

**Establishing a multi-purpose biorefinery for the recycling
of the organic content of Absorbent Hygiene Products
waste in a circular economy domain**

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EMBRACED PROJECT
SHORT REPORT
 January 2020

**From People
 Care to
 Planet Care**
*Closing the Loop
 for Absorbent Hygiene
 Products Waste*

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Introducing Embraced project

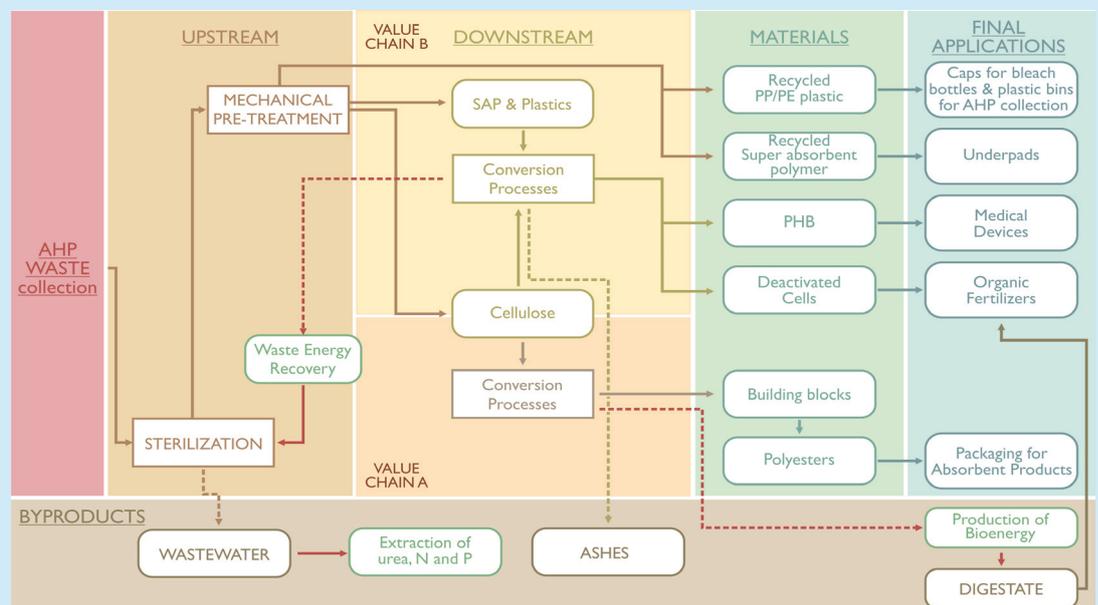
Absorbent Hygiene Products (AHPs) have become essential everyday products to society and their use has increased substantially. As with every consumer product, also AHPs end up in solid waste after their use. Today, they represent approximately 3-4% of the total municipal solid waste and are considered 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: FaterSMART 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). With a continuous research activity that aims at reaching breakthroughs in every field, the next step through the EMBRACED project is the further valorisation of the secondary raw materials and of all the process by-products into high value bio-based materials and products, as a perfect example of circular economy. Embraced is an EU funded project, involving 13 partners from businesses, academia, and research institutions. The objective of the project 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 (Figure 1) can be divided in six main phases along the value chain:

- AHP waste separate collection by waste operators from households and Institutions and transport to the pre-treatment plant
- Pre-treatment plant, which allows the recycling of AHP waste for the recovery of cellulose, plastic and Super Absorbent Polymer (SAP)
- Value chain A: cellulose from the AHP pre-treatment is hydrolysed towards obtaining second-generation sugars. Sugars then feed a fermenter for producing bio-based building blocks that is used for producing bio-based polyesters targeted at film applications
- Value chain B: cellulose containing SAP and part of the plastic fraction undergo a gasification process targeted at producing gas (CO₂ and H₂). The cleaned gaseous stream is then fed to a bioreactor for producing bio-based polyhydroxybutyrate (PHB) and Protein Hydrolysates (PH) via fermentation with selected microorganisms
- Application into final products: all the materials and by-products from the upstream (SAP and plastic) and downstream (PHB, PH and bio-based polyesters) 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 valorisation into bioenergy and fertilizers production.

The EMBRACED project started in June 2017 and will end in May 2022 and during the first two years and a half of implementation is fully on track. The articles in the present booklet provide an overview of the main outcomes and results achieved so far. This project has received funding from the Bio-Based Industries Joint Undertaking under the European Union's Horizon 2020 research and innovation program under grant agreement No. 745746. ●

Figure 1 – EMBRACED biorefinery model



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The Upgraded Pre-treatment Plant in Italy



Figure 2 – Overview of the AHP waste recycling plant

A first AHP waste pre-treatment plant for AHP waste at pilot scale was developed and demonstrated at TRL5 by FATER, in cooperation with CONTARINA, within the RECALL project (2012-2015), funded under the 'Competitiveness and innovation framework programme' (CIP-EIP-Eco-Innovation-2011). The plant, located at Lovadina di Spresiano (Treviso, Italy), was able to handle 1,500 tonnes/year of AHP waste through a newly designed (108 patents worldwide by FATER) non-contact steam autoclave process for sterilizing, de-composing and drying the input waste flow, transforming it in two high-value secondary raw materials (plastic and cellulose mixed with superabsorbent polymer). Starting from the experience of the RECALL project, within the EMBRACED project, FaterSMART focused the activities on the scale-up, adaptation and enhancement of the existing pre-treatment plant, demonstrating the achievement of two main objectives: Optimization of the sterilisation phase; Recovery of a third fraction – the super absorbent polymer - beyond cellulosic and plastic fractions. Thanks to the activities developed, the upgraded plant is now up and running in Italy, representing a first-in-the world industrial scale plant. The

plant has a capacity of 10,000 tons/year of AHP waste and is able to recover 100% of the three main components of an absorbent hygiene product:

*Cellulose
Plastic*

Super Absorbent Polymer (SAP).

