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1 Executive summary

The AFTERLIFE project proposes a flexible, cost- and resource-efficient process for recovering and valorising the relevant fractions from wastewater. The AFTERLIFE process separates the different components of value using a series of membrane filtration units that extract all the solids in the wastewater. These are treated to obtain high-pure extracts and metabolites or, alternatively, to be converted into value-added biopolymers, polyhydroxyalkanoates (PHAs). In addition to the value extracted from the solids, the remaining outflow of the water will be ultrapure and ready for reuse.

As part of the project, a social and socio-economic analysis of the impacts of the AFTERLIFE process and products has been carried out by nova-Institut GmbH to identify social perceptions and possible socio-economic and policy pitfalls at an early stage of the development in order to guide the process design optimisation, using a feedback loop approach.

- To analyse policy aspects related to the cultivation and applications (e.g., food additives and food packaging regulations), the relevant regulatory framework of the specific project-relevant applications were investigated in a desktop analysis. NOV provided support to the partners in charge of the evaluation.
- The socio-economic assessment is based on the current developments of processes and products developed in AFTERLIFE. A SWOT analysis was performed, which was enhanced by a classification of impact categories with several indicators following the guidelines for social life cycle assessment of the United Nations Environmental Program (UNEP 2009).
- The study included a survey with stakeholders (including NGOs, policy makers, industry) to reveal views and potential interest in the development and implementation of industrial biotechnology to produce value-added products and materials for various applications. The online survey was disseminated throughout the nova Institute's extensive networks and beyond. Unfortunately, the number of respondents was insignificant, and the survey set-up did not allow to make use of the answers. However, the results were included in the result chapter.
- Two consumer focus groups were conducted to analyse consumer acceptance of industrial biotechnology processes and the production of value-added compounds and materials from wastewater. In these focus groups, the products and processes were explained in an easily understandable way. A guided group discussion on the use of the products was then led, taking into account both rational and intuitive arguments for and against AFTERLIFE products and production processes.

The results show that up to this moment, the regulatory regime for PHA production from wastewater fractions is very favourable as recovering feedstocks from wastewater should not encounter any regulatory hurdles in the EU framework. Furthermore, PHA production, especially in view of the PHA products considered in AFTERLIFE project, is not handled differently in EU policy depending on its feedstock. Nevertheless, a drawback is that AFTERLIFE's PHA products and applications have currently no specific support or favouritism in the regulatory framework of plastics for the reason that bio-

plastics and/or bio-degradable as well as compostable plastics have not been specifically excluded or preferred. However, the European Commission is working on a new framework for biobased, biodegradable and compostable plastics that is set to address these issues and provide a clear and well evaluated supportive framework for these plastics (including PHA) in comparison to fossil-based plastics.

The study on socio-economic issues showed the great interest of the stakeholders, such as the public authorities in the Region of Murcia that are concerned about the water scarcity in the region. A particular driver for the development of the technology and products is the fact that there are important researchers in the region. In general, the socioeconomic impacts of PHA products derived from wastewater differ significantly from those of conventional biobased PHA. Compared to fossil-based plastics, PHAs have the advantage of being degradable in soil. In this regard, the health and environmental benefits are a primary reason for products made exclusively from PHA. The biodegradability characteristics and uncertain certification environment are considered a major threat to the products. The socio-economic impacts of wastewater biorefinery mainly affect the surrounding areas. While a wastewater refinery can provide opportunities for rural development and allows companies to demonstrate their commitment to sustainability, a social threat is Nimbyism (Not-in-my-Backyard) and oppositions due to odour, noise, and nuisance. For this reason, it is important to take advantage of existing opportunities such as retrofitting buildings and using bio-based materials, involving universities in the region in the development of the plant and process, and planting trees with the community to increase engagement.

The acceptance analysis showed that the risk of possible non-acceptance due to the assumed food contact of bioplastic trays could be neglected, as none of the participants had concerns about food contact of wastewater-derived PHAs. The acceptance factors that seem most relevant are resource savings and end-of-life. To date, there has been little awareness of the food and feed debate. Although participants were sceptical when being informed about biobased resources, they did not emphasise the strength of wastewater PHA technology in not having to cultivate crops. Price sensitivity and price-quality ratio also played a role for participants. Many indicated that they would not pay the Green Premium price for SUP cutlery if it was not biodegradable or compostable.

The overall result of the social and socio-economic evaluation may enable the project partners to better understand the motivation behind public perception and potential pitfalls in communication campaigns on the AFTERLIFE products to general consumers and to the local societies near to potential wastewater biorefineries.

2 Introduction

The aim of the AFTERLIFE project is to demonstrate the technical feasibility of a flexible, cost- and resource-efficient process for recovering and upgrading the relevant fractions from wastewater. The AFTERLIFE process separates the various valuable components using a series of membrane filtration units that remove all solids in the wastewater. These are then treated to yield high-purity extracts and metabolites (i.e., essential oils, amioacids and phenolic compounds such as flavonoids) that can be used as food additives or, alternatively, converted into value-added biopolymers, polyhydroxyalkanoates (PHAs). In addition to the value extracted from the solids, the remaining water effluent can be reused in the production process. The organic matter not converted into PHAs or high-purity extracts is valorised for biogas production. The PHAs will be usable for many products in the consumer market. Thereby, it is relevant to find out the impacts that the technology development has on society at a large scale as this gives a first idea about the acceptability of the new technology. In this way, early potentials of Nimbyism (Not-in-my-Backyard) can be determined. Nimbyism is referred to as local opposition towards industrial facilities that are considered beneficial for society and has widely been studied.

In a study by V. Pérez et al. (2020), PHA production from biogas in waste treatment plants was investigated in terms of socioeconomic impacts. IChemE Metrics social indicators were used and the focus was on the different social acceptability of bioproducts (PHA) and bioenergy (CHP) and the acceptance of such plants by the local population. While biogas is considered a renewable energy source, its social acceptability remains controversial. The study assumed that public opposition to biogas production, and to waste processing facilities in general, may develop due to odour, noise, and other nuisances. An increase in demand for biobased products and sustainable technologies was seen as a possible solution to minimize the associated nimbyism. In this way, more positive emotions and focus on the benefits of the polymer production could be triggered. The benefits that biopolymer production could bring to local communities were seen as the development of a secondary biopolymer-based industry, improved employment opportunities, increased local tax revenues, or an indirect boost to local economic activity. There would be is a huge potential for creation of indirect jobs associated to the new markets for these innovative biobased products, their future commercialization and distribution within the circular bio-economy.

Next to the socioeconomic impacts, a successful market entry requires to outline the consumer and market acceptance beforehand. In this regard, it is one of the main questions which factors play a role in the social acceptance and general perception of consumer products made from converted wastewater PHAs. Since the AFTERLIFE process is new, the production method has not yet been tested for its social acceptance. However, the societal perception of biobased products has been investigated, which can provide initial insights into the acceptance of PHA. The study by Niedermeier, Emberger-Klein, and Menrad (2021) investigated consumer segmentation of green fast-moving consumer goods with regard to factors that may distinguish consumer segments for biobased general-purpose adhesives in Germany. Based on an online survey of 709 respondents, they identified green consumer

segments distinguished primarily by green consumer benefits, perceived consumer effectiveness, and trust. Other clusters could be distinguished by price sensitivity. Among non-buyers, price-quality and cost perceptions also played an important role. However, this segment could include people who do not want to switch from fossil resources to biomass. In addition, habits are also an important influencing factor for the group of brand-affiliated consumers. (Nierdermeier, Emberger-Klein, & Menrad, 2021)

Further insights can be provided by studies on the acceptance factors of Carbon Capture Utilization (CCU) products, as the technology can be considered similarly complex to the AFTERLIFE process. The most recent studies on these issues were conducted by Arning et al. (2017), van Heek et al. (2017) and Arning et al. (2018), who looked at a converted CO2 foam mattress developed by polymer manufacturer Covestro and launched in 2015. For example, Arning et al. (2017) investigated individual perceptions and acceptance of this mattress by analyzing consumer profiles based on demographic characteristics, risk perceptions, and different perceptions and attitudes toward environmental awareness. The general results showed a rather positive perception of the mattress as a product example, although prior knowledge about CCU technology was scarce. The comparative importance of acceptance factors was investigated in conjoint studies by van Heek et al. (2017). Disposal conditions were identified as crucial for product acceptance, followed by the resource saving factor. Disposal conditions must be as good as for conventional products to enable acceptance. Achieving the same emissions represents the tipping point between rejection and acceptance. With regard to resource savings, a linear pattern emerges. The more fossil resources saved, the more acceptance increased. The second study included potential health complaints as well as individual knowledge level and risk perception, which had a significant influence on the acceptance of CCU products. In another study by Arning et al. (2018), researchers classified their participants by technical and less technical occupations, gender, age, and personal attitudes toward innovation, risk perception, and their environmental awareness using a previously administered questionnaire. They found that technical background and personal attitudes toward innovation and the environment correlated positively with the acceptance of CCU products.

The question of the social acceptance of CO2 in consumer goods thus depends on a whole range of factors that are difficult to narrow down. As a result, many influencing factors must be addressed for a successful market launch and should be accompanied by a good communication and marketing strategy. In the next chapter, we provide a brief overview of the current political framework that should be considered for a successful market introduction of PHA-based wastewater products in Europe. We then explain the methodological design of our study, which consists of a SWOT analysis of AFTERLIFE products and biorefinery/process, an online survey of key stakeholders, and two online focus groups. This is followed by an analysis of our findings and a discussion with subsequent recommendations for action on how AFTERLIFE products should best be communicated and pitfalls to consider when developing a communication and marketing strategy for PHA consumer products from converted wastewater.

3 EU policy landscape on wastewater utilization

The EU considers a transition towards a more circular economy and more sustainably sourced feedstocks as a key to reach its climate goals. The Commission adopted the so-called New Circular Economy Action Plan in March 2020 as one of the main building blocks of the European Green Deal. It comprises of specific actions to be taken by policymakers and stakeholders to support and accomplish this transition. The actions are and will be taken along the entire life cycle of products and specifically promote circular economy processes. The measures are targeting sectors with the most resource consumption and where the potential for a transformation to circularity is high. Among others, there are sectors being named, that fit the scope of the AFTERLIFE project: The packaging, plastics, food, water and nutrients sectors. Increasing the recycled content in products as well as sustainably sourced feedstocks is one of the main goals of the Action Plan. Overall, the New Circular Economy Action Plan consists of 35 actions, partly already taken and partly going to be introduced in the near future. The most relevant actions and measures in the scope of AFTERLIFE are evaluated in this chapter.

To evaluate the EU policy landscape of waste water utilisation and the specific application cases deployed in the AFTERLIFE project, there are various other policy documents besides the actions in the NCEAP, that have to be considered. Fundamentally, there is a regulatory framework in place setting the rules for waste water, waste water treatment and sludge treatment in general. The Water Framework Directive (Directive 2000/60/EC) is the fundamental legislation regarding water in the EU and deals with general rules of water preservation, protection of aquatic water systems and the sustainable use of water. It is complemented by the Sludge Directive (Directive 86/278/EEC), which is dedicated to the protection of soil, when waste water or sewage sludge is used in agriculture. AFTERLIFE is not considering the use of unprocessed sludge directly in agriculture, but the application of sludge as fertiliser after anaerobic digestion is studied in the scope of the project.
Therefore, there are definitions in place, that potentially may also be adopted outside of the scope of this Directive. The term ‘sludge’ is defined as (i) ‘residual sludge from sewage plants treating domestic or urban waste waters […]’, (ii) ‘residual sludge from septic tanks […]’, and ‘residual sludge from sewage plants other than those referred to in (i) and (ii)’. Further legislation, that may be introduced at a later point with regards to sludge utilisation may adopt these definitions for other application cases.

