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POTENTIAL FOR CIRCULARITY OF DIAPERS AND INCONTINENCE

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POTENTIAL FOR CIRCULARITY IN DIAPERS AND INCONTINENCE CARE PRODUCTS

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This report represents the research for opportunities to reduce environmental impact of diapers and incontinence materials throughout the whole production and supply chain through circular design, service models and materials reuse. On the basis of literature, market research and interviews the main obstacles and opportunities when primary raw materials are replaced by bio-materials or by recycled materials are formulated, on the condition that the high quality and functionality of the product is maintained. The latest achievements in sustainable, modular design and innovative business models with reusable systems in health care or day care centres are investigated and reviewed for environmental impact, feasibility and growth opportunity. The study was followed up by a OVAM-steering committee and a board of representation of producers, distribution and the recycling sector in Flanders and Europe. A long list of obstacles is identified, but also a set of recommendations that can act as follow-up steps to the transition to circular diapers and/or incontinence pads.

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CONTENT

SUMMARY

In Flanders, the household waste stream consists for 12 % of hygienic waste such as diapers and incontinence care products, resulting in 84 million kg of hygienic waste per year. Diapers and incontinence care products are currently not separately collected for recycling (nor in any other country), so the waste generally ends up at the incineration facilities. Flanders wants to make the transition towards sustainable materials management and a circular economy. In the '*Uitvoeringsplan huishoudelijk afval en gelijkaardig bedijfsafval'* (2016) from OVAM, a specific action has been set to optimize the waste stream of single use diapers and incontinence care products. To accomplish the reduction of the waste stream of single use diapers and incontinence care products, OVAM has set up a steering group and a round-table with representatives from the industry, government and recyclers of the diaper and incontinence care products, to jointly optimize the waste stream through supply chain collaboration and a circular material and product approach.

The objectives of this study are to gain insights in the potential for circular design and circular material use in diapers and incontinence care products. The ultimate goal is to identify opportunities to reduce the environmental pressure through the entire supply chain without compromising on the quality or the functionality of the product.

There are various strategies to reach a more circular economy, of which some strategies are more effective than others. Smarter product manufacture and use (R0-R2) are preferred over product lifespan extension (R3-R7). Material recycling and energy recovery from incineration and anaerobic digestion (R8-R9) are the least effective in stimulating the transition towards a circular economy. In general, the most effective and successful circular strategies (R0-R3) require the most innovation in the core technology, product design, revenue model and the highest socio-institutional acceptance.

Circular and eco-design can facilitate all circular strategies from R0 to R9, as it is a tool which can be used to completely rethink a product or its function (R0) but also to develop strategies to increase recyclability of products (R8). Eco-design is already common practice for many companies in the Absorbent Hygiene Products (AHP) sector. The sector has made significant steps in the area of material reduction, production efficiency and transport efficiency. Circular design on the other hand is still in its infancy. As we could not find any examples of producers of single use diapers or incontinence care products that consider design for disassembly or recycling or reconsider the function of their product.

In this study we have also investigated examples and opportunities in the sector for high circularity strategies. R0: Refuse is the most challenging strategy as it focuses on making products redundant by abandoning its function or by offering the same function with a radically different product. The most viable R0 strategy seems to be making diapers redundant by getting children to be toilet-trained earlier. In recent years a growing number of children in Flanders are getting toilet-trained at a later age. Overall it can be said that various factors are likely to contribute to the later age of toilet-training of children in Belgium such as: cultural norms, higher day-care attendance, higher percentage of working parents, less authoritarian style of education, and possibly type of diaper used. However, if diaper type is really of influence can be debated, especially with the newer, much more comfortable generation of reusable diapers.

With the R1 strategy the ambition is to make the product use more intensive, reusable diapers and incontinency products are of course an excellent example of this. The market of reusable diapers and incontinency materials seems to have grown significantly in recent years. Promoters for the uptake of reusable diapers and incontinency care products are the costs, social stigma, natural materials, no chemicals and better for the baby skin. Barriers for the uptake are expectations on convenience, comfort and leakage standards, and the required 'one time bulk' purchase, unfamiliarity with the product and existing prejudgments.

In the study we have also looked into what is better from an environmental perspective: reusable or single-use diapers. A full life-cycle LCA study from the Environment Agency in the UK has shown that reusable diapers do not necessarily have a lower GreenHouseGas (GHG) impact due the energy and water needed for laundering. Research from MilieuCentraal does show that reusable diapers have a lower carbon footprint. A difference in the assumptions on the age of toilet-training, temperature of washing and energy efficiency of washing machines could explain the difference in outcomes of both studies.

A LCA only takes into account the impact on the environment, but whether a product is sustainable depends also on the other aspects such as the impact on humans, societies and communities. The total cost of ownership method takes a broader sustainability approach in which all the costs associated with a product over its lifetime are considered.

The circularity strategy R2 focuses on using fewer natural resources through the use of recycled, renewable or biodegradable materials in the three main components of diapers and incontinence care products, namely non-wovens, SAP and fluff pulp. In general, it can be said that the sustainable alternatives are struggling to compete with the fossil-based materials due to the low oil prices and because of difficulties in meeting the technical requirements such as absorbency capacity. Currently no post-consumer recycled materials are used as raw material for the production of AHP. It is also not expected to be a realistic option in the near future due to the very strict health and safety requirements for materials used in AHP products need to meet. Additionally, in recent years the focus of the industry has been on increasing the percentage of fossil based/synthetic materials in diapers and reducing the percentage renewable/natural materials.

For the three main components (SAP, fluff pulp and non-wovens) we identified the technical requirements, as available in public literature. Meeting the technical requirements such as absorbency capacity is crucial for market acceptance of the sustainable materials. Since the technical requirements for the materials seem to be relatively easy to find, it seems that not knowing the technical requirements is not the restraining factor, but meeting the technical requirements is the real challenge.

The recycling of used diaper and incontinence materials is an area that is undergoing rapid development, recently a number of promising recycling initiatives have been brought to market by BTU Elsinga, Unicharm and Fater. However, there are a number of barriers for the large-scale implementation of post-consumer recycling, namely the costs of the recycling process, lack of market for the recycled products, financial and logistics implications and the willingness of municipalities to set up separate waste collection and possible residues of pathogens and medicines in the recycled materials.

In the study a number of accelerators have been identified which can function as next steps to accelerate the transition towards a circular AHP sector. OVAM and the roundtable members, representing the major actors in the material chain of the AHP sector, have identified the following six accelerators as the most valuable next steps for the transition towards a circular economy. They are grouped into the different circular strategies:

- Rethink: gain a broader acceptance of the potential environmental benefits for new business models such as reusable diapers and service models.
    1. Review, complement and built-upon the study from MilieuCentraal which shows that reusable diapers are better environment, make the study ISO compliant and publically available. Consider to extend the scope of the study with various types of reusables and to also include a service model.
    2. Conduct a comparative study of reusable and disposable diapers with a more holistic approach taking into account all the environmental and societal costs and benefits associated with the diapers over its lifetime. This way the costs of the waste of disposable diapers on society can be taken into account as well as the social benefits of diapers and incontinence care products can be taken into account in such an assessment.
- Standards& legal framework: assure that the right legal framework and standards are established to stimulate the transition towards more circularity in the AHP sector.
    3. Explore how a legal framework can be created assuring safety of the post-consumer recyclables, and at the same time allowing the recycled materials to access the market. Such as: investigate the possibility to set-up strict legislation for using recycled paper in AHP, to stimulate the use of recycled materials in AHP products in line with the EU regulation for recycled plastic for food contact, which is already in place.
    4. Explore the opportunities for a more prominent place for sustainability in the public procurement policies of care facilities. Governments can play an important role in the purchase policy of care facilities as they are often subsidized by government. Perhaps there is room to stimulate care facilities to take sustainability into account when purchasing incontinence and diaper products.
- Recycle: create an environment which allows post-consumer recycling of AHP products to become mainstream.
    5. Show the business case of the upcoming recycling techniques. Show that the recycled products have a market value and are of the promised quality.
    6. Investigate the opportunities of high-grade post-consumer SAP recycling and the potential markets for recycled SAP. SAP is considered one of the most valuable raw materials in the diapers, but currently high-grade end-of-life recycling of SAP is not yet feasible.

1 INTRODUCTION

1.1 CURRENT SITUATION WITH HYGIENIC WASTE

1.1.1 Significant waste streams

In Flanders, the household waste stream consists for 12 % of hygienic waste such as diapers and incontinence care products[1], resulting in 84 million kg of hygienic waste per year[2]. These numbers exclude the professional waste from child-care and other care facilities, while also there a significant waste stream can be expected. Approximately 70 % of the total waste in the region of Flanders is recycled, and an additional 28 % is valorised through incineration. Diapers and incontinence care products are currently not separated for recycling (nor in any other country), so the waste generally ends up at the incineration facilities.

Due to the decline in population growth, the market and accompanying waste stream of single-use diapers is not expected to grow much (+1%) in the coming years. In contrast, the waste stream of incontinence care products is expected to grow significantly in the coming years due to the rapidly growing elderly population. It is therefore important to find a solution for the waste streams from not only from diapers but also from incontinence care products.

1.1.2 Efforts of OVAM

Since 1981, the Openbare Vlaamse Afvalstoffenmaatschappij (OVAM) takes care of efficient and high quality waste, materials, and soil management in Flanders (Belgium). OVAM continuously strives for the best environmental and health outcome, taking into account the effects that occur throughout the entire life cycle of a product, amongst others via the stimulation of prevention and reuse, or alternatively recycling or energy recovery. Moreover, they also ensure that the management of material circuits and wastes does not endanger human health and does not adversely affect the environment. Flanders wants to make the transition towards sustainable materials management and a circular economy.

In order to reach their objectives, OVAM wants to drastically reduce the total quantity of residual waste from households, companies, and organizations during the 2016-2022 period. OVAM will do this by imposing various targets of residual waste for each cluster of municipalities including waste prevention, reuse, and use of recycled materials. In the *Uitvoeringsplan huishoudelijk afval en gelijkaardig bedijfsafval* from OVAM a specific action has been set to optimize the waste stream of single use diapers and incontinence care products through a supply chain collaboration.[3] Additionally, there is a growing awareness in Belgium of the waste stream coming from diapers and incontinence products. Consumers, governments and retailers have all recognized the waste stream coming from these products and have started to ask questions on how the waste stream can be reduced. Also the industry has recognized the need to stimulate the reduction of the waste stream coming from single-use diapers and incontinence care products. Multinational producers such as Procter & Gamble[4], Ontex[5], Essity (former SCA)[6]and Kimberly and Clark[7] have all recognized the need to address and reduce the end-of life waste streams. Therefore, OVAM has set up a steering group and a round-table with representatives from the industry, government and recyclers of the diaper and incontinence care products to optimize the material chain of single

[1] http://www.euromonitor.com/nappies-diapers-pants-in-belgium/report
[2] Vlaanderen in cijfers 2014, studie dienst van de Vlaamse regering, www.vlaanderen.be/svr
[3] Uitvoeringsplan huishoudelijk afval en gelijkaardig bedrijfsafval, OVAM, september 2016
[4] https://fatergroup.com/ww/news/press-releases/recycling-project
[5] P 19, Sustainability report 2016 Ontex
[6] http://reports.sca.com/2016/sustainability-report/value-creation/value-creation-for-nature/waste-management.html
[7] http://www.kimberly-clark.com/sustainability/Pages/Stories/WasteandRecycling.aspx

use diapers and incontinence care products through supply chain collaboration by a circular material and product approach.

1.2 STUDY OBJECTIVES

The objectives of this study are to gain insights in the potential for circular design and circular material use in diapers and incontinence care products. The ultimate goal is to identify opportunities to reduce the environmental pressure through the entire supply chain without compromising on the quality or the functionality of the product. We distinguish three different research topics, each with their own research questions (see also Figure 1):

1.2.1 New business models

Examples of relevant research questions regarding new business models for diapers and incontinence materials include:

- Can the lifespan of diapers or incontinence care products be increased compared to its original lifespan?
- Can the product be refused or used as a service?

1.2.2 Circular design

Examples of relevant research questions regarding the circular design of diapers and incontinence materials include:

- Can the product be designed in such a way that it becomes easier to disassemble and the quality of materials to be recycled can be guaranteed?
- Can the design of diapers and incontinence products foresee the use of recycled materials?
- Are the products and its components designed for high-grade recycling (without increasing environmental pressure)?

1.2.3 Production

Examples of relevant research questions regarding the production of diapers and incontinence materials include:

- What are the quality requirements (health, safety and technical) which the recyclables should meet?
- Can the overall use of primary and secondary raw materials be decreased?
- Are there opportunities to move to models with increased reuse of products and components, or models based on providing a service rather than offering a product?

1.2.4 Waste

Examples of relevant research questions regarding the waste of diapers and incontinence materials include:

- Is production moving towards lower levels of waste generation?
- To what extent is high grade-recycling possible?
- To what degree is recycling effective with regard to costs and environment?

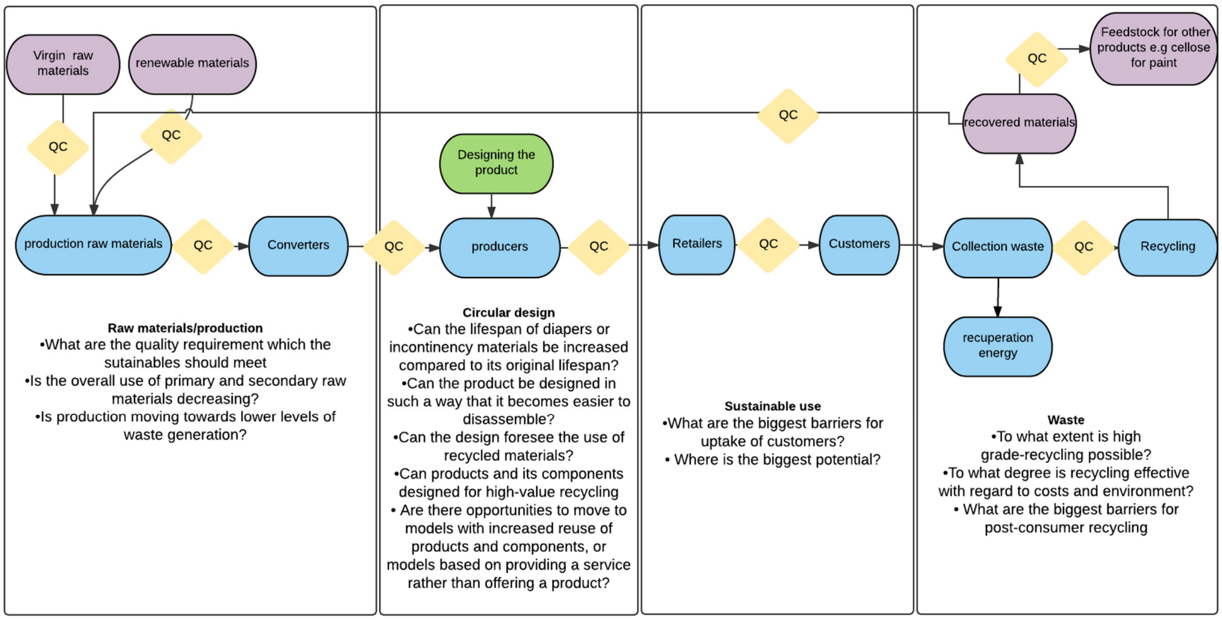

Figure 1: Research questions throughout the supply chain.

In order to gain insights in the potential for circular design and circular material use in diapers and incontinence care products, it is important to understand the concept of a circular economy first.

1.3 WHAT IS A CIRCULAR ECONOMY?

1.3.1 The transition from linear to circular

The Ellen McArthur foundation defines the Circular Economy (also referred to as CE) as follows: [8]

"A circular economy aims to redefine products and services to design waste out, while minimizing negative impacts."

Three types of transition toward a circular economy can be distinguished: [9]

1. ***A transition driven by a new technology***: the emergence of a specific, radically new technology which enables the transition. This means radical innovation in the core technology, i.e. the specific technology around which a product is centered. For example, the emergence of the technology to produce bioplastics enabling circularity in the plastic industry.
2. ***A transition driven by a socio-institutional change***: transitions in which socio-institutional change is central and where technological innovation plays a secondary role (incremental innovation in core

[8] Ellen McArthur Foundation (EMF), 2013. Towards the circular economy. Economic and business rationale for an accelerated transition.
[9] PBL (2017). Circular economy: measuring innovation in the product chain, J.Potting, M. Hekkert, E. Worrell et al.

technology). For example, the acceptance of reusable sanitary napkins in Africa, due to lower costs compared to single-use.

3. ***A transition driven by a combination of a socio-institutional change and a technology***: transitions in which a socio-institutional change is central, and which are facilitated by an enabling technology. An example is the transition to what has become known as the sharing economy. This transition from owning a product to purchasing its services primarily involves socio-institutional change, but this is not possible without information technology to link service providers and users.

Innovations in radical new technologies have the power to radically change the industry. They don't come around often, but can be stimulated by the sector and government. Transitions 2 and 3 are more common and examples of this can be found in the diaper and incontinence care sector already, as will be discussed later on (see chapter 4).

1.3.2 Strategies to reach circularity

There are various strategies to reach a more circular economy (see Figure 2). A study from the Netherlands Environmental Assessment Agency (Planbureau voor de Leefomgeving, PBL) showed that some strategies are more effective than others.[10]

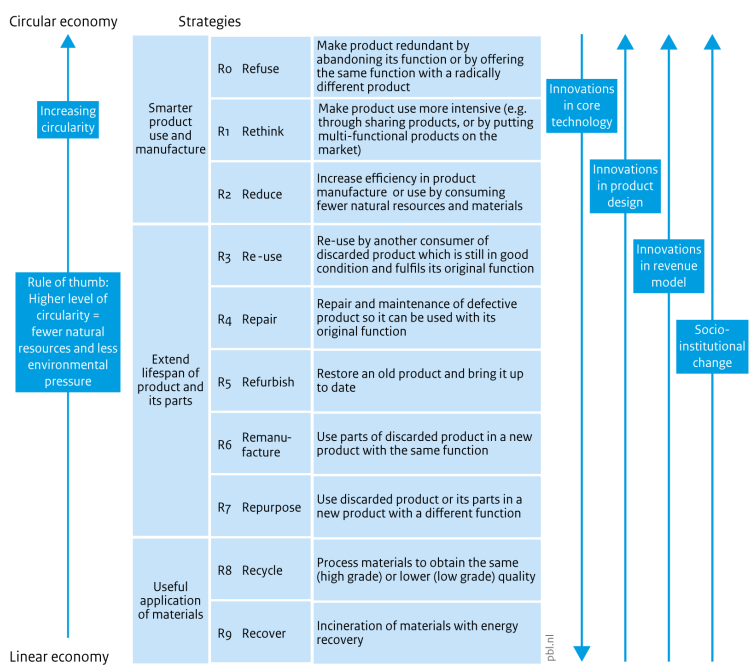

Figure 2: Strategies to circularity (source PBL[10])

[10] PBL (2017). Circular economy: measuring innovation in the product chain, J.Potting, M. Hekkert, E. Worrell et al.