From 1 tonne of AHP waste are obtained 150 kg of cellulose, 75 kg of plastics and 75 kg of SAP. The remaining part of the waste stream consists mainly in process losses and is partly discarded as wastewater.

The treatment process consists of four main steps:

*Storage
Sterilization
Drying
Separation and extrusion*

An overview of the plant is shown in Figure 2.

The process requires the presence of steam to be used during the sterilization phase and electrical energy to run all motors and pumps. A supervision system makes sure all the process parameters are constantly monitored. Below, there is a detailed description of all the different phases of the process.



Storage of incoming waste

Trucks coming from the source segregated collection of diapers unload the waste on a conveyor, which conveys waste into a closed storage chamber designed to reduce as much as possible the dispersion of odorous substances.

Autoclave

After the AHP waste bags have been collected and stored, they are transported from the storage to the autoclaves by a set of conveyors and cochlea. The autoclave is a jacketed metal tank where the combined action of the rotation and temperature, generated both by the injected steam (contact steam) and the steam circulating in the jacketed part (no-contact steam), produce the total sterilization of the products. The patented process of sterilization within the autoclave does not require preopening the bags before the autoclave.



Shredder and buffer

Right after the autoclave treatment, diapers are sent to a battery of shredders necessary in order to send suitable material to dryer and separators. The shredded material is then stored in a buffer unit and treated for potential drug residuals removal.

Dryer

Shredded material is sent to the air dryer which is made up of five different "floors" where diapers are heated up by hot air coming from a heat exchanger and by a battery of microwaves. A proper heating of the material is important to improve separation efficiency. Exhausted air is sent to a scrubber in order to remove cellulose particles and other contaminations.



Separation system

Dried diapers are sent by a cochlea to a battery of separators, the first two operate the separation of a mix of cellulose/SAP from plastics, the third one separates the cellulose from SAP. The separation is mechanical based, and the material obtained is stored in big bags (approx. 1 ton) and sent to the warehouse.

Optical separator

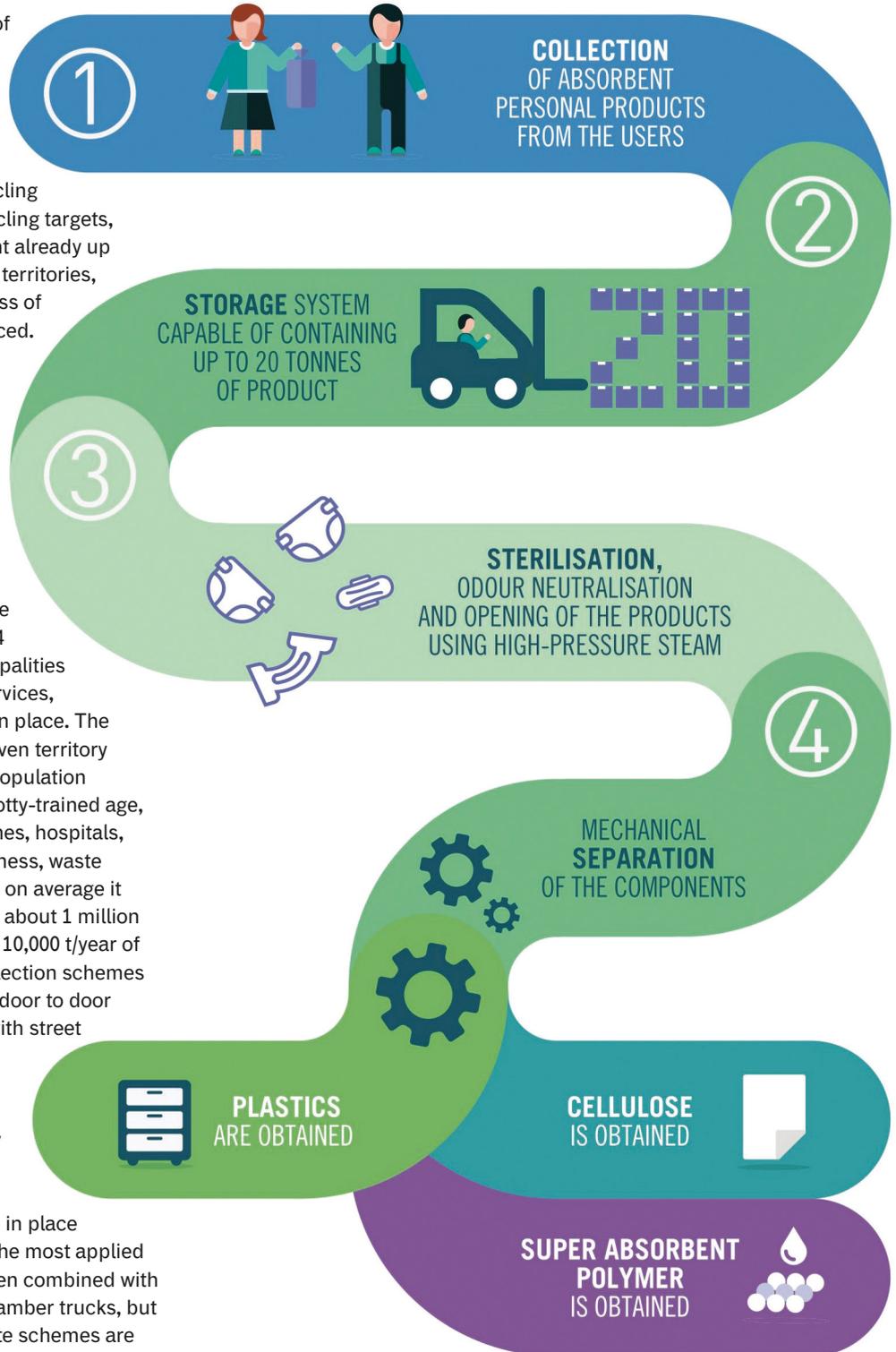
Plastics coming from mechanical separation are sent to an optical separator, which optically sorts PP and PE from PET and cellulose residuals. Once the plastics have been separated from the rest of the components, they are pelletized by using an optimized extruder. ●