Furthermore, there is the Urban Waste Water Management Directive (Directive 91/271/EEC) to prevent harmful discharging of urban waste water in the environment. It sets fundamental rules for the collection, treatment and discharge of waste water originating from urban sources. Especially for the treatment of waste water and the separation of solids and water, which could then be used in a production process as feedstocks, the Directive lays down definitions and ensures that several treatment steps have to be taken when handling waste water and that sludge arising from waste water treatment shall be re-used whenever appropriate. The AFTERLIFE process likely has to follow these rules as well, even though the initial AFTERLIFE process considers food industry waste water specifically. The process could later be extended to other kinds of waste water as well.

Another important Directive concerning the handling of waste is the Waste Framework Directive (2008/98/EG). It sets the main principles applied to waste production, collection and treatment and offers fundamental definitions and the concept of waste management. In the Waste Framework Directive, the term 'waste' is defined as 'any substance or object which the holder discards or intends or is required to discard'. Also, the waste hierarchy is defined providing an order of priorities in waste management:

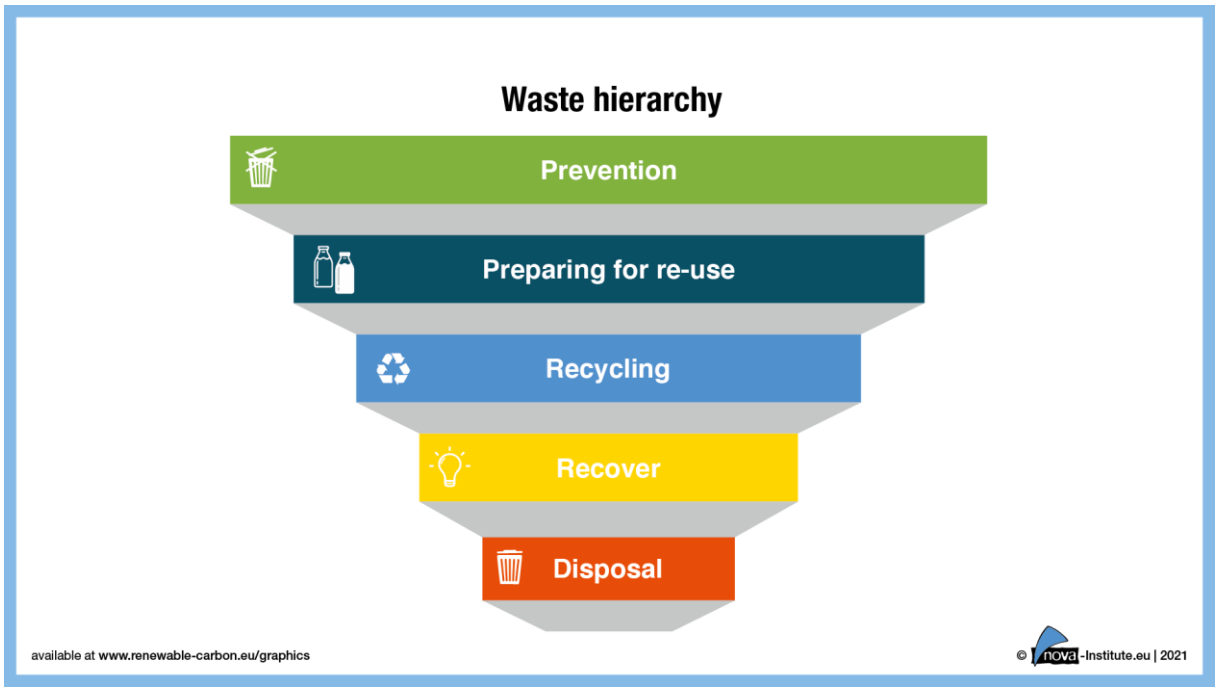

Figure 1 The waste hierarchy

For the AFTERLIFE case, the recovery step of the waste hierarchy likely applies. 'Recovery' is defined as 'any operation the principal result of which is waste serving a useful purpose by replacing other materials which would otherwise have been used to fulfil a particular function, or waste being prepared to fulfil that function, in the plant or in the wider economy'.
Annex II sets out a non-exhaustive list of operations which count towards the recovery of waste. In this list there are operations likely applying to the AFTERLIFE scope:

- Recycling/reclamation of organic substances which are not used as solvents (including composting and other biological transformation processes)

Going one step further on the value chain, when the waste water has been treated and the valuable feedstocks gained from these treatment steps cease to be waste (as per the Waste Framework Directive), additional legislation comes into play. In the REACH Regulation (Registration, Evaluation, Authorisation and Restriction of Chemicals) the basic principles for the protection of human health and the environment from risks imposed by chemicals are laid down. The regulation applies to every chemical in the European Union and requires a registration, evaluation and authorisation of a chemical for it to be used in the EU. It can also restrict the use of a chemical if the evaluation process results in

this measure. Polymers, such as PHA, are a somewhat special case as the registration and authorisation process do not apply to polymers. The 'Guidance for monomers and polymers' further defines the situation of polymers according to REACH: It introduces the special case of natural polymers and sets the respective definition, which was also already adopted by other legislation pieces.
Natural polymers are defined as polymers which are the result of a polymerisation process that has taken place in nature, independently of the extraction process with which they have been extracted. This means natural polymers are not necessarily 'substances which occur in nature' when assessed according to the criteria set out in Article 3(39) of the REACH Regulation. This definition is crucial and was applied and interpreted in the controversial Single Use Plastic Directive in mid 2021.

In terms of plastic regulation, the Single Use Plastic Directive (Directive 2019/904) is one of the most recent legislative pieces that also had a lot of impact when it entered into Member State law in mid 2021. It introduces restrictions and other measures for specific single use plastic products to substantially decrease their impact on the environment. It was accompanied by a guidance document on how to interpret the measures in the Directive which included interpretations that are especially unfortunate for PHA specifically. The SUPD adopted the definition of 'natural polymer' as an argument to be excluded from the scope of the directive, which initially opened the door for PHA products to be a valuable alternative to the now restricted products. However, the Commission's interpretation of this definition resulted in PHAs not being understood as a natural polymer, as fermentation is not understood as a natural process. This interpretation is potentially also going to be adopted in further EU legislation concerning plastics and is a huge burden for PHAs in general. Also, the SUPD did not make any exceptions for biodegradable or bio-based plastics in its restrictive scope.

The Packaging and Packaging Waste Directive (2018/852), which is currently being revised, sets out the framework for packaging materials and the handling of packaging waste in the EU. In its upcoming revision, the Directive is set to include specific targets of recycled content in packaging materials, which are going to increase over time. How these targets are going to be accounted for and what will be understood as recycled content remains uncertain until the revision is published. It is also likely going to recognise sustainably sourced and produced materials being used in packaging applications which may be applicable to the PHAs produced in the AFTERLIFE process.

The general legislative framework of bio-based and biodegradable plastics is currently not sufficiently developed yet. The role of bio-based plastics (BBP) and biodegradable and compostable plastics (BDCP) is set to become much bigger with the transition towards a more sustainable and circular economy. Therefore, the Commission is currently developing a policy framework to specifically target BBP and BDCP. The framework aims to overcome general issues with these plastics. These issues include misconceptions about BBP and BDCP, clear labelling rules, general criteria to evaluate the sustainability of BBP and BDCP and many more. The current understanding of this is, that biodegradable and compostable plastics are only going to be accepted and favoured in very specific application cases. Which applications may be included is currently still uncertain. This initiative generally aims to define the role of BBP and BDCP in the EU's efforts towards its circularity and carbon-neutrality goals.

Food additives are regulated in the so-called Regulation on Food Additives (Regulation 1333/2008). It lays down rules on food additives with a focus on a high level of protection of the human health and the consumers. It provides lists of approved food additives (Annexes II and III) as well as substances, that are not considered to be food additives with the latter including amino acids and their salts. Hence, amino acids are not considered to be food additives.

In terms of materials, that come into contact with food, the Food Contact Materials Regulation (1935/2004) applies. It provides the basis for securing a high level of protection of human health and the interests of consumers. Any material intended to be brought into contact with food, already in contact with food or reasonably expected to be brought into contact with food is covered by this regulation. These materials shall be produced in compliance with good manufacturing practice to ensure, under normal or foreseeable conditions of use, they do not transfer their constituents to food in quantities which could endanger human health, that there is no unacceptable change in the composition of the food and that there is no deterioration in the organoleptic characteristics thereof. Annex I comprises a list of materials which may be covered by specific measures that may be adopted or amended by the Commission and the list includes plastics as one of these materials.

Overall, the feedstocks used in PHA production are not going to be cause for different treatment of the final material in terms of EU legislation, especially in the application cases considered in the AFTERLIFE project. In terms of circularity, the general direction of the EU is clearly in favour of products from a circular production process and utilizing second-generation feedstocks. This is going to be a great potential for PHAs from waste water, especially when the legislation for bio-based, biodegradable and compostable plastics has been further developed and established. However, PHAs and all bio-based and biodegradable plastics in general currently lack any specific support or favouritism in EU legislation when compared to fossil-based plastics. This is set to change when the Commission finalises and publishes its policy framework on bio-based, biodegradable and compostable plastics.

4 Methodology: SWOT analysis, online survey, focus group discussions

The study on socioeconomic impacts of the wastewater biorefinery process requires an in-depth view of different angles of several different stakeholders. A SWOT analysis, an online survey and focus group discussions with potential consumers provided a broad, but detailed picture on this issue. In this chapter, the methodologies of these three research instruments are outlined.

4.1 SWOT analysis on waste water utilization

As part of this task, we addressed the social and socioeconomic impacts of the process. The specific objectives were: Assess the socioeconomic aspects related to the production of PHA and high value metabolites and extracts from wastewater for different applications (SWOT analysis). To evaluate the socio-economic aspects related to the production of PHA and high value-added metabolites and extracts from wastewater for different applications, SWOT analyses of the production process and the products was conducted. The products considered were:

- PHA mulch film for agricultural purpose
- PHA plastic bags
- PHA plastic trays for food packaging
- Extracts (rich in phenolic compounds) for food enrichment
- Amino acids for feed enrichment
- Essential oil

Generally, a SWOT analysis aims to determine strengths, weaknesses, opportunities and threats of a company's business decision. Thereby, external and internal factors of the venture are considered. The matrix is assessed as can be seen in Table 1. Strengths and weaknesses can be seen as the internal factors that describe attributes of the AFTERLIFE project and products while opportunities and threats can be seen as external factors that five information about the environment of the project/products.

