Intended for
EDANA

Document type
Report

Date
23rd February 2023

EDANA - AHP WASTE TO RESOURCE INITIATIVE

Bright ideas. Sustainable change.

EDANA - AHP WASTE TO RESOURCE INITIATIVE

Project name	**EDANA AHP waste to resource initiative**
Recipient	**EDANA**
Document type	**Report**
Version	**1**
Date	**23rd February 2023**
Prepared by	**Dr. Anna Berninger, Felicitas Frick, Maria Burgstaller**
Checked by	**Elisabeth Zettl, Bernhard Brackhahn**
Description	**Report**

Ramboll
Werinherstraße 79
Gebäude 32a
81541 München
Germany

T +49 89 978970-100
https://de.ramboll.com

Ramboll Deutschland GmbH
Jürgen-Töpfer-Straße 48
22763 Hamburg
Germany

District Court Hamburg, HRB 168273
Managing Directors:
Stefan Wallmann, Hannes Reuter and Dr.-Ing. Matthias Behrens

BNP Paribas S.A. Branch Germany
IBAN: DE40512106004223034010
BIC: BNPADEFFXXX

CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

AHP	Absorbent Hygiene Product
AHPs	Absorbent Hygiene Products
B2C	Business to Consumer
BAT	Best Available Techniques
BMUV	The Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection
BREFs	EU Best Available Techniques Reference documents
CEIGS	Circular Economy Innovation Grant Scheme
DDT	1,1,1-trichloro-2,2-bis (4-chlorophenyl) ethane
ECHA	European Chemicals Agency
EIB	European Investment Bank
EoL	End-of-Life
EoW	End-of-Waste
EPR	Extended Producer Responsibility
EU	European Union
IED	Industrial Emissions Directive
LCA	Life Cycle Assessment
LIFE	Programme for Environment and Climate Action
LoW	List of Waste
MCA	Multi-criteria Analysis
MSW	Municipal Solid Waste
NHS	National Health Service
NIR	Near InfraRed
OVAM	Flemish Waste Management Agency
PCB	Polychlorinated biphenyls
PCDD/PCDF	polychlorinated dibenzo-p-dioxins and dibenzofurans
PE	Polyethylene
PP	Polypropylene
REACH	Registration, Evaluation, Authorisation and Restriction of Chemicals
SAP	Super absorbent polymers
UBA	Federal Environment Agency (Umweltbundesamt)
WFD	Waste Framework Directive
WSR	Waste Shipment Regulation

1. EXECUTIVE SUMMARY

Absorbent hygiene products (AHPs) are used to absorb human fluids (e.g., urine, blood) through different stages of a human's life. In general, AHPs are products that become waste after one use. Therefore, AHPs account for a non-negligible share of municipal solid waste (MSW) in Europe.

This report addresses the growing demands for a stronger circular economy in the absorbing hygiene products sector and is an integral part of the AHPs industry's ambition to enable and support circular solutions to AHP waste. The overall goal of the study is building knowledge with a specific focus on waste streams, and how collection, separation, and recycling of AHP waste can be established to improve circularity in this sector.

AHP overall consumption, waste generation and treatment

During the investigation, waste streams for AHP, more precisely waste streams for baby diapers, incontinence products and feminine hygiene products, were first developed based on literature and expert knowledge. This allowed for the identification of the quantity of different material components becoming waste. Materials that are mainly used in AHPs are wood pulp, cotton, super absorbent polymer (SAP), polyester, polyethylene (PE) and polypropylene (PP). However, up to 2/3 of the weight of used AHP is comprised of on organic components.

As a result of this analysis, it was found that used AHPs form approximately 7.4 % of the MSW in Europe. Of this, the largest share of AHP waste comes from adult incontinence products with a share of 60 %. Baby diapers account for 36 % and feminine hygiene products for 4 % of AHP waste.

In Europe only a few recycling plants for AHP waste could be identified, located in the UK, the Netherlands, and Italy. However, some of those plants have already been discontinued. Due to this low level of recycling plants for AHPs in EU-28, only a share of up to **0.2 %** of AHPs are treated sustainably. 55 % of the AHP waste is used for energy recovery, while the remaining 45 % is disposed of. The majority of the 45 % disposed waste ends up in landfills (89 %), while the rest (11 %) is incinerated. Furthermore, single-use menstrual products like tampons are sometimes flushed down the toilet by consumers and enter the wastewater release system.

Technology scanning regarding sustainable treatment of AHP waste

Besides the development of waste streams, a technology scanning based on literature research and expert interviews was performed. The aim of this screening was to identify and analyse already existing AHP collection systems as well as separation and recycling initiatives/technologies with (potential) relevance for AHP waste.

As result 42 global studies and initiatives for AHP collection, separation and recycling in different stages of development were identified. The studies include mechanical recycling, chemical recycling and pyrolysis, but also out of the box ideas like the growing of mushrooms or algae on AHP waste. However, at least 5 initiatives were discontinued in recent years and for some initiatives, it is unclear if they are ongoing. Reasons for the discontinuation were, among others, a lack of input material, low recyclate yields, lacking capacity, economic challenges etc. For most recycling processes the recycling success depends on the separation of different materials. The 42 studies and initiatives were therefore analysed regarding their treatment of the main components - PE/PP, SAP, cellulose and organics- of the AHP waste.

Identifying promising projects for a sustainable AHP treatment

To get an overview on the weaknesses and strengths of the identified initiatives/technologies, a multi-criteria analysis was performed. It was found that none of the studies seem to be a perfect fit for effectively recycling AHP waste in the near future. Many of the examined initiatives are not mature enough to scale, not sufficiently developed to be transferred in a pilot or lack economic data for a more accurate assessment. Already existing AHP recycling facilities are promising, but interview partners mentioned low recyclate yields and challenges with wastewater treatment.

The research showed that collecting and recycling AHP waste is very complex, and that no initiative/technology offers a perfect technically and economically successful solution. This result proves that further investigation and research in AHPs and their recycling is needed, and that industry engagement is crucial. There are various ongoing projects and business models for both collection and recycling which can be further developed.

Developing of promising pilots for a more circular approach

The AHP industry must define its role in a circular economy, push research and consider establishing pilot plants. Cooperation with waste companies and authorities should also be continued and further developed. To give a starting point, the present study proposes two collection and two recycling pilots. As each identified initiative/technology has drawbacks, different initiatives were merged into possible pilots.

The first proposed collection pilot focuses on diaper waste from care homes (elderly persons) and day care centres (children), i.e., commercial clients. The idea is to combine delivery of new products with the pickup of used ones. The second collection pilot aims to allow AHP waste collection for people in certain stages of life (e.g., when having children from 0-3, when caring for an elderly person in the family etc.). The pilot is based on the idea that many people only need AHP waste collection in certain times in their lives and therefore the system should be flexible and allow registration and deregistration at any time. The pickup can also be combined with delivery (see pilot 1) or be organised via underground containers or other bring systems.

Additionally, two separation and recycling pilots were developed/identified as promising based on the identified initiatives/technologies. The first pilot includes several elements of established diaper recycling facilities (e.g., autoclave process), but combines them with less established technologies like chemical recycling for the plastic fraction. The second recycling pilot is mainly a fermentation process, turning cellulose and organics in biogas. However, the separation of SAP will be a challenge in this pilot. Similar to pilot 1, the dried plastic fraction could serve as input material for mechanical or chemical recycling processes.

Legal framework for the development of pilots for a more circular AHP treatment

Besides the analysis of promising techniques for the treatment of AHP, an examination of the legal framework for starting a pilot project was carried out. Since most AHP recycling initiatives involve the collection and recycling of various fractions of AHP waste, the activities of EDANA members and their contractors will most likely fall within the scope of EU waste management legislation. However, as recycling aims to produce secondary raw materials which will be placed on the market, EU chemicals and product law was also considered (especially in the context of end-of-waste status).

However, recycling is not the only way to become circular, but reuse, reduction and redesign are other strategies to implement when possible. There are already some alternative reusable products on the market. Most consumers, though, are not willing to adopt reusable products yet, which can be seen in the current adoption rates. That is why research on recycling of single-use AHPs continuous to be relevant.

2. BACKGROUND AND AIM

In recent years, there has been an increased interest in the environmental impact of single-use products, especially regarding their end-of-life (EoL). Absorbent hygiene products (AHPs) are used to absorb human fluids (e.g., urine, blood) through different stages of a human's life. Single-use baby/children diapers, menstrual products, and incontinence products are thus all AHPs, which have become an essential part of our lives. Products like diapers decreased in weight by nearly 50 % within the last decades (EDANA 2015). However, the use of AHPs is constantly increasing, and will continue to do so in the foreseeable future. An alternative to (single-use) AHPs would be the use of reusable products. However, most consumers are not willing to adopt reusable products yet, which can be seen in the current adoption rates. That is why research on recycling of single-use AHPs is so relevant.

AHPs are made from plastics, pulp and super absorbent polymers (SAP) and typically become waste after they have been used once. Different studies have shown that AHPs contribute to approximately 4-10 % of the municipal solid waste (MSW), depending on the country. Since AHPs are currently recycled only to a small extent (<1 %), the main part of this waste is disposed of in landfills and burned in incinerators.

Most life cycle assessments (LCAs) have identified that the major environmental impacts are in the selection and use of raw materials, but also EoL scenarios involving incineration and landfilling were found to have a contribution to the global warming potential. With the EU target of sending less than 10% of municipal solid waste to landfill by 2030, it will be more and more important to divert products from landfill. We see that in order to have climate impact and improved circularity we need to increase incineration with energy recovery and establish recycling of used products as a complementary waste management.
We need to establish recycling that is both environmentally and financially sound compared to current incineration.

To date, several private companies and institutions – such as universities – either within or outside the AHP sector, have developed pilot-scale collection and recycling initiatives with the aim of further scaling and developing these in the future. However, previous attempts to scale and develop such models has been challenging in the past due to technical obstacles and the limited economic feasibility of existing recycling technologies. Therefore, the current solutions available are not perfectly "circular" in terms of material recycling, and it will be important to understand the climate impact for a complete business model from different perspectives such as for the society, producers and waste management companies.

In the autumn of 2021, EDANA kicked-off an industry-led "waste-to-resource" initiative with the aim of addressing the growing AHP waste issue and exploring how to enable a circular economy approach within the AHP sector. Through this initiative, EDANA aims to operationalise its "Sustainability Vision" on circularity by "engaging with all stakeholders in developing optimal waste and circular economy solutions". The report at hand is set within the context of the raising demand by regulators and authorities for increased circularity within the AHP sector. The report is part of the ambition of the AHP industry to enable and support circular solutions for AHP waste disposal. EDANA regards the first step of its initiative to be a knowledge building exercise, to enable a more specific focus on relevant arising waste streams and to determine promising pilot projects with regards to collecting, separating and recycling AHP waste. Based on the project results, EDANA envisages establishing real-life pilot programmes that demonstrate industry leadership in catalysing potential solutions for the EoL phase of AHPs.

3. AHP WASTE DATA

The following section describes the generation of AHP waste based on consumption data in the EU-28 (including UK, as part of the EU-28 in 2018). Hereby, the weighs of used products are considered. Due to data availability data from 2018 was used for all calculations. AHPs are divided into the three main types: baby/children diapers, feminine hygiene products and adult incontinence products, and treated as individual sub-streams. Combining these products at the end gives the overall AHP waste.

The share of products like breastfeeding pads, puppy pads and so forth, is negligible and therefore not considered here.

3.1 Screening of relevant literature

A literature review was performed to analyse data on AHP waste generation and composition, as well as current collection and treatment routes. Relevant databases and literature were identified through desktop research, and expert interviews were conducted with several EDANA members (see Chapter 4.1.2 Interviews with experts). To enable a structured and consistent analysis of the relevant studies and databases, relevant findings from the literature review were compiled in a data management tool.

3.2 Baby/children diapers

In this section of the report the waste generation based on baby/children diapers, hereinafter referred to as only "baby diaper", is estimated.

3.2.1 Separate collection schemes

Based on the literature review and the feedback received during interviews with experts from the nonwovens industry, it can be concluded that separate collection of baby diapers only occurs to a limited extent. There have been/are only a few collection schemes in the EU, including for example:

- The collection of used baby diapers in the city of Amsterdam[1]
- A baby diaper waste collection trial in the city of Copenhagen (from September to December 2022)[2]
- Separate collection schemes in communities in Northern-Italy[3]

Therefore, for the development of the mass flow, it was assumed that all baby diapers are disposed of as part of the "household and similar waste".

3.2.2 Waste generation

As outlined in chapter 2.3.1, there is a lack of data on the generation of baby diaper waste. For the development of the mass flow, the consumption of baby diapers in the European Union (EU) was estimated and used as a basis for the waste generation.

To this end, the following parameters were calculated based on available information compiled from various studies and other relevant sources:

- frequency of use (i.e., number of baby diapers used per day per child)
- period during which children use/need baby diapers

[1] https://www.nonwovens-industry.com/contents/view_breaking-news/2019-02-19/pilot-diaper-recycling-program-underway-in-amsterdam/
[2] https://circularcph.cphsolutionslab.dk/cc/diapers/diaper-waste-collection-trial
[3] Based on information collected during expert interviews

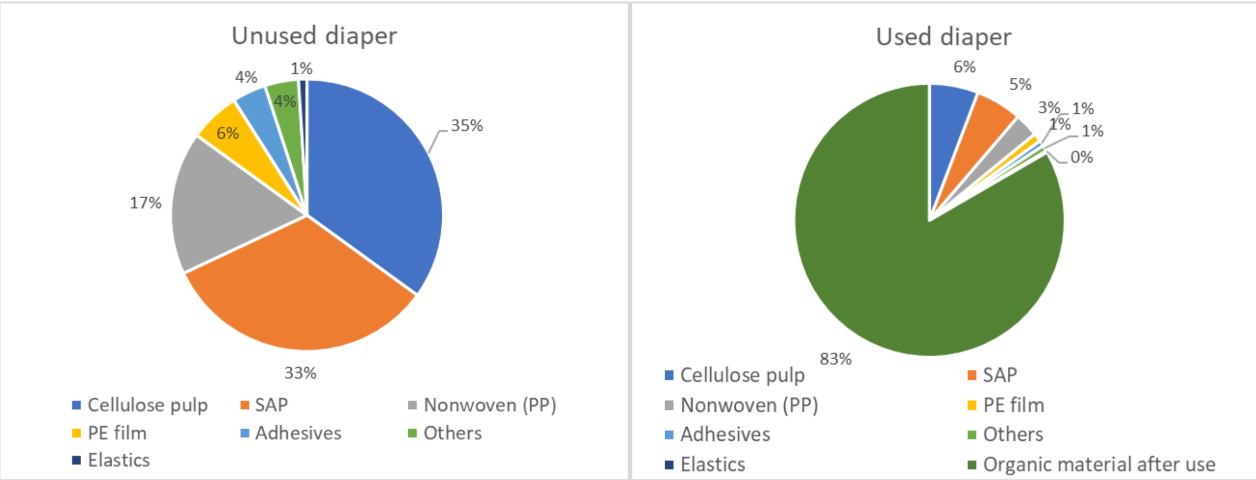
- share of children wearing baby diapers
- share of children wearing single-use baby diapers
- weight of used baby diapers

The weight of an unused disposable baby diaper for children is approximately 35 grams (g), and results from different components, mainly cellulose, SAP and different plastics such as polypropylene (PP)polyethylene (PE)). The average composition (in%) of disposable unused and used baby diapers is shown in Tabel 1 and it should be noted that wet wipes and other items wrapped in used baby diapers do not form part of this calculation.
The following calculation for baby diaper waste is based on **used** baby diapers.

Table 1: Average composition of disposable baby diapers (own table adapted from Ntekpe et al., 2020)

Component	Weight (g)
Cellulose pulp	12.25
SAP	11.55
Polypropylene	5.95
PE film	2.1
Adhesives	1.4
Elastics	0.35
Others	1.5
Organic material after use	175

Figure 1: Share of different materials in unused and used baby diapers (own graphic adapted from Ntekpe et al. 2020)



Frequency of use

The following table (Table 2) provides an overview of the sources used for calculating the number of baby diapers used per child and per day.

Table 2: Number of baby diapers used per child and per day

Source/reference	Frequency of use (baby diapers used per child and per day)
Perez et al. (2021)	6.0
Wagner et al. (2022)	6.0
Khoo et al. (2019)	7.0
Cabrera and Garcia (2019)	6.0
Thaman and Eichenfeld (2014)	5.0
UK Environmental Agency (2005)	6.1
Ntekpe et al. (2020)	5.8
Gerina-Ancane (2016)	4.6
Median value (baby **diapers used per day and child)**	**6.0**

As Table 2 shows, the number of baby diapers used per child and per day ranges between 5 and 7, also depending on the age span considered; some studies assumed that children wear fewer baby diapers a day as they get older. To account for these variations, the median was calculated to be six baby diapers per day. The median was used for further calculation and to compensate for outliers.

Period during which children use/need baby diapers and share of children using/needing baby diapers

The next step was to determine up until which age children wear baby diapers. For this purpose, data from several sources was analysed (see Table 3).

Table 3: Period during which children use baby diapers

Source/reference	Period in which children use baby diapers in years
Wagner et al. (2022)	3
Perez et al. (2021)/Edana 2008 (Sustainability report)	3
Healthline 2018[4]	3.5
Zero Waste Europe (2021)	2.5
Cabrera and Garcia (2019)	2.2 - 2.5
Khoo et al. (2019)	2.5
UK Environmental Agency (2005)	2.5
Median value	**2.5**

The literature showed that two methods for calculating baby diaper consumption were used. The first one considered the number of children that are of an age when baby diapers are typically worn, and then multiplied this by the daily number of baby diapers (Velasco Perez et al., 2021; Wagner et al., 2022). Based on the sources analysed, it can be concluded that children on average use baby diapers during the first 2.5 years of their life (median). In the EU-28 in 2018, Eurostat recorded that there were 12,760,933 children aged between 0 and 2.5 years old. It was assumed that those children who wear baby diapers for a longer time balances out with those who stop wearing baby diapers earlier.

[4] https://www.healthline.com/health/parenting/average-age-for-potty-training#readiness-signs

The second way to calculate the baby diaper consumption value considered that the age when a child needs little to no baby diapers a day is very individual (Wagner et al., 2022). According to data from the United Kingdom (UK), for example only 11 % of children aged between 24 to 36 months old use baby diapers (Aumonier & Collins, 2005).

In order to take the varying usage of baby diapers during the first three years of life into account, data from available literature (Aumonier & Collins, 2005; Ntekpe et al., 2020) was used and applied to the overall quantity of children younger than 3 years in the EU-28. Population data was also retrieved from Eurostat (reference year 2018) and results in 8,800,415 children using baby diapers (see Table 4).

Table 4: Share of children wearing baby diapers depending on the age

Age of the child	Average share of children wearing baby diapers* [%]	Population data (based on 2018; EU-28)	Quantity of children wearing baby diapers
Up to 12 months	98	5,043,743	4,942,868
12 to 24 months	64	5,142,298	3,291,071
24 to 36 months	11	5,149,784	566,476
Sum (up to 36 months)			**8,800,415**

* The average share was calculated based on data from Aumonier & Collins, 2005; Ntekpe et al., 2020.

Share of children wearing disposable baby diapers

To calculate the overall consumption of disposable baby diapers, the share of children wearing reusable baby diapers must also be considered. For calculating the overall share of children wearing reusable baby diapers, further sources were considered (see Table 5). It was concluded that around 95 % of children are using disposable baby diapers.

Table 5: Share of children wearing disposable baby diapers

Source/reference	Average share of children wearing disposable baby diapers [%]
Plotka-Wasilka (2022)	95
Wagner et al. (2022)	90
Diaper Facts and Statistics in 2022[5]	95
Median value	**95**

* It needs to be highlighted that some of the data refers to individual EU countries, while some refers to the whole EU. Therefore, the median value was calculated.

Generation of baby diaper waste

Based on the parameters described in the sections above, the annual overall consumption of disposable baby diapers in the EU-28 was estimated using an average of six baby diapers a day (see Table 6). The overall consumption was then used to calculate the overall baby diaper waste generation, assuming that all baby diapers used are generated as waste in the same calendar year. Similar approaches have been carried out in other studies such as Cabrera & Garcia, 2019; Cordella et al., 2015; Velasco Perez et al., 2021. The average weight of used disposable baby diapers ranges from 200-212 g (Cabrera & Garcia, 2019; Ntekpe et al., 2020; Velasco Perez et al., 2021; Wagner et al., 2022). The waste generation in ton

[5] https://realdiapers.org/diaper-facts/#:~:text=95%25%20of%20mothers%20in%20the,afford%20diapers%20for%20their%20children.

(t) was calculated using a median weight of a used baby diaper of 210 g[6]. Using the different literature methods of calculating the number of children wearing baby diapers, the overall amount of baby diaper waste results in the range of **3,863,255 t – 5,601,866 t** in 2018 in the EU-28.

Table 6: Baby diaper consumption in the EU-28

consumption	value	unit
Total number of baby diapers used per day in the EU-28	52,802.491 – 76,565,598	baby diapers per day
Total number of baby diapers used in one year (1 year = 365 days)	19,272,909,069 – 27,946,443,270	baby diapers per year
Total number of disposable baby diapers used in one year	18,309,263,616 – 26,549,121,106	disposable baby diapers per year
Total volume of used baby diaper waste produced in the EU-28 in one year (based on disposable diapers)	**3,863,255 t – 5,601,866 t**	ton

Comparison with other available data

To check the validity of these results, a comparison was made with values from other studies. According to Colon et al.(2011) and Cordella et al.(2015), the share of baby diapers in municipal solid waste in the EU ranges between 2 and 3 %. The indicated shares were applied to the overall amount of household and similar waste generated within the EU based on data from Eurostat[7], which would result in a range of **3,315,000 t – 4,972,500 t** waste from used baby diapers. Furthermore, Velasco Perez et al.(2021) indicated shares of different AHP fractions in MSW in several EU and Non-EU countries. Looking at EU countries, values range between 1.5 % in Denmark and 3.4 % for baby diapers in Poland. The median share of all EU countries is 2.6 %. Calculating the amount of waste based on this share of MSW, means that **4,309,500 t** of baby diaper waste would be generated in EU-28.

Another study estimating the baby diaper waste generation based on consumption data was carried out by Cabrera & Garcia (2019). The authors concluded that in total **6,731,000 t** of disposable baby diapers were generated in the EU-28 in 2017. The difference can be explained by the fact, that Cabrera & Garcia (2019) assume that 100 % of more than 15 million children aged 0 - 2 years use disposable baby diapers with an average of six baby diapers a day. In contrast, our calculation takes into account the decreasing usage of baby diapers with increasing age (see Table 4) as well as the share of children using reusable baby diapers (5 %).

According to Euromonitor the total number of disposable baby diapers consumed in the EU-28 per year is 21,229,100,000. Using the same weight for a used baby diaper (210 g) to calculate the amount of waste from those single-use baby diapers for children, the total volume of waste for one year is **4,458,111 t**.

Considering this data, the calculated range from 3,863,255 t – 5,601,866 t of used baby diapers seems reasonable. For the calculation of the mass flow the average weight of **4,732,561 t** of waste was used.

[6] The average weight of used diapers as outlined in different studies ranges between 200 and 212 g (see (Cabrera & Garcia, 2019; Ntekpe et al., 2020; Velasco Perez et al., 2021; Wagner et al., 2022)). Based on the values indicated in these studies, a median value of 210 g has been calculated.

[7] The following waste stream was used as basis: "Generation of waste by waste category, hazardousness and NACE Rev. 2 activity (env_wasgen)". Data was retrieved on the 01.09.2022 using the following settings:

- Hazard class: non-hazardous waste
- Waste categories: Household and similar wastes
- All NACE activities plus households
- Reference year: 2018

3.2.3 Treatment routes and resulting mass flow

Specific data on waste treatment of baby diapers in the EU is rare. According to Mendoza et al. (2019), 48.7 % of used baby diapers are directed towards incineration with energy recovery, while 45.4 % are sent to landfill and incinerated without energy recovery. Cordella et al. (2015) used the following disposal scenario for baby diapers in their study: 63 % of baby diaper waste is disposed of in landfills, while 25 % and 12 % are incinerated with and without energy recovery respectively.

In the absence of more specific data, the shares for waste treatment of "household and similar waste" available on Eurostat were used for the quantitative scoping of treatment routes.
To this end, the following assumptions were made:

- Baby diapers are disposed of as part of the non-hazardous fraction of the waste stream "household and similar waste".
- Treatment routes of this waste stream can be considered to be representative of treatment routes for the share of baby diapers being disposed of as part of this waste stream.

However, only treatment routes relevant for the disposal of baby diapers have been taken into consideration. Thus, the treatment routes for baby diapers calculated based on Eurostat data include:

- Recovery – Energy Recovery
- Disposal – Landfilling
- Disposal – Incineration

The share of the single treatment routes is explained in detail in the mass flow.

As regards recycling, our research found that recycling of AHP waste takes place only to a very limited extent. Plants for the recycling of AHP waste in Europe exist in the UK, the Netherlands and in Italy (Table 7). The general approach for recycling AHPs follows these steps: shredding, sorting, separating of plastics and fibres, and removal of contaminants. Based on expert input, the capacities outlined in Table 7 were identified. For simplification, it was assumed that the full recycling capacity of these facilities is used.

Table 7: Capacities of existing AHP waste recycling initiatives

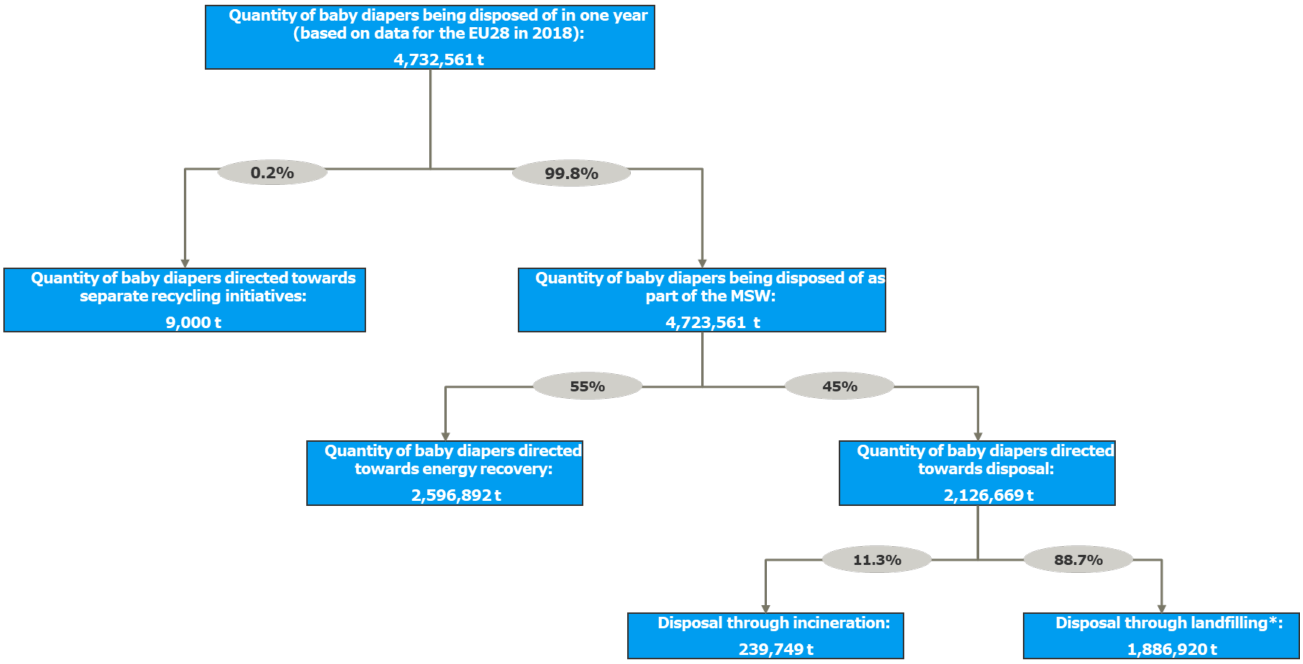
Country (company)	Max. capacity (t/a)
UK (Knowaste)	not active
NL (ARN BV and Remondis)	10,000
Italy (Fater)	10,000
UK (Nappi Cycle)	5,000
Total amount of AHP recycled in the EU by these initiatives	**25,000**

As these recycling initiatives treat different kinds of AHPs, the share of baby diapers, feminine hygiene products and incontinence products in MSW was proportionally calculated. Hence it was assumed that i) baby diapers account for around 36 % (ca. 9,000 t), ii) feminine hygiene products for 4 % (ca. 1,000 t) and iii) incontinence products (mainly adult diapers) for 60 % (15,000 t) of the AHP waste recycled by these initiatives.

By doing so, an estimation of the shares directed towards recycling could be carried out and used for the development of the mass flow. This waste stream does not only include mixed municipal waste (waste code 20 03 01), but also other fractions such as bulky waste (waste code 20 03 07) or street-cleaning residues (20 03 03).

To construct a mass flow, the average (**4,732,561 t**) of the estimated range of baby diaper waste (**3,863,255 t – 5,601,866 t**) was used, considering that there are certain uncertainties.
Thus, the resulting mass flow looks like the following:

Figure 2: Mass flow - baby diapers (own graphic)



* This includes disposal operations D1, D5, D12

As Figure 1 shows, only a very limited share of approximately 0.2 % of baby diapers are recycled. The largest fraction of baby diapers with 2,596,892 t is energetically recovered (ca. 55 %) while a slightly smaller fraction containing 2,126,669 t is directed towards disposal (ca. 45 %). When baby diaper waste is directed towards disposal, landfilling is by far the most relevant treatment method (88.7 %) while incineration without energy recovery only plays a subordinate role (11.3 %).

3.3 Feminine hygiene products

Feminine hygiene products mainly consist of tampons, panty liners and pads, all of which are examined in the following estimation.

3.3.1 Separate collection schemes

Only one study was found on separate collection schemes for feminine hygiene products. It is based on numbers for the UK that were extrapolated to the EU-28 (Blair et al., 2022). Blair et al. (2022) state that 56 % of feminine hygiene products are disposed of in sanitary bins, while 19 % are discarded in household waste. The remaining 25 % in this study are flushed down the toilet. This seems to be a particular problem in the UK and is not referred to in other EU countries (Alda-Vidal et al., 2020). While some used products may be disposed of in the toilet, due to a lack of data we assume this to be negligible overall in the EU-28.

For the development of the mass flow, it was thus assumed that all feminine hygiene products are disposed of as part of “household and similar waste”; which includes sanitary bins and household waste.

3.3.2 Waste generation

As outlined above (chapter 3.1) for baby diapers, there is a lack of data on the generation of feminine hygiene product waste. Thus, to develop the mass flow, the consumption of feminine hygiene products in the EU-28 was estimated and used as basis for the waste generation.

The following parameters were calculated based on the information available in various studies and other relevant sources:

- frequency of use (i.e., number of feminine hygiene products used per female per period)
- age range during which females menstruate to estimate the total number of products used
- share of females wearing single-use feminine hygiene products
- weight of “used” feminine hygiene products

Frequency of use

Table 8 shows the number of feminine hygiene products a female uses per period, according to the literature. The number of consumed products varies per author between 16.5 and 42, with an average of 25.3 and a median of 21.3 per menstrual cycle. When calculating the waste later on, the median was used to compensate for any outliers. Due to the uncertainty regarding the estimation of used products, an uncertainty range of ±10 % was used when calculating the amount of waste. The average female menstrual cycle lasts 28 days, which results in 13 periods per year (Cabrera & Garcia, 2019; Leroy et al., 2016). The length of a period can vary between 3 – 7 days.

Table 8: Number of menstruation products per period per female

Source/reference	products per period [number of pads etc]
Perez et al. (2021)	42.0
Project: REUSABLE SANITARY PADS FOR ALL![8]	22.3
ACOG (2015)	20.3
Blair et al. (2022)	16.5
Cabrera & Garcia (2019)	32
Hait & Powers (2019)	18.5
Average value (products per period)	**25.3**
Median value (products per period)	**21.3**

Period during which females need menstrual products

The second step was to determine the average age range during which females require menstrual products. For this purpose, data from several sources was analysed (Table 9).

Table 9: Average age ranges when females need menstrual products

Source/reference	Start	End
Perez et al. (2021)/EDANA 2008 (Sustainability report)	13	52

[8] https://www.w4.org/en/project/reusable-sanitary-pads-for-all/

Is this normal? Your period in your 20s, 30s and 40s[9]	12	52
What Is the Average Age a Woman Stops Menstruating?[10]	13	50
Cabrera and Garcia (2019)	13	49
Blair et al. (2022)	12	55
Average value	**12.6**	**51.6**
Median value	**13**	**52**

Based on the sources analysed, it was assumed that females of reproductive age on average need menstrual products between the ages of 13 to 52 years. To quantify the amount of menstrual waste produced annually in the EU-28, secondary data was collected from Eurostat. It is necessary to consider that not all females of reproductive age menstruate, e.g., due to pregnancy or health issues, and it is not only cisgender women who menstruate. In order to simplify the calculation, and due to lack of data of the menstruating population, data from all women was utilized for this analysis. The total number of all females in the EU-28 aged between 12 – 52 is **131,251,443** (Eurostat, reference year 2018).

Share of females wearing single-use feminine hygiene products

However, not all females in Europe use single-use menstrual products; the number varies by age, ethnicity, access to menstrual products, health, and country. A small number of menstruators use reusable products. In the literature the share of women using single-use feminine hygiene products varies between 75 % to 85 % depending on the country (Blair et al., 2022; Velasco Perez et al., 2021).

Due to the increasing number of reusable alternatives, we assumed the share of females consuming single-use feminine hygiene products to be 80 - 85 % for EU-28, which accounts for 105,001,154 - 111,563,727 females (Table 10). For calculation purposes, a share of 85 % of females using disposable products was utilized.

Table 10: Number of females in the EU-28 in 2018 of reproductive age and share of females using single-use feminine hygiene products

	Females in EU-28 in 2018 (Eurostat)
All females in EU-28	131,251,443
Share of females using single use feminine hygiene products in Europe (80 %)	105,001,154.4
Share of females using single use feminine hygiene products in Europe (85 %)	111,563,727

Weight of used feminine hygiene products

The chosen product – tampon, panty liner or pad – varies by menstruator. The main components of pads usually include plastics such as polyethylene, cellulosic fibres, viscose, or cotton (Blair et al., 2022). The dry weight of a pad lies in a range of 8 – 10 g (Blair et al., 2022; Leroy et al., 2016). Tampons are usually made up of a surface material, an absorbent core, a string and in some cases wrappers or applicators that are made of either plastic or cardboard. The dry weight of a tampon ranges between 2.5 – 5 g (Blair et al., 2022; Leroy et al., 2016). Table 11 displays the distribution of materials used in different feminine hygiene products.

[9] https://www.allinahealth.org/healthysetgo/care/is-this-normal-your-period-in-your-20s-30s-and-40s
[10] https://www.medicinenet.com/what_is_the_average_age_a_woman_stops_menstruating/article.htm

Table 11: Distribution of components for a tampon (dry, 2.5 g), a standard sanitary pad (dry, 10 g), and a panty liner (dry 4,66 g) (according to Leroy et al. (2016); Cabrera & Garcia (2019); Cordella (2015); Hait & Powers (2019))

	Tampon		Standard Sanitary pad		Panty liner	
Component	Weight (%)	Weight (g)	Weight (%)	Weight (g)	Weight (%)	Weight (g)
Cellulose pulp	90	2.25	48	4.8	67	3.42
SAP	-	-	6	0.6	-	-
PP, PE, PET	9	0.23	36	3.6	7	0.31
Adhesives	-	-	7	0.7		
Silicone paper	-	-	3	0.3	20	0.93
Cotton cord)	1	0.02	-	-		
Organic material after use		6-18		6-25		3-8

According to literature, the weight for used menstrual hygiene products varies from a minimum 5.7 g to a maximum of 89 g depending on the product, with a median of 14.9 g (Sasidaran et al., 2021) for all feminine hygiene products. Due to a lack of concrete values for the EU, we averaged the values from different studies as displayed in Table 12, which resulted in a median weight of 12 g. To account for any uncertainties, the median ±10 % is used in the following calculations.

Table 12: Average weight of feminine hygiene products

Source/reference	Information	Average weight (used) [g]
Leroy et al. (2016)	Tampon (dry tampon =2,5 g, absorbency rate of tampons 6-18 g)	10.0
Leroy et al. (2016)	Sanitary pad ultra-thin /panty liner dry	8.0
Sasidaran et al (2021)	Median for all used feminine hygiene products	14.9
Cabrera and Garcia (2019)	Product average used	12.0
Perez et al. (2021)Click or tap here to enter text.	Menstrual pad used	35.0
Average weight		**16.0**
Median weight		**12.0**

Waste generation of feminine hygiene products

Based on the parameters described above, the overall consumption of disposable feminine hygiene products per year in the EU-28 was estimated (see Table 13). The overall consumption was then used to calculate the overall feminine hygiene waste generation in the same year. Similar approaches have been carried out in other studies (Blair et al., 2022; Cabrera & Garcia, 2019; Velasco Perez et al., 2021). The waste generation in t was calculated by multiplying the median of the number of products (21.3 ±10 %) with the median weight of a used feminine hygiene product (12 g ±10 %) with the share of females using those products. The feminine hygiene product waste generation for the EU-28 in 2018, thus lies in the range of **299,098 – 448,106 t**.

Table 13: Consumption of feminine hygiene products in the EU-28 in 2018 and the resulting amount of waste

consumption	value	unit
total number of feminine hygiene products used per month in the EU-28	2,513,591,337 – 3,372,167,189	tampons/panty liner/pads per 28 days

total number of feminine hygiene products used in one year (1 year = 13 periods)	32,676,687,378 – 39,938,173,462	tampons/panty liner/pads per year
total number of disposable feminine hygiene products used in one year	27,775,184,271 – 33,947,447,443	disposable tampons/panty liner/pads per year
total volume of used feminine hygiene products waste produced in the EU-28 in one year (based on disposable products)	**299,098 – 448,106**	ton

Comparison with other available data

To check the validity of these results, a comparison was made with values from other studies. According to Perez et al. (2021), the share of feminine hygiene products in municipal solid waste in the EU ranges between 0.4 and 0.8 % with an average of 0.49 % and a median of 0.5 %. Taking the municipal solid waste in 2018 (Eurostat[11]), this would result in an average of **812,175 t** of waste generated by feminine hygiene products. Cabrera & Garcia (2019) stated, that the share of feminine hygiene products in municipal solid waste in the EU-28 in 2017 was 0.2 % and calculated this to result in **590,000 t** of waste generated by feminine hygiene products. Based on Euromonitor's consumption data the total amount of feminine hygiene products consumed in the EU-28 in 2018 was 38,616,200,000. Using the same weight range for a used product (12 g ±10 %) to calculate the amount of waste, the total volume of feminine hygiene product waste for one year is **417,055 – 509,734 t**.

Sasidaran et al. (2021) calculated the waste generated from feminine hygiene products during a woman's lifetime to be 137.5 kg. For comparison purposes we calculated the annual amount of waste for females within the EU-28. Given, that a woman menstruates during her lifetime on average 459 times (35 years with 13 periods per year) the annual amount of waste created is 3.9 kg per menstruator. Multiplied by the number of menstruating females living in the EU-28 in 2018, this results in **408,999 t** of annual waste generated by feminine hygiene products. Blair et al. 2022 carried out a similar study for the UK. Their study found that an estimated 28,114 t of waste is generated annually by menstrual products from 15,019,716 menstruators (menstruators are here given as 85 % of females of the age 12 – 55 years old in the UK). For comparison purposes we extrapolated this from the UK to the EU-28. Using the same numbers as the authors, we first calculated the annual feminine hygiene waste per female in the UK, which resulted in 1,9 kg. This amount was then multiplied by the number of menstruators given in the EU-28 (which are here given as 80 % of females of the age 12 – 52 years in the EU-28). The result was that the annual amount of waste generated by feminine hygiene products is equal to **196,542 t**.

Discrepancies between the different studies can be explained by the use of assumptions for the parameters, such as the reproductive age, the weight/type of products, the number of products used per year, and the share of females using single-use products. To address this uncertainty the median ±10 % the number of needed products and ±10 % of the weight of the used products were used to calculate the range of the waste generated by feminine hygiene products.

3.3.3 Treatment routes and resulting mass flow

Several knowledge gaps exist on waste treatment of feminine hygiene products in the EU. For example, Anand et al. (2022) state that "at the end of 2021 literature does not provide a reliable and affordable evaluation of the waste generated by menstrual hygiene products [globally]."

[11] The following waste stream was used as basis: "Generation of waste-by-waste category, hazardousness and NACE Rev. 2 activity (env_wasgen)". Data was retrieved on the 01.09.2022 using the following settings:
- Hazard class: non-hazardous waste
- Waste categories: Household and similar wastes
- All NACE activities plus households
- Reference year: 2018

To this end, the following assumptions were made:

- feminine hygiene products are disposed of as part of the non-hazardous fraction of the waste stream “household and similar waste” (see Chapter 3.3.1).
- the treatment routes of this waste stream are representative of treatment routes for the share of feminine hygiene products being disposed of as part of the waste stream.

However, only the relevant treatment routes for the disposal of single-use feminine hygiene products were taken into consideration. Thus, the treatment routes for single-use feminine hygiene products calculated based on Eurostat data include:

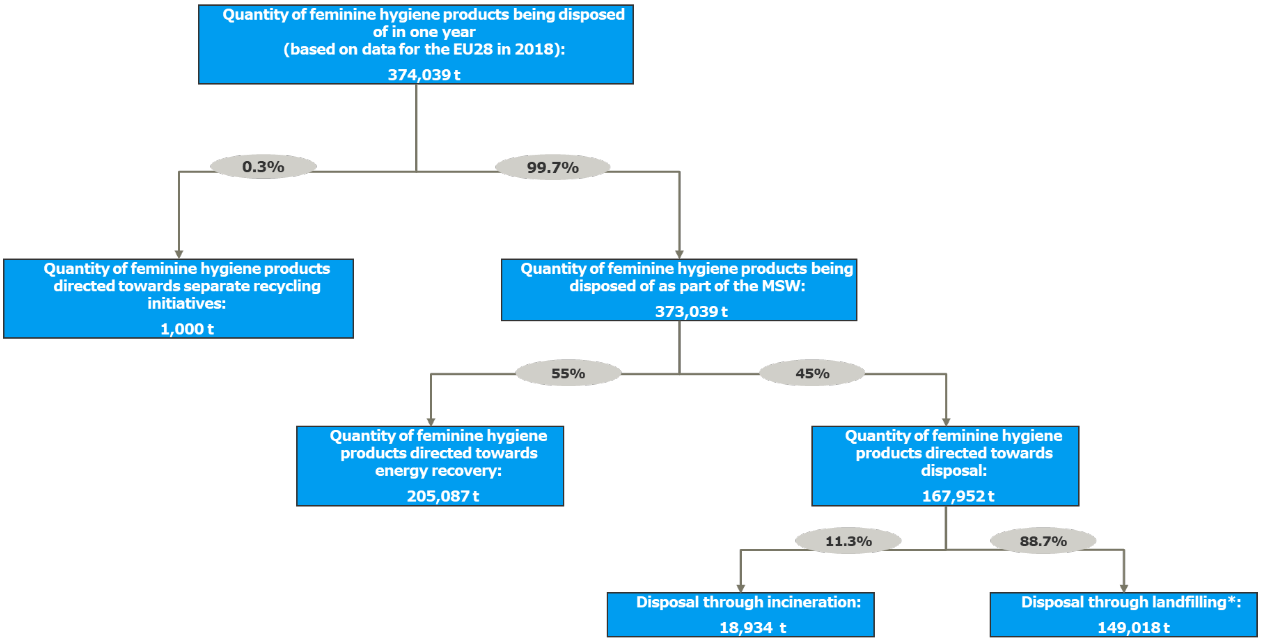
- Recovery – Energy Recovery
- Disposal – Landfilling
- Disposal – Incineration

As regards recycling, our research has shown that recycling of AHP waste takes place only to a very limited extent. Further details on the share of AHP waste recycled can be found in chapter 3.2.3. The respective share of materials directed towards recycling (see chapter 3.2.3) were used for the development of the mass flow.

