(Projects funded under the Call 2014 onwards must use this format)

LIFE Project Number

LIFE18 ENV/SI/000056

Final Report

Covering the project activities from 1st July 2019[1] to 31st Dec 2022

Reporting Date[2]

31st Dec 2022

LIFE PROJECT NAME or Acronym

LIFE BioTHOP

[1] Project start date

[2] Include the reporting date as foreseen in part C2 of Annex II of the Grant Agreement

Data Project

Project location:	Czech Republic, Germany, Portugal, Slovenia, Spain
Project start date:	01/07/2019
Project end date:	30/06/2022 **Extension end date:** 31/12/2022
Total budget:	1,919,901 €
EU contribution:	1,055,945 €
(%) of eligible costs:	55.00 %

Data Beneficiary

Name Beneficiary:	Slovenian Institute of Hop Research and Brewing
Contact person:	Dr Barbara Čeh
Postal address:	Cesta Žalskega tabora 2, 3310 Žalec, Slovenia
Telephone:	386 3 712 1612
E-mail:	barbara.ceh@ihps.si
Project Website:	https://www.life-biothop.eu/

*Biodegradable BioTHOP PLA twine for hop plants developed by **Lankhorst** in collaboration with **IHPS***

*Modified fibres from hop waste residues - extracted by **Zelfo Technology***

*Bio-composite formulation from hop waste residues developed by **TECNO***

*First generation of biodegradable planting pots for hop-growing sector developed by **TECOS***

*Design for biodegradable bottle packaging, prepared by **TRIDAS***

*Hop biomass compost with biodegradable BioTHOP twine – done at **IHPS***

1 Table of contents

2 List of key-words and abbreviations

GHG – greenhouse gases

Hop biomass – hop biomass after hop cones harvest (leaves and bines, intertwined with twine, which was used as support for hop climbing plants during the growth season)

IHPS – Slovenian Institute of Hop Research and Brewing

LEP – Lankhorst Yarns (project partner)

PLA – polylactic acid

PP – polypropylene

TECNO – Tecnopackaging (project partner)

ZT – Zelfo Technology (project partner)

3 Executive Summary (maximum 2 pages)

The main objective of the project LIFE BioTHOP was to introduce circular economy in hop production. The goal was to replace polypropylene (PP) twines used on the hop fields as hop plants support with a biodegradable twine made of polylactic acid (PLA). By using a PLA twine, the hop plant biomass after harvest (leaves and stems, intertwined with twine) can be used as material for composting and to produce biodegradable products (bio-composites, planting pots, and bottle packaging), which is beneficial for economy. In addition, the agro-waste is drastically reduced, what is significant benefit to environment. The goal is to completely upcycle the hop waste.

The project was coordinated by the **Slovenian Institute of Hop Research and Brewing (IHPS)** and consisted of 6 partners from 5 EU states. Portuguese **Lankhorst Yarns (LEP)** was in charge of development of on-site compostable PLA twine for hop-growing sector. German **Zelfo Technology (ZT)** was developing a technology to reengineer hop waste fibres to be usable in fibre pulp moulding applications and extrusion compounding transforming processes. **TRIDAS** from Czech Republic was transforming hop fibres into pulp moulded 100 % biodegradable bottle packaging. Spanish **Tecnopackaging (TECNO)** was leading the development and production of hop fibre PLA compounds and replication. In Slovenian company **TECOS** they made plating pots for horticulture. The 3rd Slovenian partner was **Development Agency Savinja** that unites 6 municipalities of Lower Savinja Valley, demo region of the project and they disseminated the results.

Preparatory actions A have been successfully completed on time. We pre-tested the existing PLA twine to get information which modifications are needed to develop twine, which will resist hop plants biomass during the season, spraying and to be on site compostable as well (Sub-action A1.1). We tested the BioTHOP PLA twine in 2019 on 25 ha of hop fields by IHPS with participating hop growers in the demo region. In August/Sept 2019 IHPS collected 375 tons of biomass after harvest (Sub-action A1.2) for first demo composting and first delivery of hop biomass to ZT for fibre extrusion (Sub-action A1.3). ZT reviewed the necessary fibre processing steps required to modify hop/PLA residual materials for both plastics and natural fibre moulding technologies. By this, we were able to set the guidelines for future project implementation which were written in three deliverables.

The implementation actions started 3 months after the project start date. IHPS and LEP were focused on PLA twine modifications for hop growing sector and compostability of the biomass intertwined with PLA twine. Overall, 930 t of hop biomass were composted during the project. **Technological guidelines for proper on-site composting** started to be prepared by the first year's results and before the end of the project, the IHPS finished complete guidelines which can be used by farmers.

In Sub-action B2.1, LEP was modifying the existing PLA twine after first results from the 2019 season. IHPS made testing with the modified twine in every season. Several different types of BioTHOP modified twine were installed overall on 62 ha, focusing on three focus areas, namely strength, efficiency of installation and removal, and compostability. This allowed LEP to rationally design a stronger, leaner twine with a robust behaviour in the crops and a good efficiency during the harvesting operation. Composting was done without difficulties. There were some problems with twine at some growers, it didn't cut well on the harvest machine. The final version of the twine was made stiffer, and was cut on the harvest machines without problems, so it was marked as the most optimal twine, made within the project and is now available on the market. IHPS also made guidelines for maintenance of the harvest machine during harvest, which will help hop growers to harvest hop with PLA twine without difficulties. The twine also received biodegradability certificate (deliverable B2.D3 Certification that produced BioTHOP twines are biodegradable in industrial and if proven possible with an improved recipe, home composting).

Hop biomass transformation into fibres was the task for ZT, experienced in ligno-cellulosic fibre engineering from various agro wastes (Sub-action B1.2). It was done in three seasons. TECNO, TECOS and TRIDAS were required to further define any fibre & processing improvements as required. Processing the input material in two different forms for both end user requirements gave two outputs: **fibres for production of fibre-reinforced composites** by TECNO (in Sub-action B1.3) and **fibres that were used at TRIDAS for adaptation of hop waste fibre crumbs for use in the pulp moulding process** (in Sub-action B3.1).

The main objective of the Sub-action B1.3 was to use the hop fibres to produce **hop-based composites** by blending them with other commercial biopolymers to obtain natural fibre reinforced composites. In order to achieve the desired properties various formulations for injection purposes were tested by TECNO. The main output of this action is the **up-scaling of the best performing formulations**, which allowed TECOS to produce **the first prototypes of injected planting pots** in Sub-action B4.2. The best performing formulations studied have been adapted to the injection process in parallel during action B4.1 with the feedback provided

by TECOS. TECNO worked with the new tailored composite material based on the engineered hop fibres and biodegradable PLA matrixes supplied by TECNO's new material. The formulations were in process of testing for mechanical properties (Sub-action B4.1) as well as in testing for its suitability for planting pot production (Sub-action B4.2). The resulting demonstrators were validated for the cultivation of hop seedlings by IHPS and test composted at local Slovenian composting plant. The planting pots also received positive evaluation on material characterization, disintegration, ecotoxicity and compost quality tests and are in compliance with EN 13432 limits (the criteria for the industrial compostability of packaging- deliverable B4.D3 Certification that produced BioTHOP planting pots are biodegradable/industrially compostable).
In Sub-action B3.1 there were some problems at TRIDAS with fibre, as it was not clean enough and the fibre length was not regular for adaptation of hop waste fibre crumbs for pulp moulding process. The solutions were found in communication with ZT. With the second material batch (cellulose twine + hop fibres) better results were obtained to find out perfect mix of hop waste fibre mixed with pulp. The best formulation was proved to be 50% of cardboard and 50% of ZT material batch. The **bottle packaging** was tested for biodegradability and proved to be biodegradable (deliverable B3.D3 Certification that produced BioTHOP trays are biodegradable.)
Replication and transferability (Action B5) of the project results were started in 2020. The replication focused on twine (it was replicated in different regions of EU and Serbia, also used in greenhouse and outdoors tomato, peppers and eggplants production, high bean production and high bean production on hop trellis), we have made guidelines for hop growers from other regions for use of PLA twining technology (deliverable B5.D1 Guidelines for replication the BioTHOP twining methodology in other EU regions). Biocomposites and fibres, made within project, were used to make different products, all together 12 replicated products were made (coffee capsules, harvest machine fingers protection, paper, PLA panels, etc.). Guidelines for use of these materials were also made (deliverable B5.D2 Guidelines for transferring the BioTHOP materials to other industrial sectors). Industrialisation plan was made within this action (deliverable B5.D4 Final report on industrialisation plan of the resulted BioTHOP solutions).
Action C1 included key indications for a successful project execution and completion, project monitoring and impact evaluation (deliverable C1.D3 Indicators for the socio-economic impact of the project). Both were in the role of the effective measure for the correctly assigned project progress and for timely perception of any potential delays, technical and/or economical conflicts, which could occur during the implementation of the project. As required, the environmental indicators of the project (Sub-action C1.3) were followed regularly. In order to prepare the market uptake plan (C2.3), coordination with Close to Market (C2M) EASME team was in progress and it involved whole consortium. Conclusions and Recommendations of the project (C2) were based on the monitoring. The evaluation compared expected objectives with the progress results of the preparatory action (A1) and implementation actions (B1-B5) to evaluate the project's outputs and the benefits of its products.
This action was completed with the analysis of the socio-economic impact of the project, making new policy recommendations by incorporating the good practices, and the best ways predicted to protect the BioTHOP's results in order to ensure an effective collaborative strategy to commercialise the generated products and services. The main objectives of the communication strategy (D1) was to ensure a proper and correct delivery of information, and sufficient impact of the project's development & results. We also released the influential results to the targeted audiences, with the use of adequate media and interactive communication channels (deliverable D1.D5 Layman report released). All partners also disseminated the project results at local, regional and international level and boosted the involvement of stakeholders during the project execution. Actions contributed to raise awareness among the citizens, municipalities, agro cooperatives, research institutes, government institutions, etc. We prepared different events / meetings with stakeholders and hop growers of the Lower Savinja Valley. We issued 43 videos on YouTube and have many followers on Instagram, LinkedIn and Facebook pages. We published professional articles (17) in magazines and articles in newspapers (28). Networking with other LIFE or NON-LIFE projects were frequent. We regularly updated and published news and data on the project web site: www.life-biothop.eu and social media (FB, Instagram, YT, LinkedIn).
There were some problems with COVID 19, some tasks were slightly delayed because of that, that's also the reason why we proposed for the amendment of the project. At the end, all planned deliverables and milestones were done and reached as planned. Within Action E1, we prepared partnership agreement, which was signed and is followed by all partners (deliverable E1.D1 Signed Partnership Agreement).

4 Introduction (maximum 2 pages)

4.1 Background, problems and overall and specific objectives

The amount of plastics used in agriculture worldwide is estimated to be 2% of the global production, therefore Jansen et al. (2019) assumed the consumption of 6.96 million tons in year 2017. The plastic is mostly used in greenhouses, 'polytunnels', mulch film, netting, piping, silage wraps, twines, ropes and pots, plastic reservoirs/irrigation systems and packaging of agricultural products. When agro-waste is mixed with plastics, it becomes contaminated and its use is limited. The waste hierarchy of the Waste Framework Directive (Directive 2008/98/EC) gives biological treatments of bio-waste priority over combustion and encourages transformation of agriculture waste into a compost. The only way to efficiently use agro-waste is to stimulate bio-waste recycling and/or separate collection so that the bio-waste is composted or anaerobically digested. Bioplastics in the agriculture and horticulture sectors are a great example for the challenges and opportunities through the convergence of circular economy and bioeconomy.

The world hop production in year 2020 exceeded the acreage of 62,000 ha, with about 30,000 ha in Europe with leading countries Germany (20,706, ha), Czech Republic (4,966 ha) and Poland (1,791 ha) (IHGC Report, November 2020). A representative hop plant weights about 11 Kg and only 1/3 is consists of cones that are used for brewing industry. Beside cones, the stems and leaves are also harvested and these presently have no particular end of life value due to plastic twines that are mixed within the organic mass. Hop training systems in Europe are at present still based on wire in combination with polypropylene (PP) twine namely, these are attached to wire systems which are usually suspended about 6-7 meters above the ground on poles. Roughly 5.5 dt/ha of steel barbed wire, or alternatively 45 km of PP twines/ha for twining, each season. In regard to the plastic-based system this results in consumption of 62 Kg of PP per ha, therefore about 91 tons of PP per year in Slovenia alone (1,480 ha in year 2020) intertwined in organic mass of 15 t/ha – 22.200 tons of such biomass each year in Slovenia alone. These practices are far from the EU's environmental objectives, since the after-harvested biomass cannot be properly composted, recycled or landfilled.

Burning hop biomass

with polypropylene twine

Circular economy in BioTHOP

The project BioTHOP aimed to reach 100% elimination of fossil-based plastics twine, which are currently used as hop plants support during growth by introducing compostable polymer twines based on polylactic acid (PLA). The PLA version delivers the same characteristics as PP twines, but is biodegradable and on site (on farm) compostable, enabling an environmentally sustainable hop industry. The BioTHOP team wanted to modify and test the viability of various BioTHOP conceived PLA twines for future use in the hop industry. The objective was to deliver mechanical characteristics equal to traditional PP twines, improved resistance towards the weathering conditions and to improve on site use for farmers.

Besides introducing this twine, composting tests with hop biomass were planned in order to find the most appropriate technological guidelines for composting on farms, which will result in fine degraded, quality organic matter (compost) with completely degrade BioTHOP twine to CO_2, water and organic mass. Such compost can be returned to the arable land allowing closure of the 'material use' circle on the farm – by returning organic matter and nutrients back to the soil.

BioTHOP was also aimed to work on feasibility of turning the harvested hop waste into new valuable feedstock resources, namely: pulp fibre, reinforcing filler additives and biocomposite compounds, via various

manufacturing technologies (pulp moulding, injection moulding & extrusion compounding). In regard to plastics-based end products, this was planned to be achieved by initially converting the hop waste into secondary raw materials using ZT fibre engineering technology, followed by biocomposite plastics masterbatch production delivered by TECNO and by biodegradable and compostable injected product production. Through this process BioTHOP project wanted to prove that a complete reduction of agro waste is possible. In regard to pulp moulded products 100% biodegradable bottle packaging was produced by TRIDAS, again originating from engineered hops biomass supplied by ZT. In summary: BioTHOP wanted to produce and validate economically-competitive products made of recovered hop wastes for packaging and horticulture sector.
The objective was to contribute to the Commission's target of banning recyclable material landfills by 2025. With biodegradable plastic alternatives, we can protect the rural landscape against pollution, contributing to more sustainable and prudent use of hop biomass, either with an option of on-site composting or by its conversion to fibrillated feedstock for novel bioproducts. The planned changes in the hop industry were planned on three-fold level: (1) reviewing other transformation processes (extrusion blow moulding), (2) new applications (protective agricultural bio-films), and (3) the spread of transregional (BioTHOP) practice which will be spread along the 20 Member States of the International Hop Growers' Convention (IHGC). The demonstrative replication will be implemented in at least 5 other EU States: Austria, Czech Republic, Croatia, Spain & Germany.

4.2 Expected long term results

BioTHOP introduced a new circular economy model for the hop industry – with improved waste management that combines bioplastic twining materials and cascade valorisation of hop crop waste for composting and for the production of new products in packaging & horticulture. By introducing a compostable twine, the practice of hop growing was made more sustainable as a result of the recyclability / upcycling of the remaining crop harvest residuals. In this way, hop-growers were given an opportunity to decide how they want to redirect their side products after the harvesting process based, letting the market forces bring a sustainable business case for the hop crop's by-products. IHPS works hand in hand with hop growers on a daily basis to improve general standards of practise and the awareness of sustainable methods of production as its regular work; IHPS will work on implementing BioTHOP solutions into hop growers practise also after the project ends. The long-term result is a cleaner environment resulting from an economically sound and sustainable 'closed circle' model.
The Replication and Transfer of the results of BioTHOP was implemented individually by the consortium core and external members (LOIs), both jointly through the communication and multiplier dissemination activities at the project local level and on the EC level though the synergies with other EU-funded projects and bio-materials initiatives running at EU and national levels. The coordinated actions run among the entrepreneurs, public authorities, associations, research, education and training organizations. These were designed to stimulate local economies and meet the growing demand for locally, sustainably, produced products. BioTHOP concepts were communicated on broad scale, ensuring a deep and long lasting effect of the principles embedded in the project.
New agricultural practices can eliminate hop crop wastes, which when the targeted scale of 100 % implementation, a complete reduction of CO_2, CH_4, N_2O, CO, NMHC, NO_x and SO_2 emissions, currently evoked by sometimes still uncontrollable burning of these agro-wastes on site. In the long term, it is intended that BioTHOP is a model for all hop growers in EU to reach zero waste to landfill, decrease pollution and to reduce dependency on limited fossil resources, ultimately delivering a positive effect on their business on an economic and societal level.
A further long-term result is also innovation and cost-reduction in the bioplastic sector. Bioplastics are a family of materials that offer advantages over traditional polymers, with a major role to play in the circular bio-economy. Hop fibres can be used as natural reinforcements, to increase the mechanical properties of the biopolymers, decrease their cost, and enhance biodegradability properties. It is intended that BioTHOP materials will be effectively used in multi mass production sectors. Production processes are scalable and reproducible for the extraction and conversion of other agro-wastes. The circular economy in agriculture is enhanced by closing the loop regarding biomass in the hop sector, BioTHOP enhanced sustainable farming, optimised resource efficiency on the farm and helped hop growers towards reducing emissions from agriculture.

5 Administrative part (maximum 1 page)

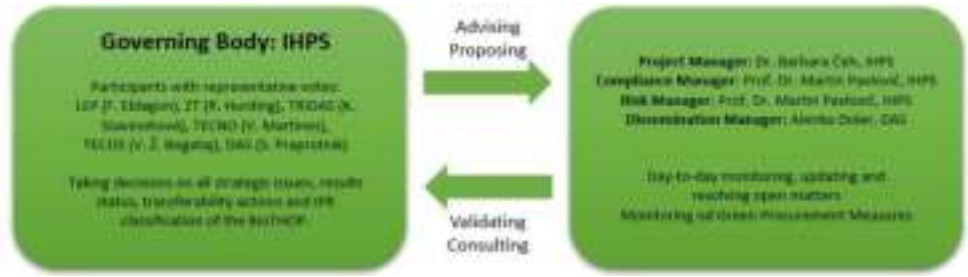
The project was coordinated by the Slovenian Institute of Hop Research and Brewing (IHPS) and consists of 6 partners from 5 EU states. All partners had an important role, each benefiting the project according to their individual area of competence.

IHPS as coordinating beneficiary dealt with the management, reporting and monitoring of the technical progress of the project, as well as on dissemination and KPI indicators. It was responsible for technical work in Sub-Actions: A1.1, A1.2, B1.1, B2.2, and together with DAS for Sub-Actions B5.1, B5.2. DAS stimulated active hop-growers involvement, disseminated, exploited and transferred the project results regionally & internationally and worked on socio-economic topics and indicators. LEP was responsible for development of on-site compostable PLA twine for the hop-growing sector - for Sub-Action B2.1. ZT was responsible for re-engineering of hop waste fibres for use in fibre pulp moulding applications and in extrusion compounding/transformation processes - for Sub-Actions A1.3, B1.2 and B3.1. TRIDAS lead the pilot action on hop-waste fibre transformation into pulp moulded packaging products. It was responsible for Sub-Action B3.2. TECNO was in charge of the production of hop fibre PLA compounds for pilot injection moulding purposes & replication. It was responsible for Sub-Actions B1.3, B4.1 and B5.2. TECOS lead the pilot action on injection moulding of plating pots for horticulture. It was responsible for Sub-Action B4.2.

5.1 Description and schematic presentation of the working method

IHPS attended the LIFE Welcome Meeting in Brussels in Autumn 2019. The Grand Agreement was signed at the end of August 2019. We had 7 SC meetings (July 2019, Dec. 2019, June 2020, Dec. 2020, June 2021, Dec. 2021, June 2022). Partnership Agreement was signed by all partners. We had 4 Monitor Visits with external monitor Mr Pečenko and 1 with Mr Politano (Dec. 2019, Sept. 2020, Oct. 2021, Nov. 2022). All partners opened cost centres for the EU LIFE18 ENV/SI/000056 BioTHOP, except ZT - their accounts are administered manually.

The Steering Committee Board consisted of all partners' representatives: Barbara Čeh, IHPS, Fernando Eblagon, LEP, Richard Hurding, ZT, Klára Stavinohová (2019-2021) and Kristina Suková (2021-2022), TRIDAS, Vanesa Martinez, TECNO, Vesna Žepič Bogataj (2019-2021) and Peter Fajs (2021-2022), TECOS, Stojan Praprotnik, DAS. The management of the project was carried out in compliance with project application, Grant and Partnership Agreements. The project team members worked together and / or independently on their assigned activities and in general the consortium was well defined, balanced and working well. The project team consisted of 56 staff members all together. Day-to-day communication among management structures, Technical Action Leaders and the project manager was good. The Consortium has developed close cooperation using various communications media such as e-mail, telephone, web meetings, etc. In case of difficulties, partners informed the lead partner without delay in order to jointly find solutions. In summary, communications between the parties were functioning well.



5.2 Communication with the Commission and Monitoring team

All partners prepared written reports on technical progress of the activities and financial reports every three months and send them to the project manager Barbara Čeh, IHPS. A joint consortium written report on progress of the project was submitted to the external monitor (Mr. Nikolaj Pečenko) afterwards. The project manager was also in regular contact fielding questions and giving advice and suggestions as required. She was also in contact with the representatives of project co-financers (Ministry of the Environment and Spatial Planning, municipalities of Lower Savinja Valley and Association of Slovenian Hop Growers).

5.3 Changes due to amendments to the Grant Agreement

From August 2020, there is new legal representative at the coordinating beneficiary IHPS, Mr. Bojan Cizej, new director of IHPS. BioTHOP got extension of 6 months to complete the tasks because of the COVID 19 pandemic within the same financial frame.

6 Technical part (maximum 25 pages)

6.1 Technical progress, per Action

ACTION A1 Field tests with current PLA Twine and hop waste preparation

Preparatory actions included 3 sub-actions in the first half of the year of the project. Their purpose was to evaluate the unmodified twine for hop support and to collect and evaluate the biomass after harvest.

Foreseen start date: 1/07/2019	Actual start date: 1/7/2019	STATUS: completed
Foreseen end date: 31/12/2019	Actual end date: 31/12/2019	

A1.1 Field test with current PLA twine

Activities, progress and results

LEP produces PLA twine that is used for tomato in greenhouses, which IHPS tested in the hop fields in 2019. The demo region of this test was 25 ha of hop fields in Lower Savinja Valley by 13 hop growers and IHPS (Figures 3 and 4). Different twine types were tested to see if the twine is suitable for hop support and how the twine alters the process of hop harvesting. IHPS performed regular observations of the twines performance in the field, reported their finds and held discussions with LEP by video and telephone, as well producing written reports. The procedure of harvesting was tracked and twine sampled. Samples of all tested types of PLA twine were taken by IHPS from the field just before the hop harvest and sent to LEP for further analyses. Information gathered in this exercise formed the base for Action B2.1.

Milestone A1.M1 'Introductory list of requirements for modified PLA twine prepared and shared with consortium' was reached in Sept. 2020 (on time) - prepared and shared with Consortium.

BioTHOP twine type 400 in 2019 on the field

BioTHOP twine type 700 in 2019

Problems

This action was completed without problems.

Deliverables

✓ A1.D1 Requirements and limitations over current PLA twine for hop growing sector

A1.2 Collection of hop waste

Activities, progress and results

Different ways of hop waste collection were explored by IHPS:

- Option 1. Post harvest hop biomass was separated into leaves and 15 cm long cut stems in the harvest machine itself,
- Option 2. The leaves and stems were shredded into +/- 3 cm fragments and collected together,
- Option 3. (not widespread practice) Collection of separated leaves and uncut stems.

The complete separation of leaves from stems is not possible.

On the 11th September, after the hop harvest, **3.5 tonnes of hop biomass (stems), intertwined with the PLA twine, was sorted by IHPS to be transferred by truck to partner ZT to Germany**. With the completion of this task, **milestone A1.M2 was reached** on time. Besides hop biomass interlaced with BioTHOP PLA twine, an additional sample of biomass containing sisal twine was collected separately. This was needed for the first trials at TRIDAS in order to do step by step technological experiments (initial tests were with fibres without PLA). 100 tonnes of the hop biomass after harvest (leaves and stems, intertwined with twine) was sorted to prepare for the composting experiments, which started at IHPS in September within Sub-Action B1.1., also all the rest of the produced biomass (270 tons) was composted by farmers themselves.

Problems

The fresh harvested biomass that was shipped to ZT by truck heated up and unwanted degradation of material occurred. However, with careful selection of the usable biomass/twine there was enough good material to produce sufficient fibres for all planned activities that followed this action.