Table 1 Description of the SWOT analysis in terms of the AFTERLIFE project

Strengths (S)	**Weaknesses (W)**	**Opportunities (O)**	**Threats (T)**
Internal Factors (attributes of the organisation/product)		**External Factors** (attributes of the environment)	
Things that AFTERLIFE products do well, qualities that separate it from other competitors	Things that AFTERLIFE lacks, where competitors do better	Elements in the external environment that could increase the integrity and profitability of AFTERLIFE	Elements in the external environment that could endanger the integrity and profitability of AFTERLIFE

The assessment of socioeconomic impacts considered employment, regional development, and other impacts using desktop research and modelling of impacts based on known data. In order to not miss any important social impact aspects, the SWOT analyses of this study investigated specific impact categories. **SIA** (Social Impact Assessment) indicators were used for the SWOT analysis of the AFTERLIFE wastewater biorefinery while indicators of **S-LCA** (Social Life Cycle Assessment) helped in the SWOT analyses of the AFTERLIFE products. The indicators were consistent with the objective and scope of the study and represented socioeconomic topics of interest expressed in terms of affected stakeholders. The topics of interest included health and safety, human rights, working conditions, socioeconomic impacts, and governance.

In a first step, a group of nova experts (Olaf Porc (Economy); Francesco Longhini (LCA); Nicolas Hark (policy); Svenja Dahl (social)) firstly brainstormed on the strengths, weaknesses, opportunities and weaknesses of the AFTERLIFE biorefinery/processes and the products in view of the SIA and SLCA factors. In a second step, the results of the SWOT analyses were sent to the partners in the AFTERLIFE project. After the feedback round, additional information on the SWOTs was included.

According to the SLCA guidelines, every product examined had to be **compared** to a reference counterpart. The following were chosen for the AFTERLIFE products:

Table 2 Afterlife products and reference counterparts for SWOT analyses

AFTERLIFE product	Reference counterpart
Biodegradable mulch film for agricultural purpose from Waste Water-PHA	• Fossil-based counterpart plastic [Foss] • First generation bio-based feedstock-based counterpart - (starch-PHA-based) [Starch]
Biodegradable plastic bags from Waste Water-PHA	
Biodegradable plastic trays for food packaging from Waste Water-PHA	
Polyphenols (60% hesperidin) for food enrichment from Waste Water	• *First generation bio-based feedstock-based counterpart* - (e.g. limonene extracted from lemon - 60% hesperidin)
Amminoacids for animal feed enrichment from Waste Water	• *First generation bio-based feedstock-based counterpart* - Amminoacids for animal feed enrichment from Biotechnological fermentation industry from soy/wheat

Essential oil (70% Limonene) for food from Waste Water	• *First generation bio-based feedstock-based counterpart* - Lemon essential oil for food/feed (70% Limonene) from Lemon tree cultivation

Key points/assumptions:

- These SWOT analyses are comparative assessments; therefore, the investigated products were compared to their counterpart products. Only in the case of the PHA-based products there was not a unique reference as for the other applications, but two; was clearly indicated for every bullet point in the SWOT which counterpart product is considered (Fossil-based counterpart [***Foss***], starch-PHA-based [***Starch***])
- The AFTERLIFE products were assumed to have the same functionalities and properties (e.g. mechanical resistance, biodegradability, food grade,) as their counterpart reference products.
- The production of all considered reference products was assumed to take place in the European Union. Given that, it is guaranteed that ethical/moral/civil rights (e.g. safe working conditions, working rights, no child labour,etc.) are respected. Nevertheless, several cells in the matrixes have been labelled as "**none in the E.U.**".

4.2 Survey for key stakeholders of AFTERLIFE

To identify the relevant stakeholders who will benefit from the products and processes developed in the AFTERLIFE project, a comprehensive stakeholder analysis was conducted prior to this survey. See also Deliverable D.8.1 Exploitation and Dissemination Plan. Key stakeholders were generally considered to be organizations that have both a strong interest in the AFTERLIFE platform and a large potential impact on the project. For the AFTERLIFE project, the stakeholder analysis revealed that mainly wastewater treatment plant operators and packaging manufacturers are interested in the development and implementation of industrial biotechnology to produce value-added products and materials for various applications. However, non-governmental organizations and policy makers (both local and national) are also important stakeholders for the successful implementation of AFTERLIFE technology. Through an online survey, these key stakeholders (including NGOs, policy makers, industry) were asked about their views and potential interest in the development and implementation of industrial biotechnology for the production of value-added products and materials for various applications. The survey was distributed through several channels. First, 2 mailings were sent to key stakeholders. Second, 5 newsletter articles called for participation within the nova network. Last but not least, the call was also distributed via the project website and LinkedIn.

These were the questions for the survey:

1. Do you think the process developed in AFTERLIFE will make a significant contribution to better utilisation of wastewater? (likert-scaled)

2. Do you think the supply of PHA from the AFTERLIFE process will become steady and secure in the near future? (likert-scaled)
3. Do you think the investment in AFTERLIFE could generate a high production volume of PHA from waste water for industrial use in the long-term? (likert-scaled)
4. Do you think that recycled PHA from Waste Water will represent a significant source of income in the future? (likert-scaled)
5. Which changes to national and international regulation do you think would make recycling of wastewater for PHA production more attractive? (open question)
6. Which additional environmental and health factors should be considered in the AFTERLIFE process? (open question)
7. Would you invest in a technology that produces PHA from Waste Water? (open question)
    a. If so, why? (open question)
    b. If not, what conditions would have to be in place for you to invest? (open question)
8. For which products would you/your customers seriously consider using PHA produced from wastewater? (open question)
9. Which products would you/your costumers not consider for using wastewater PHA as a feedstock? If not, why? (open question)

Only the first four were, however, answered by all respondents. For this reason, only the results of these first four questions are presented in this report. As only 30 respondents answered the survey, it must be noted that this sample is non-significant. Nevertheless, the results of the survey are included in the socio-economic and social impact analysis because they show a tendency of the market acceptance of the AFTERLIFE products.

4.3 Consumer perception – concept for a focus group discussion

To analyse consumer acceptance of industrial biotechnology processes and the production of value-added materials and substances from wastewater, consumers' views on the products and the production process were investigated in two focus group discussions. Two online focus groups with end consumers were designed to both complement the expert statements from the previously conducted online survey and to generate additional statements and insights. In this focus group discussion, the aim was to obtain both rational and intuitive arguments for and against AFTERLIFE products and production processes. In this way, we wanted to gain an impression of the consumers' view of AFTERLIFE's developed processes and products. We also aimed to identify potential pitfalls in market access for innovative products and to develop an action list to strengthen consumer acceptance.

Focus groups are a popular tool to elicit common opinions. The focus groups were composed of end users, people who are expected to buy and use products made from PHA from wastewater. We chose

to make them as homogeneous as possible within each group in terms of attitudes and demographics. In this way, both focus groups more comparable. The participants were all from German-speaking countries and the focus groups were held in German, which made it easier for the participants to express their thoughts and ideas about the products. Since the topic of wastewater utilization is very specific and complex, and is not usually in the public eye, it had to be assumed that the participants in this focus group were not familiar with the process and products. Test products were sent to the participants without them knowing what they were. The test products were commercially available forks and spoons made from 1.) conventional fossil PE and 2.) bio-based PHA. It was not possible to use products actually made from the AFTERLIFE process for the test because (a) they were only prototypes, which would have confused consumers, and (b) not enough PHA had been produced to provide each participant with a product. In the first part of the focus group discussion, participants were asked about their perceptions of these products. In the next part, the difference between fossil-based and bio-based plastics production was explained through a presentation by nova polymer expert Pauline Ruiz (see presentation in the Appendix). Following this presentation, participants were shown a short video clip about the AFTERLIFE project and the processes used to convert wastewater into plastic (https://www.youtube.com/watch?v=n-g-uCDnU60). In the last part, the test products were discussed based on the new findings and the participants were asked for their opinion on plastics that are produced from wastewater.

The two focus groups served to extract expected and perhaps unexpected hypotheses and statements on the acceptance of AFTERLIFE products and, based on these, to draw conclusions for targeted consumer communication. Of interest here was the willingness of consumers to pay a certain Green Premium for recycled multifunctional plastic products. In addition, insights were gained into how consumers fundamentally perceive the process and products of plastics made from wastewater and whether they perceive them as more sustainable than the manufacturing process of conventionally produced plastic.

The study of organoleptic properties, which has been developed by CTC (deliverable D.6.5), assesses the consumer acceptance of food products complemented with AFTERLIFE extracts like essential oils, amino acids and phenolic compounds such as flavonoids.

Results & Analysis

This chapter presents the results of the SWOT analysis, the online survey and the focus group discussions.

4.4 SWOT Analysis

The SWOT analysis contained several SWOT analyses on the AFTERLIFE biorefinery process as well as on the products. Strengths, weaknesses, opportunities and threats were discussed with experts in view of SIA and S-LCA impact categories.

Strength, weaknesses, opportunities and threats of the AFTERLIFE biorefinery / process

For the identification of social strength, weaknesses, opportunities and threats of the biorefinery process the all of the SIA-categories could be used. Though for some cases not all SWOT dimensions could be determined. Table 3 shows the SWOT.

Table 3 SWOT of the AFTERLIFE biorefinery /process in consideration of SIA impact categories

SIA impact category	Strengths	Weaknesses	Opportunities	Threats
	Internal Factors (attributes of the organisation/product)		External Factors (attributes of the environment)	
Regulatory Framework (relevant international standards, national/regional legislation, sector specific legislation customary law)	No direct regulation on wastewater utilization Just general legislation (see UWWD)	Limitation of the use of the process products in alimentary applications since they are sourced in a waste stream (Idener, Spain)	NONE	Besides the general Urban Waste Water Directive (UWWD) there is no additional regulation on waste water utilization Regulation restrictions apply to the products made from PHA (e.g. waste management directive, or plastic packaging directive) Especially for the extracts regulation restrictions apply to the products

				(valorised from wastewater) produced in food industry (e.g. Novel Food)
Administrative divisions and governance structure (national, regional, local levels of governance, international relations)	Authorities and industry in region of Murcia are really concerned about water scarcity: each drop of water is considered as gold (CTC, Murcia, Spain)	More regional funds should be directed to waste water treatments research and development No disruptive companies in water issues in the Region of Murcia (south of Spain) Usually great investments are needed (CTC, Murcia, Spain)	Contributing in developing better standards for this kind of Wastewater biorefineries. Giving authorities a better understanding of what can be gained from wastewater. High regionality in Europe which might support a cluster for a broader bioeconomy Water is a priority in Region of Murcia with a Water and Environment Regional Ministry Universities and many Research Centres have important researchers. Technological Centres also play an important role in this field. (CTC, Murcia, Spain)	Future changes in the administrative divisions and governance structure could hamper this kind of Wastewater biorefineries. High regionality in Europe → different administrative structures might hamper the implementation of the process Water is like a political flag in the Region of Murcia (south of Spain) but sometimes it is only this: a flag (CTC, Murcia, Spain)