Smarter product manufacture and use (R0-R2) are preferred over product lifespan extension (R3-R7). Material recycling and energy recovery from incineration and anaerobic digestion (R8-R9) are the least effective in stimulating the transition towards a circular economy. In general the most effective and successful circular strategies (R0-R3) require the most innovation in the core technology, product design, revenue model and the highest socio-institutional acceptance.

1.4 STUDY APPROACH

The study used a combined approach of literature research and interviews. Based on the information that is publically available on circular design and circular material use in diapers and incontinence care products, we set up a list of research questions tailored per partner in the supply chain. As a result, we had a different set of questions for the partners involved with raw materials and converters, for the Absorbent Hygiene Products (AHP) producers, and for the post-consumer recyclers. A list with suggestions for the people to be contacted for an interview was provided by EDANA. Interviews were done per telephone, or in when it had the preference of the interviewee via an online meeting. An overview of the interviewees is given in Table 1. A steering group composed by OVAM was consulted for feedback on the findings from the literature and interviews in quarterly updates. During these meetings, the list of people that were still to be interviewed were also fine-tuned, depending on the interest and remaining questions of the steering group. Unfortunately, we could not find a representative from Abena[11]- a large producer of eco-brand diapers and incontinence products- who was willing to be interviewed for this study.

Interviewee	Company		Interviewee	Company
Pierre Conrath	Edana		**Wim Elsinga**	ARN
Inge deWitte	Go4circle		**Thomas Broch**	Fibertex
Geert Cuperus	Rijkswaterstaat		**Hilde Vrankx**	Kinderdagverblijf Ukkepuk
Cecile Gouedard	Henkel		**Ann Hendrikx**	Doekjes & Broekjes
Stijn Devare	Centexbel		**Linde Raport**	Delhaize
Tom Berry	Kimberly and Clark		**Susan Janols**	Essity (Former SCA)
Paul Waller	RKW		**Sven Smet**	Drylock
Koichi Shobatake	Unicharm		**Astrid Baeten**	Colruyt
Mark Paterson	Tech absorbants		**Marcello Somma**	Fater / P&G
Marianna Pierobon	BASF		**Frank Wauters**	Suez
Bart Jansen	Ontex Global			

Table 1: Overview of the interviewees and their affiliation

[11] https://www.abena.com/

1.5 STRUCTURE OF THIS REPORT

Chapter 1 has given you an overview of the motivation to study the potential for circular design and circular material use in diapers and incontinence materials, including background information about the OVAM, the concept of a circular economy, and the approach of the current study.

The following chapters will provide insights into the state of the art in this field:

- ***Chapter 2*** explains in more details the products within scope, how they are made, what kind of materials are used, etc.
- ***Chapter* 3** provides more insights into circular and eco-design.
- ***Chapter 4****:* explains the opportunities and current practice of smarter product use.
- ***Chapter* 5** explains the options to use sustainable raw materials in the production of diapers and incontinence materials.
- ***Chapter* 6** summarizes the requirements that are applicable to diapers and incontinence materials. These include health and safety, technical, and end-of-waste requirements.
- ***Chapter* 7** provides an overview of the potential for post-consumer recycling and the existing initiatives in this field.
- ***Chapter 8*** lists our conclusions and the opportunities that were identified to reach higher circularity.

2 INCONTINENCE PRODUCTS AND DIAPERS

In this chapter, we will discuss the products which are within the scope of this study, their composition and production process.

2.1 DESCRIPTION SINGLE-USE PRODUCTS

Single- use incontinence products for adults

Incontinence products are used for absorbing and locking away urine and faeces, to prevent leakage and keep the users' skin dry and healthy[12]. Incontinence care products facilitate hygiene, cleanliness, odour reduction and independence as the product range is extensive and adapted to different degrees of incontinency. This way they meet the needs of people of different ages and both genders. Light incontinence care products are generally used at home, whereas products for heavy incontinence care products are generally used in care and elderly facilities. The current study focuses on medium to heavy incontinence products, which have composition similar to a baby diaper.

Single-use children diapers

For the first two to three years of their lives, children usually wear diapers. Over 95% of these children in Europe use single-use diapers[13]. Single-use children's diapers are used for absorbing and retaining infant's urine and faeces while keeping the skin dry and healthy. There is a wide range of sizes available to fit different age groups of children. The entire range of children diapers is included in the present study.

2.1.1 Composition

Incontinence products for adults and single-use diapers have a similar composition, containing more than 20 different materials, consisting of the following elements:

- Topsheet or acquisition and distribution layer (ADL)
- Absorbent core
- Backsheet or outer cover
- Minor components, e.g. adhesives and elastics

We will now further describe all of the elements. Figures 3 and 4 show a schematic overview.

[12] Edana, factsheet. Incontinence products, 1-10-2008, www.edana.org,
[13] Edana, factsheet , disposable baby diapers,1-10-2008, www.edana.org,

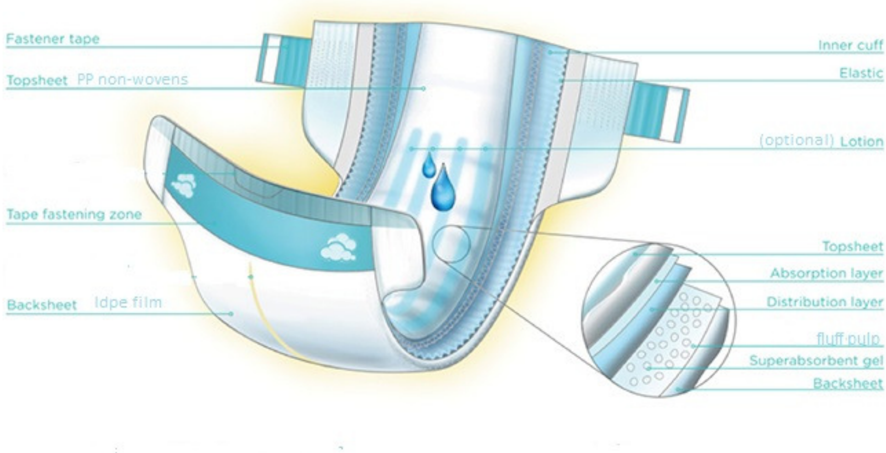

Figure 3: Composition of a baby diaper [14]

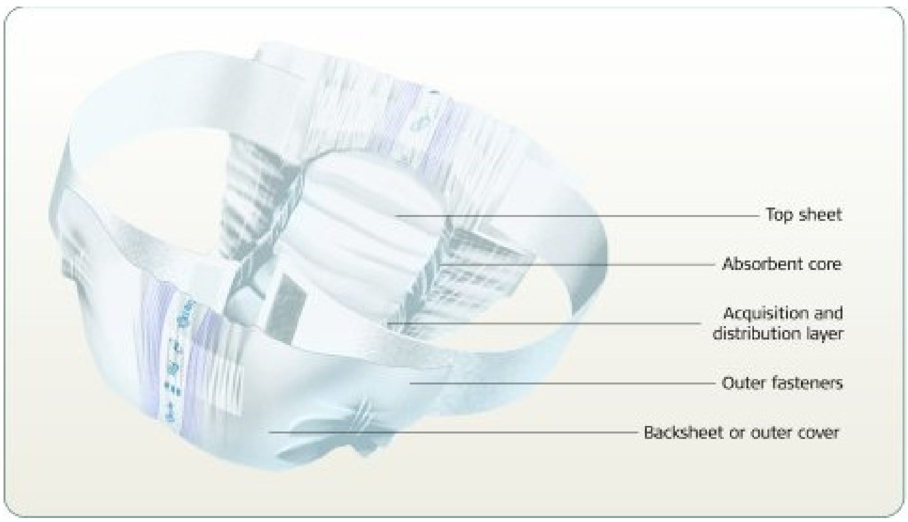

Figure 4: Composition of an incontinence diaper [15]

2.1.1.1 Topsheet

The topsheet or acquisition and distribution layer (ADL) stores the liquid temporarily before it is distributed through capillaries to the absorbent core. This is the layer closest to the skin through which urine easily passes to be collected in the subsequent layers. It minimizes contact time with the skin, thereby preventing irritation and infection. Polypropylene (PP) nonwovens are mostly used for the topsheet.

[14] Edana, factsheet , disposable baby diapers,1-10-2008, www.edana.org
[15] Edana, factsheet. Incontinence products, 1-10-2008, www.edana.org

2.1.1.2 Absorbent core

The absorbent core structure is the main component of diapers and acts as liquid storage component. The two main functions of the absorbent core are quick absorption of liquids, and liquid distribution through the core structure. The single-use diaper core consists of fluff pulp and superabsorbent polymers (SAP).

- *Fluff-pulp*
  Fluff pulp is used in diapers because of the ability to absorb water and to give the product volume and strength. Fluff pulp is a chemical pulp (from which lignin has been removed without affecting the cellulosic fibres) made of soft long-fibres from wood, cotton or hemp. The bleaching of the pulp, as far as necessary, is nowadays carried out with chlorine-free bleaches such as ozone or hydrogen peroxide.

- *Super Absorbent Polymers (SAP)*
  SAP becomes a gel when it comes in contact with liquid. The liquid is stored within the gel structure. This storage is irreversible; even under pressure (e.g. when sitting or lying down on the saturated diaper) the liquid is not released. Superabsorbent polymers absorb and retain about 30 times their own weight. Acrylic acid is currently the raw material for most commercially available SAPs.

2.1.1.3 Backsheet

The main function of the backsheet, also called outer cover, keeps the diaper together, is ensure the pleasant feel of the diaper, but it also has a marketing function as it shows the print on the diaper. The backsheet is most commonly made of low density polyethylene (PE) film or of a combination of film and nonwovens.

2.1.1.4 Minor components

- *Adhesives*
  Adhesives are used to fixate the various components. In general hot-melt adhesives are used for diapers and incontinence care products. The advantage of hot-melt adhesives is that they do not contain hazardous chemicals, such as Formaldehyde, which can be the case in solvent based adhesives

- *Elastics and tapes*
  Diapers also contain composite materials such as tape and elastic materials to hold the diaper in place. In addition to non-woven fabric and adhesives, these composite components may contain polymer types other than those named above, such as elastane, polystyrene and styrene ethylene butadiene styrene copolymers. Overall, these polymers account for a low proportion of the product.

Additionally, in some diapers, lotions and scents are used to enhance the pleasant feel and scent.

2.1.2 Material use

In table 2 the generic distribution of the various materials is shown for single-use diapers and incontinence care products. There are differences between the amounts used for the various components in incontinence care products and diapers. This can partly be explained by differences in testing methods in the ISO standards, as the absorbency tests in the ISO standards are different for incontinence products and diapers. The absorbency test for incontinence products can be met more easily with a higher percentage of fluff pulp in the product[16]. Updated ISO standards for incontinence material with a different test method have recently become available, therefore it is likely that as a result the percentage of SAP used in incontinence materials will increase in the coming years.

Component	Diapers	Incontinence materials
SAP	33%	14 %
Fluff pulp	24 %	65 %
Top sheet (PP)	21%	11%
PE film (backsheet)	5%	6%
Elastics and adhesive tape	13%	11%

Table 2: Composition of diapers and incontinence materials [17]

[16] Interview Pierre Conrath, Edana
[17] Life Cycle assessment and Trend Analysis of the environmental performance of incontinency products, Executive summary, ERM, June 2013

2.1.3 Manufacturing process

In Figure 5, a schematic representation of the production process of diapers and incontinence materials is given. Water, electricity and (auxiliary) chemicals are used to combine the in paragraph 2.1.1 listed elements into diapers or incontinence material.

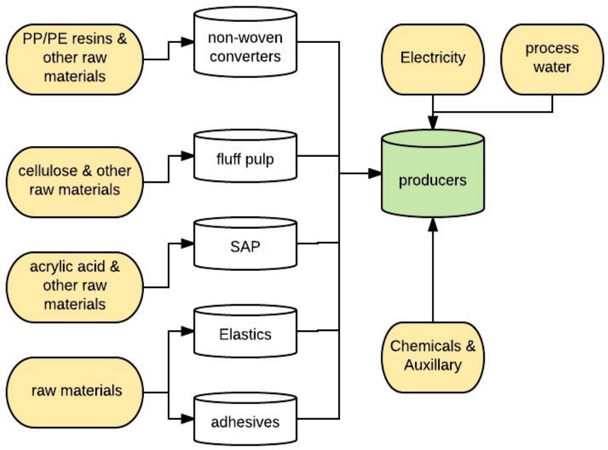

Figure 5: Overview of the manufacturing process for diapers and incontinence materials

2.1.3.1 Production steps

The production of children's diapers and incontinence care products is a stepwise process:

1. ***Production of absorbent pads:*** Fluff pulp is fiberized, superabsorbent polymer is added and absorbent pads are formed
2. ***Production of the non-woven substrates:*** The topsheet, backsheet and the leg-cuffs are also referred to as non-wovens. Together they account for a significant part of diaper. The plastic fibres need to be arranged into a sheet or web to produce the non-wovens. This process is referred to as the non-wovens conversion and further explained in paragraph 2.1.3.2.
3. ***Lamination of absorbent pads:*** The pads are then laminated with films, nonwoven substrates and elastic.
4. ***Shaping of final product:*** The pads are shaped, cut, folded and packaged.

The technology behind the development and manufacture of single-use diapers is continuously evolving in order to find more efficient processes and designs which utilize materials that are thinner and lighter. Substrates are laminated using hot melt adhesives. The final diaper or pad must be cut into an anatomic shape, resulting in cut-off waste, which can be recycled, disposed of or reused (see paragraph 5.3.1 for more on recycling manufacturing waste in the sector). Waste generation during production is often minimized for cost reasons and therefore it can be estimated to be marginal (<3-5%).[18]

[18] Development of EU Ecolabel criteria for Absorbent Hygiene Products, Preliminary report- Draft v.5, European Commission, DEKRA, PE international, January 2013

2.1.3.2 Conversion of non-wovens

An important step in the production of diapers and incontinence materials is the production of the non-woven substrates. In short, there are four main production processes to arrange the fibres in a sheet or a web to produce non-wovens, namely: [19]

- ***Drylaid-carding:*** This is a mechanical process, which starts with the opening of bales of fibres that are blended and conveyed to the next stage by air transport. They are then combed into a web by a carding machine, which is a rotating drum or series of drums covered in fine wires or teeth.
- ***Drylaid-airlaying:*** In drylaid-airlaying, the fibres, which can be very short, are fed into an air stream and from there to a moving belt or perforated drum, where they form a randomly oriented web.
- ***Wetlaying:*** The principle of wetlaying is similar to paper manufacturing. The difference lies in the amount of synthetic fibres present in a wetlaid nonwoven. A dilute slurry of water and fibres is deposited on a moving wire screen and drained to form a web. The web is further dewatered, consolidated by pressing between rollers, and dried.
- ***Spunmelt-spunlaying*:** In this process, polymer granules are melted, and molten polymer is extruded through spinnerets. The continuous filaments are cooled and deposited on to a conveyor to form a uniform web. This technique manufactures non-wovens directly from the thermoplastic polymers, therefore the spuntmelt techniques are generally seen as the most efficient and environmental friendly[20]. Not surprisingly, it is the leading production process for non-wovens. Approximately 48.7 % of the non-wovens in 2015 were produced with the spunmelt technique.[21]

2.2 REUSABLE DIAPERS AND INCONTINENCE CARE MATERIALS

In addition to the single-use diapers and incontinence care products there are also the reusable diaper and incontinence care products on the market. We could not find reusable incontinence products for medium or heavy incontinence which is the focus of this study. However, we did find some example of reusable light incontinence materials which we will discuss in chapter 4. Modern cloth diapers are available in a variety of systems, we will discuss the three main varieties in this paragraph:

- **All-in-Twos- Hybrid, Pre-fold, Flat, Fitted**

  All-in-Two diapers are the classic kind of cloth diaper system and are composed of two pieces: a waterproof cover and an absorbent cloth insert. Often the waterproof cover and the diaper insert are sold separately.

  There are four types of absorbent cloth inserts, namely:

  1. *Prefold:* This is the classic cloth diaper. The prefold is a piece of cloth folded multiple times which is than fastened with diaper fasteners. Examples of prefolds are Ozycozy[22] and Bummis[23]
  2. *Hybrid:* Hybrids bridge the gap between cloth and disposables as different types of inserts can be interchanged most hybrid brands offer organic cloth, synthetic and disposable inserts. Sometimes the brands state that the disposable pads are compostable but this is in not true in most cases as most disposable pads contain SAP[24]. g-Nappies was sued by the Federal Trade Commission in the U.S. because they claimed amongst others that there pads were

[19] https://www.edana.org/discover-nonwovens/how-they're-made/formation
[20] Interview Fibertex and https://www.nonwovens-industry.com/issues/2017-02-02/view_breaking-news/sustainable-nonwovens-set-to-grow/
[21] http://www.smitherspira.com/resources/2015/december/five-key-trends-in-the-future-of-global-nonwovens
[22] http://www.osocozy.com/
[23] https://www.bummis.com/
[24] Treatability and impact of gDiaper disposable diaper within municipal sewer and waste water system, D.Wise and L. Longshore, City of Vancouver

biodegradable[25]. Unlike a pre-fold, the hybrid inserts are custom shaped and sewn to fit their cover. To use it in a diaper change, the insert can be placed directly into the cover. Examples of this solution are Totbots [26] and g-Nappies.[27]

3. *Flat:* Flat is similar to a prefold but only one layer thick and requires more folding and fitting than the prefold. Examples of this are the "hydrofiele luiers".
4. *Fitted*: A fitted diaper is an insert that has either a snap or velcro-like closure sewn into it. Rather than just placing the insert in a cover, and to hold it in place, a fitted insert can be placed which secures a good fit on a baby.

- **All-in-One diapers**
  The cloth is already attached to the diaper. Very similar to a single use diaper, with the main difference that the system can be washed. This system requires washing the complete diaper. An example of this solution is Bumgenius.[28]

- **Pocket diapers:**
  Pocket diapers have two parts: a cover and an insert. There is a pocket opening in the cover, either in the front or back, into which the insert is stuffed. The pocket basically acts like a liner between the baby's skin and the absorbent insert, and it can hold one or more inserts to serve as the absorbent core. An example of a pocket diaper is little lamb nappies.[29]

Which diaper system is best suited can vary per consumer. For example all-in- one diapers are very easy to use as they are very similar to single use diapers but they require more washing as the whole diaper needs to be washed, they take longer to dry and are more expensive on the long term as they require more washing. Doekjes and broekjes indicated that all in two's are generally the most popular type of diapers in Flanders.

[25] https://www.ftc.gov/news-events/blogs/business-blog/2014/01/ftc-says-diaper-claims-didnt-pass-smell-test
[26] https://www.totsbots.com/
[27] https://www.gnappies.com/
[28] http://www.bumgenius.com/
[29] https://www.littlelambnappies.com/

3 CIRCULAR AND ECO DESIGN (R0-R9)

This chapter will discuss the potential and examples of circular and eco design, including their focus and examples of such initiatives in the incontinence and diaper sector. Circular and eco-design can facilitate all circular strategies from R0 to R9 as it is a tool which can be used to completely rethink a product or its function (R0) but also to develop strategies to increase recyclability of products (R8).