Conclusions / solutions: The post-harvest material (hop biomass with twines) should preferably be composed of stems with limited quantities of leaves and must be dried before such long distance shipping. Alternatively the extrusion processing of fibres should be done on site where hop biomass is located (on-farm or somewhere near). The biomass has to be clean, without foreign materials.

Deliverables

✓ **A1.D2 Protocols for collection and sorting of hop waste defined**

A1.3 Protocol definition on hop waste modification

Activities, progress and results

ZT received 3.5 tonnes of hop biomass that was shipped in a standard 'ex works' condition from IHPS. A percentage of this material proved to be usable, using ZT reduction and processing systems. Important first assessment of the processing and resulting fibre mass was achieved. Initial results proved the outline suitability for use in pulp moulding (TRIDAS). In additional benefit in the form of a bio-extract also emerged during the biomass processing session. ZT salvaged enough material to produce a first batch of fibre, which could be processed for use in pulp moulding. Steps involved manually cutting the PLA strings in order that the entire batch could be granulated before processing. As a result, a total of 10 Kg dry weight of PLA/hops fibre was available for test purposes in first phase. Liquid extracts were also taken from the finished material and were examined for further income streams. Further work was done with approximately 25 Kg (fresh) material to produce material for plastic compounding by TECNO. ZT contacted Pierret material reduction technologists in Belgium. They ran a short trial with the 25 mm fibre to test their guillotine system, which was successful. ZT testing a sink/swim system to remove the metal clips and similar components (which caused some damages on ZT machines at first) etc. was successful. Enough extra fine material was produced to enable TECNO to produce their first two types of Hops/PLA based granulate within the Action B1.3. ZT had access to further needed hop biomass after harvest (without PLA) and processed this for TRIDAS who wished to trial the hop biomass after harvest without PLA in the first instance. ZT provided different batches of input materials for TRIDAS to test. At the end of Dec 2019, the milestone **A1.M3 Modification protocols on hop waste prepared and shared with Consortium** was reached. The experiences were transferred to Action B1.2.

TECNO tested 7 types of fibre during the 3 stages of the project, giving feedback to ZT about how the length and geometry of the fibre influenced on the extrusion of the biocomposite. The following table details the amount of fibre received and the formulations produced.

Table: BioTHOP fibre quantities recieved during the project

1st harvesting period			
NAME	**DATE**	**AMOUNT**	**Formuations produced**
FILTERED	September 2019	2,6 Kg	F1 to F2
FILTERED	October 2019	8,4 Kg	F1-2,5 to F10
NON-FILTERED	October 2019	10,3 Kg	F11 to F15
2nd harvesting period			
NAME	**DATE**	**AMOUNT**	**Formuations produced**
ROUGH	October 2020	7 Kg	none
FINE	October 2020	8,7 Kg	F16 to F20
2 PASS	November 2020	5,5 Kg	F21
POWDER	January 2021	16,5	F25' to F28
3rd harvesting period			
NAME	**DATE**	**AMOUNT**	**Formuations produced**
FINAL	October 2021	250 Kg	FINAL BIOTHOP MASTERBATCH

Problems

Technical problems regarding hop biomass degradation and other technical issues were solved promptly. Guidelines for proper handling of hop biomass after harvest were written.

Deliverables

✓ A1.D3 Regulations and protocols on modified hop-waste components defined

ACTION B1 Hop waste transformation into new valuable feedstock

B1.1 Compostability and anaerobic digestibility assessments

Foreseen start date: 01/10/2019	Actual start date: 01/09/2019	STATUS: finished
Foreseen end date: 31/08/2022	Actual end date: 31/08/2022	

Activities, progress and results

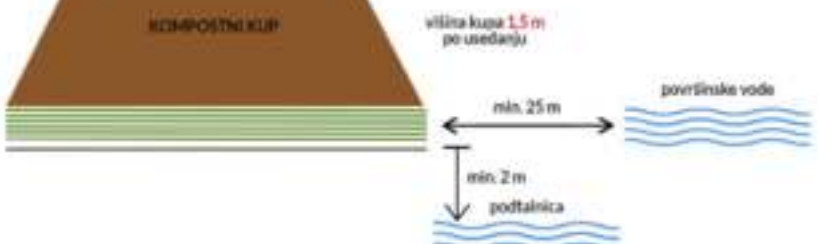
Hop biomass (750 t all together) after harvest was collected in August/September 2019, 2020, 2021, 2022 and composted for 7 months according to different protocols. Over 10 different protocols were tested. IHPS worked in close collaboration with 12 hop growers of Lower Savinja Valley – the project demo region. Some composting piles were set at IHPS, the majority at hop growers. All compost piles were sampled after 7 months of composting each year and analysed for compost quality and BioTHOP twine degradation. Chemical and biological tests were performed in order to assess the compost quality. Remaining BioTHOP twines from the core of the piles were sampled and sent to LEP. Starting material was sampled and sent to the lab for chemical analysis each year. Hop growers were turning the composts after consultation with BioTHOP team of IHPS on the basis of temperature measurements.

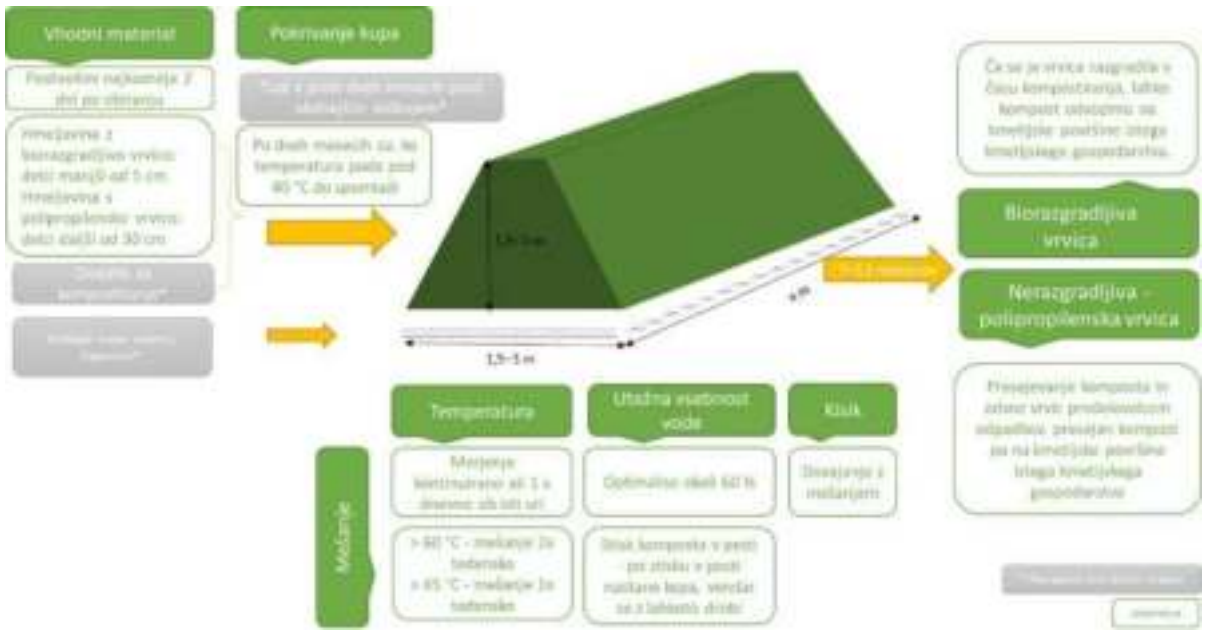
The first steps comprised of the study of the post-harvest hop biomass, the nutritional content, the size of various particles and different ways of collection. The degradation of biomass was followed by the daily measurement of the temperature and by visual observation. Samples were taken and both maturity and phytotoxicity were checked. The tests showed that piles had low respiration rate and low phytotoxicity. Reports of the testing of the piles were prepared according to standard scientific protocol as well as following the methods employed in our preliminary testing. The twine in the compost piles lost its strength and almost degraded. The type and arrangement of the blades in the harvester impacts (accelerates) the twine degradation after half year – the smaller the pieces, the faster the degradation.

11 composting piles were made in Sept. 2019 in order to test a broad list of different methods, in Sept. 2020 12 compost piles were formed. The compost piles have been formed and the temperature was being measured daily. In Sept. 2021, the experiments were designed based on previous experiences, 3 compost piles were followed in detail. Difference among piles was in the size of the particles that the biomass was cut to and in composting approaches - adding biochar, efficient microorganisms and one pile was without composting accelerators.

Also, before setting the piles in year 2020 and 2021, trays for collection of leachate were set under composting piles. Beside the condition of compost piles, temperatures, sampling of compost, also leachate and its properties were checked. A diversity of compost fauna was examined. According to the findings, compost piles should be covered with semipermeable membrane/cover urgently after the thermophilic phase, so there is as low leachate amount as possible.

The first year of composting experiments with compostable PLA twine showed that uncontrolled composting processes do not provide optimal conditions for hop biomass and PLA twine degradation. By reducing the size of stems and twine fragments to 5 cm or less, turning the pile, and maintaining proper moisture, the composting conditions were optimal, and twine was degraded. Aerated composts with small particles provided better environment for PLA degradation. Results show that composting whole biomass after harvest (leaves and stems) is more efficient as it provides more nutrients thereby generating a longer thermophilic phase, which is crucial for PLA twine degradation and higienisation of the biomass at the same time. Composts stimulate germination and growth of selected plants. Respiration tests have shown that composts after 7 months of proper composting are mature, with low respiration rate. Microscopy revealed the dominance of bacteria compared to fungi in all samples. Chemical composition indicates suitability for compost use in arable land. A ton of compost with 70% moisture content, contains 8.1 Kg of total





nitrogen (N), 1.14 Kg of total phosphorus (P) or 2.6 Kg of P_2O_5 in 3.24 Kg of total potassium (K) or 3.8 Kg of K_2O.
IHPS prepared **guidelines for the post-harvest management of hop biomass on hop farms in collaboration with the Ministry for Environment and Spatial Planning of the Republic Slovenia and the Ministry for Agriculture and Forestry of RS**. Guidelines were published on the BioTHOP and IHPS websites and printed version was sent at the same time to all Slovenian hop growers and workers in a hop industry in Slovenia. Guidelines on the BioTHOP website are available in free access, this way available to all farmers, who might want to compost their crop biomass waste, not only hop growers in the EU, but also for example vegetable growers.

- ✓ Guidelines for the post-harvest management of hop biomass on hop farms:

https://www.life-biothop.eu/wp-content/uploads/2022/08/Smernice_hmeljevina-AVGUST-2022_FINAL-VERZIJA-1.pdf

Guidelines for proper composting videos have been prepared in Slovene and English languages and are available free in the BioTHOP website as well as on the BioTHOP YouTube channel; they will be available for knowledge transfer permanently:

- ✓ Technological guidelines for proper composting:

https://www.youtube.com/watch?v=LvyuwnvcJQ0

- ✓ Turning of hop biomass compost pile in 3 steps:

https://www.youtube.com/watch?v=bVyju1pymsc

- ✓ Measuring the temperatures in composting piles in SLO language

https://www.youtube.com/watch?v=7tmJo66aoCc

- ✓ Cleaning of cutter in the harvest machine:

https://www.youtube.com/watch?v=uBf3wpXCTmE

Problems

No technical problems have been encountered during the execution of this action. However, the testing of many variants for composting scaled up both the number of tests/chemical analysis needed, which exceeded the predicted costs for this Action. However, this was essential to get comprehensive data to create substantive technological guidelines for proper on-site composting.

Deliverables

- ✓ Deliverable B1.D1. Complete quality analyses and guidelines for on-site hop biomass composting process was finished in 8/2022.

Milestones

- ✓ Milestone B1.M1 First batch of fibre sheets & fibre reinforced material available for Action B3 and B4 was finished in March 2020.
- ✓ Milestone B1.M2 First compost assessment and second batch of fibre sheets & fibre reinforced material available for Action B3, B4 and B5 was finished in 31/03/2021.
- ✓ Milestone B1.M3 Final compost formulation and third batch of fibre sheets & fibre reinforced material available for Action B3, B4 and B5 was finished in 31/10/2021.

B1.2 Valorisation, post-treatment and production of hop fibre materials (ZT)

Foreseen start date: 1/1/2019	Actual start date: 1/1/2019	STATUS: completed
Foreseen end date: 31/12/2021	Actual end date: 31/12/2021	

Activities, progress and results

ZT has processed both first and follow-on batches of hops materials as well as further trial twine-less hops for pulp moulding technology-handling assessment. Incremental improvements have been made according to project partners' comments and requirements. During stage one, ZT up-cycled (engineered) the IHPS supplied biobased (Hops/PLA) agricultural residual materials for both project material and end product developers (TECNO/TECOS/TRIDAS). For the second stage, based on feedback, ZT supplied further quantities of engineered fibre for second stage testing. Hop biomass, containing natural twine, was also processed and sent for TRIDAS assessment. A third stage of extra fine material has been produced for TECNO/TECOS. Feedback from both the plastics and pulp end-users will be followed up by the supply of a final quantity for the up-scaled

production of end products. **Milestone B1.M1 First batch of fibre sheets and fibre reinforced material available for Actions B3 and B4** was reached in time (March 2020).
The various trials and incremental progress made in 2021 through discussions with IHPS on the fibre conditioning side, and with TECNO/TRIDAS on the fibre processing side have allowed to optimise hop fibres treatment:

- Post-treatment: hop fibres have to be dried and ideally pre-cut on the grower site. The separation between hop fibres grown with plastic/bio-plastic twine and with natural fibres twine is key for valorization at a second stage.
- Production for plastic injection: ZT developed multiple screw profiles to reach the targets set by TECNO in terms of fibre size, regularity, and dry content. The end-product targeted (plant pots) needs high flexibility, which means the hop fibres have to be very finely ground. In this case, the fibres are used as a filler. The use of plastic contaminated fibres is possible for this application with the contamination levels observed.
- Production for pulp moulding: only the "natural" (cellulose, sisal, hemp, etc) twine-contaminated hop fibres can be used for this application - plastic contamination is not accepted in the TRIDAS system. In this case, the hop fibres need to be re-engineered and functionalized, to give them some self-agglomeration properties. ZT uses its patented process & proprietary screw elements to work on the fibres and render them usable in the pulp moulding process – this will be later detailed in B3.1.

After further work in 2020/21 following Milestone B1.M1, all targets have been met and the parameters for final productions have been set.

Difference between Fibres for pulp moulding (left) and for plastics (right)

Problems

The condition, quantity and physical form of the initial delivery of the hop material provided storage, logistical and feeding issues. Limited quantities of the material were salvaged which were sufficient for 'first look' trials by the BioTHOP project partners. Later deliveries have largely surmounted these problems.
ZT had to learn about the use of natural fibres as part of a plastic compound – ZT's original technology is made for fibre engineering and not grinding. ZT was very comfortable providing hop fibres for pulp moulding applications, but ZT had to adapt its process to plastic targets, which are opposite to ZT's traditional targets. ZT have enjoyed finding solutions to this new problem, learning along the way and delivering partners with the right hop fibre quality – but believes there are alternative technologies that are better suited for these applications. ZT has been looking for these alternative technologies and have presented them to the project partners.

Deliverables

✓ Deliverable B1.D2 Hop fibre sheet optimisation and production was due on 31/12/2021 and has been reached on time.

B1.3 Valorisation, post-treatment and production of hop fibre reinforced composites

Foreseen start date: 1/10/2019	Actual start date: 1/10/2019	STATUS: completed
Foreseen end date: 31/12/2021	Actual end date: 31/12/2021	

Activities, progress and results

Sub-action B1.3 involves the preparation of hop fibre reinforced composites using the processed fibres by ZT and the selected bioplastic matrices according to the final application (planting pots). The duration of this action spanned from period M4 to M30 of the project (December 2021) and it consists of 3 demo-stages. The 1st demo stage ran up to M9, the 2nd up to M21 and the final stage up to M30.

During the previously indicated periods, TECNO worked on the improvement and scale-up of the formulations developed, experimenting with up to different matrixes to check which one achieved the best performing level for the final users. Masterbatches of these blends were sent to TECOS for injection of planting pots in action B4 and for the production of replication products in action B5.

To realize this task, TECNO used an extrusion compounding machine to mix the selected biobased materials with the hop fibre and other additives needed to improve the blend of the materials (see Figure above for explanation of the compounding process).

To address known disadvantages of natural fibres various treatments were studied to improve the matrix-fibre adhesion in natural fibre reinforced composites. Issues addressed were their low permissible processing temperatures, their tendency to the formation of clumps, and their hydrophilic nature.

Until the end of the project, a total of 24 formulations based on recovered fibres from ZF were prepared, including:

- percentages of fibre from 5% to 40%.
- 5 biobased and compostable matrixes.
- 6 types of hop fibres: washed, unwashed, rough, fine, micronized in 2 pass, pulverized.
- 2 types of additives (plasticizers).

During the extrusion-compounding of the hop fibre composites a cooling-down process was implemented using a water bath. As a consequence, the filament up-took a high amount of water which had to be removed before further processing (e.g., injection of planting pots). This issue was solved with an intensive drying step which is an important consideration for the processing of the new materials. The hop fiber does not suffer thermal degradation when submitted to temperatures above 100ºC for periods of time longer than 8 hours. The maximum amount that could be included when using rigid matrixes (while running a 100% automatic process) was of 20%. However, once flexible matrixes were introduced this percentage could be doubled. The increase in the percentage of fibre was also thanks to the micronization performed previous to the introduction of the fibre into the compound.

After scale-up trials at TECOS in sub-action B4.1, in which the masterbatches produced were mixed with a more rigid biopolymer during the injection molding step, the final formulation for the BioTHOP materials was established.

Problems

No problems have been encountered during the execution of this action.

Deliverables

information and results obtained from this action were included in deliverable B1.D3: Hop fibre reinforced composite optimization and production" which was submitted in December 2021 (M30).

ACTION B2 Adjustability of PLA twine for hop-growing sector

Foreseen start date: 01/10/2019	Actual start date: 01/10/2019	STATUS: completed
Foreseen end date: 31/12/2022	Actual end date: 31/12/2022	

This action was split in two sub-actions, which iteratively produce both material and know-how in order to achieve its goal. Sub-action B2.1 deals with the tests aimed at developing an optimized twine for guiding and supporting hop crops. This task is composed of iterative tape laboratory extrusion tests, twisting of twines,

mechanical tests and production of samples on industrial production lines. The know-how, results and samples are then fed onto sub-action B2.2 where the produced samples are field tested, performance evaluated and then composted at the end of the season. The results obtained by sub-action B2.2 are then fed back onto B2.1 to iteratively develop the optimum twine for hop crops.

B2.1 PLA twine modification to weather resistance and mechanical performances

Activities, progress and results

The first part of this task focused on analysing the results from Action A1.1 carried out early in the project by LEP and IHPS. The results from this first test, using standard compostable twines, gave a first insight on the range of twine runnage to be used for the development of the hop twine.

The project then moved onto twine development/modifications by LEP and focused on three areas: strength, efficiency and compostability. By strength we mean the specific strength of the twine, which will determine the cost for the growers since weaker twines need to be made thicker in order to carry the weight of the plants. By efficiency we mean the costs incurred by the farmers during installation, removal and cone separation. The twine needs to be designed in order to minimize these costs. By compostability we mean the ability to facilitate the composting operation of the twines. The twine is already certified industrially compostable for runnage up to 15000 denier, nevertheless, the aim is to extend this in order to make the twine compostable on-site (on farms).

This led to a series of tests carried out in LEP's laboratory in order to extrude (13 samples), twist (7 samples) and run dynamic and static tests on a series of twines composed of different raw materials (3 samples with varying degrees of stereo-isomer content), additives (2 samples) and construction (3 samples). The tests rendered a series of improvements in the aforementioned areas presented to the steering committee in December 2019.

Once the development tests had been completed, LEP defined a series of twine candidates to be tested in the 2020 field trials in Slovenia in Action B2.2 with farmers from the region surrounding IHPS. In discussions with IHPS, LEP and IHPS jointly decided how to distribute the 9 different twine candidates between the 12 farmers, focusing on testing each twine in more than one farmer and aiming to test the twines in the hop varieties where they would be best suited for. This would allow LEP to push the envelope down in terms of twine runnage without putting at risk the farmers' hop crops.

A total of 1,512 Kg of twine were produced and shipped by LEP for the tests in 2020. During the 2020 season, IHPS accompanied the tests in the field feeding back data regarding the behaviour of the twines and breakages in the farms. In parallel, LEP started working on the testing of new solutions for the 2021 season, focusing again on strength and efficiency. The reason why compostability was not in focus in this new iteration was that considering the on-site composting results from the 2019 and 2020 season and also taking into account know-how from other crops where compostable PLA twines are used. These led us to believe that no further improvement in compostability would be needed for the heavier twines used in hop crops. More details on the composting behaviour can be found below.

A 12-month aging test was also carried out by LEP in order to consolidate the know-how pertaining the degradation of twine in soil. The results confirmed that PLA twines buried in soil would not undergo significant degradation. The feedback from IHPS in sub-action B2.2 led LEP to modify the geometry of the twine for the 2021 season, focus on higher strength twines, reduce the use of high D-lactic acid isomer and define the absolute minimum for twine strength in order to safely support hop crops for both heavy and light varieties.

The 2020 development tests by LEP focused on resin blends (3 samples), additives to increase strength (3 samples), tape geometry (1 sample) and put-up (prototype order on standard product to test maximum extrusion put-up on 40-ton batch). Both resin blend and additives led to no changes or reduction in dynamic strength and a net reduction in the static mechanical properties of the twines. This would be translated into runnage increase in order to keep the same safety factor developed for the twines and will not be used in the field tests in 2021. Tape geometry tests, which focused on increasing the thickness of the twine whilst keeping the runnage constant did translate into a product with a higher stiffness. The higher stiffness is needed in order to minimize the downtime and stops in the harvesting and cutting machines. The put-up tests were successful with a permanent modification onto our standard compostable twines and a new standard packaging for the product to be shipped in 2021.

During discussions with the farmers and hop specialists, we found out that each grower does cut their own twine depending on the system to be used and cutting the twine in LEP's factory would not be well suited for reasons of efficacy and transport costs. In addition, 50 Kg bobbins such as those consumed by some agricultural

markets is not well suited for the application since the installation is carried out on platforms, which would have to be modified in order to accommodate such bobbins.
The composting tests carried out in two growth seasons where the twine was tested have rendered a great deal of information regarding the behaviour of these heavy twines in on-site composting. The twine has been able to compost effectively when the right conditions are met. At defined conditions the twine is able to degrade with such a speed that both, the twine with the additives that would increase degradation speed and the normal twine degraded before the samples could retrieved for the intermediate evaluation. This means that adding an additive could improve the degradation but that the twine without the additive can already degrade at a fast enough pace in on-site composting conditions. Since the addition of any additive would make the twine more expensive for the growers, with clearly no benefit versus the standard recipe, we decided to discontinue further testing with this approach. Other variables tested such as thickness and crystallinity were not be pursued in the 2021 season since an effective composting behaviour could be obtained with the reference twine. It is important to point out that any changes in thickness or crystallinity could affect the mechanical properties of the twine and could only be justified if the heavy hop twine could not be composted on site.
The 2021 season focused on the optimization of the product in three discrete areas. The first target was efficiency, i.e. increasing the uptime of the harvesting machines in order to put the product on the same operational costs as the PP benchmark. This was achieved via a stiffening of the twine. The second are was resilience and involved testing another PLA polymer in the application. This is so that in case any supply issues may appear with the standard polymer; growers can be supplied in time with a product that can both secure the plants and be composted efficiently at the end of the season. The third are was cost and involved testing of a thinner twine variety to be used in the lighter hop types, where the loads are smaller and allow for cost reduction for the farmers.
The field tests were successful in all three areas. The second supplier PLA twine was able to secure the plants, albeit at a higher raw material cost. The lighter twine was able to secure and guide the plants successfully. Finally, the stiffer twine was better than the previous version during harvest. Nonetheless, there was still a difference in efficiency between the BioTHOP twine and the PP twine in terms of harvesting machine uptime. The operators had to stop the machine more often in order to clean the twine which wrapped around the cutter. The product also showed very good composting behaviour and in a visit in late 2021, it was observed on site the fast disappearance of the twine in the composting heap.

Hop biomass compost with BioTHOP twine.

In order to further improve the behaviour of the twine in the harvesting operation, eight different twine varieties were produced in LEP and tested internally in order to evaluate the stiffest solution that would not negatively affect the breaking strength of the twine. In discussions with IHPS it was decided to test the best two product configurations on a harvesting machine using bean stalks as a reference cutting substrate since no hop plants were available. These tests were carried out on site at IHPS in November 2021, ahead of the 2022 season. The results showed that even though there was an improvement in the cutting behaviour, the tests were not conclusive due to the different behaviour of the beans and hop plants.
At this stage, it was decided to advance with an iteration in 2022 using the latest product design and apply it in an area of 1.5 ha at a hop farm in the Savinja valley. The tests were accompanied by IHPS during the 2022 season and the harvest and cutting observed in order to ascertain the impact of the new design. The results showed that the new twine had a better behaviour in the cutters and allowed for a 4-hour continuous production between cleaning operations which matched the time normally used by the growers between stops.