Infrastructure (utilities, electricity, telecommunications, waste management, housing, transport infrastructure, markets/trade links, recreational facilities)	Contribution to regional economic development Utilization and valorisation of (local) waste streams	Initial large investment (utilities, electricity, telecommunication, waste management, transports). This investment is even bigger if the infrastructure is a brand-new location.	Smart use of already present infrastructures (transport roads, buildings). Make a new building with environmentally friendly approaches and materials. Retrofitting	Infrastructure failure Unexpected blackouts could create problems to the living micro-organisms raised. Long distances might reduce the eventual environmental benefit (transport)
Community health, safety and security (health of population, mortality rates, health services, water/sanitation, road safety, fire services, disaster management services, police, security services, access to justice)	The AFTERLIFE's PHA will replace some petrol-based plastic (less GHG production = better for the community health) Potentially safer working conditions Less toxicity	Noise, smell and pollution produced by the factory. B2B transports might increase in the surroundings of the biorefinery	Planting trees to reduce noise, smell and pollution (opportunity to support the commitment of the community building a biorefinery)	Leakages of the waste water stream in the environment "Rebound effect" on waste in water. -> waste in water might increase due to waste technology improvements
Education (literacy, education levels by gender, education and training institutions/services)	Gaining of knowledge and skills utilizing waste streams Regional specialisation in waste water management (unique selling point)	NONE	Eventually involving schools in educational activities in the Wastewater biorefinery. Locate the biorefinery in an area where Universities and schools are near → making students curious about the work in biorefineries Possibility of knowledge transfer	NONE
Social Problems (crime, alcohol/drugs, prostitution,	NONE	NONE	NONE	Local resistance e.g. if a new waste water treatment plan/ or a

child/forced labour, employment inequalities, social tensions and conflicts)				pipeline needs to be build Smell nuisance Gaining negative press and media attention (e.g. for above mentioned scenarios)
Land tenure and use (type of land and natural resource use, water use and availability, private/customary forms of use and ownership, types of agriculture/livestock ownership)	Products made from wastes do not have problems associated with first generation feedstocks (land use)	Land use requirements water, sealed area	The land not used for producing the products can be employed for other purposes (e.g. biodiversity conservation) "It is not clear for me. The process can produce water for the reuse in the own process and the water producing process. The land use is only related to the deployment of the equipment "(María López Abelairas Idener, Seville, Spain)	Loss of biodiversity "I do not see a direct relationship with the process" (María López Abelairas ,Idener, Seville, Spain)
Cultural heritage (archaeological finds, indigenous sacred site, historical buildings)	NONE	NONE	NONE	Any issue of the cultural heritage can become problem for biorefinery plant location
Civil society (trust, civic involvement, press freedom, freedom of association, civil society activism, trade unions, mass media, social media, indigenous rights groups, environmental	Build people trust in Wastewater biorefineries.	NONE	Gaining positive press and media attention on Wastewater biorefineries.	Environmental groups may argue about any pollution problem related to AFTERLIFE.

groups, non-governmental community support organisations)				

The SWOT analysis of the AFTERLIFE process shows that there are many socio-economic aspects that need to be considered in the development. A major strength is the legal situation, as there are still no restrictions on the use of wastewater. In addition, there is a high urgency in the Murcia region to optimize resources and especially water flows, which is particularly requested by the authorities. The AFTERLIFE process has the strength of being able to significantly optimize resource and water use, and compared to bio-based PHA, wastewater-based PHA does not pose risks related to the food or feed debate. Weaknesses lie mainly in the high initial investments required. These could be even higher if the plant is built in a completely new location where the existing infrastructure cannot be used. The introduction of the biorefinery process also offers great opportunities for governance and education, as agencies can learn from the development what opportunities there are to increase water and resource efficiency. In addition, there are many important researchers in the region. Building the biorefinery plant near a university could also provide opportunities for students to get involved. Threats are mainly related to the regulatory framework, as there may be restrictions on PHA as well as product-related restrictions that hinder development. Future changes in administration also play a role. The administration is very different in Europe, which may make the transferability of the process difficult. Last but not least, local resistance, which can form for a variety of reasons, must be considered one of the biggest potential barriers to development.

Strength, weaknesses, opportunities and threats of the AFTERLIFE products

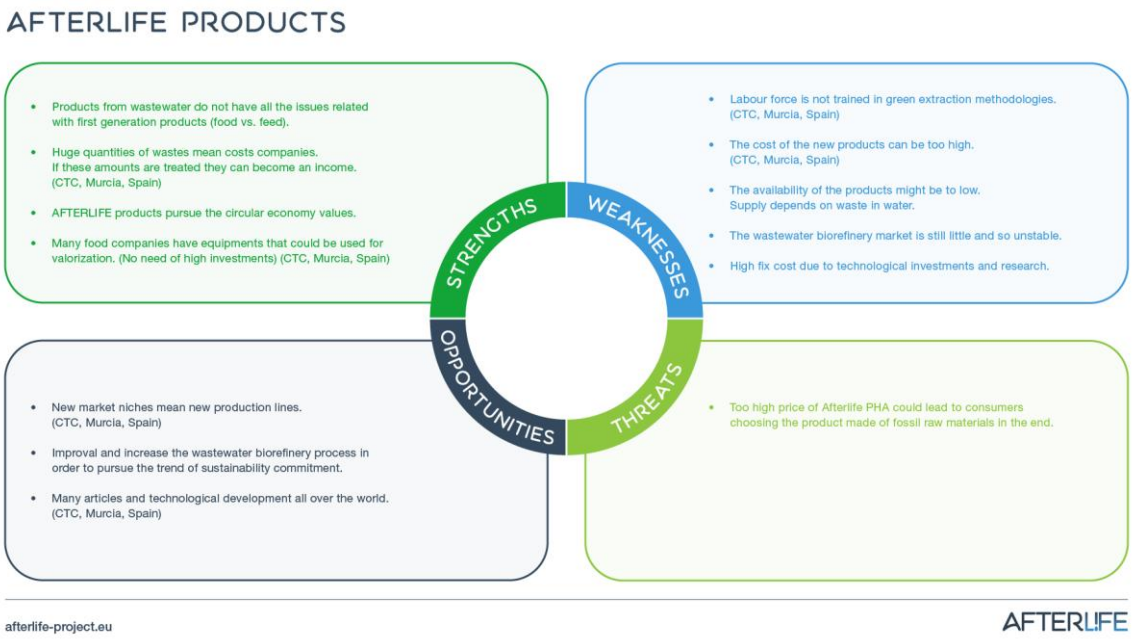

Figure 2 SWOT of AFTERLIFE products

In general, AFTERLIFE products are considered beneficial because they are not subject to the problems associated with first-generation products, such as the food or feed debate, where bioplastics from primary bioresources are criticized due to land consumption. Since the AFTERLIFE production method of PHA can be considered as circular, the use of circular economy can be considered as one of the main drivers, also because the costs incurred for the disposal of large amounts of waste are converted into revenues. That being said, many food companies already have facilities that can be used for recycling, so little or no investment is required. It is a great opportunity that improving and increasing the wastewater biorefinery process can demonstrate a company's commitment to sustainability. Also, new market niches for production equipment and technological development in this area should be considered as a basic requirement for a profitable business. However, the weaknesses of the products are that the supply depends on the wastewater, which can lead to too high a price and too low availability. Overall, it should be noted that the biorefinery wastewater market is still small and unstable, and the products have high fixed costs due to technological investment and research. Therefore, there is a risk that the too high price could lead customers to choose the fossil alternative in the end.