The Separate Collection of AHP Waste

A pre-requisite for the implementation of AHP recycling is the set-up of separate collection services for this waste stream from households or other relevant producers (nursing homes, hospitals, day care centers), in order to secure a stable input flow to the recycling plant. As the EU moves towards its recycling targets, AHP waste has quickly risen to represent already up to 15-25% of the residual waste in some territories, where residual waste drops to 30% or less of all Municipal Solid Waste (MSW) produced. Consequently, and due to the nuisance associated to this waste stream, many municipalities across the EU are already implementing separate collection schemes for AHP waste and a quick growing trend is observed, in particular in areas where collection frequencies for the residual waste are low (fortnightly or even lower) and Pay-As-You-Throw charging systems are in place. In Italy, for example, already 14 million inhabitants in almost 900 municipalities are covered by AHP waste collection services, even where no recycling solution is yet in place. The amount of AHP waste collectable in a given territory is driven by many different factors, i.e. population distribution by age, AHP's use habits, potty-trained age, presence of big producers (nursing homes, hospitals, day care centers), environmental awareness, waste collection system in place etc. However, on average it can be assumed that a territorial area of about 1 million inhabitants can generate approximately 10,000 t/year of AHP postconsumer waste. Different collection schemes can be applied to AHP waste, including door to door collection services, bring site systems with street bins or smart bins located in strategic sites, containers located at municipal waste collection centres or at the big producers sites. The service is generally provided to registered users and the choice of the collection scheme largely depends on the waste collection system in place for the other waste streams. Currently, the most applied scheme is a door-to-door collection, often combined with the collection of bio-waste with dual-chamber trucks, but successful good practices with bring site schemes are also in place.

A report prepared in the framework of the EMBRACED project (Deliverable 1.7 "Blueprint for the replication of the AHP pretreatment technology") provides a review of some exemplary AHP waste collection case studies with guidelines for the replication in Europe and Worldwide of the unique AHP waste recycling solution at the core of EMBRACED. ●



To read the full report:
<https://www.embraced.eu/results>



LOG IN
Pampers Recycling

LOCATE
bin at daycare or
Etos

BRING
diapers to bin

OPEN
bin with code
and drop diapers

TRACK
your contribution

The Collection of Diaper Waste Through Smart Bins in Amsterdam

The Diaper Waste Collection Pilot

The diaper waste collection pilot was launched in January 2019 in the framework of the EMBRACED project. Initially, nine bins were installed in two neighborhoods of the City of Amsterdam. The program started by involving 200 families that volunteered to join and got expanded to include now more than 500 families who registered and joined the program. The pilot focuses on the “smart bin” idea which is carried out in partnership with Etos (drug retailer) and two daycare chains (Companany & Partou) as well as with the Municipality of Amsterdam. The diapers are collected for recycling.

Until today, 12 smart bins have been installed in three Amsterdam neighborhoods and a recycling app that gives consumers access to the program has been launched. Smart bins are placed in high frequency areas (e.g., in front of a drug store) and day care centers to better reach the target audience.

Parents can participate by downloading the app, locate the closest bin in the app and generate a unique code to unlock the bins and deposit their diapers. To encourage the desired behavior and to keep them engaged in the program, participating parents are rewarded. They see their contribution to the environment via a tangible impact page (“your recycled diapers

are equivalent of X chairs, X papers, etc.”) and via milestones and thank you cards (e.g. “you came 4th time, it is a habit”).

They can also get a discount for their next diaper purchase after having dropped diapers for four times.