Harvest machine tests with bean stalks at IHPS – November 2021

OK Compost certificate for BioTHOP twine


CERTIFICATE FOR AWARDING AND USE OF THE 'OK COMPOST INDUSTRIAL' CONFORMITY MARK

TA8011904062

Another area where the project focused in 2022 was the extension of the twine range to 30000 denier or 300 m/kg. This is the typical runnage used by hop growers in Western Europe. Samples of twine with this higher runnage were produced an also sent for tests in Belgium and France in order to obtain feedback on their behaviour.
In order to certify the product for compostability, third party tests were carried out in 2022 with a certified laboratory with twine up to 30000 denier and using both the standard PLA used in the project and also the alternative PLA tested in 2021. The results were positive and the OK Compost certification was obtained for the hop twine.

The project aimed at demonstrating the feasibility of using a modified PLA twine in the hop growing industry. In total, more than 62 ha of hop area was grown using the BioTHOP twine during the 3 years of the BioTHOP project. The project helped not only develop a product tailored for the hop growing industry, but also allowed LEP to advance the state of the art of compostable PLA twines by pushing the strength of the product by a significant margin.
Despite the limitations that the COVID 19 pandemic placed during the project, LEP was able to maintain its commitments in terms of deliverables and milestones. The project extension also allowed an additional field trial season in 2022 with the help of IHPS which led to significant operational efficiency improvements for the hop farmers.

In summary, the work carried out in the BioTHOP project have allowed LEP to design a twine with a significant reduction in runnage of 10% and 20% versus the initial benchmark, which translated into a more sustainable solution for the growers. The laboratory and field tests confirmed the suitability of the developed product for on-site composting and the new put-up and geometries allowed for a smoother and more efficient operation in the harvesting and separating machines.

Deliverables and milestones

- ✓ B2.D1 Report on modified PLA twine, specifically adapted to the hop growing industry 23/12/2021
- ✓ B2.D3 Certification that produced BioTHOP twines are biodegradable in industrial and if proven possible with an improved recipe, home composting 15/11/2021
- ✓ B2.M3 Optimized PLA twine available for replication project in B5 18/02/2021

B2.2: Validation of new PLA twine on hop field testing trellis

Foreseen start date: 28/02/2020	Actual start date: 28/02/2020	STATUS: completed
Foreseen end date: 31/12/2022	Actual end date: 31/12/2022	

Activities, progress and results

The bobbins of the twine were delivered by LEP to IHPS before the growth season 2020 and dispatched to participating hop growers by IHPS. Each hop grower got detailed instructions on types of the twine and at which variety should the twine be tested at, as well as the needed tags to be put on the field. The installation of 9 different types of the twine began at the end of March and lasted to the end of April 2020 on 12 different locations at different hop growers and IHPS estate and with different hop varieties. The twine was easy to install and made no problems to hop growers.

Sampling of the twine after growth season by IHPS for Lankhorst

Regular cleaning of tangled twine on the cutter prevents further problems in the time of harvest

Perfectly cut twine on the harvest machine

The knives on harvest machine must be as close as possible for good cutting of the twine and hop stems

The progress of hop plants growth and twine response on the field was followed by IHPS during 3 growth seasons. In case of disturbing events, such as wind or heavy rain, the hop growers were in touch with IHPS in order to report breakages. There were no major problems with the twine, in case of breakages, the plants were

counted and type of breakage was reported to LEP as well as twine samples were sent to them. Dynamic tests on the field showed that BioTHOP twine is stronger than polypropylene (PP) twine. Similarly, the hop growers reported the quality of the BioTHOP twine is comparable to the PP twine or even better. The samples of the twines were collected on the field just before the harvest at the end of all investigated growth seasons and sent by IHPS to LEP for further investigation and modifications on the twine formula.
Based on the results during the growth seasons, modifications were made on the twine and several different twine types were made for next season to see which would be most suitable for hop support and how they will alter the process of hop harvesting. All together in the project, **the BioTHOP twine was tested on 62 ha**.
We made a **video with guidelines how to install the twine**, so also replicative regions will be able to learn this procedure: https://youtu.be/f-yPiEqVk_o
As there were mostly no major problems on the field, the focus of IHPS and LEP was in the second half of the project on the performance of the twine on harvest machine, where at the start some problems appear due to poor knife sharpness or bad adjustment of the cutter on harvest machine. The twine was a bit too soft and it was wounding on the rotating parts. The hop growers have various types of harvesting machines namely, therefore the adjustments for this type of twine were needed for some of them. However, the BioTHOP twine is similar to PP twine which they mostly use, so the adjustments were not enormous. After second season, LEP made another, improved version of the twine, which was stiffer and it was expected that it will be cut easier on harvest machines. This type didn't make any problems to hop growers and was considered as optimal version at the end of the project.
Proper setting of harvest machine before the harvest, sharpened knife and regular cleaning of the machine should prevent any major problems in the time of harvesting. We prepared a **video guidelines how to sharpen and align the harvest knife and how often to clean the harvest machine**, which can be found on the BioTHOP YT channel: https://youtu.be/uBf3wpXCTmE
Composting was performed with hop waste biomass after harvest, where we observed the compostability and degradation of the BioTHOP twine. It was excellent.
Since the appearance of the BioTHOP twine is indistinguishable with the polypropylene twine, IHPS recommend to colour the final version of the BioTHOP twine (green or yellow).
With all these steps considered, the hop growers shouldn't have any problems with use of BioTHOP twine. Most of the hop growers are satisfied with the twine and are very interested to test and use it in the future, if it will be affordable to them. At the end of the project, we can proudly say that the twine is suitable for hop growing sector, and it doesn't require any major changes for hop growers, who have their technology adapted for use of polypropylene twine. The twine has been commercially available in Slovenia since Spring 2022.

Problems
Lack of PLA rescheduled the twine tests and its amounts in the first years, but overall amounts of twine tested were not altered. In 2021, there were still some problems with twine performance on harvest machines at some growers, so it was useful that the project was extended for half a year, so we could test the improved twine once more improve the twine and test it in season 2022 through whole growing season and solve all issues.

Deliverables and milestones
- ✓ Deliverable B2.D1 Report on modified PLA twine, specifically adapted to the hop growing industry was reached on 31/12/2021.
- ✓ Deliverable B2.D2 Validation report on novel PLA twine performances from hop field experiments was reached on 10/10/2022.
- ✓ Deliverable B2.D3 Certification that produced BioTHOP twines are biodegradable in industrial and if proven possible with an improved recipe, home composting was done on 11/11/2021.

- ✓ Milestone B2.M1 First field training tests on modified PLA twine started achieved in March 2020.
- ✓ Milestone B2.M2 Second field training tests on optimized PLA twine started achieved in March 2021.
- ✓ Milestone B2.M3 Optimized PLA twine available for replication project in B5 was achieved in March 2021.
- ✓ Milestone B2.M4 Training & harvesting hop field experiments on novel PLA twine concluded and validated was achieved in October 2021.

Instalation of BioTHOP twine in spring

Yellow coloured BioTHOP twine instalation

ACTION B3 Demonstration Pilot in Packaging sector

B3.1 Adaptation of hop waste fibre crumbs to pulp moulding process (ZT)

Foreseen start date: 01/01/2020	Actual start date: 01/01/2020	STATUS: completed
Foreseen end date: 31/3/2022	Actual end date: 31/03/2022	

Activities, progress and results

Initially ZT provided fibre of a quality similar to material normally accepted by other pulp moulding partner companies. Although ZT already had minimal experience of fresh (moist) hop stems in 2019, the fibre used for the TRIDAS project was already dry and therefore required different preparation method. Two fibre types have been delivered by ZT to TRIDAS in 2020. The second based on feedback from earlier in the year and on modifications required to deal with the inclusion of natural sisal twine (substitute for PLA in the first trial year, so the procedure is prepared only for hop fibres firstly; later in the project we will test hop fibres with rests of PLA in them on the basis of these first trials results). Following further forming trials at TRIDAS in 2021, ZT proceeded to further adapt its screw profiles to increase self-binding abilities of the fibres. The target is to reach a higher de-fibrillation in order to maintain good mechanical properties on the end product.

Milestone B3.M1 – Designs of box insert packaging validated as final was reached in time in March 2020. The bottle divider/packaging product to be produced by TRIDAS will be closable with top and bottom part so the wine will have good protection.

Problems

Processing did not produce any unexpected issues.

Deliverable

Deliverable B3.D1 Report on Adaptation of Hop Waste fibre for Plastics Injection moulding systems & Pulp-moulding processes reached in time on 12/2021.

B3.2 Demonstration of packaging product solutions based on transformed hop waste (TRIDAS)

Foreseen start date: 01/01/2020	Actual start date: 01/01/2020	STATUS: completed
Foreseen end date: 31/12/2022	Actual end date: 31/12/2022	

Activities, progress and results

Fibre processing was relatively stable. All fibre filtered to clear out fines to avoid pulp forming sieve blocking problems. This produced good (ZT relative) fibre with a lighter colour tone than standard non filtered fibre. Filtrate to be tested in future for nutrients/bio-based chemicals. No significant signs of twines remaining in the fibre mass. TRIDAS was to make final assessment relative to fibre quality/fit for purpose.

Milestone B3.M1 – Designs of box insert packaging validated as final was reached in time in March 2020. The bottle divider/packaging product to be produced by TRIDAS are closable with top and bottom part so the wine will have good protection.

After the adaption process of material from ZT and all necessary tests, Hops/Cellulose Fibre twine was selected as the most suitable input material for production. TRIDAS made final assessment relative to fibre quality/fit for purpose. TRIDAS reported successful testing of received material from ZT. Fibre form and condition was

satisfactory, co-blending with other fibres in the product forming system was good, end product was robust and met project target expectations and extracts were rich and plentiful.
Action B3.2 involved the adaptation of hop waste fibre crumbs to the pulp moulding process and the development of premium quality wine bottle transport packaging. The product wanted to be made from pulp and hop recovered/modified hop waste fibre prepared in sub–Action B3.1.
During the 1st demo stage TRIDAS was testing the first batch of material received from ZT. Testing showed that the material should have more regular and clearer fibres. The received material was tested with a Schopper Riegler tester, a fibre 'freeness test' whereby the fibre is diluted with and filtered through a mesh. The fibre openness (via water flow characteristics) is logged (1° = low/13°=Standard Cellulose/20° – 40° Recycled Paper/ Above 41° to 86°+/-– becoming Microfibrillated). Thereafter the collected matt was dried to estimate the fibre quality and fibre type range. The biggest difference between materials we normally use is fibre stability and length.
Final part of the first general testing regime was carried out using a TRIDAS pilot moulded fibre machine. The main objective was to acertain the percentage of hops-based fibre against standard fibre pulp that is required to make wine bottle transport packaging. Testing of the material in a pre-production system revealed that during the mixing, water got really dirty and generated quantities of foam which required the use of a 'defoamer' which is not normally used in production. The received material contained a lot of dust and soft particulars. The first sample from 100% hop material did not hold together and it got stuck on the form. The mix of 70% hop material with 30% pulp showed better results and was not possible to demould. It was however more stable. This result was discussed with ZT with the requirement to produce a second batch which would allow cleaner production water and eliminate the foam problem. The second batch has been delivered and testing has begun – somewhat later than scheduled starting in January 2021 due to the COVID 19 situation at the moment.
In 2021 was selected and evaluated the best possible input material combinations for the first generation of wine bottle packaging. This process was realized by testing the material in different ratios. In addition to hop waste material (without PLA), cardboard offcuts and virgin pulp, were also used as input material, which are normally used in TRIDAS for the production of moulded fibre packaging.
The first generation of packaging was produced on a conventional line. According to all the tests carried out, the ideal combination of input materials was proved 50% cardboard offcuts and 50% hop waste. The wine bottle packaging made with a combination of these input materials was determined to be the most suitable and final one. The stability of the material was defined as the greatest and there was no visible handling problem during the wet or dry phase of the production process.
Manufactured wine bottle packaging was subjected to regular use and were testing of their heat resistance, cushioning properties, mechanical properties, physical and climatic properties within the validation process. The validation process of the packaging was also subjected to 3A ISTA testing, which tested the protective effect of the packaging under transport loads in the supply chain. A cardboard box was required for this testing. All packaging testing was conducted in an ambient temperature between +20°C and 25°C at a relative humidity (RH) between 40% and 60%. The packaging was conditioned in a standard environment for 24 hours prior to testing.
During ISTA 3A testing by the action forces were caused only partly corner damages on the box after the Shock-Drop, only insignificant defects on the packaging. The whole unit itself remains without any kind of damages or defects. Packaging provided sufficient protection and fixation of the unit inside. The result of ISTA 3A testing based on protective packaging components was the wine bottle packaging successfully passed this test.
Packaging was officially validated as proper protection for wine bottle packaging.
After testing the additional material from ZT required for production, the same ratio of the two input materials was determined as in the previous production process of the 1st generation of wine bottle packaging.
The best ideal combination of input materials was found 50% hop waste and 50% cardboard offcuts again. It was started the testing and validation process of the second production of 1,000 wine bottle packaging. Manufactured wine bottle packaging was subjected to regular use and were testing the material stability, mechanical test of elasticity, heat resistance, flexural strength, deflection and strength, physical and climatic properties within the validation process.
In February was also performed 3A ISTA testing, same as with the first generation of wine bottle packaging. During this testing the protective effect of the packaging under transport loads in the supply chain was tested. A cardboard box was required for this testing. The same cardboard box was used as in the first generation of wine bottle packaging. Internal dimensions of this box are 400x131x110 mm.

When performing 3A ISTA testing, during which mechanical forces were imposed on the packaging after the Shock-Drop, the corners of the box were only partially deformed. Only minimal and insignificant defects were visible on the wine bottle packaging. The whole package remained intact, without any defects or damages. The packaging sufficiently fulfilled the protective function and fixation of the wine bottle inside. As a result of 3A ISTA testing based on the protective packaging components, the wine bottle packaging successfully passed this test.

Packaging from second production round was officially validated as proper protection for wine bottle packaging. After receiving batch of 125 Kg from ZT, TRIDAS started first production of 1,000 demos wine bottle packaging.

The whole process started with mixing collected waste paper (cardboard and newspaper) mixed with hop waste material in the hydro pulper. Here the material was mixed with water and within 15 to 20 minutes it was de-fibred to establish pulp. This mixture was pumped through a two-stage filtration where, in the first cycle, heavy impurities (small stones, sand, paperclips) are separated and, in the second cycle, all light impurities are separated (wood, plastic, polystyrene, and adhesive tapes). Pure pulp was stored in tanks and ready for subsequent use. The last step of the pulp preparation was its mixing to reach required operation parameters.

The second productions step was the pumping of pulp to the forming section of the line where it was sucked onto aluminium moulds. After residual water has been exhausted, the already finished product was transferred into hot forming moulds. During the drying process, still wet packaging was pressed under high pressure. The product drying time varies between 60 and 150 seconds, in relation to the size and weight of the packaging.

First, TRIDAS tried 100% hop waste material which, as expected according previous tests, this mix didn´t work. The material was too squashy so it didn´t hold together. Then 70% mix of hop waste material and fiber showed better result, but not perfect for wine bottle packaging. The bottle packaging was torn and didn´t hold the shape. Surprise for everyone was that mix of 50% fiber with 50% hop waste material worked perfectly and the packaging hold together. It was surprise as the previous tests showed that this mix will not work out, but the reality in production changed the expectations.

On the 12th Nov. 2021 TRIDAS received two big bags of material without PLA from ZT. Together it was 170 Kg batch of hop waste with the fibre SR value is +/- 40°. TRIDAS was testing material for production and after testing started the second production of 1,000 wine bottle packaging on time. The best ideal composition for production of wine bottle packaging was found again 50% hop waste and 50% cardboard.

In May 2022 TRIDAS decided to improve the current wine bottle packaging to make it look more sophisticated and have a smooth appearance. TRIDAS decides to offer wine bottle packaging to demanding customers who produce more luxurious product - Prosecco or Champagne. For that reason, TRIDAS bought a new machine for over moulding (after-pressing) the product. The new product design was created. After the delivery of the pressing machine, the products will be pressing and will contain the BioTHOP logo. In Aug. 2022, the moulding after-pressing form and the moulding transfer sheets needed to mould the product were delivered to TRIDAS.

The pressing machine was delivered in Sept. 2022 as first step a make an improving the existing product – wine bottle packaging. About 100 samples of wine bottle packaging, one group of samples from hops (50% hops and 50% carton) and from 100% carton were after-pressed to compare the results.

Preparation for the final biodegradability testing of the wine bottle packaging has begun in Jan. 2022. After testing and validation, the second production of 1,000 wine bottle packaging, started final biodegradability testing of this packaging.

The final biodegradability testing is providing Institute for Testing and Certification, a.s. with cooperation Tomas Bata University in Zlín. The biodegradability testing with certification that produced BioTHOP bottle packaging is 100% biodegradable and is providing in compliance to standard ČSN EN 13432 Packaging - Requirements for compostable and biodegradable packaging, which is the Czech version of the European Standard EN 13432:2000 on the biodegradability of the product. The university performs tests that cannot be performed at ITC and ITC performs additional tests and subsequent product certification. The whole testing of biodegradability will take 7 months and 2 weeks.


ACCREDITED LABORATORY
TEST REPORT

Biodegradability testing day zero

Biodegradability testing day sixteen

Problems

Processing did not produce any unexpected issues. This relates to both the non-twine and sisal twine containing material types. Comments on the first fibre quality were forthcoming from TRIDAS, generally these focused on the differences between paper/cellulose fibre and fibre developed direct from agricultural residuals. ZT had experience of this situation and could work with TRIDAS to develop a methodology for use (forming) and to modify the fibre morphology for TRIDAS future use.

The after-pressing turned out perfectly for the 100% carton samples. For samples with hops, the product lost the necessary quality and some samples broke in the middle of the product, splitting into 2 pieces. TRIDAS was working then on repeating the after-pressing process with minor adjustments in pressure intensity. The pandemic situation in the years 2020 and 2021 lead to delay of the work, because there could not be so many people in the factory at the same time. However, the work went on as planned, it was just delayed.

Due to the unfavourable market situation, there were very long lead times for these cardboard boxes, so the ISTA testing was not conducted until October 2021. For testing was used Cardboard box FEFCO: 0201, DIN2.8BC with internal dimensions 400x131x110 mm.

Deliverables and milestones

- ✓ B3.D1 *Report on the adaptation of hop waste fiber materials to pulp moulding process*
- ✓ B3.D2 *Report on waste hop fibre moulded box insert demonstrator for packaging applications*
- ✓ B3.D3 *Certification that produced BioTHOP trays are biodegradable*
- ✓ Milestone B3.M1 – *Designs of box insert packaging validated as final*
- ✓ Milestone B3.M2 – *First generation of packaging demonstrator validated* was reached in March 2022.
- ✓ Milestone B3.M3 – *Final generation of packaging demonstrator validated and optimized* was reached in June 2022.

ACTION B4 Demonstration Pilot in Horticulture Accessories Sector

B4.1 Adaptation of hop fibre reinforced composites to injection moulding process

Foreseen start date: 1/01/2020	Actual start date: 1/01/2020	STATUS: completed
Foreseen end date: 31/12/2022	Actual end date: 31/12/2022	

Activities, progress and results

The initial formulations studied during Sub-action B1.3 have been adapted in parallel during Sub-action B4.1 by using a special temperature profile control to ensure that PLA is completely melted in the first three extruder zones. The screw configuration of the extruder has been also designed to enable gentle fibre processing thus avoiding the alteration of their natural properties. During action 1.3, different temperature profiles were set up, to ensure the best performing behaviour of the matrix and a well mix-up of the bioplastic with the hop fibres. Following the established end-product requirement of a maximum deformation under flexural conditions of 5%, all the blends developed were tested according to ISO 527-1-2"Plastics: Determination of tensile properties part 1: General principles, and part 2: Test conditions for moulding and extrusion plastics" and ISO 178 "Plastics — Determination of flexural properties" respectively.

After characterization, the blends displaying potential right properties for the final products were scales up in batches of 5-6 Kg, which were sent to TECOS for injection purposes (ref. image – right side).

During September 2021 the last batch of material was produced using the fibre extracted and processed by ZT in the 3rd harvesting period. 250 Kg of hop fibre were received at TECNO facilities in September 2021, and more than 200 Kg of material were produced, achieving fabrication at industrial scale level. From the quantity produced, 110 Kg were sent to TECOS to manufacture the necessary planting pots for the final demonstration period, while the rest of the material remained at TECNO for replication activities.

Problems

The expected challenges of the task were faced and solved, and no unexpected problems were encountered during the execution of this action for the reporting period. Actions or budget within this task were not modified.

Deliverables

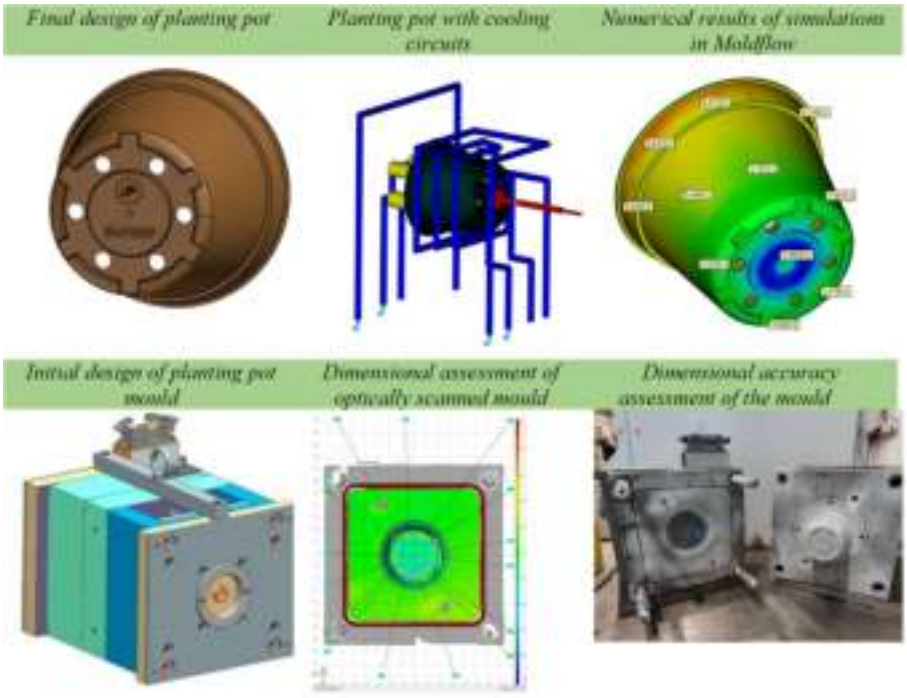
- ✓ The information and results obtained from this action were included in deliverable B4.D1: *Report on optimal formulation of hop waste fibre reinforced PLA for injection moulding* submitted in December 2021 (M30).

B4.2: Demonstration of horticulture product accessories based on transformed hop waste

Foreseen start date: 1/01/2020	Actual start date: 1/01/2020	STATUS: completed
Foreseen end date: 31/03/2022	Actual end date: 31/12/2022	

Activities, progress and results

Three different designs of plant pots were constructed and modelled during this Sub-action by TECOS. The 3D CAD models were presented to IHPS, and the best design (in terms of final functionalities and aesthetic appeal) was selected for further prototyping. A small series of plant pots with the preferred design was produced with 3D printing technology. Following this the functional suitability of the printed plant pot was tested on an automatic planting machine at IHPS to confirm its adequacy for later use in the automatic planting line.



Concurrent with the fine-tuning of final product design, numerical simulations of injection moulding process was done with the help of Autodesk Moldflow Software. Simulation results gave us an insight over the operative processing parameters, technological window limits and guidance for construction and manufacturing of a prototype mould, needed to obtain aesthetically appropriate and functional parts with shortest possible process cycles. Injection mould for plant pots was constructed and manufactured in the first trimester of 2020, while several iterations followed to improve its overall operation validity.

Milestone B4.M1 Designs of plant pots validated as final was reached in time (M9).

Prototype mould for planting pot was constructed based on several iterations of injection moulding simulations. The construction was manufactured and assembled in March 2020 (M9). Initial part production started in April 2020 (M10) when preliminary tests with a more rigid biopolymer and PP granulate were performed. Around 200 pcs were injected at this stage. After receiving the F12 BioTHOP material formulation from TECNO at the end of May 2020 (M11), first trials were performed in June 2020, where 50 pieces of planting pots were produced. First dimensional accuracy assessment was performed on both, planting pots and mould. With accurate optical scanner, it was confirmed, that the wall thickness of the planting pot was uneven. We solved this issue with a proper mould construction and repairing cycle and tested the mould afterward. A null series of the parts was produced which confirmed that mould and injected parts are within the required tolerances.