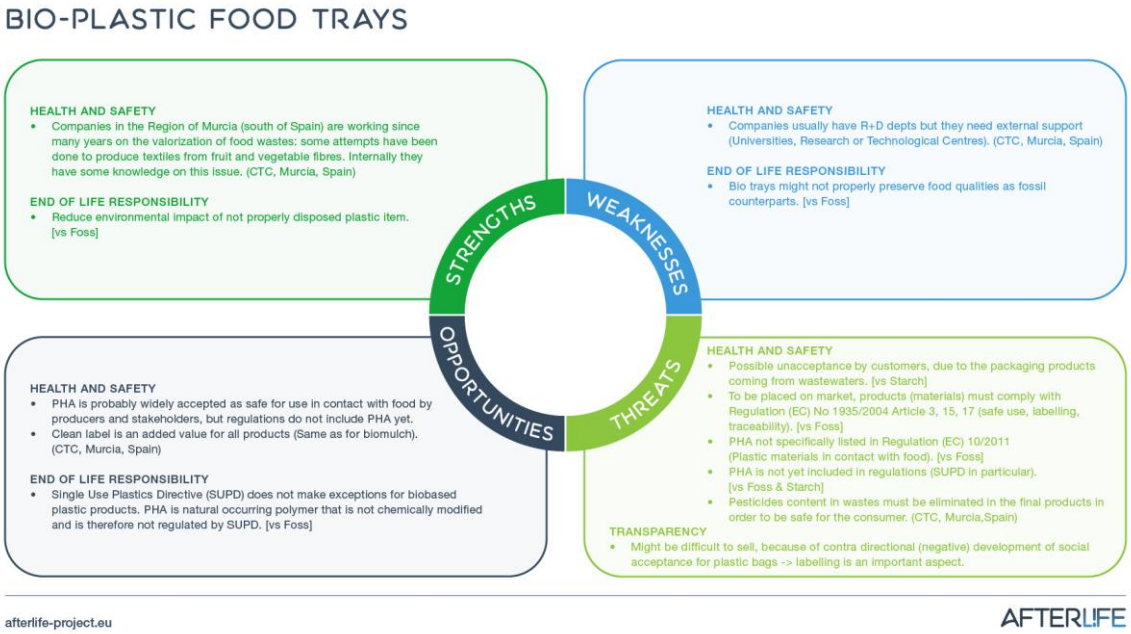

Figure 3 SWOT of bio-plastic food trays

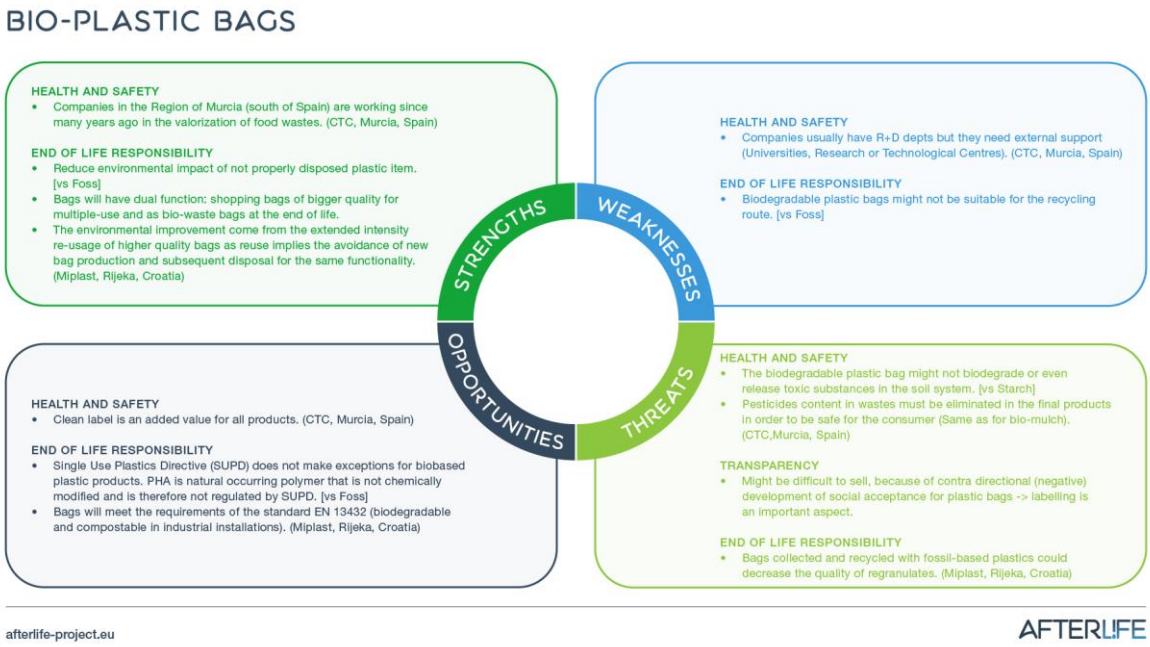

Figure 4 SWOT of bio-plastic bags

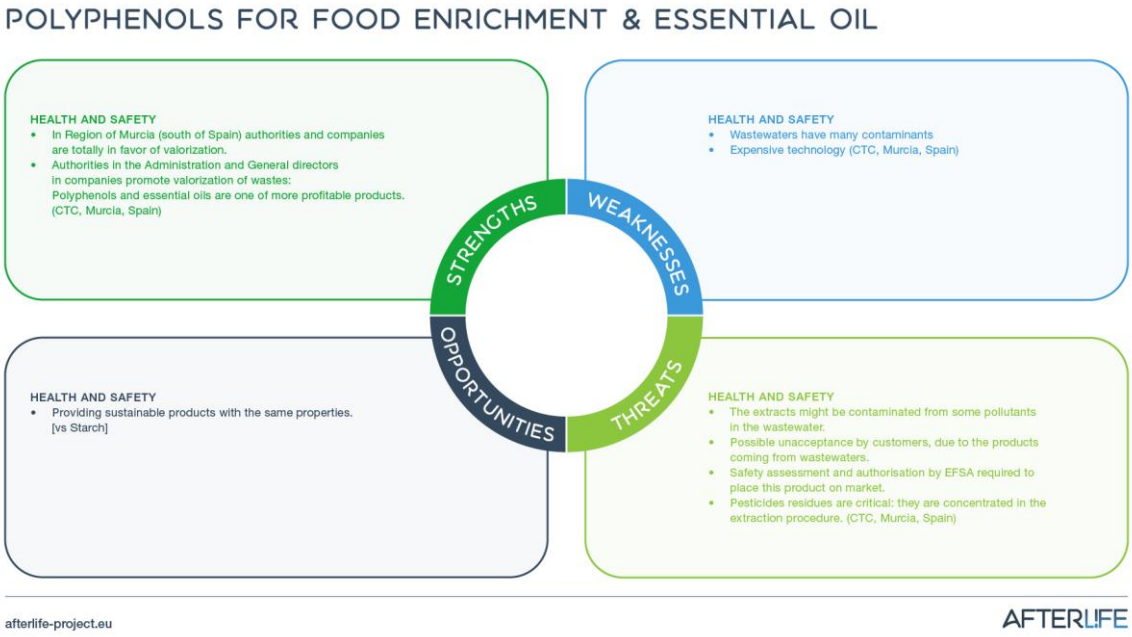

Figure 5 SWOT of polyphenols for food enrichment and essential oil

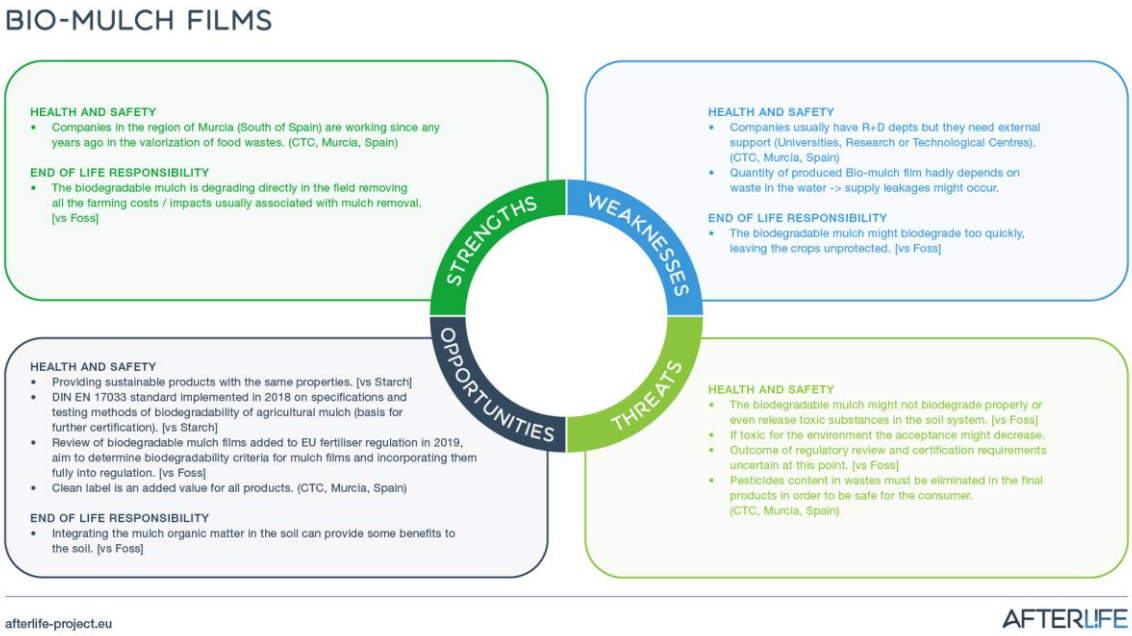

Figure 6 SWOT of bio-mulch films

The main S-LCA impact categories relevant to the different AFTERLIFE products were health and safety and end-of-life (EoL) responsibility. In terms of health and safety, it is considered a strength for all the products that the companies in the Murcia region (southern Spain) have been working on food waste recovery for many years and therefore have a lot of experience with the processes. The weakness most commonly identified in terms of health and safety is that the companies working on it often have R&D departments and rely on external support. Compared to starch-based PHAs, AFTERLIFE products could

offer sustainable products with the same properties. The major health and safety risks are that PHAs are that the derived extracts might be polluted from contaminants in wastewater. Furthermore, the wastewater-derived PHA is not as well biodegradable as pure PHA, which could potentially cause lower acceptance. Apart from that some products made from wastewater PHA, such as bio-plastic trays, are generally thought to have lower acceptance due to hygiene concerns related to food contact.

The EoL strength of the products is that they can reduce the environmental impact of improperly disposed plastics compared to fossil-based plastics. However, one problem is that PHAs are not currently recycled in existing recycling systems, while the fossil-based PE counterpart can enter these recycling streams. Therefore, the biodegradability of PHA-based products is not beneficial in all product streams that can be collected and recycled. However, it should be emphasized that PHAs are also technically recyclable and the problem lies more in the economies of scale of recycling systems. When bio-based plastics reach a critical volume, it is expected that recyclers will also invest in separation and processing technologies for them. Other EoL threats compared to fossil-based plastic products could be that biodegradable mulch films degrade too quickly and could leave crops unprotected. However, they also present opportunities because biodegradable mulches degrade directly in the field, eliminating all the costs and impacts to agriculture normally associated with mulch removal. In addition, integrating the organic matter of the mulch into the soil can provide some benefits to the soil.

4.5 Online Survey

The first four quantitative likert scale questions of the survey were all answered by the 30 respondents.

The majority of respondents were positive about the wastewater biorefinery process: over 86% rather think or are convinced that the AFTERLIFE process will contribute to the utilisation of wastewater. Only around 13% see this as less likely.

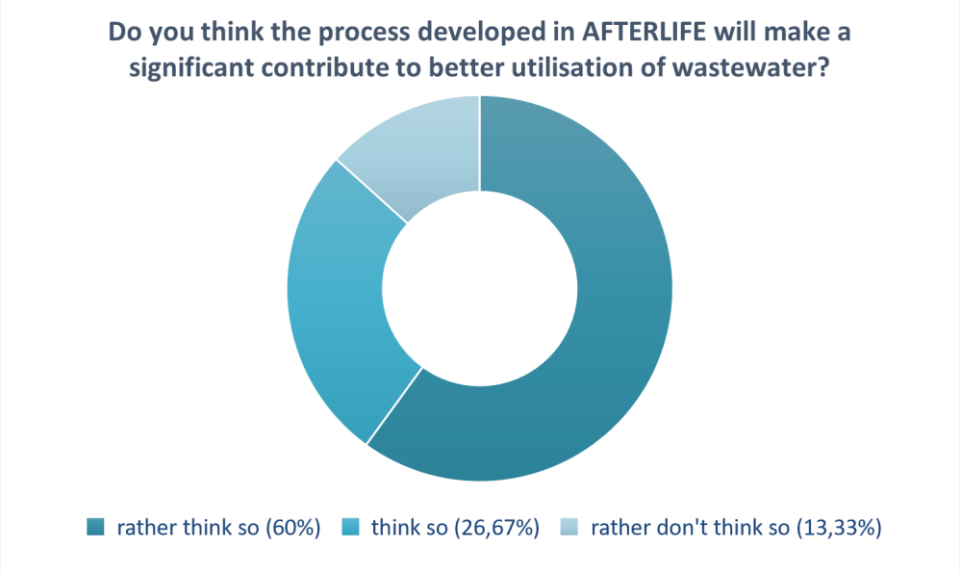

Figure 7 Results question 1 (n=30)

The respondents were not as optimistic about the second question. Here, around 50% rated that the supply of PHA will become steady and secure in the near future. Most respondents (n=14) rather don't think that this will be the case.

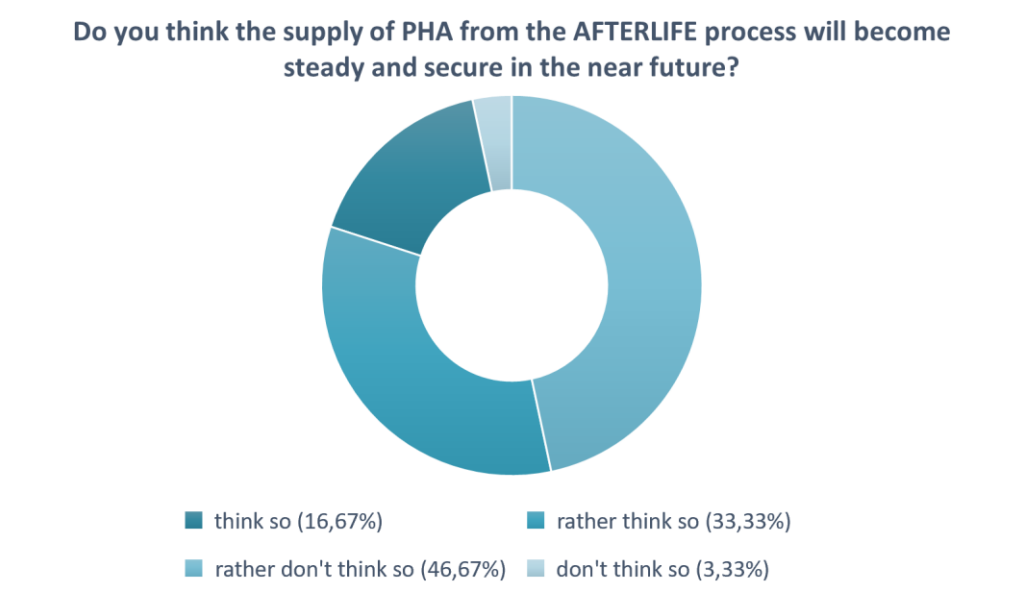

Figure 8 Results question 2 (n=30)

Basically, the same result is seen in the question whether the investment in AFTERLIFE could generate high production volumes of PHA from wastewater in the long-term. 20% agree to this and around 37% rather agree, while 40% rather disagree and around 3% totally disagree.