3.1 FOCUS OF CIRCULAR DESIGN

Circular design aims to make improvements in materials selection and product design by standardisation or modularisation of components, purer material flows, and design for easier disassembly.[30] Circular design focuses on the rethinking of products by asking fundamental questions, such as: [31]

- Do we need the product or do we need the service it provides?
- How could the product be designed in such a way that it can be reused?
- How could the current product be designed in such a way that it can be easily repaired or upgraded to prolong its lifespan?
- Could the product be designed in such a way that it can be remanufactured into a new product if it is returned the manufacturer? For example, returning the outer pants of a diaper or incontinence care products to be reused in the manufacturing process.
- How could the product be designed in so that it can be used for high-grade recycling?

Circular design requires taking one step back, to rethink the function and the impact of the product before starting the actual design. Hence, it starts a fundamental discussion, and opens the floor for an entire new product design or proposition of services and a truly circular approach. Asking these kinds of questions is not part of the traditional, more linear design approach, and still relatively new for companies. Eco-design is often only considered after the prototype is already designed. In that case, questions arise like:

- How we can we use more environmental friendly materials?
- How could we use less materials while retaining the same function?
- How could our current product be recycled?

However the traditional eco-design is also integrating and stimulating the circular thinking to a greater extent. The LiDS wheel[32] is an excellent example in which eco-design has integrated the circular approach.

[30] A toolkit for policy makers v 1.1., Ellen MacArthur Foundation, 26-06-2015
[31] Circular design guide, Ellen MacArthur foundation
[32] http://www.ecodesignlink.com/nl/ecodesign

3.2 ECO-DESIGN

In this paragraph we will discuss the current status on eco-design in the incontinence and diaper sector. It will be done on basis of the eight strategies in the life-cycle of a product from the LiDs wheel.

1. *Replacing raw materials*

This step looks into the opportunities to replace harmful or energy intensive materials with for example recycled or renewable materials. The current status of the sector in using recycled and renewable materials is discussed in detail in chapter 5. Overall, it can be said that currently recycled materials are not being used due to health and safety issues. Renewable materials are used sporadically due to the economic costs and the technical requirements that the materials need to meet.

2. *Material efficiency*

The amounts of materials which are used in incontinence care products and diapers have been reduced significantly during the last years, thereby improving the environmental performance of diapers and incontinence products. In 1987 the average disposable baby diaper in Europe had a mass of 65 gram and 81% of this weight was fluff pulp. Between 1987 and 1995 the average weight of the product decreased with 14% and between 1995 and 2005 with another 27%.[33] This was mainly due to the increased use of other materials than fluff pulp. Particularly the use of SAP increased significantly from 1% of the weight in 1987 to 32% in 2005[34]. In recent years, the average weight decreased even further: by 12% between 2005 and 2011. Since the composition of average diapers did not change much in that period the further decrease in weight may be associated with the improved production and functionality of materials, components and layout of the product. It is expected that the reduction of weight will continue at a slower rate in the future.

3. *Process efficiency*

The production process of diapers and incontinence products have been optimized in recent years by minimalizing the required energy and inputs and generating limited amounts of manufacturing waste. Modern manufacturing processes also facilitate the production of lighter products. For example, newer generation spunbond lines are capable of producing 8-10 Grams per Square Meter (GSM) hygiene nonwovens, instead of the previous norm of 10-12 GSM. The same effect is achieved with substituting a completely different type of nonwoven; for example, spunlace wipes with a GSM of 35 are said to be replacing airlaid nonwovens that have a feasible minimum of around 55 GSM.[35] Using less raw materials will further reduce the environmental impact of the products.

4. *Optimizing distribution*

The sector has looked into optimizing its transport by more efficient packaging and transport modes. The reduction in weight of the diapers has also significantly contributed to minimalizing the environmental impact of transport. By replacing the fluff pulp with lighter SAP, the total weight of the diapers has been reduced. Heavier materials require more fuel to transport, so the lighter the diaper the lower the environmental performance.

[33] EDANA, 2008. Sustainability Report 2007e2008: Absorbent Hygiene Products. EDANA, Brussels. Available online at: http://www.edana.org

[34] Evolution of disposable baby diapers in Europe: Life cycle assessment of environmental impacts and identification of key-areas of improvement, M. Cordella et.all, 2014

[35] http://www.smitherspira.com/resources/2015/december/five-key-trends-in-the-future-of-global-nonwovens

5. Optimisation use

The performance of diapers and incontinence care products has increased significantly in recent years. As a results diapers and incontinence care products need to be changed less frequently than in the past. Nowadays diapers absorb urine much more efficiently, and are therefore still comfortable to wear even when lightly soiled. However, some work still needs to be done about the consumer perception, as often consumers do not realize that they do need change diapers that frequently anymore.

6. Design for disassembly/recycling

We could not find any examples in the literature, or in any of the interviews with the producers of single use diapers or incontinence care products that consider design for disassembly or recycling.

The following reasons could be underlying to this:

- In most countries there is no separate waste collection for diapers and incontinence care products, and therefore no recycling schemes. Making any upgrades in the recyclability of the products not worthwhile at the moment.
- There are various post-consumer recycling schemes which show potential but none of them have taken the lead. To design a product for high grade recycling, it needs to be completely clear which recycling will take the lead and what could changes in the design of diapers and incontinence materials could improve their recycling process.
- Separate waste collection of one brand of diapers and incontinence care products is unlikely, so any changes made to increase the recyclability will need to be a joined effort of the entire sector.
- To understand how diapers and incontinence care products could be better recyclable, collaboration within the value chain between producers, suppliers, retailers, recyclers and municipalities is necessary.

Probably, post-consumer recycling first needs to take place, starting collaborations throughout the value-chain before design for recyclability can take off.

7. Increase life expectancy and rethink & Optimization of the function e.g. modular design or service model.

We have found no examples in the literature, or in any of the interviews with the producers of single use diapers, or incontinence care products that fundamentally rethink the life expectancy or the function of the product. However reusable diapers and incontinency materials, which are washable, are of course an excellent example of increasing the life expectancy. The same can be said about modular design, with the current producers of single diapers and incontinency products there are almost no examples of modular design to be found. All in two’s reusable diapers are on the other hand an excellent example of modular design as they can be dissembled in two parts, which can be washed separately but also recycled separately. Especially since the absorbent cloths have a shorter live expectancy than the water proof cover.

3.3 DESIGN INNOVATIONS IN THE SECTOR

The major design innovations in the diaper sector in recent years have focused on a thinner absorbent core, thereby phasing out fluff pulp. Below there is a short description of some interesting innovations, namely: Dry-lock, Goodnites from Kimberly and Clark the Dry Max technology from P&G and the service model for diapers.

Dry-lock[36]

Drylock Technology produces the first fully fluffless diaper and incontinence care products. The absorbent core is made of super absorbent polymer encapsulated between two layers. The distinctive feature is that SAP are contained in small pockets formed by combination of two layers and are kept in place without (or with a very small amount) additional thermoplastic material but only by means of bonds all over the two webs. These bonds are designed to allow controlled and gradual loosening when SAP swallow and expand. Additionally dry-lock does not use any adhesives in their product. Thereby this innovative product has two components less than ‘regular’ diaper and incontinency materials: the fluff pulp and the adhesive. In general it can be said that products with less components are easier to disassembly or recycle. Despite the fact that the main reason for developing the Dry-lock technology was not to facilitate easier recycling or disassembly this might well be the case.

Goodnites[37]

In 2014 Kimberly and Clark has introduced Goodnites which are real washable cotton blend fabric underpants with super absorbent insert which can be replaced. Goodnites are training pants for children to potty train them during the night and are therefore not suitable for day-time and heavy soiling. This innovation is particularly interesting as it takes a modular design approach similar to the reusable diapers on the market such as g-Nappies but is initiated by Kimberly and Clark, a large producer of single-use diapers. In general, to change a market, acceptance and uptake of the major players in that market is needed.

Dry Max technology[38]

In 2010, Procter & Gamble introduced the Dry Max line to the market with an absorbent gel that improved diaper efficiency while cutting materials and costs by 20%. The diapers were thinner thereby aiming to give more user comfort while also reducing cost and environmental impact. The innovation was so impressive that former president Bill Clinton praised it for reducing landfill waste. The interesting aspect of this innovation is the enormous consumer backlash it received. Consumers claimed that the new, thinner design resulted in more diaper rash and the thinner diapers were a low cost replacement other than an innovation. P&G had to put much effort into convincing their consumers that the new diapers were not to blame for the diaper rash.[39]This shows that with innovations in diaper design it is very important to thoroughly inform the consumers about the how and what of the innovation and that user comfort and their perception of comfort are the most important features which should always be central in all innovation and communication.

[36] https://drylocktechnologies.com/
[37] https://www.goodnites.com/en-us/bedwetting-products/boys/goodnites-tru-fit
[38] https://www.pg.com/en_US/downloads/innovation/factsheet-PampersDM.pdf
[39] http://gillin.com/blog/2012/08/attack-of-the-customers-the-pampers-dry-max-crisis/

Service model for single use diapers from eco-brands

Eco-diaper brands generally have a higher consumer price. Partially due to higher material costs but also because of how they position themselves on the market. They tend to target environmentally conscious parents, who do not mind paying a small premium for environmentally and socially conscious products. In general eco-brands are more transparent when it comes to their materials (no hazardous chemicals/materials), offer more personalization (several prints can be selected) and provide a service model to deliver diapers on a monthly/weekly basis (gives bulk discount and extra convenience for the consumer). The examples we came across are from the U.S:

<u>The Honest Company</u>

The Honest Company is a wellness brand that distinguishes itself on being environmentally and socially conscious and on the fact that their products do not contain any harmful materials. They have a full baby range, including diapers and wipes. Consumers can get a monthly subscription[40] service that bundles diapers and wipes together at better price and early access to new diaper designs. Most of the Honest Diapers sales come through the subscription service.

<u>Parasolco</u>

Parasolco positions itself as eco-friendly design brand, which is sold via Amazon. The diapers are produced with the Dry-lock technology[41] . The premium diapers and wipes, or diapers only are available only as a monthly subscription

A drawback of the service models from the Honest Company and Parasolco is that they do not include the collection and recycling of the waste. As these brands distinguish themselves on sustainability it would be expected that they also look into the waste-collection aspect for a full R0 circular strategy.

Patents on design innovations

The manufacturers of absorbent hygiene products protect their technologies, even those not currently used with patents. Drylock has patented most of its technology as has have Procter and Gamble and Essity (formerly SCA). A patent is valid for either 17 years from its issue date, or 20 years from the filing date of the earliest application. This means that the innovations cannot be used by other players in the sector for at least 17 years. It is likely that the high number of patents is a barrier towards circular economy transition of the sector. As one of the three drivers for a circular economy is technology innovation through a specific radically new technology (see paragraph 1.3.1 for more detail).

[40] https://www.honest.com/baby/honest-diapers-bundle.html
[41] https://www.parasolco.com/subscriptions/diapers-wipes

3.4 CONSTRAINTS AND ACCELERATORS

In the table below we describe some of the constraints we have identified towards the transition strategy design for disassembly & recycling and which accelerators could potentially reduce these barriers

Triggers for circularity	Constraints	Accelerator	Circular strategy
Design for disassembly & recycling	All significant innovations in the sector are patented and cannot be used by other players in the market. This inhibits an important driver for the circular economy transition, namely emergence of new technologies.	Investigate opportunities to open up patents, which are significant from a sustainable perspective.	R3-R7 extend lifespan of products and its parts
	Design for recycling needs to be a joined effort of the entire sector as separate waste collection/recycling for only one producer is not realistic because the waste stream cannot be separated per brand.	Set up roundtable of producers to discuss opportunities for a joint effort as a sector on design for disassembly and recycling.	
	There is no dialogue between recyclers and producers. As a result producers have no insight in what is needed to improve recyclability and recyclers do not know what improvements are feasible.	Set up dialogue between producers and recyclers to identify opportunities to improve recyclability. The outcomes of this dialogue should be summarized and shared through the sector.	
	Diapers and incontinency materials consist of various components e.g. fluff pulp, SAP, PE & PP non-wovens, adhesives and elastics. This is a limiting factor for recyclability and disassembly.	Investigate the business case of Dry-lock are these products better to recycle and disassembly. Do they result in higher value recyclables?	R8-R9 useful application of materials
		Investigate opportunities with frontrunner producers to further reduce the number of components in AHP products. For example, can the non-wovens be produced with one type of plastic resin?	

4 SMARTER PRODUCT USE AND MANUFACTURE (R0,R1-R3)

In this chapter we will discuss the examples and opportunities in the sector for the high circularity strategies namely R0: Refuse, R1: Rethink and R3: Re-use. R2: Reduce will be discussed in chapter 5 and has also been discussed in chapter 3.

4.1 R0 REFUSE: EARLIER TOILET TRAINING

This is the most challenging circularity strategy as it focus on making products redundant by abandoning its function or by offering the same function with a radically different product. A R0: refuse innovation has a very high impact but generally requires innovation in the core technology and socio- institutional change. This is very difficult to facilitate and does not occur often.

The most viable R0 strategy seems to be making diapers redundant by getting children to be toilet-trained earlier. This would save a large amount of diapers and has significant benefits for parents e.g. cost and burden of changing diapers. The age that children are going to school has a significant influence on the average age at which they are toilet-trained (2.5 years in Belgium, 3 years in Germany and 3.5 years in the Netherlands). Stimulating toilet-training at an earlier age could reduce the use of single-use diapers. In Belgium children are generally toilet-trained at an early age, as they need to be able to use the toilet before they start nursery school at 2.5 years. However there is a growing percentage of children in Flanders who are not toilet-trained when they start nursery school. A study from the University of Antwerp[42] shows that more than a third of the childcare workers feel that parents pass on their responsibility to toilet-train their child to the day-care personnel and that parents do not pay enough attention to toilet-training. More than 73 % of the nursery teachers stated that the opinions of parents on toilet-training have changed. Previous studies have showed that parents are less consistent and authoritarian and more liberal in their education. They are also short on time, mainly as a consequence of both parents working outside the home, which contributes to the postponement of the toilet training age.

There are also some organizations saying that the introduction of disposable diapers increased the average age at which children are toilet-trained. They explain the increase in the average age by the fact that disposable diapers keep babies comfortable after they have used their diapers, thereby making children less inclined to be toilet trained. However, a study in Japan[43] comparing two groups, one using cotton diapers and the other disposable diapers revealed that the time when they were toilet-trained was the same in both groups: the average was 27 months (6 months later than the average 20 years ago). In addition, the same study was performed with identical twins, one sibling using cotton and the other, disposable diapers. Also in the study with the identical twins, no difference was observed as to notice before discharge, notice after discharge, or period of use.

[42] Toilet training in day-care centers in Flanders, Belgium, G. van Hal et. al, European Journal of paediatrics, December 2011
[43] Investigation of the age of release from the diaper environment, E. Takahashi et. al, Paediatrician 14 Suppl 1:48-52 · February 1987

A comparative study on basis of a 1966 study[44] about toilet-training in Eindhoven and de Kempen region in Netherlands did show that type of diaper used was an additional factor for bladder control at all ages but was statistically significant only for 3 year olds.
A study from P&G[45] also showed that cultural norms greatly influence the age at which a baby begins toilet-training. High cloth diaper usage markets, such as India and China, tend to begin toilet-training babies when they are younger than 1 year. Russia, although predominately a disposable diaper usage market, also follows this practice of early toilet-training. In European countries, such as Germany, France, and the United Kingdom, as well as the United States and Japan, babies typically do not begin toilet-training until approximately 2 years old.

Overall it can be said that various factors are likely to contribute to the later age of toilet-training of children in Belgium such as: cultural norms, higher day-care attendance, higher percentage of working parents, less authoritarian style of education, and possibly type of diaper used. However, if diaper type is really of influence can debated, especially with the newer, much more comfortable generation of reusable diapers.

4.2 R1 RETHINK: DIAPERS AS A SERVICE

With the R1 strategy the ambition is to make the product use more intensive, for example through sharing product or by bringing multi-functional products on the market. The most famous example of this approach is that consumers no longer buy the product but that they rent it as a service.

There are various initiatives which rent out reusable diapers. The services such as Washcot [46] in Belgium and Tiny Tots [47] in the United States provides cotton diapers on weekly basis, collect them after use and wash them. When the cotton diapers reach their end-of-life, they are recycled or composted by the services. The services are available for both professional day-care facilities and consumers.

The biggest disadvantage for consumers and day care facilities of the service model is the cost. In general the service model is significantly more expensive than regular single use diapers or washing reusable diapers yourself. A study of Brussels Instituut voor Leefmilieu[48] showed that for a day-care facility the cost per child per year was € 188,86 for single-use diapers, the service model with reusable diapers was €381 and the use reusable diapers when child-care facilities do their own washing was € 144,- per child. Another disadvantage for consumers is that often they would like to receive back their own diapers, which is very difficult to organize for diaper washing services.

Another consideration for the service model is the environmental impact of the transport. Bringing and picking up of the diapers for washing does require additional transport. Professional washing facilities are usually more efficient in energy and auxiliary material use. However the services process soiled diapers from different children and therefore it is very important to assure sterile washing (which often requires washing at higher temperatures) to prevent any cross contamination.

[44] Bladder control in 1-4 year olds in the Eindhoven and de Kempen region (the Netherlands) in 1996 and 1966, B E Horstmanshoff et. al, Nederlands tijdschrift voor geneeskunde 147(1):27-31 · February 2003
[45] Diapering habits: A global perspective, L.A. Thaman & L.F. Eichenfield, Pediatric Dermatology Vol. 31 Suppl. 1 15–18, 2014
[46] http://www.washcot.be/luier-service/wat
[47] http://tinytots.com/diaperservice/what-is.html
[48] wasbare luiers invoeren in uw kinderdagverblijf, Brussels Instituut voor Leefmilieu, maart 2010

4.3 R1 RETHINK- USE PRODUCT MORE INTENSIVE

With the R1 strategy the ambition is to make the product use more intensive, reusable diapers and incontinency products are of course an excellent example of this. The market of reusable diapers and incontinency materials seems to have grown significantly in recent years. We could not find market data on the percentage of reusable diapers or incontinency materials in Belgium, but media outlets[49] and interviewees mention a growing user group of reusable diapers. For reusable incontinency materials we could not find any literature.
A study for P&G [50]showed that it is not uncommon in many countries for a baby to wear a combination of cloth and disposable diapers, as well as traditional underpants and disposable training pants as shown in figure 6. In for example the Philippines 80 % of the mothers report using cloth underpants over disposable pants on their babies. This illustrated in figure 6 where you see both a high use of disposable diapers and cloth underpants in the Philippines. The preferences of diaper type are influenced by habits, cultural norms, and income. Primarily in developing regions, some babies use disposable diapers exclusively for sleep or outings.