To generate the mass flow the average of the range of feminine hygiene products waste, shown in Table 13, was calculated at 374,039 t.
As Figure 2 shows, only a very limited share of approximately 0.3 % of feminine hygiene products are recycled. 373,039 t are disposed of as part of the MSW, with a large proportion – equal to 205,087 t – being energetically recovered (ca. 55 %) while a slightly smaller proportion – equal to 167,952 t – is directed towards disposal (45 %). When menstrual hygiene waste is directed towards disposal, landfilling is by far the most relevant treatment method (88.7 % or 149,018 t), while incineration without energy recovery plays a minor role (11.3 % or 18,934 t).

In accordance with our study, UNEP (2021a) found that the “vast majority of [single use-menstrual products] are landfilled or incinerated”. Other authors assume that in Europe 87 % of waste generated by feminine hygiene products ends up in landfills (Arena et al., 2016; Cabrera & Garcia, 2019).

Figure 3: Mass flow - feminine hygiene products (own graphic)



* This includes disposal operations D1, D5, D12

3.4 Incontinence products

3.4.1 Separate collection schemes

Available information on separate collection schemes is addressed in chapter 3.2.1. It should, however, be noted that for the development of the mass flow for incontinence products we assumed that products purchased away from home also result in waste generation away from home, such, as for example in hospitals or retirement homes (business to consumer, b2c). On the other hand, products that are obtained from retailers (b2c) are more likely to be disposed of as part of household waste. Euromonitor based consumption data estimates that the share of adult incontinent products for "away from home" is 45 %, while 55 % are obtained from retail. Considering these different sources of incontinence product waste, different waste streams were used for the quantitative scoping of treatment routes (see chapter 3.4.3).

3.4.2 Waste generation

As outlined above (chapter 3.2.2), there is a lack of data on the generation of incontinence products waste. Thus, to develop a mass flow, the consumption of incontinence products was estimated and used as basis for the waste generation.

The following parameters were calculated, based on available information in various studies and other relevant sources:

- Period during which adults use/need incontinence products
- Frequency of use (i.e., number of incontinence products used per day)
- Share of adults wearing incontinence products
- Weight of incontinence products

Period during which adults use/need incontinence products

The causes of incontinence vary and don't only occur in elderly people, for example disease and pregnancy can also lead to incontinence. However, the severity and form of incontinence (urinary, faecal or both) varies a lot and affects the product selection. The most commonly used incontinence products are liners and slips (UBA Evaluation *2022*, 2022), the data available for these types of products is limited and does not allow for the development of a mass flow. Only a small amount of people suffers from faecal incontinence (1.4 % of the population above 40 years old in the UK), therefore the amount of e.g., anal tampons is low compared to other products (Worldwide Adult Incontinence Products Industry to 2030- Rising Number of People Suffering with Incontinence Is Driving Growth, 2022). Overall, about 9 million people in Germany suffer from incontinence of all types and severity, which is 11 % of the German population (UBA Evaluation, 2022).

Due to the lack of available data calculation only considers adults who require disposable diapers/pads/liners due to urinary incontinence referred to in the following as "incontinence products". Table 14 gives an overview of the share of people suffering from incontinence according to the literature.

Table 14 Number of people suffering from incontinence

Source/reference	Shares and statement
Perez et al.(2021)	35 % of women and 17.5 % of men over 65
UBA Leitfaden (DE) (2022)	about 5 million people in Germany (DE)
Europe National Health Service (NHS) report (UK) (2018)	3 – 6 million people in the UK

By using the information on the number of people wearing incontinence products and the number of citizens living in DE and UK, the share of people wearing incontinence products can be calculated for these countries.

By extrapolating this number to the EU-28, following numbers can be derived (Table 15). Since there is a high variation between the numbers, a minimum and maximum amount of waste generated by incontinence products was estimated based on the range of people suffering from incontinence.

Table 15 Adults which require incontinence products because of urinary incontinence

Source/reference	Adults that require incontinence products due to urinary incontinence
Perez et al. (2021)	27,767,457
UBA Leitfaden (DE) (2022)	30,783,405
Europe National Health Service (NHS) report (UK) (2018)	34,797,724
Euro Carers 2020 4 % of Europe[12]	20,499,285
Median value (adults suffering from urinary incontinence that require a incontinence products)	**29,275,431**

Share of adults wearing disposable incontinence products (incontinence products/disposable diapers)

[12] https://eurocarers.org/Incontinence/

Information on the share of adults wearing disposable incontinence products was not found. However, reusable incontinence products in the form of incontinence panties and pants also exist. Additionally, reusable bed pads can be bought (Washable Incontinence Products, n.d.). These products are mostly designed for mild to moderate incontinence problems and therefore most of the time do not provide an alternative to disposable incontinence products. Thus, a share of 99 % was estimated for adults wearing disposable incontinence products, which in this context is mainly disposable diapers.

Frequency of use

The frequency of use of incontinence products depends on the severity of incontinence. Table 16 provides a list of typical frequency of use of adult diapers per day per person.

Table 16 Frequency of use (incontinence products)

Source/reference	Frequency of use (incontinence products used) per person and per day
Perez et al. (2021)	4.0
UBA (2022)	2.0
Median value (incontinence products used per day and person)	**3.0**

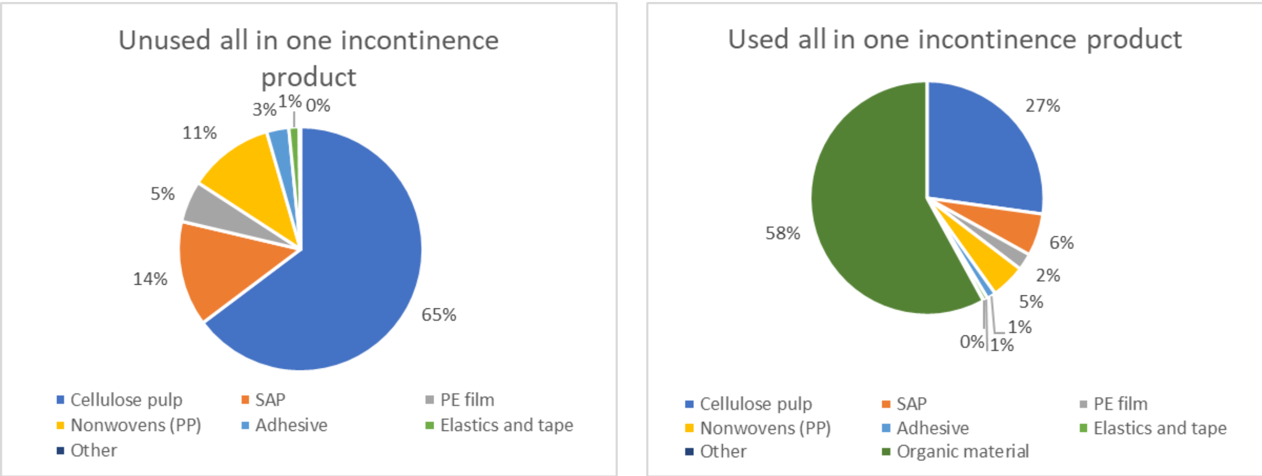
Weight of incontinence products (disposable diapers)

In recent decades incontinence products and diapers have become lighter. This is mainly due to the fact that the amount of SAP, which can absorb multiple times its own weight in liquid, used in the products increased, and other components subsequently decreased. However, the weight of the used incontinence products can vary depending on the type of incontinence and the size of the person using the product (Table 17 and Figure 3).

Table 17: Average all in one incontinence product composition with an empty weight of 109.2 g, light incontinence product 21 g, insert pads 73.6 g (EDANA 2013)

	All in one product	Light incontinence products	Insert pads
component	Weight (g)	Weight (g)	Weight (g)
Cellulose pulp	70.7	13.2	55.1
SAP	15.2	4.5	10.4
Polypropylene	12.4	0.9	2.8
Polyethylene	6.0	1.3	3.6
Adhesives	3.2	0.6	1.4
Elastics	1.5	0.1	0.2
Others	0.2	0.4	0.1
Organic material after use	210		

Figure 4: Share of different components in unused and used incontinence products (own graphic adapted from EDANA 2013)



UBA (2022) states that an unused incontinence product has a weight of 90 – 220 g. However, according to EDANA's LCA & Trend Analysis of Incontinence Products (2013), an unused all-in-one solution (diaper) weighs in average 109 g, one interviewed company stated that an unused heavy incontinence product has an average weight of 83 g (data from 2021). Analysing the weights of different products according to the information shared on producer's websites results in a dry weight range from 40 – 130 g, which goes up to 220 g for heavy incontinence products (Table 18). According to Arena et al. (2016) incontinence products can weigh up to three times as much as an unused one. This assumption was confirmed by EDANA member companies. The current average weight for unused incontinence products is – according to EDANA members – 63 – 65 g. EDANA members have further stated, that used (heavy) incontinence products can weight up to 300 – 330 g. Considering all data found in the literature, the median weight of used disposable diapers is 260 g for both light and heavy incontinence products.

Table 18: Weight of a used adult diaper

Source/reference	Weight of used adult diaper [g]
Perez et al. (2021)	320
Measuring Guide For Adult Diapers 2022[13]	258
UBA (2022)	260
Average value (weight of a used adult incontinence product)	**279**
Median value (weight of a used adult incontinence product)	**260**

Generation of incontinence waste

Based on the parameters described above, the overall consumption of disposable incontinence products per years in the EU-28 was estimated (Table 18). The overall consumption was then used to calculate the overall incontinence product waste generation in the same year. Similar approaches have been carried out in other studies such as NHS European Office, 2018; UBA Evaluation, 2022; Velasco Perez et al., 2021. The waste generation in t was then calculated using a median weight for a used adult diaper product of 260 g. The median was used to compensate for any outliers. Since the numbers of people suffering from incontinence varies greatly according to the literature, a range amount of waste generated by incontinence products was estimated based on the range of people (Table 15 Adults which require

[13] https://www.cwimedical.com/size-chart

incontinence products because of urinary incontinence). This resulted in an overall waste generation of **5,830,310 – 9,897,005 t** of used incontinence products (Table 19).

Table 19 Consumption of adult diapers

Consumption	Value	Unit
total number of incontinence products used per day in the EU-28	61,497,856 – 104,393,172	incontinence products per day
total number of needed incontinence products used in one year	22,446,717,425 – 38,103,507,654	incontinence products per year
total number of disposable incontinence products used in one year	22,424,270,708 – 38,065,404,146	disposable incontinence products per year
total volume of used incontinence products waste produced in the EU-28 in one year (based on disposable products)	**5,830,310 – 9,897,005**	ton

In comparison, the consumption data according to Euromonitor provided a retail source with a number of 5,147,000,000 products (heavy and light incontinence products combined). For away from home another 4,223,400,000 products were assumed. This results in a total of 9,370,500,000 products for 2018 in the EU-28. Using the same weight for a used incontinence product (260 g) the overall amount of waste generated by incontinence products is calculated at **2,436,330 t.**

On the other hand, Velasco Perez et al. (2021) indicated shares of different AHP fractions in MSW in several EU and Non-EU countries. Looking at EU countries, values for incontinency products range between 2.9 % in Ireland and Luxembourg and 7.4 % in Germany. The median share of all EU countries is 5.4 %. Calculating the amount of waste based on this share of the EU-28 MSW in 2018, **8,950,500 t** of incontinence product waste would be generated.

3.4.3 Treatment routes and resulting mass flow

In the absence of specific data on the treatment routes of incontinence products, available data on the waste treatment routes from Eurostat was used for the quantitative scoping. To this end, two relevant waste streams were identified:

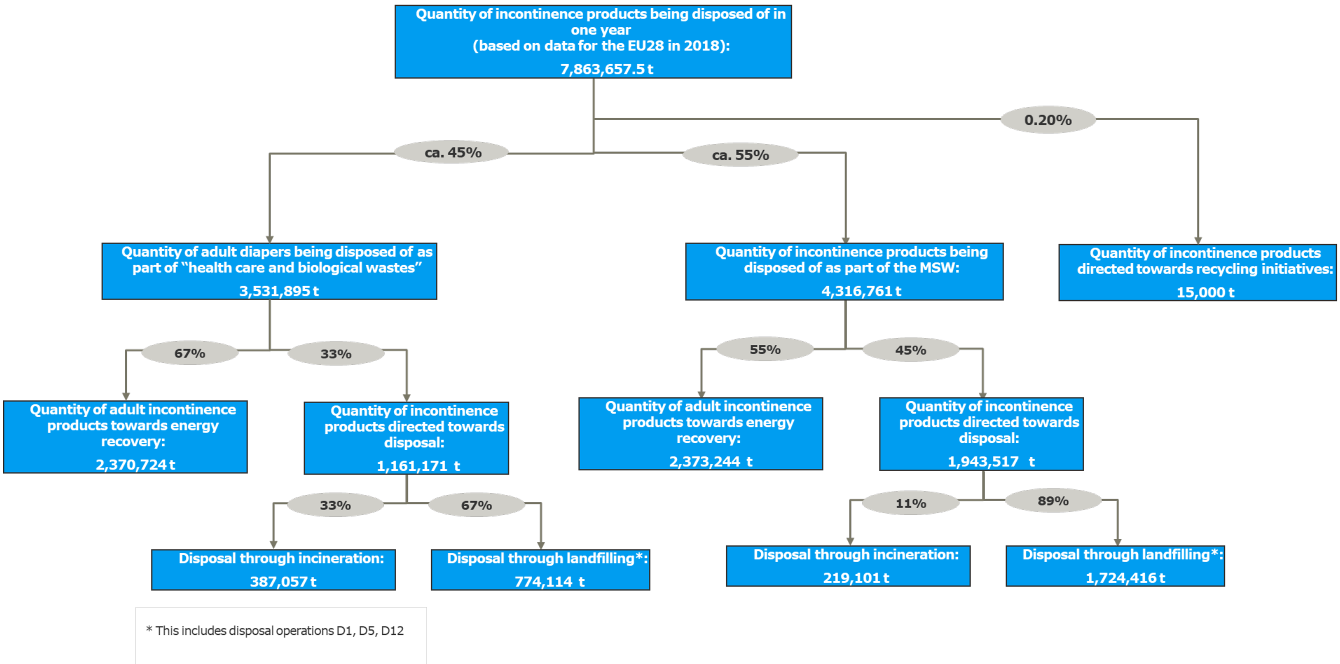
- Household and similar waste: It was assumed that incontinence products are disposed of as part of the non-hazardous fraction of the waste stream “household and similar waste”.
- Non-hazardous fraction of the waste stream “health care and biological wastes”: It was assumed that incontinence product waste from health care institutions (e.g., hospitals) or nursing homes are disposed of as “wastes whose collection and disposal is not subject to special requirements in order to prevent infection” (EWC: 18 01 04). According to Takaya et al. (2019) AHPs, in particular baby diapers and incontinence products, form the main components of this waste stream. Their findings show that 76 % of the contents found in rubbish bags collected from different health care institutions in England was made up of AHPs. Also in Germany, baby diapers from nursing homes or hospitals are part of this waste stream (18 01 04) (Wagner et al., 2022). On Eurostat, this waste stream is part of the non-hazardous fraction of the waste stream “health care and biological wastes”.

Euromonitor's share of incontinence product supply (heavy and light incontinence products) indicates that 45 % of the products are purchased “away from home” and 55 % are obtained from retail. Based on these figures, it was assumed that 45 % of incontinence products are disposed of as part of the waste stream “health care and biological wastes”, while ca. 55 % are disposed of as part of “household and similar waste”.

Overall, it was assumed that the treatment routes of these waste streams are representative for the treatment routes of the share of incontinence products being disposed of as part of these waste streams.

Regarding recycling, the research has shown that recycling of AHP waste takes place only to a very limited extent. Further details on the share of AHP waste recycled can be found in chapter 3.2.3. The respective shares directed towards recycling have been used for the development of the mass flow for incontinence products. For an easier generation of the mass flow the average of the calculated range of waste (7,863,658 t) was used as a reference. The resulting mass flow is shown in Figure 4. It can be concluded that 45 % of incontinence product waste is disposed of as “health care and biological waste” whereas 55 % is disposed of as “municipal solid waste”. 67 % of the health care and biological waste is directed towards energy recovery; the remaining 33 % is directed towards disposal, with the majority of this (67 %) ending up in landfills and 33 % being directed towards incineration. Of the waste disposed of as municipal solid waste, 55 % is directed towards energy recovery and 45 % is disposed of. Again, the majority of this stream ends up in landfills (89 %), while 11 % is incinerated.

Figure 5: Mass flow - incontinence products (own graphic)



3.5 AHP waste total

The following chapter discusses total AHP waste, as the sum of the sub-streams “baby diapers”, “feminine hygiene products” and “incontinence products”. Other specific sub-streams are considered as negligible.

3.5.1 Waste generation

The amount of AHP waste generated was estimated from the previously discussed single sub-streams of AHPs. The sum of the overall amount from each sub-stream (baby diaper, feminine hygiene products and incontinence products) results in the overall amount of AHP waste.

3.5.2 Treatment routes and the resulting mass flow

In order to generate the AHP mass flow, the average amount of waste generated by the different sub-streams was used. Table 20 displays the share of the three product categories in the overall AHPs sector. Incontinence products have the highest share at 61 % of all AHPs, following by baby diapers at 36 %. Feminine hygiene products account for only 3 % of AHPs. Velasco Perez et al. (2021) show similar shares for AHPs waste generated as displayed in Table 20. On the other hand, AHP waste streams calculated using Euromonitor's consumption data from 2018 show a different proportion of baby diapers and incontinence products, but a similar share for feminine hygiene products. The reason for these discrepancies might be due to missing numbers regarding adult diapers/incontinence products in the Euromonitor database.

Table 20: Shares of product sub-streams within the AHP waste total. For comparison purposes the share of Velasco Perez at al. 2020 and Euromonitor for the year 2018 is displayed

Product sub-stream	Ramboll	Perez et al. (2021)	Euromonitor 2018
Baby diapers	36 %	30 %	61 %
Feminine hygiene products	3 %	6 %	6 %
Incontinence products	61 %	64 %	33 %

By summing up the three categories baby diapers, feminine hygiene products and incontinence products, the AHP waste stream was developed (see Figure 6). Using the average amount of waste per sub-stream, Ramboll calculated an overall share of **AHPs in the MSW of 7.8 %** in 2018 based on the EU-28. Baby diapers account for 2.9 %, feminine hygiene products for 0.2 % and incontinence products for 4.7 %. Wet wipes, often wrapped in used baby diapers, were not part of the calculation since the number of used diapers was calculated by multiplying the number of consumed diapers with the average value of a used diapers; thus, the actual mass could be slightly higher.

UNEP (2021b) states, that the average share of AHPs in MSW ranges from 2.9 – 12.4 %, depending on the country. Cabrera & Garcia (2019) state that baby diapers, wet wipes, and feminine hygiene products account for 3 % of the MSW in EU-28 in 2017; incontinence products were not considered in their analysis. Velasco Perez et al. (2021) identified AHPs in MSW in European countries in the range of 4.9 – 11.2 % with an average share of 8.4 %. According to Arena et al. (2016) values range between 2 – 7 % in the USA and Europe, with proportions as high as 15 % in some countries. Furthermore, EMBRACED (2020) argued that since the EU is moving towards the recycling targets, the proportion of AHP waste has increased up to 15 – 25 % of residual waste.

Besides the differences in AHP waste generation per country, data from Germany shows that the quantity of waste from hygiene products (including hygienic paper, baby diapers, incontinence products, etc.) also varies depending on the settlement structure within the country itself (Dornbusch et al., 2020), Table 26, displaying the weight and percentage of the overall amount of AHP waste per specific settlement structure):

- Germany overall: 17.3 kg/habitant*year (13.5 %)
- Germany – rural areas: 15.5 kg/habitant*year (12.4 %)
- Germany – densely populated rural areas: 18.8 kg/habitant*year (17 %)
- Germany – urban areas: 16.9 kg/habitant*year (11.2 %)

According to the literature, AHP waste is normally collected with unsorted residual fractions of MSW and disposed of through incineration or landfilling (Arena et al., 2016).

It was found (Figure 6) that 0.2 % of AHP waste is treated in special initiatives set-up to recycle AHP waste in the EU-28 (UK, the Netherlands and in Italy, see Table 7). The remaining 99.8 % are disposed of as part of the municipal solid waste (ca. 73 %), or in the case of adult diapers coming from hospitals as part of the health care and biological waste (ca. 27 %). Both waste streams, however, are treated similarly in the end. The main part of both waste streams is directed towards energy recovery (55 %). The remaining 45 % of AHP waste is directed towards disposal, which is then split into disposal through incineration and disposal through landfilling. To date, the main part of the disposed AHP waste is discarded through landfilling. In a landfill AHPs need up to 500 years to completely break down.

Figure 6: Overview of the share of baby diapers, feminine hygiene products and adult diapers/incontinence products in AHP (own graphic)

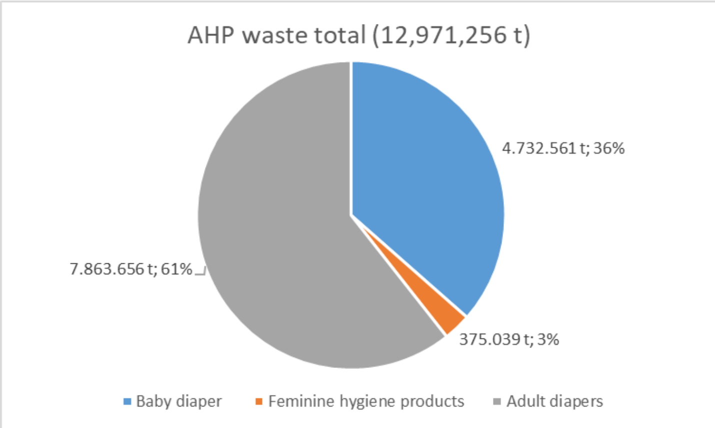
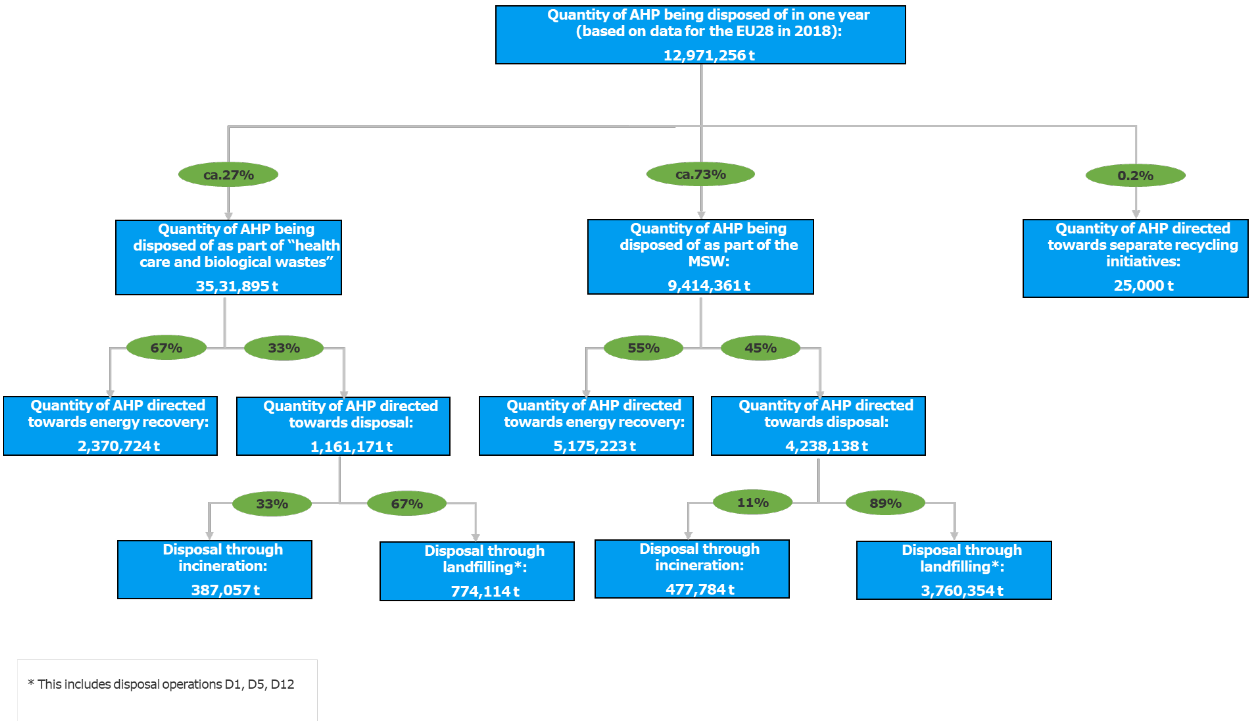


Figure 7: Mass flow – AHP waste total (including baby diapers, feminine hygiene products and adult diapers/incontinence products, own graphic)



4. TECHNOLOGY SCANNING

4.1 Approach

The aim of the technology scanning was to identify and analyse already existing collection systems as well as separation and recycling initiatives/technologies with (potential) relevance for AHP waste.

The data collection for the technology scanning was performed in three steps:
1. Literature research;
2. Interviews with industry and academic experts;
3. Request by e-mail to initiatives and research owners for written input.

The results of the technology scanning were compiled in a data management tool that allows for an overview and compares the AHP collection systems and separation and recycling initiatives and technologies. The data management tool includes four main categories which seem to be relevant to describe a technology holistically:
1. Technical data;
2. Commercial data;
3. Policy and regulatory data;
4. Project data.

Each category contains several sub-aspects that aim to make the researched results comparable with each other. The tool also reflects the fact that technologies are at different stages (e.g., by describing the technological maturity). The data management tool forms the basis for the factsheets that were extracted for the majority of initiatives and technologies (see Annex 1).

4.1.1 Literature research

As a first step of the technology scanning, relevant literature was identified and read. These included:
- Academic and research publications;
- Online commercial information (e.g., websites of recycling companies);
- And other publicly available literature.

It should be noted that the identified information included different levels of technologies such as research projects but also established facilities and different types of aspects (e.g., some focussed on process descriptions, others made comparisons based on LCAs or explained the setup of an experiment).

The respective literature base is included in the factsheets (see Annex 1) and in the present report.

4.1.2 Interviews with experts

In order to ensure that collected data is up to date, complete, and comprehensive, in-depth interviews concerning collection systems and separation and recycling technologies with experts were conducted (Table 21). The selection of the experts was based on extensive research on knowledge centres which have expertise in AHP waste. Out of the knowledge centre list, three experts agreed to be interviewed. The primary aim was to select experts with a holistic view on recycling processes and/or experts who are knowledgeable on relevant technologies.

Additionally, five EDANA members who were involved in AHP collection or recycling projects were consulted. These interviews were also used to discuss AHP waste data (see chapter 3.1) and to collect quantitative data on AHP waste.

The questionnaire for the interviews with the external experts (non-EDANA members) can be found in Annex 2.

Table 21: Interview partners

Interview partners	Interviewed for AHP waste data (see chapter 3.1)	Interviewed for technology scanning (see chapter 4.1.2)
Remondis		x
Holy Grail Initiative 2.0		x
Technische Hochschule Mittelhessen		x
Ontex (EDANA member)		x
P&G (EDANA member)	x	x
Essity (EDANA member)	x	x
Borealis (EDANA member)	x	x
Exxonmobile (EDANA member)	x	x

4.1.3 Development of factsheets

After the compilation of collected data in the data management tool and the conduction of interviews, factsheets for identified initiatives and technologies were prepared. The factsheets are provided in Annex 1.

After preparing the factsheets, the documents were sent out to the respective organisations which were indicated as responsible for the initiatives/technologies. The aim was to gather more in-depth information (e.g., on costs) and to double check the collected data. However, the response rate was very low. Four replies were received.

4.2 Overview on identified AHP collection systems as well as separation and recycling technologies

This chapter aims to give an overview on identified collection systems as well as separation and recycling technologies for AHP waste. Additionally, ideas from the 2021 EDANA hackathon are presented.

4.2.1 Identified initiatives and/or technologies

In total, 42 initiatives and technologies on AHP waste collection, separation and recycling were identified. The following table (Table 22) gives an overview on the identified collection systems and separation and recycling technologies for AHP waste. 11 of the initiatives are supported by one or several EDANA members (P&G, Ontex etc.) whereas two of these initiatives (Embraced and Fater) could be considered as one technology. As displayed in the table, four of the initiatives can be considered a pure collection system whereas 12 include collection, separation and recycling steps. There are 26 technologies/initiatives that focus on separation and recycling and do not consider collection. The table also indicates which initiatives have stopped and which are ongoing. Since several entries relate to research projects or single studies, a definite status cannot be given. More detailed information on each initiative/technology can be found in the respective factsheets in Annex 1.

Table 22: Overview on identified initiatives (see factsheets in Annex 1 for further details on each initiative)

	Initiative/Technology	Involved EDANA members	Status
	Exclusively collection		
1	Clean Green Future		Ongoing – test phase 9.22 – 12.22
2	Medisort		Ongoing
3	Copenhagen Circular		Ongoing
4	Ontex and Woosh	Ontex	Ongoing
	Collection, separation AND recycling		
5	Diaper Recycling Europe (Knowaste Technologies Inc.)		Knowaste has stopped, Diaper Recycling Europe is ongoing
6	Terra Preta (biotechnological approach)		
7	Nappicycle		
8	Envirocomp composting plant' in Rochester		Seems to have stopped
9	DiaperRecycle		
10	Soil Moisture retainer		
11	INKOCYCLE (THM)		Finished but are willing to restart
12	Exxtend technology (by Exxonmobil)[14]	Exxonmobil	Ongoing
13	University of Michigan	P&G	
14	Renewi Joins Forces with Essity on Nappy Recycling in Netherlands	Essity	Ongoing
15	Bioethanol production		Published in 2018
16	Unicharm/Oxidation with ozone	Unicharm	Unclear if ongoing
	Separation and recycling		
17	ARN BV (collaboration with: Elsinga Policy Planning & Innovation)		Ongoing
18	REFIBRA		Ongoing
19	Super Faith Inc. SFD Systgem Super Faiths Inc.		
20	Mushroom cultivation nutrients		
21	Birzitek		Ongoing
22	Pyrolytic diapers as a soil amendment for agricultural purposes		
23	Energy recovery (Indian Research)		
24	Anode materials for lithium-ion batteries		Published in 2018
25	Austrian Centre of Industrial Biotechnology (acib)		Stopped
26	Separation of cellulose and plastics (BTU)		Patent published in 2013
27	Microwave pyrolysis	P&G	
28	Chung Hua University and Multiply Energy Co.		
29	Hydrothermal carbonization		Published in 2019
30	Bio-hydrogen generation		
31	Diaper Recycling technology (Singapore)		
32	Synthesis of glycerol carbonate using diaper waste		Published in 2020
33	PyroPure		

[14] As example for chemical recycling. Other industry initiatives on chemical recycling are ongoing.

34	Devolatilization in a Bubbling Fluidized Bed		
35	Bisphenol degrading		
36	Concrete viscosity modifying admixture		
37	EMBRACED[15]	P&G	Stopped
38	Pampers nuovavita = FATERSMART	P&G	Stopped, one Fater plant remaining in Italy
39	Ontex Les Alchimist compostability of diapers	Ontex	2021 – 2022
40	Nippon Shokubai, LiveDo Corporation and Total Care System	Nippon Shokubai	Ongoing
41	ZUIKO foundation (no factsheet available)		Ongoing
42	Recyc PHP (no factsheet available)		Ongoing

The last two initiatives (41 and 42) were added to the research results at a later stage and are therefore not represented in a factsheet or included in the multi-criteria analysis (see chapter 5). Instead, the following boxes aim to give a short overview on ZUIKO foundation and Recyc PHP. It should be considered that the Recyc PHP technology is based on post-industrial waste (unused AHPs) and therefore cannot necessarily be transferred to post-consumer waste (used AHPs).

ZUIKO foundation[16]
ZUIKO foundation is an AHP producer that was founded in 1946 in Japan and obtained its first patent in 1980. It collects used diapers in sealed bags and shreds, ferments, dries and sterilizes them to produce residue derived fuel (RDF) fluff for pelletizing. The pellets can be used as fuel for biomass boilers. The machine can process a maximum of 600 kg of waste per day. The number of produced pellets can provide 980 m³ of space with heat. During this process 86 kWh/day of electricity as well as 30 – 40 m³/day of gas (LPG) are used.

Recyc PHP[17]
Recyc PHP is a Canadian company that mechanically separates post-industrial hygiene products. It produces polyacrylate-free fluff pulp (FCB-M85PNS), first grade fluff pulp with sodium polyacrylate (FCB-M85P), and sodium polyacrylate (SAG-A06P or SAG-B06P), whilst faeces and water are sent to a composter. The procedure was first set up in 2006 and processes 3500 MT per year, with a recycling rate of 99.5 %. The operation will be carbon neutral starting in 2023.

4.2.2 Compilation of EDANA Hackathon ideas

Table 23 presents a summary of all ideas of a hackathon EDANA conducted in 2021. Students were invited to develop solutions for AHP waste collection and recycling. The hackathon ideas were not transformed into a factsheet since they do not present a whole technology or system. However, it is worth considering the ideas presented below.

Table 23: Hackathon ideas[18]

Name	Description	Challenges
Team 1 – IDExperts	A created app with games allows people to locate waste bins and sort used diapers. After playing the game, people can get discounts on their next purchase. Recycle process via microwave pyrolysis to create syngas, liquid oil and solid char/bio char.	The technology and cost for industrial plants to do microwave pyrolysis is not defined.

[15] The EMBRACED project has finished. Parts of the project cannot be extracted for a pilot as information cannot be accessed due to confidentiality.
[16] https://www.zuiko.co.jp/en/machine/diaper_recycle/
[17] https://recycphp.com/en/p/solutions-en/production-of-baby-diapers-with-reclaimed-materials/
[18] https://www.edana.org/how-we-take-action/edana-sustainability-initiatives/Hackathon-Circular-Diaper

Team 2 – Di-cycle	Cellulose from diapers is used as an insulation building material. The diaper waste is first collected in smart bins in communities and then transported to a certain location for further sterilisation and dehydration. The processed diapers are assembled in insulation panels.	The technology and cost for sterilization and dehydration of used diapers are not mentioned.
Team 3 – Grappies	The collection of used diapers is based on reverse vending machines (RVM) in supermarkets, kindergartens, pharmacies and hospitals. The sanitary products are disposed in hygienic and smell-proof bags which is recognized by RVM. Customers receive discounts for their next purchase. Both reusable and recyclable diapers can be recycled under this condition.	The technology and cost for excess material recovery is not defined.
Team 4 – Go Green	Soiled diapers are collected both at supermarkets and local councils. Customers scan a QR code and get 2 % discount on their next purchase. After breaking, shortening of absorbent polymer chains and the use of a solvent, PE, Cellulose and SAP are recycled as adhesive polymers.	The technology and cost for the recovery of SAP are not defined. For the conversion from absorbent polymers to adhesive polymers a lot of water and solvent will be used. The disposal of these solvents is a huge problem.
Team 5 – ForLifers	Smart bins are used for the collection of used diapers. With the help of Blockchain, individual items through the recycling supply chain can be tracked. Recovered cellulose is used as molded pulp packing.	The technology and cost for the recovery of cellulose are not defined.
Team 6 – ARPASEL	A smart app indicates the location of the smart bin. It also shows whether the bin is full or ready to collect the diapers. The recovered SAP are used in roofing to reduce fire hazards.	The technology and cost for recovering SAP and the conversion of SAP to roofing material are not defined.
Team 7 – FLOSS	Waste diapers at nurseries are collected and processed by shredding machines. The shredded diapers are fed to algaes and bacteria, which will be converted to bioplastic and biofuel. Two alternative solutions: Pleurotus ostreatus fungi can degrade 90 % of the mass and volume of diapers in 70 days. The fungi are edible and can be used to extract proteins and other nutrients. BioHydrogen can be obtained from diapers, based on the solid substrate anaerobic hydrogen fermentation with intermittent venting and headspace flushing.	The technology and cost for algae and bacteria harvesting equipment are not defined.
Team 8 – Eins, Zwei, Dry	The recovery of diapers is included in a subscription model. Used diapers are collected when new diapers are delivered either by a partner company or the diaper company. The used diapers are classified into diaper waste and organic waste. They can be further processed to non-woven fabrics, cellulose and bioplastics, which have different applications.	The technology and cost for recycling process of used diapers are not defined.
Team 9 – Koala	The recovery of diapers is included in a subscription model. The service includes the delivery of new diapers and the recovery of used diapers. The nutrients extracted from diaper waste can be utilized to cultivate plants. The other materials from the used diapers like plastic, cellulose and super absorbent materials are repurposed into making products for trees, such as tree wraps, fruit protection bags and tree bandages. One tree will be planted from every 100 recycled diapers.	The technology and cost for conversion of used diapers to plastics, cellulose and super absorbent materials and their further applications are not defined.
Team 10 – ASAP	The used diapers are first collected. Super absorbent polymer (SAP) is separated from the rest of the used diapers, which can be resold. After the deactivation and sterilization of SAP, it will be put in sandbags for flood management use. Recovered PP and PE can be chemically recycled.	The technology and the cost for separating SAP from the rest of used diapers are not defined.

4.3 Main findings of technology scanning and interviews

4.3.1 General findings of technology scanning

The technology scanning revealed that AHP waste collection, separation and recycling is subject to examination in several countries. Research studies and existing plants were identified from/in different European countries (such as Netherlands, Germany, Spain, Austria, UK, Italy), in Japan, China, India, Taiwan, Mexico and Australia.

The following observations were made from the scanning of collection schemes:

- Several collection systems focus on AHP waste from households, but collection from elderly nursing facilities/care homes, childcare nurseries/day-care centres and hospitals was also investigated.
- Not all research studies and collection schemes cover all AHP waste (diapers, incontinence products, feminine hygiene products). Some focus on specific parts of this waste stream, e.g., only children's diapers, only diapers with urine, only diapers and incontinence material but no feminine hygiene products, only unused diapers etc. Diapers seem to get the most attention (more than feminine hygiene products). Although some studies focus on specific inputs, this does not mean that a process is only suitable for these inputs. However, to test all AHP waste as input waste, further experiments would need to be conducted.
- Many initiatives try to combine collection systems with recycling processes. This makes sense since a successful recycling process depends on reliable quantities of input waste.
- To make collection economically viable, the initiatives evaluated different business models. A very common approach is to deliver empty bags (e.g., 60 litre sacks) to customers which they can fill with used diapers. The filled sacks get collected again by the provider (e.g., once a week). In some regions consumers are asked to register for this kind of diaper collection system and to pay monthly fees or a pre-paid tariff. In other regions the collection is free of charge. Bring systems (as is known, for example, from waste glass) do not seem to be common for AHP waste collection.

With regard to separation and recycling, the following observations were made:

- Most initiatives and technologies consider separation and recycling together, as they are closely connected.
- Some technologies entail a specific separation step to gain different waste fractions (e.g., cellulose gets separated from plastic), whereas others treat the AHP waste as a whole (e.g., pyrolysis of diapers).
- The AHP waste technologies that are currently researched are very diverse and entail mechanical and chemical recycling as well as biological processes.
- Several research studies have a strong output focus, i.e., they especially examine the recyclate use instead of developing a whole recycling process (e.g., research if output of some AHP waste streams can be used as input material for sticky notes or research on how to turn diaper waste into nutrients to grow mushrooms).
- In contrast to conventional recycling processes where plastic is turned into pellets, flakes or thick-walled applications, the AHP technology scanning revealed that more creative solutions are examined (e.g., using SAP recyclate in batteries). This probably shows that this type of recycling is much more difficult, and that more out-of-the-box solutions may be required.

Despite intensive research and enquiries with initiative owners, it was difficult to obtain commercial information about the various initiatives/technologies.

As recycling is not an end in itself but should contribute to sustainability, several technologies have conducted LCAs to prove their contribution to environmental protection and sustainable goals. The boxes below summarize the LCA results for the two well-known AHP recycling technologies by ARN BV and Fater:

ARN BV– LCA results
In contrast to waste incineration, the process of the ARN BV facility has positive environmental impacts on human health, ecosystems and raw materials. The plastics are recycled and agricultural nutrients are obtained from excreta. Cellulose and SAP are converted to biogas, and thereafter energy. There is a lower electricity consumption of the process because it is mainly chemically driven. Moreover, the production of biogas supplies its own heat during this process.[19] The energy source in the TPH process is steam that originates from waste incineration instead of traditional fossil energy sources, which results in 899 kg of avoided CO_2 emissions per ton of diapers and 70 % less CO_2 emissions than gas-powered steam generation. Another study shows that this process saves 480 kg CO_2eq per ton compared to energy recovery[20]. When fossil plastics in the diapers are replaced by biobased PLA, the avoided CO_2 can rise from 899 kg CO_2 per ton of diaper waste to 1,236 kg CO_2 per ton of diaper waste. Due to the high pressure and temperature in the process, drug residue and pathogen requirements can be met without the use of chemicals.