Short shots on thinner side of the planting pot

In August 2020, a 2nd dimensional accuracy assessment of the mould was carried out, since critical problems were identified during the injection moulding cycle. It was discovered that the mould was producing planting pots with uneven wall thicknesses (up to 0.2 mm difference), which causes problems at filling phase (short shots on thinner side, trapped air, weld lines). Uneven wall thickness was eliminated with the change of cavity position in the injection side of the mould. In November 2020 an additional 150 pcs were produced from 2nd Generation of BioTHOP compounds, based on starch matrix mixed with a more rigid biopolymer.

In July/August 2020 TECOS in close cooperation with Tecnopackaging (TECNO) carried out study of biodegradable matrices, suitable for development of BioTHOP composite (intermediate tests) and produced 200 pcs of pots. Variety of bio-material grades (bio-based, biodegradable or both) were considered in study to choose the optimal one. Several optimization iterations and material studies were performed in the middle of November 2020, January 2021, March 2021 and May 2021. At the end of 2nd demo stage, 220 pcs of fexible matrix 1 based composite were produced and another 620 pcs on fexible matrix 2 based composite and sent to IHPS on testing.
In the 2nd period of year 2022 TECOS implemented 3rd Demo Stage, where we manufactured 1400 plantings pots of final material formulation and delivered them to IHPS in May 2022 for automatic planting.
Throughout the duration of the project more than 2800 plantings pots were injection moulded in various batches and tests.
After testing a lot of different material formulations, flexibility and other characteristics, together with TECNO and others partners we determined, that the final material formulation.

Final material formulations granulate

Evaluation of planting pot performance at IHPS

In the last period of year 2021 the evaluation of 2nd generation of demonstrators for horticulture sector was performed. This was done after 5 months of use (June->November->(March)). Pots were exposed to regular wetting, PPP fertilizers and some UV exposure. Tables were prepared, where the properties of the pots were described in detail (label, Date of IM, Material formulation, quantity of pots, pots mass and flexibility). At the evaluation stage additionally mechanical changes, homogeneity and colour changes were observed. Additional notes were taken regarding the exterior of pots, surface structure etc.

Biodegradability testing at Simbio was started on 3rd of June 2022, where 672 pots were tested for industrial biodegradability in real industrial scenario. We are testing different scenaros, where pots are a) crushed and grounded b) individual and c) assembled together. Biodegradability was evaluated twice, i.e. after 1 month and after 2 months (3.7.2022 & 3.8.2022).

Biodegradability testing at Simbio

Already after the 1st assessment in July, no remains of the pots were visible in the pile itself, which confirms biodegradability compliaces, achieved by Archa. After 2 months we repeated the assesment to make sure that we did not miss during the first evaluation any of theremaings of the pots and confirmed the conclusions of the 1st assessment.
The evaluation of material biodegradation was done also at certified company for biodegradation tests, confirming that even though the maximum thickness of pot is 1,41 ± 0,03 mm, the material and the end products are conformed to criteria defined by EN 13432 Standard. The following experimental steps were performed for the assessment of the conformity to the standard: Identification and characterization of the product, Quantitative disintegration including effects on the biological treatment process and Effect on the final substrate quality and ecotoxicity test. In the check list for the final assessment of the compliance with EN 13432 it was presented that overall results of the evaluation was marked as accepted and positive.

	Parameters		Official method to verify the compliance	Judgement	Test report n.
Characterization	Volatile solids		APHA Standard Methods 2540G 1997	COMPLIANT	22107529/1
	Heavy metals	Cu, Zn, Ni, Cd, Pb, Hg, Cr, Mo, Se, As	UNI EN 13657:2004+UNI EN ISO 17294-2:2016	COMPLIANT	22107529/1
	Fluorine		UNI EN 14582:2016+UNI EN ISO 10304-1:2009	COMPLIANT	
Disintegration			ISO 16929:2021	COMPLIANT	22107529/4
Substrate quality	Chemical - physical parameters	Moisture content	APHA Standard Methods 2540G 1997	COMPLIANT	22107529/3 and 22107529/5
		pH	ISO 10390:2005	COMPLIANT	
		Total Organic Carbon	DM 21/12/2000 GUn 21 26/01/2001 supp 6	COMPLIANT	
		C/N ratio	DM 21/12/2000 GUn 21 26/01/2001 supp 6 e UNI 10780:1998 APP.I1	COMPLIANT	
	Heavy metals	Cd, Cr, Cu, Hg, Ni, Pb, Zn	UNI EN 13657:2004+UNI EN ISO 17294-2:2016	COMPLIANT	
		Cr (VI)	EPA 3060A 2007+EPA 7196A 1992	COMPLIANT	
	Phytotoxicity and Ecotoxicity		UNI EN 13432:2002+OECD 208:2006	COMPLIANT	22107529/2 and 22107529/6

Check list for the final assessment of the compliance with EN 13432

Life cycle assessment was performed in the first half of 2022. Traditional and improved compostable planting pot was analysed– ISO 14040

- Two examples were studied:
  - PP planting pot: traditional planting pot produced from PP granulate (25g)
  - BioTHOP planting pot: improved planting pot that is suitable for industrial composting (40g)
- Environmental indicators include: global warming, depletion of abiotic resources, acidification, eutrophication, ozone layer depletion, photo-oxidant creation, land use, human toxicity, water depletion, particulate matter creation and energy demand

After evaluation of LCA analysis was concluded, that BioTHOP plantings pots have possibility for improvement if the wall thickness of the planting pot will be reduced (and mould with more cavities introduced).

BioTHOP planting pots with thin wall cannot be produced at testing facilities in TECOS but there is a realistic possibility to achieve injection moulding of thin walled BioTHOP planting pots with stronger injection moulding machine, which is plan for after life activities.
The improved planting pots have possibility for improvement also if the input materials would be mass produced and supply chain would be optimized. At the moment the contribution of raw material production, production of planting pots and transport phase are contributing to much environmental load, compared to traditional PP planting pots) that can not be compensated by eco-friendly composting EOL scenario.

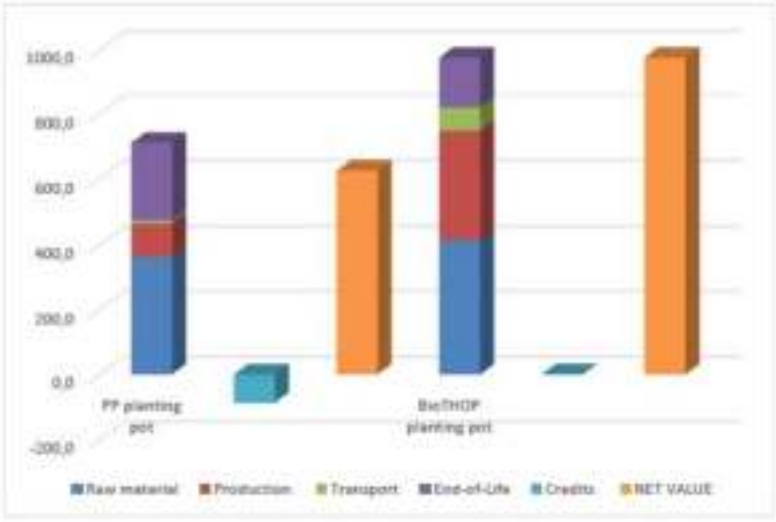


Figure 8: Global warming potential (GWP) for different planting pots (kg CO_2-Eq)

LCA results of GWP for BioTHOP and conventional planting pot

Problems

Some minor problems with mould were identified, i.e. the uneven thickness of walls, consequently short shots on thinner side of planting pot and flash of material on the other thicker side of planting pot were observed. With a minor redesign of mould construction, we obtained better processing conditions, i.e. more even thicknesses (deviation up to 0.12 mm) and planting pots without flash of material. Injection mould was in later stage upgraded with additional ejector to ease the ejection of planting pot and engraved biodegradability logo to mark al the planting pots for end-users.
Planting pots are low-cost product. In order to maximize the cost reduction, the lightest version of the planting pots was developed, suitable for demo pilot line and BioTHOP compost. With initial version of mould, several problems occurred in filling phase and ejection phase. During the filling phase of thin-walled product is crucial to have walls with uniform thickness. Several iteration of mould repairment were done, i.e. installation of positioning pins were done to optimize the thicknesses of pot.
Furthermore, to enhance automation of the process and ejection of the pots, additional ejector was installed into the mould. We produce around 40% more planting pots during the development as planned in proposal to ensure optimal quality of the pots and optimization of the process.

Final design and material formulation of planting pot

Deliverables completed and Milestones achieved

- ✓ B4.D1 Report on optimal formulation of hop waste fiber reinforced PLA for injection Moulding (31/12/2021)
- ✓ B4.D2 Report on planting pot demonstrators for horticulture applications (31/10/2022)
- ✓ B4.D3 Certification that produced BioTHOP planting pots are biodegradable/industrially Compostable (31/10/2022)
- ✓ B4.M1 Designs of planting pots validated as final (31/03/2020)
- ✓ B4.M2 First generation of planting pot demonstrators validated (30/06/2021)
- ✓ B4.M3 Final generation of planting pot demonstrators validated and optimized (31/12/2021)

ACTION B5 Replicability and Transferability

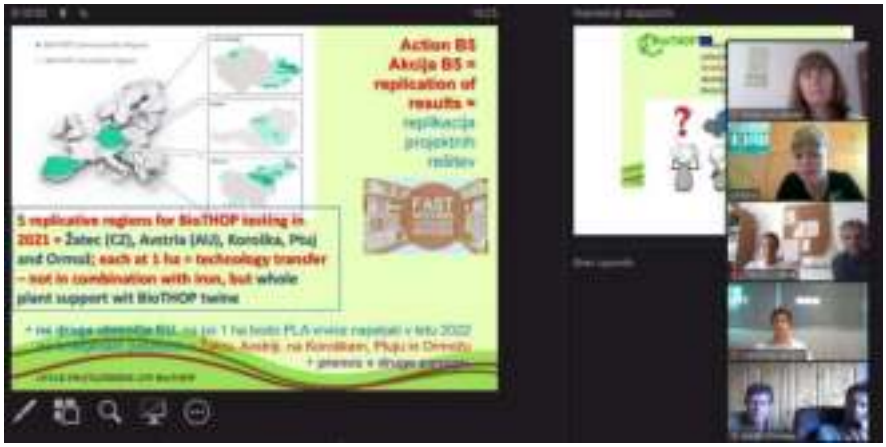
This action was focused on the replication and transfer the BioTHOP results to other EU regions (Sub-action B5.1) and other industrial sectors (Sub-action B5.2). The mission was to communicate a valid technical solution via a reliable dissemination strategy, details of which were defined in Sub-action B5.3. Action B5 was due to start in M18. However, as a consequence of travel complications (COVID 19 situation) it was decided to begin earlier than planned and to intensify our efforts on this Action working as planned to reach the pre-agreed publicity targets.
In the start of the action, we organised photo competition "HOPs and the ENVIRONMENT" in order to connect us with our target groups through an on-line activity. The main aim was to spread the word about BioTHOP project to the target audience.

B5.1 Replicability in other EU regions

Foreseen start date: 1/12/2020	Actual start date: 1/1/2020	STATUS: completed
Foreseen end date: 31/12/2022	Actual end date: 31/12/2022	

Activities, progress and results

This Sub-action focuses on reaching other hop growing regions who may wish to replicate the BioTHOP methodology. In start of the project, we contacted several regions and presented our web page and current stage results to them.
The regions involved in BioTHOP twine system replication in the proposal are **AT, CZ,** and **3 from SI**: **Koroška**, **Ptuj** and **Ormož.** Replication in Slovenia started in March 2020. In addition, **Portugal**, **Belgium, France, Germany, Spain and Serbia** tested the twine as well. **Notranjska region (SI)** also tested the twine in 2020 in a small demo field. The twine was also used on some farms in vegetables and high beans production and on small biodynamic vegetable farm. They performed composting as well.



BioTHOP twine in bean production

Composting biodynamic way

The process of explanation and introduction of BioTHOP twine for partner regions wishing to replicate the BioTHOP system was done. IHPS organised virtual meetings in order to connect LEP, the producer of PLA

twine with regions of replication. Additional videos about installation of the twine and composting process were made and showed to replication regions.
In CZ and AT, they had problems with twine, as their technology is adapted to metal wire. Later, in CZ, they made a trial with PLA twine only for connection of metal wire with top of the hop construction, which was successful. In some SLO regions, hop growers had problems on harvesting machines, as they were adapted to other types of plastic twines. Apart from longer operating time of harvest machine, due to cleaning of coiled twine, they didn't report other problems.

Problems /

Deliverables

- ✓ Deliverable B5.D1 Guidelines for replication the BioTHOP twining methodology in other EU regions reached in November 2021. Video with guidelines was prepared in 2021:

in English: https://www.youtube.com/watch?v=f-yPiEqVk_o
in Slovene: https://www.youtube.com/watch?v=1Yj_9OWObAM

- ✓ Milestone B5.M1 BioTHOP twines trained on the hop field plantation in the replicated region was reached in October 2021.

B5.2 Transferability to other sectoral applications

Foreseen start date: 1/12/2020	Actual start date: 1/12/2020	STATUS: completed
Foreseen end date: 31/07/2022	Actual end date: 31/07/2022	

Activities, progress and results

TECNO analyzed the data collected during the 1st and 2nd Demo stages, assessing the potential fo the transfer of the project results to other applications, adopted by different EU regions. During the sub-action more than >235 Kg of material have been made for small scale tests, pilot scale trials, and functional prototypes. 7 sectors were approached: Fashion industry, cosmetic industry, toys, automotive industry, agricultural sector, packaging and FFMCG sector.
In total 12 products were produced between TECNO and TECOS, for different stakeholders interested on natural reinforced materials. 5 transformations techniques were used: Injection molding, casting extrusion, vacuum thermoforming, 3D printing and film blowing.

Main output of BioTHOP project (planting pots) + products made for replicability action

Based on the obtained results and taking in consideration indicators like the amount of fiber that can be included, how easy is to process the material, or the range of applications associated to the transformation technique, the following products are the ones with higher potential for replication of the BioTHOP materials:

- Rigid parts (Injection molding): Injection molding allows up to 40% of fibre inclusion

- Semi-rigid parts (Casting extrusion+vacuum thermoforming): Casting extrusion allows up to 10% of fibre inclusion, and plasticizers are needed for improving the stretching ratio.
- Flexible films (Film blowing): Film blowing allows up to 5% of fibre inclusion.
- 3D printed parts: The material is not printable currently. A more extensive work focused on 3D printing of hop fibers could be beneficial for assessing how to approach this technique.

Problems

To reach the number of replicative regions detailed in the proposal (3 EU regions along with the 2 proposed in action B5.1) the additional time granted by the European Commission was beneficial to increase the efforts on the activities and the targeted replication products and countries were achieved at the end of the task.

Deliverables

The guidelines for transferring the results obtained from this action were included in deliverable

✓ B5.D2: Guidelines for transferring the BioTHOP materials to other industrial sectors which was submitted in July 2022 (M37) thanks to the granted extension of the project.

B5.3 Replicability, transferability and industrialisation plan

Foreseen start date: 1/12/2020	Actual start date: 1/12/2020	STATUS: completed
Foreseen end date: 31/12/2022	Actual end date: 31/12/2022	

Activities, progress and results - Replicability and transferability plan

The objective of the present deliverable is to identify most promising products or processes for replication and transferability into other sectors and other countries. Partners defined the replicability and transferability plan, supported by the sound information elaborated throughout the project. IHPS collected the data of partners and its own and then carried out SWOT and Market Analysis (mix marketing - 4P). With obtained results the group defined the target applications and needs that should be covered. Based on that, a selection of the most promising processes and products for replication and transferability has been made. The analyses results showed that we can promote composting as one of the best options of dealing with waste hop biomass. The guidelines for composting of hop biomass were transferred to as many farmers as possible. Videos with guidelines and instructions are published on BioTHOP YouTube channel. The BioTHOP twine has been commercialized in Slovenia and LEP is actively developing supply routes for other countries in Europe and the Americas. Further development will depend on market research and customer value analysis. LEP will look into the baler twine market to ascertain the possibility of adapting the BioTHOP twine for this very large market. The technology of hop fibre extraction, developed by ZT, is a plug & play solution that can be installed in most moulded fibre production unit. The resulting fibres can be used for all type of moulded fibre products, from food packaging to protective packaging. The planting pots marketing can be transferred to sectors where needs of planting pots is smaller, such as ecologic herbs and plants. TECOS will also try to find a suitable interested company that would be ready to injection mould plant pots with BioTHOP material on a fully industrial line. The bottle packaging will be adapted to more luxury design in order to reach more consumers, such as for sparkling wines or slightly modified design packaging for smaller regional breweries for specialty beers in glass bottles of 1 litre or more. Harvesting knife guards could be used in agriculture equipment sector, especially in European market. Some processes and products showed potential promising results and will be performed and produced also after the project, while some of them are facing more obstacles.

Activities, progress and results – industrialization plan

The BioTHOP compounds industrialization plan stands in the deliverable B5.D4, defining the requirements for adapting the current production facilities for compounded materials. Business case based on the applications demonstrated during the project and developed over three models of Business Plan are also included in this plan to compare the investment requirements for the industrialization with the potential income coming from the exploitation of the new materials. Preparation activities begun in June 2022 as a document First draft. During last six months, we have four revisions of the document and we finalized it in December 2022.

Problems

No unexpected problems were encountered during the task.

Deliverables

✓ Deliverable B5.D3 Replicability and transferability plan defined was reached on 30/08/2022.
✓ Deliverable B5.D4 Final report on industrialisation plan of the resulted BioTHOP solutions - Dec 2022
✓ Deliverable B5.D5 Replication and/or Transfer Strategy was reached on 30/08/2022.

ACTION C1 Monitoring of the project impact

C1.1 Monitoring over technical project progress

Foreseen start date: 1/7/2019	Actual start date: 1/7/2019	STATUS: completed
Foreseen end date: 31/12/2022	Actual end date: 31/12/2022	

Activities, progress and results

IHPS supervised the technical progress at general level and prototyping progress in Actions B1, B2, B3 & B4. The day-to-day communication of the Project Manager with the Action leaders assured that information remained up-to-date, this information was shared with the Compliance Manager in order intervene in time if matters did not go as planned. All the results were assessed during the SC meetings to ensure they were consistent as well as accurate. Technical work was done on time; technical actions went on as planned. All milestones and deliverables were achieved and were of the appropriate standard.

Problems

No unexpected problems were encountered during the task.

Milestones

✓ Milestone C1.M1 Updated LIFE Key Project –level Indicators was finished 30.6.2020.
✓ Milestone C1.M2 First monitoring report (internal document) reached in time in December 2020.
✓ Milestone C1.M3 Second monitoring report (internal document) was finished 31.3.2022.
✓ Milestone C1.M4 Updated LIFE Key Project-level Indicators reached in time – in October 2022

Deliverables

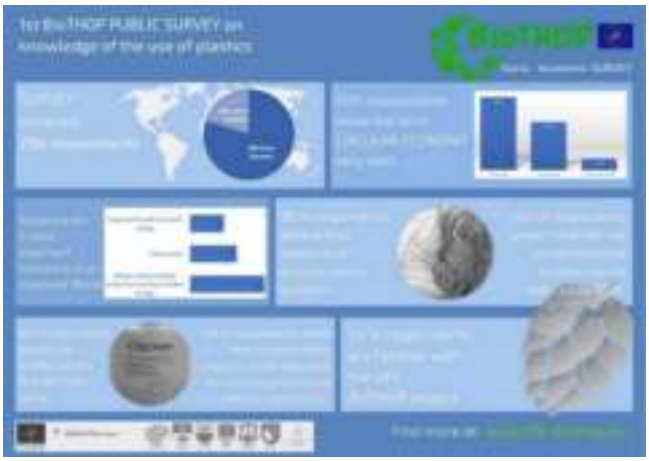
✓ Deliverable C1.D1. Updated LIFEPROJECT Specific Indicators was finished in 31.12.2020.
✓ Deliverable C1.D2. Updated LIFE Project Specific Indicators was finished 31.12.2020.
✓ Deliverable C1.D3. Indicators for the socio-economic impact of the project was finished in 30.9.2022.
✓ Deliverable C1.D4. LCA and LCC analyses was finished in 31.3.2022.
✓ Deliverable C1.D5. Final LIFE Project Specific Indicators was finished in 15.10.2022.

C1.2 Monitoring the environmental and socio-economic impact

Foreseen start date: 1/10/2019	Actual start date: 1/10/2019	STATUS: completed
Foreseen end date: 30/06/2022	Actual end date: 30/09/2022	

Activities, progress and results

Deliverable *The Indicators for the socio-economic impact of the project & socio-economic analysis of BioTHOP solutions* includes two key indications for the successful progress and closure of the project -project monitoring and impact evaluation. The newly developed products were implemented and continuously monitored to follow the progress and success of the project and to ensure that public funds were successfully invested. One of the key goals of the project was to increase social awareness and acceptance of the environmental benefits and behavioural impact on the life of current and future community members.



For the preparation of mentioned deliverable two public opinion surveys were carried out. They were prepared as online public opinion questionaries for residents of EU and non-EU countries. The 1st was prepared at the beginning of the project and the 2nd in 2022.
The main goal of both surveys was to monitor the development of public opinion on the issue and draw conclusions about the impacts of the LIFE BioTHOP project.

Both surveys were prepared in Slovene and English language by DAS. They were published on different social media and distributed by e-mail. The results of the research were analysed and used as a basis to prepare an assessment of the project socio-economic impact, specifically the assessment of the success of the project implementation and the effectiveness of the info-graphics not only in the demonstration site but also in other transferability sites. According to the results, the project's actions have a positive impact on the local economy and local communities.

Problems

No unexpected problems were encountered during the task.

C1.3 Monitoring and up-dating KPI indicators

Foreseen start date: 1/2/2020	Actual start date: 1/2/2020	STATUS: completed
Foreseen end date: October / 2022	Actual end date: Oct. / 2022	

Activities, progress and results

Sub-action C1.3 is focusing on the monitoring and updating the key project-level indicators, that correspond to the 4th Priority Area: Resource Efficiency in relation to BioTHOP's proposed solutions. Beyond the selected set of priority descriptors, reporting & updating of the complementary key indicator under the 3rd Section: 'Waste' is also involved as a reflection of the multi-dimensioned character of the project and the synergies that it creates. Key indicators concerning the project's societal & economic outcomes (information and awareness) were also assessed & up-dated via the LIFE KPI Webtool. IHPS assembled all the relative information, values and data from partners in order to update the LIFE KPIs. Data was collected each 3 months from partners and logged in Excel as well as being uploaded to the Webtool.
In the project proposal, it was foreseen that we will implement PLA twine on a total of 60 ha in two seasons. Thus, the indicators related to the implementation of the PLA twine were recalculated to 30 ha on an annual basis. In order to facilitate the monitoring of the indicators and also related to the determination of the Specific Context in the Webtool to the demo region and replicative regions, we carried out a recalculation of the indicators for the implementation PLA Twine on a 55 ha for the demo region and 5 ha for the replicative regions. Also, pursuit of the result exactly as planned was prevented due to the lack of the PLA substrate on the market in 2019/2020, due to not predicted big increase in demand, the numbers of ha per year are not the same as predicted in the proposal (30 ha). However, regardless of this, we met and even exceeded the PLA twine implementation plan during the project.
All project indicators showed positive expected trends, in the whole duration of project (2019-2022), we tested PLA twine on 62,5 ha. There was 900 tons of hop biomass after harvest intertwined with PLA twine. Because hop biomass was not burned but composted or was transformed (small amount) into BioTHOP products the

participated air-emission was nullified. Trough whole duration of project we also manage to less polluted soil for 551 Kg (0,551 t) of PP.
During the whole project length, we pay a lot of attention to dissemination or awareness raising project-actions. The result is large impact to concerning the project's societal & economic outcomes indicators: public awareness, achievements of involvement of nongovermental organisations and other stakeholders in project activities, the numbers of views and followers of the website and social channels. We used different media for dissemination and reaching /raising awareness of the general public (local, national radio/TV, print media, social media). Achievements are recorded in table 1 in Deliverable: C1.D1 Updated LIFE Project Specific Indicators and described in more detail in 3 monthly reports.

Problems

No unexpected problems were encountered during the task.

C1.4 Monitoring of dissemination activities

Foreseen start date: 01/10/2019	Actual start date: 01/10/2019	STATUS: completed
Foreseen end date: 30/06/2022	Actual end date: 30/06/2022	

Activities, progress and results

Regular monitoring of target dissemination values has been carried out by Dissemination Manager Alenka Doler from DAS. New subscribers were continuously updated, on-line event participants, and people visiting Website, social networks (FB page, LinkedIn page and Instagram) were monitored. Distribution of materials, press releases, articles, etc. were counted. DAS has been permanently updating its list of participants of events (in accordance with GDPR) to contact them about further project information as important stakeholders for the BioTHOP project. Participants of events were registered; list of contacts is regularly updated. The whole consortium was active to reach our target groups through webinars, social media, and partners websites. Together with IHPS DAS prepared indicators and data on LIFE Project Specific Indicators.
The Project results have been transferred to 13 other products. At least seven sectors were approached. We were active to reach stakeholders in different sectors.
Furthermore, we disseminate the project on various occasions to smaller groups of participants as predicted in application (local events, fairs, workshops, seminars) because of pandemic situation; we have been more active on-line through webinars and on social media with the goal to reach all the planed targets.

