seedlings were also produced in Greek nurseries for the local trials and replications. These seedlings were supplied and used in the GFF demonstration sites.

Production of Typha domingensis seedlings

- **GFFs design.** The GFFs design was defined by UPM, while Volterra trialled different materials for the filters.

Trials made with polystyrene.

Trials made with coconut fiber.

Trials with filters made with mycelium

Polyethylene, the material that better worked for cultivation.

4.2 Biomass production

The second step of the project is the implementation of the GFFs in different water bodies and the growth of the *Typha domingensis* for **biomass production**. The establishment of the GFFs in different water bodies, the monitoring of their growth, and later harvesting procedure have been carried out by UPM, CERTH and VOLTERRA.

- **GFF establishment and growth of *Typha domingensis* plants.**

CERTH, UPM and VOLTERRA started the establishment of GFFs in different sites in Spain and Greece. These trial sites were important not only to produce biomass, but also to understand in which conditions the *Typha domingensis* plants would grow better.

Greece:
More than 80,000 individuals of *Typha domingensis* were established in multiple waterbodies for trial and replication activities.

Trial sites
CERTH's team proceeded to establish GFFs in six places in the Region of Western Macedonia. GFFs were tested in physical and artificial lakes, irrigation channels, and in ponds of two natural wastewater management systems.

Replication sites
Eight successful replication activities with stakeholders from different fields were completed. The main stakeholders were Municipalities with artificial lakes and industries of olive processing, brewery and biogas units.

Spain:
More than 68,000 individuals of *Typha domingensis* were established in multiple waterbodies for trial and replication activities.

Trial sites
UPM team was in charge of establishing the GFFs' in Spain. Two trial sites were implemented close to the Comunidad de Madrid. One of the sites was set in the UPM facilities as they assumed the responsibility of implementing a contingency plan for biomass production.

Replication sites
Volterra carried out the replication activities. The GFF's were established in three different locations throughout Spain. The main stakeholders were municipalities and animal farms interested in the cleaning capacity of the filters.