Fater – LCA results
The autoclavic treatment used in the Fater plant allowed for the sterilisation, decomposition and drying of AHP. Therefore, a large portion of the energy use in the Fater technology is electricity. According to the report[21] by SGS research, using electricity directly from a waste incineration plant would reduce the risk of global warming and CO_2 emissions. Moreover, in order to recover cellulose and SAP, water needs to be removed by evaporation, which is a very energy intensive process. However, in total, the Fater process generates a positive balance of 15 kg CO_2 per ton. This is also due to the savings realised from recycling: 1 ton of recycled waste leads to the recovery of 150 kg cellulose, 75 kg plastic and 75 kg SAP.[22] The secondary plastic can be used in new manufacturing like street furniture or industrial packaging. Other fractions can be used as fertiliser and return nutrients to soils. The operators state that if the system were active worldwide, 9 million metric tons of CO_2 emissions could be saved yearly.[23]

4.3.2 Lessons learned from expert interviews: Challenges and possible solutions

The conducted interviews gave insights in challenges that occur around AHP waste collection, separation, and recycling. Possible solutions and ideas to tackle these challenges were also reported.

Collection

To access AHP waste, two methods were primarily discussed:

1. Installation of a separate collection system;
2. Sorting out of AHP waste from existing mixed waste streams (e.g., sorting out of residual municipal waste stream).

1. Separate collection:

In the majority of EU Member States, there is no obligation for the separate collection of AHPs from households nor from commercial waste from the health care sector. However, according to interview partners, many countries offer separate collection of diapers, e.g., to keep the organic waste bin clean as numerous consumers throw used diapers in the organic bin in the misbelief that diapers are biodegradable. Where this is not done, AHP waste is collected with mixed municipal waste or other commercial waste (e.g., medical waste). To recycle AHP waste a separate waste stream, which can be generated via separate collection schemes, is key. As separate collection generates additional costs as of today, there need to be incentives for the relevant actors (e.g., producers) to offer separate collection schemes for AHP waste. In consequence, a recycling process must be profitable (e.g., by selling high

[19] Microsoft Word - 2021 02 24 Vergelijkende mLCA luier afvalverwerking - Herzien.docx (vanluiernaargrondstof.nl)
[20] Evaluation der Erfassung und Verwertung ausgewählter Abfallströme zur Fortentwicklung der Kreislaufwirtschaft (umweltbundesamt.de)
[21] Microsoft Word - 2021 02 24 Vergelijkende mLCA luier afvalverwerking - Herzien.docx (vanluiernaargrondstof.nl)
[22] Pampers Nuova vita a Verona | Fater (fatergroup.com)
[23] Fater SMART - Diaper Recycling | Interreg Europe - Sharing solutions for better policy

quality recyclates) to cover additional collection costs. One interview partner concluded that separate collection itself is not the challenge, but rather to develop recycling processes that are able to generate high quality recyclates to finance the additional costs of collection. Another interview partner concluded that a recycling facility should be close to the location of separate collection to avoid expansive transport costs. When comparing a AHP recycling process with current incinerations costs, these additional collection costs for the recycling process must be factored in.

The present report focuses on diapers, feminine hygiene products and incontinence products. However, interview partners pointed out that a separate collection system that considers these three product categories as one waste stream might cause problems for downstream recycling processes as the material composition of the various AHP products are very diverse. A separate collection scheme for each of these products might be more effective for recycling.

Interview partners reported that in general, municipalities are interested in recycling solutions for AHPs and are open to separate collection of AHPs to enable recycling. However, the challenge of financing the system remains (see above). Municipalities especially are very strict when an additional separate collection system leads to changes in the municipal fee budget.

Interview partners also highlighted that waste collection and waste legislation differ per country and therefore different solutions for AHP waste collection might be appropriate for different countries. Moreover, waste shipment between countries is a challenge and should be considered when setting up a collection system. The separate collection of incontinence products from hospitals is in general a bigger challenge as they might contain contaminated waste. Further legal details and related challenges will be presented in chapter 5. Additionally, it should be considered that the efficiency of a separate collection scheme depends on the population density as the costs for logistics are linked to the number of users in a geographic area.

Different solutions are not only required for different countries but there might also be the need to apply different business models to households and commercial clients. Since commercial actors (e.g., hospitals) require contracts with waste management companies for waste collection, separate collection schemes can be installed in another way than for households. In addition, commercial institutions generate AHP waste continuously, while households generate consistently higher volumes of AHP waste only at certain times of life (e.g., when children are between 0 and 3 years old).

As described in earlier sections, separate collection systems have already been tested in some regions. However, a large part of the separately collected AHP waste is still sent to incineration. One interview partner reported that he feels there is a chicken-and-egg problem with AHP recycling: should one start with setting up a separate collection system or with a proper recycling process first?

Another interview partner mentioned that discussions around obligatory Extended Producer Responsibility (EPR) schemes and recycled content rates for AHP waste are ongoing. He emphasized that AHP producers should work together and exchange experiences and data to tackle AHP waste collection and recycling. Another stakeholder agreed that an appropriate financial system is key to start successful AHP waste recycling as the biggest challenge seems to be financial rather than technical. However, the stakeholder did not agree that EPR was a solution.

2. Sorting of AHP waste out of existing waste streams (e.g., sort out of mixed municipal waste stream, sort out of medical waste streams):

The current discussion around the emission trade for incineration plants might bring some movement in separate collection ambitions as it will set incentives to sort out plastics from household waste to save

CO_2 emissions. If incineration plants become part of the emission trade, pre-sorting of household waste might become more common and thus facilitating the sorting out of AHPs as well. An example of Oslo shows how pre-sorting of mixed household waste could work: Customers are delivered with different coloured bags that should be filled with different types of waste. The facility in Oslo then has a pre-sorting unit that sorts the different coloured bags. A similar process, called Optimo[24], gets applied in Limburg, Belgium. Equivalently, one could try to implement a coloured bag including AHP waste in Germany, which could be shot out of the household waste mixture with NIR (Near InfraRed) sensors and compressed air. However, with regard to the heavy weight of full AHP waste bags, automatic separation (e.g., using NIR technology and compressed air) seems difficult. In addition, an accompanying awareness campaign would be a prerequisite for such a system to avoid households disposing of waste other than AHP waste in the coloured bags. In Germany a system using different bags seems to be difficult, as much of the household waste is loose in the bin and not in a bag. Nevertheless, it might be worthwhile to follow up on this solution. When thinking about sorting out AHP waste from commercial waste, it should be considered that there are many legal challenges with medical waste, as syringes, for example, can be collected in the same waste stream. Therefore, it is not possible to put this type of waste into a mechanical (pre-)sorting facility where many people work manually.

Another interview with the Holy Grail 2.0. initiative gave insights in the water mark technology (see box below for more details) that is about to evolve to sort difficult-to-sort waste. The Holy Grail 2.0 initiative aims to print a specific water mark on products to make them uniquely identifiable. However, for AHP waste such a water mark might be difficult to use because the high-resolution print would have to be applied to all sides, which is not possible in the hygiene sector. If only individual smooth surfaces of diapers were printed (e.g., adhesive fastener) and not the entire surface of the diaper, it could happen that the only printed area is covered during waste sorting and no sorting can take place. Moreover, diaper material is probably too soft to print on. As an alternative, a watermark could be included in the printed diaper foil. Another interview partner confirmed that the system of Holy Grail 2.0. could allow to sort single diapers (instead of full bags) but will not be economically viable if household waste gets only sorted for AHPs. If in the future, other waste gets sorted out of household waste (e.g., to allow more chemical recycling and to reduce CO_2 emissions from incineration plants) the economic situation could change. However, it should be considered that AHPs coming from a mixed collection with household waste will show increased dirtiness and contamination. Cellulose especially might suffer from contamination which leads to recyclates with lower quality and lower benefits. In separate collection systems this is less of a challenge.

Holy Grail 2.0 – Water mark to individually sign products
The Holy Grail 2.0 initiative uses a software to imprint small dots into a print design of a packaging. The dots contain a string of numbers which can be read by another software and works thus as a product passport. The string of numbers includes any information about recycling, additional information for end consumers (e.g., access via smartphone) or even the supermarket checkout. If the watermark is used for recycling, cameras in sorting plants can read the dots and recognise additional information about the product such as the material. While different types of plastic are already recognised and separated with NIR technology today, Holy Grail watermarks can be used, for example, to recognise whether a package comes from the food sector or not. The imprinted dots are so small, that they are invisible to the human eye and do not disturb the layout of the packaging even when evenly distributed over the whole design. The homogenous distribution of the dots is important since the dots must be readable regardless of how the packaging lies in the end on the belt of the sorting plant. A further advantage of this technique is that the watermark consists of embossed dots and no pollutant is added to the packaging or the product. Furthermore, the dots can be printed to all materials, regardless of colour, if the surface to be printed is smooth enough.

Separation and recycling

[24] Movie on Optimo process: https://www.limburg.net/nieuws/optimo-sorteerinstallatie-verwerkt-elke-dag-330-ton-afval

According to an interview partner, one of the main challenges of AHP recycling is the mix of different polymers. Due to the different polymers, it is difficult to generate pure materials which is the precondition for high quality recyclates. Currently, a considerable amount of AHP polymer recyclates ends up in think-walled objects (“downcycling”) generating less revenue. In addition, the fraction of a diaper that would be suitable for recycling (i.e., polymers) is much smaller than the organic fraction. An interview partner estimates that a used diaper consists of 30 % recyclables and 70 % organics which is also reflected in chapter 2.2.3 and 2.4.3. In consequence, 70 % will not generate considerable revenue. Other stakeholders mentioned that not only the polymer mix, but also pharmaceuticals contained in the organic fraction and the mix of organics and plastics is a challenge.

As another challenge mentioned is the difficult-to-treat super absorbent polymer (SAP). Some initiatives try to use SAP as soil improvement. According to a report from Technische Hochschule Mittelhessen (THM) on the INKOCYCLE technology (Theilen et al., 2016), this is not recommended because it is inefficient and might cause microplastic contamination. Moreover, SAP is at risk to end up in the process water. When setting up an AHP waste recycling process it should be taken into account whether the process water must be treated as industrial water. One stakeholder explained that studies which aim to examine the decomposability and biodegradability of different SAP types (e.g., sodium polyacrylates and other polyacrylates) are ongoing.

To create an economically viable recycling process a regular and large enough input stream and a sellable and valuable output material is required. However, these aspects (among others) are still major challenges for AHP waste recycling processes. In general, material separation and recycling of AHPs are still challenging. Incomplete separation leads to unstable new products and the quality of the recycled materials needs to be improved in order to use the regained secondary materials in new AHPs again. Furthermore, the interview partners pointed out that it should be taken into account that users usually roll up used diapers and stick them together. Cleaning wipes are often placed in the diaper and rolled up as well. The mixing of different products makes separation of materials and their recycling more complicated.

Moreover, most AHP recycling processes require high energy to ensure sterilisation of the waste. Interview partners also explained that AHP recycling is still a high business risk as it depends, for example, on governmental acceptance. Odour nuisances are considered a smaller challenge. However, they should always be considered when planning a recycling plant (e.g., in the approval phase). To remove odour from recyclates, specific technologies can be used (e.g., thermal treatment). However, such treatment is currently only economically feasible for high quality recyclates and not for mixed plastics due to additional costs.

Possible solutions proposed by the interview partners

Each of the identified technologies and initiatives within the technology scanning tries to find a solution to the listed challenges. A more detailed assessment of the potential of these initiatives is presented in chapter 6. According to one interview partner, the technologies used by ARN B.V., Fater and Nappicycle are the most advanced ones. According to an expert from TU Delft, the idea of using algae for environmental solutions is a no-go as it requires too much land or is too expensive. Unfortunately, an interview with this expert was not possible.

The views of the interview partners on possible solutions to tackle AHP waste are listed below:

- Re-design of AHPs is one solution to make these products fit for recycling. For example, compostable diapers can be a solution. However, common composting plants have too short composting times to allow full composting, i.e., specific AHP waste treatment plants are also needed for this approach. Since the present report does not focus on re-design, this solution will not be further considered.

- One stakeholder believes that research on AHP recycling should continue as many options are not yet looked at. Moreover, interests and external pressure have changed over time allowing new recycling options.
- In the interviews it was also raised that one of the biggest levers could be to investigate the type of recyclate and the potential buyers. It is important to know which company will buy which recyclate and to what extent. To get realistic offers, a sufficiently large amount of recyclate has to be sent to the potential customers. To find a suitable recycling solution, it is therefore necessary to think "from the back/the end". The current technology scanning showed that several research projects already follow this approach and do research on possible output fractions and suitable recyclates.
- The interviewees explained that chemical recycling can be a solution. Chemical recycling is considered very expensive, but on the other hand, it could provide valuable results to offset the higher costs. It has to be noted that chemical recycling also needs pre-sorted waste streams, i.e., separate collection might be needed as well.

5. LEGISLATION

5.1 Introduction

This chapter assesses the main regulatory aspects and points of attention concerning circular economy initiatives for AHP. As most of such initiatives concern the collection and recycling of different fractions of AHP waste, the activities of EDANA members and their contracted partners will most likely fall under the scope of EU waste management law. As such, the biggest part of this chapter concerns the most relevant aspects of this legal framework. However, as recycling aims to produce secondary raw materials which can be placed on the market, EU chemicals and product law may also be relevant (especially in the context of end-of-waste status).

This chapter mainly focuses on relevant current and near-future regulatory obligations which are likely to apply to AHP recycling operations. However, where relevant, regulatory developments on Member State level will be highlighted to ensure that important potential bottlenecks on Member State-level are taken into account.

Finally, this chapter also highlights a number of EU funding and subsidy opportunities which may benefit AHP recycling initiatives.

5.2 Classification of AHP waste

A first step to determine the applicable regulatory framework is the classification of the AHP waste in accordance with the methodology laid down in Commission Decision 2014/955/EU on the EU List of Waste (**hereafter:** LoW).[25] In certain cases, classification will have been carried out by the generator of the waste. An example of this would be health institutions which generate AHP waste with potential pathogenic risks. However, in other cases (e.g., households of after separation steps), classification will have to be conducted by the waste management company.

Classification of waste has two aims:

- The assigning of a waste code indicating the origin and composition of the waste; and
- The determination of the hazardous or non-hazardous status of the waste.

In terms of codes, the LoW contains chapters and sub-chapters based on the origin of specific waste streams. To determine the applicable code, the holder of the AHP waste will have to match its origin with one indicated under a chapter and sub-chapter, after which the composition of the AHP waste will be matched with the more detailed code under the sub-chapter. Most relevant chapters and sub-chapters for AHP waste are listed in Table 24.

Table 24: Most relevant chapters and sub-chapters from the LoW addressing AHP waste

Chapter	Sub-chapter(s)	Code(s)
Chapter 18: Wastes from human or animal health care and/or related research (except kitchen and restaurant wastes not arising from immediate health care)	18 01: wastes from natal care, diagnosis, treatment or prevention of disease in humans	18 01 03*: wastes whose collection and disposal is subject to special requirements in order to prevent infection
		18 01 04: wastes whose collection and disposal is not subject to special requirements in order to prevent infection (for example dressings, plaster casts, linen, disposable clothing, **diapers**)

[25] See: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32014D0955

Chapter 19: Wastes from waste management facilities, off-site waste water treatment plants and the preparation of water intended for human consumption and water for industrial use	19 12: wastes from the mechanical treatment of waste (for example **sorting**, crushing, compacting, pelletising) not otherwise specified	19 12 11*: other wastes (including mixtures of materials) from mechanical treatment of waste containing hazardous substances
		19 12 12: other wastes (including mixtures of materials) from mechanical treatment of wastes other than those mentioned in 19 12 11
Chapter 20: Municipal wastes (household waste and similar commercial, industrial and institutional wastes) including separately collected fractions	20 01: separately collected fractions (except 15 01)	20 01 99: other fractions not otherwise specified
	20 03: other municipal wastes	20 03 01: mixed municipal waste

In terms of the determination of the hazardous or non-hazardous status of the waste, the LoW provides two complementary systems. Firstly, waste containing any of the following substances in a concentration exceeding the concentration limits indicated in Annex IV to Regulation (EU) 2019/1021 on persistent organic pollutants (POPs) regulation will be automatically considered hazardous:

- polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDD/PCDF);
- DDT (1,1,1-trichloro-2,2-bis (4-chlorophenyl)ethane);
- Chlordane;
- hexachlorocyclohexanes (including lindane);
- dieldrin;
- endrin;
- heptachlor;
- hexaclorobenzene;
- chlordecone;
- aldrine;
- pentachlorobenzene;
- mirex;
- toxaphene hexabromobiphenyl; and
- PCB (polychlorinated biphenyls).

Secondly, waste which does not contain the substances listed above will be classified on the basis of the asterisk system. This system is based on three types of code-entries in the LoW:

- Absolute hazardous entries (indicated with an asterisk *);
- Absolute non-hazardous entries (no asterisk); and
- Mirror entries (two identically described codes, of which one has an asterisk and one does not).

With regard to the mirror entries, the methodology provided in the LoW states the following:

"An entry in the harmonised list of wastes marked as hazardous, having a specific or general reference to 'hazardous substances', is only appropriate to a waste when that waste contains relevant hazardous substances that cause the waste to display one or more of the hazardous properties HP 1 to HP 8 and/or HP 10 to HP 15 as listed in Annex III to Directive 2008/98/EC. The assessment of the hazardous property HP 9 'infectious' shall be made according to relevant legislation or reference documents in the Member States."

And

"A hazardous property can be assessed by using the concentration of substances in the waste as specified in Annex III to Directive 2008/98/EC or, unless otherwise specified in Regulation (EC) No

1272/2008, by performing a test in accordance with Regulation (EC) No 440/2008 or other internationally recognised test methods and guidelines, taking into account Article 7 of Regulation (EC) No 1272/2008 as regards animal and human testing."

It is important to note that Member States are allowed to apply a stricter classification system. As such, it is recommended to always assess whether any stricter or differing systems apply in the Member State in question.

Based on the system of the EU LoW, a number of preliminary indications concerning the potentially relevant classification of AHP waste can be highlighted.

For AHP waste generated in health care facilities, it is assumed that diapers and incontinence material will be classified with the code 18 01 04 which refers explicitly to "diapers" as an example of wastes whose collection and disposal is not subject to special requirements in order to prevent infection. However, it should be noted that this reference concerns a non-binding example. It may be necessary to classify AHP waste generated in health care facilities under the code 18 01 03* if the collection and disposal of such waste is subject to special requirements in order to prevent infection. This could, for example, be the case for AHP waste originating from certain parts of the health care facilities with higher risks of infections.

For AHP waste generated in households or similar commercial, industrial and institutional sources, the most likely codes to be assigned concern absolute non-hazardous entries, regardless of whether the AHP waste is collected separately or mixed with other waste fractions.

Point of attention concerning potential hazardous substances in AHP waste
Various sources highlight potential contamination of AHP waste, most notably diapers, with potentially hazardous substances such as pathogens and medicine residues (C. Takaya et al., 2020). In addition, certain actors have raised their concerns concerning the unintentional occurrence of other hazardous substances such as PCBs or PAHs in AHPs (ANSES, 2018). As such, it will be relevant for EDANA and its members to assess the merit of such concerns and carefully identify which substances may be contained in which AHP waste streams. Data on the matter will enable accurate classification of AHP waste and this compliance with relevant regulatory obligations on the management and recycling of such waste.

5.3 Shipments of AHP waste

AHP recycling initiatives may involve the shipment of collected and separated AHP waste across the borders of EU Member States. The reasons for this could be, e.g., the location of recycling facilities or the need to accumulate a sufficient volume of material to ensure economic and technical feasibility of recycling operations. The transboundary shipment of AHP waste across EU Member State borders (and also to third non-EU countries) will trigger obligations under EU Regulation (EC) No 1013/2006 on shipments of waste (Waste Shipment Regulation, **hereafter:** WSR).[26]

The main obligations under the WSR are the prior notification and green list procedures. Whether the shipment of a specific waste is subject to one of these procedures depends on whether it is listed in one of the Annexes to the WSR or whether it fulfils one of the additional criteria set out in Article 3 of the WSR. The following table (Table 25) provides a general overview.

Table 25: Prior notification procedure and green list procedure

Prior notification procedure	Green list procedure

[26] See: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A02006R1013-20210111

i. wastes destined for disposal; ii. wastes listed in Annex IV, which include, inter alia, wastes listed in Annexes II and VIII to the Basel Convention; iii. wastes listed in Annex IVA; iv. wastes not classified under one single entry in either Annex III, IIIB, IV or IVA; v. mixtures of wastes not classified under one single entry in either Annex III, IIIB, IV or IVA unless listed in Annex IIIA; vi. Shipments of mixed municipal waste (waste entry 20 03 01) collected from private households, including where such collection also covers such waste from other producers, to recovery or disposal facilities; vii. wastes listed in Annex III, but which display any of the hazardous characteristics listed in Annex III to Directive 2008/98/EC on waste.	i. waste listed in Annex III or IIIB; ii. mixtures, not classified under one single entry in Annex III, of two or more wastes listed in Annex III, provided that the composition of these mixtures does not impair their environmentally sound recovery and provided that such mixtures are listed in Annex IIIA.

The prior notification procedure requires the person who intends to ship waste to submit a prior written notification to and through the competent authority of dispatch. Such a notification must be accompanied by several documents and requires considerable administrative activities. Articles 4, 5 and 6 contain the main requirements for notification through the competent authority of dispatch. Furthermore, as a notification needs to be forwarded to relevant competent authorities of Member States or countries of transit and destination for their consent, the procedure may take a considerable amount of time. The WSR provides an official maximum timeframe of 30 days for the notification procedure, but it is not uncommon for authorities to exceed this timeframe. It should be noted that it is possible to submit a general notification which allows for multiple shipments with only one notification for a period up to one year. However, these shipments should involve the same type of waste which should be indicated in the notification.

The green list procedure is considerably less burdensome as it does not require prior notification of a waste shipment. Instead, the person under the jurisdiction of the country of dispatch who arranges the shipment shall ensure that the waste is accompanied by the document contained in Annex VII to the WSR. The document contained in Annex VII shall be signed by the person who arranges the shipment before the shipment takes place and shall be signed by the recovery facility or the laboratory and the consignee when the waste in question is received.

Based on the Annexes of the WSR, it is likely that the collected AHP waste, especially if it is still mixed with other household or similar waste, will be subject to the notification procedure if shipped across Member State borders. AHP waste or its specific fractions do not appear in Annex III or IIIB to the WSR. Furthermore, based on the definition of “mixture”[27] under Article 2(3) of the WSR, it does not seem likely that point ii from the table above is applicable. As such, the transboundary shipment of AHP waste as feedstock for recycling operations will likely need to be notified.

The output of AHP waste recycling operations, assuming that it does not attain the end of waste status immediately (see section 5.5), may be subject to the lighter green list procedure, depending on the composition and nature of this material. For example, if polypropylene or polyethylene are recycled as output material and then they would correspond with code 3011 from Annex III to the WSR:
“Plastic waste listed below, provided it is almost free from contamination and other types of waste: Plastic waste almost exclusively consisting of one non-halogenated polymer, including but not limited to the following polymers:

- *Polyethylene (PE)*
- *Polypropylene (PP)*
- *(…)”*

[27] Waste that results from an intentional or unintentional mixing of two or more different wastes and for which mixture no single entry exists in Annexes III, IIIB, IV and IVA. Waste shipped in a single shipment of wastes, consisting of two or more wastes, where each waste is separated, is not a mixture of wastes

In any event, the output material ought to be as pure as possible to make sure that it is not considered a contaminated waste stream which exhibits a hazardous characteristic. For example, if the output PP or PE is too contaminated with a hazardous substance, code AC300 in Annex IV may apply:

"Plastic waste, including mixtures of such wastes, containing or contaminated with Annex I constituents, to an extent that it exhibits an Annex III characteristic"

5.4 Best available techniques (BAT) for waste treatment

If AHP recycling initiatives prove to be successful, they may be scaled up to process bigger volumes of AHP waste. Beyond specific volumes and depending on the classification of AHP waste as hazardous or non-hazardous, obligations under Directive 2010/75/EU on industrial emissions (**hereafter:** IED)[28] and related best available techniques (BAT) documents may apply.

Annex I of the IED lists a number of recycling activities which may also apply to AHP waste recycling:

a. Disposal or recovery of hazardous waste with a capacity exceeding 10 t per day involving one or a combination of a number of listed activities including biological treatment and physic-chemical treatment.
b. Recovery, or a mix of recovery and disposal, of non-hazardous waste with a capacity exceeding 75 t per day involving one or a combination of a number of listed activities including biological treatment[29]; and
c. Temporary storage of hazardous waste pending any of the activities listed in point (a) above with a total capacity exceeding 50 t, excluding temporary storage, pending collection, on the site where the waste is generated.

For activities listed in Annex I, the IED requires Member States to ensure that relevant activities are operated on the basis of issued permits which have to reflect various requirements stated in the IED and BAT. The latter are found in the EU Best Available Techniques reference documents (BREFs) and in binding BAT conclusions. For waste treatment, BAT conclusions were adopted in 2018.[30] These conclusions concern BATs for e.g.,:

- Overall environmental performance;
- Monitoring;
- Emissions to air;
- Noise and vibrations;
- Emissions to water;
- Emissions from accidents and incidents;
- Material efficiency;
- Energy efficiency; and
- Reuse of packaging.

5.5 End-of-waste status

EU waste management law, including various obligations discussed in previous sections, will apply to materials derived from AHP waste recycling until such secondary material attains end of waste status. For the attainment of this status, the secondary material will have to meet the end of waste (**hereafter:**

[28] See: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A02010L0075-20110106
[29] When the only waste treatment activity carried out is anaerobic digestion, the capacity threshold for this activity shall be 100 t per day.
[30] See: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv%3AOJ.L_.2018.208.01.0038.01.ENG&toc=OJ%3AL%3A2018%3A208%3ATOC

EoW) criteria specified in Directive 2008/98/EC on waste (Waste Framework Directive, **hereafter:** WFD).[31] As such, there is a clear benefit linked to the attainment of the EoW status for the recycled material. The continued management of the secondary material under the regulatory framework for waste may constitute a burden for the recycler and the buyers of the secondary material which may diminish the economic feasibility of the initiative. In addition, the attainment of the EoW status sends a clear message to (potential) buyers that the material meets relevant quality and safety requirements.

Article 6(1) WFD states that: *"Member States shall take appropriate measures to ensure that waste which has undergone a recycling or other recovery operation is considered to have ceased to be waste if it complies with the following conditions:*

a. *the substance or object is to be used for specific purposes;*

b. *a market or demand exists for such a substance or object;*

c. *the substance or object fulfils the technical requirements for the specific purposes and meets the existing legislation and standards applicable to products; and*

d. *the use of the substance or object will not lead to overall adverse environmental or human health impacts."*

For certain materials, more specific/tailored EoW criteria have been adopted on the EU level (e.g., for glass cullet and copper scrap). No specific criteria have been adopted on the EU level for materials contained in AHP materials.

Where more detailed criteria have not been set at the EU-level, Member States may establish detailed criteria on the application of the conditions a-d to certain types of waste. Those detailed criteria shall take into account any possible adverse environmental and human health impacts of the substance or object and shall satisfy a number of requirements specified in Article 6(2) of the WFD. If Member States do not set detailed criteria, they will have to apply the general criteria of Article 6 WFD on a case-by-case basis.

At the moment, only Italy and the Belgian region of Flanders have adopted detailed EoW criteria which are relevant for AHP waste recycling:

- Italian Decree of the 15th of May, No. 62 concerning a Regulation governing the cessation of the status of waste from absorbent products for the person (PAP)[32]; and
- EoW criteria for single-use diaper recycling adopted by the Flemish Waste Management Authority (OVAM), 7th of January 2021[33].

In addition, the Dutch National Institute for Public Health and the Environment issued a report concerning a framework for the assessment of the recycling of diapers and incontinence material in 2019.[34] Most notably, the report provides a "Step-by-step plan and risk assessment framework for potential risks of substances and pathogens in product". It should be noted that the Flemish EoW criteria are based on the Italian and Dutch frameworks.

Important aspects of the detailed EoW criteria as laid down in the Italian, Flemish and Dutch documents concern:

[31] See: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A02008L0098-20180705

[32] See: https://www.normattiva.it/uri-res/N2Ls?urn:nir:ministero.ambiente.e.tutela.territorio.e.mare:decreto:2019-05-15;62!vig=

[33] See: https://ovam.vlaanderen.be/documents/177281/925821/EindeAfvalCriteria_Luierecyclage_Eindrapport_Finaal07012021.pdf/f52922d3-37b0-44eb-8453-5d40c26e6d29?t=1650984098066&download=true

[34] See: https://www.rivm.nl/bibliotheek/rapporten/2019-0111.pdf

- Type of input material;
- Criteria for the recycling processes;
- Requirements concerning the output material, e.g., concerning:
    - Levels of medicine residues;
    - Occurrence of pathogens; and
    - Level of heavy metals; and
    - Compliance with applicable products legislation.
- The allowed applications for the resulting material.

Point of attention concerning potential hazardous substances in AHP waste
Various sources highlight potential contamination of AHP waste, most notably diapers, with potentially hazardous substances such as pathogens and medicine residues (C. Takaya et al., 2020). In addition, certain actors have raised their concerns concerning the unintentional occurrence of other hazardous substances such as PCBs or PAHs in AHPs (ANSES, 2018). Some of the aforementioned substances may be regulated by EU or Member State products or chemicals law and, as such, should be taken into consideration for the fulfilment of EoW criterion (c). In addition, non-regulated substances may raise doubts concerning the fulfilment of EoW criterion (d), since such substances may lead to adverse environmental or human health impacts. As such, EDANA and its members may have to assess the merit of such concerns and carefully identify which substances may be contained in which AHP waste streams. Data on the matter will enable the assessment of compliance with EU or Member State products or chemicals law, as well as the assessment of any adverse environmental or human health impacts.

Based on the general EoW criteria, as well as the more specific ones adopted by various Member States, it can be expected that material resulting from AHP recycling will have to meet the products and chemicals legislation. The applicability of specific products and/or chemicals legislation will depend on the nature of the recycled material and/or its envisaged applications. Table 26 provides a general overview of EU legislation which may become relevant. However, it is important to note that additional regulatory requirements for materials, products or applications may apply on the Member State level. As such, a mapping of applicable national regulatory requirements is recommended when determining the location of any recycling pilot projects and the markets for the output of such pilots.

Table 26: potentially applicable legislations depending on the nature of the recycled material and/or its envisaged application

Nature/Application	Potentially applicable legislation
Substances	• Regulation (EC) No 1907/2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) • Regulation (EU) 2019/1021 on persistent organic pollutants (POP Regulation)
Mixtures	• Regulation (EC) No 1907/2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) • Regulation (EU) 2019/1021 on persistent organic pollutants (POP Regulation) •
Articles[35]	• Regulation (EC) No 1907/2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) • Regulation (EU) 2019/1021 on persistent organic pollutants (POP Regulation)
Packaging	• European Parliament and Council Directive 94/62/EC on packaging and packaging waste
Food contact material	• Regulation (EC) No 1935/2004 on materials and articles intended to come into contact with food

[35] The term "article" is defined in EU chemicals law as an object which during production is given a special shape, surface or design which determines its function to a greater degree than does its chemical composition. As such, most products will meet this definition.

Construction material	• Regulation (EU) No 305/2011 laying down harmonised conditions for the marketing of construction products
Fertiliser	• Regulation (EU) 2019/1009 laying down rules on the making available on the market of EU fertilising products

A highly relevant piece of EU chemicals legislation which is very likely to apply to recycled material concerns the EU Regulation (EC) No 1907/2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH). This regulation contains, among other things, restrictions on the use of a considerable number of substances in mixtures or articles (i.e., products) and the requirement that substances on their own, in mixtures or in articles are registered with the European Chemicals Agency prior to their placing on the internal market. As such, REACH is highly likely to apply to any materials resulting from AHP waste recycling. Therefore, assessment of any applicable requirements, most notably those concerning registration, restrictions and authorisation will have to be taken into consideration.

With regard to registration, it is relevant to note that, on the basis of Article 2(7)(d) REACH, the registration obligations of REACH will not apply to substances, on their own, in mixtures or in articles, which have been registered in accordance with Title II REACH and which are recovered in the EU if:

i. the substance that results from the recovery process is **the same** as the substance that has been registered in accordance with Title II; and
ii. the information required by Articles 31 or 32 REACH relating to the substance that has been registered in accordance with Title II is available to the establishment undertaking the recovery.

5.6 Contractual and regulatory arrangements for collection

When assessing suitable sources of AHP waste for subsequent recycling initiatives, EDANA and its members may want to consider the contractual and regulatory arrangements in place in a specific location or region regarding the collection of waste. For example, companies or institutions may have contracted waste management companies for the collection of their mixed or separate waste streams which may contain AHP waste. The contract may grant the waste management company the exclusive right to collect and subsequently manage the waste in question. Similar excusive claims to waste collection and subsequent management may also follow from regulatory responsibilities and competences of public authorities such as municipalities or public utility companies.
Such exclusive arrangements may block or impede the setting up of separate collection initiatives for EDANA and its members. Waste management companies with current exclusive rights to the waste may object to such initiatives as they may decrease volumes collected by them (and thus, e.g., the caloric value of the waste if incinerated).

As such, it is recommended that EDANA and its members, upon identifying relevant sources of AHP waste, assess the existing contractual and/or regulatory arrangements concerning the collection of such waste. This may enable EDANA and its members to assess feasibility of such sources or consider a dialogue with current collectors concerning a shared collection arrangement or the diversion of the collected waste to EDANA recycling initiatives.

5.7 Funding opportunities

The following table (Table 27) provides a non-exhaustive overview of funding and subsidy programmes which may be relevant for AHP waste recycling initiatives. Programmes have been identified on the EU level and for Member States with a known active approach to the transition to a circular economy.

Table 27: Overview of funding and subsidy programmes which might be relevant for AHP waste recycling initiatives

Funding opportunity	Description	Country/ region	Link
BMUV-Umweltinnovation-sprogramm	The Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection (BMUV) supports you in the large-scale initial application of new technological processes and process combinations that avoid or reduce environmental pollution. One of the topics that is funded is "Waste prevention, recycling and disposal", and a second is "Resource efficiency and material savings". Up to 70 % of the eligible costs can be subsidized. In the case of investment grants, share financing of up to 30 % is provided.	Germany	Förderdatenbank - Förderprogramme - (foerderdatenbank.de)
Programme for Environment and Climate Action (LIFE)	The financial envelope of the LIFE Programme is implemented via four sub-programmes: Nature and Biodiversity Circular Economy and Quality of Life Climate Change Mitigation and Adaptation Clean Energy Transition https://ec.europa.eu/environment/pdf/funding/2021-2024_WorkProgramme.pdf	Europe	Programme for Environment and Climate Action (LIFE) | European Commission (europa.eu)
Horizon Europe – the Framework Programme for Research and Innovation	Horizon Europe is the EU's key funding programme for research and innovation with a budget of €95.5 billion. The programme facilitates collaboration and strengthens the impact of research and innovation in developing, supporting and implementing EU policies while tackling global challenges. It supports creating and better dispersing of excellent knowledge and technologies.	Europe	Horizon Europe
UK Research and Innovation	We offer funding and support across all academic disciplines and industrial areas from the medical and biological sciences to astronomy, physics, chemistry and engineering, social sciences, economics, environmental sciences, and the arts and humanities. There are always upcoming projects for the UK.	UK	Our councils – UKRI
Wrap Circular economy fund	Not currently accepting applications for grants.	UK	Circular Economy Fund | WRAP (wrapcymru.org.uk)
Circular Economy Innovation Grant Scheme (CEIGS)	The purpose of this grants scheme is to provide support to projects which work in the Circular Economy space, with the aim of advancing the Circular Economy in Ireland and raising awareness of the need to transition to a Circular Economy. By funding circular economy projects and enterprises, the CEIGS directly supports the growth of the circular economy in Ireland and provides high-profile examples of best practice. The total CEIGS is €250,000 for the 2021 call. The maximum year 1 grant available will be €50,000 – the indicative funding range for projects is €10,000 - €50,000. This grant closed in 2021 but normally can be applied to for follow up projects.	Ireland	gov.ie - Whole of Government Circular Economy Strategy 2022 – 2023 'Living More, Using Less' (www.gov.ie)

European Investment Bank (EIB)	Projects supporting Circular Economy large scale projects of public as well private sector entities (from 15 million project budget) can be directly financed by the EIB. For municipalities, the EIB offers municipal framework loans that can be used for multi-component investment programmes, for example with a circular thematic focus. EIB's average ticket size for this kind of programme tends to be between €50 and 100 million. Private sector projects can also be supported through senior as well as sub-ordinated financing for amounts of at least €7.5 million.	Europe	Circular economy (eib.org)
France Gouvernement Ademe (Environment and Energy Management Agency)	The ambitious objectives set for 2020-2025 to start the transition to a circular economy require a significant volume of investment, as well as innovation support to accelerate the transition dynamic. For a first contact, consult the website of the Ademe management of your region. Up to €1 million in aid, your file will remain processed at regional level, only an opinion of the CRA (Regional Aid Commission) is requested. Beyond that, files that have had a positive opinion from the CRA are submitted to the CNA waste (National Aid Commission of Ademe), which meets 3 to 4 times a year.	France	Financing of | projects Ministries Ecology Energy Territories (ecologie.gouv.fr)
L'économie circulaire en Wallonie	The "circular economy" cheque makes it possible to finance consulting services to support you in your projects. The aim is to support sustainable initiatives and make circular economy projects a reality. For whom: Companies Instrument: Financial support. The cheque entitles you to assistance of up to €45,000 for benefits of up to €60,000 over a period of 3 years. Your company share amounts to 25 % of the total amount of the benefit. Description: Do you want to make better use of resources, in a logic of circular economy and sustainable transition? Do you have ideas to use fewer materials, dismantle a product more easily to recycle it or change its components, extend its life, reuse it? The Circular Economy Voucher makes it possible to conduct feasibility studies in this direction. On the one hand, these studies analyse the economic aspects: impacts on prices, market analysis, business plan, financial package, etc. On the other hand, the studies can also focus on the technical aspects: mapping of resources, analysis of the status of materials (waste or not?), technical approvals, identification of potential suppliers, production of test series, design costs.	Belgium	Calls for projects and | funding The circular economy in Wallonia| The circular economy in Wallonia (wallonie.be) https://www.sowalfin.be/eco-transition/beneficiez-des-cheques-entreprise-economie-circulaire/
NEXT circular Wallonia	NEXT plays a role of financial lever in Walloon Circular Economy projects in the growth phase Does your project concern one of the 4 axes of the Circular Economy? Does your project have an industrial vocation? Do you want to expand it or accelerate its growth? Are you looking for a specialized partner who	Belgium	NEXT • Financement de votre projet d'Économie Circulaire (circularwallonia.be)

	understands the challenges and characteristics of this economic model but also its risks? For Start-up, SME or Large Company.		
Klimatklivet	Klimatklivet supports local climate investment, with the aim of increasing the pace at which the environmental quality goal of limited climate impact and its milestone targets are achieved. In 2018, the total programme amounted to SEK 1.5 billion, approximately 14 % of the Swedish state's expenditure on environmental policy. Investment aid comes from the Climate Leap initiative (Klimatklivet). The Climate Leap initiative can support organisations such as enterprises, regions, county councils, municipalities, municipal companies and others. Private individuals cannot receive aid through the Climate Leap.	Sweden	Klimatklivet | Climate Policy Database https://www.lansstyrelsen.se/skane/om-oss/other-languages/english/environment-and-water/energy-and-climate/climate-investment-aid.html

5.8 Recommendations and points of attention

The information highlighted in the previous sections leads to the following recommendations and points of attention for the development of AHP waste recycling initiatives (see Table 28).

Table 28: recommendations and points of attention for the development of AHP waste recycling initiatives

Theme	Recommendations

Waste classification	• Ensure correct classification of AHP waste collected and treated under the envisaged pilot projects in terms of:
	  ○ Applicable LoW code; and
	  ○ Status as hazardous or non-hazardous.
	• For the assessment of hazardous or non-hazardous, carefully identify which substances may be contained in which AHP waste streams.
	• Re-assess the relevant AHP waste regularly (e.g., on change of composition) to ensure that the classification remains correct.

Waste shipments	• Assess whether the envisaged AHP recycling pilots involve shipment of AHP waste across EU Member State borders. • If transboundary shipment will occur, carefully assess the nature of the shipped waste and match it with the lists of waste included in the Annexes of the WSR. • Based on the listing of the AHP waste in the Annexes of the WSR, determine whether the procedure of prior written notification or green list procedure applies. • Depending on the applicable procedure, ensure compliance with relevant procedural requirements. • If the more burdensome procedure of prior written notification applies, then consider whether a general notification for multiple shipments can be submitted. • For material resulting from AHP recycling processes (i.e., recycled AHP), assess whether the EoW status has been reached. If this status has not been reached, the recycled material will remain waste and will have to be shipped in compliance with the WSR.
Best available techniques (BAT)	• Assess whether the envisaged AHP recycling pilots involve the recycling of AHP waste which can be considered as hazardous. • Monitor the development of the volumes processed in the envisaged AHP recycling pilots and carefully compare them with the thresholds laid down in Annex I of the IED. • Proactively discuss with the competent authorities the updating of environmental permits on the basis of applicable BAT conclusions.
End-of-waste-status	• Identify detailed EoW criteria on Member State level for recycled AHP and/or identify how Member State authorities apply the general EoW criteria laid down in the WFD. • Attempt to harmonise the detailed EoW criteria and other approaches of Member State authorities in a harmonised list of criteria. • Discuss the harmonised list of criteria with relevant Member State authorities (e.g., of state of recycling and of potential national markets) to ensure that they agree with the criteria.

	• Adapt harmonised list of EoW criteria on the basis of any feedback from relevant Member State authorities.
	• Align AHP waste recycling operations with the final harmonized list of EoW criteria.
	• Pay special attention to issues related to hazardous substances in AHP waste and the risk of the perpetuation of these substances in recycled AHP.
	• Regularly review the harmonized EoW criteria on the basis of developments in Member States, e.g.,:
	  o Adoption/adaptation of detailed EoW criteria (e.g., those of Italy and Flanders);
	  o Changes in interpretation and application of the general EoW criteria of the WFD by Member State authorities without detailed criteria; and
	• The development of detailed EoW criteria on EU level.

Contractual arrangements for collection	• Identifying relevant sources of AHP waste; • Assess the existing contractual and/or regulatory arrangements concerning the collection of such waste; • Assess the feasibility of such sources based on the existing contractual or regulatory arrangements; and • Consider a dialogue with current collectors concerning a shared collection arrangement or the diversion of the collected waste to EDANA recycling initiatives.

6. PROMISING TECHNOLOGIES AND POTENTIAL PILOTS

One objective of this report is to propose pilots that have the potential to contribute to further AHP waste recycling. According to stakeholders, there is still huge potential to do research on AHP waste recycling and to develop further ideas on AHPs' collection, separation and recycling. This chapter aims to reflect on the identified technologies and initiatives (see chapter 4.3) and to give ideas for potential pilots. A pilot does not necessarily have to be one existing technology that will be further developed but can be a combination of several technologies and ideas as well.