The majority of the population “feel good” about participating in the program when they see others doing it, too. For this reason, “the neighborhood impact” has been included in the app so that the users can feel part of the movement (“your neighbors recycled in total XX diaper, equivalent of XX chairs/YY papers”).

Recently, this technique has been integrated into the program communication platforms (instore, digital) with the message “your neighborhood already collected X diapers for recycling, join the program and start recycling your diapers too”. By showing how many other people are doing the right thing, the need for conformity is encouraged. A partnership with drug stores and daycare centers (who put the bin in front of/next to their building) in order to interact with citizens and to encourage them to join the program has been established.

Results

Since January 2019, more than 500 families registered and tried the program. In total,



over 30,000 kg of used diapers – that equals to approximately 145,000 diapers – have been collected for recycling. 92% of the consumers rate the program positive with keys like ease of use and meeting their needs.

Odor control is working: despite the very warm summer in 2019, no smell was detected by the participants.

Overall the collected diaper waste quality has proven to be excellent with a purity of 98%. The remaining 2% consists mainly of plastic bags and wipes.

The program was expanded by installing three more bins, starting in August 2019 with two bins, and completing in September with the additional third bin. First learnings show that bins in front of Etos are attracting participation while the other bins require some communication to drive more traffic. However, overall the results are very good and encouraging.

Media coverage

A joint press release was issued on January 29th, 2019, announcing the collection pilot in Amsterdam. The communication highlighted the partnership of Pampers, AEB, TerraCycle and FaterSMART who joined forces to collect diaper waste with innovative “smart bins”, facilitated by the Municipality of Amsterdam, a globally first-of-its-kind collection pilot.

There was a positive coverage behind the launch, ranging from articles in leading national dailies and items on one of the most watched news

broadcasts to regional and local media (e.g., AD, NPO2, RTL Nieuws, Parol, RTL4, AT5, Trouw, Ouders van nu etc.). The story generated media interest outside the Netherlands, and was picked up, e.g., in the US, and in Germany by the national TV channel RTL.

External recognition

On October 17, 2019, the diaper waste collection pilot in Amsterdam was awarded with the prestigious AIM Nudging For Goods Award 2019. AIM, the European Brands Association, awards every two years the “Nudging for Goods” Awards to inspire brands, and promote the “Nudging for Good” concept. Nudging looks at influencing people’s behavior positively and without constraints, based on behavioral Insights. Nudging is becoming a key tool for policy-makers. Also, among the branded goods industry this concept gains increased support. Brands have a unique role to play in helping people to improve their behaviors and adopt more responsible and sustainable lifestyles.

P&G together with FaterSmart won this prestigious AIM Award 2019 for the diaper recycling project in Amsterdam developed in the framework of the EMBRACED project. The collection of used diapers – of all diaper brands – through “smart bins” aims to recycle Absorbent Hygiene Products waste. The program gives a new life to recycled diapers that are then turned to secondary raw materials for valuable products, such as bottle caps or cat litter. ●

A smart bin located in a high frequency area in the city of Amsterdam.

Participating parents are rewarded via milestones and thank you cards.



Creating virtuous models of cooperation among the stakeholders involved along the AHP Value Chain

Engagement with stakeholders along the AHP value chain (e.g. diapers' producers, waste management companies, biobased processes developers, biopolymers producers, products developers, research and education organisations, policymakers, local authorities, non-governmental organisations and last but not least citizens) typically seeks to develop networks and collaboration between organisations, in support of business and research activity, and to inform and influence policy-making and social acceptance of new technologies and products. EMBRACED project partners believe that the cumulative experience and the commitment of the partners along with a network of stakeholders, will help in gaining acceptance through the value chain and in paving the ground towards future replication of the biorefinery model.

During the first two years and a half of the project, a first stakeholders list has been settled. Today 20 stakeholders from 11 different countries, mainly Waste Operators, Universities, International Organizations and Public Authorities, have joined the stakeholders group.

The first Stakeholders Group Meeting took place at ECOMONDO in Rimini, Italy, the 7th of November 2018. Besides introducing the project for the first time, the meeting was aimed at learning from the stakeholders their experience in AHP collection systems and obtaining feedbacks on the AHP recycling perspectives and the replication potential in Europe. The stakeholders showed interest in understanding how this project could be replicated in their countries/regions, considering the positive impact on the waste management system and as an additional service to the population.

