



Summary of the context and overall objectives of the project

Absorbent Hygiene Products (AHPs) have become essential everyday products to society and their use has increased substantially. As with every consumer product, also AHP's end up in solid waste after their use. Today, they represent approx. 3-4% of the total municipal solid waste and are considered a non-recyclable fraction, which is usually incinerated or landfilled. Over the past 20 years there has been great progress by AHPs manufacturers to reduce the environmental impact of AHPs, for example, the average weight of baby diapers was reduced by around 50%. However, to meet society's needs for sustainable consumption there is further innovation required: Fater has developed and patented an innovative recycling solution for post-consumer AHP waste creating secondary raw materials for higher value applications. This is already demonstrated through an industrial scale unit based in Lovadina di Spresiano (Treviso–Italy).

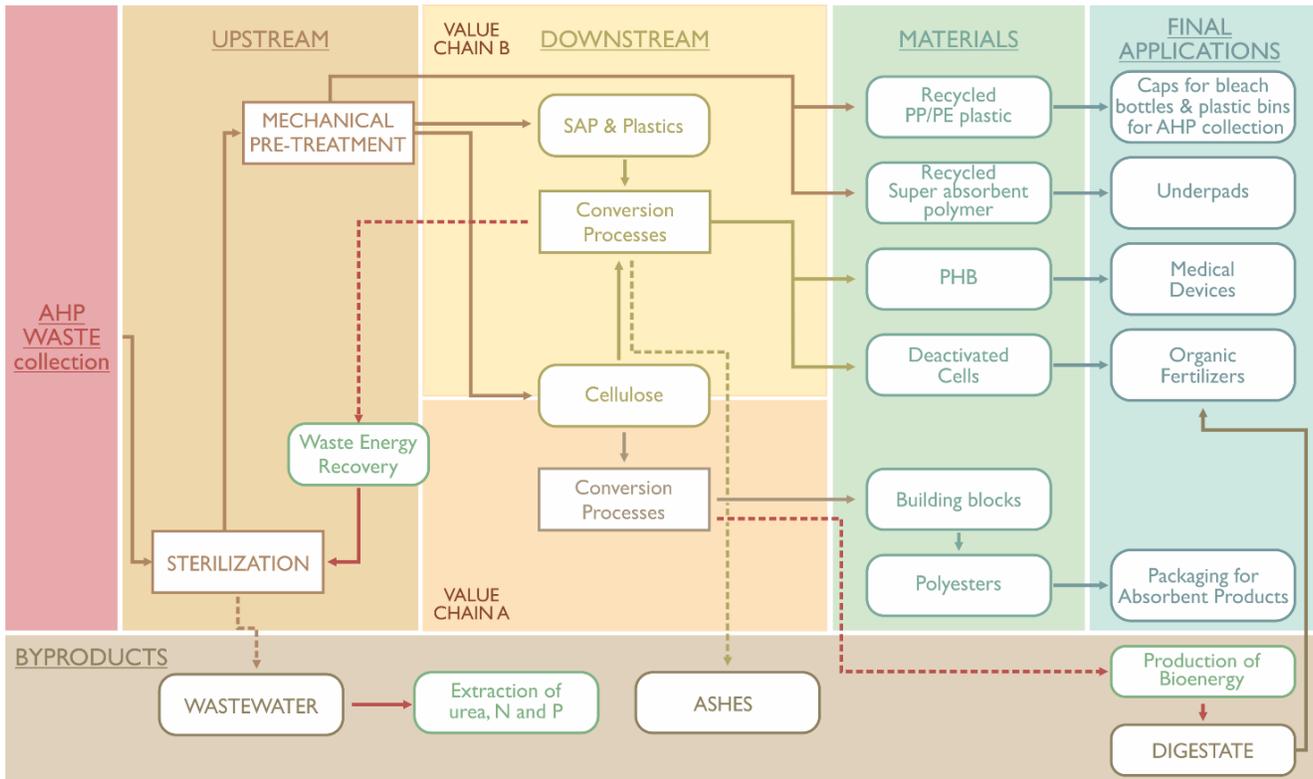
EMBRACED is aimed at closing the loop for AHP waste, reducing CO₂ emission and increasing sustainability in Europe. The objective of EMBRACED is the establishment of a first-of-its-kind demonstration plant of an integrated biorefinery in The Netherlands, with a throughput of 10,000 t/year, based on the valorisation of the cellulosic fraction of AHP waste towards the production of bio-based building blocks, polymers and fertilizers. EMBRACED will operate valorising all the fractions from the process, to obtain marketable end-products fully competitive in terms of cost, quality and sustainability. Importantly, the project will follow a circular economy approach, closing the cycle of raw materials and minimizing the use of primary resources, through the establishment of virtuous models of cooperation among all the involved stakeholders.

The EMBRACED biorefinery model can be divided in six main phases along the value chain:

1. AHP waste separate collection by waste operators from households and Institutions and transport to the pre-treatment plant
2. Pre-treatment plant, which allows the recycling of AHP waste for the recovery of cellulose, plastic and Super Absorbent Polymer (SAP)
3. Value chain A: cellulose from the AHP pre-treatment is converted into bio-based building blocks used for producing bio-based and biodegradable materials for film applications
4. Value chain B: cellulose containing SAP and part of the plastic fraction undergo a gasification process targeted at producing syngas. The cleaned gaseous stream is then fed to a bioreactor for producing bio-based PHB via fermentation with selected microorganisms
5. Application into final products: all the materials and by-products from the upstream (SAP and plastic) and downstream (PHB, biodegradable and compostable materials and cells) are further processed towards the validation into end products with increased sustainability, competitive cost and relevant market impacts



- Recovery of by-products:** extraction of nutrients from wastewaters, recovery of waste energy from gasification process, recovery of cells from fermentation broths and further valorization into bioenergy and fertilizers production



EMBRACED biorefinery model

Work performed during the second reporting period (December 2018- November 2020)

During the second period of EMBRACED, a pilot test of the innovative Direct to Consumer collection services for AHP waste collection from households has been successfully carried out in Amsterdam. The new services for AHP waste collection from private users, whose design and initial testing had been started during the first period of the project, have leveraged the use of Smart Bins. The pilot test has been active as of January 2019 and has been up and running until March 2020 when it had to be suspended for the COVID lockdown. The pilot allowed acquiring relevant learnings for the scale-up of the collection services in view of the feedstock conferral to the biorefinery.