6.1 Approach of multi-criteria analysis

Based on the learnings from the technology scanning and the challenges reported in interviews, potential pilots for AHP waste collection, separation and recycling will be developed and presented. As a basis to assess the potentials of the different initiatives/technologies identified in chapter 4, a multi-criteria analysis (MCA) was conducted. However, this analysis will not be used to derive a total score or final results, but to map out the potentials of the different technologies (e.g., high qualitative output, less energy needed etc.).

The multi-criteria analysis is based on the data management tool resulting from the technology scanning. Therefore, the used criteria are very similar to the criteria used for the data management tool and the factsheets. However, some criteria were excluded, and others were extended. The extensive list of the criteria and the respective scoring can be found in Annex 3. For every criterion a scoring with scores from 0-3 was introduced. 0 = is equal to "no information available" (exemption: within the criteria 'technological maturity' 0 = blueprint) and 3 is the best option from an EDANA perspective (e.g., lowest costs, best recyclate quality). For the criterion 'potential negative environmental impacts' the scoring was turned into a negative one, i.e., the points -1, -2 and -3 were applied.

To choose promising initiatives/potential pilots without using the final scores of the multi-criteria analysis only, some assumptions were made:

1. The best scoring initiative is not necessarily the most promising technology for EDANA. Usually, very mature and established technologies receive a high scoring. However, each of the established technologies have weaknesses (e.g., lacking input material, too high costs etc.). Otherwise, a satisfactory solution for AHP recycling would already be widespread. Therefore, it is not helpful for the industry to copy existing, fully developed and mature technologies. On the contrary, it is more of an aspiration to find promising emerging technologies (with possible lower total scores).

2. Moreover, processes that do not fulfil certain basic criteria will not be considered as a potential pilot. The criteria for direct exclusion are as follows:
    a. Input is not post-consumer waste, but post-industrial/pre-consumer waste;
    b. Input is not conventional AHP, but e.g., compostable AHP;
    c. The recovery process is pure energy recovery;
    d. The initiative has stopped.

3. If possible, a potential pilot should consider as many output fractions as possible and make them available for recycling and return them into highly valuable secondary materials (such as plastic, cellulose, SAP etc.); i.e., material separation is key. Notably, the separation of SAP should be considered.

4. Challenges highlighted in chapter 4.3.2 (e.g., difficult use of algae, use of SAP in soils) will be considered for the decision of a potential pilot.

5. Scalability and economic viability are important aspects for a pilot. However, financial information was especially difficult to obtain from desktop research and interviews.

6. Since several AHP recycling technologies require extensive amounts of energy, this topic should be considered when thinking about pilots. Technologies with lower energy consumption are of particular interest.

The legend included in the results (see next sub-chapter) gives insights on the listed additional criteria EDANA considers relevant. The leaf icons indicate if the initiative treats or partially treats compostable AHP waste. The white circle icon indicates if one or several EDANA members are involved in the initiative. A red cross was added to the initiative if one or several of the above mentioned knock out criteria (e.g., input is post-industrial waste instead of post-consumer waste) applied. A green dot indicates that parts of the technology are included in one of the pilots (see chapter 6.3 and 6.4)

Please note that the results of the multi-criteria analysis entail several limitations and should therefore be treated with appropriate caution:

- The multi-criteria analysis is lacking data and information (e.g., commercial data). Therefore, not every criterion or initiative could be fully assessed.
- It was attempted to make the scoring transparent and comprehensible. However, awarding points to specific criteria is always subjective to a certain degree.

6.2 Results of multi-criteria analysis and description of promising technologies

The figures below give an overview on the results of the multi-criteria analysis. The initiatives are sorted along the categories 'exclusively collection', 'collection, separation and recycling' and 'separation and recycling'. All initiatives are listed in Annex 1. After each block of four initiatives, some supplementary information is provided.

Exclusively collection initiatives

Figure 8: Exclusively collection initiatives

Clean Green Future [green dot: partly mentioned in pilot]

Input: Nappies, nappy sacks, incontinence care products, catheter bags, etc.

Process: Registration for AHP collection to get a 60 litre sack which is kerbside collected

Medisort [icon: involvement of an EDANA member]

Input: Single-use instruments, sharps, medical waste and AHP

Process: Scheme in the Arun district in the South of England collecting nappies, feminine hygiene products, PPE and incontinence waste from Households.

Copenhagen Circular [icon: compostable AHP partly as input]

Input: Diaper waste, including compostable ones

Process: Conducts a large-scale sorting and collection pilot for used nappies in autumn 2022 including a manual sorting test performed by ECONET

Note: Results will be published in beginning of 2023

Ontex and Woosh [icon: involvement of an EDANA member; green dot: partly mentioned in pilot]

Input: Diapers from day care centres

Process: Collecting used diapers from more than 200 day care centres; plans to expand the service to more than 1,000 day care centres by 2024

Indicators	Clean Green Future	Medisort	Copenhagen Circular	Ontex and Woosh
Origin of waste	3	3	3	3
Process description	0	0	0	0
Process - Input material	3	0	2	2
Process- Treatment of PE/PP	0	0	0	0
Process- Treatment of SAP	0	0	0	0
Process- Treatment of Cellulose	0	0	0	0
Process- Treatment of organics	0	0	0	0
Process- Treatment of whole AHP (no seperation)	0	0	0	0
Collection/ Seperation/ Recycling capacity	0	0	0	0
Operational input	0	0	0	0
Potential positive environmental savings	0	0	0	0
Potential negative environmental savings	0	0	0	0
Level of technological maturity	2	2	2	2
Comment on level of technological maturity				
Level of commercial maturity	0	0	0	0
Intellectual property rights	0	0	0	0
Comment on intellectual property rights				
Involved parties and their roles	0	0	0	0
Funding and support received for initiative/project	0	2	0	0
Possibility for scale-up	0	0	3	0
Sum	8	7	8	7

Input: Compostable AHP as input · Input: Compostable AHP partly as input · Involvement of an EDANA member · Partly mentioned in pilot · One of the knock out criteria applies

Supplementary information and considerations:

- *Medisort is open for discussion and sharing of knowledge.*
- *Copenhagen Circular did a pilot with conventional and with compostable diapers.*

Combinations of collection systems and separation and recycling technologies

Figure 9: Combinations of collection systems and separation and recycling technologies - I

Diaper Recycling Europe (Knowaste Technologies Inc.)

Input: AHP from public and social institutions and Households

Process: Curb site collection of AHP; Separation through shredding, washing and treating with salts; Recycling of the individual materials

Output: Plastic pellets, long-length fibres

Terra Preta (biotechnological approach)

Input: Biodegradable inlays from reusable diapers

Process: Collection system from Households; Worm composting and Terra Preta Method

Output: Nutrient-rich humus

Input is compostable waste

Nappicycle

Input: Domestic nappy and AHP incontinence wastes

Process: Kerbside collection for 22 local authorities in Wales; hydro-recovery process

Output: Cellulose fibre (production of fibre boards, acoustic panelling)
Plastics

Envirocomp composting plant in Rochester

Input: Diapers

Process: Collection in pre-paid compostable bin bags; shredding and composting; separation of plastic

Output: Soil, and plastic for energy recover

Indicators	Diaper Recycling Europe (Knowaste Technologies Inc.)	Terra Preta (biotechnological approach)	Nappicycle	Envirocomp composting plant' in Rochester
Origin of waste	3	3	0	3
Process – Level of separation into components	3	1	3	2
Process - Input material	3	1	2	2
Process- Treatment of PE/PP	3	0	2	1
Process- Treatment of SAP	2	0	0	0
Process- Treatment of Cellulose	3	0	2	0
Process- Treatment of organics	0	0	0	3
Process- Treatment of whole AHP (no seperation)	0	2	0	0
Collection/ Seperation/ Recycling capacity	3	0	0	1
Operational input	0	0	0	0
Potential positive environmental savings	3	0	0	0
Potential negative environmental savings	0	0	0	-1
Level of technological maturity	3	3	3	2
Comment on level of technological maturity				was stopped
Level of commercial maturity	0	0	0	0
Intellectual property rights	0	0	0	1
Comment on intellectual property rights				
Involved parties and their roles	0	0	2	2
Funding and support received for initiative/project	0	0	0	0
Possibility for scale-up	3	0	0	0
Sum	29	10	14	16

Input: Compostable AHP as input · Input: Compostable AHP partly as input · Involvement of an EDANA member · Partly mentioned in pilot · One of the knock out criteria applies

Supplementary information:

- *Knowaste has stopped as of 2006 and a facility in Birmingham was closed. According to interviewed stakeholders the project did not start at the right time. Odour nuisance was also mentioned as a possible reason for the closure. Interview partners suggested that the facility was planned for too high of a needed input and that the quality of the recycled fluff part was too low. It was pointed out that, in general, the Knowaste process could work when starting at a small scale and ensuring the quality of the products. Diaper Recycling Europe is the follow-up project of Knowaste but is still in the prototyping phase.*
- *Terra Preta focuses on reusable diapers.*
- *Nappicycle is similar to Knowaste, meaning that it risks having the same negative aspects as Knowaste. Insiders reported that it is difficult to run Nappicycle economically. One reason could be the low-end technology of the recyclate (pellets for the road).*
- *Envirocomp first promoted recycling, later landfilled AHP waste and finally tried pyrolysis. It seems that the initiative has stopped.*

Figure 10: Combinations of collection systems and separation and recycling technologies - II

DiaperRecycle

Input: Single-use diapers

Process: Collection per registration and payment per month; separation of plastic and fibres

Output: Plastic (plastic recycler), super absorbent polymer (SAP) used for cat litter

Soil Moisture retainer

Input: Diapers containing only urine

Process: Collection from local users; manual separation of super absorbent polymer (SAP) from cellulose; reactivation of SAP

Output: SAP hydrogel

INKOCYCLE (THM)

Input: Diapers and Incontinence Material from hospitals and care facilities

Process: Collection and sealing in a vacuum system; shredding and fermentation (50-57°C)

Output: Biogas and plastic

Chemical recycling (e.g., Exxtend, Reoil etc.)

Input: Sorted (polyolefinic - no PVC) industrial and post-consumer waste

Process: Chemical recycling, including high temperatures

Output: Turn plastic waste into virgin polymer similar to fossil oil based polymer, which can then be used to make all kind of new products

Indicators	DiaperRecycle	Soil Moisture retainer	INKOCYCLE (THM)	Chemical recycling
Origin of waste	0	3	0	3
Process – Level of separation into components	0	2	3	2
Process - Input material	2	3	2	2
Process- Treatment of PE/PP	3	0	3	2
Process- Treatment of SAP	2	2	2	0
Process- Treatment of Cellulose	0	0	0	0
Process- Treatment of organics	0	0	2	0
Process- Treatment of whole AHP (no seperation)	0	0	0	0
Collection/ Seperation/ Recycling capacity	0	0	1	3
Operational input	0	0	1	0
Potential positive environmental savings	0	2	2	2
Potential negative environmental savings	0	-1	0	0
Level of technological maturity	2	1	1	3
Comment on level of technological maturity				
Level of commercial maturity	0	0	0	0
Intellectual property rights	0	0	0	0
Comment on intellectual property rights				
Involved parties and their roles	0	0	3	1
Funding and support received for initiative/project	1	0	1	0
Possibility for scale-up	0	0	0	3
Sum	10	12	21	21

Input: Compostable AHP as input · Input: Compostable AHP partly as input · Involvement of an EDANA member · Partly mentioned in pilot · One of the knock out criteria applies

Supplementary information and considerations:

- *DiaperRecycle focusses on the plastic fractions in used diapers.*
- *The research on 'Soil Moisture retainer' focused on diapers containing urine. This kind of technology poses a risk of microplastic release in the environment.*
- *INKOCYCLE was a university research project that is not active for the time being. According to one of the people involved, however, the research can be resumed at any time and cooperation with industry is appreciated.*
- *Several companies are developing chemical recycling processes (e.g., see Exxtend technology, Reoil etc.).*[36]

Figure 11: Combinations of collection systems and separation and recycling technologies - III

University of Michigan

Input: Super absorbent polymer

Process: Kind of chemical recycling, break some bonds to break down the polymer, make it a bit more soluble, esterification

Output: Other useful polymer (pressure sensitive adhesive)

Renewi Joins Forces with Essity on Nappy Recycling in Netherlands

Input: Diapers, incontinence products

Process: /

Output: valuable raw materials such as high quality cellulose fibre
Little information

Bioethanol production

Input: Household waste, postconsumer AHPs

Process: Biological process, AHPs are sanitized and dried; separation of cellulose and plastic, enzymatic saccharification, and microbial fermentation

Output: Bioethanol

Oxidation with ozone

Input: Diapers

Process: Washing, centrifugally separation of plastic and SAP-pulp, separation of SAP and pulp by dehydration through ozone oxidation

Output: Plastics (incineration), SAP, pulp (as raw materials)

Indicators	University of Michigan	Renewi Joins Forces with Essity on Nappy Recycling in Netherlands	Bioethanol production	Oxidation with ozone
Origin of waste	0	0	3	0
Process description	2	2	3	3
Process - Input material	1	0	0	2
Process- Treatment of PE/PP	0	0	0	1
Process- Treatment of SAP	2	0	0	0
Process- Treatment of Cellulose	0	2	2	0
Process- Treatment of organics	0	0	0	0
Process- Treatment of whole AHP (no seperation)	0	0	0	0
Collection/ Seperation/ Recycling capacity	0	0	0	0
Operational input	0	0	1	3
Potential positive environmental savings	3	0	2	0
Potential negative environmental savings	0	0	0	0
Level of technological maturity	1	1	1	1
Comment on level of technological maturity				
Level of commercial maturity	0	0	0	0
Intellectual property rights	0	0	0	0
Comment on intellectual property rights				
Involved parties and their roles	0	0	2	0
Funding and support received for initiative/project	0	0	3	0
Possibility for scale-up	3	0	0	0
Sum	12	5	17	10

Input: Compostable AHP as input · Input: Compostable AHP partly as input · Involvement of an EDANA member · Partly mentioned in pilot · One of the knock out criteria applies

Supplementary information and considerations:

- *The University of Michigan team has developed a technique to untangle absorbent polymers and recycle them into materials similar to the gooey adhesives used in sticky notes and bandages.*
- *Only few information (from 2018) is available for the joint initiative of Renewi plc and Essity.*

[36] Note: The scoring and assessment of the chemical recycling is based on the Exxtend technology (see Figure 9)

- *Bioethanol production: This study investigated the viability of recycling the cellulose component from postconsumer AHPs, demonstrated the fermentability of obtained cellulosic sugars for bioethanol production, and evaluated the technical feasibility of the process through scale-up.*

Separation and recycling technologies

Figure 12: Separation and recycling technologies - I

ARN BV (Elsinga)

Input: Diapers

Process: Separation of plastics, paper pulp and biomass in a kettle at min. 40 bar and 250 °C with about 30 % of digested sewage sludge for 3 hours

Output: Plastic pellets, paper & biogas

REFIBRA

Input: Cellulose rich textile waste

Process: Chemical recycling

Output: Man-made cellulosic fibres

Focus only on one fraction

Super Faith Inc. SFD Systgem Super Faiths Inc.

Input: Diapers

Process: Sealed bags containing diapers are directly put in the SDF machine; SDF machine shreds, ferments and dries the used diaper

Output: Fuel chips, which can be processed to energy pellets

Not enough capacity

Mushroom cultivation nutrients

Input: Diapers containing only urine from children below 2 years

Process: Separation of the diaper core; subsequent heating in the autoclave at 121 °C

Output: Edible or medical mushroom substrate

Only for specific soils

Indicators	ARN BV (Elsinga)	REFIBRA	Super Faith Inc. SFD Systgem Super Faiths Inc.	Mushroom cultivation nutrients
Origin of waste	0	3	0	0
Process - Level of separation into components	3	2	1	1
Process - Input material	2	1	2	2
Process- Treatment of PE/PP	3	0	0	0
Process- Treatment of SAP	0	0	0	0
Process- Treatment of Cellulose	0	2	0	0
Process- Treatment of organics	1	0	0	0
Process- Treatment of whole AHP (no seperation)	0	0	1	1
Collection/ Seperation/ Recycling capacity	3	0	1	0
Operational input	0	3	2	0
Potential positive environmental savings	2	3	2	0
Potential negative environmental savings	0	0	0	0
Level of technological maturity	3	3	2	2
Comment on level of technological maturity				
Level of commercial maturity	0	3	0	0
Intellectual property rights	0	0	0	0
Comment on intellectual property rights				
Involved parties and their roles	2	3	0	0
Funding and support received for initiative/project	0	0	0	2
Possibility for scale-up	0	0	0	1
Sum	**19**	**23**	**11**	**9**

Input: Compostable AHP as input | Input: Compostable AHP partly as input | Involvement of an EDANA member | Partly mentioned in pilot | One of the knock out criteria applies

Supplementary information and considerations:

- *ARN is an established facility but according to interview partners the recyclate yield is still improvable. As the SAP remains in water, expensive water treatment is needed.*
- *REFIBRA focuses on the treatment of cellulose, which can be interesting for some sub-process in an AHP waste recycling process.*
- *It was reported that Super Faith Inc. does not have enough capacity to be economical. The treatement of the plastic is incineration.*
- *The 'Mushroom cultivation nutrients' is only suitable for certain soils, and it is unclear if scale up is possible.*

Figure 13: Separation and recycling technologies - II

Birzitek

Input: Children's diapers, incontinence products, feminine hygiene products

Process: Separation after crushing and sanitization; additional washing drying and storing

Output: Cellulose and Plastics

Pyrolytic diapers as a soil amendment

Input: Diaper

Process: Pyrolysis at 500-900 °C

Output: Pyrolytic products with high phosphorus oxide concentrations

Energy Recovery (Indian Research)

Input: Sanitation products for children and menstrual hygiene

Process: Separation of plastics and cellulose; subsequent incineration at 850-900 °C

Output: Energy and ash

Pure energy recovery

Anode materials for lithium –ion batteries

Input: Super absorbent polymer (SAP) of baby diapers

Process: Separation of SAP; processing to green nickel nitrate to form hydrogel with freeze-drying and pyrolysis

Output: 3D-porous carbon composites used for Li-batteries

Focus on SAP

Indicators	Birzitek	Pyrolytic diapers as a soil amendment	Energy recovery (Indian Research)	Anode materials for lithium-ion batteries
Origin of waste		0	3	0
Process - Level of separation into components	3	1	3	2
Process - Input material	2	2	2	1
Process- Treatment of PE/PP	2	0	1	0
Process- Treatment of SAP	0	0	1	2
Process- Treatment of Cellulose	2	0	1	0
Process- Treatment of organics	0	0	1	0
Process- Treatment of whole AHP (no seperation)	0	2	0	0
Collection/ Seperation/ Recycling capacity	0	0	2	0
Operational input	0	3	3	0
Potential positive environmental savings	2	2	2	0
Potential negative environmental savings	0	0	0	0
Level of technological maturity	2	1	1	1
Comment on level of technological maturity				
Level of commercial maturity	0	0	0	0
Intellectual property rights	0	0	0	0
Comment on intellectual property rights				
Involved parties and their roles	3	0	0	0
Funding and support received for initiative/project	0	0	0	3
Possibility for scale-up	0	0	1	0
Sum	**16**	**11**	**21**	**9**

Input: Compostable AHP as input | Input: Compostable AHP partly as input | Involvement of an EDANA member | Partly mentioned in pilot | One of the knock out criteria applies

Supplementary information and considerations:

- *Pyrolytic diapers as a soil amendment for agricultural purposes: this undertaking is only suitable for very specific soils and potential negative effects of the use in soils have to be anticipated. Legal aspects for use in soil have to be examined.*
- *Energy Recovery (Indian Research): this process should be discarded because it focusses on energy recovery.*
- *The undertaking 'Anode materials for lithium-ion batteries' focusses on SAP which is interesting.*

Figure 14: Separation and recycling technologies - III

Austrian Centre of Industrial Biotechnology (acib)

Input: Diapers

Process: Separation of cellulose and plastic with an enzymic procedure

Output: Glucose and plastic fibres (production of polymers or use as platform chemicals)

Research stopped ✖

Separation of cellulose and plastics (BTU)

Input: Incontinence products

Process: Incontinence products mixed with water are autoclaved at 150-250°C for up to 6 hours to separate plastics

Output: Separated cellulose hydrolysate plastic agglomerate

Mainly energetic use

Microwave pyrolysis

Input: AHPs

Process: Microwave pyrolysis after drying

Output: Oil, aliphatic hydrocarbons and char products

Chung Hua University and Multiply Energy Co.

Input: AHPs

Process: Disinfection, shredding and separation performed in one unit

Output: Trash bags, cardboards, absorbent pads, absorbents for rare earth elements and nutrients

Note: Recycling at home

Indicators	Austrian Centre of Industrial Biotechnology (acib)	Separation of cellulose and plastics (BTU)	Microwave pyrolysis	Chung Hua University and Multiply Energy Co.
Origin of waste	0	0	0	0
Process - Level of separation into components	3	3	1	3
Process - Input material	2	0	3	3
Process- Treatment of PE/PP	2	1	0	2
Process- Treatment of SAP	0	0	0	2
Process- Treatment of Cellulose	2	1	0	2
Process- Treatment of organics	0	0	0	3
Process- Treatment of whole AHP (no seperation)	0	0	2	0
Collection/ Seperation/ Recycling capacity	0	0	0	0
Operational input	2	0	3	1
Potential positive environmental savings	2	0	0	0
Potential negative environmental savings	0	0	0	0
Level of technological maturity	1	1	1	1
Comment on level of technological maturity	was stopped			
Level of commercial maturity	0	0	0	0
Intellectual property rights	2	1	0	0
Comment on intellectual property rights		applying for patent		
Involved parties and their roles	0	0	0	2
Funding and support received for initiative/project	0	0	1	0
Possibility for scale-up	3	0	0	0
Sum	**19**	**7**	**11**	**19**

Input: Compostable AHP as input · Input: Compostable AHP partly as input · Involvement of an EDANA member · Partly mentioned in pilot · One of the knock out criteria applies

Supplementary information and considerations:

- *The Acib research was lacking funding and therefore the research was stopped. The ambitions to restart the research seem low.*
- *The 'Separation of cellulose and plastics' from BTU has a patent for separation of plastic and cellulose. The final use of these fractions is mainly energetic.*
- *Chung Hua University and Multiply Energy Co.: the quality of each output fractions seems to be medium quality, but considerations were made for the use of every fraction. The initiative developed a specific wastewater treatment and has a recycling prototype in place.*

Figure 15: Separation and recycling technologies - IV

Hydrothermal carbonization

Input: Diapers (for the study unused diapers)

Process: Shredding, absorption of water and heating between 200 and 300 °C, later drying at 105 °C for 24 hours

Output: Hydrochar

Bio-hydrogen generation

Input: Diapers

Process: Collection and cooling at 4 °C; fermentation process in a bioreactor at 37 °C

Output: bio-H2

Diaper Recycling technology (Singapore)

Input: Diapers, fem. hygiene products **(factory waste)**

Process: Providing machines for diaper recycling, vertical stacking technology for plastic purification and pulp-SAP separation, ideal for recycling with constrained space

Output: Raw materials

Pre-consumer waste is input ✖

Synthesis of glycerol carbonate using diaper waste

Input: Diaper waste

Process: Drying, shredding, shredded pieces are impregnated into nickel nitrate, again drying, calcined above 400 °C

Output: Used diaper waste materials are now magnetic catalysts for synthesis of glycerol carbonate

Indicators	Hydro-thermal carboni-zation	Bio-hydrogen generation	Diaper Recycling technology (Singapore)	Synthesis of glycerol carbonate using diaper waste
Origin of waste	0	0	3	3
Process description	1	0	3	1
Process - Input material	2	0	0	2
Process- Treatment of PE/PP	0	0	0	0
Process- Treatment of SAP	0	0	0	0
Process- Treatment of Cellulose	0	0	0	0
Process- Treatment of organics	0	0	0	0
Process- Treatment of whole AHP (no seperation)	1	2	0	2
Collection/ Seperation/ Recycling capacity	0	0	2	0
Operational input	3	3	3	2
Potential positive environmental savings	0	0	2	2
Potential negative environmental savings	0	0	0	0
Level of technological maturity	1	1	3	1
Comment on level of technological maturity				
Level of commercial maturity	0	0	0	0
Intellectual property rights	0	0	0	0
Comment on intellectual property rights				
Involved parties and their roles	0	0	0	0
Funding and support received for initiative/project	0	0	0	3
Possibility for scale-up	0	0	0	0
Sum	**8**	**6**	**16**	**16**

Input: Compostable AHP as input · Input: Compostable AHP partly as input · Involvement of an EDANA member · Partly mentioned in pilot · One of the knock out criteria applies

Supplementary information and considerations:

- *The hydrothermal carbonization was mainly tested for unused diapers and is at a very early research state.*
- *The Diaper Recycling technology (Singapore) focus in pre-consumer waste and therefore is not of interest as a potential pilot.*
- *'Synthesis of glycerol carbonate using diaper waste': Used diaper waste materials are used as magnetic catalysts for the synthesis of glycerol carbonate by impregnation and calcination techniques.*

Figure 16: Separation and recycling technologies - V

PyroPure

Input: On site AHPs and other wastes

Process: Small-scale pyrolyser (550–700 °C), including a cyclone that separates ash from exit gas

Output: Ash, gas for hot water generation
Note: Recycling at home

Devolatilization in a Bubbling Fluidized Bed

Input: AHP waste

Process: Experimentally investigated the devolatilization of shredded diapers, in a laboratory-scale bubbling fluidized bed made of sand

Output: Syngas (energy recov.)

Bisphenol degrading

Input: Diapers

Process: Enriching diapers that have a high level of urea with cobalt during carbonisation

Output: Peroxymonosulfate

Concrete viscosity modifying admixture

Input: Diapers

Process: Shredding and mixing with cement superplasticizer, limestone powder, sand and gravel

Output: Viscosity modifying admixture (VMA) for cement grouts and concrete

Indicators	PyroPure	Devolatilization in a Bubbling Fluidized Bed	Bisphenol degrading	Concrete viscosity modifying admixture
Origin of waste	3	3	0	0
Process description	0	0	1	1
Process - Input material	3	1	2	2
Process- Treatment of PE/PP	0	0	0	0
Process- Treatment of SAP	0	0	0	0
Process- Treatment of Cellulose	0	0	0	0
Process- Treatment of organics	0	0	0	0
Process- Treatment of whole AHP (no seperation)	2	0	2	2
Collection/ Seperation/ Recycling capacity	1	0	0	0
Operational input	3	0	0	0
Potential positive environmental savings	0	0	2	0
Potential negative environmental savings	0	0	0	0
Level of technological maturity	1	1	1	1
Comment on level of technological maturity				
Level of commercial maturity	0	0	0	0
Intellectual property rights	0	0	0	0
Comment on intellectual property rights				
Involved parties and their roles	0	0	0	0
Funding and support received for initiative/project	0	0	0	1
Possibility for scale-up	0	0	0	0
Sum	13	5	8	7

Input: Compostable AHP as input · Input: Compostable AHP partly as input · Involvement of an EDANA member · Partly mentioned in pilot · One of the knock out criteria applies

Supplementary information and considerations:

- *PyroPure seems to be energy recovery rather than material recycling.*
- *Devolatilization in a Bubbling Fluidized Bed seems to be energy recovery rather than material recycling.*

Figure 17: Separation and recycling technologies - VI

EMBRACED

Input: AHP waste

Process: Obtaining fermentable sugars from AHP waste cellulose converted through biotech process into biobased building blocks of industrial interest

Output: Biobased building blocks, polymers, and fertilizers

Pampers nuovavita (former FATERSMART)

Input: AHP waste

Process: High pressure steam to sterilize used diapers, mechanical separation of cellulose plastic

Output: raw materials like cellulose plastic

Ontex Les Alchimistes compostability of diapers

Input: Diapers (compostable)

Process: Reusable outer diaper made of cotton; disposable diaper pad which is designed to be industrially compostable

Output: Depending on recycling technology that will be installed in BE region
Input is compostable waste

Nippon Shokubai, LiveDo Corporation and Total Care System

Input: Diapers

Process: Separation into three compounds; recycling of disposal diapers via water-solubilization treatment

Output: Pulp as raw material for building materials, Fuel, SAP

Indicators	EMBRACED	Pampers nuovavita (former FATERSMART)	Ontex Les Alchimistes compostability of diapers	Nippon Shokubai, LiveDo Corporation and Total Care System
Origin of waste	3	3	0	3
Process description	3	3	0	3
Process - Input material	3	2	1	2
Process- Treatment of PE/PP	3	0	0	0
Process- Treatment of SAP	3	0	0	0
Process- Treatment of Cellulose	2	0	0	0
Process- Treatment of organics	0	0	0	0
Process- Treatment of whole AHP (no seperation)	0	0	0	0
Collection/ Seperation/ Recycling capacity	3	0	0	0
Operational input	0	0	0	0
Potential positive environmental savings	3	2		2
Potential negative environmental savings	0	0	0	0
Level of technological maturity	3	3	2	3
Comment on level of technological maturity				
Level of commercial maturity	0	0	0	0
Intellectual property rights	0	0	0	0
Comment on intellectual property rights				
Involved parties and their roles	3	0	2	3
Funding and support received for initiative/project	0	0	0	2
Possibility for scale-up	0	0	0	0
Sum	29	13	5	18

Input: Compostable AHP as input · Input: Compostable AHP partly as input · Involvement of an EDANA member · Partly mentioned in pilot · One of the knock out criteria applies

Supplementary information and considerations:

- *EMBRACED: As mentioned above, the EMBRACED project is no longer running. Due to reasons of confidentiality, parts of the project cannot be extracted and information cannot be accessed.*
- *FATER as initiative was supported by the EMBRACED project to enable among others international reach. As FATER was one outcome of the EMBRACED project it was stopped as well. Nowadays, Pampers nuovavita (former FATERSMART) is the only FATER plant and is running in Italy. According to interview partners, the FATER technology had a medium to good success level but more development work would be needed to bring it on a new level.*
- *Ontex Les Alchimistes has a focus on organic recycling.*
- *Nippon Shokubai, LiveDo Corporation and Total Care System seems to be promising. The three companies divided the development work as follows:*
  - *Nippon Shokubai: Development of materials that are easy to recycle and related processing technologies.*
  - *LiveDo Corporation: Development of disposable diapers that are easy to recycle and related processing technologies.*
  - *Total Care System: Examination and development of facilities and processing conditions suitable for recycling.*

The multi-criteria analysis shows that several diaper recycling initiatives are ongoing and that others are about to do research on further technical progress. Therefore, a broad range of final scores can be observed. Due to a lack of information and data gaps, some initiatives only achieve an overall score of 5. Others - mainly those technologies which are available at a larger scale - achieve overall scores up to 29. The exclusive collection systems need separate consideration since many of the criteria concern (recycling) process parameters which are not relevant for an exclusive collection system, i.e., lower final scores can be achieved. The identified collection schemes all attain final scores of 7 or 8.

6.3 Potential pilots for AHP waste collection

In the following section, ideas and considerations for two AHP waste collection pilots are presented. To get the best of the different collection initiatives, it was decided to not choose one existing collection system as a pilot but instead to mix several ideas. Although the pilots are far from being perfect, they are intended to provide an initial example and initiate discussions about future AHP collection options.

Pilot 1 – Diaper collection in care homes (elderly persons) and day care centres (children)

Target group: For the first pilot it seems reasonable to start collection of AHP waste within care homes for elderly persons and day care centres. These commercial institutions need contracts with waste companies and therefore it is easier to make arrangements for separate collection. Due to the hazardous nature of medical waste, AHP waste collection in hospitals should only be considered as a second step.

Focus AHP waste: Diapers for children and elderly persons are used in day care centres and in care homes for elderly persons and are therefore attractive in terms of volume. Feminine hygiene products are assumed to be used rarely in these institutions (if so, then probably by the female staff rather than by the patients). The AHPs of focus in the first pilot are thus diapers for every age.

Collection on site: To avoid odour nuisances, specific diaper pails can be used for the on-site collection in care homes and day care centres. Ideas to vacuumize diaper waste (see INKOCYCLE) to have the waste safely sealed also exist. The collector should offer to provide specific containers (e.g., in a certain colour) to the customers to facilitate on site collection. Such a collection system probably works better in densely populated areas than in the countryside. However, existing and exclusive contracts between waste collectors and commercial institutions should be considered (see chapter 5.6).

Business model: Good service is key for a commercial separate collection. Care homes and day care centres should get enough support to correctly and in conveniently collect diaper waste. It could be an option to offer delivery services for new diapers and exchange those with used diapers (see Ontex & Whoosh) to make the collection economically attractive.

External communication: When offering a system with delivery and pick up, it should be considered that specific permits are needed to allow transporting products and waste in the same vehicle. The respective competent municipalities and authorities must be contacted.

Pilot 2 – AHP waste collection for people in certain stages of life

Target group: The second pilot focuses on waste that is generated in private households. The target group are persons with children from 0-3 (typical age for diaper wear) and persons that care for elderly persons.

Focus AHP waste: Ideally, a collection from private households should cover diapers and incontinence material to address the needs of different target groups.

Collection on site: Similarly to pilot 1, specific diaper pails or vacuum machines (see INKOCYCLE) can be used to collect diaper's and incontinence waste without odour nuisances. The waste collector should offer to provide pails or bags so that the collection at home is easy. As mentioned under pilot 1, such a collection system probably works better in densely populated areas than in the countryside where the transport routes are long and expensive.

Business model: We assume that this type of waste collection is mainly interesting for persons in specific life stages (at the age of having children between 0 and 3, when caring for elderly relatives, when one gets older etc.), i.e., flexible and time limited systems with variable start and end dates seem interesting. Existing collection systems offer apps and a registration system (e.g., see Nappicycle, Clean Green Future) that allow for users to take part in a collection system for a certain time span. Registration systems also allow to take fees from the customers. In return, bags or bins for collection should be provided.

Similarly to pilot 1, a combination between delivery and collection system could be established. Delivery is very common for many consumers and ordering diapers for at home delivery can ease the life of many parents and caregivers. The revenue of the delivery business would then (partly) finance the waste collection. Similar systems already exist for cloth diapers in many cities (cleaned diapers are delivered and the used ones are picked up for washing). The same legal implications as mentioned above (e.g., waste transport) must be considered.

In general, bring systems should not be ruled out. For example, underground containers at specific places (e.g., at playgrounds) in the city could be a discreet way to discard AHP waste. An obvious collection of AHP waste in front of houses seems unrealistic as many people would not want to be seen as in need of an AHP waste container.

External communication: When collecting waste from household waste, dialogues with municipalities are always key and preconditioned. Stakeholders reported that municipalities support AHP waste collection when the municipal waste fees are not influenced.

6.4 Potential pilots for AHP waste separation and recycling

Separation of materials is a key step on the recycling treatment of AHP. The output fractions PE/PP, SAP, cellulose and organics are considered the most important fractions that can be derived from AHP waste. The exemplary data of a used diaper show the expected share of each of the mentioned fractions in a used diaper (see percentages in table below). The table below aims to give an overview of which of the identified initiatives/technologies allow for separation and/or recycling of these AHP materials. Regarding the fact that SAP has to be deactivated for further recycling, deactivation of SAP is included in the column of separation and pre-treatment.

It should be noted that technologies that treat AHP waste as a whole (e.g., pyrolysis initiatives) are not mentioned in this table. To treat the different fractions, mechanical and chemical recycling and biological solutions are presented. Since water treatment is also an important aspect to allow for a clean AHP waste recycling, specific initiatives working on water treatment are additionally presented in the table below (Table 29).

Table 29: Reflections on separation and recycling processes and possible output uses (focus on diapers, but without compostable or biodegradable diapers)

Output fractions	Approx. share of output fraction in used diaper[37]	Separation/Pre-treatment process	Initiatives applying these technologies	Recycling methods and possible output use	Initiatives applying these technologies
PE/PP	4 %	**Plastic float/gets filtered out/Water-solubilization**	Knowaste (ongoing as DRE) ARN BV. Unicharm patent and Nippon and co.	**Mechanical recycling leading to recyclates**	ARN BV Knowaste (pellets)
		Agglomeration of plastics	BTU (patent for separating cellulose from plastic)	**Mechanical recycling but with unclear downstream path**	INKOCYCLE Birzitek
		Enzymatic separation	Acib (research stopped)	**Chemical recycling leading to chemicals**	e.g., Exxtend, Reoil
		Separation cellulose from plastic but without further description	Bioethanol production Bizitek Nappicycle Chung Hua	**Hydro recovery leading to recyclates (cellulose and plastic)**	Nappicycle
SAP	5 %	**Deactivation with salt**	Knowaste	**Use of SAP output as soil retainer**	Soil moisture retainer
		Manually separating SAP from cellulose	Soil moisture retainer	**Use of SAP output for 3D-porous carbon composites used for Li-batteries**	Anode materials for lithium –ion batteries
		Separation of SAP and pulp by dehydration through ozone oxidation	Unicharm		
		Water-solubilization (SAP sinks to bottom)	Unicharm patent and Nippon and co.		
Cellulose	6 %	**Washing and cleaning to regain fibres**	Knowaste	**Fermentation leading to biogas (together with organics)**	INKOCYCLE

[37] See chapter 2.2

Output fractions	Approx. share of output fraction in used diaper[37]	Separation/Pre-treatment process	Initiatives applying these technologies	Recycling methods and possible output use	Initiatives applying these technologies
		Hydrolysis of cellulose	BTU	**Chemical recycling leading to fibres**	REFIBRA
		Water-solubilization	Unicharm patent and Nippon and co.	**Use of output pulp as raw material for building materials (exterior wall or interior materials etc.)**	Nippon and co.
Organics	83 %	/	/	**Fermentation leading to biogas**	INKOCYCLE
		/	/	**Use of organics a soil amendment**	PyroPure Pyrolytic diapers as a soil amendment for agricultural purposes Terra Preta Mushroom cultivation initiative
Water treatment		**Focus on water circulation**	Nippon and co. INKOCYCLE	**Wastewater treatment via Green Fairy technology** (a combination of micro-bioreactor, PVA-immobilized algal beads and PVA-immobilized cell beads with nitrifies, denitrifies and Bacillus)	Chung Hua University
Dis-infection of AHP waste		**Autoclave**	ARN BTU Mushroom cultivation initiative	/	/
		Acidic water	Chung Hua University	/	/

It was decided to not choose one existing recycling facility or research project as a pilot but to mix several ideas as each initiative/technology has a certain drawback. The table above helped to piece together the two following presented pilots.

Pilot 1 – Diaper recycling in a rather conventional manner combined with chemical recycling

Input material: Diapers from collection pilot 1 and AHPs from collection pilot 2 are delivered in sealed and vacuumized bags

Pre-treatment: Vacuumized bags get relaxed and opened

Treatment: Diapers are placed in a kettle (autoclave) and treated at a pressure of at least 40 bar and a temperature of 250 °C together with approx. 30 % digested sewage sludge from an external source in a liquid reactor, during which the plastics melt. Germs and antibiotics are destroyed, and the plastic is melting (see ARN).

Separation: When the plastic has cooled, it floats to the top and can be further processed (see ARN).

Treatment and use of PE/PP: The plastic fraction (PP and PE) floats on the liquid (see ARN or Knowaste) and can be separated from the liquid. As the plastic recyclate yield is improvable when looking at existing diaper recycling facilities, other processes like chemical recycling could be considered for plastic recycling. With chemical recycling, the floated PP and PE is returned to its monomers and can be used in new products.

SAP: Several existing technologies highlight that SAP needs deactivation, e.g., Knowaste performs deactivation with specific salts. The Nippon Shokubai, LiveDo Corporation and Total Care System consortium works on SAP recycling separation via water-solubilization (see Nippon und co).

Cellulose: To make valuable secondary raw materials out of the pulp, the REFIBRA technology may be worth looking at (if it was possible to separate cellulose from the rest). REFIBRA focuses on chemical recycling for cellulose from textiles, but a transfer to cellulose from AHP waste should not be ruled out. As a first step, it should be checked if dirty fibres are a suitable input. Before transferring the cellulose to a chemical recycling process a step to dry the wet fibres seems necessary.

Organics: The remaining organics will be fermented to gain sellable biogas (see parts of INKOCYLE, ARN).

Water treatment: To ensure proper waste treatment of the whole process, the Green Fairy technology of the Chung Hua University may be worth looking at. The Nippon and co. consortium and INKOCYCLE explicitly mention water circulation which can be used as an example.

Pilot 2 – AHP recycling with biogas

Input material: Diapers from collection pilot 1 and AHPs from collection pilot 2 are delivered in sealed and vacuumized bags

Pre-treatment: Vacuumized bags get relaxed, opened and the AHP waste gets shredded.

Process: Disinfection with acidic water (see Chung Hua) and fermentation of shredded AHP waste in a lying reactor at 55°C (see INKOCYCLE). Since this temperature might be too low to destroy all pathogenic germs, the pre-step of disinfection was chosen.

Organics and Cellulose: In this pilot, both fractions, cellulose and organics get returned into sellable biogas (see parts of INKOCYCLE, Embraced, ARN)

Treatment and use of PE/PP: After the fermentation, the plastic containing fermentation residue is sieved and the larger sieving fraction gets washed and dewatered (using a press). After some drying steps, the gained plastic could be made available for mechanical (see ARN) or chemical recycling. However, PE and PP is present in a mixed fraction which is considered a lower quality fraction.

SAP: It cannot be ruled out that some of the SAP gets processed in the fermentation or ends up in the process water. As a good solution to separate SAP from the other materials, innovative ideas like its use in batteries can be considered. Due to the risk of microplastics it is not recommended to use SAP as soil amendment.

In addition to the proposed technologies in the pilot projects, other technologies are part of research projects. For example, several research projects focus on pyrolysis. In general, it is difficult to find a pilot project that covers all aspects of successful recycling. On the one hand, this means that no pilot project is technically or economically perfect. On the other hand, it depends on the priorities of the promoters which technology should be promoted, e.g., a project that only investigates one sub-technology (e.g., SAP recycling) may also make sense. In practice, the available collection quantities and the collection area (e.g., densely populated areas) also play an important role in the decision for or against a pilot project. The size of a recycling plant and its economic viability also depends directly on the collection quantities. As suggested by one of the interviewees, the most important challenge to address is to ensure that saleable recyclate is generated by a recycling process. This may also indicate that pilot projects focusing on the production of such recyclates should be promoted first.

When it comes to the future of AHP recycling promotion, opinions differ among stakeholders. Some report that companies have been trying to establish AHP recycling for many years (including research, pilot projects, etc.), while others see a need for more research and believe that today's society is more ready for AHP recycling. Some research projects (such as Inkocycle) reported that they would continue their research if they could get the funding.