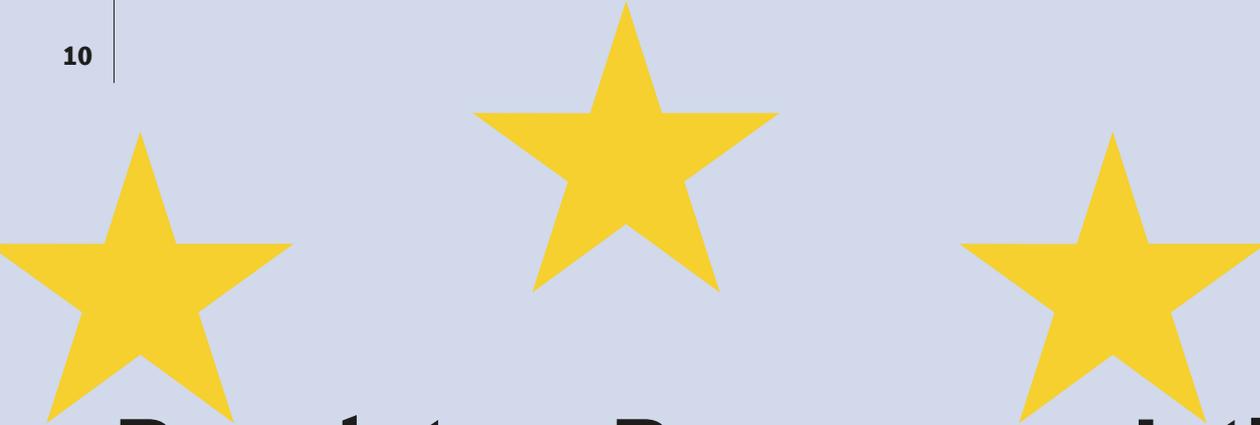
EMBRACED second Stakeholder Group meeting

was hosted by Bio-based Industries Joint Undertaking (BBI – JU) in Brussels, the 14th of May 2019. The meeting was focused on the legislative barriers to AHP waste recycling in Europe, with a focus on the implementation of End of Waste criteria for this specific waste stream and the related market uptake of the secondary raw materials recovered through the Embraced project. The main results achieved after two years were presented to the stakeholders. The End of waste criteria progresses and learnings were analysed from the Italian and Dutch perspectives, in order to share information about the most advanced experiences on the implementation of End of Waste criteria for AHPs. On the other hand, the legislative barriers for AHP waste recycling that persist in Europe and the ways to overcome them were examined through the analysis carried out by the environmental organization Legambiente within the project.

In the future, the effort for including other relevant stakeholders will continue. Engagement with stakeholders laterally and vertically across the EU will raise awareness on the Embraced biorefinery model, will build public trust in the materials cycle, will result in a shared vision of best practice in waste management that would enable to envisage and implement exploration practices that are more acceptable to society. Based on stakeholders' dialogue and research, the EMBRACED project will produce a considerable amount of documents that will prioritize recommendations and plans, with the goal to improve systems for AHP waste collection, to foster the replication of the biorefinery model, and the market uptake and social acceptance of the related bio-based materials and products. ●

The first Stakeholders Group Meeting at ECOMONDO fair in Rimini, Italy.





Regulatory Recommendations to Overcome Legislative Barriers



The circular economy is a new economic paradigm characterising recent productive and economic approaches. This new approach has begun to shape the choices made by industrialised countries and companies whose annual turnover may exceed 3 trillion dollars worldwide.

The circular economy represents an opportunity for revolutionising the use of natural resources and waste management, leaving landfill and the energy recovery as last options. However, the current level of innovation and development does not allow for the adequate recovery of secondary raw materials.

The innovative aspect of the new circular economy development paradigm resides in transforming the economic functionality of resources. This means, among other things, fighting food waste, isolating organic components for use in energy generation via anaerobic digestion, lengthening the life of consumer products, making items more recyclable and reusable in terms of design and ending programmed obsolescence.

Reducing “waste” production, recovery and reuse all become an integral part of processes, together with other measures aimed at reducing production costs, lowering dependence on primary raw materials and increasing job opportunities. This approach also allows for reducing climate emissions within supply chains, limiting the pollution producing effects of new goods and services and lowering production process waste and emissions.

The EMBRACED project provides an exemplary case study of implementation of the circular economy approach. By closing the loop of Absorbent Hygiene Products it minimises the use of primary resources while generating a positive cooperative model among the actors involved. As for many other front-running projects in the circular economy domain, in the pathway for

the project implementation there is a need to overcome some legislative barriers.

In the framework of EMBRACED, a specific study has been therefore carried out to analyse the legislative barriers and to propose regulatory recommendations regarding AHPs which are based on best evidence from diverse countries and the most advanced processes. It adopts both an Italian and European focus. Once the bureaucratic regulatory process has followed its course, it may be necessary to make these criteria generalizable to other countries that seek to promote circular resource processes based on secondary raw materials.

The main legislative barrier encountered in the project implementation is related to the End of Waste (EoW) concept, which plays an important role in giving wastes a new function and allowing them to be re-introduced and marketed in the same way as primary raw materials. This can help reduce consumption of the latter and overall natural resource use. It also offers both environmental and economic advantages due to the existing market for secondary raw materials. In this way, waste will become a new resource which can benefit society as a whole by reducing primary resource use and waste quantities. As such, EoW can help solving some of the main environmental problems currently affecting our society.

For this reason, updating existing legislation linked to EoW is in order. It is also important to establish new criteria and regulations that specify the treatments, reuses and secondary materials recoverable from different types of waste. In this context, AHP waste and secondary raw materials derived from it, are examples par excellence in terms of the need for this prompt regulatory change.