Already during the first period of the project, furthermore, the logistics for achieving 10,000 t/year of feedstock collection from households and institutions and an adequate storage system in Amsterdam



had been defined. Further, during the second project period, a first logistic plan to deliver the targeted quantity of AHP waste to the biorefinery in Amsterdam has been finalized and the feedstock availability for the biorefinery in the Amsterdam Metropolitan Area over the target of 10,000 t/year could be assessed.

Unfortunately, during the second project period, an issue occurred with the waste operator AEB, which had to terminate its participation to the project due to external factors that prevented the company to continue working at the project. Hence, a new waste operator, SUEZ Recycling Service BB, was involved and took up the obligations of AEB within the project. Accordingly, a new site for the biorefinery in Amsterdam had to be defined with the new partner SUEZ, and the activities for preparing the site and for building and applying for the environmental permit were immediately restarted.

The upgrade of the pre-treatment plant in Italy, at Contarina's premises, has been completed. During the second period of EMBRACED, furthermore, the ability of the upgraded pre-treatment plant for achieving secondary raw materials compliant with the Italian End of Waste criteria has been assessed, along with its effectiveness for achieving the project objectives of the two EMBRACED value chains.



AHP waste pre-treatment plant



The second period of EMBRACED furthermore saw the further development of the two bioconversion processes (involved in both value chain A and value chain B) based on AHP waste cellulose to produce building blocks to be used in polymer synthesis for different applications, with the achievement of relevant results in particular for value chain A.

Within value chain A, in fact, the conversion of AHP waste cellulose into biobased building blocks and polymers has been successfully accomplished at progressively increasing scales achieving good results in terms of yield and quality of biopolymers. The obtained biopolymers have also successfully processed into the formulation of biodegradable and compostable biomaterials suitable which have been validated into films for non-food packaging applications.

Within value chain B, activities in the second project period have been mainly focused on the selection of the gasification technology able to produce syngas which is suitable for the feeding of the downstream gas-bioprocessing and on the development of process and design of a bioreactor for the production of PHB. Also, the gasification protocol for the selected technology has been developed, and lab scale gasification trials have been conducted. The bioprocess protocol has been also developed and an alternative downstream process -to replace the original method that uses chloroform- for PHB extraction and purification has been identified and tested. Finally, the chemical and physical properties of the PHB obtained via the developed process have been evaluated in view of the bio-based polymer's applications into final bio-based products.

In addition, during EMBRACED second period, the thermal-integration models analysis of the AHP pre-treatment process has been finalized, with the identification of energy savings ranging from 12 to 27%. The most suitable recovery material for the extraction of nutrients from the AHP pre-treatment process wastewater has been moreover identified and a preliminary techno-economic feasibility analysis has been developed. The second EMBRACED project period also saw the successful validation of the final applications of AHP recycled plastic and SAP (waste collection bins, detergent cups and underpads). In view of closing material loops, valorization of wastewaters from different processes has been addressed to further increase environmental sustainability and economic competitiveness.

A preliminary sustainability assessment of the EMBRACED biorefinery model has been moreover completed by delivering the first LCA, LCC, S-LCA study.

During the project's second period, moreover, the legislative barriers for the recovery of AHP waste as secondary raw material have been assessed at Member State and EU level and recommendations for overcoming the identified barriers have been drawn, with a specific focus on the End of Waste criteria by leveraging the approval in Italy of the End of Waste Decree for this specific waste stream. Also, the Action Plan for the social acceptance of the biorefinery in the Netherlands is being implemented and the social acceptance of the EMBRACED bio-based products has been assessed via a dedicated consumer survey.



Last but not least, the project's Key Exploitable Results have been fully identified and characterized, allowing for the definition of a preliminary, yet comprehensive, exploitation roadmap of the project results from an industrial point of view.



EMBRACED final products

Progress beyond the state of the art and expected results until the end of the project

Currently, AHPs find their way to landfills or incineration, leading to important environmental concerns and causing loss of valuable material resources and high economic and societal costs. Composting of AHP waste is also applied in some territories, but presents many technical and environmental hurdles: it does not allow the recovery of the valuable raw materials; it worsen the industrial composting process because of the non-biodegradable plastic and SAP content; it allows only the production of a low grade quality compost that potentially contains zinc, pathogens and drugs residues.

EMBRACED - Establishing a Multi-purpose Biorefinery for the Recycling of the organic content of AHP waste in a Circular Economy Domain



Recycling of AHP waste is the most environmentally friendly option, as it offers the potential to avoid the main issues associated with landfilling, incineration and composting. The EMBRACED biorefinery allows the full recovery of AHP waste into high value bio-based and biodegradable products diverting 10,000 t/year of AHP waste from landfilling and incineration, thus generating clear advantage for the environment, municipalities and citizens, the industry and creating new employment.

Address (URL) of the project's public website

<https://www.embraced.eu/>



Funded by the Horizon 2020
Framework Programme of the
European Union



This project has received funding from the Bio Based Industries Joint Undertaking under the European Union's Horizon 2020 research and innovation programme under grant agreement No. 745746