When starting a pilot project, it should be ensured that all permits and requirements are met, such as environmental permits for the facility, waste transport requirements, etc. It is especially important to identify which substances may be contained in which AHP waste streams (see chapter 2).Table 30 summarises legal considerations for the selected pilots.

Table 30: Legal considerations for selected recycling pilots

Legal considerations	Note	Pilot 1	Pilot 2
Classification		Suggested waste code: 20 01: separately collected fractions (except 15 01)	Suggested waste code: 20 01: separately collected fractions (except 15 01)
Shipment	Especially important when collecting waste from different countries	Geographical coverage was not considered	Geographical coverage was not considered
End-of-waste status	Important for sale of recyclates	Mainly relevant for outcome of plastic recycling	Mainly relevant for outcome of plastic recycling

7. CONCLUSION AND OUTLOOK

This report addresses the growing demands from regulators and authorities for a stronger circular economy in the absorbing hygiene products (AHP) sector. This study therefore aims to build knowledge through which a more specific focus on relevant arising waste streams and promising pilot projects regarding collection, separation and recycling of AHP waste can be established. Based on the project results, EDANA envisages the establishment of possible real-life pilot programmes for a more sustainable treatment of AHP waste.

During the investigation, waste streams for AHPs, more precisely waste streams for baby diapers, incontinence products and feminine hygiene products, were developed based on literature and expert knowledge. This allowed, in a later step, for the identification of the quantity of materials that can be recycled in specific initiatives. Materials that are mainly used in AHPs are wood pulp, cotton, viscose rayon, super absorbent polymer (SAP) and other components such as polyester, polyethylene (PE), polypropylene (PP) and adhesives. However, it is important to note, that up to 2/3 of the weight of used AHPs is comprised of organic components (e.g., urine, blood). Due to industrial research to improve AHPs and the material used, AHP products have become significantly lighter in recent decades. Nevertheless, it was estimated, having 2018 as a reference year, that approximately **7.4 % of the MSW** in Europe consists of AHP waste. Of this, the largest share of AHP waste comes from adult incontinence products with a share of 60 %. Baby diapers account for 36 % of the AHP waste followed by feminine hygiene products with 4 %.

In Europe only a few recycling plants for AHP waste could be identified, located in the UK, the Netherlands, and Italy. Due to this low level of recycling plants for AHPs in EU-28, only a share of up to **0.2 %** of AHPs are treated in recycling plants. 55 % of the AHP waste is used for energy recovery, while the remaining 45 % is disposed of. Of the 45 % disposed waste the majority ends up in landfills (89 %) and 11 % is incinerated. Furthermore, single-use menstrual products like tampons are sometimes flushed down the toilet by consumers and enter the wastewater release system.

A technology scanning based on literature research and expert interviews identified all together 42 global studies and initiatives for AHP collection, separation and recycling in different stages of development. The studies include mechanical recycling, chemical recycling and pyrolysis, but also out of the box ideas like the growing of mushrooms or algae on AHP waste. At least 5 initiatives were discontinued in recent years and for some initiatives, it is unclear if they are ongoing. The reasons for discontinuation were, among others, a lack of input material, low recyclate yields, lacking capacity, economic challenges etc. For most recycling processes, the recycling success depends on the separation of materials. The output fractions PE/PP, SAP, cellulose and organics are considered the most important fractions that can be derived from AHP waste.

Although 42 initiatives were mapped, of which 37 include recycling processes (excluding the exclusive collection schemes and pure energy recovery), none of them seem to be a perfect fit for effectively recycling AHP waste in the near future. Many of the examined initiatives are not mature enough to scale, are not sufficiently developed to be transferred in a pilot or lack economic data for a more accurate assessment. Existing AHP recycling facilities like ARN B.V. are promising, but interview partners mentioned low recyclate yields and challenges with water treatment. Moreover, ARN B.V. is too mature to have pilot character.

As a major outcome of the study, two collection and two recycling pilots have been proposed for further research. Hereby, different initiatives were merged into one pilot to complement each other and to thus overcome the drawbacks of the existing researched initiatives/technologies.

The first proposed collection pilot focuses on diaper waste from care homes (elderly persons) and day care centres (children), i.e., commercial clients. The idea is similar to the Ontex & Whoosh system that combines delivery of new products with the pickup of used ones.

The second proposed collection pilot aims to allow AHP waste collection for people in certain stages of life (e.g., when having children from 0-3, when caring for an elderly person in the family etc.). The pilot is based on the idea that many people only need AHP waste collection in certain times in their lives and therefore the system should be flexible and allow registration and deregistration at any time. The pickup can also be combined with delivery (see pilot 1) or be organised via underground containers or other bring systems. When offering systems for households it seems to be especially important to consider the psychological side and to give people the opportunity to dispose of the AHP waste discreetly.

Additionally, two possible separation and recycling pilots were suggested based on the identified initiatives/technologies (see factsheets in Annex I). The first pilot includes several elements of established diaper recycling facilities (e.g., autoclave process as performed at ARN BV.), but combines them with less established technologies like chemical recycling for the plastic fraction. The second recycling pilot is mainly a fermentation process, turning cellulose and organics into biogas. The separation of SAP will be a challenge in this pilot. Similar to pilot 1, the dried plastic fraction could serve as input material for mechanical or chemical recycling processes.

Besides the analysis of promising techniques for recycling of AHP, an examination of the legal framework was carried out. Relevant current and near-future obligations that are likely to apply to AHP recycling operation were analysed. As a result, regulatory development on a Member State level were highlighted to ensure potential bottlenecks in further AHP treatment. As most AHP recycling initiatives will concern the collection and recycling of different fractions of AHP waste, the activities of EDANA members and their contracted partners will most likely fall under the scope of EU waste management law. However, as recycling aims to produce secondary raw materials which will be placed on the market, EU chemicals and product law is also relevant (especially in the context of end-of-waste status).

It is furthermore recommended that EDANA, upon identifying relevant sources of AHP waste, assess the existing contractual and/or regulatory arrangements concerning the collection of such waste. This may enable EDANA and its members to assess feasibility of such sources or consider a dialogue with current collectors concerning a shared collection arrangement or the diversion of the collected waste to EDANA recycling initiatives.

Besides the legal recommendations, different subsidy programmes for further research and development are presented. Programmes have been identified on the EU level and for Member States with a known active approach to the transition to a circular economy. Altogether, 11 programmes were identified and described.

The study shows that further investigation and research in AHPs and their recycling is needed, and that industry engagement is crucial. There are various ongoing projects and business models for both, collection and recycling, which can be further developed. Stakeholders also signalled that they are willing to continue research with (industry) funds. The AHP industry especially must define its role in a circular economy, push research and consider establishing pilot plants. Cooperation with waste companies and authorities should also be continued and further developed.

The industry also needs to consider that recycling is not the only way to become circular, but reuse, reduction and redesign are other strategies to implement when possible. There are already some alternative reusable products on the market. However, most consumers are not willing to adopt reusable products yet, which can be seen in the current adoption rates. That is why research on recycling of single-use AHPs continuous to be relevant.

8. REFERENCES

Alda-Vidal, C., Browne, A. L., & Hoolohan, C. (2020). "Unflushables": Establishing a global agenda for action on everyday practices associated with sewer blockages, water quality, and plastic pollution. In *Wiley Interdisciplinary Reviews: Water* (Vol. 7, Issue 4). John Wiley and Sons Inc. https://doi.org/10.1002/wat2.1452

Anand, U., Vithanage, M., Rajapaksha, A. U., Dey, A., Varjani, S., & Bontempi, E. (2022). Inapt management of menstrual hygiene waste (MHW): An urgent global environmental and public health challenge in developed and developing countries. *Heliyon*, *8*(7), e09859. https://doi.org/10.1016/j.heliyon.2022.e09859

ANSES. (2018). *OPINION of the French Agency for Food, Environmental and Occupational Health & Safety on the safety of feminine hygiene products*.

Arena, U., Ardolino, F., & di Gregorio, F. (2016). Technological, environmental and social aspects of a recycling process of post-consumer absorbent hygiene products. *Journal of Cleaner Production*, *127*, 289–301. https://doi.org/10.1016/j.jclepro.2016.03.164

Aumonier, Simon., & Collins, Michael. (2005). *Life cycle assessment of disposable and reusable nappies in the UK*. Environment Agency.

Blair, L. A. G., Bajón -Fernández, Y., & Villa, R. (2022). An exploratory study of the impact and potential of menstrual hygiene management waste in the UK. *Cleaner Engineering and Technology*, *7*. https://doi.org/10.1016/j.clet.2022.100435

Cabrera, A., & Garcia, R. (2019). *SINGLE-USE MENSTRUAL PRODUCTS, BABY NAPPIES & WET WIPES*.

Colón, J., Ruggieri, L., Sánchez, A., González, A., & Puig, I. (2011). Possibilities of composting disposable diapers with municipal solid wastes. *Waste Management and Research*, *29*(3), 249–259. https://doi.org/10.1177/0734242X10364684

Committee on Adolescent Health Care. (2015). *Menstruation in Girls and Adolescents: Using the Menstrual Cycle as a Vital Sign*. http://www.acog.org/-/media/Practice-

Cordella, M., Bauer, I., Lehmann, A., Schulz, M., & Wolf, O. (2015). Evolution of disposable baby diapers in Europe: Life cycle assessment of environmental impacts and identification of key areas of improvement. *Journal of Cleaner Production*, *95*, 322–331. https://doi.org/10.1016/j.jclepro.2015.02.040

Dornbusch, H.-J., Böhm, C., Wüst, S., Zwisele, B., Siepenkothen, H.-J., & Kanthak, M. (2020). *Vergleichende Analyse von Siedlungsrestabfällen aus repräsentativen Regionen in Deutsch-land zur Bestimmung des Anteils an Problemstoffen und verwertbaren Materialien*.

EDANA (2013). LCA & Trend Analysis of incontinence products.

EDANA (2015). Sustainability Report. 4th Edition. https://www.edana.org/docs/default-source/sustainability/edana-sustainability-report---2015.pdf?sfvrsn=e58c600a_2

EMBRACED. (2020). *Closing the loop of Absorbent Hygiene Products-Blueprint for the replication of the EMBRACED recycling model*. www.embraced.eu/

Gerina-Ancane, A., & Eiduka, A. (2016). *RESEARCH AND ANALYSIS OF ABSORBENT HYGIENE PRODUCT (AHP) RECYCLING*.

Hait, A., & Powers, S. E. (2019). The value of reusable feminine hygiene products evaluated by comparative environmental life cycle assessment. *Resources, Conservation and Recycling*, *150*. https://doi.org/10.1016/j.resconrec.2019.104422

Khoo, S. C., Phang, X. Y., Ng, C. M., Lim, K. L., Lam, S. S., & Ma, N. L. (2019). Recent technologies for treatment and recycling of used disposable baby diapers. In *Process Safety and Environmental Protection* (Vol. 123, pp. 116–129). Institution of Chemical Engineers. https://doi.org/10.1016/j.psep.2018.12.016

Leroy, Y., Yannou, B., Murthy, L., Lallmahomed, A., & Yannou-Le Bris, G. (2016). WHICH HYGIENIC PRODUCTS FOR WHICH CONTINENT? DESIGN FOR USAGE AND SUSTAINABILITY. In *Dubrovnik-Croatia*.

Mendoza, J. M. F., Popa, S. A., D'Aponte, F., Gualtieri, D., & Azapagic, A. (2019). Improving resource efficiency and environmental impacts through novel design and manufacturing of disposable baby diapers. *Journal of Cleaner Production*, *210*, 916–928. https://doi.org/10.1016/j.jclepro.2018.11.046

NHS European Office. (2018). *Annual report 2017/18*.

Ntekpe, M. E., Mbong, E. O., Edem, E. N., & Hussain, S. (2020). *Disposable Diapers: Impact of Disposal Methods on Public Health and the Environment*. https://www.researchgate.net/publication/346641495

Płotka-Wasylka, J., Makoś-Chełstowska, P., Kurowska-Susdorf, A., Treviño, M. J. S., Guzmán, S. Z., Mostafa, H., & Cordella, M. (2022). End-of-life management of single-use baby diapers: Analysis of technical, health and environment aspects. In *Science of the Total Environment* (Vol. 836). Elsevier B.V. https://doi.org/10.1016/j.scitotenv.2022.155339

Sasidaran, S., Kachoria, P., Raj, A., Ramalingam, S., Stoner, B. R., Sellgren, K. L., & Grego, S. (2021). Physical properties of menstrual hygiene waste as feedstock for onsite disposal technologies. *Journal of Water Sanitation and Hygiene for Development*, *11*(3), 474–482. https://doi.org/10.2166/washdev.2021.262

Takaya, C. A., Cooper, I., Berg, M., Carpenter, J., Muir, R., Brittle, S., & Sarker, D. K. (2019). Offensive waste valorisation in the UK: Assessment of the potentials for absorbent hygiene product (AHP) recycling. *Waste Management*, *88*, 56–70. https://doi.org/10.1016/j.wasman.2019.03.022

Takaya, C., Carpenter, J., Muir, R., Brittle, S., Sarker, D. K., & Cooper, I. (2020). Safety and passivation of faecal contamination in waste. *Access Microbiology*, *2*(7A). https://doi.org/10.1099/acmi.ac2020.po0112

Thaman, L. A., & Eichenfield, L. F. (2014). Diapering habits: A global perspective. In *Pediatric Dermatology* (Vol. 31, Issue s1, pp. 15–18). https://doi.org/10.1111/pde.12468

Theilen, U., Herbert, S., Weigand, H., Heynemann, J. (2016). Entwicklung eines energetischen und stofflichen Verwertungskonzeptes für Inkontinenzabfälle: Kurztitel: InkoCycle: Abschlussbericht. https://doi.org/10.2314/GBV:871628260

UBA Evaluation 2022. (2022). https://www.umweltbundesamt.de/en/topics/water/drinking-water/distributing-drinking-water/evaluation-criteria-guidelines

UNEP. (2021a). *vast majority of [single use-menstrual products] are landfilled or incinerated*.

UNEP. (2021b). *vast majority of [single use-menstrual products] are landfilled or incinerated*.

Velasco Perez, M., Sotelo Navarro, P. X., Vazquez Morillas, A., Espinosa Valdemar, R. M., & Hermoso Lopez Araiza, J. P. (2021). Waste management and environmental impact of absorbent hygiene products: A review. In *Waste Management and Research* (Vol. 39, Issue 6, pp. 767–783). SAGE Publications Ltd. https://doi.org/10.1177/0734242X20954271

Wagner, J., Steinmetzer, S., Theophil, L., Strues, A.-S., Kösegi, N., & Hoyer, S. (2022). *Evaluation der Erfassung und Verwertung ausgewählter Abfallströme zur Fortentwicklung der Kreislaufwirtschaft Abschlussbericht von*.

Worldwide Adult Incontinence Products Industry to 2030- Rising Number of People Suffering with Incontinence is Driving Growth. (2022).

Zero waste europe. (2021). *It's time to clear out plastic & chemicals from nappies, not the poo*.

Note: References used to understand the identified initiatives are indicated as footnotes in the factsheets (see Appendix I).

9. ANNEX

APPENDIX 1 –FACTSHEETS OF COLLECTION SYSTEMS AND SEPARATION AND RECYCLING TECHNOLOGIES

EXCLUSIVELY COLLECTION SCHEMES

CLEAN GREEN FUTURE

Indicators	Type of content and preferred unit	Clean Green Future
Technical data		Introduction of a fortnightly waste collection service for disposable nappies and other absorbent hygiene products (AHPs) such as incontinence waste care products.
Collection/Separation/Recycling technology		Collection (recycling)
Origin of waste (e.g., household waste, hospital waste etc.) - mainly important for collection systems		Household waste
Process description - Process type - Involved technology and tools - Dealing with hazardous substances and pathogenic germs - Decontamination techniques	*description*	1) Residents using disposable nappies or other AHPs can register for AHP collection. Residents will then be provided with 60 litre sacks for AHP waste. For residents this is free of charge. 2) Developed "A guide to Implementing an Absorbent Hygiene Product (AHP) collection into your domestic kerbside collection service" (not publicly available); As part of the Clean Green Future initiative, in September 2019, the Pembrokeshire County Council introduced a new subscription-based fortnightly waste collection service for disposable nappies and other absorbent hygiene products (AHPs) such as incontinence waste care products. Other local authorities in Wales also provide for separate collection.
Process objectives	*description*	Collection and treatment of AHPs
Focus/Input material	*list of possible input material*	Collected products: Nappies and nappy sacks, Incontinence care products such as liners, Wipes and paper tissues, Bed and chair pads, Plastic gloves, Disposable aprons, Colostomy/stoma bags, Catheter bags
Output fractions - Target material of process - Resulting recyclates and their applications/markets - Other output materials and their application/markets	*description*	No information identified
Quality/value of output recyclate	*description + ranking if possible (e.g., high, medium, low)*	No information identified
Required skills for operation	*description*	No information identified
Collection/Separation/Recycling capacity	*tons/year*	No information identified
Operational input (e.g., energy, water)	*in MWh, in litres etc.*	No information identified
Potential environmental savings (GHG etc.)	*in CO_2/tons, CO_2-eq/ton, in €/ton etc.*	No information identified

Level of technological maturity	*Blueprint/concept OR Lab test, prototype OR Demonstration/low scale/not fully developed OR Full-scale operation*	No information identified
Commercial data		
Level of commercial maturity	*description*	No information identified
Investment costs	*in €*	No information identified
Operational costs	*in €/ton*	No information identified
Policy and regulatory data		
Intellectual property rights	*description*	No information identified
Level of policy attention in EU	*description*	No information identified
Regulatory considerations	*description*	No information identified
Project data		
Description and name of Initiative/plant/type of organisation/vendor	*description*	The Clean Green Future (Wales, UK) support from the Welsh Governments Small Business Research Initiative (SBRI).
Involved parties and their roles (e.g., authorities, waste companies)	*description*	No information identified
Geographical area/coverage	*region/country*	Wales, UK
Type of project	*indicate if pilot project, research project etc.*	No information identified
Start date and duration of initiative/project	*month/year*	Procurement notice for a kerbside collection has been published on sell2wales.gov in November 2020.
Funding and support received for initiative/project	*in €*	No information identified
Data on transfer and scale up		
Suitability of technologies to AHPs (e.g., diapers, incontinence & female hygiene products) or specific fractions	*description*	No information identified
Application in other industry sectors/to other products	*description*	No information identified
Possibility for scale-up	*description*	No information identified
Challenges/potential barriers	*description*	No information identified
Dependencies on specific collection systems or other systems	*description*	No information identified
Sources: 1) Clean Green Future https://cleangreenfuture.wales/procurement 2) Clean, Green, Future Project Moves Forward Clean, Green, Future Project Moves Forward - NEWS.WALES		

MEDISORT

Indicators	Type of content and preferred unit	Medisort
Technical data		Medisort collects, processes and disposes of healthcare waste including single-use instruments, sharps, medicinal waste and absorbent hygiene products from a range of customers.
Collection/Separation/Recycling technology		Collection (recycling)
Origin of waste (e.g., household waste, hospital waste etc.) - mainly important for collection systems		Research focus on AHPs in care homes Scheme in the Arun district in the south of England collecting nappies, feminine hygiene products, PPE and incontinence waste from households.
Process description - Process type - Involved technology and tools - Dealing with hazardous substances	*description*	Weekly collection in Arun District of soiled AHPs and distributions of Yellow Tiger replacement bags.

and pathogenic germs - Decontamination techniques		Chemical disinfection with hypochlorite of sodium and calcium. "At Medisort, we value sharing ideas!"
Process objectives	*description*	No information identified
Focus/Input material	*list of possible input material*	No information identified
Output fractions - Target material of process - Resulting recyclates and their applications/markets - Other output materials and their application/markets	*description*	No information identified
Quality/value of output recyclate	*description + ranking if possible (e.g., high, medium, low)*	No information identified
Required skills for operation	*description*	No information identified
Collection/Separation/Recycling capacity	*tons/year*	No information identified
Operational input (e.g., energy, water)	*in MWh, in litres etc.*	No information identified
Potential environmental savings (GHG etc.)	*in CO_2/tons, CO_2-eq/ton, in €/ton etc.*	No information identified
Level of technological maturity	*Blueprint/concept OR Lab test, prototype OR Demonstration/low scale/not fully developed OR Full-scale operation*	Demonstration/low scale/not fully developed
Commercial data		
Level of commercial maturity	*description*	No information identified
Investment costs	*in €*	No information identified
Operational costs	*in €/ton*	A number of factors influence the viability of AHP recycling including cost-effective sorting and separation, public perceptions, and sustainable recyclate market outlets.
Policy and regulatory data		
Intellectual property rights	*description*	No information identified
Level of policy attention in EU	*description*	No information identified
Regulatory considerations	*description*	No information identified
Project data		
Description and name of Initiative/plant/type of organisation/vendor	*description*	Medisort and University of Brighton (researcher Chibi Takaya)
Involved parties and their roles (e.g., authorities, waste companies)	*description*	No information identified
Geographical area/coverage	*region/country*	UK
Type of project	*indicate if pilot project, research project etc.*	No information identified
Start date and duration of initiative/project	*month/year*	The project was in its nascent stages, conducting lab test at the University in March 2019, and is still ongoing and is expected to run until Spring 2022. Start of a trial with the Arun District Council in May 2021. Start in another West Sussex district in September.
Funding and support received for initiative/project	*in €*	Support from the Profitnet group and Green Growth Platform.
Data on transfer and scale up		
Suitability of technologies to AHPs (e.g., diapers, incontinence & female hygiene products) or specific fractions	*description*	No information identified
Application in other industry sectors/to other products	*description*	No information identified

Possibility for scale-up	*description*	No information identified
Challenges/potential barriers	*description*	No information identified
Dependencies on specific collection systems or other systems	*description*	No information identified
Sources: 1) Medisort https://www.medisort.co.uk/ 2) AHP trials to continue FTF https://www.medisort.co.uk/2022/08/31/ahp-trials-to-continue-ftf/ 3) Tackling nappy waste: Decontamination and recycling of absorbent hygiene wastes from the healthcare sector Tackling nappy waste: Decontamination and recycling of absorbent hygiene wastes from the healthcare sector — The University of Brighton		

COPENHAGEN CIRCULAR

Indicators	Type of content and preferred unit	Copenhagen Circular
Technical data		
Collection/Separation/Recycling technology		Collection/Sorting
Origin of waste (e.g., household waste, hospital waste etc.) - mainly important for collection systems		Household waste
Process description - Process type - Involved technology and tools - Dealing with hazardous substances and pathogenic germs - Decontamination techniques	*description*	Collection Sorting by ECONET Specific pilot also on compostable diapers. Results of the pilots shall be used to generate sufficient information to develop a tender for a diaper recycling solution in 2023.
Process objectives	*description*	Objective defined in the waste and resource management plan of Copenhagen: collecting and recycling 2,500 tons of diaper waste annually by 2024.
Focus/Input material	*list of possible input material*	Pilot 1: diapers. Pilot 2: compostable diapers in selected kindergartens.
Output fractions - Target material of process - Resulting recyclates and their applications/markets - Other output materials and their application/markets	*description*	No information identified
Quality/value of output recyclate	*description + ranking if possible (e.g., high, medium, low)*	No information identified
Required skills for operation	*description*	No information identified
Collection/Separation/Recycling capacity	*tons/year*	No information identified
Operational input (e.g., energy, water)	*in MWh, in litres etc.*	No information identified
Potential environmental savings (GHG etc.)	*in CO2/tons, CO2-eq/ton, in €/ton etc.*	No information identified
Level of technological maturity	*Blueprint/concept OR Lab test, prototype OR Demonstration/low scale/not fully developed*	No information identified

	OR Full-scale operation	
Commercial data		
Level of commercial maturity	*description*	No information identified
Investment costs	*in €*	No information identified
Operational costs	*in €/ton*	No information identified
Policy and regulatory data		
Intellectual property rights	*description*	No information identified
Level of policy attention in EU	*description*	No information identified
Regulatory considerations	*description*	No information identified
Project data		
Description and name of Initiative/plant/type of organisation/vendor	*description*	Copenhagen Circular, ECONET
Involved parties and their roles (e.g., authorities, waste companies)	*description*	No information identified
Geographical area//coverage	*region/country*	No information identified
Type of project	*indicate if pilot project, research project etc.*	No information identified
Start date and duration of initiative/project	*month/year*	September to December 2022
Funding and support received for initiative/project	*in €*	No information identified
Data on transfer and scale up		
Suitability of technologies to AHPs (e.g., diapers, incontinence & female hygiene products) or specific fractions	*description*	No information identified
Application in other industry sectors/to other products	*description*	No information identified
Possibility for scale-up	*description*	Aim is to implement a system for the whole city.
Challenges//potential barriers	*description*	No information identified
Dependencies on specific collection systems or other systems	*description*	No information identified
Sources: 1) Diaper waste collection trial in Copenhagen https://circularcph.cphsolutionslab.dk/cc/diapers/diaper-waste-collection-trial		

ONTEX AND WOOSH

Indicators	Type of content and preferred unit	Ontex and Woosh
Technical data		
Collection/Separation/Recycling technology		Collection and recycling (planned)
Origin of waste (e.g., household waste, hospital waste etc.) - mainly important for collection systems		Diapers from day care centres
Process description - Process type - Involved technology and tools - Dealing with hazardous substances and pathogenic germs - Decontamination techniques	*description*	Collection of diapers. Plans to help set-up the first diaper recycling plant in Belgium for diapers.
Process objectives	*description*	No information identified
Focus/Input material	*list of possible input material*	Diapers from day care centres
Output fractions - Target material of process - Resulting recyclates and their applications/markets - Other output materials and their application/markets	*description*	Depends on the recycling technology that will be installed in BE region.
Quality/value of output recyclate	*description + ranking if possible (e.g., high, medium, low)*	No information identified
Required skills for operation	*description*	No information identified

Collection/Separation/Recycling capacity	*tons/year*	Collecting used diapers from more than 200 day care centres; plans to expand the service to more than 1,000 day care centres by 2024.
Operational input (e.g., energy, water)	*in MWh, in litres etc.*	No information identified
Potential environmental savings (GHG etc.)	*in CO2/tons, CO2-eq/ton, in €/ton etc.*	No information identified
Level of technological maturity	*Blueprint/concept OR Lab test, prototype OR Demonstration/low scale/not fully developed OR Full-scale operation*	No information identified
Commercial data		
Level of commercial maturity	*description*	No information identified
Investment costs	*in €*	No information identified
Operational costs	*in €/ton*	No information identified
Policy and regulatory data		
Intellectual property rights	*description*	No information identified
Level of policy attention in EU	*description*	No information identified
Regulatory considerations	*description*	No information identified
Project data		
Description and name of Initiative/plant/type of organisation/vendor	*description*	Ontex Group, Woosh
Involved parties and their roles (e.g., authorities, waste companies)	*description*	No information identified
Geographical area/coverage	*region/country*	Belgium
Type of project	*indicate if pilot project, research project etc.*	StartUp
Start date and duration of initiative/project	*month/year*	January 2021, ongoing
Funding and support received for initiative/project	*in €*	No information identified
Data on transfer and scale up		
Suitability of technologies to AHPs (e.g., diapers, incontinence & female hygiene products) or specific fractions	*description*	No information identified
Application in other industry sectors/to other products	*description*	No information identified
Possibility for scale-up	*description*	Woosh aims to add 40 day cares to its network every month in 2022. The ultimate goal is to create favourable conditions for the first diaper recycling facility in the Flanders region of Belgium.
Challenges/potential barriers	*description*	No information identified
Dependencies on specific collection systems or other systems	*description*	No information identified
Sources: 1) Ontex supports Woosh to make diaper recycling a reality in Belgium Ontex supports startup Woosh to make diaper recycling a reality in Belgium		

Collection, separation and recycling

DIAPER RECYCLING EUROPE (KNOWASTE TECHNOLOGIES INC.)

Indicators	Type of content and preferred unit	Knowaste Technologies Inc.
Technical data		

Collection/Separation/Recycling technology		Collection/Separation/Recycling
Origin of waste (e.g., household waste, hospital waste etc.) - mainly important for collection systems		Operators collect absorbent hygiene products (AHPs) from washrooms, hospitals, elderly nursing facilities and childcare nurseries. They offer enhanced kerbside services for families and households that use complimentary, bi-weekly AHP kerbside and reduced capacity residual collections.
Process description - Process type - Involved technology and tools - Dealing with hazardous substances and pathogenic germs - Decontamination techniques	*description*	Materials are collected or delivered; post-consumer diapers are sterilized. AHPs are shredded and forwarded to a pulper to start processing. Washing process with sanitation and exposure to chemical treatment to deactivate the super-absorbent polymers of the diapers, followed by a plastic removal and separate processing. Filtration and cleaning of plastic components to compress them into small pellets. These can be sold for easy reuse. Remnants are screened for plastic particles and other organic material and are treated with inorganic salt to deactivate SAP. Precise washing, cleaning and screening of the remaining fibres creates a long-length fibre to be used in several products. With this technology, the SAP remains with the cellulose fibre.
Process objectives	*description*	The object is to collect, separate and recycle AHWs (Absorbent Hygiene Wastes).
Focus/Input material	*list of possible input material*	AHW (especially Plastic and Fibre/pulp)
Output fractions - Target material of process - Resulting recyclates and their applications/markets - Other output materials and their application/markets	*description*	Recycled plastic pellets used for collection containers, roof tops. Fibre used for pet litter/bedding, cardboard packaging, concrete and tarmac additive, bricks, insulation materials. Water is captured and recycled back into the system. The SAP was recovered.
Quality/value of output recyclate	*description + ranking if possible (e.g., high, medium, low)*	They say "excellent".
Required skills for operation	*description*	No information identified
Collection/Separation/Recycling capacity	*tons/year*	Plastics: 4,000 tpa (11 % of plant capacity) per plant into plastic pellets. Fibre: 8,000 tpa (22 % of plant capacity) per plant providing a range of recycled products. Knowaste has gained considerable experience designing, building and operating a number of facilities, large and small, with a capacity range for 36,000 to 70,000 t per year.

		Now sharing knowledge through consulting services and licensing arrangements.
Operational input (e.g., energy, water)	*in MWh, in litres etc.*	**Water**, sea salt, CaCl2, alum, NaCl
Potential environmental savings (GHG etc.)	*in CO_2/tons, CO_2-eq/ton, in €/ton etc.*	626 CO_2-eq per tonne AHW saved in comparison to landfill. Reduction of carbon emissions up to 70 % compared to landfill and energetic recovery possible.
Level of technological maturity	*Blueprint/concept OR Lab test, prototype OR Demonstration/low scale/not fully developed OR Full-scale operation*	Full-scale operation
Commercial data		
Level of commercial maturity	*description*	No information identified
Investment costs	*in €*	No information identified
Operational costs	*in €/ton*	High treatment technology costs, due to the complicated sterilization process. Process is not self-contained.
Policy and regulatory data		
Intellectual property rights	*description*	No information identified
Level of policy attention in EU	*description*	No information identified
Regulatory considerations	*description*	No information identified
Project data		
Description and name of Initiative/plant/type of organisation/vendor	*description*	Knowaste LLC Company no longer operational 2020: Change of business model to licensing of the technology by territory
Involved parties and their roles (e.g., authorities, waste companies)	*description*	No information identified
Geographical area/coverage	*region/country*	Canada Knowaste, UK, the Netherlands (Diaper Recycling Europe), South Africa, also working in Korea, Japan, US Plans for a new plant in London were rejected.
Type of project	*indicate if pilot project, research project etc.*	Recycling
Start date and duration of initiative/project	*month/year*	Started in 1989 with continuous improvements. Today the company is no longer in operation.
Funding and support received for initiative/project	*in €*	No information identified
Data on transfer and scale up		
Suitability of technologies to AHPs (e.g., diapers, incontinence & female hygiene products) or specific fractions	*description*	Approved recycling system
Application in other industry sectors/to other products	*description*	No information identified
Possibility for scale-up	*description*	High (using licensing arrangements)
Challenges/potential barriers	*description*	Very high operational costs and odour concerns Problems keeping up the capacity utilisation, because of high competition with existing contracts with energy recovery plants.
Dependencies on specific collection systems or other systems	*description*	No information identified
Sources: 1) Feasibility of Superabsorbent Polymer Recycling in Disposable Absorbent Hygiene Products		

Feasibility of Superabsorbent Polymer Recycling in Disposable Absorbent Hygiene Products (umich.edu)

2) Diaper Recycling: let's not wait any longer
https://diaperrecyclingeurope.eu/en/homepage/

3) UBA Evaluation der Erfassung und Verwertung ausgewählter Abfallströme zur Fortentwicklung der Kreislaufwirtschaft
https://www.umweltbundesamt.de/sites/default/files/medien/479/publikationen/texte_31-2022_evaluation_der_erfassung_und_verwertung_ausgewaehlter_abfallstroeme_zur_fortentwicklung_der_kreislaufwirtschaft.pdf

4) The Knowaste Recycling Process
https://www.knowaste.com/the-knowaste-recycling-process.html

5) Pilot trial on separation conditions for diaper recycling
Pilot trial on separation conditions for diaper recycling - ScienceDirect

6) RESEARCH AND ANALYSIS OF ABSORBENT HYGIENE PRODUCT (AHP) RECYCLING
https://www.tf.llu.lv/conference/proceedings2016/Papers/N175.pdf

TERRA PRETA

Indicators	Type of content and preferred unit	Terra Preta (biotechnological approach)
Technical data		
Collection/Separation/Recycling technology		Collection and Recycling
Origin of waste (e.g., household waste, hospital waste etc.) - mainly important for collection systems		Special collection system from households.
Process description **- Process type** **- Involved technology and tools** **- Dealing with hazardous substances and pathogenic germs** **- Decontamination techniques**	*description*	Biodegradable inlay for reusable diapers (100 % plastic free and bio-based, containing only natural fibres and no parts made of oil). After use, the inlays are fed into a worm composter and afterwards converted into humus using the Terra Preta method. Terra Preta Method: Microorganisms, charcoal powder and excrements are collected in a barrels and fermented under anaerobic conditions for approximately 6 weeks (possibly longer). The fermented mass is then buried under soil together with more charcoal (up to 10-15 volume-%) until no more waste is recognisable.
Process objectives	*description*	Improvement of soil quality and reduction of household waste.
Focus/Input material	*list of possible input material*	Biodegradable Diapers
Output fractions **- Target material of process** **- Resulting recyclates and their applications/markets** **- Other output materials and their application/markets**	*description*	Output: Nutrient-rich humus from biodegraded diapers.
Quality/value of output recyclate	*description + ranking if possible (e.g., high, medium, low)*	No information identified
Required skills for operation	*description*	No information identified
Collection/Separation/Recycling capacity	*tons/year*	No information identified
Operational input (e.g., energy, water)	*in MWh, in litres etc.*	No information identified
Potential environmental savings (GHG etc.)	*in CO_2/tons, CO_2-eq/ton, in €/ton etc.*	No information identified
Level of technological maturity	*Blueprint/concept OR Lab test, prototype*	Further research is needed

	OR Demonstration/low scale/not fully developed *OR Full-scale operation*	
Commercial data		
Level of commercial maturity	*description*	No information identified
Investment costs	*in €*	No information identified
Operational costs	*in €/ton*	No information identified
Policy and regulatory data		
Intellectual property rights	*description*	No information identified
Level of policy attention in EU	*description*	No information identified
Regulatory considerations	*description*	No information identified
Project data		
Description and name of Initiative/plant/type of organisation/vendor	*description*	DYCLE
Involved parties and their roles (e.g., authorities, waste companies)	*description*	No information identified
Geographical area/coverage	*region/country*	Germany
Type of project	*indicate if pilot project, research project etc.*	No information identified
Start date and duration of initiative/project	*month/year*	No information identified
Funding and support received for initiative/project	*in €*	No information identified
Data on transfer and scale up		
Suitability of technologies to AHPs (e.g., diapers, incontinence & female hygiene products) or specific fractions	*description*	No information identified
Application in other industry sectors/to other products	*description*	No information identified
Possibility for scale-up	*description*	No information identified
Challenges/potential barriers	*description*	No information identified
Dependencies on specific collection systems or other systems	*description*	No information identified
Sources: 1) Diaper Cycle – Windelkreislauf https://dycle.org/de		

NAPPICYCLE

Indicators	Type of content and preferred unit	Nappicycle
Technical data		1) Providing kerbside collection to all 22 Local Authorities in Wales for AHP. 2) Treatment of AHP waste.
Collection/Separation/Recycling technology		Collection/recycling
Origin of waste (e.g., household waste, hospital waste etc.) - mainly important for collection systems		No information identified
Process description - Process type - Involved technology and tools - Dealing with hazardous substances and pathogenic germs - Decontamination techniques	*description*	Through a hydro-recovery process, cellulose and plastic materials are recovered for future use.
Process objectives	*description*	Aim was to provide a low impact, cost-efficient AHP recycling facility in Wales.
Focus/Input material	*list of possible input material*	Domestic nappy and AHP incontinence wastes
Output fractions - Target material of process	*description*	Cellulose fibre: used e.g., for the production of fibre boards and acoustic panelling.

- Resulting recyclates and their applications/markets - Other output materials and their application/markets		Plastics: sent to secondary re-processors for recycling.
Quality/value of output recyclate	*description + ranking if possible (e.g., high, medium, low)*	No information identified
Required skills for operation	*description*	No information identified
Collection/Separation/Recycling capacity	*tons/year*	< 5,000 tons/year (total input not only diapers)
Operational input (e.g., energy, water)	*in MWh, in litres etc.*	No information identified
Potential environmental savings (GHG etc.)	*in CO_2/tons, CO_2-eq/ton, in €/ton etc.*	No information identified
Level of technological maturity	*Blueprint/concept OR Lab test, prototype OR Demonstration/low scale/not fully developed OR Full-scale operation*	No information identified
Commercial data		
Level of commercial maturity	*description*	No information identified
Investment costs	*in €*	No information identified
Operational costs	*in €/ton*	No information identified
Policy and regulatory data		
Intellectual property rights	*description*	No information identified
Level of policy attention in EU	*description*	No information identified
Regulatory considerations	*description*	No information identified
Project data		
Description and name of Initiative/plant/type of organisation/vendor	*description*	NappiCycle
Involved parties and their roles (e.g., authorities, waste companies)	*description*	Partner: Natural UK Ltd Partner: Pura (funded) Awareness raising: Asda supermarket
Geographical area/coverage	*region/country*	Wales, UK
Type of project	*indicate if pilot project, research project etc.*	No information identified
Start date and duration of initiative/project	*month/year*	No information identified
Funding and support received for initiative/project	*in €*	No information identified
Data on transfer and scale up		
Suitability of technologies to AHPs (e.g., diapers, incontinence & female hygiene products) or specific fractions	*description*	No information identified
Application in other industry sectors/to other products	*description*	No information identified
Possibility for scale-up	*description*	No information identified
Challenges/potential barriers	*description*	No information identified
Dependencies on specific collection systems or other systems	*description*	No information identified
Sources: 1) NappiCycle https://www.nappicycle.co.uk/		

ENVIROCOMP COMPOSTING PLANT' IN ROCHESTER

Indicators	Type of content and preferred unit	Envirocomp composting plant' in Rochester
Technical data		

Collection/Separation/Recycling technology		Composting
Origin of waste (e.g., household waste, hospital waste etc.) - mainly important for collection systems		Household waste
Process description - Process type - Involved technology and tools - Dealing with hazardous substances and pathogenic germs - Decontamination techniques	*description*	Nappy collection in pre-paid compostable bin bags from commercial premises by sister company, Cannon Hygiene. Nappies are shredded. Shredded nappy waste is composted with green waste for non-food land restoration using a patented in-vessel composting technology invented by HotRot Organic Solutions. Plastics are separated for Energy from Waste (EfW) use.
Process objectives	*description*	No information identified
Focus/Input material	*list of possible input material*	Diapers
Output fractions - Target material of process - Resulting recyclates and their applications/markets - Other output materials and their application/markets	*description*	Nappies to be composted. Plastic for energy recovery.
Quality/value of output recyclate	*description + ranking if possible (e.g., high, medium, low)*	No information identified
Required skills for operation	*description*	No information identified
Collection/Separation/Recycling capacity	*tons/year*	Composter processed about 4.6 million nappies (about 700 t) in 2014.
Operational input (e.g., energy, water)	*in MWh, in litres etc.*	No information identified
Potential environmental savings (GHG etc.)	*in CO_2/tons, CO_2-eq/ton, in €/ton etc.*	No information identified
Level of technological maturity	*Blueprint/concept OR Lab test, prototype OR Demonstration/low scale/not fully developed OR Full-scale operation*	The company no longer composts the diapers. They first switched to landfilling and later stopped the project.[38]
Commercial data		
Level of commercial maturity	*description*	No information identified
Investment costs	*in €*	No information identified
Operational costs	*in €/ton*	No information identified
Policy and regulatory data		
Intellectual property rights	*description*	Using a patented in-vessel composting technology invented by HotRot Organic Solutions.
Level of policy attention in EU	*description*	No information identified
Regulatory considerations	*description*	No information identified
Project data		
Description and name of Initiative/plant/type of organisation/vendor	*description*	Envirocomp
Involved parties and their roles (e.g., authorities, waste companies)	*description*	Karl and Karen Upstone HotRot Organic Solutions
Geographical area/coverage	*region/country*	Rochester UK
Type of project	*indicate if pilot project, research project etc.*	No information identified
Start date and duration of initiative/project	*month/year*	Project started in 2013 and did not continue

[38] https://www.stuff.co.nz/business/89182483/environmentally-friendly-nappy-disposal-service-sends-waste-to-landfill

Funding and support received for initiative/project	*in €*	No information identified
Data on transfer and scale up		
Suitability of technologies to AHPs (e.g., diapers, incontinence & female hygiene products) or specific fractions	*description*	No information identified
Application in other industry sectors/to other products	*description*	No information identified
Possibility for scale-up	*description*	No
Challenges/potential barriers	*description*	Composting was not viable and the presence of plastics in the compost was problematic.
Dependencies on specific collection systems or other systems	*description*	No information identified
Sources: 1) Offensive waste valorisation in the UK: Assessment of the potentials for absorbent hygiene product (AHP) recycling [Offensive waste valorisation in the UK: Assessment of the potentials for absorbent hygiene product (AHP) recycling - ScienceDirect] 2) Nappy Composting Plant to Treat Hygiene Waste in Rochester [Nappy Composting Plant to Treat Hygiene Waste in Rochester | WMW (waste-management-world.com)]		

DIAPERRECYCLE

Indicators	Type of content and preferred unit	DiaperRecycle
Technical data		1) Collection (registration and payment per month) 2) Treatment of nappies: separation of plastic and the fibre: - The plastic goes to plastic recyclers, - From the super absorbent fibre, cat litter is produced. The fibre can also be composted by industrial composters.
Collection/Separation/Recycling technology		Collection/recycling
Origin of waste (e.g., household waste, hospital waste etc.) - mainly important for collection systems		Post-consumer nappies (biodegradable nappies not accepted)
Process description - Process type - Involved technology and tools - Dealing with hazardous substances and pathogenic germs - Decontamination techniques	*description*	1) Collection system 2) Shredding and washing Output: plastic granulates
Process objectives	*description*	No information identified
Focus/Input material	*list of possible input material*	Nappies
Output fractions - Target material of process - Resulting recyclates and their applications/markets - Other output materials and their application/markets	*description*	Plastic: goes to plastic recyclers, Super absorbent fibre: cat litter is being produced/or can be industrially composted
Quality/value of output recyclate	*description + ranking if possible (e.g., high, medium, low)*	No information identified
Required skills for operation	*description*	No information identified
Collection/Separation/Recycling capacity	*tons/year*	4300 diaper waste subscribers per plant 7.5 M nappies per year diverted from landfill 1.6 M litres per year cat litter produced AUS$ 2.5 M revenue per year per plant.
Operational input (e.g., energy, water)	*in MWh, in litres etc.*	No information identified

Potential environmental savings (GHG etc.)	*in CO_2/tons, CO_2-eq/ton, in €/ton etc.*	No information identified
Level of technological maturity	*Blueprint/concept OR Lab test, prototype OR Demonstration/low scale/not fully developed OR Full-scale operation*	Demonstration/low scale/not fully developed
Commercial data		
Level of commercial maturity	*description*	No information identified
Investment costs	*in €*	No information identified
Operational costs	*in €/ton*	No information identified
Policy and regulatory data		
Intellectual property rights	*description*	No information identified
Level of policy attention in EU	*description*	No information identified
Regulatory considerations	*description*	No information identified
Project data		
Description and name of Initiative/plant/type of organisation/vendor	*description*	Diaper Recycle Kelland Environmental Technology Pty Ltd.
Involved parties and their roles (e.g., authorities, waste companies)	*description*	No information identified
Geographical area/coverage	*region/country*	Australia
Type of project	*indicate if pilot project, research project etc.*	Start-up company
Start date and duration of initiative/project	*month/year*	No information identified
Funding and support received for initiative/project	*in €*	RISE Innovation Award 2022
Data on transfer and scale up		
Suitability of technologies to AHPs (e.g., diapers, incontinence & female hygiene products) or specific fractions	*description*	No information identified
Application in other industry sectors/to other products	*description*	No information identified
Possibility for scale-up	*description*	No information identified
Challenges/potential barriers	*description*	No information identified
Dependencies on specific collection systems or other systems	*description*	No information identified
Sources: 1) DiaperRecycle https://diaperrecycle.com/ 2) DiaperRecycle Wins RISE Innovation Award DiaperRecycle Wins RISE Innovation Award | Nonwovens Industry (nonwovens-industry.com)		

SOIL MOISTURE RETAINER

Indicators	Type of content and preferred unit	Soil Moisture retainer
Technical data		
Collection/Separation/Recycling technology		Collection, separation and recycling of SAP
Origin of waste (e.g., household waste, hospital waste etc.) - mainly important for collection systems		Collection of diapers from local users **containing only urine.**
Process description - Process type - Involved technology and tools - Dealing with hazardous substances and pathogenic germs - Decontamination techniques	*description*	Soil moisture retainer to regulate irrigation. Manual separation of SAP from cellulose in disposable diapers. Then, a reactivation step: washing and filtering (both 3 times to eliminate salt) and sterilizing at 125 °C for 15 min. Drying for 24 h at 60 °C.