In Italy the recovery of AHP is now possible, because on the 15th of May 2019, the EoW decree has been approved and signed by the Minister



of the Environment, Mr. Sergio Costa. With regard to the assessment of impacts on the environment and human health, two Italian institutions, ISPRA (Istituto Superiore per la Protezione and Environmental Research) and ISS (Istituto Superiore di Sanità - Superior Institute Health) have issued a qualified favourable opinion regarding AHP and confirmed an absence of negative impacts. The first AHP recovery plant in Italy has been purposefully developed using now proven cutting-edge and high-performance technology.

The EU circular economy Action Plan states that materials which can be reasonably recycled should be re-introduced into the economy as new raw materials, thereby increasing certainty of supply. Secondary raw materials can be generated within a national economy and, as with primary ones, they can also be exchanged, imported or exported.

Legambiente has been active in collecting information to get a complete and detailed overview of the circular economy and, in particular, End of Waste criteria and the recovery of Absorbent Hygiene Products (AHP). To gain some numerical insights, it fielded a survey of companies, institutions and organisations active in AHP activity across Europe. 38 surveys in total were completed from 10 countries: Italy, Belgium, Spain, Portugal, France, Scotland, Poland, Finland, Holland and Montenegro. The largest number of participants were from Italy, Holland and Scotland.

The survey had two sections: (1) general questions on the circular economy and End of Waste criteria and (2) specific questions on AHP waste recovery.

The main purpose of many of the questions was to identify the major obstacles to circular economy efforts and the development of specific End of Waste criteria. The survey also aimed

to identify existing AHP recovery and recycling activity in Europe.

The synthesis of results showed that only 12.5% of respondents saw a lack of adequate and targeted scientific research as an obstacle. Most emphasised that ground-breaking and efficient technical knowledge on material recovery was already available.

The main obstacle to the development of the circular economy identified was instead associated with problems in the current national legislations at European-countries level. This was seen as out of step with technological and scientific development in the field of material recovery (62.5% of respondents indicated this). Moreover, 50% reported a lack of economic resources and sufficient investment.

The definition of specific EoW criteria for AHP waste will mark the beginning of the transition to a circular economy. It will also provide a green light to existing technologies and plants. This would contribute to enhance excellence in the recovery and recycling field in both Italy and Europe.

We consider this as fundamental and necessary for promoting the consolidation of existing or currently approved “circular” policies like EoW criteria in Italy. In turn, this may serve as a valid model for processes and formalisation procedures in other EU states.

Once the bureaucratic regulatory process has followed its course, it may be necessary to make criteria applicable in other countries which may want to promote circular resource processes based on secondary raw materials.

It is also important to establish minimum European EoW criteria which Member States would adhere to and which would form the basis for the development and use of secondary raw materials across Europe.

To read the full report:

www.embraced.eu/results. ●

Resources are limited and increasingly expensive. We need to use them in a sustainable and efficient way through rethinking the traditional model of production-consumption-disposal of products with a system-based approach, that means starting with renewable raw materials to produce manufactured goods which at the end of their lives will be converted into a new resource. The EMBRACED project pursues this objective by demonstrating a first-of-its kind integrated biorefinery transforming AHP waste into high value bio-based materials and products. Two different value chains are exploited within the project.

The value chains promote a replicable, circular, economically viable and environmentally sustainable model of biorefinery based on:

- valorisation of the cellulosic fraction of Post-Consumer Absorbent Hygiene Products waste towards the production of bio-based and biodegradable products;
- cascading approach, where side-streams from the bio-based processes are valorised to increase cost competitiveness and environmental sustainability;
- 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 continuous interactions among all project partners and their synergic know-how, has revealed to be essential to find a solution to the identified technical challenges related to the innovativeness of the feedstock.

Value chain A: from cellulose to building blocks and polymers passing through fermentable sugars

Novamont within EMBRACED project, in collaboration with Fater and Contarina is demonstrating a first of its kind value chain, which will convert the cellulosic fraction of Absorbent Hygiene Products (AHP) waste into biobased building blocks for application into biodegradable and compostable bioplastics for different application sectors.

One of the applications of the new Embraced bioplastics is the packaging of the Absorbent Hygiene Products closing the loop and promoting a circular bioeconomy model, opening up new business perspectives for all the involved stakeholders (waste management operators, industrial producer of Absorbent Hygiene Products and chemical industries expert into bio-based processes) while providing environmental and societal benefits along the whole value chain. Several progresses have been made in the project up to now, validating efficient and sustainable protocols for converting AHP waste into bioplastic

The Biorefinery Value Chains





formulations through a virtuous integration of biotechnology and chemistry.

Value Chain B: From cellulose to PHB and PH via gasification of the cellulose

Fater within EMBRACED project, is demonstrating a first of its kind value chain, which will turn recycled secondary raw materials from used Absorbent Hygiene Products into bio-polymer. Kiverdi's technology will be used to convert gas from AHP waste cellulose into advanced materials.