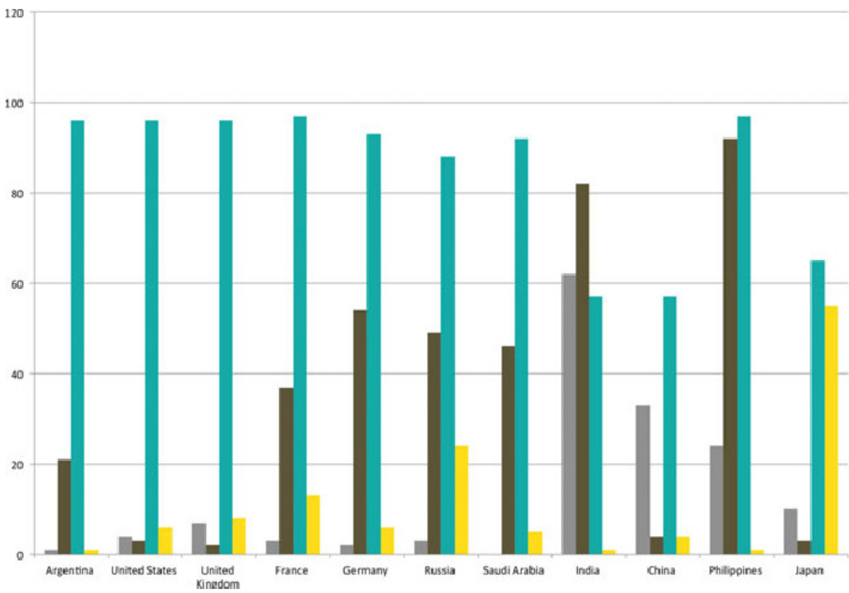

Figure 6: Use of cloth and disposable diaper forms according to country in infants aged 0 to 24 months old (%). Grey: cloth diaper; Brown: cloth under pant; Blue: disposable diaper; Yellow: disposable training pant

It seems that in developing countries when the disposable income increases parents start replacing their reusable diapers with disposable diapers whereas in Europe and North America where there is growing social and environmental awareness, an increasing number of parents start replacing their disposable diapers for reusable diapers.

[49] https://nieuws.vtm.be/vtm-nieuws/binnenland/herbruikbare-luiers-steeds-populairder
[50] Diapering habits: A global perspective, L.A. Thaman & L.F. Eichenfield, Pediatric Dermatology Vol. 31 Suppl. 1 15–18, 2014

4.4 PROMOTERS AND BARRIERS IN THE USE OF REUSABLE DIAPERS

We have identified the following promoters and barriers for the uptake of reusable diapers and incontinency materials.

4.4.1 Promoters

Costs

In Africa reusable hygiene products are a rapidly growing market with companies such as Lunapads [51], Thinx [52] and Afripads [53] amongst others, because the cost are significantly lower than for the single-use products. Also in developing countries reusable diapers are predominantly used, because of the lower costs (see paragraph 4.1.3). MilieuCentraal[54] has calculated that using a reusable diaper instead of a disposable diaper can save consumers up to € 500,-. Also in Belgium the cost is an important argument for parents to use reusable diapers instead of disposable ones.

Social stigma

In Africa the growing market of the reusable hygiene products can also be explained by the social stigma, which still surrounds periods and incontinency. The reusable pads have to be purchased only once, thereby reducing the discomfort when purchasing the product. Many companies producing reusable hygiene products also produce washable incontinence care products for light incontinency for the European market, e.g. Freda [55], wundies [56]and Lunapads [51]. Also in Europe consumers can experience feeling of shame when they need to wear incontinency products. The washable incontinence products have a similar feel and look as ‘regular’ underwear which takes away some of the social discomfort of having to wear incontinency products.

Natural materials & no chemicals

Consumers are more and more concerned about hazardous chemicals and materials in products. Disposable diapers contain some materials which a growing group of consumers mistrusts,[57] such as SAP and plastics. This group of consumers feels that in the past SAP has been linked to toxic shock syndrome and to allergic reactions. Reusable diapers are generally made of natural materials such as hemp, bamboo and cotton and reusable diaper producers are often very transparent about the use and sourcing of their raw materials.

Better for the baby skin

Another reason for parents to use reusable diapers is that they think that reusable diapers are better for the baby’s skin. They feel that disposables contain fragrances and chemicals that can irritate a baby’s skin. We could not find any research to support this claim, but it is an often heard argument in favour of reusable diapers.

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[51] https://lunapads.com/?geoip_country=US
[52] https://www.shethinx.com/
[53] http://afripads.com/
[54] https://www.milieucentraal.nl/bewust-winkelen/spullen-en-diensten/luiers/#geld
[55] https://myfreda.com/
[56] http://award.designtoimprovelife.dk/nomination/2448
[57] http://www.nontoxicrevolution.org/blog/non-toxic-diapers

4.4.2 Barriers

Reusables need to meet the convenience, comfort and leakage standards

An important barrier for the uptake of more circular products is the consumer acceptance. Consumers of hygiene products set very high standards on user convenience, comfort and diaper leakage. The reusable diapers available on the market are often perceived as not meeting these standards, thereby hampering the socio-economic acceptance. It is important to take away this perception as most reusable diapers can meet the same convenience comfort and leakage requirements as disposable diapers.

One time bulk purchase

Reusable diapers require quite a larger upfront investment. A starter kit generally consists of 24 reusable diapers liners and lengtheners for bodysuits and is an investment of around the € 400,-. To pay such amount upfront can be a barrier for some customers. However, there are some municipalities in Belgium who subsidize the purchase of reusable diapers with € 125,-. The reasoning behind this subsidy is that less waste needs to be collected by the municipalities thereby lowering waste collection costs. This subsidy is perceived as a positive effect on the consumer adoption of reusable diapers.

Unfamiliarity

The current generation of parents is not familiar with reusable diapers and incontinency products. Information events are needed to inform parents on how to use reusable diapers and which types of diapers are available. This requires a much higher level of commitment from parents than when they start using disposable diapers, which can be purchased at any store. Also parents usually purchase one starter kit, after which it is very costly to switch brand or type. However, there is growing number of stores, which allow users to rent reusable diapers so they can test them before purchasing a starter kit.

Prejudgments of consumers and child care facilities

Quite some people associate reusable diaper with unhygienic and requiring a lot of work. Especially the older generation still associates reusable diapers with the reusable diapers from the past, which needed more folding (more work) and were less hygienic than the current generation of reusable diapers. A pilot in the Netherlands with reusable diapers showed that the socio-economic acceptance was one of the biggest hurdles.[58] Consumers have quite some prejudices about washable diapers, therefore, the main objective after the pilot phase is to change the perception of professionals and consumers on reusable diapers. However, another pilot called mazzelkontjes [59,60] was a big success. Two thirds of the forty parents continued to use reusable diapers after the pilot phase.

Also childcare facilities are very hesitant about reusable diapers, assuming they are less hygienic and more work than disposable diapers. Despite the fact that there are some child care facilities in Belgium which successfully use reusable diapers for many years and have actively communicated about this, most child care facilities remain reluctant to switch, due to their prejudgments.

[58] Verslag workshop preventie in de luierketen 6 oktober 2016
[59] https://www.bndestem.nl/breda/project-mazzelkontjes-enlsquo-jongens-plassen-meer-naar-vorenenrsquo~aea3d782/
[60] https://www.milieucentraal.nl/nieuws/2017/geslaagde-mazzelkontjes-proef-gemeente-breda/

4.4.3 Reusable versus disposable: The sustainable perspective

A full life-cycle LCA study[61] from the Environment Agency in the UK has shown that reusable diapers do not necessarily have a lower GreenHouseGas (GHG) impact due the energy and water needed for laundering. Research from MilieuCentraal does show that reusable diapers have lower GHG emissions. MilieuCentraal does not have publically available LCA, but was willing to provide background information on their study[62]. The outcomes of both studies are significantly different, where the study from the U.K. Environment agency shows that disposable nappies with an average consumer use have a slightly lower carbon footprint than reusable diapers and a significantly lower carbon footprint when the reusable diapers are tumble dried. The study from MilieuCentraal shows exactly the opposite, namely that reusable diapers always have a lower carbon footprint, even when the diapers are tumble dried (see table 3).

Scenario	**Study Environment Agency**	**Study MilieuCentraal**
Use of disposable nappies	550 kg CO_{2eq}	588 kg CO_{2eq}
Use of reusable nappies average scenario (mix line drying and tumble drying)	570 kg CO_{2eq}	
Average use of reusable nappies line drying		242 kg CO_{2eq}
Average use of reusable nappies only tumble drying		425 kg CO_{2eq}
Use of reusable diapers with line drying, full load washing and reuse on second child	270 kg CO_{2eq}	
Use of reusable nappies only tumble drying	815,1 CO_{2eq}	

Table 3: Comparison of studies from Environment Agency and MilieuCentraal

As the study from MilieuCentraal is not publically available we could not do a direct comparison of both reports. However from the personal communication with MilieuCentraal the following assumptions could explain the difference in outcomes of both studies:

- The Environment Agency assumes that children are on average toilet trained at the age of 2 years and 6 months, MilieuCentraal assumes that children are on average toilet trained at the age of 3 years and 2 months.
- The Environment Agency assumes that reusable diapers are washed at 60 degrees, while MilieuCentraal assumes that reusable diapers are washed at 40 degrees.
- Since the study from the Environment Agency in 2008 washing machines and diapers have become much more water and energy efficient. MilieuCentraal worked with the most recent figures from the Netherlands, and as table 4, shows this makes a significant difference in energy use of a washing machine.

[61] An updated life-cycle assessment study for disposable and reusable nappies, Environment Agency, DEFRA and WRAP, October 2008
[62] E-mail and phone conversations with Jappe Zijlstra from MilieuCentraal

Temperature	MilieuCentraal	Environment Agency
30 degrees	0,35 kwh per load	
40 degrees eco	0,36 kwh per load	0,60 kwh per load
40 degrees	0,50 kwh per load	0,64 kwh per load
60 degrees eco	0,65 kwh per load	1,00 kwh per load
60 degrees	0,90 kwh per load	1,06 kwh per load
90 degrees	1,45 kwh per load	1,77 kwh per load

Table 4: Average energy use washing machine used in MilieuCentraal study and Environment Agency report

Producers of single-use diapers often refer to the study of the Environment Agency, which is perceived as a publically available study from a trustworthy organization to caution the uptake of reusable diapers. For a broader acceptation of reusable diapers and acceptance of their potential environmental benefits we would advise to publicize the LCA study from MilieuCentraal, make the study ISO compliant and peer reviewed.

A LCA only takes into account the impact on the environment, but whether a product is sustainable depends also on the other aspects such as the impact on humans, societies and communities. The total cost of ownership method takes a broader sustainability approach in which all the costs associated with a product over its lifetime are considered, so what are the costs for environment e.g. what are the costs for the society due to GHG emissions, the societal costs e.g. what are the cost of the waste generated, human costs and financial costs. An interesting new methodology is currently being developed by Wageningen University and True Price to measure the true price of products taking into account financial capital, intellectual, natural, human, produced capital and social capital. The method is expected to become publically available in the coming months.

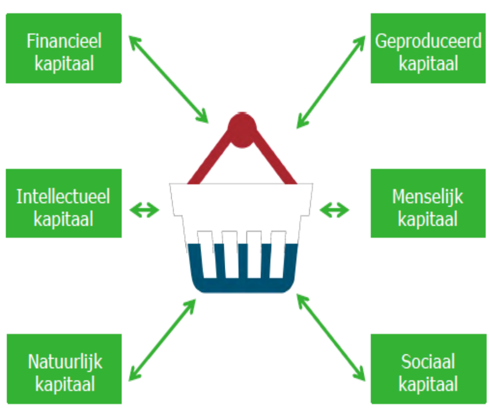

Figure 7: Method to measure true price of products

When taking a broader sustainability approach than LCA, the societal cost of processing the waste from the disposable diapers will be taken into account e.g. MilieuCentraal calculated that the use of disposable diapers generates 22 kilo of waste per month. Also the potential social benefits and community benefits of washing diapers locally will be included. This might provide a clearer picture on whether disposable or reusable diapers are more sustainable.

4.5 CONSTRAINTS AND POTENTIAL ACCELERATORS

In the table below we describe some of the constraints towards the transition of smarter product use and manufacturing and which accelerators could potentially reduce these barriers.

Triggers for circularity	Constraints	Accelerator	Circular strategy
SMARTER PRODUCT USE AND MANUFACTURE	Cultural norms play an important role on the age at which parents start toilet training their children. Parents are often not aware that you can start toilet training already at an earlier age and how they can best approach toilet training	Kind & Gezin could possibly play a more active role in stimulating toilet training at an earlier age. In their folder *ABC van baby to Kleuter*[63] toilet training is now advised between the ages 2 to 5, possibly they could stimulate toilet training at the age of two.	R0: refuse
		Make parents more aware of the role they have in toilet training their children and stress that this is not something they can hand-over to child care facilities and nursery schools.	
	The service models for single-use eco-brand diapers currently do not consider end-of-life. Thereby not taking a full circular approach	Discuss with brands if there are opportunities for collecting their product similar to e.g. Nespresso which retrieves its capsules after use.	R1: Rethink
	Producers of single-use diapers often refer to the study of the Environment Agency, which is perceived as a publically available study from a trustworthy organization) to caution the uptake of reusable diapers.	For a broader acceptation of reusable diapers and acceptance of their potential environmental benefits we would advise to publicize the LCA study from MilieuCentraal, make the study ISO compliant and peer reviewed.	
	A recurring argument against reusable diapers is whether they are actually better for the environment. The LCA studies conducted have not considered societal costs and human capital.	Conduct study to investigate the total cost of ownership of single use diapers versus reusable diapers which will provide a more complete picture than a LCA	

[63] Het ABC van baby tot kleuter, 2014, Kind & gezin

	There is a high level of unfamiliarity with reusable diapers. Child care facilities, municipalities and employees of Kind & Gezin are often not fully familiar with the newest generations of reusable diapers and often have prejudgments concerning hygiene and amount of work needed.	In Finland and some municipalities in Belgium a reusable diaper is provided in free baby box which the government gives to new parents. Such an approach helps parents to become aware of reusable diapers and consider them as an option.	
		In Leuven information evenings on reusable diapers are organized together with the municipalities. This shows parents and child care facilities that reusable diapers are a trust-worthy option.	
		Provide an independent information brochure on the advantages and disadvantages of reusable and disposable diapers and how to get started with reusable diapers.	
	Hygiene and amount of work are the main arguments for child-care facilities for not allowing children with reusable diapers.	Conduct an independent study on whether there are any differences in the hygiene and amount of time spent when using reusable or disposable diapers at a child care facility.	
	The required bulk purchase of reusable diapers can discourage the use of reusable diapers.	Municipalities provide a subsidy on the purchase of the starter kit of reusable diapers of around € 125, - , which lowers the barrier for consumers.	

5 REDUCE RAW MATERIAL USE IN THE PRODUCTION (R2)

In this chapter we will discuss the potential for the circularity strategy R2: by using fewer natural resources through the use of recycled, renewable or biodegradable materials in the three main components of diapers and incontinence care products, namely non-wovens, SAP and fluff pulp.

5.1 DEFINING SUSTAINABLE MATERIALS

It is important to note that the source of the materials and the properties are two separate characteristics. Biodegradable plastics are not necessarily made of materials directly coming from nature, and vice versa, plastics made from natural materials are not necessarily biodegradable.

We use the following definitions for recycled, renewables and biodegradables:

- ***Recycled:*** raw or processed material that can be recovered from a waste stream by any kind of recycling technique, e.g. mechanical, chemical, or organic recycling, and is this way directly available for use in a product.[64]
- ***Renewables:*** made from a source that can be renewed in nature (plant etc.) Renewable materials can be defined as materials, which are produced with inputs from natural resource, and hence can be replenished naturally with the passage of time. Renewable materials do not use any fossil based resources as feedstock.
- ***Biodegradables****:* materials that are broken down by micro-organisms into mineral salts, biomass, CO_2 or CH_4 and H_2O.[65] A special type of biodegradation is composting, in which the material is broken down into a nutrient-rich substrate. Specific rules apply to the time frame and quality of the composting process.

5.2 SUSTAINABLE VERSUS FOSSIL-BASED

Most of the examples of sustainable material-use we found are in single-use diapers such as Libero[66], Eco-by-naty[67], Moltex [68] and Bambo Nature nappies[69]. There are much fewer examples of sustainable materials use in incontinence care products. The reason for this could be that most of the incontinence care products are purchased by health and elderly institutions, where costs are the main driver and sustainability has much lower priority. This is probably due to the fact that professional purchasers are responsible for sourcing the incontinence care products, they are given a set of criteria the products need to meet. Cost is often high on this list and sustainability of much less importance or even not taken into account. The purchase of single-use diapers by consumers is a much more personal decision and depending on the customer sustainability can be a very important decision criteria. Abena and Essity (formerly SCA) are examples of companies with a progressive sustainability program, which includes sustainable material use for their incontinence care brands. Abena for example has partially certified its incontinence care products line with the Nordic Ecolabel, which requires that at

[64] http://www.ovam.be/sites/default/files/atoms/files/Folder%20Hoe%20kunnen%20we%20bioplastics%20recycleren.pdf
[65] http://www.ovam.be/sites/default/files/atoms/files/Folder%20Hoe%20kunnen%20we%20bioplastics%20composteren.pdf
[66] https://www.libero.com/
[67] https://www.naty.com/nl/
[68] http://en.moltex.eu/home/
[69] http://www.bambo-nature.com.au/faqs/

least 50% of the materials in the product comes from renewable, recycled sources or at least 20% of the primary packaging comes from recycled or renewable sources.

In general, it can be said that the sustainable alternatives are struggling to compete with the fossil-based materials due to the low oil prices. Fossil fuels are the main raw materials for the non-wovens and the SAP. The fossil fuel prices are now at a much lower price and higher supply than it has been for several years. Recyclables, biodegradables and renewables already have difficulties competing with petroleum based alternatives but the drop in oil prices has decreased the demand even more, due to increasing price gap between ‘sustainable alternatives’ and the petroleum based products. As a result the market growth of sustainable nonwovens (now-wovens from renewable and or bio-degradable materials) has slowed down significantly in 2016. During 2012 and 2017 sustainable nonwovens grew 50-70% faster than all nonwovens but projected growth for sustainable nonwovens 2017-2022 is only +3% in tonnage.

Additionally, in recent years the focus of the industry has been on increasing the percentage of fossil based/synthetic materials in diapers by for example increasing the percentage of SAP and reducing the percentage renewable/natural materials, such as the fluff pulp. This is positioned as more environmentally friendly because less trees have to be grown and the weight of the AHP product can reduced. However, synthetic products are much more difficult to compost, than renewable products. This is not so much a problem in west European countries like Belgium and the Netherland where AHP waste is incinerated with energy recovery. But for countries where the waste goes to landfill, the increasing use of synthetic materials in AHP products could have a significant negative environmental impact.

5.3 POTENTIAL FOR RECYCLABLES

In this paragraph we look into the potential to use recycled materials in non-wovens, SAP and fluff-pulp. In Chapter 7 the potential of recovery of recyclables from post-consumer AHP materials is discussed.
Ideally within a circular economy, the recycled materials preserve their original quality and technical characteristics, and could be reused as a raw material in the production of the same product. Ultimately this would lead to the situation where the production of raw materials is no longer necessary, and the disposal of a product no longer leads to waste. However this scenario (e.g. recyclables from post-consumer AHP products) is currently considered not realistic for the AHP sector, therefore we will explore all scenarios for using recyclables in the AHP sector. There are three scenarios of use of recyclables:

- Recyclables from industrial waste (production-waste)
- Recyclables from other post-consumer sources such as PET bottles
- Recyclables from post-consumer AHP products

In general, the main challenge for the use of recyclables in AHP is meeting the regulatory quality requirements on safety and health, which are extremely high for diapers and incontinence care products. This is because the product is intended for vulnerable groups (babies, elderly and sick people) and these products are generally in contact with the skin for a long period of time. Often, recycling results in materials of lower quality and durability than the virgin alternative and it is very difficult to rule out contamination of post-consumer recycled materials.