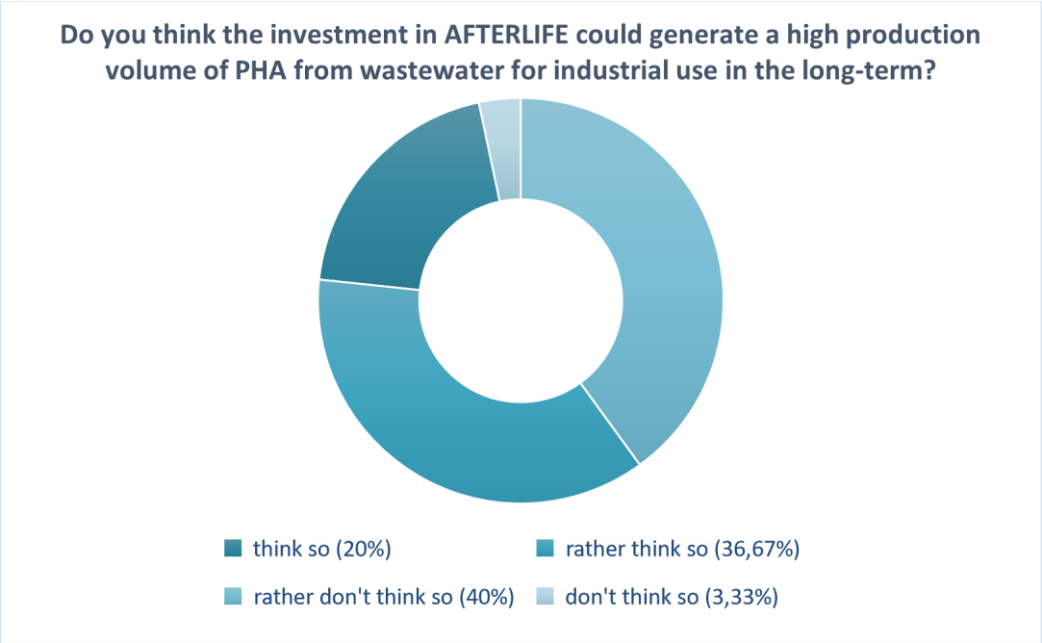

Figure 9 Results question 3 (n=30)

The minds of the respondents diverge most on the last answered question if the AFTERLIFE process will present a significant source of income in the future. Around 23% think that this can be the case and round 37% rather think so. About 27%, however, rather prognose that it will not become a relevant feedstock and around 13% do not propose that.

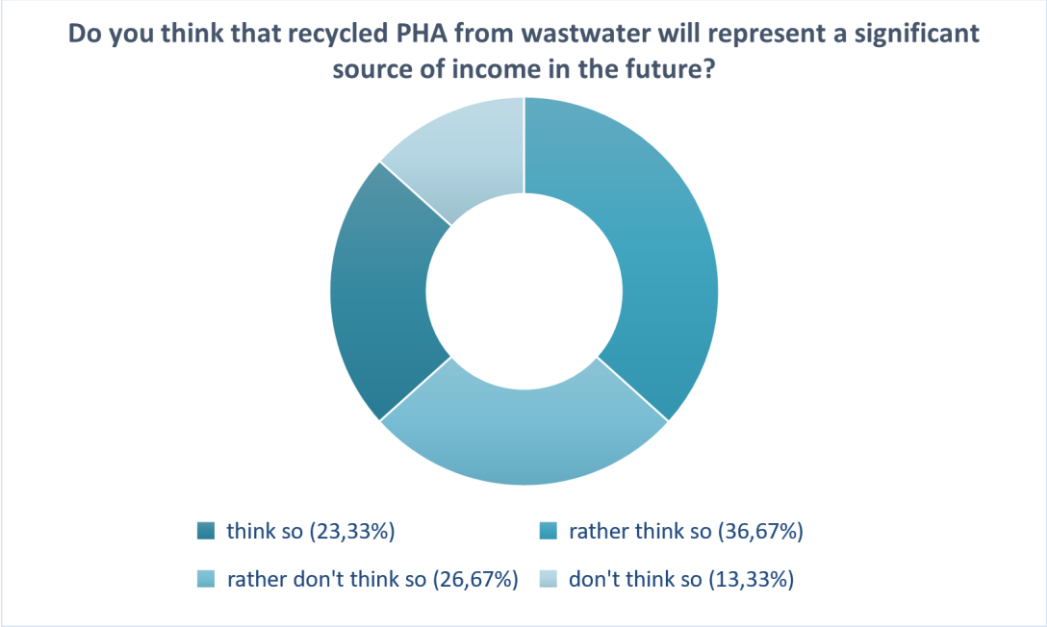

Figure 10 Results question 4 (n=30)

As already mentioned, the number of survey participants is a non-significant sample. Even with many mailings and posts on the project and nova websites, it was not possible to generate more participants. In addition, since no introductory questions were asked about the expertise and origin of the

respondents, but only the first quantitative questions were answered, the survey provides very vague results that can hardly be taken into account in the sense of the study. For this reason, it was decided not to include the results in the discussion.

4.6 Focus group discussions

After a small round of introduction, we started the group discussion about the products we had sent them in advance (a fossil-based SUP cutlery and PHA cutlery). As we also had not given the participants any information about the products or even about similarities in advance, they had no idea and thus described shape, colour, smell and functionality. In most cases, the comparable AFTERLIFE product was rated positively mainly due to the colour or the smell although some did not like the shape of the fork or said that it looked poorly processed due to fibres sticking out. One participant said that when eating ice cream with the fossil plastic spoon it broke right away. In the next step we asked the participants what they knew about plastics and plastic production. We simply let the participants write down and discuss their initial ideas and thoughts. Overall, plastic was perceived negative due to environmental pollution. The discussion of the first focus group was rather focused on solution of the plastics problem, while the second focus group discussed about the production problems. For example, two of the second group first of all suggested that it is made from oil. Generally, knowledge about the feedstock of plastic and the different polymers was rather low. The participants also did not know the exact production process but all said that the production is very harmful as it is polluting the environment and causes many emissions. In both groups the problems of microplastic and ocean plastic were also addressed. A participant highlighted that plastic settles in the body. One participant said that the SUP-cutlery would already be prohibited. Someone of the first group stated that plastic will never be fully replaceable so that solutions against plastic waste are needed. Another participant said that the responsibility lies in the hand of policy makers and big corporations. Others said that consumers could not push the change of packaging plastics even though a correct consumption behaviour would be a start.

After everyone had shared their feedback and knowledge about plastic and plastic production, nova polymer expert Pauline Ruiz gave a short and very simple presentation about plastic production especially highlighting the differences of fossil-based and bio-based plastic as well as the AFTERLIFE plastic production process (see annex). Afterwards we showed the project video (with German subtitles) from AFTERLIFE to give the participants also a little bit a more visual input about this very technical topic. When our speaker had finished and we had presented the video, the participants were asked to talk and discuss about their impressions of what they had just seen. Of course, they were also allowed to ask questions about the topic. The information about the technology, which had been unknown to consumers until then, was generally very well received. Still, the participants were surprised that there are different types of plastic that can have different properties. Especially interesting was that also recycled materials can be used for plastic production. The education about forms of plastic production prompted curious questions about costs and energy consumption. Also,

the biodegradability of the different plastics raised questions. In view of the AFTERLIFE production of plastic the participants were neutral to positive. They found it useful that plastic can be made from wastewater. One participant was rather sceptical about bio-based plastics due to land-use issues and saw benefits of wastewater recycling and recycling of food scraps. However, it must be said that the difference between bio-based and biodegradation was not really understood. Some said that they would see AFTERLIFE products as a more sustainable alternative but when they would be biodegradable. In each group a participant thought that such innovations such as the AFTERLIFE biorefinery process are overdue and considered it as problem that they are just now being promoted. Most were rather surprised that you do not hear much about such projects in general. Overall, it became clear that most participants would be willing to pay a little more for such products but not more than double.

In the final discussion round the participants were asked if they would consider the raw material or other sustainability values the next time, they buy a plastic product or a product with plastic packaging. The general tenor was that alternative plastic products as ones that are comparable to the AFTERLIFE products are still far too expensive. A green premium would only be paid biodegradability or maybe for special events if the price is not too high. If the price would be lower, some would also go for the more sustainable alternative due to the poor quality of the fossil-based plastic cutlery. For others the new information would not change their choice or consumption behaviour.

5 Discussion

The discussion of the methodologies is divided in two parts. First, the main research question on the social and socioeconomic impacts of the AFTERLIFE process and products is answered. The second part addresses the social acceptance of wastewater-derived PHA (products). Lastly, recommendations on the communication and marketing strategy can be given.

What are the social and socioeconomic impacts of the AFTERLIFE process and products?

As the policy and SWOT analyses have shown, one of the greatest strengths of the biorefinery process is the regulatory regime. On the one hand, PHA production is not treated differently in EU policy depending on the feedstock. On the other hand, the recovery of feedstock from wastewater for the production of PHA products is not expected to face regulatory hurdles in the EU framework. So far, there are no restrictions on the use of wastewater. In addition, AFTERLIFE technology itself offers major benefits in terms of climate change mitigation as it 1.) makes efficient use of residues contained in wastewater, 2.) supports water efficiency, and 3.) solves the debate on food or feedstock for bio-based plastics as no bio-based resources need to be cultivated. In a region like Murcia that suffers from water scarcity, authorities are therefore highly in favour of the technology.

The AFTERLIFE biorefinery impact opportunities are in the areas of administration and governance, infrastructure, population health, education, and land tenure. AFTERLIFE technology will contribute to the development of standards and regional development where the biorefinery plants are located. It will also enable government agencies to understand how wastewater from the food industry can be recycled. Universities and research centres located near the biorefinery also play an important role here. In the region of Murcia important researcher are located. Additionally, involving students is a great R&D opportunity. The project can have a positive impact on infrastructure if existing infrastructure such as transportation routes and buildings are used intelligently. Retrofitting and building with environmentally friendly materials can be an opportunity to increase the acceptance of a biorefinery in the region, even in the immediate vicinity. Public opposition to biorefineries and waste processing facilities in general is based on noise, pollution, and other nuisances. Planting trees could be one way to support community engagement. But also, involving schools in biorefinery educational activities can promote education and community engagement.

One of the major weaknesses identified in the SWOT analyses is the high initial investment. If the biorefinery plant is built at a completely new site, the capital expenditures may be even higher because the existing infrastructure cannot be used. In some cases, food companies already have facilities that can be used for recycling so that the investments can be is decreased. This is a great opportunity for companies to demonstrate their commitment to sustainability. Future changes in administration could become a problem for the development. It should be noted that the administration in Europe is very different, which could make the transferability of the process difficult. Last but not least, local resistance, which can form for a variety of reasons, must be considered one of the biggest potential barriers to development.