With specific reference to the polymers, polyhydroxybutyrate (PHB), a bio-based and biodegradable polymer belonging to the polyhydroxyalkanoates (PHA) family, will be produced for the first time ever at demo scale, achieving a key milestone towards its first industrial production. Both medical and non-medical applications have been considered in order to increase the future market applications of bio-based PHB materials. Relevant results have been achieved so far: definition of a process protocol which fulfil yield and productivity targets, LCA and LCC confirmed the environmental and economic sustainability of the innovative process, all process variables and equipment's have been tested and validated in long run on smaller scale and they are ready for the scale up to demo size, also the by-products obtained from the bio-process have been demonstrated to have relevant bio-stimulant performance for the use in agriculture. ●



First Applications of the Pretreatment Secondary Raw Materials into Final Products



Figure 1:
AHP recycled plastic in sheets form



Figure 2:
AHP recycled plastic in pellets form



Figure 3:
Cap samples produced using different compositions of virgin and AHP recycled plastic

In the EMBRACED project, all the materials and by-products from the AHP waste pre-treatment plant (cellulose, SAP and plastic) and the biorefinery (PHB, PH and bio-based polyesters) are further processed towards the validation into end products with increased sustainability, competitive cost and relevant market impacts.

Within the first two years and a half of the project implementation, the validation into final products has been already finalized for the plastic fraction recovered by the pre-treatment plant, constituted by polypropylene (85%) and polyethylene (15%).

Thanks to the very high quality of the raw materials used to manufacture Absorbent Hygiene Products and to the effectiveness of the AHP waste pre-treatment technology, the recovered plastics are also of high quality and may be employed to manufacture objects for different contexts. They are particularly suitable for injection moulding processes, both as they are and blended with different plastics (virgin or recycled). They also meet the most stringent health and hygiene criteria, specifically:

- **MICROBIOLOGICAL:** the material has been sterilized following same international norms used for surgical instruments (UNI EN ISO 17665, 11138, 14161 e UNI EN 285);
- **CHEMICAL/DRUGS:** the pre-treatment process is designed to eliminate any potential pharmaceutical residues;
- **CYTOTOXIC:** academic studies show no evidence of any types of cytotoxic activity induced by the material;
- **CUTANEOUS:** third party HRIPT (Human Repeat Insult Patch Testing) with Challenge Test exclude any phenomena of skin irritation and sensitization induced by the most critical material.

The possibility to employ the recovered plastics has been demonstrated in many different applications (e.g. chairs, school desks, cloth pins, bins for waste collection).

A specific focus in EMBRACED has been dedicated to closed loop applications, i.e. applications where the recycled plastic is used in Fater's & P&G's branded products, and very good results have been achieved for the production of detergents' caps, to be used in the home care detergent products produced by the two companies involved in the project.

As the plastic fraction is recovered from the pre-treatment plant in sheet form (Figure 1), the first step for the development of the detergent caps, as well as any other application, consists in its transformation into plastic pellets (Figure 2) through an extrusion process, in order to allow the feeding of the injection moulding machines.

After the transformation in pellets, the research activities have been focused on finding the plastics compound presenting the best physical and mechanical properties, by also evaluating the effects of the addition of virgin polymeric material.

Several samples were composed with different percentages of virgin materials with post-consumer AHP recycled plastic and masterbatch in order to obtain several performance information for defining the best formula (Figure 3).

The activities carried out made it possible to validate the use of the plastic fraction obtained from the AHP waste pre-treatment plant for the production of plastic detergent caps with great industrial exploitation potential. Even if some improvements will be necessary the AHP recycled plastic blended with different compositions of virgin materials have demonstrated so far to be a good material for this kind of application.

The market opportunity for this application is significant for Fater and P&G in terms of marketing, costs saving (the first estimate is around 20% to 30% of cost reduction) and environmental performance increase (for each ton of virgin plastic substituted with post-consumer AHP recycled plastic it is possible to save up to 2 tons of CO₂). ●

EMBRACED considers social acceptance of bio-products and co-products derived from AHP waste as a key aspect for the successful performance of the project. With the objective of assessing the social perception on EMBRACED products, a 1600 participants survey, targeting consumers, has been carried out in France, Germany, Italy and Spain. Complementary insights about consumers' behaviours and preferences towards bio-products has also been extracted from interviews of consumers associations and NGOs from several Member States.

To better understand the key moments when consumer behaviours could be influenced, both by reinforcing own preferences and by external market strategies, the five-stage model of consumer buying process is selected. The five stages and their main internal psychological process are depicted in the following scheme.

The decision of purchasing starts with a Need Recognition to be fulfilled, that could be also externally triggered by marketing. Consumers' preferences and knowledge at this stage are crucial as they may lead to different levels of satisfaction between the alternatives available to satisfy this need. In this sense, around 66% of surveyed consumers state that they can identify a bio-based product and its characteristics but, in fact, slightly above the half of them (53%), identify correctly the term bio-based when given several definitions to choose from. Experts clarify that the "bio" expression generates confusion even leading to