Therefore in general (post-consumer) recycled materials are not used as raw material for the production of AHP, and the AHP sector also does not expect any use of post-consumer recyclables in the near future[70].

5.3.1 Recyclables from industrial waste

Recyclables from industrial waste are losses during the production of the AHP and their components. The contamination of these materials is minimal as these products never reach the use phase and are therefore not soiled with faeces or urine. As a result recycling from industrial waste provides high-grade recyclables. Due to the minimal risk of contamination and the output of high-grade recyclables, industrial waste recycling makes sense from an environmental and an economic perspective. A distinction can be made between manufacturing waste during the production of the components (SAP, non-wovens and fluff pulp) and the manufacturing waste during the assembly/production of the AHP products. Recycling of manufacturing waste in the production lines of the components is less complex because the different components are not yet mixed. As a result, a growing percentage of the component producers have set-up recycling program for their manufacturing waste. For example, Fibertex has non-wovens on the market with a percentage of recycled industrial waste from their own production processes[71]. For AHP manufacturers it is a bit more complex as the SAP and fluff pulp are mixed during production and need to be separated to be recovered. The waste stream is however significant. It is estimated to be around 15,000 to 30,000 tonnes industry wide annually. Hartmann, a producer of amongst others incontinence care products has implemented a recycling program which allows the separation of the rejects into their components of cellulose fluff and super-absorbents[72], to permit the raw materials to be returned into the continuous production process. The minimum value of 95 % purity of SAP is said to be significantly exceeded during the recovery process. Essity, formerly known as SCA, also separates their manufacturing rejects into fluff pulp and super absorbents, and a significant percentage is reused as raw material in the manufacturing process[73]. The American company Recyc PHP[74] has built their business model around collecting AHP rejects from manufacturing waste, separating them in the various components and reselling them as raw materials for AHP products.

The major challenge lies in the use of post-consumer recyclables from diapers or other sources.

5.3.2 Recyclables from other post-consumer sources than AHP-products

Materials used in AHPs need to meet very strict requirements on trace residues and chemical contamination (see paragraphs 6.2 and 6.3 for more detail on the health and safety requirements). In general it is very difficult for any post-consumer recyclable to meet these regulatory requirements. Additionally, many customers such as big retailers are also hesitant about using recycled materials due to the potential liability. Hygiene products are very sensitive for public debates on their material use as they generally used closed to the skin by vulnerable target groups e.g. babies and elderly. This also illustrated by the discussion on potential hazardous chemicals in female hygiene products. This has led to pressure from stakeholders on producers to make the composition of their product public.

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[70] Interviews Ontex, SCA and Fibertex
[71] http://www.infrastructurene.ws/2016/11/30/fibertex-prides-itself-on-100-recyclable-products/
[72] http://se.hartmann.info/128983.php
[73] http://www.scagennep.nl/index.php?option=com_content&view=article&id=4&Itemid=5
[74] http://recycphp.com/en/company/business-activities/

The Nordic Ecolabel for absorbent hygiene products states that the use of recycled material is not allowed in the sanitary product (e.g. in cotton, paper and fluff) with the exception of recycled plastic. The main reason is the risk of toxin migration to the end-user, which can occur in recycled materials. Nordic Ecolabel feels that the systems in place are not good enough to ensure that recycled materials do not contain chemicals that are harmful to health and the environment. After all, the products are often in direct contact with the skin for a longer period of time. The label feels that these assurances can be made for recycled plastics as they need to fulfil the EU requirement set to recycled plastic for food contact. This regulations state that recycled plastics intended for food contact need to provide complete traceability of the materials.[75]

The EU legislation for recycled plastic for food contact is very strict, and such legislation is not yet in place for recycled paper. It might be interesting to explore the potential for more stringent legislation for recycled paper in contact with AHP products. This legislation could ensure producers that recycled paper to be used in AHP products does not have any risks of toxin migration. This could potentially stimulate the acceptance of recycled paper in AHP. This said we could also not find any examples of diaper and incontinency brands that use recycled plastic in their products, most likely due to the fact that AHP producers and retailers are concerned about the potential liability.

5.3.2.1 Recyclables from other post-consumer sources in non-wovens

The Ecosure fibre[76] from the Poole Company, is produced from recycled fibre from post-consumer PET bottles, and can be used to produce non-wovens for AHP products. However we have not come across any AHP products which use these non-wovens. Additionally, there is the company DS fibres from Belgium who produces non-wovens from recycled fibres of PET bottles for the automotive industry. They currently do not consider the AHP sector as a potential market for their product, but they are open to consider new applications. We have not found any examples of commercial brands on the market, which use recycled post-consumer materials in their AHP products. Producers have indicated during the interviews[77] that this is not likely to change in the future. This can be explained by the fact that the regulatory quality requirements on safety and health are extremely high for diapers and incontinence care products as it is product intended for vulnerable groups (babies, elderly and sick people).

5.3.2.2 Recyclables from other post-consumer sources in SAP

As far as we know SAP cannot be recycled in a way that meets the technical requirements of SAP in AHP products (see also paragraph 6.1.1). It is therefore not surprising that we have not found any examples of recycled SAP from other post-consumer sources.

5.3.2.3 Recyclables from other post-consumer sources in fluff-pulp

We have not found any examples of fluff pulp from other post-consumer resources. One of the reason is that it is difficult to meet the health and safety requirements, also the Nordic Ecolabel does not allow recycled paper in AHP products. A possible opportunity could be, as discussed in paragraph 5.3.2, to develop regulations for recycled paper in AHP products, which take away concerns on toxin migrations, as has been done in the EU regulation for recycled plastic for food contact. Additionally, fluff pulp is mainly produced from soft cellulose fibres

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[75] EU Commission Regulation (EC) No 282/2008 on recycled plastic materials and articles intended to come into contact with food and amending regulation EC No 2023/2006
[76] http://www.nonwovens-industry.com/issues/2011-09-15/view_features/wipes-with-recycled-fibers/
[77] Interview with Essity and Ontex

due to their technical properties. Paper, on the other hand, is produced from a mix of hard and soft fibres, it is likely that quite a lot of other post-consumer sources do not have the right fibre mix to be recycled as fluff pulp. We imagine a post-consumer resource would need to be found with the right mix of fibres.

5.3.3 Recyclables from post-consumer AHP products

Recycling post-consumer waste of diapers and incontinence care products for use in diapers and incontinence care products does not seem a very likely prospect at the moment, because of the risks of medicine and pathogen contamination, particularly in recycled materials from incontinence care products (see paragraph 7.3.4 for more detail). The health and safety requirements for AHP products are so high that it seems unlikely that any changes will occur on the short term.

Unicharm, the leading producer of baby diapers and incontinence care products in Asia, is exploring the possibilities to use post-consumer recycled fluff pulp from diapers and incontinence care products in their diapers (see paragraph7.2.3). Recycled fluff pulp can meet the technical requirements; whereas health and safety is the remaining barrier.

We will now discuss the potential for recycled alternatives e.g. fluff pulp, SAP and non-wovens coming from post-consumer AHP products.

5.3.3.1 Recycled fluff pulp

Recycled fluff pulp from diapers and incontinence care products shows potential as it seems to be able to meet the technical requirements and the recycling process already exists[78]. We did not come across any examples of producers using recycled fluff-pulp. In Asia Unicharm and the National University of Chunchon[47] have ambitions to use recycled fluff-pulp in diapers in Asia from, and may provide interesting examples in the near future. The main barrier for the uptake of recycled fluff pulp in Europe and Asia seems to be health and safety, legislation and liability issues.[79]

5.3.3.2 SAP

We did not come across any recycled SAP for the AHP sector. From the interviews it became clear that recycled SAP for the AHP market is not expected any time soon. The main consensus is that recycled SAP will have difficulties meeting the technical quality requirements, e.g. the absorbency power, and the safety requirements.

5.3.3.3 Non-wovens

We have not come across any examples of post-consumer recycled non-wovens from AHP products. From the interviews it seems that quality of the recycled plastic coming from AHP products is too low (most likely due to the fact that recovered material from AHP products is mix of plastics) and that it, therefore, cannot be reused as raw material for the production of now-wovens. Additionally the health and safety legislation and the liability risk will also be an issue even when there is an opportunity to recycle the non-wovens for reuse in the production of AHP products as recycled materials from other post-consumer sources are barely used in the production of non-wovens.[80]

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[78] Properties of fluff pulp and Handsheet recycled from paper diapers, Kyong-Hwa Choi et all, 2015
[79] Interviews with SCA, fibertex, tech absorbants and Kimberly and Clark
[80] Interviews with SCA, fibertex, tech absorbants and Kimberly and Clark

5.4 POTENTIAL FOR RENEWABLE MATERIALS

Renewable materials are made from a source that can be renewed in nature (plant etc.) and hence can be replenished naturally with the passage of time. Renewable materials contribute to sustainable development through reduced CO_2 emissions and reduced use of materials from fossil sources. However, materials based on renewable resources are not automatically sustainable. There are several key problems concerning the cultivation and production of the renewable materials, such as land use in competition with food production, use of pesticides, chemicals and water in the production processes. Although there is a general desire to switch from fossil raw materials to renewables, there is a fierce debate how much more sustainable these renewable alternatives are.

A cradle-to-gate Life Cycle Assessment (LCA) of a bio-plastic based diaper has shown that the use of biopolymers in diapers can improve the environmental performance of disposable diapers, but that there is a risk of burden-shifting from GreenHouse Gas emissions (GHG) to land occupation and water use.[81] Another issue is that there is not sufficient production of such renewable materials to satisfy the demand. Even if the AHP industry would want to switch to only renewable alternatives, it would not be feasible because of their availability.

However, the so-called second-generation renewable materials, which are produced from forest raw materials or waste products (such as bagasse from sugar production) are entering the market. Since they are not produced on agricultural land like the so-called first generation renewable materials, these second-generation renewable materials have much potential to be truly sustainable alternative for fossil-based Which will likely have a lower environmental impact on all impact categories instead of only on GHG emissions and resource depletion.

For the non-wovens, PE and PP drop-in bioplastics have entered the market. These bio-based plastics have the same properties as fossil plastics, and can also be recovered and recycled in a similar way as the fossil based PE and PP. An LCA done for the renewable PE and PP from Braskem [82]shows that these renewable resources have a significantly lower environmental impact on greenhouse gas emissions and renewable resource depletion compared to fossil based resin, but have a higher impact on all the other impact categories such as land occupation, water depletion, human toxicity, ozone depletion etc.

In general, it can be said that the market of renewables is an emerging market, which is expected to mature in the coming years, especially for bio-plastics with the development of drop-in alternatives and second generation renewable materials.

5.4.1 Fluff pulp

Fluff pulp is already a renewable and bio-degradable material, as it is made from wood. In recent years, the sector has worked on replacing fluff pulp with SAP as less SAP is needed for similar absorbance power. This has contributed to the reduction of the weight of the single-use diapers and thereby the environmental impact of single-use diapers. However, these assessment have not taken into account the potential for recycling or composting, as SAP currently cannot be recycled or composted whereas fluff-pulp can. It is not sure whether SAP would still be a more sustainable alternative if the potential for recycling would be taken into account.

[81] The influence of bio-based in mass consumption products: life cycle assessment of a bio-based disposable diapers, N. Mirabella, V. Castellani, S. Sala
[82] Confidential client study, PRé Consultants, October 2015

5.4.2 SAP

SAP is a relatively new product, so there is still much research ongoing on renewable SAP alternatives. Currently, there are two renewable alternatives on the market:

5.4.2.1 BioSAP

The most used renewable SAP in the industry is biosap [83] from ADM, which is carboxyalkyl cellulose polymer and starch polymer blended in water. The absorbency level is lower than for regular SAP, so a mix 20% biosap and 80% regular SAP is generally used.

5.4.2.2 Hysorb-SAP with a calculated renewable content

BASF has SAP with a calculated renewable content on the market. Hysorb is counted to be renewable based on the mass-balance system. A percentage of the feedstock of the total production process of a factory is replaced with renewable feedstock. This percentage is then allocated to a selected product, i.e. the SAP (see figure 8 for more detail).

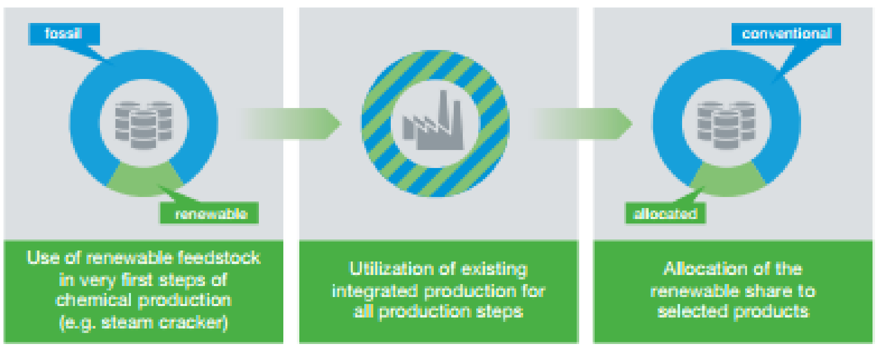

Figure 8: BASF mass balance system

Hysorb itself is still produced from acrylic acid from a fossil resource. The Ecolabel however does recognize Hysorb as a SAP from a renewable resource[84].

Currently, there is no truly renewable alternative for SAP on the market that can meet the technical requirements for use in diapers. However, there is a great deal of research and development work ongoing in this area, and this is expected to result in a wider range of commercial products offering better quality and environmental performance in the near future. The most promising initiatives are:

5.4.2.3 Tethex

Tethex is said to be producing a corn-starch-based SAP with a similar technical performance as traditional acrylic acid-based SAPs. It is expected to be cheaper than synthetic SAP, because it does not need to be co-located with other chemicals such as synthetic SAP. Tethex expects that the cost issue may be even more attractive than Tethex's green profile as most diaper manufacturers focus on economics first. The company is currently setting up a pilot line in the U.S. and hopes to be able to make 10,000 tons of the material in 2018.

[83] https://www.adm.com/products-services/industrials/superabsorbents
[84] Factsheet Hygiene accelerator: Hysorb Biomass balanced, BASF

5.4.2.4 Itaconix & AkzoNobel

Itaconix produces bio-based polymers from Itaconic acid, which are obtained from sugars through fermentation. They are working together with AkzoNobel who will pursue the development and commercialization of bio-based polymers from Itaconinc acid. Itaconic acid is said to show great market potential to meet the technical and economic requirements. Itaconix and AkzoNobel have recently reached a commercial agreement to develop these bio-based polymers for commercial use in construction and coatings, it is likely that a similar agreement can be reached to develop bio-based SAP for commercial use.

5.4.2.5 Novozymes, Cargill and OPX BIO

Novozymes and Cargill have collaborated on renewable acrylic acid technology since 2008. Both companies have worked to cultivate microorganisms that can efficiently convert renewable feedstock into 3-hydroxypropionic acid (3-HP), which is one possible chemical precursor of acrylic acid. In 2015, Cargill acquired OPX BIO, which has been working on converting renewable feedstock into 3-hydroxypropionic acid (3-HP) (see schematic overview in Figure 9) using the patented EDGE technology. It is expected that Cargill will further develop the OPX BIO technology to make the renewable SAP commercially available for the AHP market.

Figure 9: Production process from OPX bio

5.4.3 Non-wovens

The non-wovens market is much more mature in using renewables than the SAP market. Whereas for SAP most of the alternatives are still in the pilot phase, renewable materials use for non-wovens is much more common practice. There are two approaches on more sustainable material use in non-wovens and these will be explained further in the next paragraphs.

- Using sustainable polymers (blends with biopolymers and bio-sourced polypropylene)
- Using a higher percentage of viscose- cellulose based raw material (wood pulp, cotton, hemp)

5.4.3.1 Bio-based plastics

The non-wovens market is the most mature market concerning sustainable material alternatives for the AHP sector. Most eco-brands on the market use sustainable non-wovens in their brands. According to Smithers and Pira the whole sustainable non-wovens market (including also other applications than AHP) is 3.7 million tons, or 94.8 billion square meters.[85]

The PE and the PP in the non-wovens are replaced by bio-plastics of renewable alternatives from resources such as maize starch and sugar cane. Two types of bio-plastics can be distinguished: the drop-in bio-plastics with the same chemical structure and bioplastics with a different chemical structure, which than can also have different characteristics than the fossil based plastics such as biodegradability.

PE and PP drop-in bioplastics have the same properties as fossil based plastics, they are not compostable and are included in the regular plastic recycling systems. A very big advantage of these bioplastics is they can be used in the current production processes of non-wovens that without any adjustments (drop-in). This advantage has most likely contributed to high acceptance of the sustainable non-wovens in the AHP sector. One of the most well-known producers of drop-in PE and PP resin of renewable resource is Braskem.

There are also non-wovens produced from Poly-Lactic-Acid (PLA). Non-wovens produced from PLA have different technical characteristics, one possible advantage of PLA non-wovens is they are generally bio-degradable. One of the draw-backs of these PLA non-wovens it that they need a dedicated production process and that these fibres generally cannot be ‘dropped in’ in the regular production spunlaid production process. Drylaid is the most popular production process for sustainable fibres, as input fibres can be varied relatively easily, thereby facilitating renewable fibres such as PLA or cotton.[86] However, due to the cost-effectiveness and performance advantages of spunlaid, it is not likely that producers will switch their production process to facilitate renewable fibres.[87] Well-known producers of bio-based and bio-degradable plastic films are Mater-Bi from Novamont and Igneo from NatureWorks. Mater-Bi is a biodegradable plastic made from natural components (such as maize starch and vegetable oil derivatives) and from biodegradable synthetic polyester. The material is thus certified as biodegradable and compostable, but it is not 100% from renewable sources. Moltex Nappies have a topsheet made from a mix of PLA (40%) and PP (60%). The use of mix would suggest that the PLA alone cannot meet the required technical requirements or that the costs of the PLA is too high

5.4.3.2 Viscose/ Cellulose- based non-wovens

Viscose based non-wovens are made from regenerated cellulose fibres from cotton, hemp or bamboo. Viscose used to be much more widely used in nonwovens, but nowadays mostly PET and PP is used. This likely because the modern production methods for nonwovens in PP and PET give the same cotton-like feel that the viscose products were known for, but have material properties that provide greater development opportunities in terms of process technology.

However, in the field of sustainable non-wovens, cellulose based non-wovens are increasingly popular and are seen as a sustainable alternative to fossil-based non-wovens. This is also supported by a market study from

[85] http://www.smitherspira.com/industry-market-reports/nonwovens/the-future-of-sustainable-nonwovens-to-2022
[86] http://www.nonwovens-industry.com/issues/2017-04-01/view_features/smithers-pira-outlines-key-drivers-for-the-growing-sustainable-nonwovens-market/15280
[87] http://www.nonwovens-industry.com/issues/2017-04-01/view_features/smithers-pira-outlines-key-drivers-for-the-growing-sustainable-nonwovens-market/15280

Smither Pira.[88] Which shows that all nonwovens, cellulose-based raw materials (wood pulp, rayon, bamboo, cotton and others) account for only 17% of raw materials consumed in 2017; for sustainable nonwovens that percentage increases to almost 32.6%.