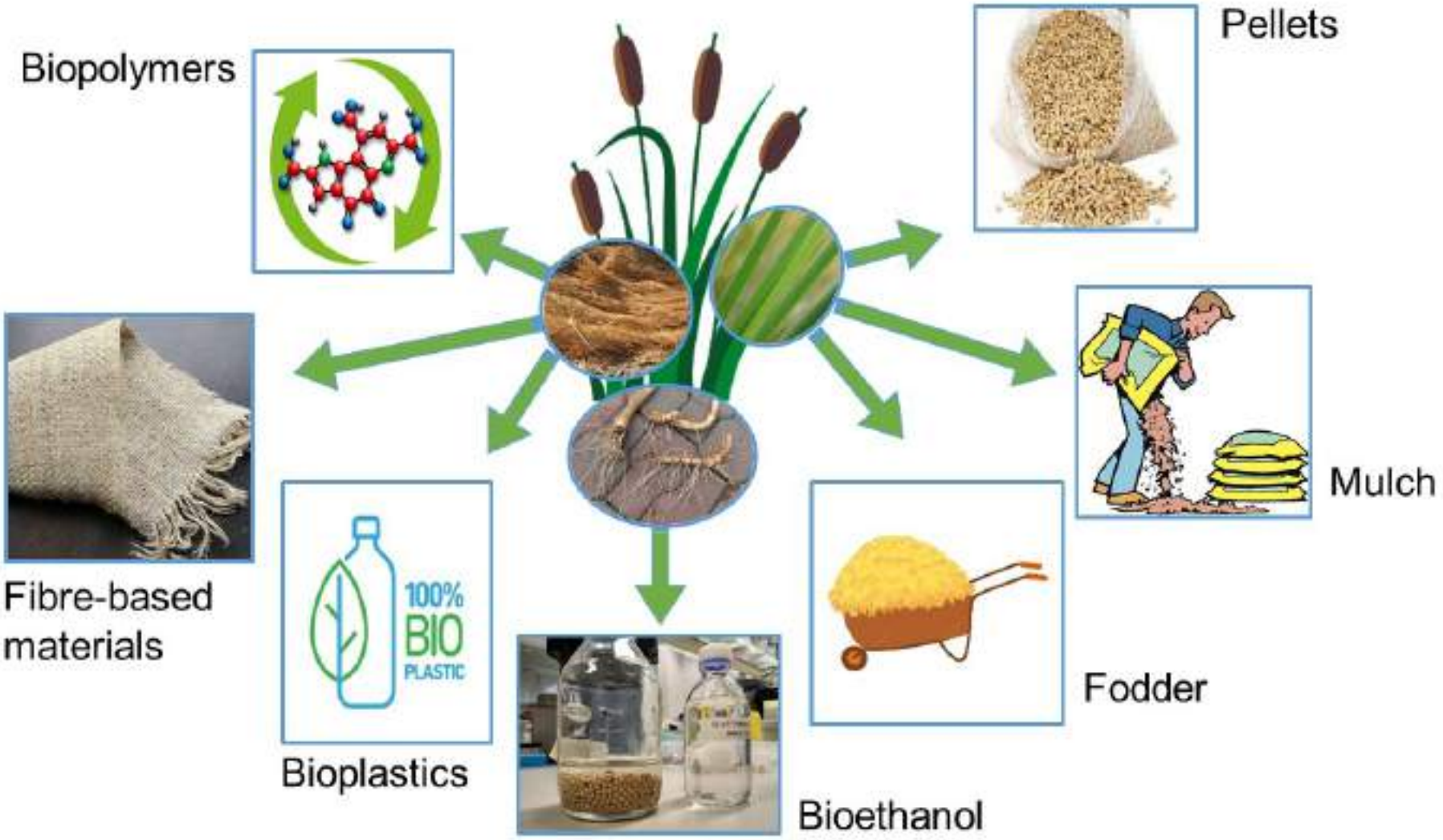
Growth of Typha domingensis in GFFs

- **Biomass harvest.**

Once the cattails have completed a yearly cycle, the biomass is ready to be harvested. During the project, the biomass has been harvested several times.

Cattails biomass can be separated into emerged (stems, flowers and leaves) and submerged (roots and rhizomes). This project focuses mainly on submerged biomass, which is composed of roots and rhizomes with high starch content. This submerged biomass will be later transformed into bioethanol.

Regarding aerial biomass (emerged), alternative uses for the *Typha domingensis* have been studied by CERTH and UPM. The aerial biomass has been analysed for energy properties, fiber content and fiber composition, and then it was tested as pellet feedstock and phytodepuration and phytoremediation abilities.



Crop products of Typha domingensis grown in GFFs: emerged biomass (dry aerial biomass) and submerged biomass (roots + rhizomes).

4.3 Bioethanol production

The third step of the project is the conversion of harvested biomass (rhizomes and roots of *Typha domingensis*) to bioethanol. The conversion of the biomass into bioethanol was done by CARTIF.

CERTH has operated on a smaller scale, developing an integrated model for bioethanol production based on a two-stage saccharification pathway. Simulation results proved that the bioethanol production yield could be quite high using *Typha* biomass.

Biomass shredded to the appropriate particle size

Hydrolyzed biomass

Fermentation broth

Bioethanol resulting from the whole process

CARTIF carried out experiments at a pilot-scale plant for the conversion of harvested biomass to bioethanol in continuous, fully automated bioreactors from 1-200 L capacity, including a self-designed 200 L multipurpose bioreactor, which can be used in batch and fed-batch operation mode for pre-treatment of lignocellulosic biomass or microbial cultivation.
Succesfully conducted trials replicated the full bioethanol production process, including biomass pretreatment hydrolysis (chemical and enzymatic), fermentation of the resulting hydrolysate, phase separation, bioethanol purification and bioethanol dehydration. It was the first time an experiment of this kind was performed at this scale.
5 L of bioethanol 98% (v/v) were produced after purification and dehydration, proving the concept is achievable at an industrial scale.

4.4 Trials of Biofuel obtained

Bioethanol samples, produced using both laboratory and pilot scale reactors at CARTIF's facilities, have been certified by HELPE Lab to the European quality standard EN 15376 (Automotive fuels - Ethanol as a blending component for petrol - Requirements and test methods). Bioethanol samples have been shown to be on specification and suitable for blending with petrol. Following this, bioethanol-petrol blends were produced in the Lab and certified to the European Standard EN 228 (Automotive fuels - Unleaded petrol - Requirements and test methods) to prove that indeed they fully comply and are suitable for Petrol engines.

Finally, a quantity of bioethanol produced using the pilot scale reactor at CARTIF will be used to feed the ETBE and TAEE (Ethyl t-Butyl Ether and t-Amyl Ethyl Ether) production units currently operated at Helleniq Energy facilities.

Bioethanol quality control

5. Life cycle analysis and carbon sequestration

Regarding the sustainability of the Biomass C+ concept, an LCA methodology was applied in order to estimate the overall environmental footprint. For this reason, a number of pathways was examined based on the production of the end-product.

In specific, for the utilization of aerial part, the pathways for production of pellets, animal feed and bioplastics were investigated, while for the underwater part, the bioethanol production and bioplastic production were examined. In all the scenarios, a comparison with conventional fuel and products was carried out leading to avoided CO_2eq emissions. In addition, BIOMASS C+ gave emphasis on the efficient use of resources. For example, no conventional fertilizers were applied, while the GFFs have the potential to be further recycled leading to additional saving emissions. Regarding the Typha plant itself, it was measured that it can capture more than 6 kg CO_2 / m2 GFF · year, depending on the climate profile of the demo site.

To conclude, by taking into consideration the use of the end product, LIFE BIOMASS C+ leads to production of sustainable production of fuels and bioproducts proving negative emissions in the all targeted pathways.