		The swelling ratio of SAP hydrogel [g hydrogel]/[g water]: 189 in 30 min No specific plan for what happens to the rest of the diaper. Suggestions for combining with composting of cellulose content and recycling of plastic components.
Process objectives	*description*	No information identified
Focus/Input material	*list of possible input material*	AHW (Absorbent Hygiene Waste) (especially Plastic and Fibre/pulp)
Output fractions - Target material of process - Resulting recyclates and their applications/markets - Other output materials and their application/markets	*description*	Improved water retention with the use of SAP hydrogel.
Quality/value of output recyclate	*description + ranking if possible (e.g., high, medium, low)*	No information identified
Required skills for operation	*description*	No information identified
Collection/Separation/Recycling capacity	*tons/year*	No information identified
Operational input (e.g., energy, water)	*in MWh, in litres etc.*	No information identified
Potential environmental savings (GHG etc.)	*in CO_2/tons, CO_2-eq/ton, in €/ton etc.*	An improvement of 35 % water retention in sandy soil which was treated with SAP hydrogel can be seen 12 days after the initial irrigation. This reduces the need for constant irrigation. Improvement of water retention in red soil with SAP hydrogel. Irrigation could be reduced by 15-50 %.
Level of technological maturity	*Blueprint/concept OR Lab test, prototype OR Demonstration/low scale/not fully developed OR Full-scale operation*	No information identified
Commercial data		
Level of commercial maturity	*description*	No information identified
Investment costs	*in €*	No information identified
Operational costs	*in €/ton*	No information identified
Policy and regulatory data		
Intellectual property rights	*description*	No information identified
Level of policy attention in EU	*description*	No information identified
Regulatory considerations	*description*	No information identified
Project data		
Description and name of Initiative/plant/type of organisation/vendor	*description*	No information identified
Involved parties and their roles (e.g., authorities, waste companies)	*description*	No information identified
Geographical area/coverage	*region/country*	No information identified
Type of project	*indicate if pilot project, research project etc.*	No information identified
Start date and duration of initiative/project	*month/year*	No information identified
Funding and support received for initiative/project	*in €*	No information identified
Data on transfer and scale up		

Suitability of technologies to AHPs (e.g., diapers, incontinence & female hygiene products) or specific fractions	*description*	No information identified
Application in other industry sectors/to other products	*description*	No information identified
Possibility for scale-up	*description*	No information identified
Challenges/potential barriers	*description*	Not suitable for all types of soil e.g., high salinity or highly alkaline soils. Problems with slow degradation of SAP in the soil which leads to microplastic in the soil due to difficulties removing it from the ground and possible microplastic contamination.
Dependencies on specific collection systems or other systems	*description*	No information identified
Sources: 1) Recovery of hydrogel from baby diaper wastes and its application for enhancing soil irrigation management [Recovery of hydrogel from baby diaper wastes and its application for enhancing soil irrigation management - ScienceDirect] 2) New open-loop recycling approaches for disposable diaper waste [New open-loop recycling approaches for disposable diaper waste (cdnsciencepub.com)] 3) Effects of Super-Absorbent Polymer on Soil Remediation and Crop Growth in Arid and Semi-Arid Areas [Sustainability | Free Full-Text | Effects of Super-Absorbent Polymer on Soil Remediation and Crop Growth in Arid and Semi-Arid Areas (mdpi.com)]		

INKOCYCLE (THM)

Indicators	Type of content and preferred unit	INKOCYCLE (THM)
Technical data		INKOCYCLE: Producing biogas from diapers and incontinence material under anaerobic conditions and recover plastics and superabsorbent polymers from the digestate.
Collection/Separation/Recycling technology		Collection, recycling
Origin of waste (e.g., household waste, hospital waste etc.) - mainly important for collection systems		Diapers and incontinence material from hospitals and care facilities.
Process description - Process type - Involved technology and tools - Dealing with hazardous substances and pathogenic germs - Decontamination techniques	*description*	Waste is separated into incontinence waste + care cloths and non-incontinence waste within the homes for elderly. Weekly collections and sealing of the products with a vacuum system. Shredding of diapers and incontinence material. Material undergoes fermentation in a fermentation reactor (55°C). Fermentation residue is separated by washing and dewatering (using a press). Plastic (polyethylene and polypropylene) is then ready for material recycling or energetic recovery. SAP could be used as soil improvement, but it is not recommended because it is inefficient. Digestate is processed into a substitute fuel. Components of the plant:

		- Shredder as processing step before the fermenter - Fermenter (thermophilic) - Biogas collection (quantity measurement and determination of composition) - Separation units for separating the digestate - Hydro press for separation of the wash water
Process objectives	*description*	Develop a holistic approach: economical, ecological process. Focus also on logistics (e.g., how to integrate this process directly in clinics or care facilities).
Focus/Input material	*list of possible input material*	Diapers and incontinence material from hospitals and care facilities.
Output fractions - Target material of process - Resulting recyclates and their applications/markets - Other output materials and their application/markets	*description*	Biogas Plastic components SAP Substitute fuel
Quality/value of output recyclate	*description + ranking if possible (e.g., high, medium, low)*	Concentration of biogas components: 54-57 % methane, 43-46 % CO_2 and 225-290 ppm H_2S.
Required skills for operation	*description*	No information identified
Collection/Separation/Recycling capacity	*tons/year*	The experimental reactor has a volume of 1 m³. It processes 8 to 12 kg of diapers per day.
Operational input (e.g., energy, water)	*in MWh, in litres etc.*	Water, which is then forwarded to a sewage treatment plant (Significantly increased pollution compared to municipal wastewater). Specific CO2 emissions during collection and other steps in the process are outweighed by the energy production.
Potential environmental savings (GHG etc.)	*in CO_2/tons, CO_2-eq/ton, in €/ton etc.*	Improvement of odour pollution
Level of technological maturity	*Blueprint/concept OR Lab test, prototype OR Demonstration/low scale/not fully developed OR Full-scale operation*	No information identified
Commercial data		
Level of commercial maturity	*description*	No information identified
Investment costs	*in €*	341,320 € at a small project with only 200 t/ a. 2,150,960 € at a project with 3,700 t/a, 25 % of incontinence products of Hesse.
Operational costs	*in €/ton*	303.57 €/t, at a small project with only 200 t/ a. 53.52 €/t, at a project with 3700 t/a, 25 % of incontinence products of Hesse.
Policy and regulatory data		
Intellectual property rights	*description*	No information identified
Level of policy attention in EU	*description*	No information identified
Regulatory considerations	*description*	No information identified
Project data		
Description and name of Initiative/plant/type of organisation/vendor	*description*	Technical University Mittelhessen
Involved parties and their roles (e.g., authorities, waste companies)	*description*	Vitos Wilmüster GmbH, Gießener Ingenieure, Abena GmbH, Theocare GmbH (Bergisch-Gladbach), University Gießen
Geographical area/coverage	*region/country*	No information identified
Type of project	*indicate if pilot project, research project etc.*	No information identified
Start date and duration of initiative/project	*month/year*	Research was finished in 2016

Funding and support received for initiative/project	*in €*	As part of the FHprofunt funding, the Federal Ministry of Education and Research was supporting the project with 312,000 €.
Data on transfer and scale up		
Suitability of technologies to AHPs (e.g., diapers, incontinence & female hygiene products) or specific fractions	*description*	No information identified
Application in other industry sectors/to other products	*description*	No information identified
Possibility for scale-up	*description*	No information identified
Challenges/potential barriers	*description*	No information identified
Dependencies on specific collection systems or other systems	*description*	No information identified
Sources: 1) Inkontinenzabfälle: Verwertung statt Verbrennung Feinstes Biogas aus Windeln https://medizin-und-technik.industrie.de/allgemein/feinstes-biogas-aus-windeln/		

EXXTEND TECHNOLOGY (BY EXXONMOBIL)[39]

Indicators	Type of content and preferred unit	Exxtend technology (by Exxonmobil)
Technical data		
Collection/Separation/Recycling technology		Chemical Recycling
Origin of waste (e.g., household waste, hospital waste etc.) - mainly important for collection systems		Sorted (polyolefins - no PVC) industrial and post-consumer waste
Process description - Process type - Involved technology and tools - Dealing with hazardous substances and pathogenic germs - Decontamination techniques	*description*	Exxtend technology returns difficult to recycle plastics in molecular building blocks for producing new products. Uses advanced recycling (chemical recycling). Uses existing refining installations in addition with new units to breakdown plastic waste and to feed it back into the refinery circuit to make monomers for the polymerization process. Preferred streams of polyolefins such as Chlorine (PVC) or Nitrogen (PA) cannot be processed and the presence of Oxyten (PET, EVOH) reduces the yield of the process. In theory Exxtend technology can deal with hazardous substances and pathogenetic germs provided the waste can be handled safely. High temperatures are used during the refining process. E.g, Vistmaxx (recycled polymers) as input material for diapers - Compatibilization/compounding - Upgrading recycle streams through compounding
Process objectives	*description*	Objective of the process is to recycle waste streams which are difficult to recycle e.g., barrier films and other mixed waste streams.

[39] As example for chemical recycling. Other industry initiatives on chemical recycling are ongoing.

Focus/Input material	*list of possible input material*	All waste streams which are (mainly) polyolefins.
Output fractions - Target material of process - Resulting recyclates and their applications/markets - Other output materials and their application/markets	*description*	Virgin polymers similar to fossil oil-based polymer, which can then be used to make all kinds of new products.
Quality/value of output recyclate	*description + ranking if possible (e.g., high, medium, low)*	High quality.
Required skills for operation	*description*	Refining operation knowledge.
Collection/Separation/Recycling capacity	*tons/year*	Capacity planned for 2025: 500 kT globally
Operational input (e.g., energy, water)	*in MWh, in litres etc.*	Similar to normal refining process to produce PE and PP.
Potential environmental savings (GHG etc.)	*in CO2/tons, CO2-eq/ton, in €/ton etc.*	Replacing oil with plastic waste. Reducing greenhouse gases (CO_2) as plastic waste does not have to be incinerated.
Level of technological maturity	*Blueprint/concept OR Lab test, prototype OR Demonstration/low scale/not fully developed OR Full-scale operation*	Mature (running at industrial scale), scale up limited by the availability of adequate plastic waste streams.
Commercial data		
Level of commercial maturity	*description*	No information identified
Investment costs	*in €*	No information identified
Operational costs	*in €/ton*	No information identified
Policy and regulatory data		
Intellectual property rights	*description*	No information identified
Level of policy attention in EU	*description*	No information identified
Regulatory considerations	*description*	No information identified
Project data		
Description and name of Initiative/plant/type of organisation/vendor	*description*	
Involved parties and their roles (e.g., authorities, waste companies)	*description*	Cylex - waste collector and sorter
Geographical area/coverage	*region/country*	Global
Type of project	*indicate if pilot project, research project etc.*	Using recyclates Enhancing properties of recyclates
Start date and duration of initiative/project	*month/year*	Running
Funding and support received for initiative/project	*in €*	No funding
Data on transfer and scale up		
Suitability of technologies to AHPs (e.g., diapers, incontinence & female hygiene products) or specific fractions	*description*	Provided the separation of the SAP from the AHPs of children/ incontinent adults is possible, AHP waste would be a perfect source for Exxtend technology.
Application in other industry sectors/to other products	*description*	No information identified
Possibility for scale-up	*description*	No information identified
Challenges/potential barriers	*description*	No information identified
Dependencies on specific collection systems or other systems	*description*	No information identified
Sources: 1) Rethink Recycle: Transform polymer waste from diapers to high-value applications [Rethink Recycle: Transform polymer waste from diapers to high-value applications (exxonmobilchemical.com)]		

UNIVERSITY OF MICHIGAN

Indicators	Type of content and preferred unit	University of Michigan
Technical data		
Collection/Separation/Recycling technology		The super absorbent polymer is recycled into a different useful polymer (pressure-sensitive adhesives), giving it a second life.
Origin of waste (e.g., household waste, hospital waste etc.) - mainly important for collection systems		Baby care diapers, adult incontinence pads, and feminine hygiene products.
Process description - Process type - Involved technology and tools - Dealing with hazardous substances and pathogenic germs - Decontamination techniques	*Description*	A series of steps to create a different type of polymer from the original. Conversion of one value-added material into a different value-added material, a kind of chemical recycling.Breakage of some bonds to break down the polymer, make it a bit more soluble, and then functionalize it. Took the **polymerized form of acrylic acid (polyacrylic acid)** from the SAP and functionalized it into **pressure-sensitive adhesives. Esterification** step is performed last **using the repurposed poly(acrylic acid) polymer** from the diaper materials.
Process objectives	*description*	No information identified
Focus/Input material	*list of possible input material*	Superabsorbent polymer (SAP) provided by P&G in diapers. Working with diapers that are already clean.
Output fractions - Target material of process - Resulting recyclates and their applications/markets - Other output materials and their application/markets	*description*	Repurposes superabsorbent polymers into pressure-sensitive adhesives. Outcompetes the petroleum-derived syntheses on nearly every metric, including global warming potential and cumulative energy demand.
Quality/value of output recyclate	*description + ranking if possible (e.g., high, medium, low)*	No information identified
Required skills for operation	*description*	No information identified
Collection/Separation/Recycling capacity	*tons/year*	No information identified
Operational input (e.g., energy, water)	*in MWh, in litres etc.*	No information identified
Potential environmental savings (GHG etc.)	*in CO2/tons, CO2-eq/ton, in €/ton etc.*	**22 % reduction in global warming potential** and a **25 % reduction in cumulative energy demand**, as compared to the traditional pressure-sensitive adhesive synthesis method that creates polymer from petroleum-based sources.
Level of technological maturity	*Blueprint/concept OR Lab test, prototype OR Demonstration/low scale/not fully developed OR Full-scale operation*	No information identified
Commercial data		
Level of commercial maturity	*description*	No information identified
Investment costs	*in €*	No information identified
Operational costs	*in €/ton*	No information identified

Policy and regulatory data		
Intellectual property rights	*description*	No information identified
Level of policy attention in EU	*description*	No information identified
Regulatory considerations	*description*	No information identified
Project data		
Description and name of Initiative/plant/type of organisation/vendor	*description*	P&G
Involved parties and their roles (e.g., authorities, waste companies)	*description*	No information identified
Geographical area/coverage	*region/country*	USA
Type of project	*indicate if pilot project, research project etc.*	Research study/chemical reaction
Start date and duration of initiative/project	*month/year*	No information identified
Funding and support received for initiative/project	*in €*	No information identified
Data on transfer and scale up		
Suitability of technologies to AHPs (e.g., diapers, incontinence & female hygiene products) or specific fractions	*description*	No information identified
Application in other industry sectors/to other products	*description*	No information identified
Possibility for scale-up	*description*	"has the potential to be industrially scalable"
Challenges/potential barriers	*description*	No information identified
Dependencies on specific collection systems or other systems	*description*	No information identified
Sources: 1) McNeil Lab: Recycling disposable diapers into sticky notes McNeil Lab: Recycling disposable diapers into sticky notes | U-M LSA Chemistry (umich.edu) 2) Giving superabsorbent polymers a second life as pressure-sensitive adhesives Giving superabsorbent polymers a second life as pressure-sensitive adhesives (nature.com)		

RENEWI JOINS FORCES WITH ESSITY ON NAPPY RECYCLING IN NETHERLANDS

Indicators	Type of content and preferred unit	Renewi Joins Forces with Essity on Nappy Recycling in Netherlands
Technical data		
Collection/Separation/Recycling technology		No information identified
Origin of waste (e.g., household waste, hospital waste etc.) - mainly important for collection systems		No information identified
Process description - Process type - Involved technology and tools - Dealing with hazardous substances and pathogenic germs - Decontamination techniques	*description*	Method to process and recycle incontinence materials to recover the valuable raw materials including a high-quality cellulose fibre. Recovered cellulose should be used for the chemical industry.
Process objectives	*description*	No information identified
Focus/Input material	*list of possible input material*	No information identified
Output fractions - Target material of process - Resulting recyclates and their applications/markets - Other output materials and their application/markets	*description*	No information identified
Quality/value of output recyclate	*description + ranking if possible (e.g., high, medium, low)*	No information identified
Required skills for operation	*description*	No information identified

Collection/Separation/Recycling capacity	*tons/year*	No information identified
Operational input (e.g., energy, water)	*in MWh, in litres etc.*	No information identified
Potential environmental savings (GHG etc.)	*in CO2/tons, CO2-eq/ton, in €/ton etc.*	No information identified
Level of technological maturity	*Blueprint/concept OR Lab test, prototype OR Demonstration/low scale/not fully developed OR Full-scale operation*	No information identified
Commercial data		
Level of commercial maturity	*description*	No information identified
Investment costs	*in €*	No information identified
Operational costs	*in €/ton*	No information identified
Policy and regulatory data		
Intellectual property rights	*description*	No information identified
Level of policy attention in EU	*description*	No information identified
Regulatory considerations	*description*	No information identified
Project data		
Description and name of Initiative/plant/type of organisation/vendor	*description*	Essity
Involved parties and their roles (e.g., authorities, waste companies)	*description*	No information identified
Geographical area/coverage	*region/country*	No information identified
Type of project	*indicate if pilot project, research project etc.*	No information identified
Start date and duration of initiative/project	*month/year*	No information identified
Funding and support received for initiative/project	*in €*	No information identified
Data on transfer and scale up		
Suitability of technologies to AHPs (e.g., diapers, incontinence & female hygiene products) or specific fractions	*description*	No information identified
Application in other industry sectors/to other products	*description*	No information identified
Possibility for scale-up	*description*	No information identified
Challenges/potential barriers	*description*	No information identified
Dependencies on specific collection systems or other systems	*description*	No information identified
Sources: 1) Renewi, Essity Form Partnership https://www.nonwovens-industry.com/contents/view_breaking-news/2018-07-05/renewi-essity-form-partnership/		

BIOETHANOL PRODUCTION

Indicators	Type of content and preferred unit	Bioethanol production
Technical data		
Collection/Separation/Recycling technology		Recycling, Separation
Origin of waste (e.g., household waste, hospital waste etc.) - mainly important for collection systems		Household Waste, postconsumer AHPs
Process description - Process type - Involved technology and tools - Dealing with hazardous substances and pathogenic germs - Decontamination techniques	*description*	Process type: mainly biological. Before the main investigation/treatment: for biosafety, AHPs were sanitized in an autoclave (121 °C for 1 h) and dried. Separation of the cellulosic

		fraction (containing SAP) and the plastic fraction was conducted. After these processes the AHPs are named "recycled AHPs" in the paper. Investigated processes include effective plastic and SAP removal, cellulose recovery, enzymatic saccharification, and microbial fermentation. In the experiment, six different deconstruction routes for the recycled AHPs were tested with different combinations of mechanical/ chemical pre-treatment and enzymatic saccharification. Cellulose and SAP rich fractions of the recycled AHPs were mechanically separated (mill + vibratory sieve shaker).
Process objectives	*description*	Objective of the process is the production of bioethanol from AHP-derived cellulose as an alternative feedstock. In the experiment, an integrated process that converts postconsumer AHPs to intermediate sugars and bioethanol was developed. The technical feasibility of the process through scale-up within the experimental set up was investigated.
Focus/Input material	*list of possible input material*	Cellulose fraction after separation from plastic: further separation in cellulose-rich materials (for scale-up studies) and SAP-rich fraction. The carbohydrate content of cellulose-rich material reached 68.8 % after SAP separation.
Output fractions **- Target material of process** **- Resulting recyclates and their applications/markets** **- Other output materials and their application/markets**	*description*	Target material: bioethanol. Output: During enzymatic saccharification up to 83.5 % glucose and 46.0 % xylose yields were achieved. Through separate hydrolysis and fermentation a maximum 89.9 % ethanol theoretical yield was achieved.
Quality/value of output recyclate	*description + ranking if possible (e.g., high, medium, low)*	Mechanical removal of SAP from AHPs: this process has been demonstrated to be efficient in the study. Upgrade into high value product: It is stated that the results of the experiment show the feasibility of recycled AHPs as an alternative feedstock for value-added biofuel production.
Required skills for operation	*description*	(scientific)
Collection/Separation/Recycling capacity	*tons/year*	No information identified
Operational input (e.g., energy, water)	*in MWh, in liters etc.*	Preparation of postconsumer AHP: operational input for sanitizing, drying and plastic removal. Biological treatment: Enzymes (cellulase, hemicellulase).
Potential environmental savings (GHG etc.)	*in CO2/tons, CO2-eq/ton, in €/ton etc.*	Potential positive impact on environment if the recycled AHPs benefit fuel biorefineries/ related biomanufacturers and are thereby relieving or eliminating AHPs from landfills.

Level of technological maturity	*Blueprint/concept OR Lab test, prototype OR Demonstration/low scale/not fully developed OR Full-scale operation*	Experiment
Commercial data		
Level of commercial maturity	*description*	(Only at FATER's facility)
Investment costs	*in €*	No information identified
Operational costs	*in €/ton*	No information identified
Policy and regulatory data		
Intellectual property rights	*description*	No information identified
Level of policy attention in EU	*description*	No information identified
Regulatory considerations	*description*	No information identified
Project data		
Description and name of Initiative/plant/type of organisation/vendor	*description*	FATER S.p.A, a P&G and Angelini joint venture, and other institutes.
Involved parties and their roles (e.g., authorities, waste companies)	*description*	Study conducted by/at Advanced Biofuels and Bioproducts Process Development Unit, Lawrence Berkeley National Laboratory and Energy and Environmental Science and Technology, Idaho National Laboratory
Geographical area/coverage	*region/country*	Italy
Type of project	*indicate if pilot project, research project etc.*	Research project/ recycling project
Start date and duration of initiative/project	*month/year*	No information identified
Funding and support received for initiative/project	*in €*	Funding from: - FATER S.p.A. - Department of Energy (DOE) Office of Energy Efficiency and Renewable Energy's Bioenergy Technologies Office (BETO) - American Recovery and Reinvestment Act
Data on transfer and scale up		
Suitability of technologies to AHPs (e.g., diapers, incontinence & female hygiene products) or specific fractions	*description*	Established an integrated process to produce bioethanol from recycled AHPs which was proven successful in the study. The specific fraction in focus is the cellulose-rich material of recycled AHPs.
Application in other industry sectors/to other products	*description*	No information identified
Possibility for scale-up	*description*	Unclear/ not developed (scaled up within experimental set up: millilitre to litre scales)
Challenges/potential barriers	*description*	Process to scale up to commercial maturity
Dependencies on specific collection systems or other systems	*description*	No information identified
Sources: 1) Upgrading of Postconsumer Absorbent Hygiene Products for Bioethanol Production Upgrading of Postconsumer Absorbent Hygiene Products for Bioethanol Production (escholarship.org)		

UNICHARM/OXIDATION WITH OZONE

Indicators	Type of content and preferred unit	Unicharm
Technical data		

Collection/Separation/Recycling technology		Separating and Recycling
Origin of waste (e.g., household waste, hospital waste etc.) - mainly important for collection systems		No information identified
Process description - Process type - Involved technology and tools - Dealing with hazardous substances and pathogenic germs - Decontamination techniques	*description*	Recycling disposable diaper waste pulp: -Diapers are washed, undergo centrifugal separation of plastics and SAP-pulp mix. SAP and pulp are separated by dehydration through ozone oxidation. Plastics are sent to incineration. Involved technology and tools:centrifugal separator, reactor (ozone generator, oxygen generator, on-line ozone analyser). The crushing process is characterized by dissolving the diapers in an organic acid solution of pH 2.5 or lower, which prevents a reduction in treatment efficiency as there is no loss of liquidity in the treatment tank caused by the swollen highly water absorptive polymer. Patent Publication No. 2017-209675. As the SAP recovered from the crushing/cleaning/separating process is inactivated, it is necessary to recover the water absorption performance so that it can be used instead of virgin SAP. Patent Publication No.; 2013-198862
Process objectives	*description*	No information identified
Focus/Input material	*list of possible input material*	Diapers
Output fractions - Target material of process - Resulting recyclates and their applications/markets - Other output materials and their application/markets	*description*	Plastics, SAP, pulp Reusing the pulp recovered from the crushing/cleaning/separating process as raw materials for paper diapers requires that the pulp be recycled to a sufficient quality usable for sanitary materials. Ozone treatment uses ozone water to dissolve and solubilize SAP contained in the recovered pulp as residue, then discharges the ozone water to remove the SAP from the pulp, thereby extracting pulp ingredients only. Patent Publication No. 2014-217835
Quality/value of output recyclate	*description + ranking if possible (e.g., high, medium, low)*	No information identified
Required skills for operation	*description*	No information identified
Collection/Separation/Recycling capacity	*tons/year*	No information identified
Operational input (e.g., energy, water)	*in MWh, in litres etc.*	Ozone, water
Potential environmental savings (GHG etc.)	*in CO2/tons, CO2-eq/ton, in €/ton etc.*	No information identified
Level of technological maturity	*Blueprint/concept OR Lab test, prototype OR Demonstration/low scale/not fully developed OR Full-scale operation*	No information identified
Commercial data		
Level of commercial maturity	*description*	No information identified
Investment costs	*in €*	No information identified
Operational costs	*in €/ton*	No information identified
Policy and regulatory data		
Intellectual property rights	*description*	No information identified

Level of policy attention in EU	*description*	No information identified
Regulatory considerations	*description*	No information identified
Project data		
Description and name of Initiative/plant/type of organisation/vendor	*description*	Article written by Kochi University and Unicharm (2020) LCA written by Tokyo City University and Unicharm Patent: Unicharm Corporation,Method for Decomposing Used Sanitary Goods and Method for Separating Pulp Fibre from Used Sanitary Goods, Patent Publication No. 2017-209675 Unicharm Corporation, Method for Recovering Pulp Fibres from Used Hygiene Products, Patent Publication No. 2014-217835.
Involved parties and their roles (e.g., authorities, waste companies)	*description*	No information identified
Geographical area/coverage	*region/country*	Japan
Type of project	*indicate if pilot project, research project etc.*	No information identified
Start date and duration of initiative/project	*month/year*	No information identified
Funding and support received for initiative/project	*in €*	No information identified
Data on transfer and scale up		
Suitability of technologies to AHPs (e.g., diapers, incontinence & female hygiene products) or specific fractions	*description*	No information identified
Application in other industry sectors/to other products	*description*	No information identified
Possibility for scale-up	*description*	No information identified
Challenges/potential barriers	*description*	No information identified
Dependencies on specific collection systems or other systems	*description*	No information identified
Sources: 1) Recycling Unicharm disposable diapers Study Note 1: Unicharm's circulation-based recycling of disposable diapers-Unicharm Company Information 2) Recycling disposable diaper waste pulp after dehydrating the superabsorbent polymer through oxidation using ozone Recycling disposable diaper waste pulp after dehydrating the superabsorbent polymer through oxidation using ozone - ScienceDirect 1) Life Cycle Assessment of the Closed-Loop Recycling of Used Disposable Diapers Resources | Free Full-Text | Life Cycle Assessment of the Closed-Loop Recycling of Used Disposable Diapers (mdpi.com)		

Separation and recycling

ARN BV (COLLABORATION WITH: ELSINGA POLICY PLANNING & INNOVATION)

Indicators	Type of content and preferred unit	ARN BV (collaboration with: Elsinga Policy Planning & Innovation)
Technical data		
Collection/Separation/Recycling technology		Separation/Recycling
Origin of waste (e.g., household waste, hospital waste etc.) - mainly important for collection systems		No information identified
Process description - Process type - Involved technology and tools - Dealing with hazardous substances and pathogenic germs - Decontamination techniques	*description*	Diapers are placed in a kettle at min. 40 bar and 250 °C together with about 30 % of additionally added digested sewage sludge for about three hours. Germs and antibiotics are destroyed, and the plastic melts. When the plastic has cooled down, it floats to the top and can be further processed into plastic pellets (7 %). The resulting paper pulp

		and biomass can be converted into paper and biogas (93 %).
Process objectives	*description*	No information identified
Focus/Input material	*list of possible input material*	Diapers and incontinence material
Output fractions - Target material of process - Resulting recyclates and their applications/markets - Other output materials and their application/markets	*description*	Hard plastic agglomerates (70 % PP, 30 % PE). The resulting sludge (about 93 % of the mass) can then be fermented into biogas. In this procedure cellulose fibres cannot be recovered.
Quality/value of output recyclate	*description + ranking if possible (e.g., high, medium, low)*	Customers can produce high-quality products from the plastic agglomerates. Supply of 150,000 MWh electricity and 800 Tj heat per year.
Required skills for operation	*description*	No information identified
Collection/Separation/Recycling capacity	*tons/year*	Diapers: 15.000 t/a
Operational input (e.g., energy, water)	*in MWh, in litres etc.*	No information identified
Potential environmental savings (GHG etc.)	*in CO2/tons, CO2-eq/ton, in €/ton etc.*	Recycling saves 899 kg of CO_2 per ton of diaper waste. Another study shows that this process saves 480 kg CO_2eq per ton compared to energy recovery [47]. When fossil plastics in the diapers are replaced by biobased Polylactic acid (PLA), the avoided CO_2 can rise from 899 kg CO_2 per ton of diaper waste to 1,236 kg CO_2 per ton of diaper waste. Due to the high pressure and temperature in the process, drug residue and pathogen requirements can be met without the use of chemicals.
Level of technological maturity	*Blueprint/concept OR Lab test, prototype OR Demonstration/low scale/not fully developed OR Full-scale operation*	Full-scale operation
Commercial data		
Level of commercial maturity	*description*	No information identified
Investment costs	*in €*	No information identified
Operational costs	*in €/ton*	No information identified
Intellectual property rights	*description*	No information identified
Level of policy attention in EU	*description*	No information identified
Regulatory considerations	*description*	No information identified
Project data		
Description and name of Initiative/plant/type of organisation/vendor	*description*	ARN BV/Elsinga Policy Planning & Innovation
Involved parties and their roles (e.g., authorities, waste companies)	*description*	University Cottbus-Senftleben, Remondis, Afvalverwerking Regio Nijmegen (MARN)
Geographical area/coverage	*region/country*	Netherlands
Type of project	*indicate if pilot project, research project etc.*	Recycling project
Start date and duration of initiative/project	*month/year*	Test series started in 2013 Project started in Sept. 2021
Funding and support received for initiative/project	*in €*	No information identified
Data on transfer and scale up		
Suitability of technologies to AHPs (e.g., diapers, incontinence & female hygiene products) or specific fractions	*description*	No information identified
Application in other industry sectors/to other products	*description*	No information identified

Possibility for scale-up	*description*	No information identified
Challenges/potential barriers	*description*	No information identified
Dependencies on specific collection systems or other systems	*description*	No information identified

Sources:

1) ARN - uw duurzame partner https://www.arnbv.nl/over-arn/bedrijfsprofiel/
2) Windeln verbrennen? Ganz sicher nicht die beste Idee https://www.remondis-nachhaltigkeit.de/handeln/windelrecycling/
3) Interview mit Gerd Terbeck zum Thema „Windelrecycling“ https://www.abfallmanager-medizin.de/blick-ins-ausland/verwertung-von-windeln-und-inkontinenzmaterial-in-den-niederlanden/
4) Offensive waste valorisation in the UK: Assessment of the potentials for absorbent hygiene product (AHP) recycling Sustainable energy recovery from recycling and incineration of waste absorbent hygiene products | IEEE Conference Publication | IEEE Xplore
5) UBA Evaluation der Erfassung und Verwertung ausgewählter Abfallströme zur Fortentwicklung der Kreislaufwirtschaft https://www.umweltbundesamt.de/sites/default/files/medien/479/publikationen/texte_312022_evaluation_der_erfassung_und_verwertung_ausgewaehlter_abfallstroeme_zur_fortentwicklung_der_kreislaufwirtschaft.pdf

REFIBRA

Indicators	Type of content and preferred unit	REFIBRA
Technical data		
Collection/Separation/Recycling technology		Separation/Recycling Separate collection does not require specific effort of the consumer, does not depend on the purchase of new products and/or a brand owner.
Origin of waste (e.g., household waste, hospital waste etc.) - mainly important for collection systems		[N/A] – Textile collectors
Process description - Process type - Involved technology and tools - Dealing with hazardous substances and pathogenic germs - Decontamination techniques	*description*	Chemical recycling of textile waste
Process objectives	*description*	Recover cellulose fraction from textile waste.
Focus/Input material	*list of possible input material*	Cellulose rich textile waste
Output fractions - Target material of process - Resulting recyclates and their applications/markets - Other output materials and their application/markets	*description*	Man-made cellulosic fibres
Quality/value of output recyclate	*description + ranking if possible (e.g., high, medium, low)*	High – virgin like qualities
Required skills for operation	*description*	No information identified
Collection/Separation/Recycling capacity	*tons/year*	[N/A]
Operational input (e.g., energy, water)	in MWh, in litres etc.	Few inputs (e.g., only Energy OR water) are required but sterilisation IS guaranteed or not needed.
Potential environmental savings (GHG etc.)	*in CO_2/tons, CO_2-eq/ton, in €/ton etc.*	Improves at least two environmental factors (e.g., CO_2 reduction, soil improvement, resource reduction, etc.).
Level of technological maturity	*Blueprint/concept OR Lab test, prototype*	Full-scale operation

	OR Demonstration/low scale/not fully developed *OR Full-scale operation*	
Commercial data		
Level of commercial maturity	*description*	Full-scale operation
Investment costs	*in €*	No information identified
Operational costs	*in €/ton*	No information identified
Policy and regulatory data		
Intellectual property rights	*description*	No information identified
Level of policy attention in EU	*description*	No information identified
Regulatory considerations	*description*	No information identified
Project data		
Description and name of Initiative/plant/type of organisation/vendor	*description*	No information identified
Involved parties and their roles (e.g., authorities, waste companies)	*description*	Cooperation of stakeholders (from different sectors): >3 stakeholders
Geographical area/coverage	*region/country*	No information identified
Type of project	*indicate if pilot project, research project etc.*	No information identified
Start date and duration of initiative/project	*month/year*	No information identified
Funding and support received for initiative/project	*in €*	No information identified
Data on transfer and scale up		
Suitability of technologies to AHPs (e.g., diapers, incontinence & female hygiene products) or specific fractions	*description*	No information identified
Application in other industry sectors/to other products	*description*	No information identified
Possibility for scale-up	*description*	No information identified
Challenges/potential barriers	*description*	No information identified
Dependencies on specific collection systems or other systems	*description*	No information identified
Sources: 1) Filled out with support from Lenzing		

SUPER FAITH INC. SFD SYSTEM SUPER FAITHS INC.

Indicators	Type of content and preferred unit	Super Faith Inc. SFD System Super Faiths Inc.
Technical data		
Collection/Separation/Recycling technology		Separation/recycling (currently rather energy recovery)
Origin of waste (e.g., household waste, hospital waste etc.) - mainly important for collection systems		No information identified
Process description - Process type - Involved technology and tools - Dealing with hazardous substances and pathogenic germs - Decontamination techniques	*description*	Pelletizing: Used diapers need to be put into plastic bags, which are then sealed. Anyone can place the diaper bags in the SDF machine, no special skills are needed. The diapers will then be automatically shredded, fermented and dried. The outcome are bacteria-free fluffy fuel chips, which are then deodourised with an effective catalyst designed to not emit the exhaust air. The fuel chips are then processed into energy pellets.