An LCA study by Utrecht University conducted for Lenzing seems to support this conclusion by showing that the different regenerated cellulose fibres produced from Lenzing have a lower environmental impact (for non-renewable energy, greenhouse gas emissions, toxic impact, water consumption and land use) than other fibres made from cotton, PET and PP. [89] TJ Beall has also recently introduced a topsheet made of 100% cotton and cotton-synthetic blends, which claims to meet the same technical requirements as polypropylene spundbond non-wovens.

5.5 POTENTIAL FOR BIODEGRADABLES

It is not yet feasible to produce diapers or incontinence care products completely made from bio-degradable materials. Various research initiatives focused on this topic, such as the WooDI project from amongst others Essity (formerly known as SCA) and Chalmers, which aimed to develop a diaper fully produced on raw-materials from wood. [90] Currently the Poly-bioskin project aims to develop in the research project a biodegradable diaper with a skin-compatible surface enriched with anti-microbial and anti-oxidant functionalities (to prevent skin reddening and inflammation), and with a biopolymer-based superabsorbent.[91] Beaming babies[92] claims to be a fully bio-degradable diaper, this however seems to be more a marketing claim than reality, as there are as far as we know no fully bio-degradable diapers on the market yet.

5.5.1 Biodegradable SAP

In general, a higher starch percentage results in better degradation and lower technical performance e.g. absorbency power. We have not found any commercial offerings of bio-degradable SAPs. Also many of the renewable alternatives work on creating acrylic acid from a renewable resource. The acrylic acid, however, keeps the same technical characteristics and is therefore not bio-degradable or recyclable, just like its fossil-based counterpart.

5.5.2 Biodegradable non-wovens

Both NatureWorks and Novamont have bio-degradable non-wovens on the market. There are several eco-brands for single-use diapers, such as Beaming baby nappies, Moltex nappies and Bambo nature on the market who use non-wovens with PLA. As far as we understood, the PLA is mixed with regular PP and/or PE, possibly to meet the required technical performance. Due to this mix of PLA and fossil-based plastics, the non-wovens will likely not be completely bio-degradable. The bio-degradable non-woven are currently a niche-market used by the brands who market themselves as environmental friendly.

[88] http://www.smitherspira.com/resources/2017/june/key-drivers-for-sustainable-nonwovens
[89] Li Shen and Martin K. Patel: Life cycle assessment of man-made cellulose fibers. 2010.
[90] http://www.woodi.se/index.htm
[91] http://www.european-bioplastics.org/polybioskin-develops-biopolymers-for-high-demand-skin-contact-applications/
[92] https://beamingbaby.co.uk/nappies/eco-nappies.html

5.6 CONSTRAINTS AND POTENTIAL ACCELERATORS

In the table below we describe some of the constraints towards the transition of smarter product use and manufacturing and which accelerators could potentially reduce these barriers.

Triggers for circularity	Constraints	Accelerator	Circular strategy
SMARTER PRODUCT USE AND MANUFACTURE	The current renewable SAP cannot meet the technical requirements and is used in a mix with regular SAP.	There are some promising developments in the market which, could maybe be tested in pilot projects to stimulate market acceptance	R2
	Incontinence care products are often purchased by professional purchaser at health care facilities. Sustainability is often not included or low on the list of purchase criteria	Governments can play an important role in the purchase policy of care facilities as they are often subsidized by government. Perhaps there is room to stimulate care facilities to take sustainability into account when purchasing incontinence and diaper products.	
	The sector has focused on innovation which increases the percentage of synthetic materials used in diapers and AHP products instead of innovation on sustainable renewable and biodegradable materials	As a sector stimulate diaper and incontinence innovation on materials that are more sustainable and ideally from renewable resources and biodegradable. Emphasize the importance for a sector to move away from synthetic fossil based materials.	
	Creating fluff pulp from other sources such as tissue or paper is not yet done	Investigate if it feasible to produce recycled fluff pulp from other post-consumer sources	
	Retailers and producers are reluctant to use recycled materials in their products due to risks of chemical and hazardous traces in the recycled materials and the liability risk	Discuss with producers what could be done to take away the hesitance of producers to use recycled materials	
	Nordic Ecolabel cannot be ensured by the current legislation that there is no contamination from other sources in the recycled papers due to the lack of strict legislation and therefore does not allow recycled paper in AHP product	Investigate the possibility to set-up strict legislation for using recycled paper in AHP, to stimulate the use of recycled materials in AHP products In line with the EU regulation for recycled plastic for food contact, which is already in place.	

6 THE STANDARDS WHICH NEED TO BE MET

In this chapter we will look into the technical and health & safety requirements that new innovative sustainable raw materials in the AHP sector need to meet. The idea is that these requirements provide some guidelines for innovative sustainable material producers or recyclers who are exploring if they can meet the requirements to become a material supplier for the AHP sector thereby contributing to the R2 strategy by consuming fewer materials and natural resources.

6.1 TECHNICAL REQUIREMENTS

For the three main components (SAP, fluff pulp and non-wovens) we identified the technical requirements, as available in public literature. If available, the technical requirements of a sustainable alternative are also included. Unfortunately the sector would not provide their information at this stage of the project, as this was regarded as confidential company information. Hence, the technical information of the products was taken from technical information sheets published on the internet. It is not sure if these are representative for all of the products in the sector, but we expect that the variation between technical characteristics of the main stream products is limited. An advised next step would be to validate with the AHP sector if the technical requirements found on the internet for the three main component correspond with the technical requirements for their raw material. An additional disadvantage of taking the publically available technical requirements is that we did not have the in-house knowledge to interpret the criteria, assess them on relevance and whether they represent an industry average. We would highly recommend this as a next step.

6.1.1 SAP

The technical requirements of a generic SAP and a biodegradable SAP can be found in Table 5. There are some differences between the generic and biodegradable SAP, especially in absorption capacity and free absorbency. This seems to confirm the fact that renewable SAP cannot yet meet the technical requirements. This also supported by the fact that the industry usually uses a mix of a renewable SAP and generic SAP (generally 20% Biosap and 80% regular SAP) is in diapers and incontinence care products. However, the product data sheet used as a reference is quite old (2009) and new initiatives are entering the market, which claim that they will be able to meet the technical requirements (see paragraph5.4.2 for more detail). Also so-called ‘drop in’ SAP (i.e. acrylic acid produced from renewable resources) are expected to enter the market, which will have exactly the same technical proprieties as SAP from a fossil resource. These will have the same technical performance as fossil based SAP, and will therefore also not be biodegradable.

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Characteristics	Generic SAP [93]	Biobased SAP-lysorb Nowadays known as BIOSAP [94]
Appearance	White granules	Off white
Moisture content (wt%)	3.2	13.0 max
Free Absorbency		
Free Absorbency(g/g)	58.0	
Free absorbency 0.9 NaCL		24.0 min
Free absorbency Tap water		49.0
Free absorbency tap water		55
Retention Capacity (g/g) :	34.0	Not specified
Absorption Under Load (0.7psi)(ml/g)	22	6.4
Residual monomer(ppm)	350	Not applicable
Bulk density (g/ml)	0.64	0.52-0.70
pH	6.1	5.5 – 7.5
Particle size distribution (%):		
Retain on 20 mesh (850 µm)	0.5	1.0 max
Retain on 30 mesh (600 µm)		30.0 max
Retain on 60 mesh (200 µm)		40.0 min
Retain on 100 mesh (150 µm)		45.0 max
Through 100 mesh (150 µm)	2.5	10.0 max

Table 5: Technical characteristics of generic and renewable SAP

6.1.2 Fluff pulp

The technical characteristics of fluff pulp can be found in Table 6. Fluff pulp is always a renewable material, because it is made from wood. In Asia they are researching the potential for using recycled fluff pulp in hygienic products such as diapers. A recent Korean study has shown that recycled fluff pulp has a slightly lower performance on the technical characteristics than commercial fluff pulp.[95] The recycled fluff pulp is fluff pulp which is recovered from used paper diapers. It is still questioned by the sector whether recycled fluff pulp can meet the required health and safety requirements for traces of chemical residues (see paragraph 6.3 for more detail)

[93] Technical data sheet Super Absorbent Polymer, Danson Technology
[94] Will alternative absorbent polymers ever be super for use in hygiene, davenport international associates
[95] Properties of fluff pulp and Handsheet recycled from paper diapers, Kyong-Hwa Choi et all, 2015

Characteristics	Commercial fluff	Recycled fluff pulp
Length (mm)	2.448	2.409
Width (㎛)	33.3	32.9
Curl (%)	14.8	17
Coarseness (㎍/m)	296.1	339.4
Kink angle	50.6	54.7
Kink index	1.666	1.805
Fines content (%)	5.8	1,0
Water retention value before beating (g/g)	1.0	1.2
Water retention value after beating (g/g)	2.1	1.9
Ash content (525C) (%)	0.8	1.5

Table 6: Technical characteristics commercial and recycled fluff pulp

6.1.3 Non-wovens PE and PP resins

Most of the top and backsheets for diapers and incontinence care products are produced using the spunlaid process. The spunlaid production process is optimized in such a way that only fibres with the same technical properties can be used. For example, Braskem produces 'I'm green™ polyethylene and polypropylene' resins from a renewable resource with exactly the same technical properties as PE and PP.[96] The technical characteristics of both types of resins are exactly the same. This also means that the renewable alternatives are not bio-degradable.

There are also non-wovens produced with regenerated cellulose based fibres such as cotton, bamboo, hemp and non-wovens from Poly-Lactic Acid (PLA). These non-wovens generally have different technical characteristics and can have different technical performance such as bio-degradability. Due to the different technical properties they often cannot be used on the current spunlaid machinery of the non-woven producers. Technical requirements for a PP resin are shown in table 7 whereas table 8 shows the technical characteristics of a PP of renewable resource. Table 9 shows the technical characteristics of PLA fibres for non-wovens, and Table 10 and Table 11 show the technical characteristics of fossil based HDPE and a renewable HDPE, respectively.

[96] http://www.braskem.com/site.aspx/Im-greenTM-Polyethylene

Characteristics	PP resin
Density	0.90 Gm/cm^3
Melt-index	36 g/10 min
Tensile strength – yield (50mm/min)	35 MPa
Elongation – Break (50mm/min)	20%
Flexural modulus (1.3 mm/min)	1500 MPa
Notch Izod Impact Strength – 23 C°	20 J/m
Hardness (Rockwell)	95 R scale
Heat deflection temperature (0.46 N/m2)	100 C°

Table 7: Technical requirements PP resin for non-wovens

Characteristics	PP resin [97]
Melt flow (230C, 2.16 kg)	2 g/10'
Flexural modulus (0, 05 in/min, 1 % secant)	170,000 psi
Flexural modulus (0, 05 in/min, 1 % secant)	1,182 MPA
Notch Izod Impact Strength – 23 C	0.4 ft-lb/in
Notch Izod Impact Strength – 23 C	27 j/m
Tensile strength – yield (2in/min)	4700 psi
Tensile strength – yield (2in/min)	32 MPA

Table 8: Technical requirements Braskem PP fiber for non-wovens

Characteristics	Staple fibre[98] for non-wovens	Polymer for spunbond applications
Relative viscosity	2.5	3.3
MFR g/10 min (210 C,2.16 kg)	65	15
Crystalline Melt temp		1,182 MPA
Melt Density (230C)	1.08	1.08
Crystalline Melt Temp	165-180	145-160
Glass transition Temp	55-60	55-60
Specific Gravity	1.24	1.24

Table 9: Technical requirements PLA fibers/nonwovens

[97] Polypropylene product and properties North America, Braskem
[98] ngeo Resin, product guide, Nature works

Characteristics	HDPE[99] resin
Melt flow rate (190C, 2.16 kg)	20 g/10 min
Density	0.955 g/cm3
Flexural modulus (0, 05 in/min, 1 % secant)	1,350 MPa
Environmental stress cracking resistance (100% Igepal)	<4 h/F50
Vicat softening temperature	124 C
Shore D Hardness	64
Notch Izod Impact Strength	25 j/m
Tensile strength – at yield	29 MPa
Deflection temperature under load (0, 45 MPa)	74 C
Minimum bio-based content	94 %

Table 10 technical requirements Braskem HDPE fiber for non-wovens

Characteristics	PE resin nonwoven[100]
Density	0.919 g/cm3
Melt-index	6.0 9/10 min
Film thickness	23 (µg/m)
MD yield 23 (µg/m) cast film	7.00 MPa
TD yield 23 (µg/m) cast film	7.00 MPa
MD break 23 (µg/m) cast film	26.0 MPa
MD break 23 (µg/m) cast film	26.0 MPa
Tensile elongation	
MD break 23 (µg/m) cast film	520%
MD break 23 (µg/m) cast film	690%
Dart drop impact	120 g
Elmendorf tear strength	
MD 23 (µg/m) cast film	250 g
TD 23 (µg/m) cast film	490 g
Film stretch performance-max elongation	340%
Film stretch performance-increasing tear-max elongation	47%
Film stretch performance-load on pallet	1300 g
Vicat softening temperature	97 ˚C
Optical gloss 20, 23 (µg/m) cast film	148
Haze 23 (µg/m) cast film	0.70%
Extrusion-melt temperature	220 to 280 ˚C
Extrusion notes	
Chill roll temperature	20 to 60 ˚C
Melt temperature	220 to 280 ˚C
Haul-off speed	150 to 300 m/min
Recommended gauge range	10 to 60 µg/m

Table 11: Technical requirements PE resin for non-wovens

[99] AF cotalogo I'm Green Polyethylen, Braskem
[100] Technical information DOWLEX, Polyethylene resin

6.1.4 Usage of sustainable alternatives differs per component

Meeting the technical requirements is crucial for market acceptance of the sustainable materials. Since the technical requirements for the materials seem to be relatively easy to find, it seems that not knowing the technical requirements is not the restraining factor but meeting the technical requirements is the real challenge.
This also demonstrated by the uptake of sustainable materials in the sector, as for non-wovens, alternatives with exactly the same technical properties are already quite widely used in the sector, e.g. the PE and PP from Braskem. In contrast, renewable SAP, which has a lower absorbency power is used far less in the sector.

6.2 SAFETY AND REGULATORY REQUIREMENTS UPSTREAM

Upstream requirements apply to the raw material suppliers of absorbent hygiene products (AHP) manufacturers. In order to ensure the regulatory compliance of finished AHPs, there is a set of minimum information which manufacturers require from their raw material suppliers. Typically, this type of information is obtained with use of supply chain questionnaires. We will now provide examples of the sort of information that suppliers can be requested to provide to manufacturers.[101]

6.2.1 Information requirements for raw materials

To document regulatory compliance, the minimum information needed from raw materials suppliers and other parties in the supply chain are:

1. Material trade name (supplier code)
2. Supplier name
3. Material type
4. Material category under the REACh regulation
5. Intended End-Use
6. Technical specifications
7. Specific composition
8. Compliance with the Biocidal Products Regulation (BPR)
9. Compliance with the REACh regulation
10. Summary of data from existing toxicological reports on the material
11. (Optional) General status of the raw material (e.g. animal derived, organic, third-party certified, etc.)
12. (Optional) Presence of specific substances of interest (e.g. substances that are part of EU Ecolabel criteria for absorbent hygiene products)

More information can be found in EDANA's guidance document to the absorbent hygiene products industry.[102]

[101] Note that this information goes beyond regulatory requirements in some cases.
[102] EDANA 2016. Supply chain information for absorbent hygiene products, version II.

6.2.2 Information requirements for categories of AHPs

For categories of AHPs and their raw materials, or products with a certain end use (e.g. medical use), there are broad guidelines to be applied on a case by case basis.

6.2.2.1 All AHPs [103]

All AHPs should be aligned with the Guidelines for the Evaluation of Personal Sanitary Products, from the German Federal Institute for Risk Assessment (BfR, 1996). Companies may deviate from the BfR's recommendations if they justify compliance with the safety requirements by other means.

6.2.2.2 All medical devices

All medical devices, including adult incontinence products, must demonstrate compliance with the Medical Devices Regulation (MDR). Conformity is presumed when harmonised standards are applied. An important standard in this context is the ISO 10993 (Biological evaluation of medical devices) with the following subsets: ISO 10993-1 (Evaluation and testing within a risk management process), ISO 10993-10 (concerns tests for irritation and skin sensitisation), ISO 10993-17 (concern's leachable substances), ISO 10993-18 (chemical characterization of materials), ISO 10993-9 and 13 (degradation products), ISO 10993-5 (concerns tests for in-vitro toxicity). [104] [105] More information can be found in EDANA's guidance document[104]

6.3 SAFETY AND REGULATORY REQUIREMENTS FOR FINISHED PRODUCTS

The minimum requirements for manufactures of 'finished AHPs' (i.e. as they are placed on the market) comprise mainly EU requirements from EU legislation, and some additional elements that are adopted by most major companies and retailers in the EU:

- General Product Safety Directive (GPSD)
- REACh regulation
- Biocidal Products Regulation (BPR)
- Medical Devices Directive (MDD), see § 6.2.2

6.3.1 General Product Safety Directive

The GSPD provides a generic definition of a safe product: "Products must be safe under normal or reasonably foreseeable conditions of use by consumers." Safety of a product can be assessed in accordance with specific national rules governing the safety of a product, or European standards pursuant to the product, Community technical specifications, Codes of good practice, or State-of-the-art and consumer expectations.

[103] With justification, this can be omitted for adult incontinence products.
[104] BSI compliance navigator, accessed July 2017.
[105] Note that, as of May this year, we are in a transition period between the Medical Devices Directive (MDD) and two new regulations: the Medical Devices Regulation (MDR), which will become applicable in three years (2020), and the In Vitro Diagnostic Medical Devices Regulation (IVDR), which will become applicable in five years (2022).

6.3.2 REACh regulation

The REACh regulation concerns chemical substances and is complementary to other environmental and safety legislation but does not replace sector specific legislation such as the MDD. Manufacturers and importers are required to gather information on the properties of their chemical substances. This way, human risks from exposure to chemicals should be managed for all stages of the life cycle.

6.3.3 Biocidal Products Regulation

The purpose of the Biocidal Products Regulation is to improve the functioning of the biocides market in the EU while at the same time providing a high degree of protection for people and the environment. Materials treated with or intentionally incorporating active substances and/or biocidal products may be 'treated articles' under the BPR, leading to further obligations.

6.4 OEKO-TEX® CRITERIA

Chemical tests are optional according to EDANA guidelines for the testing of baby diapers. As an example of a suitable standard, the OEKO-TEX® Standard 100 is listed.[106] It is a voluntary and comprehensive, third-party testing and certification system for textile products for babies. [107] It focuses on harmful substances in all stages of production. It thereby contributes to high and effective product safety from a consumer's point of view. As such, it is not specifically applicable to AHPs, but nevertheless relevant.

The precondition for the certification of products in accordance with OEKO-TEX® Standard 100 is that all parts of an article meet the required criteria (e.g. the outer fabric, sewing threads, inserts, prints etc., as well as non-textile accessories, such as buttons, zip fasteners, rivets etc.).[107] Additional preconditions are the existence and application of operational quality assurance measures, as well as the legally binding signing of undertakings and conformity declarations by the applicant.

The OEKO-TEX® Standard 100 takes account of important legal regulations, harmful chemicals, environmentally relevant substance classes, REACh requirements Annexes XVII and XIV, ECHA substances of very high concern (SVHC) Candidate List, and requirements from the US Consumer Product Safety Improvement Act (CPSIA) regarding lead.