Problems

Due to the pandemic COVID 19 outbreak and the measures taken during the project; many on-site events were cancelled. However, we successfully continued with the modified activities and put more focus on online activities and so most actions or budget within this task were not modified.

Deliverables /

ACTION C2 Conclusions and recommendations

Action C2 includes sub-action C.2.1 ‘Socio economic Impact Analysis’ which has been running since M12 in order to analyse the socio-economic impact of the project. Sub actions C.2.2 ‘Policy recommendations’ shall start in M18, these involve new policy recommendations via the incorporation of current examples resulting from improved procedures and sub-action C2.3. The results of action C2 will be assessed/documented at the project completion date (12/21 or 6/22).

C2.1 Socio Economic Impact Analysis

Foreseen start date: 01/06/2020	Actual start date: 01/06/2020	STATUS: completed
Foreseen end date: 30/06/2022	Actual end date: 30/08/2022	

Activities, progress and results

Deliverable **The Indicators for the socio-economic impact of the project & socio-economic analysis of BioTHOP solutions** includes two key indications for the successful progress and closure of the project -project monitoring and impact evaluation. The newly developed products were implemented and continuously

monitored to follow the progress and success of the project and to ensure that public funds were successfully invested. One of the key goals of the project was to increase social awareness and acceptance of the environmental benefits and behavioural impact on the life of current and future community members.
For the preparation of mentioned deliverable two public opinion surveys were carried out with stakeholders and interest groups. The 1st BioTHOP opinion survey on non-degradable plastics was carried out in 2020 with 296 participants. The 2nd BioTHOP socio-economic Survey on sustainability, the circular economy and knowledge on BioTHOP biodegradable products as excellent alternative to conventional plastics was carried out in 2022 with 509 participants.
The results of the research were analysed and used as a basis to prepare an assessment of the project socio-economic impact, specifically the assessment of the success of the project implementation and the effectiveness of the info-graphics not only in the demonstration site but also in other transferability sites. According to the results, the project's actions have a positive impact on the local economy and local communities.
Our objectives were: 1. Contributed to society, 2. Improved the quality of life on a local level 3. Directly and indirectly positively impacted economic conditions, 4. Generated visible 'Social Progress Indicators'. The Project and the results have been well received, often presented and mentioned by stakeholders and co-financiers.

Problems

Because of the pandemic situation the work was a bit delayed, but done properly.

Deliverables

✓ C2. D1 Socio-economic analysis of BioTHOP Solutions 30.9.2022

C2.2 Policy Recommendations

Foreseen start date: 01/12/2020	Actual start date: 01/12/2020	STATUS: completed
Foreseen end date: 30/08/2022	Actual end date: 31/12/2022	

Activities, progress and results

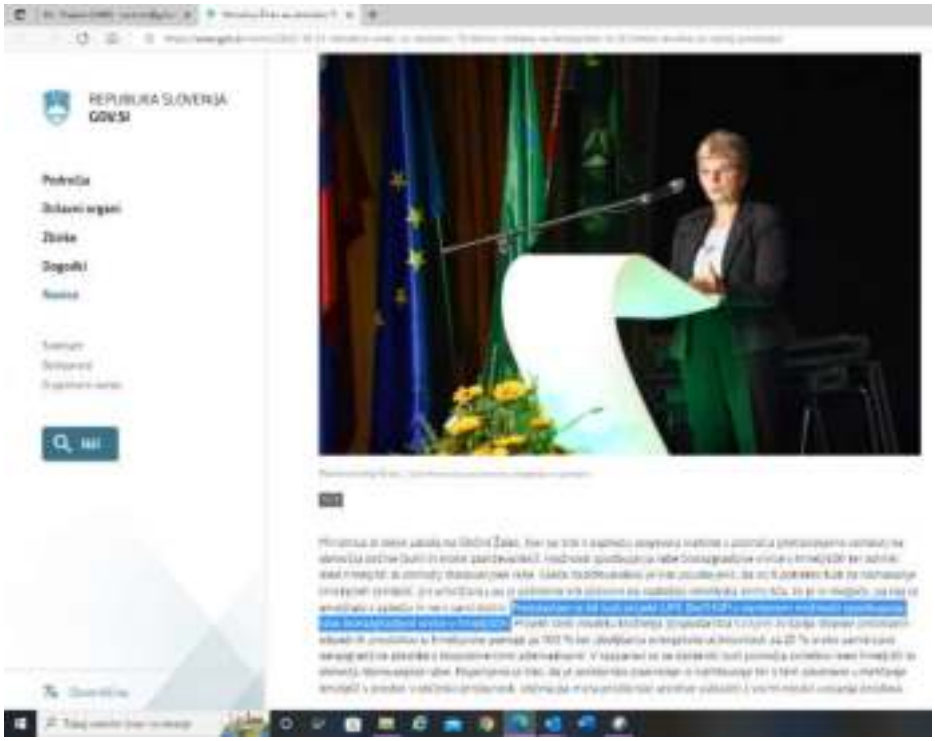
In the first stage of the project, we studied EU and national - Slovenian policy as well as existing professional guidelines and identified issues in the field of project and its results implementation. We had several meetings with Ministry for Agriculture (MKGP) employees in 2021, when BioTHOP colleagues were explaining them about **needs to allow composting on agricultural land** and give **subsidies to hop growers to use biodegradable twine and to compost their hop waste biomass**. However, in the first draft *Act on Amendments and Supplements to the Act on Agricultural Land* there was only solution for smaller hop farms with hop fields up to 15 ha, because 150 m^2 it is estimated to be enough only for hop waste biomass from 5 ha of hop fields. Therefore, we had a meeting on 19. Jan. 2022 with the **actual minister for agriculture Dr. Jože Podgoršek**, **Žalec municipality major Mr Janko Kos, member of parliament Mr Reberšek, president of Slovenian Hop Growers Association Janez Oset** (photo below) and explained them that the suggested change in the regulation does not include bigger hop farms that have up to 100 ha of hop fields, three of them even more than 100 ha. We want also them to be able to compost their waste hop biomass within the farm, in order to ger fine quality compost, which is home made organic fertilizer, allowing to return biomas, nutrients and carbon back to their agricultural land.

Finally, in the published version of the Zakon o spremembah in dopolnitvah Zakona o kmetijskih zemljiščih (pisrs.si); **Zakon o spremembah in dopolnitvah Zakona o kmetijskih zemljiščih (Uradni list RS, št. 44/22)** it was added: *On farms with an area under hops greater than 15 ha, the number of areas for composting increases proportionally to the area of the farm under hops.* With this, the

issue was solved on the national level. However, this regulation to come to practise in certain municipalities, has to be adopted by a municipal decree. So, our next step was to go to local level and talk to all municipalities in Slovenia, where hop is grown, to explain them the issue. With talks we started in August 2022 and continue in autumn and winter 2022/23.

We also asked for a meeting with both ministries that are responsible for the topics of composting on agricultural land and proper plant waste composting, that are Ministry for Agriculture (MKGP) and Ministry for Environment (MOP). Both ministries expressed their support for our efforts and confirmed that they will review the ***Guidelines for proper hop biomass after harvest composting*** that were preparing at IHPS. The guidelines contain technical guidelines how to proper compost waste hop biomass on farms themselves and also extract form the legislation, what is allowed, where and how. We managed to publish Guidelines in summer 2022: Microsoft Word - Smernice_hmeljevina AVGUST 2022_FINAL VERZIJA 1 (life-biothop.eu)

We were also in group of experts with Ministry for Agriculture (MKGP) employees for making new scheme for subsidies (on the photos below). We explained about need to give a strong support to: 1) COMPOSTING ON FARMS and 2) USE OF BIODEGRADABLE AND COMPOSTABLE TWINES, so the hop growers will start and learn theses new technologies, important for environment and circular economy establishment on hop farms. Composting and use of biodegradable twines were in plan in new regulations to be supported.



On 21st October 2022 **minister for agriculture Ms Irena Šinko** visited Žalec municipality where they were talking also about the LIFE BioTHOP project, especially about the topic how ministry can help in acceleration of biodegradable twine use in Slovenian hop fields. Later in the day (photo right) she gave a talk at the 70th anniversary of IHPS, talking about importance of collaboration between Ministry for Agriculture and IHPS, of which it is a founder.

We started talks with Surovina, a waste management company in Lower Savinja Valley, to open possibilities for hop growers to bring their plastic twine waste to their facilities, so this waste would be properly treated and we succeeded – they opened the facility for this purpose.

C2.3 Market up-take of the project products and services

Foreseen start date: 1/12/2020	Actual start date: 1/12/2020	STATUS: completed
Foreseen end date: 30/06/2022	Actual end date: 30/08/2022	

Activities, progress and results

Within partnership, we have made three C2M checklists (business model canvas), first for BioTHOP (PLA) twine, second for planting pots and third for wine bottle packaging. The objectives set in the application were achieved through the work of the consortium with the help of external contractors. Promotional Based on these elements, the businesses were defined and analysed. We had two meetings with the Close to Market (C2M) EASME team on a virtual basis in 2020; they explained their work and the type of support can we expect from them. During the meeting of July 2020, we got acquainted with the e-library: templates and other guidance materials accessible via the link: https://bit.ly/2Sn4Tmq. It was decided to hold another meeting in spring 2021. DAS started developing the 1st BioTHOP project business plan focusing on planting pots and hop plant biomass together with TECOS and IHPS. DAS and consortium prepared a market analysis of the BioTHOP

technological solutions/ products made from hop waste to explore the existing market and methods for entry to new markets within in August prepared deliverable BioTHOP Business Plan.
There are three main purposes of BioTHOP business plan:

- to clarify plans for future growth/ stage of our project and assess close-to-market potential,
- to understand financial needs and
- to attract funding from investors, banks, and lenders.

Problems /

Deliverables

✓ C2. D3 Business plan; done on 30.8.2022
✓ C2.D4 Collaboration agreement defined; done in December 2022

ACTION D1 Communication Strategy

This action is composed of Sub-Actions **D1.1 Communication and Networking** and **D1.2 Public Awareness Campaign** that will be presented in common paragraph. The results of the activities carried out in Actions D were reported in dissemination reports every three months.

Foreseen start date: 01/07/2019	Actual start date: 01/07/2019	STATUS: completed
Foreseen end date: 31.12.2022	Actual end date: 31.12.2022	

Activities, progress and results

The aim of this sub-action was to promote the project, its activities and goals. The objectives set in the application were achieved through the work of the consortium with the help of external contractors. Promotional material / items produced by the BioTHOP consortium had increased the awareness of the project at various events. We have produced project specific corporate/visual identity, templates and images (project's logo with LIFE Programme logo, Word and PPT template, roll ups, project stamp stating no. LIFE18 ENV/SI/000056 to officialise invoices and documents...) and sent these to all partners on 26th of September 2019.
A Press kit was made at the end of M3 and send to all partners in English; they are translated into their national languages.
The project's leaflets were made in all 5 languages of the project's partners (English version on the first page, national language translation on the other side).
Stakeholders' data base and mailing list was created by M3 - completed on time and still in progress. Each participant/entry is designated only by a number - consistent with GDPR.
In regard to databases & mailings, there are now over 7.700 identified stakeholders contacts which is well above target as we planned for 1.000.
An external contractor was commissioned to design the project's website and social networks. The website is available in Slovenian, English, German and Spanish language. Both the website and social networks (FB, Instagram, YT, LinkedIn) have been operational since December 2019 as planned and will continue to be available for 5 years after the project (https://www.life-biothop.eu). All platforms are clearly marked with the LIFE logo, LIFE, consortium and co-financers information, and include news and constant updates on an ongoing basis.
D1.M1 Project corporate communication visual identity, templates and images tasks was completed on time 09/2019.
BioTHOP media platforms are connected with other related accounts & websites (LIFE programme, LIFE Slovenia, European Commission, etc.). The BioTHOP website is linked by all partners. We regularly promote the website/social networks at events etc.
Media Platform Statistics:
Website: Nov. 2020: 2.676 users (16,954 page views), March 2020: 371 users (5,987 page views); Nov. 2022: 7,114 users (35,485 page views); It is interesting to see from which countries or cities people follow our website (Slovenia, Spain, USA, China / Ljubljana, Zaragoza, Celje, Shanghai, Ashburn ...).
Facebook: Nov. 2020: 508 followers, March 2020: 194; Nov 2022: 766 followers
Instagram: Nov. 2020: 154, March 2020: 86; Nov 2022: 450
LinkedIn: Nov. 2020: 56 followers, in March 2020: 34; Nov 2022: 309

The number of website views, social media views and followers is increasing and has gone beyond the number provided in the application form.
Project brochure: A4 in English and published on the IHPS's web site on 26th Sept. 2019 (https://www.life-biothop.eu/wp-content/uploads/2019/12/BioTHOP-brochure_ENG_FINAL.pdf).
1 Photo competition "Hop and the environment" in 2020 15 authors sent 25 photographs; among them more than 430 EU inhabitants voted on-line for 3 winners.
Updated brochure in August 2020 as planned (ENG language) (https://www.life-biothop.eu/wp-content/uploads/2019/12/BioTHOP-brochure_ENG_August-2020_FINAL-004_compressed.pdf).
There are 43 BioTHOP videos available at Youtube, WP, FB.
All partners sent BioTHOP e-newsletters via stakeholder's databases and mailing lists. Both lists were prepared in ENG and SI languages.

- ✓ All **7** notice boards were designed and installed at the various Consortium facilities to show that we promote LIFE BioTHOP project and to reach > 50 visitors per year per partner (3.506 visitors in our premises). We prepared **D1.D7 Life Information Boards documented and reported for the public feedback 30.10.2022**

Roll ups, posters, info-graphics and various dissemination material / items (cotton bags, T shirts, pens, key-rings, folders, a poster calendars for the year 2021, postcards) were designed to promote the project at various occasions. We created a number of promotional items and this month, together with the local philatelic association, we have designed a special LIFE BioTHOP postage stamp in December 2022, which will be given to stakeholders and co-financiers to remind them about our project.

Open free training and demonstration workshops were organised to show to our stakeholders (local people, specific interest groups, hop-growers, co-financers, policy decision makers, the agricultural, packaging, horticulture and FMCG sector industry) the current project technical solutions and results. We organised technical seminars (Technical seminar within 57th Hop Seminar in February 2020, on-line 2021 and 2022), educational visits and international fairs to explain the project aims and increase their commitment with the environment to co-financers, hop-growers, wider audience and mass media. They also work with consortium partners and involve them actively in meetings.
Layman's report: released in 6 languages and distributed to => 2.000 industrial contacts, published also on the Website.
A Press release was made at the beginning of the project and distributed to journalists. They were translated to partner's countries languages and send to wider audiences later on.
Guidelines for the post-harvest management of hop biomass on hop farms: prepared in in collaboration with 2 ministries (Ministry of the Environment and Spatial Planning - MOP / Ministry of Agriculture, Forestry and Food – MKGP), distributed to all Slovenian hop grower and published on-line.
6 Public e-newsletters about project progress.
Together with the local philatelic association, we have designed a special LIFE BioTHOP postage stamp, which will be given to stakeholders and co-financiers to remind them about our project.
Final conference: - at virtual **FINAL CONFERENCE** (15. 11. 2022) we presented project results to stakeholders, co-financers & policy authorities, general public [more than 124 attendees].

Graphical presentation of the idea to use BioTHOP twine on the website

Problems

Due to the COVID 19 pandemic all events and fairs since 16th of March 2020 till May 2020 were cancelled. All partners completed an EC pandemic impact survey on the project in March 2020. Since October 2020, once again Slovenia and its partner countries have been dealing with the circumstances relating to the epidemic and implementing measures to prevent the spread of COVID 19. To ensure the continuation of activities and to reach our potential audience, in this case through webinars, we were trained to organise such events with the ZOOM application. Some activities were transferred to Action B5 in order to reach planned audiences and to generate satisfactory results. However, we successfully continued with the modified activities and put more focus on online activities and so most actions or budget within this task were not modified.

Website

Deliverables and milestones

- ✓ D1.D1 'Website in a fully operative mode' completed on time 12/2019
- ✓ D1.D2 'Life Information Boards documented' completed on time 12/2019 / final update 6/2020
- ✓ D1.D3 Progress and results of the communication and dissemination activities
- ✓ D1.D4 Progress and results of the communication and dissemination activities
- ✓ D1.D5 Layman's report released and updated 11/ 2022
- ✓ D1.D6 Progress and results of the communication and dissemination activities
- ✓ D1.D7 Life Information Boards documented and reported for the public feedback 30.10.2022

ACTION D2 Dissemination of the project results and stakeholders involvement

This action is composed of Sub-Actions D2.1 'Local Stakeholders Plan' and D2.2 'On-line dissemination actions' and D2.3 'After Life Communication Plan' and will be presented in common paragraph. The results of the activities carried out in Action D were reported in various dissemination reports every three months

Foreseen start date: 1/07/2019	Actual start date: 1/07/2019	STATUS: completed
Foreseen end date: 30/06/2022	Actual end date: 31/12/2022	

Activities, progress and results

The aim of this activity was to network and connect good practice, concepts, solutions, and innovations and to contribute to better stakeholder awareness and possible future cooperation on transferability and replication of the BioTHOP system. During this period, meetings with hop-growers and policy makers were organised and defined. The basis for our future work has been to publicise the LIFE BioTHOP project, specifically its 'circular economy' basis, among stakeholders, the general public and the mass media. The Project results have been transferred to 13 other countries / regions. At least seven sectors were approached. We were active to reach stakeholders in different sectors by testing biodegradable materials (cosmetics industry, button production) and products (wine producers, gardeners).

We have been very active on-line, so the numbers of views and followers were increasing. We have been permanently using different channels through which we reached our target groups. During this time, we gained more than 100 new subscribers.

We prepared Local Stakeholders Plan as a report to effectively disseminate and communicate the project to all relevant stakeholders (BioTHOP Stakeholder group (hop growers, other farmers, gardeners, policy decision makers, representatives of industry, researchers, general public (media, NGO, local people) and further targeted audiences. It was reviewed twice times to ensure that the plan was meeting BioTHOP project expectations and to make some modifications if required. To inform our stakeholders about the project and promote it we designed more than 4 different project banners (references: photo competition, project name explanation, project's goals), and published 5 technical e-newsletters in EN and SI language.

More than 1 million readers have read **17 professional/ scientific articles** in specialised magazines and numerous articles/ interviews in local, regional and national newspapers (28).

Various videos were released at local TV - STV, shared on YT and FB (43 videos).

We organised an educational visit to the Czech Republic for stakeholders (30 participants).

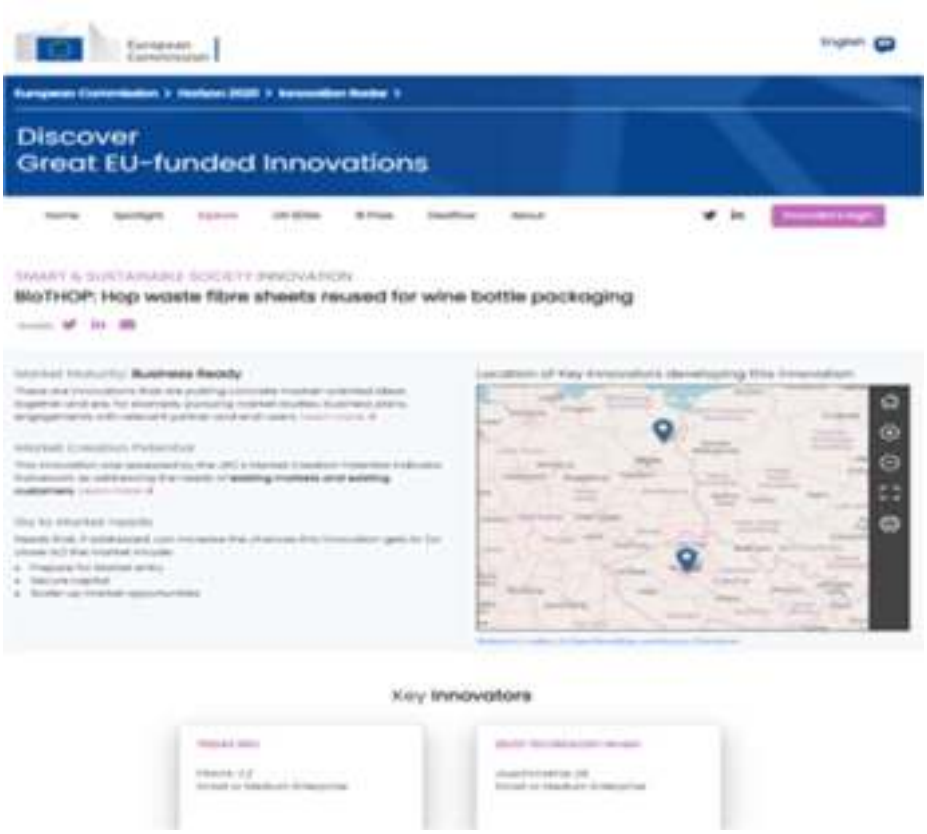
We have presented the project **to more than 900,000 visitors** at international and national fairs.

Within consortium, we prepared different in-site and on-line events / meetings to interact with stakeholders, hop growers from the Lower Savinja Valley, other hop-growing regions in Slovenia, Austria and Czech Republic.

During project, there were 3 different ministers for agriculture in Slovenia – all of them were familiar with BioTHOP project.

Additional networking events have been organised until the end of the project. All partners have been contributed to the raised awareness among the citizens, SMEs, large companies, associations, municipalities, clusters, agro cooperatives, research institutes and government institutions about the harvested hop waste management and valorisation, and bioplastic product benefits for the environment. We have established links with 40 projects (EU and non EU), 5 regions in Slovenia and 8 countries. The Project results have been transferred to 13 other countries / regions. At least seven sectors were approached. We were active to reach

stakeholders in different sectors by testing biodegradable materials (cosmetics industry, button production) and products (wine producers, gardeners).



As result of partnership contribution to raising awareness of bio-plastic product and environmental benefits we prepared **Study report of the local community feedback**. Report includes concerns, needs, opinions, questions, reactions received from stakeholders, target groups during the lifetime of the project.

Another deliverable **After LIFE Communication plan** includes steps which will help to disseminate and transfer the project results to other EU countries. It includes project objectives, target groups, the most common communication tools and a table with description and budget plan of dissemination activities for next 5 years. Each partner will carry out dissemination activities separately according to its own capacities and profile and has decided whether to present the project at conference, fair, congress, meeting or workshop. They will continue disseminating the project results beyond the end of the project to ensure better sustainability and usability of the project results.

- ✓ The LIFE BioTHOP project **has been nominated twice as key innovators and new technologies**. BioTHOP **partners ZT and TRIDAS** were announced as key innovators by the EC Innovation Radar as one of the Market Creating Innovation "Hop waste fibre sheets reused for wine bottle packaging" in December 2021.
- ✓ The LIFe BioTHOP project **has won two gold awards in June 2022** for the best innovation at local and regional level for its visibility, sustainable materials and products.
- ✓ It also **won a bronze award** in September 2022 at national level for the best innovation idea.

BioTHOP was **featured as LIFE project example** included in the impact assessment of the proposal for a Regulation on Packaging and Packaging Waste (more detailed explained in CINEA Impact assessment report, EC, nov 2022).

Problems

The implementation started as planned, in July 2019. From March 2020 till spring 2022, we were faced to cancellations of several planned events, fairs and some other dissemination activities due to the Coronavirus pandemic. However, we tried to disseminate the project on various occasions to smaller groups of participants as originally planned in our application (local events, fairs, workshops, seminars) and extend the work extensively on social media. On-line dissemination actions have been performed regularly through project website, social networks. However, we successfully continued with the modified activities and put more focus on online activities and so most actions or budget within this task were not modified.

Deliverables and Milestones

- ✓ D2.D1 'Stakeholders plan defined in the form of a report' completed on time 12/2019
- ✓ D2.D2 Study report of the local community feedback in June 2022
- ✓ D2.D3 After LIFE Communication Plan in the form of a report 10/2022
- ✓ D2.M1 Stakeholders plan reviews that we have performed more than 45% of planned activities 12/2020
- ✓ D2.M2 Stakeholders plan reviews that we have performed more than 85% of planned activities 12/2021

ACTION E1 Project Management

Foreseen start date: 1/07/2019	Actual start date: 1/07/2019	STATUS: completed
Foreseen end date: 31/12/2022	Actual end date: 31/12/2022	

E1.1 Overall Project Management

Activities, progress and results

Compliance with the action, 'Daily maintaining of a proper level of commitment from all partners' is confirmed. The Consortium partners have generated adequate tools to guarantee the organised, cost-controlled and timely delivery of all results in the project. We review the continuity of the project results and create regular reports for the project monitor. Day-to-day communication among Technical Action Leaders and Project Manager was ongoing. These parties have ensured that all deliverables and milestones planed were completed successfully and on time. Each partner informed the lead partner in good time in case of difficulties, in order when necessary to find a jointly solution.