		The process is carried out within 24 hours in a single tank to avoid infection with viruses.
Process objectives	*description*	No information identified
Focus/Input material	*list of possible input material*	Diapers
Output fractions - Target material of process - Resulting recyclates and their applications/markets - Other output materials and their application/markets	*description*	Plastic pellets as a fuel for biomass boilers. **Currently no recycling process --> fuel**
Quality/value of output recyclate	*description + ranking if possible (e.g., high, medium, low)*	With a calorie density (Q) that was 20,853 kJ/kg higher than conventional Wood pellets (Q = 17,100 kJ/kg).
Required skills for operation	*description*	No information identified
Collection/Separation/Recycling capacity	*tons/year*	150-600 kg daily depending on the machine type.
Operational input (e.g., energy, water)	*in MWh, in litres etc.*	Depending on machine size: Electricity: max. 86 kWh/day Gas: max. 50-60 kg/day
Potential environmental savings (GHG etc.)	*in CO_2/tons, CO_2-eq/ton, in €/ton etc.*	Reducing CO_2 by using biomass chips instead of fossil fuel.
Level of technological maturity	*Blueprint/concept OR Lab test, prototype OR Demonstration/low scale/not fully developed OR Full-scale operation*	Full-scale operation
Commercial data		
Level of commercial maturity	*description*	No information identified
Investment costs	*in €*	High price for the machine.
Operational costs	*in €/ton*	No information identified
Policy and regulatory data		
Intellectual property rights	*description*	No information identified
Level of policy attention in EU	*description*	No information identified
Regulatory considerations	*description*	No information identified
Project data		
Description and name of Initiative/plant/type of organisation/vendor	*description*	Super Faith inc.--> SFD system (shredding, fermentation, drying)
Involved parties and their roles (e.g., authorities, waste companies)	*description*	No information identified
Geographical area/coverage	*region/country*	Japan
Type of project	*indicate if pilot project, research project etc.*	Recycling company
Start date and duration of initiative/project	*month/year*	No information identified
Funding and support received for initiative/project	*in €*	No information identified
Data on transfer and scale up		
Suitability of technologies to AHPs (e.g., diapers, incontinence & female hygiene products) or specific fractions	*description*	Approved recycling system
Application in other industry sectors/to other products	*description*	No information identified
Possibility for scale-up	*description*	No information identified
Challenges/potential barriers	*description*	Japanese patent

Dependencies on specific collection systems or other systems	*description*	No information identified
Sources: 1) Company Super Faith Inc. Super Faiths Inc. | SFD System 2) RESEARCH AND ANALYSIS OF ABSORBENT HYGIENE PRODUCT (AHP) RECYCLING https://www.tf.llu.lv/conference/proceedings2016/Papers/N175.pdf		

MUSHROOM CULTIVATION NUTRIENTS

Indicators	Type of content and preferred unit	Mushroom cultivation nutrients
Technical data		They use diaper waste and turn it into nutrients, which are essential for the growth of mushrooms (edible Oyster mushrooms, but not intended for human consumption, rather cattle food supplement) (medical mushroom Lingzhi)
Collection/Separation/Recycling technology		
Origin of waste (e.g., household waste, hospital waste etc.) - mainly important for collection systems		Used diapers only filled with urine from kids under 2 years old collected from Taska Juhani, Malaysia.
Process description - Process type - Involved technology and tools - Dealing with hazardous substances and pathogenic germs - Decontamination techniques	*description*	The diaper core was separated from the rest of the diaper and autoclaved for 15 min at 121°C, then dried in an oven at 90°C for 2-3 days. Additional food wastes (coffee ground, eggshell, sugarcane bagasse and banana skin) were dried and blended to powder. The powder was mixed with the diaper core and forms the mushroom substrate. Mushroom spores consume the cellulose wood pulps and organic components which allows it to grow. Dried diaper formulation, diaper is immersed in water. Adjustment of pH, moisture maintained at 55-60 %. Autoclaved at 121 °C for 60 min. SAPs help with controlling the water content, improving seedling and root growth. Improves soil permeability and density and boosts the infiltration rate of water. Within 2.5 - 3 months, the diaper volume is reduced by 80 %
Process objectives	*description*	No information identified
Focus/Input material	*list of possible input material*	Diapers
Output fractions - Target material of process - Resulting recyclates and their applications/markets - Other output materials and their application/markets	*description*	Edible oyster mushrooms
Quality/value of output recyclate	*description + ranking if possible (e.g., high, medium, low)*	The harvested mushrooms were high in protein content, free from human pathogens, and suitable for human consumption.
Required skills for operation	*description*	No information identified
Collection/Separation/Recycling capacity	*tons/year*	No information identified
Operational input (e.g., energy, water)	*in MWh, in litres etc.*	No information identified

Potential environmental savings (GHG etc.)	*in CO_2/tons, CO_2-eq/ton, in €/ton etc.*	No information identified
Level of technological maturity	*Blueprint/concept OR Lab test, prototype OR Demonstration/low scale/not fully developed OR Full-scale operation*	Small scale project.
Commercial data		
Level of commercial maturity	*description*	No information identified
Investment costs	*in €*	No information identified
Operational costs	*in €/ton*	No information identified
Policy and regulatory data		
Intellectual property rights	*description*	No information identified
Level of policy attention in EU	*description*	No information identified
Regulatory considerations	*description*	No information identified
Project data		
Description and name of Initiative/plant/type of organisation/vendor	*description*	No information identified
Involved parties and their roles (e.g., authorities, waste companies)	*description*	No information identified
Geographical area/coverage	*region/country*	Asia, and similar study in Mexico
Type of project	*indicate if pilot project, research project etc.*	Research project
Start date and duration of initiative/project	*month/year*	Such studies started in 2014
Funding and support received for initiative/project	*in €*	Ministry of Education Malaysia for financial support under FRGS research grant (Vot 59482) Henan Agricultural University for the financial, facility, and technical support this research under a Research Collaboration Agreement (RCA) and Golden Goose Research Grant (Vot 55191) with University Malaysia Terengganu
Data on transfer and scale up		
Suitability of technologies to AHPs (e.g., diapers, incontinence & female hygiene products) or specific fractions	*description*	Was proven successfully
Application in other industry sectors/to other products	*description*	The mushrooms were also cultivated on waste from plastics, grape pomace, yard waste and food waste.
Possibility for scale-up	*description*	The mushroom substrate from diaper waste is still not a substitute for commercial wheat straw, which has a higher biological efficiency.
Challenges/potential barriers	*description*	Hygiene/food regularities
Dependencies on specific collection systems or other systems	*description*	No information identified

Sources:

1) New open-loop recycling approaches for disposable diaper waste
   New open-loop recycling approaches for disposable diaper waste (cdnsciencepub.com)
2) Valorisation of biomass and diaper waste into a sustainable production of the medical mushroom Lingzhi Ganoderma lucidum
   Valorisation of biomass and diaper waste into a sustainable production of the medical mushroom Lingzhi Ganoderma lucidum - ScienceDirect
3) Green application and toxic risk of used diaper and food waste as growth substitute for sustainable cultivation of oyster mushroom (Pleurotus ostreatus)
   Green application and toxic risk of used diaper and food waste as growth substitute for sustainable cultivation of oyster mushroom (Pleurotus ostreatus) - ScienceDirect
4) Growing mushrooms in diapers
   https://www.sciencedaily.com/releases/2014/09/140902092945.htm

5) USE OF OYSTER MUSHROOM (Pleurotus ostreatus) TO DEGRADE USED DIAPERS AND SANITARY PADS IN SELECTED ESATATES IN THIKA, KIAMBU COUNTY, KENYA Use of Oyster Mushroom (Pleurotus Ostreatus) to Degrade....pdf (ku.ac.ke)

BIRZITEK

Indicators	Type of content and preferred unit	Birzitek
Technical data		
Collection/Separation/Recycling technology		Sorting, Separation and Recycling
Origin of waste (e.g., household waste, hospital waste etc.) - mainly important for collection systems		No information identified
Process description - Process type - Involved technology and tools - Dealing with hazardous substances and pathogenic germs - Decontamination techniques	*description*	1. Reception of waste 2. Crushing 3. Sanitization 4. First washing and separation 5. Second wash 6. Drying 7. Storage of Final products Cellulose: between 50-52 % of cellulose with SAP are obtained from AHPs. Plastic mix: 48-50 % of plastic recovered from the AHP, mostly PE and polypropylene.
Process objectives	*description*	No information identified
Focus/Input material	*list of possible input material*	Children's diapers, incontinence products, feminine hygiene products.
Output fractions - Target material of process - Resulting recyclates and their applications/markets - Other output materials and their application/markets	*description*	Cellulose Plastic mix favoured over plastic wood.
Quality/value of output recyclate	*description + ranking if possible (e.g., high, medium, low)*	No information identified
Required skills for operation	*description*	No information identified
Collection/Separation/Recycling capacity	*tons/year*	No information identified
Operational input (e.g., energy, water)	*in MWh, in litres etc.*	No information identified
Potential environmental savings (GHG etc.)	*in CO_2/tons, CO_2-eq/ton, in €/ton etc.*	70 % reduction in GHG emissions.
Level of technological maturity	*Blueprint/concept OR Lab test, prototype OR Demonstration/low scale/not fully developed OR Full-scale operation*	No information identified
Commercial data		
Level of commercial maturity	*description*	No information identified
Investment costs	*in €*	No information identified
Operational costs	*in €/ton*	No information identified
Policy and regulatory data		
Intellectual property rights	*description*	No information identified
Level of policy attention in EU	*description*	No information identified
Regulatory considerations	*description*	No information identified
Project data		

Description and name of Initiative/plant/type of organisation/vendor	*description*	No information identified
Involved parties and their roles (e.g., authorities, waste companies)	*description*	Technological: GetGOIERRI, Goieki, SASIETA Mankomunitatea, tecnalia, GAIKER Financial: Gipuzkoako Foru Aldundia, EUSKO JAURLARITZA GOBIERNO VASCO, Grup spri Taldea
Geographical area/coverage	*region/country*	Spain
Type of project	*indicate if pilot project, research project etc.*	No information identified
Start date and duration of initiative/project	*month/year*	No information identified
Funding and support received for initiative/project	*in €*	No information identified
Data on transfer and scale up		
Suitability of technologies to AHPs (e.g., diapers, incontinence & female hygiene products) or specific fractions	*description*	No information identified
Application in other industry sectors/to other products	*description*	No information identified
Possibility for scale-up	*description*	No information identified
Challenges/potential barriers	*description*	No information identified
Dependencies on specific collection systems or other systems	*description*	No information identified
Sources: 1) Birzitek PROCESO BIRZIFAR | Birzitek Waste Engineering		

PYROLYTIC DIAPERS AS A SOIL AMENDMENT FOR AGRICULTURAL PURPOSES

Indicators	Type of content and preferred unit	Pyrolytic diapers as a soil amendment for agricultural purposes
Technical data		
Collection/Separation/Recycling technology		Recycling
Origin of waste (e.g., household waste, hospital waste etc.) - mainly important for collection systems		No information identified
Process description - Process type - Involved technology and tools - Dealing with hazardous substances and pathogenic germs - Decontamination techniques	*description*	AHPs are shredded and thermally conversed. The entire diaper undergoes pyrolysis at 500-900°C, which results in pyrolytic products. This reduces the weight, volume and foul odours. The pyrolytic diapers are then used for agricultural purposes, improving the soil quality by adding phosphorous oxide nutrients derived from human excreta.
Process objectives	*description*	The objective is agricultural purpose application, the pyrolytic diaper improves soil quality by adding high plant growth phosphorous oxide (P_2O_5) nutrients derived from human excreta contained in the diapers.
Focus/Input material	*list of possible input material*	Diapers and incontinence material
Output fractions - Target material of process - Resulting recyclates and their applications/markets	*description*	Pyrolytic diaper solids

- Other output materials and their application/markets		
Quality/value of output recyclate	*description + ranking if possible (e.g., high, medium, low)*	Heavy metal concentrations of Cr, Ni, Cu, and Zn in the diaper pyrolytic solids were less than the maximum allowable limits.
Required skills for operation	*description*	No information identified
Collection/Separation/Recycling capacity	*tons/year*	No information identified
Operational input (e.g., energy, water)	*in MWh, in litres etc.*	Energy for heating (pyrolysis process)
Potential environmental savings (GHG etc.)	*in CO_2/tons, CO_2-eq/ton, in €/ton etc.*	It improves the soil quality of acid soils.
Level of technological maturity	*Blueprint/concept OR Lab test, prototype OR Demonstration/low scale/not fully developed OR Full-scale operation*	Demonstration/low scale/not fully developed
Commercial data		
Level of commercial maturity	*description*	No information identified
Investment costs	*in €*	No information identified
Operational costs	*in €/ton*	No information identified
Policy and regulatory data		
Intellectual property rights	*description*	No information identified
Level of policy attention in EU	*description*	No information identified
Regulatory considerations	*description*	Excessive pyrolytic diaper solids in the soil may cause P_2O_5 to leach into the surrounding soil, surface water, and groundwater.
Project data		
Description and name of Initiative/plant/type of organisation/vendor	*description*	No information identified
Involved parties and their roles (e.g., authorities, waste companies)	*description*	No information identified
Geographical area/coverage	*region/country*	No information identified
Type of project	*indicate if pilot project, research project etc.*	No information identified
Start date and duration of initiative/project	*month/year*	No information identified
Funding and support received for initiative/project	*in €*	No information identified
Data on transfer and scale up		
Suitability of technologies to AHPs (e.g., diapers, incontinence & female hygiene products) or specific fractions	*description*	No information identified
Application in other industry sectors/to other products	*description*	No information identified
Possibility for scale-up	*description*	No information identified
Challenges/potential barriers	*description*	These pyrolytic diaper solids are only effective and beneficial for acidic soil.
Dependencies on specific collection systems or other systems	*description*	No information identified
Sources: 1) Characterization of the pyrolytic solid derived from used disposable diapers https://www.tandfonline.com/doi/abs/10.1080/09593330.2013.808240 2) New open-loop recycling approaches for disposable diaper waste New open-loop recycling approaches for disposable diaper waste (cdnsciencepub.com)		

ENERGY RECOVERY

Indicators	Type of content and preferred unit	Energy Recovery
Technical data		

Collection/Separation/Recycling technology		Recycling, incineration/ energy recovery
Origin of waste (e.g., household waste, hospital waste etc.) - mainly important for collection systems		Household waste
Process description **- Process type** **- Involved technology and tools** **- Dealing with hazardous substances and pathogenic germs** **- Decontamination techniques**	*description*	Experimental methodology proposed for incineration design: Sterilization of waste, separation of plastics and cellulose. Cellulose is used to produce steam with a temperature of 850-900 °C for sterilization. An ash collection chamber for proper disposal is available. A Catia design with two novel filtration techniques is located in the smoke pipe. Primary filtration for sterilization of the steam. Secondary filtration for the thermal treatment/ utilization of 65 % of the steam for energy recovery. Specifications of the proposed incinerator: Volume: 11/2 ft, Required space: 3 sq. ft, Chimney height: 10 ft, Body material: Stainless steel (SS)/Mild steel (MS) [Item code: AIM-INECO-D2, INDIAMART] Temperatures: 850° C- 950 ° C, Proposed material for combustion chamber: steel aerate alloy.
Process objectives	*description*	Objective of the process is the generation of a large amount of electrical energy with a low cost. Overall aim is to provide a solution for effective and efficient MSW management.
Focus/Input material	*list of possible input material*	Sanitation products for children and menstrual hygiene.
Output fractions **- Target material of process** **- Resulting recyclates and their applications/markets** **- Other output materials and their application/markets**	*description*	Energy (+ bottom ash--> cement)
Quality/value of output recyclate	*description + ranking if possible (e.g., high, medium, low)*	It is stated in the paper that AHP waste proves to be a valuable renewable energy resource for the proposed incineration method.
Required skills for operation	*description*	No information identified
Collection/Separation/Recycling capacity	*tons/year*	Suitable for: local communities with less than 5 t/day MSW generation (referring to India). Specifications of the proposed incinerator: Volume: 11/2 ft, Space required: 3 sq. ft, Chimney height: 10 ft, Body material: Stainless steel (SS)/Mild steel (MS) [Item code: AIM-INECO-D2, INDIAMART]
Operational input (e.g., energy, water)	*in MWh, in litres etc.*	High temperatures at 700-900°C needed
Potential environmental savings (GHG etc.)	*in CO_2/tons, CO_2-eq/ton, in €/ton etc.*	Generally: Reduction of GHG emissions
Level of technological maturity	*Blueprint/concept OR Lab test, prototype*	Experimental, prototypes are proposed

	OR Demonstration/low scale/not fully developed *OR Full-scale operation*	
Commercial data		
Level of commercial maturity	*description*	No information identified
Investment costs	*in €*	Can be manufactured at extremely low cost estimated at 51,500 INR for rural areas
Operational costs	*in €/ton*	Low operational costs, no external energy support needed.
Policy and regulatory data		
Intellectual property rights	*description*	No information identified
Level of policy attention in EU	*description*	No information identified
Regulatory considerations	*description*	No information identified
Project data		
Description and name of Initiative/plant/type of organisation/vendor	*description*	Prototype based on Catia design is proposed to be developed.
Involved parties and their roles (e.g., authorities, waste companies)	*description*	No information identified
Geographical area/coverage	*region/country*	Howrah, India
Type of project	*indicate if pilot project, research project etc.*	Research project
Start date and duration of initiative/project	*month/year*	No information identified
Funding and support received for initiative/project	*in €*	No information identified
Data on transfer and scale up		
Suitability of technologies to AHPs (e.g., diapers, incontinence & female hygiene products) or specific fractions	*description*	No information identified
Application in other industry sectors/to other products	*description*	No information identified
Possibility for scale-up	*description*	Designed for small scale. It is stated that the aim was to design a cost-effective simple incinerator for rural areas.
Challenges/potential barriers	*description*	Related to India: proper sorting and collection of waste, In rural areas: separation of organic and inorganic waste.
Dependencies on specific collection systems or other systems	*description*	No information identified
Sources: 1) Energy recovery from proper recycling and incineration of waste absorbent hygiene products for environmental sustainability [Bose 2019] Energy Recovery from Proper Recycling and Incineration of Waste Absorbent Hygiene Products.pdf 2) Sustainable energy recovery from recycling and incineration of waste absorbent hygiene products Sustainable energy recovery from recycling and incineration of waste absorbent hygiene products | IEEE Conference Publication | IEEE Xplore		

ANODE MATERIALS FOR LITHIUM-ION BATTERIES

Indicators	Type of content and preferred unit	Anode materials for lithium-ion batteries
Technical data		Using the superabsorbent polymers (SAPs) from baby diapers, the 3D porous composites decorated with NiO and Ni nanoparticles (NNSCs) have been

		prepared via a facile dissolving-freeze drying and subsequent annealing reactions.
Collection/Separation/Recycling technology		Recycling
Origin of waste (e.g., household waste, hospital waste etc.) - mainly important for collection systems		No information identified
Process description - Process type - Involved technology and tools - Dealing with hazardous substances and pathogenic germs - Decontamination techniques	*description*	SAP was first separated from the absorbent core and then submerged into green nickel nitrate [Ni (NO_3)-solution] to form a hydrogel with which 3D hierarchically porous carbon composites were fabricated through freeze-drying and high-temperature pyrolysis.
Process objectives	*description*	No information identified
Focus/Input material	*list of possible input material*	SAPs
Output fractions - Target material of process - Resulting recyclates and their applications/markets - Other output materials and their application/markets	*description*	3D porous carbon composites are used for Li-batteries. The carbon composites exhibited a specific capacity of 1075 mAh/g at 100 mA/g, which could be maintained even after 200 charge/discharge cycles at various current densities.
Quality/value of output recyclate	*description + ranking if possible (e.g., high, medium, low)*	No information identified
Required skills for operation	*description*	No information identified
Collection/Separation/Recycling capacity	*tons/year*	No information identified
Operational input (e.g., energy, water)	*in MWh, in litres etc.*	No information identified
Potential environmental savings (GHG etc.)	*in CO_2/tons, CO_2-eq/ton, in €/ton etc.*	No information identified
Level of technological maturity	*Blueprint/concept OR Lab test, prototype OR Demonstration/low scale/not fully developed OR Full-scale operation*	Lab test prototype
Commercial data		
Level of commercial maturity	*description*	No information identified
Investment costs	*in €*	No information identified
Operational costs	*in €/ton*	No information identified
Policy and regulatory data		
Intellectual property rights	*description*	No information identified
Level of policy attention in EU	*description*	No information identified
Regulatory considerations	*description*	No information identified
Project data		
Description and name of Initiative/plant/type of organisation/vendor	*description*	No information identified
Involved parties and their roles (e.g., authorities, waste companies)	*description*	No information identified
Geographical area/coverage	*region/country*	China
Type of project	*indicate if pilot project, research project etc.*	Research project
Start date and duration of initiative/project	*month/year*	Published in 2018
Funding and support received for initiative/project	*in €*	National Natural Science Foundation of China (NSFC) (Grants nos. 21671133, 21271010, 21604051, and

		21507081), Sailing Program of Shanghai Science and Technology Commission (Grant no. 15YF1404700), Shanghai Municipal Natural Science Foundation (Grant no. 15ZR1417800), Science and Technology Commission of Shanghai Municipality (Grant no. 14JC1402500) the Shanghai Municipal Education Commission (Grant nos. 15ZZ088 and 15SG49), and International Joint Laboratory on Resource Chemistry. Additionally, the study was also sponsored by "Chenguang Program" supported by Shanghai Education Development Foundation and Shanghai Municipal Education Commission (14CG54).
Data on transfer and scale up		
Suitability of technologies to AHPs (e.g., diapers, incontinence & female hygiene products) or specific fractions	*description*	Was proven successfully.
Application in other industry sectors/to other products	*description*	No information identified
Possibility for scale-up	*description*	They write it is scalable
Challenges/potential barriers	*description*	No information identified
Dependencies on specific collection systems or other systems	*description*	No information identified
Sources: 1) New open-loop recycling approaches for disposable diaper waste New open-loop recycling approaches for disposable diaper waste (cdnsciencepub.com) 2) Baby diaper-inspired construction of 3D porous composites for long-term lithium-ion batteries https://onlinelibrary.wiley.com/doi/10.1002/adfm.201704440		

AUSTRIAN CENTRE OF INDUSTRIAL BIOTECHNOLOGY (ACIB)

Indicators	Type of content and preferred unit	Austrian Centre of Industrial Biotechnology (acib)
Technical data		The acib GmbH is suggesting a project idea on a diaper recycling process in which the diapers are treated with enzymes in a first step. The process does not require high temperatures and hazardous chemicals. However, several years of research and development are necessary to develop this process.
Collection/Separation/Recycling technology		Recycling
Origin of waste (e.g., household waste, hospital waste etc.) - mainly important for collection systems		Hospital waste; diapers
Process description - Process type - Involved technology and tools - Dealing with hazardous substances and pathogenic germs - Decontamination techniques	*description*	First, there is a state of the art cleaning step to remove the organic residues in diapers. The remaining mixture of cellulose fibres and plastic fibres are then seperated with the novel enzymatic procedure:

		- Cellulose fibres are broken down by enzymes to their basic compounds, glucose, and used in fermentative processes. - The subsequently isolated remaining plastic fibres can be re-granulated for reuse or be subjected to an enzymatic degradation process for recovery of valuable building blocks. The essential compounds derived from the enzymatic separation of plastics can be used for the production of polymers or as platform chemicals.
Process objectives	*description*	Proof of concept
Focus/Input material	*list of possible input material*	Diapers
Output fractions - Target material of process - Resulting recyclates and their applications/markets - Other output materials and their application/markets	*description*	Glucose which can be used in fermentative processes. Plastic fibres which can be re-granulated for re-use or enzymatic degradation for gaining building blocks. Can be used for production of polymers or for chemicals.
Quality/value of output recyclate	*description + ranking if possible (e.g., high, medium, low)*	Are not determined in project.
Required skills for operation	*description*	Not in focus: Process development
Collection/Separation/Recycling capacity	*tons/year*	Not in focus
Operational input (e.g., energy, water)	*in MWh, in litres etc.*	No toxic or hazardous chemicals are needed.
Potential environmental savings (GHG etc.)	*in CO_2/tons, CO_2-eq/ton, in €/ton etc.*	According to acib no production of CO_2
Level of technological maturity	*Blueprint/concept OR Lab test, prototype OR Demonstration/low scale/not fully developed OR Full-scale operation*	Lab test, prototype TRL 1-2
Commercial data		
Level of commercial maturity	*description*	No information identified
Investment costs	*in €*	Project costs 400,000€
Operational costs	*in €/ton*	Not in focus
Policy and regulatory data		
Intellectual property rights	*description*	IP can be transferred to funding company.
Level of policy attention in EU	*description*	No information identified
Regulatory considerations	*description*	No information identified
Project data		
Description and name of Initiative/plant/type of organisation/vendor	*description*	Austrian Centre of Industrial Biotechnology (acib)
Involved parties and their roles (e.g., authorities, waste companies)	*description*	Company partner needed
Geographical area/coverage	*region/country*	Austria
Type of project	*indicate if pilot project, research project etc.*	Research and Development
Start date and duration of initiative/project	*month/year*	Still in the research and development phase. In 2020 they expected to need an additional three years of research and development in the laboratory.
Funding and support received for initiative/project	*in €*	Zero funding until now Riz up Genius Award in 2020

Data on transfer and scale up		
Suitability of technologies to AHPs (e.g., diapers, incontinence & female hygiene products) or specific fractions	*description*	No information identified
Application in other industry sectors/to other products	*description*	Yes: general plastic recycling
Possibility for scale-up	*description*	Yes (plans to develop industrial-scale process)
Challenges/potential barriers	*description*	Funding
Dependencies on specific collection systems or other systems	*description*	Collection is not in focus
Sources: 1) UBA Evaluation der Erfassung und Verwertung ausgewählter Abfallströme zur Fortentwicklung der Kreislaufwirtschaft https://www.umweltbundesamt.de/sites/default/files/medien/479/publikationen/texte_312022_evaluation_der_erfassung_und_verwertung_ausgewaehlter_abfallstroeme_zur_fortentwicklung_der_kreislaufwirtschaft.pdf 2) acib - Recycling of baby diapers https://acib.at/recycling-baby-diapers/		

SEPARATION OF CELLULOSE AND PLASTICS (BTU)

Indicators	Type of content and preferred unit	Separation of cellulose and plastics (BTU)
Technical data		Application for a patent: separation of cellulose and plastics from diapers for material recovery. The incontinence material mixed with water is heated in an autoclave at 150-250 °C for several hours while stirring. The plastic separated in the process can, for example, be processed as substitute fuel and the cellulose can be fermented together with liquid manure.
Collection/Separation/Recycling technology		Separation
Origin of waste (e.g., household waste, hospital waste etc.) - mainly important for collection systems		No information identified
Process description - Process type - Involved technology and tools - Dealing with hazardous substances and pathogenic germs - Decontamination techniques	*description*	The mixed cellulose-plastic products are slurred together with water. The resulting slurry is then introduced into a stirred autoclave and then the stirred autoclave is closed. The slurry is heated while being continuously stirred at a rotational speed of 50 to 350 min and a temperature of 150 to 250 °C, at a pressure of 1.2 to 3.0 MPa. This temperature and pressure remain constant during the holding time of 0.3 to 6 hours, wherein the cellulose is hydrolysed and the plastics are agglomerated into spherical shapes. The stirred autoclave is then cooled, and the pressure is released before opening. The separated cellulose hydrolysate can be used for the production of biogas by means of wet fermentation, optionally with the addition of liquid manure and/or other substrates containing nitrogen, or for denitrification in wastewater treatment plants. The separated spherical plastic

		agglomerate can be used to produce energy by means of combustion.
Process objectives	*description*	No information identified
Focus/Input material	*list of possible input material*	No information identified
Output fractions - Target material of process - Resulting recyclates and their applications/markets - Other output materials and their application/markets	*description*	Separated cellulose hydrolysate plastic agglomerate
Quality/value of output recyclate	*description + ranking if possible (e.g., high, medium, low)*	No information identified
Required skills for operation	*description*	No information identified
Collection/Separation/Recycling capacity	*tons/year*	No information identified
Operational input (e.g., energy, water)	*in MWh, in litres etc.*	No information identified
Potential environmental savings (GHG etc.)	*in CO2/tons, CO2-eq/ton, in €/ton etc.*	No information identified
Level of technological maturity	*Blueprint/concept OR Lab test, prototype OR Demonstration/low scale/not fully developed OR Full-scale operation*	No information identified
Commercial data		
Level of commercial maturity	*description*	No information identified
Investment costs	*in €*	No information identified
Operational costs	*in €/ton*	No information identified
Policy and regulatory data		
Intellectual property rights	*description*	No information identified
Level of policy attention in EU	*description*	No information identified
Regulatory considerations	*description*	No information identified
Project data		
Description and name of Initiative/plant/type of organisation/vendor	*description*	Patent on method for treating and separating mixed cellulose-plastics products by the University Cottbus-Senftenberg.
Involved parties and their roles (e.g., authorities, waste companies)	*description*	No information identified
Geographical area/coverage	*region/country*	No information identified
Type of project	*indicate if pilot project, research project etc.*	No information identified
Start date and duration of initiative/project	*month/year*	2013
Funding and support received for initiative/project	*in €*	No information identified
Data on transfer and scale up		
Suitability of technologies to AHPs (e.g., diapers, incontinence & female hygiene products) or specific fractions	*description*	No information identified
Application in other industry sectors/to other products	*description*	No information identified
Possibility for scale-up	*description*	No information identified
Challenges/potential barriers	*description*	No information identified
Dependencies on specific collection systems or other systems	*description*	No information identified
Sources: 1) Method for treating and separating mixed cellulose-plastics products https://patentimages.storage.googleapis.com/a2/56/7e/9995bcca850432/WO2013171248A2.pdf		

MICROWAVE PYROLYSIS

Indicators	Type of content and preferred unit	Microwave Pyrolysis
Technical data		
Collection/Separation/Recycling technology		Recycling
Origin of waste (e.g., household waste, hospital waste etc.) - mainly important for collection systems		For this study: from a nursery
Process description - Process type - Involved technology and tools - Dealing with hazardous substances and pathogenic germs - Decontamination techniques	*description*	Used diapers are dried in an oven at 90°C for 2 days. Microwave pyrolysis was done in a batch pyrolysis reactor (microwave oven with temperature controller and condensers to condense vapours). Oxygen-free different temperatures and microwave powers were used for testing the amount of liquid oil production/gas production.
Process objectives	*description*	No information identified
Focus/Input material	*list of possible input material*	AHPs
Output fractions - Target material of process - Resulting recyclates and their applications/markets - Other output materials and their application/markets	*description*	Oil: Chemical additives in personal care and cosmetic formulations Aliphatic hydrocarbons: chemical additives; fuel Char products: absorbent and soil additives Gas
Quality/value of output recyclate	*description + ranking if possible (e.g., high, medium, low)*	No information identified
Required skills for operation	*description*	No information identified
Collection/Separation/Recycling capacity	*tons/year*	No information identified
Operational input (e.g., energy, water)	*in MWh, in litres etc.*	Energy for microwave oven
Potential environmental savings (GHG etc.)	*in CO_2/tons, CO_2-eq/ton, in €/ton etc.*	"Transforming used baby diaper into values added products"
Level of technological maturity	*Blueprint/concept OR Lab test, prototype OR Demonstration/low scale/not fully developed OR Full-scale operation*	Lab test, prototype
Commercial data		
Level of commercial maturity	*description*	No information identified
Investment costs	*in €*	No information identified
Operational costs	*in €/ton*	No information identified
Policy and regulatory data		
Intellectual property rights	*description*	No information identified
Level of policy attention in EU	*description*	No information identified
Regulatory considerations	*description*	No information identified
Project data		
Description and name of Initiative/plant/type of organisation/vendor	*description*	No information identified
Involved parties and their roles (e.g., authorities, waste companies)	*description*	No information identified
Geographical area/coverage	*region/country*	Study conducted by Chinese, Korean and Malaysian researchers
Type of project	*indicate if pilot project, research project etc.*	Study
Start date and duration of initiative/project	*month/year*	No information identified

Funding and support received for initiative/project	*in €*	FRGS research grant (VOT 59434 and 59512)
Data on transfer and scale up		
Suitability of technologies to AHPs (e.g., diapers, incontinence & female hygiene products) or specific fractions	*description*	No information identified
Application in other industry sectors/to other products	*description*	No information identified
Possibility for scale-up	*description*	No information identified
Challenges/potential barriers	*description*	No information identified
Dependencies on specific collection systems or other systems	*description*	No information identified
Sources: 1) Microwave pyrolysis valorization of used baby diaper [Microwave pyrolysis valorization of used baby diaper - ScienceDirect]		

CHUNG HUA UNIVERSITY AND MULTIPLY ENERGY CO.

Indicators	Type of content and preferred unit	Chung Hua University and Multiply Energy Co.
Technical data		
Collection/Separation/Recycling technology		Recycling
Origin of waste (e.g., household waste, hospital waste etc.) - mainly important for collection systems		Intended for use onsite in day care centres and care homes.
Process description - Process type - Involved technology and tools - Dealing with hazardous substances and pathogenic germs - Decontamination techniques	*description*	Disinfection, cleaning, dewatering and drainage happen in the care homes with the help of a laundry machine with the Gullwing opening and the diapers are then shipped to a recycling centre. There the nappies are fed and stored, conveyed, shredded, separated, disinfected and recycled in one unit. Disinfection is performed with acidic electrolysed water, after which water and chemicals are added to aid stratification of the nappy into plastic, pulp and SAP layers. Water requirements are purportedly lower than for toilet flushing, likely because water is recirculated through a bioreactor system designed to remove N and P species. Some recyclate end uses include trash bags, cardboard, absorbent pads, absorbents for rare earth elements and nutrients. The wastewater is treated with the Green Fairy technology, which is a combination of micro-bioreactor, PVA-immobilized algal beads and PVA-immobilized cell beads with nitrifies, denitrifies and Bacillus.
Process objectives	*description*	No information identified
Focus/Input material	*list of possible input material*	AHPs
Output fractions - Target material of process - Resulting recyclates and their	*description*	PE, cellulose and sodium polyacrylate.

applications/markets - Other output materials and their application/markets		These materials can be processed into trash bags, cardboard, absorbent pads, absorbents for rare earth elements and nutrients.
Quality/value of output recyclate	*description + ranking if possible (e.g., high, medium, low)*	No information identified
Required skills for operation	*description*	No information identified
Collection/Separation/Recycling capacity	*tons/year*	Prototype is capable of handling 80–100 post-consumer AHPs per hour.
Operational input (e.g., energy, water)	*in MWh, in litres etc.*	Acidic electrolysed water 2 tons of water/day are needed for 100 capita units.
Potential environmental savings (GHG etc.)	*in CO_2/tons, CO_2-eq/ton, in €/ton etc.*	No information identified
Level of technological maturity	*Blueprint/concept OR Lab test, prototype OR Demonstration/low scale/not fully developed OR Full-scale operation*	Lab test, prototype
Commercial data		
Level of commercial maturity	*description*	No information identified
Investment costs	*in €*	No information identified
Operational costs	*in €/ton*	Profit from selling the recycled materials compensates operational costs
Policy and regulatory data		
Intellectual property rights	*description*	No information identified
Level of policy attention in EU	*description*	No information identified
Regulatory considerations	*description*	No information identified
Project data		
Description and name of Initiative/plant/type of organisation/vendor	*description*	No information identified
Involved parties and their roles (e.g., authorities, waste companies)	*description*	Chung Hua University and Multiply Energy Co. (Hsinchu County, Taiwan)
Geographical area/coverage	*region/country*	Taiwan
Type of project	*indicate if pilot project, research project etc.*	Prototype
Start date and duration of initiative/project	*month/year*	No information identified
Funding and support received for initiative/project	*in €*	No information identified
Data on transfer and scale up		
Suitability of technologies to AHPs (e.g., diapers, incontinence & female hygiene products) or specific fractions	*description*	No information identified
Application in other industry sectors/to other products	*description*	No information identified
Possibility for scale-up	*description*	No information identified
Challenges/potential barriers	*description*	No information identified
Dependencies on specific collection systems or other systems	*description*	No information identified
Sources: 1) Offensive waste valorisation in the UK: Assessment of the potentials for absorbent hygiene product (AHP) recycling Offensive waste valorisation in the UK: Assessment of the potentials for absorbent hygiene product (AHP) recycling - ScienceDirect 2) Sustainable used diaper recycler https://www.researchgate.net/publication/327201903_Sustainable_used_diaper_recycler/link/5b7fe6c14585151fd12ed1f5/download		

HYDROTHERMAL CARBONIZATION

Indicators	Type of content and preferred unit	Hydrothermal carbonization
Technical data		
Collection/Separation/Recycling technology		Recovery into a high calorific value hydrochar
Origin of waste (e.g., household waste, hospital waste etc.) - mainly important for collection systems		For the study: unused diapers
Process description - Process type - Involved technology and tools - Dealing with hazardous substances and pathogenic germs - Decontamination techniques	*description*	A diaper was cut and fed into Retsch shredder (Model SM200 Rosferi) to obtain a homogeneous feedstock material with an average particle size of 1–3 mm. experiments have been carried out in a 1 L reactor with external resistance. The reactor was filled with 25 g of the ground dry diaper (DD) and 250 g of distillate water, the water was absorbed. The reactor was then heated to the desired operational temperatures (200,225, 250, 275 and 300 °C) with an approx. heating rate of 1.5 °C/min at normal atmosphere conditions. Residence time in the reactor was 3 hours. Hydrochar was introduced to a drying oven for 24 h at a temperature of 105 °C to obtain dry char.
Process objectives	*description*	Main objective: use hydrothermal carbonization to remove water from disposable diapers and produce a high calorific value hydrochar.
Focus/Input material	*list of possible input material*	Diapers
Output fractions - Target material of process - Resulting recyclates and their applications/markets - Other output materials and their application/markets	*description*	Hydrochar
Quality/value of output recyclate	*description + ranking if possible (e.g., high, medium, low)*	Could be used for energy purposes, as they have similar properties to coal-like material.
Required skills for operation	*description*	No information identified
Collection/Separation/Recycling capacity	*tons/year*	No information identified
Operational input (e.g., energy, water)	*in MWh, in litres etc.*	Energy (heat)
Potential environmental savings (GHG etc.)	*in CO_2/tons, CO_2-eq/ton, in €/ton etc.*	No information identified
Level of technological maturity	*Blueprint/concept OR Lab test, prototype OR Demonstration/low scale/not fully developed OR Full-scale operation*	Lab test, prototype
Commercial data		
Level of commercial maturity	*description*	No information identified
Investment costs	*in €*	No information identified
Operational costs	*in €/ton*	No information identified
Policy and regulatory data		
Intellectual property rights	*description*	No information identified

Level of policy attention in EU	*description*	No information identified
Regulatory considerations	*description*	No information identified
Project data		
Description and name of Initiative/plant/type of organisation/vendor	*description*	No information identified
Involved parties and their roles (e.g., authorities, waste companies)	*description*	No information identified
Geographical area/coverage	*region/country*	No information identified
Type of project	*indicate if pilot project, research project etc.*	Research study
Start date and duration of initiative/project	*month/year*	No information identified
Funding and support received for initiative/project	*in €*	No information identified
Data on transfer and scale up		
Suitability of technologies to AHPs (e.g., diapers, incontinence & female hygiene products) or specific fractions	*description*	No information identified
Application in other industry sectors/to other products	*description*	No information identified
Possibility for scale-up	*description*	No information identified
Challenges/potential barriers	*description*	No information identified
Dependencies on specific collection systems or other systems	*description*	No information identified
Sources: 1) Hydrothermal carbonization of disposable diapers [Hydrothermal carbonization of disposable diapers - ScienceDirect]		

BIO-HYDROGEN GENERATION

Indicators	Type of content and preferred unit	Bio-hydrogen generation
Technical data		The study compared three different material compositions to find out where bio-hydrogen generation is highest when using fermentation processes.
Collection/Separation/Recycling technology		Experimental study
Origin of waste (e.g., household waste, hospital waste etc.) - mainly important for collection systems		Used baby disposable diapers (0-2 years) from the Children's Development Centre of the Universidad Autonoma Metropolitana Unidad Azcapotzalco.
Process description - Process type - Involved technology and tools - Dealing with hazardous substances and pathogenic germs - Decontamination techniques	*description*	Diapers were first collected and cooled at 4 °C until use. Diapers were ground in a Vermeer BC 1000 mill. Glass serum bottles were used as bioreactors and there were three types of treatment: WD: whole diaper, DWP: diaper without plastic, and MSD: diaper without faeces and plastic. A mineral medium ($NaHCO_3$, K_2HPO_4) and inoculum were mixed in to get a final concentration of 25 % total solids. The total solids were heated for 1 hour at 90 °C before loading into the serum bottles. After loading the serum bottles, headspaces were flushed with N_2.

		Incubator Millipore 632 was kept at 35 °C and incubator Topox IB-9052A was kept at 55 °C for 75 days. The bio-H_2 production was higher at 55 °C, particularly for WD and DWP. The cumulative bioH_2 production followed the order WD > MSD > DWP. Testing the inhibitory effects of a moisture-absorbent sodium polyacrylate (SPA) on the bio-hydrogen generation. Three types of treatments were evaluated in batch bioreactors at 37 °C: mixture of bond paper and filter paper (waste diaper-like material without SPA), SPA alone (only SPA or control), and WDM spiked with SPA (WDM-SPA).
Process objectives	*description*	No information identified
Focus/Input material	*list of possible input material*	No information identified
Output fractions - Target material of process - Resulting recyclates and their applications/markets - Other output materials and their application/markets	*description*	bioH_2: The cumulative bioH_2 production followed the order WD > MSD > DWP. The experiments indicated that WDM-SPA bioreactors exhibited bioH_2 production 25 % lower than that of bioreactors loaded with WDM but no SPA; SPA bioreactors did not produce H_2. Consequently, the study suggests considering SPA replacement in diapers.
Quality/value of output recyclate	*description + ranking if possible (e.g., high, medium, low)*	No information identified
Required skills for operation	*description*	No information identified
Collection/Separation/Recycling capacity	*tons/year*	No information identified
Operational input (e.g., energy, water)	*in MWh, in litres etc.*	Energy
Potential environmental savings (GHG etc.)	*in CO_2/tons, CO_2-eq/ton, in €/ton etc.*	No information identified
Level of technological maturity	*Blueprint/concept OR Lab test, prototype OR Demonstration/low scale/not fully developed OR Full-scale operation*	Blueprint/concept
Commercial data		
Level of commercial maturity	*description*	No information identified
Investment costs	*in €*	No information identified
Operational costs	*in €/ton*	No information identified
Policy and regulatory data		
Intellectual property rights	*description*	No information identified
Level of policy attention in EU	*description*	No information identified
Regulatory considerations	*description*	No information identified
Project data		
Description and name of Initiative/plant/type of organisation/vendor	*description*	No information identified
Involved parties and their roles (e.g., authorities, waste companies)	*description*	No information identified
Geographical area/coverage	*region/country*	No information identified
Type of project	*indicate if pilot project, research project etc.*	No information identified

Start date and duration of initiative/project	*month/year*	No information identified
Funding and support received for initiative/project	*in €*	No information identified
Data on transfer and scale up		
Suitability of technologies to AHPs (e.g., diapers, incontinence & female hygiene products) or specific fractions	*description*	No information identified
Application in other industry sectors/to other products	*description*	No information identified
Possibility for scale-up	*description*	No information identified
Challenges/potential barriers	*description*	No information identified
Dependencies on specific collection systems or other systems	*description*	No information identified
Sources: 1) Sodium polyacrylate inhibits fermentative hydrogen production from waste diaper-like material [Sodium polyacrylate inhibits fermentative hydrogen production from waste diaper-like material - Sotelo-Navarro - 2020 - Journal of Chemical Technology & Biotechnology - Wiley Online Library]		

DIAPER RECYCLING TECHNOLOGY (SINGAPORE)

Indicators	Type of content and preferred unit	DIAPER RECYCLING TECHNOLOGY (SINGAPORE)
Technical data		
Collection/Separation/Recycling technology		No information identified
Origin of waste (e.g., household waste, hospital waste etc.) - mainly important for collection systems		Post-Industrial waste
Process description - Process type - Involved technology and tools - Dealing with hazardous substances and pathogenic germs - Decontamination techniques	*description*	New airless processing technology utilizes new vertical stacking processes, allowing gravity to pass the materials from process to process, which is ideal for recycling with constrained space. Process modules such as plastic purification and pulp/SAM separation. Modules can be added or removed as desired.
Process objectives	*description*	
Focus/Input material	*list of possible input material*	No information identified
Output fractions - Target material of process - Resulting recyclates and their applications/markets - Other output materials and their application/markets	*description*	Pure plastics (PE, PP, PET, PLA), pure pulps (softwoods, hardwoods, viscose), pure SAP
Quality/value of output recyclate	*description + ranking if possible (e.g., high, medium, low)*	All recycled raw material streams need to be 100 % pure and without contamination.
Required skills for operation	*description*	
Collection/Separation/Recycling capacity	*tons/year*	Central recycling modules can process up to 500 kgs per hour.
Operational input (e.g., energy, water)	*in MWh, in litres etc.*	Energy requirements start from only 9.5 kW.
Potential environmental savings (GHG etc.)	*in CO2/tons, CO2-eq/ton, in €/ton etc.*	90 %-95 % of ongoing energy costs can be saved in contrast to conventional recycling technology. Floor space utilization can be maximized.
Level of technological maturity	*Blueprint/concept OR Lab test, prototype*	No information identified

	OR Demonstration/low scale/not fully developed OR Full-scale operation	
Commercial data		
Level of commercial maturity	*description*	No information identified
Investment costs	*in €*	No information identified
Operational costs	*in €/ton*	No information identified
Policy and regulatory data		
Intellectual property rights	*description*	No information identified
Level of policy attention in EU	*description*	No information identified
Regulatory considerations	*description*	No information identified
Project data		
Description and name of Initiative/plant/type of organisation/vendor	*description*	No information identified
Involved parties and their roles (e.g., authorities, waste companies)	*description*	No information identified
Geographical area/coverage	*region/country*	No information identified
Type of project	*indicate if pilot project, research project etc.*	No information identified
Start date and duration of initiative/project	*month/year*	No information identified
Funding and support received for initiative/project	*in €*	No information identified
Data on transfer and scale up		
Suitability of technologies to AHPs (e.g., diapers, incontinence & female hygiene products) or specific fractions	*description*	No information identified
Application in other industry sectors/to other products	*description*	No information identified
Possibility for scale-up	*description*	No information identified
Challenges/potential barriers	*description*	No information identified
Dependencies on specific collection systems or other systems	*description*	No information identified
Sources: 1) WHY CHOOSE OUR TECHNOLOGY https://diaperrecycling.technology/		

SYNTHESIS OF GLYCEROL CARBONATE USING DIAPER WASTE

Indicators	Type of content and preferred unit	SYNTHESIS OF GLYCEROL CARBONATE USING DIAPER WASTE
Technical data		The authors use diaper waste materials as magnetic catalysts for the synthesis of glycerol carbonate by impregnation and calcination techniques.
Collection/Separation/Recycling technology		Recycling
Origin of waste (e.g., household waste, hospital waste etc.) - mainly important for collection systems		Local municipal waste
Process description - Process type - Involved technology and tools - Dealing with hazardous substances and pathogenic germs - Decontamination techniques	*description*	Diaper waste was first dried at 100 °C for 4 h and the dried diaper waste was cut into small pieces. Then, diaper waste was impregnated into the nickel nitrate. The fully impregnated diaper waste was dried at 110 °C for 6 h. This diaper waste doped with nickel nitrate was calcined above 400 °C. The

		product is now called magnetic heterogeneous catalyst (MHC).
Process objectives	*description*	No information identified
Focus/Input material	*list of possible input material*	Diapers
Output fractions - Target material of process - Resulting recyclates and their applications/markets - Other output materials and their application/markets	*description*	A low-cost and high-performance catalyst for the synthesis of Glycerol Carbonates.
Quality/value of output recyclate	*description + ranking if possible (e.g., high, medium, low)*	No information identified
Required skills for operation	Chemical know-how	Chemical know-how
Collection/Separation/Recycling capacity	*tons/year*	No information identified
Operational input (e.g., energy, water)	*in MWh, in litres etc.*	Reagents like dimethyl carbonate, glycerol, nickel nitrate, and methanol.
Potential environmental savings (GHG etc.)	*in CO2/tons, CO2-eq/ton, in €/ton etc.*	It would help to reduce the amount of glycerol dumped.
Level of technological maturity	*Blueprint/concept OR Lab test, prototype OR Demonstration/low scale/not fully developed OR Full-scale operation*	No information identified
Commercial data		
Level of commercial maturity	*description*	No information identified
Investment costs	*in €*	No information identified
Operational costs	*in €/ton*	No information identified
Policy and regulatory data		
Intellectual property rights	*description*	No information identified
Level of policy attention in EU	*description*	No information identified
Regulatory considerations	*description*	No information identified
Project data		
Description and name of Initiative/plant/type of organisation/vendor	*description*	No information identified
Involved parties and their roles (e.g., authorities, waste companies)	*description*	No information identified
Geographical area/coverage	*region/country*	China
Type of project	*indicate if pilot project, research project etc.*	Research project
Start date and duration of initiative/project	*month/year*	Published in 2020
Funding and support received for initiative/project	*in €*	Open Research Fund of the State Key Laboratory of Polymer Physics and Chemistry, Changchun Institute of Applied Chemistry, Chinese Academy of Sciences (2018-02), the General Project Fund of Liaoning Education Department (LJGD2019014), and the Key Laboratory for Catalyst Synthesis Technology of Polymer of Liaoning Province, China (2010-36)
Data on transfer and scale up		
Suitability of technologies to AHPs (e.g., diapers, incontinence & female hygiene products) or specific fractions	*description*	It was proven successfully.
Application in other industry sectors/to other products	*description*	All polymeric waste could be used.