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[106] EDANA Guidelines for the Testing of Baby Diapers – Version 2. 0. April 2016 1 EDANA Guidelines for the Testing of Baby Diapers Version 2.0 – April 2016, available via: https://www.edana.org/docs/default-source/default-document-library/edana-diaper-test-protocol-2-0-final.pdf?sfvrsn=4

[107] https://www.oeko-tex.com/en/business/certifications_and_services/ots_100/ots_100_start.xhtml

6.5 END OF WASTE CRITERIA

According to the Waste Framework Directive 2008/98/EC, end-of-waste criteria specify when certain waste ceases to be waste and obtains a status of a product (or a secondary raw material).[108] In general, criteria to cease to be waste are:

- The substance or object is commonly used for specific purposes;
- There is an existing market or demand for the substance or object;
- The use is lawful (substance or object fulfils the technical requirements for the specific purposes and meets the existing legislation and standards applicable to products);
- The use will not lead to overall adverse environmental or human health impacts.

The criteria are meant to provide a high level of environmental protection and an environmental and economic benefit. They aim to further encourage recycling in the EU by creating legal certainty and a level playing field as well as removing unnecessary administrative burden. A methodology to develop the criteria was elaborated by the Joint Research Centre.[109] Since then, technical proposals for end-of-waste criteria have been laid down for, amongst others, biodegradable waste and waste plastic. [110,111] Below, the end of waste proposals for plastics are summarized:

- Product quality requirements
  - To check for content of contaminants: non-plastic components and non-targeted plastics
  - Detection of hazardousness and alignment with REACH/CLP/POPs
- Requirements on input materials
  - Limit the inputs or input sources that pose a specific environmental, health or quality concern if not treated adequately
- Requirements on treatment processes and techniques
  - To define minimum treatment conditions which are known to in all cases result in quality suitable for EoW
- Requirements on the provision of information (e.g. documentation of end use, traceability systems, labelling)
  - To minimize any onerous administrative load, recognizing when current practice is competent in providing a valuable material for recycling, respecting existing legislation, and protecting health and the environment
- Requirements on quality assurance procedures
  - To establish confidence in the end-of-waste status

However these technical proposal have not been officially recognized by the European Commission and the negotiations on these technical proposals have currently been put on hold. Currently every member state has developed their own EoW criteria on basis of the Waste Framework Directive 2008/98/EC. The EoW criteria from Flanders are defined in the raw material declaration Vlarema[112], which states that the recycled materials should meet the same technical and safety requirements as the virgin raw material.
For the recycling of diapers and incontinence products it is of crucial importance that the recycled materials can get a status of a product (or a secondary raw material) by complying with the end of waste criteria

[108] Waste Framework Directive 2008/98/EC
[109] http://susproc.jrc.ec.europa.eu/activities/waste/index.html
[110] http://ipts.jrc.ec.europa.eu/publications/pub.cfm?id=6869
[111] http://susproc.jrc.ec.europa.eu/activities/waste/documents/2014-JRC91637_ed2015.pdf
[112] https://www.ovam.be/vlaamse-wetgeving-0

6.6 POTENTIAL TO ALIGN WITH THE NORDIC SWAN ECOLABEL

From discussions with experts the question was raised whether any kind of alignment was possible between the criteria for circular AHPs and the Nordic Swan Ecolabel. The best match would be the eco-labelling for 'baby products with textile'.[113] This product group comprises baby products, where the surface in contact with the child is of textile and where the child has skin contact or other close contact with the textile on using the product.

Nordic Ecolabelling adopted the first version of the criteria for 'baby products with textile' in June 2017. The criteria focus on the chemistry used in the production of textiles, filling materials and other materials in the product. This is important for both the use stage, where the child is in close contact with the product and the possibility of recycling the materials in new products. This first generation of the criteria are valid until June 2021. For the second generation of the criteria, these areas are still considered to be the main focus. In addition, it would be relevant to look further into how product design can support the circular economy.

The product group 'baby products with textile' includes products of very different material composition. The criteria therefore include a variety of materials, whereas only a selection of these materials may be relevant for AHPs. Details on the criteria per material are given in the Nordic Ecolabeling report. Next to material requirements, requirements for test methods and laboratory analysis are included. For instance that the analysis laboratory used shall fulfil the general requirements of standard EN ISO 17025 (General requirements for the competence of testing and calibration laboratories) or have official 'Good Laboratory Practice (GLP) status. Furthermore, quality and function requirements for baby products with textile were defined, e.g. color fastness to rubbing, pilling, or dimension changes during washing.

Obviously, the quality and function requirements for textiles cannot be one to one translated to AHPs. However, because of the similarities in exposure circumstances between AHP and 'baby products with textile' (i.e. skin contact or close contact), there is a potential for alignment between circular AHPs and the Nordic Swan Ecolabel regarding the exposure and safety requirements for the use of materials in the product, and the testing of the final product. This potential should be further explored during discussions with experts, and the similarities in exposure circumstances should be used as the basis to avoid reinventing the wheel.

[113] Nordic Swan Ecolabelling of baby products with textile. Version 1.0. 14 June 2017 – 30 June 2021

6.7 CONSTRAINTS AND POTENTIAL ACCELERATORS

In the table below we describe some of the constraints we have identified towards the transition of smarter product use and manufacturing and which accelerators could potentially reduce these barriers.

Triggers for circularity	Constraints	Accelerator	Circular strategy
SMARTER PRODUCT USE AND MANUFACTURE	There is no clear overview of the health and technical requirements, which sustainable materials need to meet to be considered for AHP product.	Review the list of technical requirements and assess them on relevance and whether they represent an industry average. Adjust them where needed and make publically available	R2 & R8
	The biggest barrier for recyclers and producers of renewable raw materials for absorbent hygiene products seems not to be finding the technical requirements, but developing products which can meet the technical and health and safety requirements for an acceptable cost price.	There are quite some promising developments in the market which could be maybe tested in pilot project to stimulate market acceptance and show the business cases.	
	For recycled materials from AHP to be (re)used in products they need to regain the status of product instead of waste	Investigate if the recycled post-consumer components from AHP product can comply with the end of waste criteria.	
	There is no alignment between the circular AHP criteria and the Nordic Swan Ecolabel	Explore with experts from Nordic ecolabel and the AHP sector if alignment is possible between the ecolabel 'baby products with textile' and circular AHP criteria	

7 USEFUL APPLICATION OF MATERIALS (R7&R8)

In this chapter we will discuss the potential for post-consumer recycling of single-use diapers and incontinence care products. We will not discuss initiatives for composting or co-digestation of post-consumers diapers or incontinence care products for the following reasons:

- Recovery of biomass is the lowest circularity strategy, it makes more sense to focus the efforts on higher level strategies, such as recycling and avoidance
- Previous pilots composting or co-digestation plants have not succeeded because there is no market for the composted product, as the agricultural sector cannot use compost containing SAP fractions.
- In the Netherlands, due to the lack of demand from the market, composting or fermentation is no longer supported.

7.1 POTENTIAL TO REDUCE WASTE

Disposable diapers generate a large quantity of solid waste, but with recycling there is potential to significantly reduce this waste stream. The EU-project REcycling of Complex AHP waste through a first time appLication of patented treatment process and demonstration of sustainable business model (RECALL) has found that there is potential to reduce the waste stream with 74 % through the recycling of cellulose and plastics from post-consumer diapers (see Figure 10).[114]

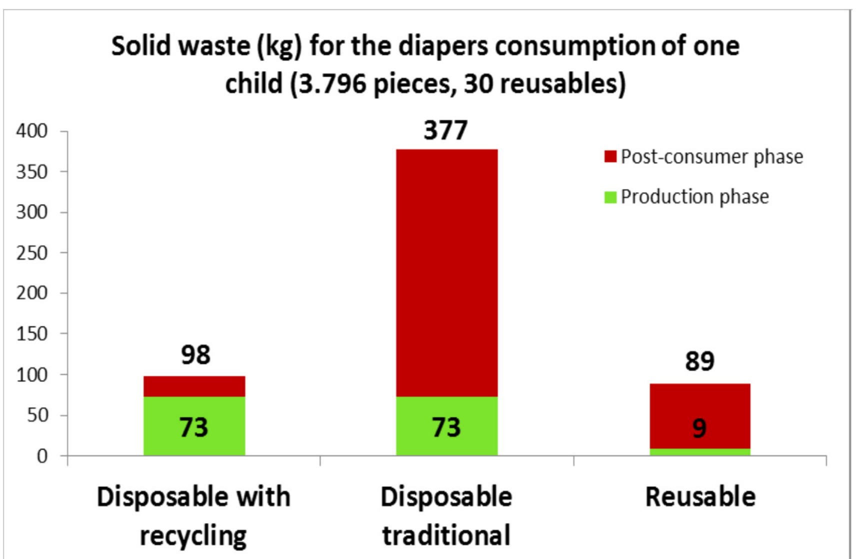

Figure 10: Amount of waste in disposable and reusable diapers

[114] Environmental benefits and costs of AHP selective collection and recycling solutions, O. Bolognani, webinar,26-05-2015, https://docs.google.com/viewer?a=v&pid=sites&srcid=ZmF0ZXIuaXR8cmVjYWxsLWVufGd4OjdlMzRiODlmZDZkNjYxODA

7.2 OVERVIEW OF POST-CONSUMER RECYCLING INITIATIVES

Recycling of post-consumer diaper and incontinence care waste recycling is an area with promising recycling initiatives entering the market (they are discussed below). It is likely that at least one of the initiatives will become successful, and that recycling of post-consumer AHP waste will become more mainstream. In Belgium incineration with energy recovery is now the standard for post-consumer diapers and incontinence material, which sets the bar high for the recycling initiatives from an environmental perspective.

In the following paragraph we discuss the most promising post-consumer recycling initiatives. Most of them are still developing and improving their outputs. We have interviewed representatives of the three initiatives. It was difficult to gain exact insight in the quality of the outputs and the costs of the recycling process. Many details of the recycling process are considered confidential and the companies could not share this information.

7.2.1 BTU Elsinga

7.2.1.1 The recycling process [115]

The process requires at least two reactors (A and B) and a flash tank (C) in operation. Reactor A is filled with digestate and/or diapers and incontinence care products. The reactor is heated to 240-250 C° and the pressure is set to 40 bar. This temperature is held for 10-40 Minutes to ensure amongst others sterilization. The temperature and pressure of reactor A is then lowered to 100 C° and 1 bar by releasing steam to reactor B. Reactor B is already filled with input material and is heated up using the steam. Excess steam can be released to the flash tank C. The organic materials of this process are split into smaller molecules using hydrolyse. The plastic fraction of the diapers and incontinence care products' melts during the process. This plastic is sieved out with a liquid separator, which creates a floating layer. The slurry is pumped through sealed pipe into the fermenter. The bacteria can easily convert the remaining organic matter during the fermentation process resulting in biogas.

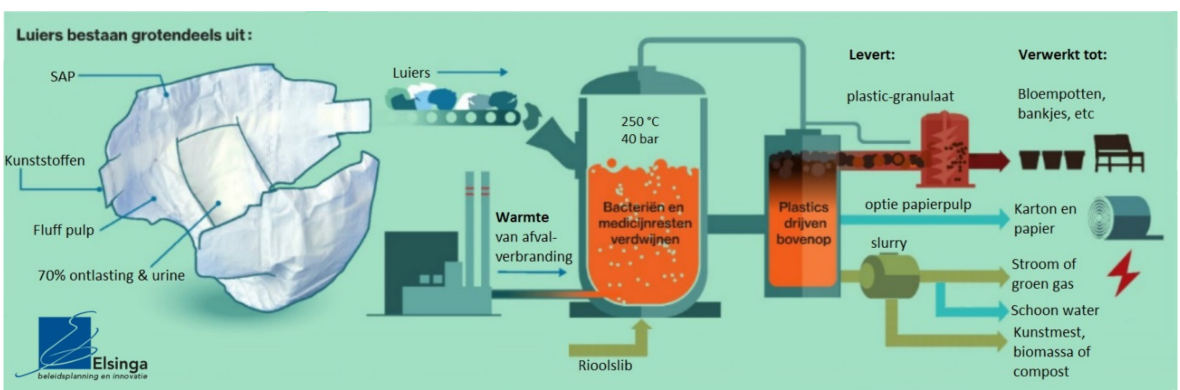

Figure 11: Recycling Process BTU Elsinga

[115] MER beoordelingsnotitie TDH ARN, Royal Haskoning DHV, 14 juli 2016

7.2.1.2 Outputs

Material input	Recycling output
SAP	The SAP is broken down to organic matter. The organic matter is converted to biogas, water and biomass
Non-wovens	Plastic fraction is extracted and can be used as feedstock for the production of benches or flower pots
Fluff-pulp	Optionally the cellulose fraction could be retrieved in the current recycling process, but this is not yet done

7.2.1.3 Current status

The recycling procedure has been proven to be successful in lab scale by the Brandenburgische Technische Universität (BTU) Cottbus in Germany. First pilot test has been conducted in a 300 litre reactor and gave promising results. Further upscaling is planned in the Netherlands.

7.2.1.4 Environmental benefits [116]

The environmental benefit is said to be 150 to 250 kg/ton avoided CO_{2eq} compared to incineration or co-digestion.

7.2.2 FATER and Procter & Gamble

7.2.2.1 The recycling process[117, 118]

The AHP wastes are sterilized in an autoclave and then sent to a sorting machine, which separates the cellulosic fraction (containing large part of the SAP) and the plastic fraction (mainly polyolefins). The autoclave is a horizontal cylindrical vessel which can treat 500 kg of AHP waste. The autoclave is heated up to about 125℃ at a pressure of 5 bar. The injection of steam for a time of 4 min provides the necessary sterilization of the AHP waste thereby killing all pathogens and eliminating the odor. The steam is continuously mixed with the AHP by rotation and alternative oscillation of the autoclave. Methane from the grid is used to produce the steam necessary for the sterilization process.

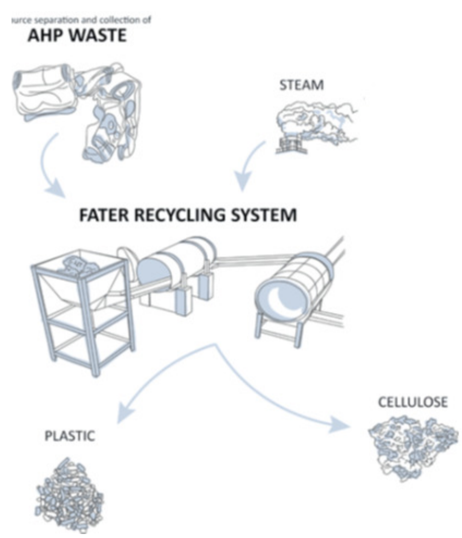

Figure 12: Schematic overview of the Fater recycling system

[116] Presentation robust and safe diaper recycling, R. Morssinkhof & W. Elsinga, Elsinga beleidsplanning en innovatie
[117] Sustainability of an intergrated recycling process of absorbent hygiene products, U. Arena et. Al., research gate, October 2015
[118] Fluizided bed gasification as part of innovative recycling process, F. di Gregorio et. All ,June 2015

7.2.2.2 The outputs

Per 1000 kg of used products, almost 500 kg of CO_2-equivalents can be saved compared to regular waste treatment of diapers (i.e. incineration with heat recovery).[119] From 100 kg of used products, 75 kg plastic and 225 kg organic-cellulose material can be obtained.

Material input	Recycling output
SAP	The SAP is broken down to a biological nutrient stream, which can be used as feedstock for the packaging/paper industry
Non-wovens	Plastic fraction is extracted and can be used as R-plastic products such as caps for bottles and benches
Fluff-pulp	The fluff pulp is broken down to a biological nutrient stream ,which can be used as feedstock for the packaging/paper industry

7.2.2.3 Current status [120]

There is pilot on industrial scale at Contarina spa in Lovadina di Spresiano in Italy. The industrial-sized machinery could serve a population of up to 1,000,000 people and up to 10,000 tons per year of AHP products. The objective of the pilot is to achieve an optimal level of efficiency that can confirm, even on a large scale, the predicted data and tests, if the pilot phase is successful there is the possibility of upscaling to 1,500 tons per year. Additionally there are plans for pilot in the Netherlands with recycler AEB.

7.2.2.4 Environmental benefits [121]

The Fater recycling process claims to have a negative CO_2 balance of -62 CO_{2eq} per ton recycled post-consumer diapers, while the incineration of 1 ton of post-consumer diapers is said to result in the emission 326 kg of CO_{2eq} (see Figure 13). [121] In figure 13 the CO_{2eq} emissions of each of the steps of the recycling and the incineration is displayed namely:

- the emissions related to the selective collection of the diapers e.g. the transport,
- the emissions related to the treatment and materials recovery e.g. how much energy is needed to incinerate or recycle the diapers
- how much GHG emissions are saved by the incineration or recycling e.g. what are the GHG emissions related to producing the virgin material or the energy.

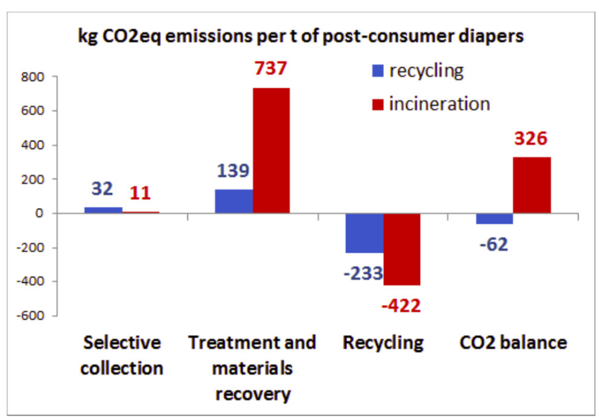

Figure 13: CO2 emissions of incineration and recycling

[119] Personal communication with Mr. Somma, Fater (27th of July 2017) - additional references attached to interview
[120] https://fatergroup.com/ww/news/press-releases/recycling-project
[121] Environmental benefits and costs of AHP selective collection and recycling solutions, O. Bolognani, webinar,26-05-2015, https://docs.google.com/viewer?a=v&pid=sites&srcid=ZmF0ZXIuaXR8cmVjYWxsLWVufGd4OjdlMzRiODlmZDZkNjYxODA

7.2.3 Unicharm

7.2.3.1 The recycling process [122]

The Unicharm recycling process consists of two-steps (see Figure 14):

1. In the first step, so-called open recycling, the AHP wastes are washed, sterilized dried and then sent to a sorting machine, which separates the cellulosic fraction (containing large part of the hydrogel used as super-absorbent) and the plastic fraction. The cellulosic fraction can be used as feedstock for the paper industry, while the plastic fraction is converted to Refuse Paper and Plastic Fuel (RPF). This step is already successfully implemented.
2. The second step, so-called closed loop recycling, is the treatment of the cellulosic fraction with ozone. In this process the remaining bacteria and pathogens are eliminated, and the SAP fraction is broken down into water and carbon dioxide by oxidization. The result would be high grade fluff pulp which could potentially be reused in diapers. This second step is still being further investigated.