6. EU policies and circular economy

By 2030, the EU aims to increase the share of renewable energy in transport to at least 14%, including a minimum share of 3.5% of advanced biofuels. However, one of the main concerns of the EU is the feedstock production expansion in areas with high environmental value. LIFE Biomass C+ solves this issue by implementing feedstock in water bodies with high content of organic matter or nutrients.
The production of biofuels is not the only objective of this project, the GFFs are a multifunctional tool that can contribute to a circular economy while decreasing the CO_2 released into the atmosphere.
The establishment of the GFFs in water bodies is an efficient method to clean polluted waters, while at the same time creating feedstock and material for added value products. The EU's recently published Commission Communication on Fertilizers recognizes the need to ensure better access to organic fertilisers and nutrients from recycled water streams. This document also encourages the use of certain animal by-products as feedstock to enhance circularity and highlights the need to develop efficient methods to recycle nutrients from organic waste.
The implementation of Green Floating Filters can aid the achievement of different EU objectives that are needed to promote the concepts of circular economy and renewable energy.

7. Conclusions of the project

1. The best material for the GFFs is EPE (Expanded polyethylene). This material can be reused several times and it facilitates the harvesting procedure of the submerged and aerial biomass.

2. The technology of GFFs based on cattails (*Typha domingensis*) is applicable to produce biomass in eutrophic water bodies not competing with agricultural land.

3. There is a relationship between GFFs performance and water quality.

4. Maintenance is needed for the GFFs. It is indispensable to establish them in water bodies that do not dry out.

5. Two crop products can be obtained: emerged biomass, which is lignocellulosic, and submerged biomass, made of roots and rhizomes, which is mainly amylaceous.

6. The aerial part is where the plant stores the contaminants, proving its phytoremediation capacities.

7. Submerged biomass has been transformed into biofuel. Results proved that the bioethanol production yield could be quite high using *Typha* biomass.

8. The production of biofuel can be done not only on a lab scale but also on a pilot scale, making the project scalable and profitable.

9. Bioethanol samples can be mixed with petrol and used by Helleniq Energy.

10. The proposed technology can contribute to mitigate/avoid carbon dioxide emissions by fixation of carbon in biomass and without using land.

8. Dissemination activities

The work and results achieved by the project have been periodically disseminated both through publications in different media and through different events, always with the aim of increasing knowledge about sustainable biofuel production and climate crisis.

It is estimated that in total the dissemination work reached about 4100 people, distributed among the website, the Facebook page, the YouTube channel, the mentions on Instagram and the different online and on-site events carried out, Since 2017, LIFE Biomass C+ has also been mentioned a total of 36 times in different Greek and Spanish press media.

Networking with 6 different LIFE projects, ranging from knowledge exchanges to joint tests on filter materials and search for appropriate enzymes to degrade biomass.

The project was presented to local communities through 7 events attended by high school and college students, irrigation communities, farmers and the general public.

Two technical seminars, one in Avila, Spain and the other in Amyntaio, Greece, were successfully held.

In addition, 7 meetings were held with various stakeholders, including decision makers, academics/researchers, and representatives of various companies.

Biomass C+ was also present at 7 international conferences in 4 European countries. These events were a good opportunity to disseminate the environmental benefits of the project and its interest in the industrial biofuels sector.

LIFE Biomass C+ meets TRIMING project

Presentation of LIFE Biomass C+ to Typha project researchers from Nigeria, USA and Spain.

Collaboration with LIFE MycoRestore for filter material testing

High school students visiting the UPM Agro-energy facilities.

Practicum students learning how to plant Typha domingensis

Participation in the Technical Seminar of LIFE The Green Link

9. The LIFE project

LIFE is the EU´s financial instrument supporting environmental and nature conservation projects throughout the EU. Since 1992, LIFE has co-financed more than 5,500 projects, contributing approximately 5,000 million euros to the protection of the environment.

http://ec.europa.eu/environment/life/

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% EU contribution: €1,125,115
Duration: 01/09/2017 – 31/12/2022
Contact:

https://biomasscarbonpositive.eu/

info@biomasscarbonpositive.eu

10. Partners

CERTH
CENTRE FOR RESEARCH & TECHNOLOGY HELLAS

Project leader
Development of protocols for trials, lab testing, pre-treatment procedures, dynamic modelling of fermentation.
Process modelling for the scale-up activities, LCA & LCC modelling.
Execution of trials and replication in Greece
Dissemination of results
Awareness-raising and networking

[CENTRO TECNOLÓGICO] CARTIF

Building and testing of scaled-up system for conversion of Typha starch into bioethanol (proof of concept at industrial level)
Dissemination of results

Proof of concept of GFFs.
Responsible for plant production activities.
Implementation of contingency plan.
Technical management.
Dissemination of results.
Awareness-raising and networking.

Blending of ethanol with gasoline for biofuel.
Replication market uptake.
Dissemination of results

Development prototype floating trays.
Tech. assist. Demonstration trials.
Responsible for replication trials.
Dissemination and communication.
Awareness-raising and networking

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