The social and socioeconomic impacts of AFTERLIFE's PHA products and applications are very similar to the impacts that PHA products have in general. Most importantly, wastewater-derived PHA products and applications currently lack specific support or regulatory preference. The current regulatory framework for plastics does not specifically exclude or give preference to biodegradable and compostable plastics. The European Commission is working on a new framework for bio-based, biodegradable and compostable plastics that will address these issues and provide a clear and well-assessed supportive framework for these plastics (including PHAs) compared to fossil-based plastics.

In general, AFTERLIFE products are considered beneficial because they are not subject to the problems associated with first-generation products, such as the food or feed debate, where bioplastics from primary bioresources are criticized due to land consumption. Furthermore, PHA is more and more known and accepted as biodegradable material. In this context, it is important to consider that blends of wastewater-derived PHA matrix with other bio-based plastics such as PLA could perform worse in terms of biodegradability than pure wastewater-derived PHA and the benefits concerning land-use.
The development of products can enable new market niches for production equipment and technological development. However, it should be noted that the biorefinery wastewater market is still small and unstable, and the products have high fixed costs due to technological investment and research. Therefore, there is a risk that the too high price could lead customers to choose the fossil alternative in the end.

What is the social acceptance of wastewater-derived PHA and AFTERLIFE products?

Because positive public perception is essential for a successful market introduction of a new technology or product, our primary objective was to determine what factors play a role in the social acceptance and general perception of products made from PHA derived from wastewater. Based on our assumptions and questions derived from previous studies, we provided a broad overview of consumer views and possible influencing factors in order to recommend best practices for communicating wastewater-derived PHA in consumer products as accurately as possible.

In general, it can be said that AFTERLIFE products were perceived positively, especially in terms of quality and function. As focus group participants were exposed to SUP cutlery, it could also be stated that there is actually no concern about food contact of wastewater-derived PHAs. Thus, the risk of possible non-acceptance due to food contact assumed for bioplastic trays can be neglected.

Although the knowledge about plastics and bioplastics was rather low, the AFTERLIFE production process was also positively received. Participants were particularly supportive of the resource savings that can be achieved with this technology. End-of-life conditions play an even greater role as a factor in willingness to pay a higher price (green premium) for AFTERLIFE products. Participants agreed that they would only pay more for the plastic if it was biodegradable and not just recyclable. In this context,

it can also be seen that there is definitely confusion when it comes to the end-of-life conditions of plastics. It is little known that not all bio-based plastics are biodegradable. Labelling has been proposed as a solution to prevent further consumer confusion. However, a recent study of consumer understanding of the labelling of various biobased plastics suggests that most consumers are completely overwhelmed by the number of different biobased labels. For this reason, it is advised to stick to End-of-life labelling, which is well-known and supported for bio-based products (Partanen et al.). Even more important is the clear communication of resource savings because of the linear pattern of increased acceptance by increased fossil resource savings. In this regard, the outcomes on the LCA should be included in the communication strategy.

Some parallels can be drawn with the acceptance factors of Co2-based products. While the two factors of disposal conditions (end-of-life) and resource savings were also identified as major factors for consumer acceptance of Co2-based products, the study also highlighted the importance of risk perception, innovation affinity and environmental awareness. In terms of environmental awareness, food and feed knowledge should be considered as a potential long-term factor. Very few of the participants were sceptical about the production of bio-based plastics, and only one mentioned the problem of land use. Educational campaigns should address this issue, as PHA derived from wastewater has the advantage of not requiring additional resources.

In addition, the acceptance factors for consumer segments of bio-based green fast moving consumer goods were consumer benefits, perceived effectiveness, and trust, while the differentiating factors for non-buyers were price sensitivity, price quality, and cost perception, as well as desire to switch from fossil resources to biomass, or brand affiliation and habits. Most of these factors were also mentioned in the discussion with focus group participants. For example, one tech-savvy respondent indicated that he would never choose the sustainable alternative. He mentioned that he would not support the new SUP strategy and that other solutions should be promoted by the government and large companies. Apart from that, he was mainly concerned about the price-quality ratio. Other respondents also disagreed that switching from biomass to fossil fuels was the best solution. Most saw the effectiveness more in reducing plastic and packaging consumption in general.

6 Conclusion

This report presents the findings from the study on the social and socioeconomic impacts of the AFTERLIFE process and products. For this study, a policy analysis of key relevant policy documents for AFTERLIFE development, a SWOT analysis of the AFTERLIFE process and AFTERLIFE products, a stakeholder survey on market acceptance, and two focus group discussions on consumer acceptance were conducted.

The AFTERLIFE technology itself offers major benefits in terms of efficient use of resources and water, and resolves the debate over food or raw materials versus bio-based plastics. In a region with water scarcity like Murcia, where a wastewater biorefinery is planned, this arouses the interest of many important stakeholders, such as public authorities. The regulatory framework is very favourable, as no legal hurdles are expected for PHA products derived from wastewater. Only with regard to the diffusion of the technology in Europe, the administration, which is handled very differently, could become an obstacle. The construction of a biorefinery plant would bring many benefits to the local community, including regional development or smart use of local infrastructure. Product development can provide new market niches for production facilities and technological developments. However, it should be noted that the biorefinery wastewater market is still small and unstable, and products have high fixed costs due to technological investment and research.

Since positive public perception is important for successful market introduction, the second objective of this study was to analyse the market and consumer perception of wastewater-derived PHA products. Unfortunately, the number of survey participants was insignificant and the survey design did not allow the survey to be used for qualitative insights. Nevertheless, the focus group provided interesting information about consumer views. The risk of possible non-acceptance due to food contact assumed for bioplastic trays could be neglected because none of the participants had concerns about food contact of wastewater-derived PHAs. The resource savings of wastewater-derived PHAs were considered the greatest strength. However, end-of-life was also very important to participants. Many indicated that they would not pay the Green Premium price for SUP cutlery if it was not biodegradable or compostable. This also suggests that the PHA should be analysed more closely if it is mixed with a bio-based plastic that is not as biodegradable. Last but not least, it was noted that there is still little awareness of the food and feed debate. Although more people are sceptical about the production of bio-based plastics, only one participant mentioned the problem of the contrast between food vs feedstock.

Overall, this leads us to give the following key marketing and communication recommendations:

- Resource savings can be distinguishing information and is therefore important for consumers to make a purchase decision. The marketing strategy and educational campaigns should make this to a core benefit.
- Educational campaigns should also train on the advantages of wastewater-derived PHA products concerning land-use issues that common bio-based plastics have.

- If you use captured wastewater PHA your products, tell people about it, because this is the only way to increase awareness and acceptance in society.
- Include already well-known brand owners in the value chain, as consumers are more inclined to trust brands they know.
- Develop demonstration products from everyday life, as they illustrate the value of converted wastewater both at the consumer level and to suppliers.
- Adapt your marketing tools to the environment in which your target group is located. For example, you may need a different strategy in a supermarket than in an explanation video or on social media
- Target your communication measures to specific groups (in terms of age, gender, social milieu, etc.).
- Labels used must be well-known.
- Use familiar terms and processes

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8 Appendices

SLCA topics (UNEP, 2009)

Stakeholder categories	Subcategories
Stakeholder "worker"	Freedom of Association and Collective Bargaining Child Labour Fair Salary Working Hours Forced Labour Equal opportunities/Discrimination Health and Safety Social Benefits/Social Security
Stakeholder "consumer"	Health & Safety Feedback Mechanism Consumer Privacy Transparency End of life responsibility
Stakeholder "local community"	Access to material resources Access to immaterial resources Delocalization and Migration Cultural Heritage Safe & healthy living conditions Respect of indigenous rights Community engagement Local employment Secure living conditions
Stakeholder "society"	Public commitments to sustainability issues Contribution to economic development Prevention & mitigation of armed conflicts Technology development Corruption
Value chain actors* not including consumers	Fair competition Promoting social responsibility Supplier relationships Respect of intellectual property rights

SIA Indicators (Wilson, 2017)

BOX 2. Indicative thematic sections for an SIA

1. **Regulatory framework** (relevant international standards, national/regional legislation, sector specific legislation, customary law)
2. **Administrative divisions and governance structure** (national, regional, local levels of governance, international relations)
3. **Population/demographics** (gender/age/ethnicity, migration trends, religion, vulnerable groups)
4. **Economy** (employment, key sectors, business environment, financial services institutions, labour rights/working conditions, informal livelihoods, income, poverty/inequality)
5. **Infrastructure** (utilities, electricity, telecommunications, waste management, housing, transport infrastructure, markets/trade links, recreational facilities)
6. **Community health, safety and security** (health of population, mortality rates, health services, water/sanitation, road safety, fire services, disaster management services, police/security services, access to justice)
7. **Education** (literacy, education levels by gender, education and training institutions/services)
8. **Social problems** (crime, alcohol/drugs, prostitution, child/forced labour, employment inequalities, social tensions and conflict)
9. **Land tenure and use** (types of land and natural resource use, water use and availability, private/customary forms of use and ownership, types of agriculture/livestock ownership)
10. **Cultural heritage** (archaeological finds, indigenous sacred sites, historical buildings)
11. **Civil society** (trust, civic involvement, press freedom, freedom of association, civil society activism, trade unions, mass media, social media, indigenous rights groups, environmental groups, non-governmental community support organisations)

Guideline focus group discussion AFTERLIFE

Composition of the focus groups

2 focus groups á 5-6 participants
Age 18-65 years
Educational level: From secondary school level (Realschuleabschluss)

BLOCK1: ca. 40 minutes

Topic introduction and agenda (2 slides)
-Brief technical introduction to the Jamboard

Link for the Jamboard: https://jamboard.google.com/d/1HFFsD4kVGnU3T9FEwcbprJUxpHp8J4C-kEBKQRwXNG0/viewer?f=6

-The link will be put in the chat in Zoom.
-It will be recorded and if no one objects we will address each other by first name and be on first name basis.

Introduction /Icebreaker

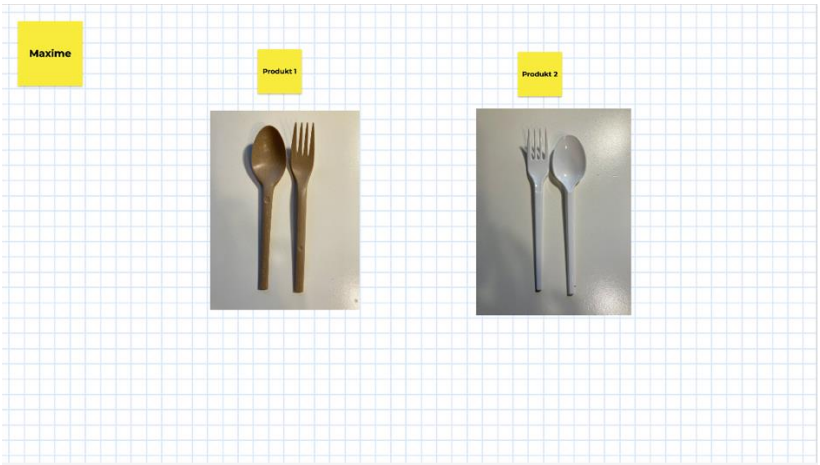
- Name,
- age
- Education
- How am I doing today (place note with name on one of the kittens).