Possibility for scale-up	*description*	Transesterification process was complicated and costly
Challenges/potential barriers	*description*	Complicated and costly
Dependencies on specific collection systems or other systems	*description*	No information identified
Sources: 1) New open-loop recycling approaches for disposable diaper waste https://cdnsciencepub.com/doi/abs/10.1139/er-2021-0033 2) Using Diaper Waste to Prepare Magnetic Catalyst for the Synthesis of Glycerol Carbonate https://www.hindawi.com/journals/ijps/2020/9403714/		

PYROPURE

Indicators	Type of content and preferred unit	PyroPure
Technical data		
Collection/Separation/Recycling technology		Pyrolysis of AHPs and other wastes
Origin of waste (e.g., household waste, hospital waste etc.) - mainly important for collection systems		On-site waste disposal systems targeted at residential sites, nursing homes and other sites with limited transport links.
Process description - Process type - Involved technology and tools - Dealing with hazardous substances and pathogenic germs - Decontamination techniques	*description*	The small-scale pyrolyser with chamber volume of up to 0.5 m^3 is fitted with catalyst(s) to reduce CO, volatile organic carbons and tar. The pyrolyser operates at 550–700 °C. A cyclone separates ash from exit gas, which is subsequently flushed into the sewer system. The process has potential for hot water generation.
Process objectives	*description*	No information identified
Focus/Input material	*list of possible input material*	AHPs and other wastes
Output fractions - Target material of process - Resulting recyclates and their applications/markets - Other output materials and their application/markets	*description*	No information identified
Quality/value of output recyclate	*description + ranking if possible (e.g., high, medium, low)*	Recycled AHPs are potential feedstocks for bio-composite and fertiliser industries.
Required skills for operation	*description*	No information identified
Collection/Separation/Recycling capacity	*tons/year*	About 70 kg of waste can be processed per day.
Operational input (e.g., energy, water)	*in MWh, in litres etc.*	Energy (heat)
Potential environmental savings (GHG etc.)	*in CO2/tons, CO2-eq/ton, in €/ton etc.*	No information identified
Level of technological maturity	*Blueprint/concept OR Lab test, prototype OR Demonstration/low scale/not fully developed OR Full-scale operation*	No information identified
Commercial data		
Level of commercial maturity	*description*	No information identified
Investment costs	*in €*	No information identified
Operational costs	*in €/ton*	No information identified
Policy and regulatory data		
Intellectual property rights	*description*	No information identified

Level of policy attention in EU	*description*	No information identified
Regulatory considerations	*description*	No information identified
Project data		
Description and name of Initiative/plant/type of organisation/vendor	*description*	No information identified
Involved parties and their roles (e.g., authorities, waste companies)	*description*	No information identified
Geographical area/coverage	*region/country*	Hampshire, UK
Type of project	*indicate if pilot project, research project etc.*	In progess
Start date and duration of initiative/project	*month/year*	No information identified
Funding and support received for initiative/project	*in €*	No information identified
Data on transfer and scale up		
Suitability of technologies to AHPs (e.g., diapers, incontinence & female hygiene products) or specific fractions	*description*	No information identified
Application in other industry sectors/to other products	*description*	No information identified
Possibility for scale-up	*description*	No information identified
Challenges/potential barriers	*description*	No information identified
Dependencies on specific collection systems or other systems	*description*	No information identified
Sources: 1) Offensive waste valorisation in the UK: Assessment of the potentials for absorbent hygiene product (AHP) recycling https://pubmed.ncbi.nlm.nih.gov/31079651/ 2) Synergistic effects of CO2 on complete thermal degradation of plastic waste mixture through a catalytic pyrolysis platform: A case study of disposable diaper https://www.sciencedirect.com/science/article/abs/pii/S0304389421015028		

DEVOLATILIZATION IN A BUBBLING FLUIDIZED BED

Indicators	Type of content and preferred unit	DEVOLATILIZATION IN A BUBBLING FLUIDIZED BED
Technical data		The study experimentally investigated the devolatilization of shredded diapers, in a laboratory-scale bubbling fluidized bed made of sand.
Collection/Separation/Recycling technology		Recycling technology (experimental study)
Origin of waste (e.g., household waste, hospital waste etc.) - mainly important for collection systems		Shredded post-industrial diapers and shredded cellulosic fraction of sterilized used diapers.
Process description - Process type - Involved technology and tools - Dealing with hazardous substances and pathogenic germs - Decontamination techniques	*description*	Laboratory-scale bubbling fluidized bed was made of sand. Each material was investigated at four temperature levels (500, 600, 700, 800 °C), with two fluidizing agents (pure N_2 or air diluted by N_2 to obtain 1.3–2.3 vol% of O_2 at the bed inlet). Gas yield, carbon conversion, and cold gas efficiency were measured.
Process objectives	*description*	Usage of waste from AHPs as a fuel for gasification or pyrolysis.

Focus/Input material	*list of possible input material*	For the experiments two raw materials were selected: 1) as-manufactured, coarsely shredded diapers (AHPam) - post-production waste 2) the cellulosic fraction of sterilized used diapers (post-consumer waste)
Output fractions - Target material of process - Resulting recyclates and their applications/markets - Other output materials and their application/markets	*description*	Syngas: The experiments indicated that at 700–800 °C under pure nitrogen, the highest syngas quality and yield were obtained.
Quality/value of output recyclate	*description + ranking if possible (e.g., high, medium, low)*	No information identified
Required skills for operation	*description*	No information identified
Collection/Separation/Recycling capacity	*tons/year*	Laboratory-scale for experimental purpose for possible scaling-up of thermochemical conversion. Processes with waste materials from AHPs as the solid fuel feedstock.
Operational input (e.g., energy, water)	*in MWh, in litres etc.*	No information identified
Potential environmental savings (GHG etc.)	*in CO2/tons, CO2-eq/ton, in €/ton etc.*	No information identified
Level of technological maturity	*Blueprint/concept OR Lab test, prototype OR Demonstration/low scale/not fully developed OR Full-scale operation*	Laboratory scale
Commercial data		
Level of commercial maturity	*description*	No information identified
Investment costs	*in €*	No information identified
Operational costs	*in €/ton*	No information identified
Policy and regulatory data		
Intellectual property rights	*description*	No information identified
Level of policy attention in EU	*description*	No information identified
Regulatory considerations	*description*	No information identified
Project data		
Description and name of Initiative/plant/type of organisation/vendor	*description*	University of L'Aquila, Italy laboratory tests
Involved parties and their roles (e.g., authorities, waste companies)	*description*	No information identified
Geographical area/coverage	*region/country*	Italy
Type of project	*indicate if pilot project, research project etc.*	Laboratory test
Start date and duration of initiative/project	*month/year*	No information identified
Funding and support received for initiative/project	*in €*	No information identified
Data on transfer and scale up		
Suitability of technologies to AHPs (e.g., diapers, incontinence & female hygiene products) or specific fractions	*description*	No information identified
Application in other industry sectors/to other products	*description*	No information identified
Possibility for scale-up	*description*	No information identified
Challenges/potential barriers	*description*	No information identified
Dependencies on specific collection systems or other systems	*description*	No information identified

Sources:
1) Experimental Study of Absorbent Hygiene Product Devolatilization in a Bubbling Fluidized Bed https://ricerca.univaq.it/retrieve/e2188bfb-7ca2-f28d-e053-d805fe0ac2bb/energies-14-02399%20%281%29.pdf

BISPHENOL DEGRADING

Indicators	Type of content and preferred unit	Bisphenol degrading
Technical data		The authors transform recycled, used diapers into a porous carbon-based material for degrading bisphenol A (BPA) in wastewater
Collection/Separation/Recycling technology		Recycling
Origin of waste (e.g., household waste, hospital waste etc.) - mainly important for collection systems		No information identified
Process description - Process type - Involved technology and tools - Dealing with hazardous substances and pathogenic germs - Decontamination techniques	*description*	Diapers with high levels of urea (CH_4N_2O) were enriched with cobalt during carbonization. The end product (peroxymonosulfate) is able to degrade BPAs.
Process objectives	*description*	The objective of this study is the recycling of waste biomass for peroxymonosulfate activation and environmental modification.
Focus/Input material	*list of possible input material*	Diapers (including the nitrogen from the urine in the diaper)
Output fractions - Target material of process - Resulting recyclates and their applications/markets - Other output materials and their application/markets	*description*	No information identified
Quality/value of output recyclate	*description + ranking if possible (e.g., high, medium, low)*	No information identified
Required skills for operation	*description*	No information identified
Collection/Separation/Recycling capacity	*tons/year*	No information identified
Operational input (e.g., energy, water)	*in MWh, in litres etc.*	No information identified
Potential environmental savings (GHG etc.)	*in CO_2/tons, CO_2-eq/ton, in €/ton etc.*	Degrading bisphenol A (BPA) and total organic carbon (TOC) in wastewater.
Level of technological maturity	*Blueprint/concept OR Lab test, prototype OR Demonstration/low scale/not fully developed OR Full-scale operation*	No information identified
Commercial data		
Level of commercial maturity	*description*	No information identified
Investment costs	*in €*	No information identified
Operational costs	*in €/ton*	No information identified
Policy and regulatory data		
Intellectual property rights	*description*	No information identified
Level of policy attention in EU	*description*	No information identified
Regulatory considerations	*description*	No information identified
Project data		
Description and name of Initiative/plant/type of organisation/vendor	*description*	No information identified

Involved parties and their roles (e.g., authorities, waste companies)	*description*	No information identified
Geographical area/coverage	*region/country*	No information identified
Type of project	*indicate if pilot project, research project etc.*	No information identified
Start date and duration of initiative/project	*month/year*	No information identified
Funding and support received for initiative/project	*in €*	No information identified
Data on transfer and scale up		
Suitability of technologies to AHPs (e.g., diapers, incontinence & female hygiene products) or specific fractions	*description*	No information identified
Application in other industry sectors/to other products	*description*	No information identified
Possibility for scale-up	*description*	No information identified
Challenges/potential barriers	*description*	Bottleneck congestion might occur in this system because the lifespan of PMS radicals is relatively short.
Dependencies on specific collection systems or other systems	*description*	No information identified
Sources: 1) New open-loop recycling approaches for disposable diaper waste New open-loop recycling approaches for disposable diaper waste (cdnsciencepub.com) 2) Recycling of nitrogen-containing waste diapers for catalytic contaminant oxidation: Occurrence of radical and non-radical pathways Recycling of nitrogen-containing waste diapers for catalytic contaminant oxidation: Occurrence of radical and non-radical pathways - ScienceDirect		

CONCRETE VISCOSITY MODIFYING ADMIXTURE

Indicators	Type of content and preferred unit	Concrete viscosity modifying admixture
Technical data		
Collection/Separation/Recycling technology		Recycling
Origin of waste (e.g., household waste, hospital waste etc.) - mainly important for collection systems		No information identified
Process description - Process type - Involved technology and tools - Dealing with hazardous substances and pathogenic germs - Decontamination techniques	*description*	The diaper waste was shredded and mixed with polycarboxylic ether-based superplasticizer, limestone powder, sand (0-2 mm and 0-4 mm), and gravel (4-8 mm and 8-16 mm) to form self-consolidating concrete. Fritsch Pulverisette 15 cutting mill was utilized for shredding the diapers Shredded waste diaper and cement are mixed at 800 rpm for 90 s at 25 °C. Water is added and mixed for 1 min at 2000 rpm. Mixture is stopped and scraped for 30 s. More water and superplasticizer are added and mixed for 1 min at 2000 rpm.
Process objectives	*description*	The objective of this study is to redirect used diapers from landfills and improve the concrete sectors.
Focus/Input material	*list of possible input material*	Diapers (shredded)

Output fractions - Target material of process - Resulting recyclates and their applications/markets - Other output materials and their application/markets	*description*	Viscosity modifying admixture (VMA) for cement grouts and concrete
Quality/value of output recyclate	*description + ranking if possible (e.g., high, medium, low)*	No information identified
Required skills for operation	*description*	No information identified
Collection/Separation/Recycling capacity	*tons/year*	No information identified
Operational input (e.g., energy, water)	*in MWh, in litres etc.*	No information identified
Potential environmental savings (GHG etc.)	*in CO_2/tons, CO_2-eq/ton, in €/ton etc.*	A sustainable source for producing viscosity modifying admixtures. Cement produced in this way was highly alkaline and free from pathogens.
Level of technological maturity	*Blueprint/concept OR Lab test, prototype OR Demonstration/low scale/not fully developed OR Full-scale operation*	No information identified
Commercial data		
Level of commercial maturity	*description*	No information identified
Investment costs	*in €*	No information identified
Operational costs	*in €/ton*	No information identified
Policy and regulatory data		
Intellectual property rights	*description*	No information identified
Level of policy attention in EU	*description*	No information identified
Regulatory considerations	*description*	A computational model was introduced to formulate the diaper waste dosages in the cement to comply with European legal frameworks and American standards (EN 1008 and ASTM C 1602).
Project data		
Description and name of Initiative/plant/type of organisation/vendor	*description*	No information identified
Involved parties and their roles (e.g., authorities, waste companies)	*description*	No information identified
Geographical area/coverage	*region/country*	Netherlands
Type of project	*indicate if pilot project, research project etc.*	No information identified
Start date and duration of initiative/project	*month/year*	No information identified
Funding and support received for initiative/project	*in €*	Stapper Duurzaam Advies
Data on transfer and scale up		
Suitability of technologies to AHPs (e.g., diapers, incontinence & female hygiene products) or specific fractions	*description*	No information identified
Application in other industry sectors/to other products	*description*	No information identified
Possibility for scale-up	*description*	Yes
Challenges/potential barriers	*description*	No information identified
Dependencies on specific collection systems or other systems	*description*	No information identified
Sources: 1) New open-loop recycling approaches for disposable diaper waste New open-loop recycling approaches for disposable diaper waste (cdnsciencepub.com)		

2) Closing the loop of Absorbent Hygiene Products EMBRACED_D1.7_Blueprint_DEF.pdf 3) Valorization of waste baby diapers in concrete Valorization of waste baby diapers in concrete - ScienceDirect

EMBRACED

Indicators	Type of content and preferred unit	EMBRACED
Technical data		
Collection/Separation/Recycling technology		Circular model of integrated biorefinery
Origin of waste (e.g., household waste, hospital waste etc.) - mainly important for collection systems		Post-consumer AHPs Collection from households or other relevant producers (nursing homes, hospitals, day care centres).
Process description **- Process type** **- Involved technology and tools** **- Dealing with hazardous substances and pathogenic germs** **- Decontamination techniques**	*description*	-Cellulose quality is enhanced by reducing SAP content from 50 % to 5 %. An innovative pre-treatment technology for obtaining fermentable sugars from AHP waste cellulose converted through a biotech process into biobased building blocks of industrial interest is implemented. Syngas from AHP waste cellulose is converted into biodegradable Polyhydroxybutyrate (PHB). Biobased and biodegradable polyesters formulation are suitable for packaging applications.
Process objectives	*description*	No information identified
Focus/Input material	*list of possible input material*	Cellulosic fraction of post-consumer Absorbent Hygiene Products (AHP) waste. Recovery of 3 high purity fractions: cellulose, plastic fraction and Super Absorbent Polymer fraction (SAP)
Output fractions **- Target material of process** **- Resulting recyclates and their applications/markets** **- Other output materials and their application/markets**	*description*	Production of biobased building blocks, polymers, and fertilisers - Recycled plastic fraction into plastic bins and caps - Deactivated cells from PHB fermentation into organic fertilisers - PHB into medical devices - Biobased polyesters into films for non-food packaging applications - Recycled SAP into innovative absorbent underpads
Quality/value of output recyclate	*description + ranking if possible (e.g., high, medium, low)*	No information identified
Required skills for operation	*description*	No information identified
Collection/Separation/Recycling capacity	*tons/year*	10,000 tons/year of AHPs (baby diapers, feminine care, adult incontinence) waste that will be upcycled into valuable material
Operational input (e.g., energy, water)	*in MWh, in litres etc.*	No information identified
Potential environmental savings (GHG etc.)	*in CO2/tons, CO2-eq/ton, in €/ton etc.*	- Target reduction of GHG emission: 0.43 tons CO_2 eq/ton AHP waste against incineration - Reduction of CO_2 emission by up to 250 kg CO_2 eq/ton PHB with respect to PHB produced from sugar feedstock - Reduction of water requirement and land use compared to the production of PHB from 1st gen sugars - Valorisation of by-products from fermentation into bio-energy production
Level of technological maturity	*Blueprint/concept OR Lab test, prototype*	No information identified

	OR Demonstration/low scale/not fully developed *OR Full-scale operation*	
Commercial data		
Level of commercial maturity	*description*	No information identified
Investment costs	*in €*	No information identified
Operational costs	*in €/ton*	No information identified
Policy and regulatory data		
Intellectual property rights	*description*	No information identified
Level of policy attention in EU	*description*	No information identified
Regulatory considerations	*description*	No information identified
Project data		
Description and name of Initiative/plant/type of organisation/vendor	*description*	Fater, P&G
Involved parties and their roles (e.g., authorities, waste companies)	*description*	Legambiente, Novamont, Contarina, Fraunhofer-Gesellschaft, CIRCE, Edizioni Ambiente, Saponia, TerraCycle, SUEZ, Fertinagro, Wittenburg
Geographical area/coverage	*region/country*	7 countries
Type of project	*indicate if pilot project, research project etc.*	No information identified
Start date and duration of initiative/project	*month/year*	Starting date of project: June 1st, 2017 Duration: 60 months
Funding and support received for initiative/project	*in €*	No information identified
Data on transfer and scale up		
Suitability of technologies to AHPs (e.g., diapers, incontinence & female hygiene products) or specific fractions	*description*	No information identified
Application in other industry sectors/to other products	*description*	No information identified
Possibility for scale-up	*description*	No information identified
Challenges/potential barriers	*description*	No information identified
Dependencies on specific collection systems or other systems	*description*	No information identified
Sources: 1) EMBRACED https://www.embraced.eu/		

PAMPERS NUOVAVITA (FORMER FATERSMART)

Indicators	Type of content and preferred unit	Pampers nuovavita (former FATERSMART)
Technical data		
Collection/Separation/Recycling technology		Collection of used diapers at the Pampers powered by Fater recycling bins.
Origin of waste (e.g., household waste, hospital waste etc.) - mainly important for collection systems		Collaboration of citizens in the specific experimental collection of used diapers for recycling.
Process description - Process type - Involved technology and tools - Dealing with hazardous substances and pathogenic germs - Decontamination techniques	*Description*	The recycling process begins with the **collection of used diapers** at the recycling bins. The collected diapers are transferred to the dedicated treatment centre. The storage system is able to contain up to 20 t of product.

		Very high-pressure steam is utilised to sterilize used diapers in an autoclave in order to eliminate bad odours and potential pathogens. Cellulose plastic is **mechanically separated.** **Raw materials are 100 % recovered** to be transformed into many different products.
Process objectives	*description*	No information identified
Focus/Input material	*list of possible input material*	Recover 100 % of the materials derived from **diapers (cellulose, plastic and super absorbent polymer).** Customers download Pampers Nuova Vita App and search for the closest diaper recycler bin. They carry used diapers in a plastic bag or the Pampers bag. They log in to the app and bring smartphone close to open the door.
Output fractions - Target material of process - Resulting recyclates and their applications/markets - Other output materials and their application/markets	*description*	From 1 t of recycled waste, 150 kg of cellulose, 75 kg of plastic and 75 kg of super absorbent polymer can be recovered.
Quality/value of output recyclate	*description + ranking if possible (e.g., high, medium, low)*	No information identified
Required skills for operation	*description*	No information identified
Collection/Separation/Recycling capacity	*tons/year*	263,892 kg of collected diapers Capacity of 5,000-10,000 tons/year (in Italy)
Operational input (e.g., energy, water)	*in MWh, in litres etc.*	No information identified
Potential environmental savings (GHG etc.)	*in CO2/tons, CO2-eq/ton, in €/ton etc.*	Byrecycling**100 kg of used diapers** and absorbent products, it is possible to avoid **40.8 kg of CO_2 emissions.** Recycling all absorbent products in the city of Verona alone means avoiding **1,400 tons of CO_2 emissions**: to achieve the same result, more than **95,000 trees** would be needed.
Level of technological maturity	*Blueprint/concept OR Lab test, prototype OR Demonstration/low scale/not fully developed OR Full-scale operation*	No information identified
Commercial data		
Level of commercial maturity	*description*	No information identified
Investment costs	*in €*	No information identified
Operational costs	*in €/ton*	No information identified
Policy and regulatory data		
Intellectual property rights	*description*	No information identified
Level of policy attention in EU	*description*	No information identified
Regulatory considerations	*description*	No information identified
Project data		
Description and name of Initiative/plant/type of organisation/vendor	*description*	Fater, P&G

Involved parties and their roles (e.g., authorities, waste companies)	*description*	No information identified
Geographical area/coverage	*region/country*	Italy (Verona)
Type of project	*indicate if pilot project, research project etc.*	No information identified
Start date and duration of initiative/project	*month/year*	No information identified
Funding and support received for initiative/project	*in €*	No information identified
Data on transfer and scale up		
Suitability of technologies to AHPs (e.g., diapers, incontinence & female hygiene products) or specific fractions	*description*	No information identified
Application in other industry sectors/to other products	*description*	No information identified
Possibility for scale-up	*description*	No information identified
Challenges/potential barriers	*description*	No information identified
Dependencies on specific collection systems or other systems	*description*	No information identified
Sources: 1) Pampers- Progetto Nuovavita Pampers - Progetto Nuovavita 2) Turning used diapers into new resources Pampers Nuova vita a Verona | Fater (fatergroup.com)		

ONTEX LES ALCHIMIST COMPOSTABILITY OF DIAPERS

Indicators	Type of content and preferred unit	Ontex Les Alchimist compostability of diapers
Technical data		
Collection/Separation/Recycling technology		Make the separate collection and composting of used, **compostable diapers** a reality. Brand Little Big Change
Origin of waste (e.g., household waste, hospital waste etc.) - mainly important for collection systems		**Families in Paris** who subscribe to Ontex's baby diaper service Little Big Change.
Process description - Process type - Involved technology and tools - Dealing with hazardous substances and pathogenic germs - Decontamination techniques	*description*	Ontex Little Big Change brand has developed a **new diaper system.** The system consists of a **reusable outer diaper** made of cotton and a **disposable diaper pad** which is designed to be industrially **compostable**. Now testing if the diaper pads can be composted on an industrial scale.
Process objectives	*description*	No information identified
Focus/Input material	*list of possible input material*	Disposable Ontex diaper pads with compostable materials. **Hybrid compostable diapers** with reusable outer diaper made of cotton and a disposable diaper pad
Output fractions - Target material of process - Resulting recyclates and their applications/markets - Other output materials and their application/markets	*description*	Compost. Les Alchimistes is investigating, with the French government, routes to commercialization.
Quality/value of output recyclate	*description + ranking if possible (e.g., high, medium, low)*	No information identified

Required skills for operation	*description*	No information identified
Collection/Separation/Recycling capacity	*tons/year*	In-vessel composter has limited capacity. Les Alchimistes is investigating other composting techniques to scale up.
Operational input (e.g., energy, water)	*in MWh, in litres etc.*	Energy to operate in-vessel composter. To make the compost, the diaper waste is first opened up and mixed with other organic waste.
Potential environmental savings (GHG etc.)	*in CO2/tons, CO2-eq/ton, in €/ton etc.*	https://librairie.ademe.fr/consommer-autrement/4426-compic-experimentation-de-la-valorisation-organique-de-couches-jetables-et-analyse-des-impacts-sanitaires-et-environnementaux.html
Level of technological maturity	*Blueprint/concept OR Lab test, prototype OR Demonstration/low scale/not fully developed OR Full-scale operation*	No information identified
Commercial data		
Level of commercial maturity	*description*	No information identified
Investment costs	*in €*	No information identified
Operational costs	*in €/ton*	No information identified
Policy and regulatory data		
Intellectual property rights	*description*	No information identified
Level of policy attention in EU	*description*	No information identified
Regulatory considerations	*description*	No information identified
Project data		
Description and name of Initiative/plant/type of organisation/vendor	*description*	Les Alchimistes, Ontex (brand LBC)
Involved parties and their roles (e.g., authorities, waste companies)	*description*	gDiapers, Les Alchimistes
Geographical area/coverage	*region/country*	Paris
Type of project	*indicate if pilot project, research project etc.*	No information identified
Start date and duration of initiative/project	*month/year*	2021, 1 year
Funding and support received for initiative/project	*in €*	No information identified
Data on transfer and scale up		
Suitability of technologies to AHPs (e.g., diapers, incontinence & female hygiene products) or specific fractions	*description*	Only suitable for separately collected diapers that are industrially compostable. So NOT suitable for current AHP.
Application in other industry sectors/to other products	*description*	No information identified
Possibility for scale-up	*description*	No information identified
Challenges/potential barriers	*description*	Technically: compostable materials, including SAP. Prices of compostable raw materials. Legal: commercialization of compost made from diapers & human organic waste.
Dependencies on specific collection systems or other systems	*description*	Dedicated Separate collection. Compostable materials in composting installation create CO_2 benefit. But same compostable products going to landfill cause methane (strong climate change effect).
Sources: 1) Belgian company Ontex working on compostability of diaper pads		

Belgian company Ontex working on compostability of diaper pads - TechnicalTextile.net 2) Ontex Tests Industrial Scale Diaper Composting https://www.nonwovens-industry.com/contents/view_breaking-news/2021-04-20/ontex-tests-industrial-scale-diaper-composting/

NIPPON SHOKUBAI, LIVEDO, TOTAL CARE SYSTEMS, TOPPAN AND SUMITOMO HEAVY INDUSTRIES ENVIRONMENT: COMPLETE MATERIAL RECYCLING SYSTEM

Indicators	Type of content and preferred unit	Nippon Shokubai, LiveDo, Total Care Systems, Toppan and Sumitomo Heavy Industries Environment: Complete Material Recycling System
Technical data		
Collection/Separation/Recycling technology		Collection/recycling
Origin of waste (e.g., household waste, hospital waste etc.) - mainly important for collection systems		Medical institutions, welfare facilities, and general households
Process description - Process type - Involved technology and tools - Dealing with hazardous substances and pathogenic germs - Decontamination techniques	*description*	Already in 2004, there was a recycling plant for disposable diapers (Love Forest Omuta Plant) which focused on the recycling of disposable diapers via water-solubilization treatment. Diapers are separated into 3 compounds (celluloses, SAP and plastic). The SAP recycling was developed by Total care systems in cooperation with Nippon Shokubai and LiveDo Corporation. Toppan Printing: Process control, application development, utilization, and sales to optimize upcycling of recycled resources. Total care system: Provision of recycling technology and know-how for used disposable diapers. Sumitomo Heavy Industries Environment: Plant design and construction of water-solubilization treatment facilities. Focus also on water circulation.
Process objectives	*description*	"A business model for used disposable diaper recycling systems that can be introduced by a large number of local municipalities and are targeting commercialization and use by such municipalities beginning in 2022."
Focus/Input material	*list of possible input material*	Diapers
Output fractions - Target material of process - Resulting recyclates and their applications/markets - Other output materials and their application/markets	*description*	Pulp as raw material for building materials (exterior wall materials, interior material etc.) Fuel SAP

Quality/value of output recyclate	*description + ranking if possible (e.g., high, medium, low)*	No information identified
Required skills for operation	*description*	No information identified
Collection/Separation/Recycling capacity	*tons/year*	The plant currently recycles over 5,000 tons of used disposable diapers
Operational input (e.g., energy, water)	*in MWh, in litres etc.*	No information identified
Potential environmental savings (GHG etc.)	*in CO_2/tons, CO_2-eq/ton, in €/ton etc.*	Recycling rather than incinerating used disposable diapers can reduce CO_2 emissions by approximately 37 %.
Level of technological maturity	*Blueprint/concept OR Lab test, prototype OR Demonstration/low scale/not fully developed OR Full-scale operation*	No information identified
Commercial data		
Level of commercial maturity	*description*	No information identified
Investment costs	*in €*	No information identified
Operational costs	*in €/ton*	No information identified
Policy and regulatory data		
Intellectual property rights	*description*	No information identified
Level of policy attention in EU	*description*	No information identified
Regulatory considerations	*description*	No information identified
Project data		
Description and name of Initiative/plant/type of organisation/vendor	*description*	Nippon Shokuba, Total Care System (Fukuoka, Japan), Toppan, Sumitomo Heavy Industries Environment Ltd.
Involved parties and their roles (e.g., authorities, waste companies)	*description*	LiveDo Corporation and Total Care System: SAP recycling development. Toppan Printing: Process control, application development, utilization, and sales to optimize upcycling of recycled resources. Total care system: Provision of recycling technology and know-how for used disposable diapers. Sumitomo Heavy Industries Environment: Plant design and construction of water-solubilization treatment facilities.
Geographical area/coverage	*region/country*	Japan
Type of project	*indicate if pilot project, research project etc.*	No information identified
Start date and duration of initiative/project	*month/year*	2005 opened the first plant
Funding and support received for initiative/project	*in €*	Ministry of the Environment Ministry of Economy, Trade and Industry
Data on transfer and scale up		
Suitability of technologies to AHPs (e.g., diapers, incontinence & female hygiene products) or specific fractions	*description*	No information identified
Application in other industry sectors/to other products	*description*	No information identified
Possibility for scale-up	*description*	No information identified
Challenges/potential barriers	*description*	No information identified
Dependencies on specific collection systems or other systems	*description*	No information identified
Sources:		

1) "Japanese Companies Develop New Recycling Technology for SAP Nippon Shokubai, LiveDo Corporation and Total Care System promote growth of diaper recycling systems" https://www.nonwovens-industry.com/contents/view_breaking-news/2020-11-17/japanese-companies-develop-new-recycling-technology-for-sap/
2) Complete Material Recycling System for Disposable Diapers https://j4ce.env.go.jp/en/casestudy/108
3) Toppan Printing, Sumitomo Heavy Industries Environment, and Total Care System Begin Collaboration on Recycling Used Disposable Diapers Toppan Printing, Sumitomo Heavy Industries Environment, and Total Care System Begin Collaboration on Recycling Used Disposable Diapers | letterpress
4) Aiming to Spread Used Disposable Diaper Recycling Systems - Developed New Recycling Technology for Superabsorbent Polymers – ２００８ (totalcare-system.co.jp)

APPENDIX 2 – INTERVIEW QUESTIONNAIRE

General part

Collection of AHP waste

- Do you believe that separate collection is key for AHP waste collection? Do initiatives exist that do not perform separate collection but sort out AHPs from the residual waste? Is it a realistic option to sort out AHP waste from residual waste?
- Only in some regions, separate collection schemes for AHPs exist. Do you think this will change in future? What would be the necessary conditions for such a change?
- Which organisations (e.g., hospitals, kindergartens or households) have the greatest potential for separate collection and why?
- Which existing separate collection systems/initiatives are the most promising ones and why?
- What are the main challenges of AHPs separate collection?
- Do you have data on separate collection costs (in general or for specific collection initiatives)?
- Do you have data on the profitability/economic feasibility of separate collection systems?
- What can we learn from other industries for AHPs collection (e.g., separate collection, take-back schemes, EPR systems)?

Separation of AHP waste

- What are the main challenges of AHPs separation (under the assumption that they were collected separately)?
- Which materials/product parts are most challenging and what are the most promising to separate?
- Which separation technologies/initiatives are the most promising ones (e.g., generates good quality, economically, scalable, environmental friendly etc.)?
- Do you have data on separation costs (in general or for specific separation technologies)?
- Do you have data on the profitability of separation technologies?
- What can we learn from other industries for AHPs treatment (e.g., multi-material treatment)?

Recycling of AHP waste

- What are the main challenges of AHP recycling?
- How can these challenges be solved?
- Which AHP materials/product parts are the most challenging and what are the most promising for recycling and use as recyclate?
- What do you think is more promising: mechanical or chemical recycling of AHP waste?
- Which specific recycling technologies/initiatives are the most promising ones (e.g., generates good quality, economically, scalable, environmentally friendly etc)?
- Do you have data on recycling costs (in general or for specific recycling technologies)?
- Do you have data on the profitability of recycling technologies?
- How can capacities in recycling facilities be increased (if this is a challenge)?
- Which materials/fractions need specific decontamination technologies?
- How can AHP related odour be eliminated (e.g., in output material)?
- What can we learn from other industries for AHP treatment (e.g., decontamination, odour control)?

Collection, Separation and Recycling of AHP waste

- Is collection, separation or recycling the most challenging step to realise a circular economy for AHP waste? On which step should the development be focused?

Initiative focus (only relevant for interview partner who are involved in one specific initiative or technology)

To our knowledge you were involved in one/several collection/separation/recycling projects. Taking into account your knowledge in this regard, we would like to ask you specific questions on this project/these projects/initiatives/research projects:

Technical data

- Can you briefly describe your initiative/technology?
- Does the initiative/technology rather focus on collection, separation or recycling technology?
- Can you explain the treatment process in more detail?
- What is the origin of the waste you treat (e.g., households, hospitals etc.)? Which AHPs (e.g., diapers, incontinence material etc.) do you treat?
- What are the main output fractions of the process?
- How high do you consider the quality of the different (output) fractions?
- What is the subsequent treatment of gained fractions (e.g., energy recovery of plastic etc.)?
- Are there specific skills needed to perform your process?
- Can you give an indication on the capacity of the facility/the experiment?
- Which operational input (e.g., water, energy) your process requires? What is the approximate order of magnitude of these inputs (e.g., in kWh)?
- Do you know the approximate order of environmental savings (e.g., GHG savings) of your process?
- How do you rate the technological maturity of the process? How do you assess the possibility/potential for a scale-up?

Commercial data

- Can you estimate the approximate investment and operational costs of the process?
- How do you rate the commercial maturity of the process?

Further project data

- Which other parties are involved in your initiative?
- What is the geographical coverage of the initiative?
- How would you describe the type of your initiative (e.g., study, prototype, plant etc.)?
- What is the start and end date/ the duration of the initiative?
- Did you receive specific funding? Can you recommend any fundings?
- What were major challenges or barriers you faced?
- Who should be contacted in case any cooperation with your initiative is desired?

APPENDIX 3 – CRITERIA FOR MULTI-CRITERIA ANALYSIS (MCA)

Indicators/Criteria	Scoring
Technical data	
Extent of waste separately collected	0: No information available 1: Separate collection is linked to purchase and delivery of new products (with the consequence that a supplier change influences the separate collection) 2: Separate collection requires consumer effort (e.g., extra box/bag needs to be ordered/picked up) 3: Separate collection do not requires specific effort of the consumer, does not depend on purchase of new products and/or a brand owner.
Process - Input material	0: No information available 1: Only specific AHP waste can be input material (e.g., only diapers with urine) 2: Diaper, incontinence OR female hygiene products waste can be input material 3: (All) AHP waste can be input material
Process - *Level of separation into components*	0: No information available 1: No separation, but prepared for recovery of the entire AHPs 2: Focus on one single component (e.g., PE/PP, SAP) 3: All/most components separated and made available for recycling: PP/PE, SAP, cellulose, organic
Process – *Treatment of PE/PP* *[Scoring is based on EU waste hierarchy]*	0: No information available 1: Energy recovery and other recovery (e.g., backfilling) 2: Chemical recycling (e.g., fuels, oil) or mechanical recycling with potential downcycling (e.g., plastic use in cement) 3: Mechanical recycling with potential close-loop (e.g., plastic recyclates)
Process – *Treatment of SAP* *[Scoring is based on EU waste hierarchy]*	0: No information available 1: Energy recovery and other recovery (e.g., backfilling) 2: Chemical recycling (e.g., fuels, oil) or mechanical recycling with potential downcycling (e.g., plastic use in cement) 3: Mechanical recycling with potential close-loop (e.g., plastic recyclates)
Process – *Treatment of cellulose* *[Scoring is based on EU waste hierarchy]*	0: No information available 1: Energy recovery and other recovery (e.g., backfilling) 2: Chemical recycling (e.g., fuels, oil) or mechanical recycling with potential downcycling 3: Mechanical recycling with potential close-loop (e.g., fibre reuse)
Process – *Treatment of organics* *[Scoring is based on EU waste hierarchy]*	0: No information available 1: Energy recovery and other recovery (e.g., backfilling) 2: Chemical recycling (e.g., fuels, oil) or mechanical recycling with potential downcycling (e.g., plastic use in cement) 3: Composting, fermentation etc. with potential close-loop (e.g., use of nutrients, other composting outputs)

Process – *Treatment of whole AHPs (if no separation performed)* *[Scoring is based on EU waste hierarchy]*	0: No information available 1: Energy recovery and other recovery (e.g., backfilling) 2: Chemical recycling (e.g., fuels, oil) or mechanical recycling with potential downcycling (e.g., plastic use in cement) 3: Mechanical recycling with potential close-loop (e.g., plastic recyclates, use of nutrients, other composting outputs)
Capacity *[Note: Capacity data in kg/d are converted to t/a, assuming 365 d/a]*	0: No information available 1. <1000 t/a 2. 1000-5000 t/a 3. >5000 t/a
Operational input (e.g., energy, water) *[since sterilisation is essential to treat pathogenic obstacles, sterilisation is included in the criterion]*	0: No information available OR several inputs (e.g., only Energy AND water) are required but sterilisation is NOT guaranteed 1: Few input (e.g., only Energy OR water) is required but sterilisation is NOT guaranteed 2: Several inputs (e.g., only Energy AND water) are required but sterilisation IS guaranteed or not needed (Note: steam is considered to be energy and water) 3: Few input (e.g., only Energy OR water) is required but sterilisation IS guaranteed or not needed
Potential positive environmental impacts *[no LCA-based scores – scoring is based on self-disclosure of initiatives and educated guess from the consultants]*	0: No information available 1: Documented that process has no positive environmental impacts 2: Documented CO_2 savings compared to landfill and/or energy recovery OR improvement of soil OR resource reduction (e.g., documented recyclate use) 3: Improves at least two environmental factors (e.g., CO2 reduction, soil improvement, resource reduction etc.)
Potential negative environmental impacts *[no LCA-based scores – scoring is based on self-disclosure of initiatives and educated guess from the consultants]*	0: No information available -1: Risk of microplastic in subsequent recycling products (e.g., fertiliser) or in water -2: Risk of microplastic in subsequent recycling products (e.g., fertiliser) and in water BUT additional treatment is in place to limit the risk (e.g., waste water treatement to eliminate SAP in water) -3: No risk of microplastic in subsequent recycling products (e.g., fertiliser) and in water
Level of technological maturity	0: Blueprint/concept 1: Lab test, prototype 2: Demonstration/low scale/not fully developed 3: Full-scale operation
Commercial data	
Level of commercial maturity	0: No information available 1: Low 2: Medium 3: High
Investment costs	Nearly no information available
Operational costs	Nearly no information available
Intellectual property rights	0: no information available

	1: yes, there are IR 2: yes, there are IR. They can be transferred to funding company 3: no, there are no IR
Level of policy attention in EU	Will be given as additional information, not included in scoring
Regulatory considerations	Will be given as additional information, not included in scoring
Possibility for scale-up	0: No information available 1: Low 2: Medium 3: High
Project data	
Description and name of nitiative/plant/type of organisation/ vendor	Not relevant for scoring
Involved parties and their roles (e.g., authorities, waste companies)	0: No information available 1: Single actor project 2: Cooperation of stakeholders (from different sectors): 2-3 stakeholders 2: Cooperation of stakeholders (from different sectors): >3 stakeholders
Geographical area/coverage	Not included in scoring
Type of project	See "Level of technological maturity"
Start date and duration of initiative/project	Not relevant for scoring
Funding and support received for initiative/project	0: No information available 1: Single actor funding 2: Funding by 2-3 stakeholders 3: Funding by >3 stakeholders