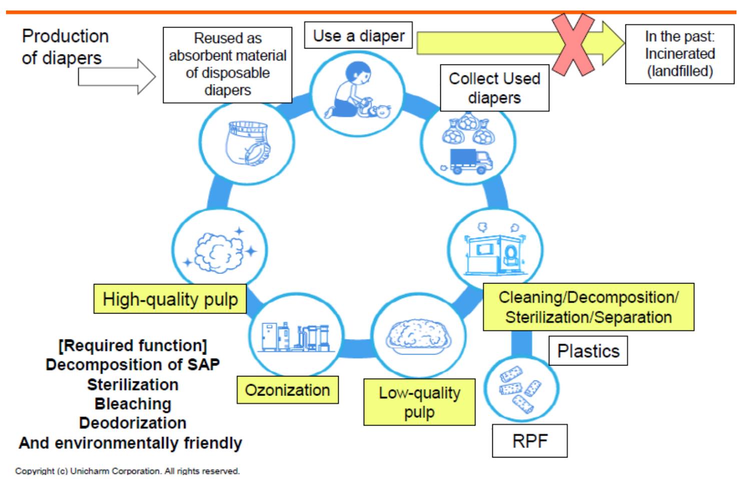

Figure 14: Unicharm recycling process

[122] Presenation: Explanation approach for recycling of used diapers for Edana meeting, M.Wada & A. Myoga, Unicharm, 15-12,2016

7.2.3.2 The outputs

Material inputs	Recycling outputs
SAP	The SAP is broken down into water and carbon dioxide by oxidization.
Non-wovens	Plastic fraction is extracted and can be used as RPF
Fluff-pulp	Is recycled to high-quality fluff pulp, which can be reused in diapers. It is said that the high-grade pulp is equally sanitary and safe as virgin pulp. Also the color can be made similar to virgin pulp.

7.2.3.3 Current Status [123]

Currently, Unicharm is carrying out a pilot of the recycling system in Shibushi City in Japan. In collaboration with local waste collection businesses and the local government a trial has started with the separate collection of used disposable diapers from homes and businesses, such as nursing homes.
The goal for Unicharm and Shibushi City is to develop a disposable diaper recycling system, which can be rolled out in Japan and internationally. After the pilot, which is expected to succeed, the aim is to set-up the separated collection and recycling of AHP products within Shibushi City by 2020.

7.2.3.4 Potential environmental benefits [124]

The recycling process, where the recycled fluff pulp is used in diapers (closed recycling) can reduce the GHG emissions by 26% compared to incineration. The water-use also reduces by 6 m^3 because of the water which is no longer required for the production of cotton. Closed recycling can also contribute as a countermeasure against resource depletion of pulps and reduction of land use (see figure 15).

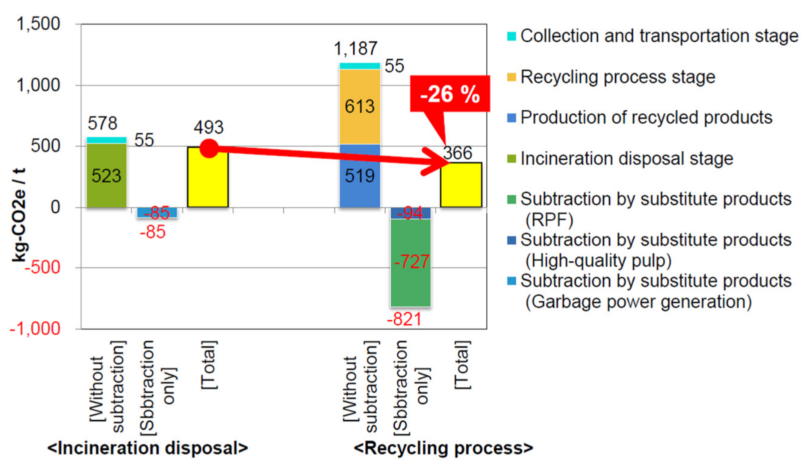

Figure 15: CO2 emissions of incineration and closed recycling

[123] http://www.unicharm.co.jp/english/csr/special03/index.html, visited 21-09-2017
[124] Environmental evaluation of pulp reuse by recycling of used disposable diapers, Norihiro ITSUBO et al. 2016

7.3 BARRIERS FOR POST-CONSUMER RECYCLING

7.3.1 Costs of recycling

The costs of recycling need to be competitive with incineration, otherwise recycling will be seen as too expensive and will not take off. This is a challenge, as incineration in Flanders is optimized and quite cost-effective. As most of the initiatives are still in the pilot phase, it cannot yet be said if this is the case, but Fater, Unicharm and ARN all say that the recycling will be beneficial from both a cost perspective as an environmental perspective. The costs for the Knowaste were said to be €125 per ton AHP. The Knowaste facility in Onterio Canada had to shut down as it could not compete with other disposal alternatives such as incineration with a price of around € 85 per metric ton.[125] So the cost of the previous described recycling initiatives will need to be lower than €125 to be able to compete with other disposal alternatives. This seems to be the case for Fater were the cost are said to be around € 90,- per ton AHP waste (see figure 16).[126] They also investigated the cost of different waste collection scenario's namely Waste Collection Center (WCC), street collection, specific door to door collection, combined door to door collection.

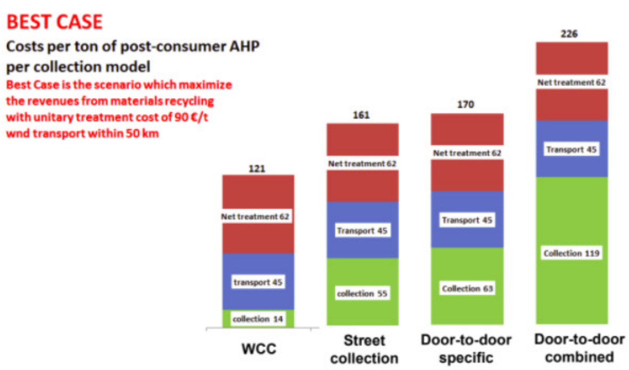

Figure 16: Costs of recycling

7.3.2 Market for the products

The lack of market for the recyclables has also contributed to lack of success of previous initiatives of post-consumer recycling of AHP. The recyclables could be rated as low-grade:

- mix of plastics (PE and PP)
- mix of SAP and Fluff-pulp

There are however currently two positive trends. First, two of the initiatives are led by multi-national producers e.g. P&G and Unicharm. They can assure a market for the recyclables in their own products e.g. bottle tops, which gives them a very sound CSR story.

Additionally, Unicharm has succeeded in separating the fluff pulp and the SAP, resulting in high grade fluff-pulp. Even if they not succeed to reuse it in their own AHP products due to Health and Safety issues, they still have a high-grade recyclable which will likely market for a higher price.

[125] Verslag samen sluiten van de luierketen, 7-09-2016
[126] Environmental benefits and costs of AHP selective collection and recycling solutions, O. Bolognani, webinar,26-05-2015, https://docs.google.com/viewer?a=v&pid=sites&srcid=ZmF0ZXIuaXR8cmVjYWxsLWVufGd4OjdlMzRiODlmZDZkNjYxODA

7.3.3 Willingness to facilitate from governments and municipalities

The recycling of AHP products requires separate waste collection. This will need to be set-up by the government and or municipalities. The separate waste collection will bring additional costs and potentially issues with odour. This means setting up the separate waste collection will require preparedness from the governments. Additional costs for the separate waste collection will need to be paid by either the municipalities or the recyclers.

7.3.4 Pathogen and medicine residues

A significant barrier is the potential contamination of the recyclables with pathogen and medicines from the urine and faeces. The RIVM has conducted an initial assessment about the composition of the waste stream and the possible risks when secondary materials enter the environment.[127] The main outcomes of this study are that SAPs are not easy degradable by fermentation or composting or when they enter the environment. Although SAP is not directly toxic, little is known about its impact in the soil. Fluff pulp is broken down well by fermentation and composting. Some of the auxiliary materials are known to be toxic in surface water. Due to the expected strong binding of the auxiliary materials to organic matter and clay particles, toxic effects on the soil-groundwater ecosystem are not expected immediately.

The faeces and urine in the diapers contain many different pathogens (bacteria, viruses and parasites). Most of the pathogens are broken down when the AHP materials are treated with a high temperature (for example 70 degrees) or sterilization. Specific pathogens such as the spore-forming bacteria Clostridium and Bacillus and heat-resistant viruses can survive high temperatures for a long time. The risk of surviving pathogens in the recyclables depends on the application or product and the recycling process. Without knowledge of the method of recycling of the AHP or the application of the recyclables it is impossible to make a risk-assessment.

The medicine residues which can be found in AHP differ between children's diapers and adult incontinence materials. Antibiotics are especially relevant for children's diapers. For adults, the expected medicine residues are more diverse. Medication prescribed in institutions, such as hospitals and care homes, is not included in the study. Sporadically used medication with assumed high toxicity, such as isotopes and cytostatics, are therefore excluded from the study. In general, the risk to the environment from medicine residues cannot be ruled out. The toxicity data found on medicine residues concern the aquatic ecosystem. However, generally, the aquatic toxicity data can give an indication of the expected toxicity to the soil ecosystem. For medicines, very limited data has been found on the degradability. To what extent the medicine residues are broken down during recycling processes such as composting or fermentation is unknown.

In order to better estimate the actual risks of medicine residues in recyclables from post-consumer AHP, the study recommends to find additional information on the environmental aspects (such as toxicity, degradation, risk of leaching) of medicines and to conduct an analysis of each of the recycling processes to assess the potential risk of medicine residues.

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[127] Verkenning en samenstelling luiers en incontinentiemateriaal, J.Spijker et. al, RIVM, 2016

7.4 CONSTRAINTS AND POTENTIAL ACCELERATORS

In the table below we describe some of the constraints we have identified towards the useful application of materials and which accelerators could potentially reduce these barriers.

Triggers for circularity	Constraints	Accelerator	Circular strategy
USEFEL APPLICATION OF MATERIALS	Many players have doubts if the current recycling strategies are economically viable due to failures of past initiatives such as Knowaste	Show the business case of the upcoming recycling techniques. Show that the recycled products have a market value and are of the promised quality	R8-R9 useful application of materials
	The promising initiatives seem to be started from a CSR perspective and were subsidized by governments or the EU e.g. recall program. However for recycling to become mainstream it also needs to make sense from an economic perspective		
	SAP is said to be the most valuable raw material. However currently is not recycled or to low value outputs	Investigate the opportunities high-grade SAP recycling and the potential markets for recycled SAP	
	The end of waste criteria (see paragraph 6.5) and risk of pathogens and medicine residues are barriers for the post-consumer recycling of diapers and incontinence material	Explore how a legal framework can be created that assures the safety of the post-consumer recyclables while at the same time allows the recyclable to access the market.	

8 CONSTRAINTS AND ACELERATORS

The ultimate goal of this study was to identify opportunities to reduce the environmental pressure through the entire supply chain of diapers and incontinence care products by the implementation of circular design, service models and material use[10.] The ambition is that OVAM and the sector can take these opportunities to start the transition toward a more circular AHP sector However, the following identified barriers are constraining the sector in making this transition.

8.1 MAIN CONSTRAINTS

8.1.1 Mismatch between ambitions and transition

The incontinence care productsand diaper sector is strongly focused on reducing cost, increasing production efficiency and meeting the customer product needs.[128] In contrast, rethinking the functionality of the AHP product or design for recycability have a much lower priority in the sector. During this study we have not come across any AHP producers who take this into account. This leads to the so-called directionality failure, which is a situation where the desired course of circular transition does not correspond with the ambitions of the sector.[129]

8.1.2 Insufficient collaboration

Another issue is that there is not sufficient trust, cooperation and knowledge sharing within the supply chains of single-use diapers and incontinence care productsmaterials and between producers. For example, design for recycling needs to be a joined effort of the entire sector as separate waste collection/recycling for only one producer is not realistic as the waste stream cannot be separated per brand. For the transition towards a circular economy, it is crucial that different supply chain partners find each other and work out joint solutions. This is important for circular transitions, since the reuse of products and their components and the recycling of materials require more cooperation between economic actors than in linear economies. It is important to address how an environment can be set-up which facilitates knowledge sharing and collaboration outside the competative environment.

8.1.3 Focus on least effective circular strategies

The final barrier is the prominent role of recycling and composting within the industry as the answer to a more circular approach. Especially the large diaper producers focus on this solution. For instance, Kimberly and Clark has a partnership with EnvironComp for composting used diaper, Unicharm is setting up a post-consumer recycling plant in Japan, and P&G is setting up pilot recycling facilities in the Netherlands and Italy.
However, recycling and composting of the post-consumer waste streams generally does not lead to any fundamental changes in the product or sector which are needed for a true transition towards a circular economy. For more ambitious circular economy strategy within the sector, it would be recommended to focus on strategies with a higher level of circularity such as strategies to reduce the amount of virgin materials needed or eco-design

[128] Personal communication (interview with Pierre Conrath from Edana
[129] Weber and Rohacher 2012. *Legitimizing research, technology and innovation policies for transformative change: Combining insights from innovation systems and multi-level perspective in a comprehensive 'failures' framework.* Research Policy 41(6): 1037-1047

to increase the recyclability at the end-of life. After all, recycling, and low-grade recycling in particular, is still mainly a linear solution.

It is important to tackle these constraints to enable the circular transition within the AHP sector. This can be done by raising awareness on the different circularity opportunities for the AHP sector and their expected effectiveness and to encourage companies within the sector to start demonstration projects to implement these strategies and show their effectiveness. OVAM has started actively approaching different producers within the sector, to stimulate the start-up of such demonstration projects.

However the most important barrier to take away is the lack of collaboration between the supply chain and industry partners. For the transition towards a circular economy, it is crucial that different supply and industry partners start sharing information on how the circular transition can be stimulated and formulate where needed shared positions and actions. Edana has indicated that they have set this as an action point for the AHP industry in the next Waste Working group.

8.2 NEXT STEPS

In the study a number of accelerators have been identified which can function as next steps to accelerate the transition towards a circular AHP sector. OVAM has reviewed these accelerators and conducted a prioritization on basis of their perceived effectiveness and implementability. The following accelerators have been selected by OVAM:

Refuse: stimulate an earlier age of toilet-training

1. Kind & Gezin could possibly play a more active role in stimulating toilet training at an earlier age. In their folder ABC van baby to Kleuter toilet training is now advised between the ages 2 to 5, possibly they could stimulate toilet training at the age of two. Het ABC van baby tot kleuter, 2014, Kind & Gezin
2. Make parents more aware of the role they have in toilet training their children and stress that this is not something they can hand-over to child care facilities and nursery schools.
3. Discuss with AHP producers if they can play a more active role in communication about toilet training and the age at which children can start

Rethink: gain a broader acceptance of the potential environmental benefits for new business models such as reusable diapers and service models

4. Review, complement and built-upon the study from MilieuCentraal which shows that reusable diapers are better environment, make the study ISO compliant and publically available. Consider to extend the scope of the study with various reusables and to also include a service model.
5. Conduct a comparative study of reusable and disposable diapers with a more holistic approach taking into account all the environmental and societal costs and benefits associated with the diapers over its lifetime. This way the costs of the waste of disposable diapers on society can be taken into account as well as the social benefits of diapers and incontinence care products can be taken into account in such an assessment.

Reduce: stimulate the use of more sustainable (renewable, recyclable and biodegradable) raw materials in diapers and incontinence care products.

6. Review the list of technical requirements for raw materials in AHP products in the report and assess them on relevance and whether they represent an industry average. Adjust them where needed and make publically available. As such producers of sustainable raw materials can gain insight if they can meet the technical requirements for the AHP sector.

Standards & legal framework: assure that the right legal framework and standards established to stimulate the transition towards more circularity in the AHP sector.

7. Explore with experts from Nordic ecolabel and the AHP sector if alignment is possible between the ecolabel 'baby products with textile' and circular AHP criteria
8. Explore how a legal framework can be created that assures safety of the post-consumer recyclables while at the same time allows the recycled materials to access the market. Such as: investigate the possibility to set-up strict legislation for using recycled paper in AHP, to stimulate the use of recycled materials in AHP products in line with the EU regulation for recycled plastic for food contact, which is already in place.
9. Explore the opportunities for a more prominent place for sustainability in the public procurement policies of care facilities. Governments can play an important role in the purchase policy of care facilities as they are often subsidised by government. Perhaps there is room to stimulate care facilities to take sustainability into account when purchasing incontinence and diaper products.

Rethink: stimulate modular design an design for recyclability in the AHP sector

10. Investigate opportunities with frontrunner producers to further reduce the number of components in AHP products. For example, can the non-wovens be produced with one type of plastic resin?

Recycle: create an environment which allows post-consumer recycling of AHP products to become mainstream.

11. Show the business case of the upcoming recycling techniques. Show that the recycled products have a market value and are of the promised quality
12. Investigate the opportunities high-grade post-consumer SAP recycling and the potential markets for recycled SAP. SAP is considered one of the most valuable raw materials in the diapers, but currently high-grade end-of-life recycling of SAP is not yet feasible.
13. Discuss with brands if there are opportunities for collecting their product similar to e.g. Nespresso which retrieves its capsules after use

8.3 SELECTION OF THE ROUNDTABLE MEMBERS

The roundtable members were asked to select the most relevant accelerators from the short-list made by OVAM. The following six accelerators were identified as the most valuable next steps for the transition towards a circular economy by the round-table members. They are grouped into the different circular strategies:

- Rethink: gain a broader acceptance of the potential environmental benefits for new business models such as reusable diapers and service models
    3. Review, complement and built-upon the study from MilieuCentraal which shows that reusable diapers are better environment, make the study ISO compliant and publically available. Consider to extend the scope of the study with various reusables and to also include a service model.
    4. Conduct a comparative study of reusable and disposable diapers with a more holistic approach taking into account all the environmental and societal costs and benefits associated with the diapers over its lifetime. This way the costs of the waste of disposable diapers on society can be taken into account as well as the social benefits of diapers and incontinence care products can be taken into account in such an assessment.
- Standards & legal framework: assure that the right legal framework and standards are in place to stimulate the transition towards more circularity in the AHP sector.
    7. Explore how a legal framework can be created that assures safety of the post-consumer recyclables while at the same time allows the recycled materials to access the market. Such as: investigate the possibility to set-up strict legislation for using recycled paper in AHP, to stimulate the use of recycled materials in AHP products in line with the EU regulation for recycled plastic for food contact, which is already in place.
    8. Explore the opportunities for a more prominent place for sustainability in the public procurement policies of care facilities. Governments can play an important role in the purchase policy of care facilities as they are often subsidized by government. Perhaps there is room to stimulate care facilities to take sustainability into account when purchasing incontinence and diaper products.
- Recycle: create an environment which allows post-consumer recycling of AHP products to become mainstream
    9. Show the business case of the upcoming recycling techniques. Show that the recycled products have a market value and are of the promised quality.
    10. Investigate the opportunities high-grade post-consumer SAP recycling and the potential markets for recycled SAP. SAP is considered one of the most valuable raw materials in the diapers, but currently high-grade end-of-life recycling of SAP is not yet feasible.

We would advise to discuss these six accelerators with the AHP-sector to validate their expected effectiveness. After which together with the roundtable members can be decided which of the accelerators could be taken up as a next step.

9 ANNEXES

9.1 ANNEX 1: LIST OF FIGURES

9.2 ANNEX 2 : LIST OF TABLES