Mood classification on the jamboard (slide 1)

Discussion round 1—> 15-20 minutes

- What did you think of the products?
- How do they feel?
- Did you notice any differences between the two products (e.g. in their feel or function)?
- What did you like about the products? Did the products work as expected?
- Did you notice any special features of the products?
- Why do you think we sent you the products / what is it about them?

Participants have to rate products -> Via notepad on their Jamboard



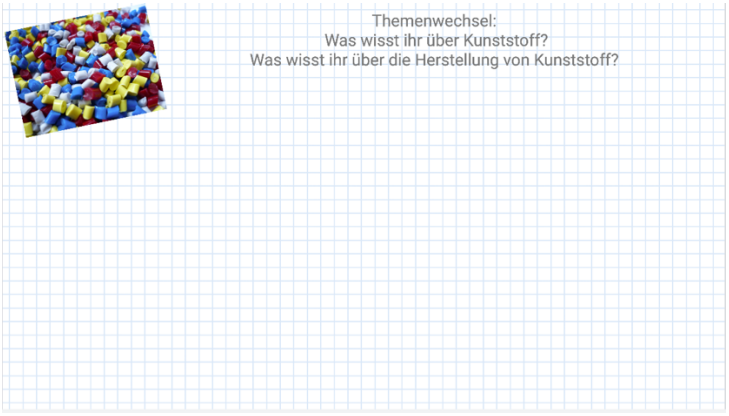
Each participant has his own jamboard (are marked with names (slide 2 -6)
Slide 2-6 assigned with name

Note: Everybody should work on his own jamboard

BLOCK2: ca. 40 minutes

Topic change: Brainstorming of participants

- What do you know about plastic?
- What do you know about the production of plastic?
- Do you know what raw materials are used to make plastic?
- What do you think, are there differences in plastics?
- What do you think, are all types of plastic equally harmful to the environment?



Slide 7 + 8
Use the next 5 minutes to write your thoughts on the jamboard (slide 7) on one or more notes. Choose the color you were assigned at the beginning.

Approx. 10 minutes

Short presentation about the different raw material sources from which plastic is produced and which advantages each raw material has (conventional and alternative) possibly with information about environmental compatibility. Pauline Ruiz 15 minutes

- Short introduction to the video of Freya

- AFTERLIFE Video (3:50) https://www.youtube.com/watch?v=n-g-uCDnU60

Resolution: One of the respective products is made of ingredients from food industry wastewater (from the AFTERLIFE process).

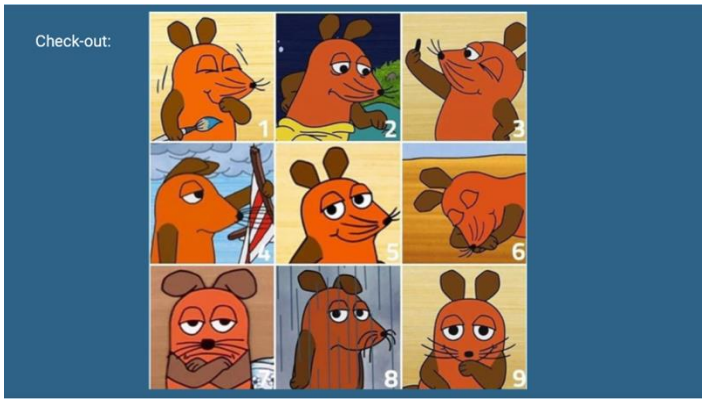
Discussion round and re-evaluate products 15-20 minutes

What do you think are the advantages and disadvantages of making products from wastewater?
- Which of the products do you think was made from PHA from wastewater? Give reasons for your statement!
- What are your initial thoughts on the topic?
- Would you continue to use the products made from wastewater components?
- Would it be okay for you if they were used for packaging food or baby food, or for hygiene or cosmetic products?
- If so, would you also buy them and would you be willing to spend more money on them than on a competitor product?

Again, rate product on jamboard with reasoning. Again, point out that the rating is on the same slide as before. This time, however, the post-It should definitely be a different colour.

Final discussion round:

- Next time you go shopping, will you think about what raw material, for example, the packaging of the products you buy is made from and how sustainable it is?
- Short feedback



Final mood

Pictures of the two test products:

Presentation of Pauline Ruiz:

Gruppendiskussion

Was ist Kunststoff?

Pauline Ruiz, 2021-10

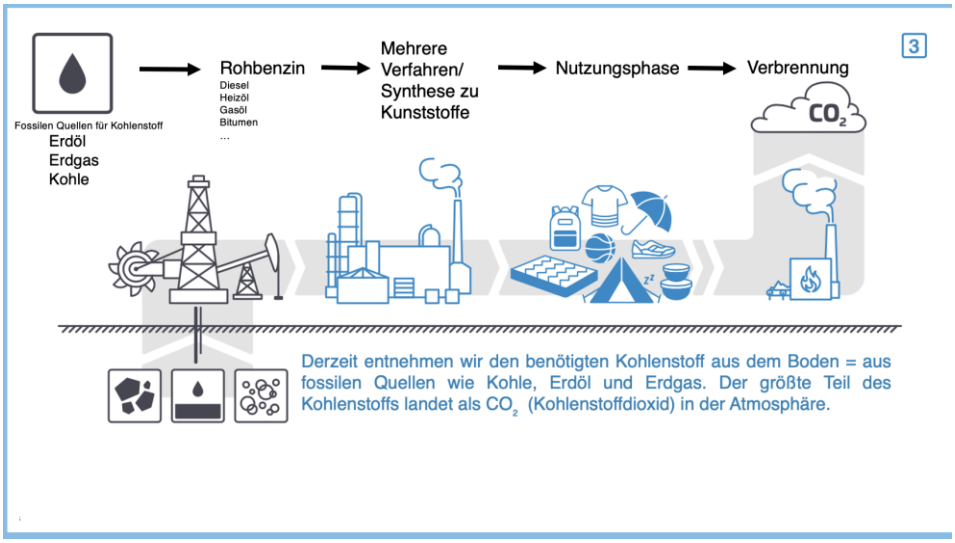
Was ist Kunststoff?

Metall

Glas

Holz

...



Was ist Kunststoff?

Kunststoffe

- Verschiedene Kunststoffe möglich je nach Anwendung: Polyethylen, Polypropylen

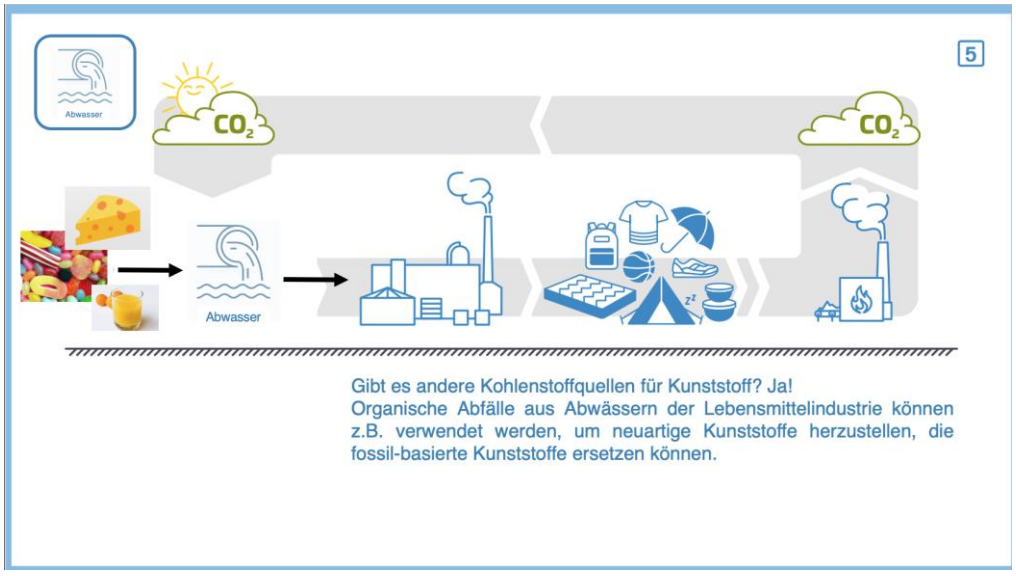
02 PE-HD 05 PP usw…

- Verschiedene **Eigenschaften** möglich: Es kann leicht, bruchfest, elastisch, temperaturbeständig, billig, langlebig, hart oder weich sein…
- In verschiedenen **Formen** herstellbar
- Kann für sehr **viele Anwendungen** verwendet werden
- Die meisten dieser Kunststoffe bestehen aus Kohlenstoff aus **fossilen Quellen**

Kohlenstoff = Atom, aus dem die meisten Lebewesen und Produkten bestehen

Der **zusätzliche fossile Kohlenstoff** (wie z.B. Erdöl oder Erdgas), den wir aus dem Boden holen und der als CO_2 oder andere Emissionen in die Atmosphäre gelangt, ist der Kern des Klimaproblems. Wenn der Zufluss verhindert wird, steigt der CO_2-Gehalt der Atmosphäre nicht mehr an

Der **Klimawandel** wird zu einem der wichtigsten Faktoren für den Verlust der **biologischen Vielfalt.**



Kunststoffe aus fossilen Quellen

Vorteile
- Technologie sehr ausgereift
- optimierte Verfahren seit Jahrzehnten
- Niedrige Preise in Moment
- Es gibt kaum Produkte des alltäglichen Lebens, in denen sich kein fossilen Kohlenstoff versteckt

Nachteile
- zusätzlicher fossiler Kohlenstoff der in die Luft freigesetzt wird, ist der Kern des Klimaproblems
- Fossile Kohlenstoffquellen (wie z.B. Erdöl oder Erdgas) sind begrenzt
- Ölverschmutzung

Kunststoffe aus Biomasse

Vorteile
- Nahrungspflanzen oder Non-Food-Rohstoffen wie Nebenprodukte und Nebenströme der Forstwirtschaft
- Keine zusätzliche Freisetzung von CO_2 im Vergleich zu fossilen Rohstoffen
- Die Herstellung gleicher Kunststoffe mit gleichen Eigenschaften aus bio-basierten Rohstoffquellen wie fossil-basierte Kunststoffe möglich
- Herstellung neue Kunststoffe mit neuen Eigenschaften möglich

Nachteile
- Begrenztes Gesamtvolumen
- Geringe Flächeneffizienz
- Potenzielle Konkurrenz zum Nahrungsmittelanbau

Kunststoffe aus Abwasser

Vorteile
- Abwasserrohstoffe: keine Nutzung von neuen Rohstoffen
- Zusätzliche Herstellung von reinem/gereinigtem Wasser
- Keine zusätzliche Freisetzung von CO_2 im Vergleich zu fossilen Rohstoffen
- Herstellung von gleichen/gleichwertigen Kunststoffen wie fossil-basierte Kunststoffe möglich
- Herstellung neuer Kunststoffe möglich mit neuen Eigenschaften möglich

Nachteile
- Begrenztes Gesamtvolumen
- Geringe Energieeffizienz
- Noch sehr teures Verfahren