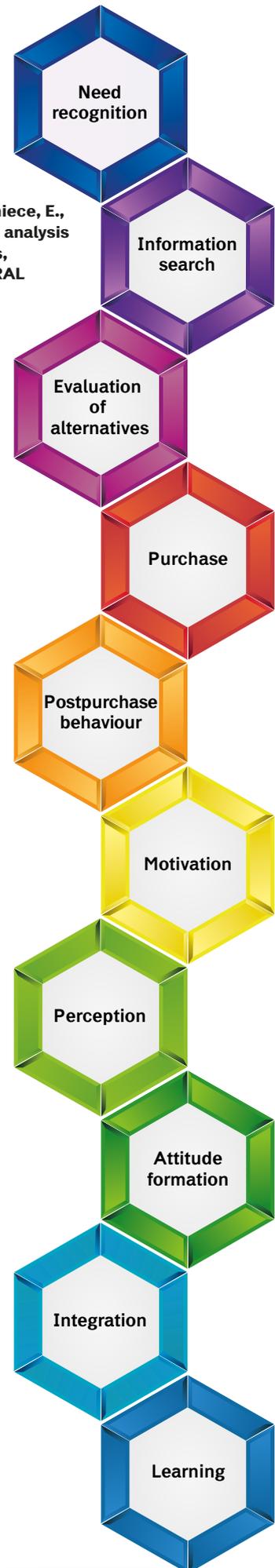
Social Assessment About Bio-based Products

certain level of distrust towards a product, as the "bio" statements might be marketing campaigning without evidence base. Furthermore, in some languages, there is not a specific translation for the term "bio-based" and needs to be further explained as "raw materials from vegetable origin".

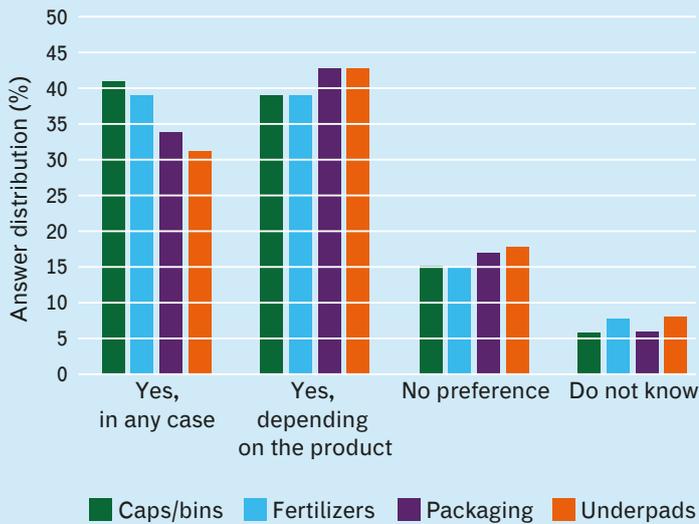
About the Information Search, 76% of the surveyed consumers agree (22%, strongly) that there is too much information to be analysed to know which the best purchasing choice is. Experts agree on this and claim that consumers get tired of reading or searching for useful information. Despite this, 39% of surveyed consumers agree that they know how to learn if a product is bio-based. Advertising campaign in the media and information in packaging is identified by experts as useful instruments to increase bio-based products awareness.

For the Evaluation of Alternatives, quality and performance (90%), user friendliness/convenience (88%) and competitive price (87%) are the most prioritized factors by consumers. 72% of consulted consumers say that they would only consider buying this kind of product, if the price is competitive. Information related to the origin of materials and end-of-life properties is nearly equally valued (66% and 69%, respectively), but experts perspective diverges, since, some state that consumers connect more with their active role, for example, when recycling, rather than the origin of materials. Others point out that consumers can be equally moved towards sustainable practices in the whole life cycle.

Viksne, K., Salkovska, J., Gaitniece, E., & Puke, I. (2016). Comparative analysis of customer behaviour models, ECONOMIC SCIENCE FOR RURAL DEVELOPMENT



If available, would you prefer the EMBRACED products over conventional alternatives?



In comparison with non-recycled/non-bio-based alternatives, recycled/bio-based products should cost...

Minimum and maximum values per country

	The same	Less	More	Do not know
	30%-32%	18%-21%	33%-34%	15%-18%
	35%-37%	30%-31%	23%-24%	7%-11%
	38%-44%	27%-31%	22%-25%	6%-7%
	43%-47%	27%-28%	14%-16%	12%-16%

On the actual Purchase, 69% agree on the fact that checking price is an effective way of simplifying complicated purchasing choices, besides buying products to which consumers are already used (66%). However, experts agree that a broad population could be targeted to be informed about biobased products and could potentially be interested in purchasing them, if involved in effective and coherent communication actions.

Finally, bio-products should be satisfactory during the Post Purchase stage, given that peer to peer advice is one of the most trusted sources of learning. Experts perceive that consumers also rely on associations, civil society and other consumers, more than on the Administration and producers.

Social acceptance of EMBRACED Products: caps and bins, fertilizers, underpads and packaging for AHP.

- Similar expected acceptance rates (around 80% of positive responses), showing that although the origin can have an impact, the potential acceptance of these products is positive.
- on the **price** of these products, there is not a definitive position among consumers. Same price is just slightly higher than lower or higher prices.
- Regarding the **feeling** of using product with recycled AHP, the expected average comfort is set on 7.4 out of 10.
- For **colour variations** in underpads (from white to light ochre), there is high variability about their acceptability. This suggest that an extra effort should be made in aesthetic properties to influence those negative perceptions.

According to stakeholders' feedback, the initiative is considered useful and potentially promising, as it could be a sustainable alternative to washable personal hygiene products. All these insights will be assessed in order to explore strategies that could boost the demand of EMBRACED products. ●



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