Professional guidelines for the new regulation for the management with hop biomass after harvest were prepared and published by IHPS.

E1.2 After-Life Plan

Each of the seven partners will contribute with its own resources, consisting mainly of man-hours made available, to the implementation of the After-Life Plan, that was developed for five years after the official end of the BioTHOP project, from 2023 to 2027. IHPS and DAS will coordinate BioTHOP communication and dissemination activities after the project ends with support from all partners.

The After Life Plan dissemination plan foresee, how the communication and dissemination of results will continue after the end of the project with the target audience up to 2027.

Problems

There was an issue at status of the staff status at partner ZT at the start of the project. IHPS was in correspondence with project monitors and the issue was solved in spring 2020.

The extension of the project LIFE BioTHOP was approved from 30/06/2022 till 31/12/2022, due to the exceptional circumstances of the COVID 19 pandemic situation that affected the project work with some delays in the implementation of certain project actions.

Deliverables

- ✓ Deliverable E1.D1 Signed partnership agreement was finished in June 2020.
- ✓ Deliverable E1.D2 Green procurement Report was finished in 30.10.2022.
- ✓ Deliverable E1.D3. Compilation of minutes from all 7 Steering Committee was finished 30.11.2022.
- ✓ Deliverable E1.D4 After-Life Plan was done 30.10.2022.

6.2 Main deviations, problems and corrective actions implemented

The project was reaching predicted objectives; however, some small alterations were made in order to optimise the processes because the pandemic situation; the consortium recorded occasional outages of the personnel due to quarantines.

IHPS prepared background for new national regulation of composting of hop biomass on farms, however because of the COVID 19 the talks on local level were a bit delayed.

Twine. In order to use the twine in replicative regions (B5), 0.5 ton of the twine was needed and not 14 tons, as predicted in proposal. In Demo region, Lower Savinja Valley, limitations of PLA on the market dictated rescheduling the tests as discussed and agreed with the project Monitor. Due to pandemic situation, partner LEP could not perform all planned test visits in Slovenia, in order to participate at the hop harvest and see the response of the twine on harvest machines, so the formation and testing of the final formulation of the twine was delayed.

Shipping of hop stems. First shipping of fresh hop biomass resulted in spoilage of part of the sent material, however enough biomass was preserved to provide enough material for tests in 1st Demo Stage. In 2nd Demo Stage, shipping of dry hop stems was done.

Fibers. In proposal, it was predicted that 1000 of wine bottle packaging (TRIDAS) and planting pots (TECOS) will be produced in 2nd and another 1000 each in 3rd Demo stage. Due to rough estimations, amounts of biocomposite for planting pots were over-dimensioned at the preparation of the project proposal as well as amounts of fibre sheets for bottle packaging, because a maximum of 30 % of fibre can be incorporated into biocomposite for planting pot injection moulding and a maximum of 50 % fibre incorporated in pulp mixture for wine bottle packaging production, the tests showed.

Due to developed formulations for planting pots and bottle packaging, the production of hop fibres was downscaled since production of 1 ton of fibres per year would leave us with great amount of stocks, creating an issue of storage at that time.

Wine bottle packaging. There was a delay because TRIDAS inquired several companies who would perform biodegradability testing, but there was no suitable ones. The testing is associated with the final certification of biodegradability. When they found the company, the tests took several months, so everything took longer than expected. Finally the result was reached before the end of the project.

Planting pots. Planting pots are low-cost product. In order to maximize the cost reduction, the lightest version of the planting pots was developed, suitable for demo pilot line and BioTHOP compost. With initial version of mould, several problems occurred in filling phase and ejection phase. During the filling phase of thin-walled product is crucial to have walls with uniform thickness. Several iteration of mould repairment were done, i.e. installation of positioning pins were done to optimize the thicknesses of pot.

Furthermore, to enhance automation of the process and ejection of the pots, additional ejector was installed into the mould. We had to produce around 40% more planting pots during the development as planned in proposal to ensure optimal quality of the pots and optimization of the process.

In the frame of dissemination, monitoring activities within actions C and D and in accordance with the project's application form, all planned reports, milestones and deliverables have been produced within the set deadlines. Despite facing the pandemic and the measures taken during the project, we successfully continued with the modified activities and put more focus on online promotional activities.

The whole consortium, relevant stakeholders (target audiences, hop growers, policy decision makers, representatives of industry, NGOs) were actively involved in all dissemination actions.

6.3 Evaluation of Project Implementation

Action	Foreseen in the revised proposal	Achieved	Evaluation
Action: A1 Field tests with current PLA twine and hop waste preparation (1/7/2019 – 31/12/2019)			
A1.1 Field tests with current PLA twine [IHPS]	Objectives: Field-tests on 30 ha of hop plantations with a currently available polylactic acid (PLA) twine.	Twine successfully tested on 25 ha in 2019 on the hop fields of IHPS and Lower Savinja Valley hop growers. PLA twines' performance and suitability for hop growing evaluated.	We tested twine on 25 ha instead on predicted 30 ha, because such area was available at the time of the project start. However, all the predicted results of this preparatory

	Expected results: Evaluation of PLA twines' performance and suitability for hop growing; Requirements and limitations of the current PLA twine for hop growing sector (deliverable).	Guidelines for twine modification defined. Deliverable *Requirements and limitations of the current PLA twine for hop growing sector* made on time.	action were in line with proposal's objectives and action successfully completed.
A1.2 Collection of hop waste [IHPS]	Objectives: Hop waste collected, analysed and used for actions A1.3 and B.1. Expected results: Suitable amount of hop waste collected and delivered for further analysis and processing (A1.3, B.1); Definition of hop waste categories; Protocols for the collection and sorting of hop waste defined (deliverable).	375 tons of hop waste was collected in Sept. 2019, analysed and used for actions A1.3 and B.1. Suitable amount of biomass was delivered from IHPS to ZT in Germany for further analysis and processing of hop fibres. The rest of the biomass was composting in Lower Savinja Valley. Protocols and requirements of hop biomass flows were defined. Deliverable *Protocols for the collection and sorting of hop waste* was prepared.	Predicted results of this preparatory action were in line with proposal's objectives and action successfully completed. The only problem was the transport of the biomass, which should be dried before putting it on the truck for a long way from SI to GER. We wrote this in the guidelines – deliverable of this action afterwards, so the issue is solved. And also on the other hand, there was enough of unspoiled biomass arrived to ZT to compete the action according to the plan.
A1.3 Protocol definition on hop waste modificati on [ZT]	Objectives: Hop waste, including remnants of PLA twines, will be processed (dried, grinded), to produce fibres, which will be used as an additive for production of composite materials. Expected results: Suitable amount of processed fibres prepared; Regulations and protocols on modified hop-waste components defined (deliverable).	Initial test batches were produced for both material processors / product developers – trays and pots - suitable amount of processed fibres were prepared and delivered. Deliverable *Regulations and protocols on modified hop-waste components defined* was prepared on time.	Predicted results of this preparatory action were in line with proposal's objectives and action was successfully completed. In addition, we were able to specify necessary hop waste condition before processing.
Action: B1 Hop waste transformation into new valuable feedstock (1/10/2019 – 31/3/2022)			
B1.1 - Composta bility and anaerobic digestibilit y	Objectives: Compostability of post-harvest hop biomass (100 t per season), including remnants of PLA twines, will be analysed. Several	370 tons of hop biomass including remnants of PLA twines was composted in the season 2019/2020, 200 tons was composted in the season 2020/2021 and 150 tons were composted in season	Achieved results of this action by now are in line with proposal's objectives. Deliverable: *Complete quality analyses & guidelines for on-site hop crop*

assessments [IHPS]	different procedures will be tested, in order to produce the compost of highest possible quality. Expected results: Complete quality analyses & guidelines for on-site hop crop composting process (deliverable)	2021/2022 and 30 tons were composted in season 2022/23. Over 10 different protocols were tested, composts were chemically and biologically assessed. Promising results regarding PLA degradation and compost quality were obtained.	*composting process* was done at 30/8/2022.
B1.2 - Valorisation, post-treatment and production of hop fibre materials [ZT]	Objectives: Post-harvest hop biomass processed into fibre materials with different properties, to be used for production of composite materials (B1.3) and fiber sheets (B3). Expected results: 1000 Kg of processed hop fibres per year produced.	Fibres were successfully extracted for 1st and 2nd demo stage with various fibre qualities supplied. Fibre quality was optimized for TECNO, who needed a smaller and more regular fibre size – the ZT process was successfully adapted to reach the target. Additionally, extract from hop biomass was examined and marked as potential fertiliser. In 2019 2.6 Kg hop fibres was produced. This is the result of the first batch being sent unsorted and wet, which led to the fibre degradation. in 2020 36 kg. In Jan 2021: 33 Kg a further batch of +/- 50 Kg has been produced in 2021 on demand. All these quantities only take into account the materials that were sent to partners TRIDAS & TECNO and not the quantities processed by ZT to experiment with the materials and find the right settings.	The expected quantities have been overestimated and it became rapidly visible that TECNO & TRIDAS would not need that kind of quantities. The processing of hop fibres has been adjusted from year to year, selecting the ones with PLA for TECNO and the ones with natural twine to TRIDAS. For TECNO, ZT produced material that would allow for better flow dynamics with the added PLA etc. This material was reduced to a powder/granular level with no visible fibre clusters. For TRIDAS, ZT improved fibre morphology and refined to a higher Schopper Riegler level (approx. 25°SR)
B1.3- Valorisation, post-treatment and production of hop fibre reinforced composites [TECNO]	Objectives: Composite materials will be produced, using hop fibres as additive, to be used in action B4 for production of demonstrators. A prototype will be developed for post-drying procedures of the compounds after the extrusion process.	For biocomposite formulation, different types and percentages of fibres were used, as well as different additives and biopolymer matrixes tested. So far, bio-composite with 30% of hop fibres seems the most promising for injection moulding. A total of 24 formulations were tried (proposal requires 3) (in total more than 340 Kg	The adjustement of material predicted in the intermediate report led to the production of 105 Kg of BioTHOP composite for the 2nd stage of the project. 24 blends were developed, using 4 different plastic matrixes. Once the final masterbatch was chosen, the 3rd stage consisted on the production of 200 Kg of biocomposite. 120 Kg were enough for

	Expected results: 3000 KKg of fibre reinforced composite material produced by the end of the project.	of BioTHOP composite material). The results were detailed on deliverable B1.D3, made by TECNO and submitted in December 2021	TECOS to produce the necessary planting pots to cover IHPS demand, and the rest remained at TECNO for replication activities. The deliverable was submitted on time and no delays were observed.
Action: B2 Adjustability of PLA twine for hop-growing sector (1/10/2019 – 31/3/2022)			
B2.1 PLA twine modification to weather resistance and mechanical performances [LEP]	Objectives: Elite®Bio Twine, manufactured by AB LEP and intended primarily to be used in greenhouses for growing tomatoes and cucumbers, will be modified specifically for growing hop. Additionally, modifications will be made in order for the twine to be suitable for on-farm composting (as existing twines are suitable only for industrial composting). Expected results: Several variations of biodegradable twine, optimised for growing hop, produced and thoroughly tested. 7.2 t of twine produced to be used for testing and validation in action B2.2. Up to 14 t of twines produced, to be used replicative regions (Action B5).	Several variations of biodegradable twine were made and tested in order to get optimised for growing hop plants. The twine runnage has been gradually reduced from the initial tests in 2019 with an average 15% reduction in runnage versus the benchmark. Modifications were made in order for the twine to be suitable for on-farm composting and thoroughly tested. 1.51 t of BioTHOP twine was produced to be used for testing and validation in action B2.2 in 2020, another 1.48 t were produced in the third demo stage and tested in 2021, which is enough **to cover all planned acreage** in Action B2.2. 0.5 t of twines were produced, to be used in replicative regions **to cover all planned acreages** (plantations in Czech Republic, Austria and 3 Slovenian hop growing regions) in 2021 within Action B5. Finally, another 150 Kg were supplied in 2022 in order to validate an improvement on the harvesting behaviour of the twine. This would reduce the TCO for the growers by reducing the stoppage on the harvesting machine.	There was an adjustment in the amount of twine to be produced since lower mass of twine was needed per hectare compared to the project assumptions. A**ll planned acreage** was covered according to the plan in Action B2.2. The data that we need to produce up to 14 t of twines to be used in the replicative regions on 5 ha (5 replicative regions, each on 1 ha) in Action B5 was incorrect; we needed for this surface 0.5 ton, which was produced by the end of year 2020 and were delivered to all 5 replicative regions in the following weeks. The twine was successfully tested in the replicative regions, with some issues being identified in the Czech Republic due to the difficulties in knowledge transfer brought by COVID 19. **This met the goal of the task, which is 5 ha in replicative regions in 2021.** In total, more than 62 ha of hop fields were planted using the BioTHOP twine. This exceeded the target 30 + 5 ha ha goal of the project and does not even take into account the area of hop fields tested in the countries outside the original plan.
B2.2 Validation of new PLA twine on hop field	Objectives: Modified PLA twines will be tested and validated for growing hop (in 2020 growing season, on up to 30 ha)	The BioTHOP twine was tested successfully on 12 farms in demo region Lower Savinja Valley on 15 ha in 2020, on 15 ha in 2021 and on 1.5 ha in 2022.	Due to limitations of PLA on the market, the twine tests have been rescheduled to 15 ha 1st Demo stage, 15 ha in 2nd Demo stage and 5 ha in 3rd Demo stage, compared to

testing trellis [IHPS]	and on-farm compostability. Expected results: Validation report on novel PLA twine performances from hop field experiments (deliverables B2.D1 and B2.D2); Certification that produced BioTHOP twines are biodegradable in industrial and if proven possible with an improved recipe, on-farm composting (deliverable B2.D3).	The response on field and harvesting process have been monitored to guarantee no negative impact in efficiency. Results were collected on field by IHPS and send to LEP in order to modify the twine for the next season. Biomass after harvest was used for both composting and up-cycling of waste into added value products in the other Actions. The tested twine has proven to be compostable on-site when the right conditions are used with a good quality compost resulting from this improved process.	planes in proposal that was 30 ha in 2019 and 30 ha in 2020. So, the rest of the planned 30 ha for 2020 season (15 ha) were tested in 2021 in agreement with the project Monitor, because by this we get also another testing season and one season more to make modifications on the twine. Additionally, another 1.5 ha were tested in 2022 which allowed the project partners to make a last adjustment in the product to improve its performance. Deliverables for this action were prepared in in the second half of 2022 - after the growing season 2022 as planned.
Action: B3 Demonstration pilot in packaging sector (1/1/2020 – 31/3/2022)			
B3.1 Adaptation of hop waste fibre crumbs to pulp moulding process [ZT]	Objectives: Recovered and modified hop waste fibre crumbs, produced in the framework of action B1.2, will be used for production of fibre sheets, and used for the packaging demonstration. Expected results: 2100 Kg of fibre sheets (in three years), to be used in action B3.2.	ZT specified non-PLA contaminated hop fibre to allow TRIDAS to proceed without bioplastics (foreign objects) in their forming equipment – this is a requirement as the PLA would melt in the thermoforming process and damage production tools. Natural twine (hemp, sisal) containing hops has been supplied by and processed by ZT and thereafter sent to TRIDAS for machine testing. 15.3 Kg was produced in two separated bags for testing in first stage, and a 50KKg batch once parameters at TRIDAS were established.	As for B1.2, the quantities have been overestimated. This can be explained by the % of hop fibres that can be included in the formula – which cannot be 100%. The quantity of fibre sheets needed is at least 400 Kg to reach the project result – 2000 bottle packaging, as stated by TRIDAS who worked intensively on the formula. ZT is waiting for final quantity needed by TRIDAS to reach this goal by the end of the project.
B3.2 Demonstration of packaging product solutions based on transformed hop waste [TRIDAS]	Objectives: Recovered and modified hop waste fibre crumbs, prepared in action B3.1 will be used as one the input materials for the production of packaging demonstrators - tray box inserts for wine bottle packaging. Expected results:	Different combinations of input material – hop fibres and cardboard offcuts - were tested. TRIDAS designed 3D design for wine bottle packaging. Recovered and modified hop waste fibre crumbs, prepared in action B3.1 was used as one the input materials for the production of bottle packaging.	First produced fibres weren't suitable for pulp moulding. The production was in line with proposed objectives. The first 1,000 wine bottle packaging was made in spring 2021, as planned. The best ideal combination of input materials were found 50% hop waste and 50% cardboard offcuts. The second production of 1,000 wine bottle packaging

	Tray box insert designed; Up to 2,000 tray box inserts produced and suitability of hop fibres for packaging industry demonstrated.		was made in winter 2021, as planned. The material received from ZT was sufficient to reach the project result - production of 2000 wine bottle packaging.
Action: B4 Demonstration pilot in horticulture accessories sector (1/1/2020 – 31/3/2022)			
B4.1 Adaptation of hop fiber reinforced composites to injection moulding process [TECNO]	Objectives: Hop fibre reinforced composite material (action B1.3) will be adapted and used for injection moulding process. Different formulations will be tested, to find the optimal content of hop fibres and other additives. Expected results: Stage 1: 500 Kg of composite material produced, with at least 5 different compositions; Stage 2: 500 Kg of composite material, in 3 fine-tuned formulations, used for production of demonstrators (planting pots); Stage 3: 1000 Kg of the final formulation, for production of planting pots. Report on optimal formulation of hop waste fiber reinforced PLA for injection moulding (deliverable B4.D1).	Mechanical testing: tensile and flexural samples were injected and tried in the 24 formulations obtained from action B1.3. Adjustments on the formulations were implemented according to the mechanical properties and the planting pots injection trials performed at TECOS. All together 105 Kg of material were produced in the 2nd demo stage, i.e., 9 material formulations in amount of 8-10 kg. The final stage consisted on the upscaling to industrial production of the final masterbatch. The results were detailed on deliverable B4.D1, made by TECOS and TECNO, and was submitted in December 2021.	As reported in action B1.3, the number of formulations developed increased to more than 25 counting not only the masterbatches developed at TECNO but also the dillutions made by TECOS after. All the blends were characterized by tensile and flexural tests. From the masterbatches, the best performing one was selected for the 3rd demo stage, upscaling the production to 200 Kg of material. The deliverable was submitted on time, without any delays.
B4.2 Demonstration of horticulture product accessories based on transformed hop waste [TECOS]	Objectives: Innovative, full biodegradable composite material, developed in action B4.1, will be used to produce demonstrators - planting pots. Planting pots certified for biodegradability and industrial compostability. Expected results:	First trials were performed in April 2020, when 200 pcs of pots were produced from pure PLA and PP/PE material to assess the mould performance. In June 2020, 50 pre-trialled planting pots were produced from 1st generation of BioTHOP material (F12). In Nov. 2020 additional 150 pcs were produced from 2nd Generation of BioTHOP (F15) compounds.	Deliverables Report on planting pot demonstrators for horticulture applications and Certification that produced BioTHOP planting pots are biodegradable/industrially compostable prepared on time (31.10.2022). In the report is presented positive evaluation of all the tests, related to biodegradability of plantings pots (disintegration and effect on the biological

	2000 planting pots produced (in two stages, 1000 each); Report on planting pot demonstrators for horticulture applications (deliverable); Certification that produced BioTHOP planting pots are biodegradable/industrially compostable (deliverable).	3rd final CAD design version out of 3 was confirmed as final in January 2020. Prototype injection mould was constructed, manufactured and assembled in March 2020. In July/August 2020 TECOS in close cooperation with Tecnopackaging (TECNO) carried out study of biodegradable matrices, suitable for development of BioTHOP composite (intermediate tests) and produced 200 pcs of pots. Variety of bio-material grades (bio-based, biodegradable or both) were considered in study to choose the optimal one. Several optimization iterations and material studies were performed in the middle of November 2020, January 2021, March 2021 and May 2021. At the end pf 2nd demo stage, 220 pcs of flexible matrix 1 based composite was produced and another 620 pcs of flexible matrix 2 based composite and sent to IHPS on testing. In the middle of September 2021 TECOS prepared a shipment for Italian company Archa, where biodegradability tests were performed and positive evaluation was received in March 2022. In the 2nd period of year 2022 TECOS implemented 3rd Demo Stage, where we manufactured 1400 plantings pots of final material formulation and delivered them to IHPS in May 2022 for automatic planting.	treatment process, evaluation of negative effects on degradation process, final substrate quality, ecotoxicity assessment). In the check list for the final assessment of the compliance with EN 13432 it was presented that overall results of the evaluation was marked as accepted and positive. Throughout the duration of the project more than 2800 plantings pots were injection moulded in various batches and tests. In the last year, 1400 planting pots from final formulation was produced and sent to IHPS.

Action: B5 Replicability and transferability (1/12/2020 – 31/12/2022)			
B5.1 Replicability in other EU regions [DAS & IHPS]	Objectives: Project replication methodology will be prepared for other hop producing EU regions, namely Saaz Region in CZ, Steiermark	Koroška region (SI) tested BioTHOP twine before time, in 2020 and 2021, on 1 ha each year. In Czech republic and in Austria, twine was	Action started before it was planned, already in 2020, because of the big interest.

	Region in AU and 3 SI hop growing regions. BioTHOP twine will be delivered to them in 2021 free of charge for their demonstrative field tests, each at 1 ha. Results will be analysed and used for preparation of replication guidelines. Expected results: Biodegradable twines used for demonstration and testing purposes in 5 EU hop growing regions in 2021, each on 1 ha; Guidelines for replication the BioTHOP twining methodology in other EU regions (deliverable).	tested in 2021 on 1 ha in each country. On small area testing was done in hop plantations in Germany, Belgium, Portugal, Spain, Serbia and Notranjska region (SI). The demand for the twine was beyond expectations – it was also tested / replicated in high beans production, vegetable production in greenhouse and in open field.	Some already tested the twine in 2020 and were satisfied. The work continued in 2021 and was completed in 2022, with tests in Belgium and Germany. Predicted results were even better compared with proposal's objectives since only 5 regions in 3 countries were considered in the project plan.
B5.2 Transferability to other sectoral applications [TECNO]	Objectives: Potential for transferring the project results to other applications will be assessed. Composite material, reinforced with hop fibres, will be used for production of bio-film material and tested by a Croatian company Bio-mi for use in agriculture. Spanish company Thermolympic is foreseen to test the composite material in injection moulding applications for "fast-moving consumer goods" products, and one German company will test it for production of disposable bio plates. Some modification on the raw materials, produced by the project, are foreseen to be made, to increase their suitability for these applications. Expected results: Up to 250 Kg of bio-film and 250 Kg of composite material for injection; Guidelines for transferring the BioTHOP materials to other industrial sectors.	From the start of the task until the finalization granted by the extension of the project (July 22), TECNO and TECOS have continuously been working on replication activities. Thermolympic was unable to become part of the task development. However, it was replaced for three more potential stakeholders (MOSES PRODUCTOS, CAFINSA, PRIME BIOPOLYMERS) who showed interest on the material not only for injection molding but also for casting/thermoforming. In total 12 products were developed, using 5 different transformation techniques (Injection molding, casting extrusion, vacuum thermoforming, 3D printing and film blowing.) and achieving the approach to 7 different sectors (Fashion industry, cosmetic industry, toys, automotive industry, agricultural sector, packaging and FFMCG sector). The results were collected by TECNO and TECOS in deliverable B5.D2, submitted in July 2022 as new deadline.	The action was developed as planned and any modification on stakeholders was approached by an intense search for contingency solutions. Not only the task managed to overcome difficulties but also to increase the number of expected replication products. The deliverable was submitted on time, with no delays.

B5.3 Replicability, transferability and industrialisation plan [DAS & IHPS]	Objectives: Based on results, achieved in other implementation activities, including B5.1 and B5.2, a detailed replicability, transferability and industrialisation plan will be devised. Expected results: Replicability and transferability plan (deliverable); Final report on industrialisation plan of the resulted BioTHOP solutions (deliverable); Replication and/or Transfer Strategy (deliverable).	Replication and transferability plan identified most promising products or processes for replication and transferability into other sectors and other countries. Based on its results, Replication and/or Transfer Strategy was made.	Final report on industrialisation plan of the resulted BioTHOP solutions is going to be prepared.
Action: C1 Monitoring of the project impact (1/10/2019 – 31/12/2022)			
C1.1 Monitoring over the technical project progress [IHPS]	Objectives: General monitoring of the project progress. All the results will be assessed during the SC meetings and reproduced in the minutes to facilitate the results traceability. Green Procurement Procedures will be monitored in this sub-action and managed in Action E1. The results of the monitoring activities will be reported to the Commission in project reports. Expected results: Two internal monitoring reports (deliverables).	The monitoring over the technical project progress is done on daily basis, over e-mails, telephone and Zoom meetings. Technical monitoring reports were delivered to project monitor every 3 months.	Monitoring is going well, as project is progressing as planned.
C1.2 Monitoring the environmental & socio-economic impact [IHPS & DAS]	Objectives: The environmental impact of the BioTHOP products throughout their entire life-cycle will be monitored and analysed, to prove that they are a cost-efficient solution. This action will also measure the project's impact on social awareness & acceptance of the environmental benefits and behavioural influence in life of current and future members of the local community. Expected results: LCA and LCC analyses (deliverable); Indicators for the socio-economic impact of the project (deliverable).	LIFE Project Specific Indicator are updated regularly as well as LIFE Key project level indicators. Report of social awareness public survey with explanation of the results within Socio – economic analysis of BioTHOP solutions is being prepared.	Monitoring is going well, as project is progressing as planned. Indicators for the socio-economic impact of the project were prepared.

C1.3 Monitoring and up-dating of KPI indicators [IHPS]	Objectives: Key indicators concerning the project's environmental, societal & economic outcomes will be assessed and up-dated via the LIFE KPI Webtool. Expected results: Updated initial LIFE Project Specific Indicators; Final LIFE Project Specific Indicators.	Key indicators concerning the project's environmental, societal & economic outcomes were assessed and up-dated via the LIFE KPI Webtool.	Key indicators concerning the project's environmental, societal & economic outcomes were assessed and up-dated on the basis of actions carried out during the entire duration of the project. We carried out an audit of the assessment of the fulfillment of KPI indicators after the end of the project, and additionally explained in the LIFE KPI Webtool (to the extent possible in application) Action was progressed as planned. Report of social awareness public survey with explanation of the results within Socio – economic analysis of BioTHOP solutions was prepared. Monitoring was smooth as the project progressed as planned. Indicators for socio-economic impact have also been made.
C1.4 Monitoring of dissemination activities [DAS]	Objectives: Monitoring of dissemination activities will be reported in deliverables that are part of the Actions D.	Monitoring of the project content dissemination was achieved by: recording the results of each activity, the registration of participants to events, visitors to web and demonstrating sites, counting of distributed materials - published press releases articles - links to the BioTHOP websites, etc.	In the line with proposal. Monitoring of dissemination activities went on as planned and was reported as planned. Dissemination monitoring reports were delivered to

			project monitor every 3 months.
Action: C2 Conclusions and recommendations (1/6/2020 – 31/12/2022)			
C2.1. Socio Economic Impact Analysis [DAS]	Objectives: Based on results of the socio-economic impact analysis, a cost/benefit study will be developed, to ease the exploitation of the project results by any interested party.- Newly developed products will be compared with alternatives as part of the cost/benefit analysis under the environmental and socioeconomic criteria. Expected results: Socio-economic analysis of BioTHOP Solutions (deliverable).	The action is based on the monitoring Action C1 - report of public survey (C1.2). DAS will upgrade that survey on the next level regarding project results by the end of September 2022.	DAS has upgraded the survey to the next level regarding the final project results. Activities went ahead as planned and the Social - economic analysis of the BioTHOP project was prepared.
C2.2. Policy Recommendations [DAS]	Objectives: Based on results of the project activities, various policy recommendations will be prepared. Expected results: Recommendations for more effective regulatory policies and governance Structures (deliverable).	IHPS is preparing basis for national legislation, DAS is preparing documentation in this field on the municipalities level to be reviewed in the following months until the end of the project.	The action started and goes on as planned through good communication between policy decision makers – ministries and municipalities.
C2.3. Market up-take of the project products and services [IHPS]	Objectives: Potential market up-take and commercialisation potential of several products will be assessed: Modified PLA twine for hop-growing industry; Engineered hop fiber materials; Hop fiber reinforced PLA composites; Services for adapting the production process to the BioTHOP materials; New horticulture products, i.e. planting pots or similar; New packaging products, i.e. trays or similar; Services for transferring the BioTHOP concept to flexible film production sector. Expected results:	DAS has been preparing Business Plan and Collaboration agreement.	DAS prepared Business Plan and Collaboration agreement. Activities went ahead as planned. Activities have been carried out as planned by the end of the project. Project progress and results, Communications and dissemination, Life information Commissions documented and reported were prepared.

	Business plans for selected products and services developed.		
Action: D1 Communication strategy (1/7/2019 – 31/12/2022)			
D1.1 Communication & Networking [IHPS]	Expected results: • Project's corporate communication visual identity, templates and images; • Press kit; • Stakeholder's databases & mailing list (at least 1000 addresses); • Project website; • Social network - Facebook, LinkedIn, Twitter and YouTube accounts; • Project's brochure; • At least three short videos; • Public electronic newsletters.	- BioTHOP logo with LIFE logo - Approved BioTHOP corporate communication visual identity, templates and images. - Press kit designed with the key project facts & features in English and 5 national languages. - Stakeholder's database prepared in accordance with GDPR, by now with over 7,719 addresses. - BioTHOP Website, with all information about project in 4 languages: www.life-biothop.eu, constantly updated. - FB page, LinkedIn, Instagram and YouTube project's channels constantly updated. - Project brochure published in Sept. 2019, updated in Aug 2020. - Inlay flyers in each partners' language (1000 copies). Cca. **41 videos** shot and published on website and FB, Instagram; Published public on-line electronic Newsletters (3).	The communication strategy met expectations and throughout the lifetime of the project shows many positive results.
D1.2 Public Awareness Campaign [IHPS]	Objectives: Public awareness campaign will be mainly based on the in-site activities at each partner country, targeting the agricultural, packaging, plastic, horticulture industry. Expected results: • LIFE Information boards: • Roll-ups and posters; • 2 technical workshops, with at least 40 attendees;	7 Info boards were designed for Consortium and installed at our facilities. 7 Roll-ups designed for Consortium to promote BioTHOP achievements and results. Training and workshops were organised: ▪ technical seminars organized for hop growers and hop specialists,	The project is well known in local and also national level. Action is going on as planned and we expect to reach all planned results by the end of the project. Progress and results of the communication and dissemination and Life information Boards documented

	• 3 visits to pilot production facilities, at least 60 attendees; • 4 exhibition workshops, at least 80 attendees. • Final conference, at least 150 attendees; • Commercial press release; • Layman's report.	▪ visits of pilot production facilities, ▪ meetings and regular communication with co-financers. Numerous published articles (more than 41), interviews, chats in different magazines publish to promote the project's achievements at EU and national/regional levels, etc.	and reported for the public feedback are going to be prepared
Action: D2 Dissemination of the project results and stakeholders involvement (1/7/2019 – 30/6/2022)			
D2.1 Local Stakeholders Plan [DAS]	Objectives: Local stakeholders in all participating countries will be informed and consulted regarding project aims and activities**.** Expected results: • Local stakeholders plan (deliverable); • Study report of the local community feedback (deliverable); • At least 2000 stakeholders directly contacted.	Stakeholders plan was defined in the form of a report. Local community feedback report of target groups, 1st and 2nd Report of public survey have been performed. To assure a real impact of BioTHOP project on the local community, we are regularly collecting data by using different methods. Directly contacted stakeholders by 3 working meetings with hop-growers/ stakeholders, sending emails, …)	The action goes on as planned. The consortium is efficient in reaching stakeholders via different channels and many reports had been prepared.
D2.2 On-line dissemination actions [DAS]	Objectives: Several specialised on-line activities are foreseen, targeting specific expert or business public. Expected results: • 10,000 stakeholders at European level reached; • 4 paid banners, published on selected websites; • 7 paid adverts in specialised media; • 3 newsletters sent to stakeholders.	Public electronic newsletters and technical newspapers published On-line and in-line actions involved professional/ scientific articles published in specialised magazines (more than 17) 24 articles / more than 1 mio readers BioTHOP banners (more than 4) and posters informing stakeholders about the BioTHOP project and promote the BioTHOP website Permanent involvement of supporters, co-financers of the project 2 BioTHOP public oppinion surveys / 805 participants Common BioTHOP stakeholders database with 7.719 email contacts	The action went on as planned. Predicted goals were reached and even exceeded.

		1 Photo competition in 2020 15 authors, 25 photos and 430 EU voters, 41 BioTHOP videos with 5.378 views, networking with 38 projects, 5 Si regions and 7 countries 3 nominations, 2 golden and 1 bronze awards	
D2.3 After Life Communication Plan (IHPS)	Expected results: After Life Communication Plan (deliverable).	After LIFE communication Plan was prepared as planned.	The Partnership was providing the necessary information for the preparation of the plan. DAS completed the contents in common document.
Action: E1 Overall Project Management (1/7/2019 – 31/12/2022)			
E1.1 Overall Project Management (IHPS)	Objectives: Project management team, led by Project manager, will manage technical, administrative and financial aspects of the project. Additionally, the Compliance Manager will be responsible for the stipulation of a Partnership Agreements and for the Green Procurement Strategy. Expected results: Project Steering Committee is foreseen to have at least 7 official meetings.	The work was done on daily basis, we were in close touch over e-mails and Zoom meetings, difficulties were solved promptly with emphasis of all included partners. The Grant Agreement was signed in August 2019. The Partnership Agreement was signed by all partners in June 2020. Internal quantitative indicators were gathered from all partners in order to measure the project progress, identify risks and execute contingency actions. A number of internal meetings take place, also 8 SC meetings.	Project work was proceeding as planned and no major deviations have been made. Because of the pandemic COVID 19 however the actions took more time, so the project was extended for 6 months. At the end, all predicted goals and results were reached or even exceeded.
E1.2. After Life Plan (IHPS)	Expected results: After Life Plan (deliverable).	After Life Plan finished in October 2022.	Successfully accomplished.

– Indicate which project results have been immediately visible and which results will only become apparent after a certain time period.

Right from the start of the project, we created the basis (project visual identity with templates and images, a press kit, a brochure, flyers, roll ups, notice boards, a web site and social media channels) for further work to spread the word about our LIFE BioTHOP project among our stakeholders – policy makers, industry, the general public and the mass media at local, regional and EU level. A clearly visible long-term impact of the project is the interest of the target groups on both national and international levels, giving their opinions and requests for more information about the project's actions. Stakeholders in the local and international agro-sector have also taken interest on the main outputs, and the replication products of the project. This represents an example of results that will become apparent after a certain time period, as agreements with potential clients should be carefully revised before implementation.

The interest on natural reinforced biocomposites has gotten the immediate attention of educative institutions, as the varied outputs of the project represent an optimal example of good practices in sustainability, and circular economy implementation case study. It is expected to receive more as time passes.
Liquid Extract of both PLA and Cellulose twine containing Hops residual was also generated and is potentially usable for bio-fertiliser and for bio-gas generation. We have developed planting pots made from new material, which is industrial biodegradable and contains the waste hop-fibers. Material was used also in other sector to demonstrate its versatility.
BioTHOP twine - developed and available in the market as of the end of the project. Increase in hop waste composting and impact on emissions and the environment will only be visible after more general adoption by the growers.

– If relevant, clearly indicate how a project amendment led to the results achieved and what would have been different if the amendment had not been agreed upon.

A project amendment led to the results being completed perfectly, because 6 months extension of the project let us have enough time to complete everything as predicted, since pandemic situation did not allow travels, number of people in labs was limited etc.

– Describe the results of the replication efforts.

It was planned to replicate and transfer the BioTHOP results to other EU regions and industrial sectors. The replicability and transferability of project results were on three-fold level: other transformation processes (film extrusion blow), new applications (bio-films), and trans-regional (demonstrative replication implemented in at least 5 other EU States).
The BioTHOP twine in hop production was replicated in few regions, in Steiermark Region in Austria, Saaz Region in Czech Republic, and three Slovenian regions: Koroška, Dornava and Ormož. Apart from that, it was also replicated on smaller scale in hop production in Belgium, Portugal, Serbia and Severna Primorska (SI). The twine was also transferred in vegetable production in greenhouses and outdoors. Various products from BioTHOP biocomposite were developed: thermoformed covering trays for automotive industry, buttons, playing bricks, panels, etc.

The replicative regions for BioTHOP twine in hop production were **Steiermark Region in Austria, Saaz Region in Czech Republic**, and three Slovenian regions: **Koroška, Dornava and Ormož**. The BioTHOP twine was tested there in 2021 on 1 ha in each region. The twine in Czech Republic was tested alone, as replication of BioTHOP results, and also in a combination with iron string which is their common practice; in

this technology they replaced 25 cm of plastic twine, that is commonly knotted to the iron string in order to be fit on the construction. Beside this, the twine was replicated in 2021 also to other EU hop regions on smaller scale: **Belgium, Serbia, Portugal** and **Severna Primorska region** (SI).
In all Slovenian replicative regions, Belgium and Serbia, there were no major problems with BioTHOP twine, they found it as a good replacement for polypropylene twine. The problems appear in regions, where their common technology is with iron string instead of twine; it these regions (Czech Republic and Austria) hop

growers have very different cutting systems in the harvest machines. While the iron string is because of its structure easy to cut, with softer twine there were problems with twining on the harvest knives and other rotating parts. So, for the start, the efforts of BioTHOP will be in After LIFE that BioTHOP twine in these regions replaces the 25 cm part commonly used as polypropylene twine in a combination with iron strings.
Various products from BioTHOP biocomposite were developed: **thermoformed covering trays for automotive industry, buttons, playing bricks BioTHOP**. The materials & products were transferred to other sectors & applications (example: FMCG sector in Spain or furniture sector in Germany). The guidelines for transferring the BioTHOP materials to other potential sectors and applications were elaborated for fast up-take of the project results of our products/services.

- Indicate the effectiveness of the dissemination activities and comment on any major drawbacks.

Effectiveness of the dissemination was excellent instead of the COVID 19 pandemic during the project duration. We adopted activities and finally managed to reach all results and even more.
The dissemination & communication activities were carried out at 3 different levels (local, national, EU level) and had a positive impact on all other project actions, especially in Actions B2 an B5. They also involved an increased interaction within hop-growers and stakeholders (policy-makers, industry and general public) thereby generating useful feedback. This has also led us to overcome the regional focus of the project and to develop contacts in other SI and EU regions and furthermore allowed us to evaluate other techniques used in the hop guiding and support which could potentially be substituted by compostable twines.
The dissemination & networking methods (special events, workshops, seminars, conference, webinars, webpage) and efforts of the BioTHOP project team ensure post LIFE activities, replication and transfer of the results, stimulation of local economies and meet the growing demand for sustainably, market-ready products.

- Describe how the project delivered the results foreseen in the Grant Agreement form B3 "EU ADDED VALUE OF THE PROJECT AND ITS ACTIONS".

The project envisioned a series of actions aimed at adding value. Some of them can be exemplified:

- Resource-efficient economy "Doing more with less": The commercial launch of the BioTHOP twine allows growers to compost their waste and use it for the production of corn, which can in place be used for the production of PLA, the building block of the BioTHOP twine. This is a business model which leads to a circular economy.
- Zero waste programme for Europe: The usage of the BioTHOP twine allows a significant volume of hop waste biomass to be transformed onto value-added compost that will continue to bring added value to the agricultural industry.
- Using plastic more sustainably: The replacement of PP twine with the BioTHOP compostable twine allows the growers to more responsibly and sustainably reduce their plastic consumption.
- Europe 2020 "Sustainable growth for a resource efficient, greener and more competitive economy": The usage of a compostable twine allows for significant reductions in greenhouse gases associated with the management of the green waste produced by the hop industry.

The added value of the BioTHOP project is that concrete actions and changes in the management of hop waste have been implemented, involving all key stakeholders. The partnership has provided a high added value in terms of transfer of know-how and information to the target groups in the framework of the dissemination and stakeholder engagement strategy. BioTHOP focused on combining the efforts to achieve sustainable products from renewable sources, considering the environmental impact and its influence along the entire value chain. It supported the resource-efficient policies & legislations. BioTHOP increased the competitiveness by valorisation of yet unexploited hop agro-wastes, current synthetic and costly fertilizers were partially substituted for cheaper, natural and healthier alternatives. The project followed the circular economy as much as possible. With EU's plastics strategy, single-use plastics will be phased out by 2020 and all plastic packaging will be recyclable, reusable or compostable by 2030. With placement of the BioTHOP twine on the market, it will be easier for growers to get the bioplastic products, and the change of the technology will not be needed. The BioTHOP bioplastic products can also help in this task. BioTHOP created synergies with the objectives of many other EU directives and contributed to the integration of environmental aspects into other policies on European, National & Regional level. BioTHOP also strived towards the implementation of the Green Procurement Principles.

– Policy impact

- ✓ BioTHOP succeed that in the national legislation in Slovenia in the *Law on Agricultural Land* came a possibility to compost on agricultural land. Number of locations and their size is included.
- ✓ Guidelines for proper handling with hop waste biomass were published in a collaboration with 2 Slovenian ministries; they contain not only technical guidelines but also policy rules.
- ✓ In collaboration with Žalec municipality an agreement was reached with Surovina, waste processing company, d.o.o. that they will be accepting waste plastics from agriculture in their facilities, so this material will be handled properly.
- ✓ A suggestion that composting and use of biodegradable twine will be subsidized was accepted on the current level of negotiations for the next period. We keep fingers crossed it will stay there.

6.4 Analysis of benefits

Environmental benefits

BioTHOP was focused on combining efforts to achieve sustainable products from renewable sources, in relation to environmental impact and matters relating to the value chain. In that sense, the project falls under the scope of the thematic priority relating to 'Resource Efficiency' a LIFE/Environment sub-programme regulation (Annex III, Section A, point (c) (i)).

BioTHOP is a closed loop concept based on the following points: 1. Preservation of agricultural lands through the use of agro-waste from hop crops that currently are wasted as feedstock, 2. Contributing to the production of biobased products (planting pots), 3. Improvement of local economies through a new added value chain.

Positive environmental impact was expected within 4 key targets:

1. **Zero waste to landfill**

Slovenia has a hop crop area of 1,625 ha (2022). This would translate onto 24,375 tons of green waste in one year.

Hop biomass (vines and leaves) because of the PP plastic twine residues currently contained within this material it is not appropriate for making compost and further use for fertilisation or any other use. According to current guidelines, we have to compost it first, then we sieve out the plastic twines remnants that are still mixed with biomass and take it for disposal on landfill. Therefore, our possibility is either to transport the whole biomass after harvest to landfill or sieve the biomass out of plastic remnants. However, the common practice for eliminating this biomass is often uncontrolled (illegal) burning. For each 1 tonne of hop biomass after harvest (mixed agro waste with twine) that is not put on the landfill but reused in another transforming cycles, we estimated that 3 cubic meters of landfill space can be saved.

In the time of the project, during the work carried out in Actions A1.1 and B2, the twine was used in hop production on 62.5 ha. This translated onto a total of net reduction in green waste mixed with PP twine (15 tons/ha) of 937 tons. This quantity of potential waste was avoided by the application of an environmentally suitable solution, namely – as a consequence of the new BioTHOP system it was composted over the winter and some of it was transformed to new BioTHOP products. That means for every 1 tone of mixed plastic waste (including with agro waste) that is taken from the landfill and reused in another transforming cycles, reports estimate that 23 of m^3 of landfill space can be saved. For twining is used 62 Kg/ha PP twine each season. Since the PP twine was substituted with BioTHOP PLA twine, during the project we used 3875 KKg less PP waste. The After-Life goal is to use BioTHOP PLA twine for start on at least 10 % acreages of hops fields in Slovenia, thereby completely eliminating the mixed waste of biomass and plastics. The BioTHOP Consortium is affiliated with 6 municipalities of Lower Savinja Region (SI) which in total own more than 1,180 ha of hop plantations.

2. **Decreased Pollution**

The estimated emissions for the burning of hop biomass are as follows: 1968 kg of NMHC (Non-Methane Hydrocarbons), 950 kg of NOx (Nitrogen Oxides), 112 kg of SO2 (Sulfur Dioxide), 3627 kg of PM (Particulate Matter), and 425 kg of CO2 (Carbon Dioxide) per 62.5 hectares. These calculations are based on a conversion factor of 30% dry matter content in the biomass and the respective emission factors.

Furthermore, the substitution of Polypropylene (PP) twine with BioTHOP PLA twine is considered. The emission factor for CO2 equivalents for PP is 1.7 kg CO2 eq./kg polymer, while for PLA (Polylactic Acid), it is 0.27 kg CO2 eq./kg polymer. By using PLA twine instead of PP twine at a rate of 96 kg/ha, a reduction of 79.48 kg CO2 per hectare is achieved. When considering the 62.5 hectares covered in the project from 2019 to 2022, a total reduction of 4967 kg of CO2 emissions is estimated.

Additionally, the potential emissions of other pollutants are discussed. The estimated emissions of N2O (Nitrous Oxide), a greenhouse gas with a global warming potential 300 times that of CO2, would be 759 kg for CH4 (Methane) and 19.6 kg for N2O if the hop biomass were burned. The predicted emission of CO from burning hop biomass on the 62.5 hectares is 25,875 kg.

In summary, the composting of hop biomass instead of burning shows potential for reducing emissions of various pollutants, including NMHC, NOx, SO2, PM, CO2, CH4, N2O, and CO. These findings highlight the environmental benefits of adopting alternative practices in the hop industry.

3. **Nutrition Supply**

From 1 ha of hop field, we get 13 to 20 tons of fresh hop biomass, depending on the variety, agricultural technology and weather conditions during the growing season, averagely we estimate it around 15 tons.

A ton of compost from hop biomass with an average moisture content of 70%, contains 9.6 Kg of total nitrogen (N), 1.6 Kg of total phosphorus (P) or 3.6 Kg of P_2O_5 and 6.0 Kg of total potassium (K) or 7.2 Kg of K_2O, according to current IHPS measurements. It is advised to analyse each compost for the water content and main nutrients content in order to obtain accurate information. Compost can be used within the same farm for the fertilization of the fields.

4. **Reduced dependency on limited fossil resources**

In the production system for PLA, it is used 25–55% less fossil energy than the petroleum-based polymers. With the process improvements for production of PLA (type B/WP) the use of fossil energy can be reduced than 90% compared to any of the petroleum-based polymers being replaced.

Economic benefits

Twine. Runnage reduction of the BioTHOP twine reflected in lower production prices per hectare for hop growers. This translated into a small increase in cost for LEP, which in turn allows the growers to realise a significant reduction of compostable twine needed to guide and support each hectare of hop crops. The reduction of runnage could be in the range of 10% to 20%, depending on the variety of hop plants. Compared to the cost of disposing green waste with polypropylene twine, the use of a compostable twine presents a significant cost reduction for growers. As an example, disposing of tomato waste can be reduced from 37500 €/ha to 17500 €/ha, with an increase of twine cost of 500 €/ha. The actual cost reduction for hop fields depends mainly on current disposal costs, which are a function of the availability of disposal routes in the area and enforcement of local and national environmental regulations.

Compost. Hop growers can use their hop waste for compost, which can partially replace mineral fertilizers and by this reduce their production costs.

Biocomposite. Exclusion of expensive additives in the case of the development of BioTHOP composite formulations by TECNO, preparation of masterbatch concentrates for TECOS, which diluted the selected materials, thus reducing logistics and transport costs. We strived for the shortest possible production cycles.

The development of the product material formulations at TECOS was based on demands of the final product, which was flexible planting pot. The planting pot was designed to be light and thin. The horticulture sector demands flexible pots that can be produced by adding additives/plasticizers that are normally high in cost. In order to avoid such costly mixtures, it was decided to use flexible, compostable matrices that were reasonable in price. The matrix for the BioTHOP final masterbatch was selected both, because of the performance of the material when including the fiber, the mechanical properties displayed by the composite, and the performance when mixed with selected material at the injection phase.

The development of the product material formulations at TECOS was based on demands of the final product, which is in this case a flexible planting pot and processability of the injection moulding cycle. Flexibility can be achieved by addition of costly plasticizers. As the aim was to develop low price product, we were looking for alternatives, such as different grades of matrices with high MFI values, smaller micronized particles of hop fibres etc. To minimize the shipping costs, the idea was to produce a masterbatch that is mixed with a selected material into a final formulation at TECOS.

Planting pots. The planting pot was designed to be light and as thin as possible to reduce usage of material and resources. The horticulture sector demands flexible pots that can be produced by adding additives/plasticizers that are normally high in cost. In order to avoid such costly mixtures, it was decided to use flexible, compostable matrices, that were reasonable in price. The performance of the final masterbatch presented favourable results with high flexibility, modest but suitable MFI value and proper mixture with fibers. The performance of masterbatch was displayed as suitable also at the injection phase. To obtain the final formulations, masterbatch was diluted with selected material, depending on the desired performance of the planting pots at the injection facilities at TECOS. Depending the economic benefits, biodegradable planting pots are currently not competitive with the price of conventional plantings pots. However, the higher the price of oil, the more attractive bio-plastics become. Given the long-term scarcity of oil, the financial benefit might increase over time. There is also far greater awareness of sustainability. Both industrial buyers of bioplastic granules (re-granulates) and end-consumers of plastic products are increasingly conscious of the environmental impact of their actions. By giving the fact that around 15 wt. % in final BioTHOP composites represents the fibres, obtained from hop waste biomass with great potential, the resulting materials are even more attractive and market absorbable.

In view of the target sectors in which we wish to demonstrate a meaningful use of recycled materials, the economic opportunity are as follows: Horticulture sector - The current strategy is to carry out the BIOTHOP planting pots serial production at TECOS facilities, at least for the first year of industrialization. The current production doesn't not expect additional investment and is already in operative and working form. The financial plan was made for the production of 150.000 pcs of plantings pots. The final price for the production is 58.379€. This consists of material price 31.638 €, material packaging price of 335 € (cardbox), energy, labour and other production costs and shipping. This results in the price of single pot of 0,3892€.

Bottle packaging. TRIDAS developed a new product line in relative to their standard production, namely a 'wine bottle packaging' which due to incorporation of hop fibres instead of standard recycled paper pulp enhanced the sales potential as well as the customer experience of the product and importantly be cost efficient.

Social benefits

We were engaging young people to collaborate and share their ideas to keep this circular economy wheel in motion. Indicators of new jobs and how we intend to realize / achieve them as well as a description of all the benefits that our project will bring to the general public were done in the second half of the project duration.
During the project, the modified BioTHOP PLA twine was tested on hop fields by 12 hop farms. These farms are already engaged in the composting of hop. Furthermore, these growers have influenced the whole region (approx. 1,100 persons) with their technological changes.
Rural communities possess some of the key building blocks of the bio-economy, including land and biomass. The bio-economy models implemented in the BioTHOP project could revitalize these rural communities, many of which currently have declining populations. Biomass processing facilities would typically be located in or near rural areas, close to the source of biomass, to minimize transportation costs. Rural communities which host biomass processing facilities could become manufacturing and industrial centres in themselves and experience an economic rebirth.
One of the key goals of the project was to increase social awareness and acceptance of the environmental benefits and behavioural impact on the life of current and future community members. We released two '*Reports of public opinion survey'* with an explanation of the results and two infographics. The main goal of both surveys was to monitor the development of public opinion on the issue and draw conclusions about the impacts of the LIFE BioTHOP project. The newly developed products were implemented and continuously monitored to follow the progress and success of the project and to ensure that public funds were successfully invested. Both surveys were published on different social media and distributed by e-mail. The results of the research were analysed and used as a basis to prepare an assessment of the project socio-economic impact, specifically the assessment of the success of the project implementation and the effectiveness of the info-graphics not only in the demonstration site but also in other transferability sites. According to the results, the project's actions have a positive impact on the local economy and local communities.
Bio-based materials and products which are renewable and/or derived wholly or partially from biological materials, such as the ones obtained during BioTHOP project, support the transition towards more sustainable systems of production and consumption. Such examples of novel materials foster innovative solutions to societal challenges such as climate change and the avoidance of the depletion of natural resources (e.g. fossil-based polymers). The integration of hop fibres into novel consumer products will introduce alternative sources of raw materials and the possibility of making new or improved products. The novel products generated by BioTHOP could be manufactured with a dramatically lower carbon footprint than with current fossil-based materials. Additionally, for innovative companies such as TECNO and our value chain partners (material providers, end-users etc.) the project will help with the creation of further novel solutions.

Replicability, transferability, cooperation

The first and so far the most defined project product is PLA twine. The dissemination of this product gave it a great reputation that has resulted in a high demand for replication and transferability. The twine was also used on other crops, namely to grow tomatoes, peppers, high beans as well as by Pivovarna Zajc a small Slovenian brewery that grows its own hops.
LEP visited a number of hop growing farmers in Portugal. This allowed the twine to be tested in higher temperatures and in a region with a different plant support and guiding system to that used in other countries participating in the BioTHOP project.
Replication of the PLA twine system by German and Czech hop growers has also been carried out. Current technology in these countries comprises of hop supports made of combination steel wire and polypropylene twine used to make knots in the upper part of the system – this part was replaced with PLA twine.
The replication of the twine was also done in three Slovenian regions – Koroška, Dornava and Ormož and two additional EU regions: CZ - Saaz Region (Žatec Hop Institute) and Austria - Steiermark Region. On smaller scale, it was also used in more EU regions which expressed interest in replication. The consortium supplied them with videos and written guidelines on how to use the twine and how to implement certain technological procedures.
The transfer to other sectors was realized immediately after the confirmed final material formulation. TECNO and TECOS extended their BioTHOP generated technology solutions to fashion industry, cosmetic industry, toys, automotive industry, agricultural sector, packaging and FFMCG sector. TECNO worked with over 80 costumers related to agricultural uses and automotive industry. The best formulation of the biocomposites were defined for each application tried. In addition to planting pots, TECOS used biocomposite in injection moulding of packaging for cosmetics, playing buttons, shoehorns, coffee capsules etc. Biocomposite made of

hop fibres and was later used to produce planting pots at TECOS. Different formulations of the biocomposite were tested and studied in order to suit various applications.
We have established links with 40 projects (EU and non EU), 5 regions in Slovenia and 8 countries to mutually share each other's knowledge and experiences (more detailed explained in periodically 3-months reports and progress reports).
Within partnership, three C2M checklists (business model canvas) were made, for BioTHOP (PLA) twine, planting pots and wine bottle packaging. The objectives set in the application were achieved through the work of the consortium with the help of external contractors. Promotional Based on these elements, the businesses were defined and analysed. We had two meetings with the Close to Market (C2M) EASME team, they explained their work and the type of support can we expect from them. DAS started developing BioTHOP business plan focusing on planting pots and hop plant biomass together with TECOS and IHPS. DAS and consortium prepared a market analysis of the BioTHOP technological solutions/ products made from hop waste to explore the existing market and methods for entry to new markets within in August prepared deliverable BioTHOP Business Plan.
There are three main purposes of BioTHOP business plan:

- To clarify plans for future growth/ stage of our project and assess close-to-market potential,
- To understand financial needs and
- To attract funding from investors, banks, and lenders.

TRIDAS commercialisation plan
After the end of the project, our goal is to offer wine bottle packaging to wine producers and sellers, especially in the Czech Republic, but also in other countries in Europe (e.g. in Italy, in Hungary etc.). Because of the higher price per one product, we plan to offer our more sophisticated (after-pressing) packaging to producers and sellers of more luxurious wine and also prosecco, who will be able to pay a higher price for these packaging products. We plan to participate regularly in wine fairs or wine events, especially in South Moravia Region in Czech Republic, where we will offer our packaging.
With biodegradability certificate we could also attract other customers, such as producers of BIO and natural wines. We have plans to offer packaging to specialty beer producers in the future. These are mainly smaller regional breweries that have specialty beers in glass bottles of 1 litre or more. TRIDAS will try to find a solution for existing wine bottle packaging that will be suitable for ending customers in the future. For example, closable wine bottle packaging or packaging that can be carried in the hand.

TECOS commercialisation plan
TECOS can produce planting pots on smaller scale, for example for organic seedlings production or herbs production for urban gardeners, where production is on smaller scale. As the replicability and transferability plan showed, production capacity at the moment is not big enough for mass production, however TECOS can produce around 500.000 pcs per year with single mould cavity. In case of interest for larger quantities of planting pots, TECOS could find company that will be able to inject planting pots in larger quantities.

LEP commercialisation plan
BioTHOP twine has been placed on different markets in Europe, Africa and the USA and is available to hop growers.
The LEP distribution network will continue to be expanded in hop growing countries and also training of existing commercial partners for this new product.
The twine could also be used in other crops like vegetable farming or vineyards and will be available for testing for any farmers who want to try it. A further development could see the use of the BioTHOP twine to tie bales in hay and grass machines. The twine after the usage can be composted together with the manure from the cattle in order to reduce the presence of baler twine in the fields.

ZT commercialisation plan
There is a strong demand on the market today for alternative fibres from yearly plants, particularly for moulded fibre products, which are a means to replace single-use products made from standard plastics. ZT will continue to promote its technology as well as BioTHOP related solutions, when attending relevant events and machine/technology fairs. BioTHOP fibres are obtained through a patented processing technology developed and owned by Zelfo Technology GmbH. This technology is available for all pulp moulders in Europe and

worldwide. The resulting fibres can be used for all type of moulded fibre products, from food packaging to protective packaging as in the bottle packaging.
BioTHOP fibre combinations for use in panel products used in furniture and interiors may also have a future as part of the emerging market for building/construction products. Test products have proven to have significant strength properties as well as being attractive finishing materials in themselves.
Furthermore, extracts drawn from the fibres as they are processed have potential both as bio-based fertiliser and as biogas generating medium. Such options increase the potential for profitability of the process itself, independent of the end-product. (i.e. Pulp moulded products/Panels)
In general the prospects look good for the implementation of the various options generated by the BioTHOP project, this has been underscored by the EU themselves as ZT and TRIDAS involvement has put BioTHOP in the spotlight of the European Commission's Innovation Radar team.

TECNO commercialisation plan
The product to exploit form TECNO's side would be the generated grades of natural reinforced composite materials, adapted for a wide range of transformation techniques such as injection molding, film blowing or casting extrusion.
The commercialization strategy would be first focused to any interested party on local markets related to the production of compounds and final products (TECNO & TECOS). That would be Spain and Slovenia for the first year of the project, followed in the 2nd and 3rd year by surrounding regions and countries related to the scope of the project. The strategy should need to be reviewed and updated continuously, to approach market deviations that cannot be controlled internally.
Events such as workshops, fairs and conferences (regional, national and international) can be used as channels for promotion and economical exploitation of the BioTHOP natural reinforced composites, as well as dissemination of the product range in publications related to the plastics or agricultural industry. TECNO will take advantage of its close communication with potential customers (compounders, plastic transformers, investigation institutes, etc…) to promote the exploitation of projects results. Additionally, the introduction of the biocomposites in other European projects is a potential promotion channel, if it's aligned with the proposal topic.

BioTHOP as an example of '<u>Best Practice</u>'
The raising of environmental awareness will produce results in the long term. Our strategy is to work hand in hand with hop growers, to listen to their needs and advice. We are trying to familiarise them with sustainable hop plant support systems and to reveal to them the potential end of life options for the hop biomass. We have issued guidelines for hop growers to compost on site on their farms and to engage into circular economy as much as possible. With production of the bioplastic products, we strive to eliminate plastic pollution. Our LIFE BioTHOP was featured as LIFE project example included in the impact assessment of the proposal for a Regulation on Packaging and Packaging Waste (more detailed explained in CINEA Impact assessment report, Nov. 2022).

Innovation and demonstration value
All partners strive to reach their individual market potential with their particular role in BioTHOP. The approach to the project was therefore oriented to create benefits from a number of innovative/demo pilot campaigns. Innovation is demonstrated in a number of ways; the adaptation of the twine to external climatic conditions and new crops, new materials, new fibre based raw materials, new products made from composite materials. Finally there is an end of life/loop closing aspect, which is the high-quality compost that leads to the movement of the hop industry into circular economy.
The EU funding for BioTHOP brought the opportunity to the consortium to demonstrate new methods of sustainable practice. The introduction and modification of biodegradable and compostable BioTHOP PLA twine into the hop growing sector for use in the support of hop plants gives the hop biomass new opportunities in a number of areas. The innovational aspect of the project is manifest in the revalorization of hop agricultural residues in different products, namely planting pots and wine bottle packaging, and in the promotion of the circular economy within the hop industry. The concept of the circular economy has never been implemented in hop industry, therefore, we are breaking new ground in this sector. The influence of this project is measured on a national scale as we were active in the replication of our methods in further agricultural business areas where plastics are still in use (e.g., high beans). In addition, the promising results obtained to date reveals that

the BioTHOP material compound produced will potentially be used in wider applications in high volume production sectors such as car components, packaging industry, etc.
ZT engineers (restructures) ligno-cellulose fibre for industrial/commercial purposes, fibres are obtained through a patented processing technology developed and owned by ZT. This technology is available for all pulp moulders in Europe and worldwide. ZT is already working with many innovative clusters, start-ups and associations for processing of fibres from agricultural residues.
TECNO is an innovative technology-based SME. One of their research lines is focused on the development of innovative advanced composite materials base in natural, sustainable resources. From their previous experience they have already integrated agricultural wastes with commercial biopolymers. These materials have been also tested in field obtaining outstanding results (e.g. banana fibre for protective film (BAQUA project). Regarding the BioTHOP project, their task involved the creation, optimization and characterization of the main masterbatch for the project outputs. With the target of maximizing the hop fibre percentage into biocomposite formulations. During the project TECNO developed 24 formulations at small scale, and counted with TECOS expertise in injection molding to select, upscale and validate the most suitable blends, until achieving a masterbatch to produce the BioTHOP planting pots.
TECNO was involved as well in the replication of the material for other sectorial applications such as fashion industry, agricultural mulch film, protective blade guards for harvesting machines, and semi-rigid seed trays, protective covers for automotive parts, coffee capsules for the food industry.
In total 12 products have been produced for replication activities between TECNO and TECOS, for different stakeholders interested on natural reinforced materials. 7 sectors have been approached: Fashion industry, cosmetic industry, toys, automotive industry, agricultural sector, packaging and FFMCG sector. 5 transformations techniques have been used: Injection molding, casting extrusion, vacuum thermoforming, 3D printing and film blowing.
In terms of future exploitation, TECNO made contact with stakeholders from the international market, and is currently in conversations with an Italian startup named “Groower”, dedicated to the supply of agriculture accessories and mulch film. They are interested in trying the BioTHOP outputs in a region of north Italy dedicated to the harvesting of aromatic herbs for the food cooking industry, and flowers for the decorative industry. They are in progress of reaching an agreement to supply material and receive feedback of working and properties for this kind of industry.
The search for bio-based blends is highly valued across the European Union, in demand due to economic reasons (cheaper cost than fossil-based materials). This was achieved by the introduction of the BioTHOP fibres into the main composite masterbatch.
BioTHOP partners **ZT** and **TRIDAS** were announced as key innovators by the EC Innovation Radar as one of the Market Creating Innovation “Hop waste fibre sheets reused for wine bottle packaging” in December 2021. For TRIDAS this innovation is exciting, as they have already worked just with 100% fibre mixed with cardboard or newspaper. This packaging will be something new that the company can offer to its customers and it will be the first standard/universal product in their portfolio, because they always work according to customers request as they do not have any standard tools.
The LIFE BioTHOP project has won two gold awards in June 2022 for the best innovation at local and regional level in Slovenia for its visibility, sustainable materials and products.
It also won a bronze award in September 2022 at national level for the best innovation idea in Slovenia.

Policy implications
Project BioTHOP is contributing to following policies:

- ✓ **Directive (EU) 2019/904** of the European Parliament and of the Council of 5 June 2019 on **The reduction of the impact of certain plastic products on the environment**. The subject of the project furthers the implementation of the strategy regarding the reduction of use of single-use plastics as PP twine is being replaced by PLA biodegradable twine. Bringing bioplastics into the agriculture and horticulture sectors is a great example of a methodology that meets the challenges and opportunities encountered in the convergence of the circular economy with the bioeconomy. The fact that the BioTHOP project already implemented this way of thinking before the communication was launched demonstrates how the results are aligned with the target of the European Union in terms of sustainability. Biobased blends, made during the project, are also valued for EU regulatory reasons, as the new policy framework launched by the European Commission in November 2022 focuses on increase and quantification on the renewable biomass contained within a biobased plastic, and gives priority to secondary instead of primary biomass.

- ✓ The waste hierarchy detailed in the **Waste Framework Directive (Directive 2008/98/EC)** gives biological treatments of bio-waste priority over combustion and encourages transformation of agriculture waste into a compost. It is clear that the only way to efficiently use agro-waste is to stimulate bio-waste recycling and/or separate collection so that the bio-waste is composted or anaerobically digested. This hierarchical premise was completely implemented in the project BioTHOP.
- ✓ **The New Circular Economy Action Plan (COM (2020) 98 final)** was created on the basis of the European Green Deal and is matched by all the objectives of the BioTHOP project. **For both the Commission and our project**, waste prevention remains a main priority. We are developing products based on bio-based and biodegradable materials (biocomposite based planting pots and wine bottle packaging created from pulp) removing these products from a standard non sustainable lifecycle model.
- ✓ **Regulation (EU) 2019/1009** of the European Parliament and of the Council of 5 June 2019 layed down rules on the EU market availability of fertiliser products and amended regulations to focus on providing alternative organic fertilizers. The provision of such fertilisers was the aim of the BioTHOP developed compost.

On 15th January 2020, the European Parliament voted to support the **European Green Deal**, setting out its roadmap towards a new growth policy for Europe. This growth policy is based on ambitious climate and environmental objectives and on participatory processes bringing citizens, cities and regions together in the fight against climate change and for environmental protection. The project BioTHOP is in line with its objectives- transition to a circular economy, sustainable industry, from farm to fork, eliminating pollution and the regeneration of agricultural and rural areas.

At IHPS, we prepared the basis for the legislation on biomass in regard to the handling of the hop harvest residues and for composting on hop farms, which also entered into force in Slovenia. We have performed on site experiments involving big composting piles. This included regular collection of the leachate composts and the collation of information about possible contamination. This database formed the foundation of the legislation guidelines.

7 Key Project-level Indicators

Key indicators concerning the project's environmental, societal & economic outcomes were assessed and updated in the LIFE KPI Webtool on the basis of actions carried out during the entire duration of the project. KPIs also include all mandatory indicators. In the webtool, we inserted all relevant data that serve to monitor the achieved goals. KPIs are determined based on LIFE Key Project Level Indicators LIFE Call for Proposals 2018, where indicators were envisaged for the implementation of the BioTHOP twine on a total of 60 ha in two seasons. Thus, the indicators related to the implementation of the PLA twine were recalculated to 30 ha on an annual basis. In order to facilitate the monitoring of the indicators and also related to the determination of the Specific Context in the Webtool to the demo region and replicative regions, we carried out a recalculation of the indicators for the implementation PLA Twine on a 55 ha for the demo region and 5 ha for the replicative regions. All project indicators showed positive expected trends, in the whole duration of project (2019 - 2022); we tested PLA twine on 62.5 ha. KPI in webtool shows indicators – Absolute impact recalculated per 62.5 ha of twine implementation during the project on demo region (56.5 ha) and replicative regions (6 ha) together. Some other indicators are related to the scope of used BioTHOP twine and as result they are also better.

Key indicators concerning the project's societal & economic outcomes (information and awareness) were assessed in cooperation with partner DAS.

From the IHPS's reports on the monitoring impacts of the hop agro-waste accumulation per seasonal periods, it is known that around 15 tons (fresh matter) of waste hop biomass from each harvested hectare is produced every year.

In response to this problem the project BioTHOP foreseen other ways of handling with hop biomass: composting and transformation in BioTHOP products. Firstly, introducing of biodegradable and on-site compostable BioTHOP PLA twine was urgent to implement in hop production. As a result, BioTHOP methodology positively/environmentally friendly eliminates this waste biomass and nullifies GHG emissions. The emissions were calculated according to the data in the literature: Tripathi S., Singh RN, Sharma S. [2013]. Emissions from Crop/Biomass Residue Burning Risk to Atmospheric Quality. International Research Journal of Earth Sciences, Vol. 1(1), 24-30.

If we consider that 45 km of PP twine/ha (equal to 62 kg/ha) is used to train all hop plants on each hectare of the hop fields, and we replace it with BioTHOP PLA twine/ha (equal to 96 kg/ha), which is needed to train all plants per one hop filed hectare each season, we reduce CO_2 emissions for 79.48 kg/ha. If we multiply that with the 62.5 ha acreage covered in the project in 2019, 2020, 2021 and 2022 together, the absolute values of the total CO_2 emission prevention were 4967 kg.

A summary KPIs in the deliverable: technical report C1.D5: Final LIFE Project Specific Indicators shows that the project had positive impacts/trends in all estimated impacts. In certain parameters, the target was met in whole, at certain it was exceeded, these are (for both demo and replicative region together): indicators: Project area and regarding to that: waste management, resource efficiency – soil, Air emissions and greenhouse gas emissions (reduction) for 4 %. Indicator: Humans (to be influenced by the project via dissemination or awareness raising project-action) has been exceeded for 450-times, recording data shows that more than 900.000 target audience were informed and also that we had 8644 social media followers. We had a huge impact to Involvement of nongovernmental organisations and other stakeholders in project activities, where we establish 1 common BioTHOP data base with 7719 email contacts which is 2649 more that was the target. No. Of unique visits our website was also exceeded. During the project we had 34982 page views from 6994 users; the target was 5000 No. of visits.

ANNEX 1 – DELIVERABLES AND MILESTONES SCHEDULE

MAIN DELIVERABLE PRODUCTS OF THE PROJECT

Name of the Deliverable	Code of the associated action
Signed Partnership Agreement (PA)	E1.D1
Requirements and limitations over the current PLA twine for hop growing sector	A1.D1
Protocols for the collection and sorting of hop waste defined	A1.D2
Regulations and protocols on modified hop-waste components defined	A1.D3
Website in a fully operative mode	D1.D1
Life Information Boards documented	D1.D2
Stakeholders plan defined in the form of a report	D2.D1
Progress and results of the communication and dissemination activities	D1.D3
Updated LIFE Project Specific Indicators	C1.D1
Progress and results of the communication and dissemination activities	D1.D4
Update LIFE Project Specific Indicators	C1.D2
Report on optimal formulation of hop waste fibre reinforced PLA for injection moulding	B4.D1
Report on the adaptation of hop waste fibre materials to pulp moulding process	B3.D1
Hop fibre sheets optimization and production	B1.D2
Hop fibre reinforced composite optimization and production	B1.D3
Report on modified PLA twine, specifically adapted to the hop growing industry	B2.D1
Guidelines for replication the BioTHOP twining methodology in other EU regions	B5.D1
Recommendations for more effective regulatory policies and governance structures	C2.D2
Business plan	C2.D3
Report on waste hop fibre moulded box insert demonstrator for packaging applications	B3.D2
Complete quality analyses & guidelines for on-site hop biomass composting process	B1.D1
Validation report on novel PLA twine performances from hop field experiments	B2.D2
Guidelines for transferring the BioTHOP materials to other industrial sectors	B5.D2
Report on planting pot demonstrators for horticulture applications	B4.D2
Indicators for the socio-economic impact of the project	C1.D3
LCA and LCC analyses	C1.D4
Layman's report released	D1.D5
Study report of the local community feedback	D2.D2
Certification that produced BioTHOP twines are biodegradable in industrial and if proven possible with an improved recipe, home composting	B2.D3
Certification that produced BioTHOP trays are biodegradable	B3.D3
Certification that produced BioTHOP planting pots are biodegradable/industrially compostable	B4.D3
Replicability and transferability plan defined	B5.D3
Final report on industrialisation plan of the resulted BioTHOP solutions	B5.D4
Final LIFE Project Specific Indicators	C1.D5
Socio-economic analysis of BioTHOP Solutions	C2.D1
Collaboration agreement defined	C2.D4
Replication and/or Transfer Strategy	B5.D5
Progress and results of the communication and dissemination activities	D1.D6
Life Information Boards documented and reported for the public feedback	D1.D7
After Life Communication Plan in the form of a report	D2.D3
Green Procurement Report	E1.D2
Compilation of Minutes from all Steering Committee	E1.D3
After-Life plan	E1.D4

MAIN MILESTONES OF THE PROJECT

Name of the Milestone	Code of the assoc. action
A1.M1 Introductory list of requirements for modified PLA twine prepared & shared with Consortium	A 1
A1.M2 Collected and sorted hop waste ready for the modification treatment at ZT	A 1
D1.M1 Approval of the Project corporate communication visual identity, templates and images	D 1
A1.M3 Modification protocols on hop waste prepared and shared with Consortium	A 1
B2.M1 First field training tests on modified PLA twine started	B 2
B1.M1 First batch of fibre sheets & fibre reinforced material available for Action B3 and B4	B 1
B3.M1 Designs of box insert packaging validated as final	B 3
B4.M1 Designs of planting pots validated as final	B 4
C1.M1 Updated LIFE Key Project-level Indicators	C 1
C1.M2 First monitoring report (internal document)	C 1
D2.M1 45 % of the activities of the Stakeholders plan have been already performed	D 2
B1.M2 First compost assessment and second batch of fibre sheets & fibre reinforced material available for Action B3, B4 and B5	B 1
B2.M2 Second field training tests on optimized PLA twine started	B 2
B2.M3 Optimized PLA twine available for replication project in B5	B 2
B3.M2 First generation of packaging demonstrator validated	B 3
B4.M2 First generation of planting pot demonstrators validated	B 4
B1.M3 Final compost formulation and third batch of fibre sheets & fibre reinforced material available for Action B3, B4 and B5	B 1
B2.M4 Training & harvesting hop field experiments on novel PLA twine concluded and validated	B 2
B5.M1 BioTHOP twines trained on the hop field plantation in the replicated region	B 5
B3.M3 Final generation of packaging demonstrator validated and optimized	B 3
B4.M3 Final generation of planting pot demonstrators validated and optimized	B 4
D2.M2 85 % of the activities of the Stakeholders plan have been already performed	D 2
B5.M2 Transferable BioTHOP composite materials reflected in 5 new sectoral product 5	B 5
C1.M3 Second monitoring report (internal document)	C 1
C1.M4 Updated LIFE Key Project-level Indicators	C 1