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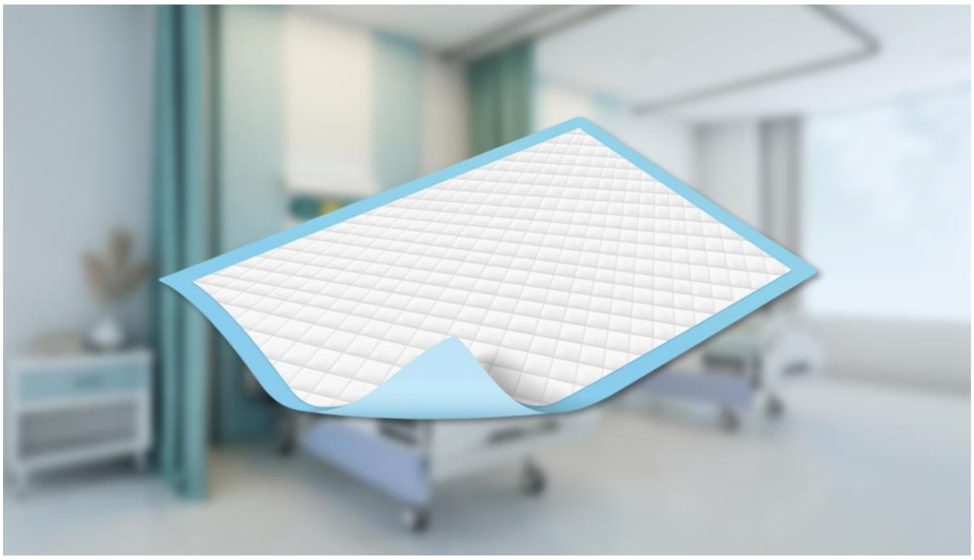
Comparative Life Cycle Assessment of absorbent underpads



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Master's project

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Abstract

Introduction

The frequent use of disposable medical products in hospitals results in emissions to air, water and soil(1). All this, while environmental problems like climate change, are the biggest health threats of the 21st century(2).

Absorbent underpads are commonly used medical devices in hospitals. The underpads are rectangular/square shaped mats which are not only used for patients with incontinence, but also for other applications e.g. hair washing, absorbing blood/wound/amniotic fluids, muffling noise from instruments on a trolley and cleaning up blood from the ground. The environmental impact of the disposable underpad from TENA and the reusable underpad from ABENA are compared in this study.

Methods

To conduct this Life Cycle Assessment (LCA) the ISO guidelines (ISO 14040/14044) are used as a framework together with the guidelines from the general Product Environmental Footprint (PEF) method. The scope of this study is 'cradle to grave'.

The functional unit is defined as: "Absorbing body fluids 1000 times with a 60x60cm underpad to keep the surface underneath and the patient's skin dry in hospitals in the Netherlands." To fulfil the functional unit; 1000 disposable underpads are compared with 10 reusable underpads, with each 100 washing cycles. Several companies and organisations have been contacted to receive as much detailed/specific information as possible. The Ecoinvent database was used with the (adapted) EF 3.1 LCIA calculation method in the program Simapro. This study focusses on the impact on acidification, climate change, particulate matter, land use, fossil resource use and water use.

Results

Both variants of underpads contain three different layers. The absorbent core of the disposable contains fluff pulp and a super absorbent polymer (SAP). Rayon is the absorbent material used in the reusable underpads. In case of the disposable underpad, the materials needed for producing contribute the most to the impact of the life cycle. In case of the reusable, the washing and drying process has the highest contribution. This is mainly caused by the use of soap, electricity and gas.

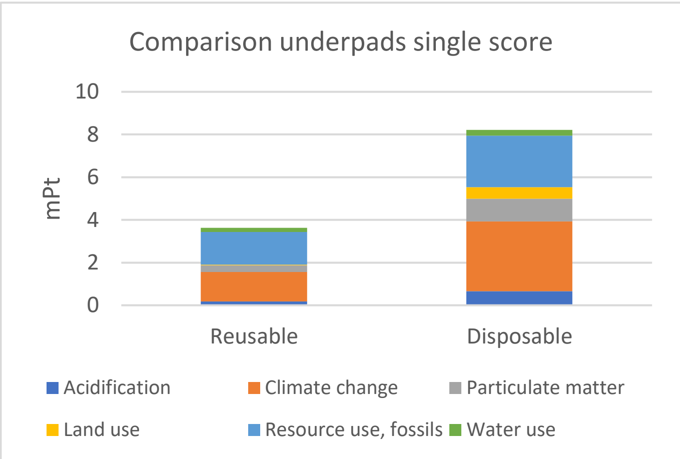


Figure 1: Comparison of environmental impact on six impact categories.

Conclusion

Refusing the use of absorbent underpads is the best strategy to decrease the environmental impact. 1000x use of a underpad leads to an impact of 117 kg CO2 equivalents and 1000x use of a reusable has an impact of 49,4 kg CO2 equivalents. In addition, the single score, showed in Figure 1, contains all six environmental impact categories which are taken into account. It can be concluded that using a reusable variant has a more than two times lower environmental impact compared to the use of a disposable variant of the same size.

Discussion

It proved to be difficult to receive all the inventory data from companies for this study. Therefore, some assumption needed to be made, which are based on literature and checked by experts. Only one comparable study was found, of which the results correspond. A redesign to reduce the absorption capacity of the underpads can decrease the environmental impact of both variants of underpads.

1 Introduction

1.1 Environmental impact of healthcare

7% of the total amount of CO_2 emissions in the Netherlands comes from the health care sector. In addition, the sector is responsible for 4% of total generation of waste, 13% of total amount of material extraction and 7% of the total amount of land use in the Netherlands(1). As an illustration, in Figure 2 and 3 the waste of an open-hart surgery is showed.

Figure 2: Picture of a ICU waste audit in the Radboudumc (Catagorise study, T.Stobernack & H.Touw)

All this, while climate change is the biggest health threat of the 21st century(2). Indirect health effects of climate change are water and food insecurity and extreme climatic events. An example of a direct effect is the increase in the number of deaths as a result of heat waves(3). These changing environmental conditions increase vector-, water-, air- and food-borne diseases. People younger than 1 year or older than 65 years and people with social disadvantages are most affected by heatwaves(4,5). In addition, due to the heat, agricultural workers must work less hours, with economic consequences. Heatwaves and changed rainfall patterns can cause extreme drought, which increases the food and water insecurity. This affects the most underserved population. Furthermore, these effects of climate change lead to migration, which can result in vulnerable housing, causing negative health effects(5). However, climate change is not the only threat to the ecosystem of the earth. Threats like biodiversity loss, freshwater depletion and ocean acidification have also serious effects to global human health(1). Besides infectious diseases and heat stress, the threats can lead to an increase of mental illness, allergies, lung disorders, heart and vascular diseases, neurological diseases and the spread of zoonoses and tropical diseases to other parts of the world(6).

Figure 3: Picture of a OR waste audit in the Radboudumc (Catagorise study, T.Stobernack & H.Touw)

At this moment, the global decarbonisation commitments are not enough to meet the ambitions of the Paris Agreement. This will lead to a global temperature rise of about 2-4° C by the end of the century. Wealthy countries (with a very high Human Development Index (HDI)) are the main contributors to CO_2 emissions(5). For this reason, more than 200 health journals worldwide have called on governments to take emergency action to tackle the catastrophic health effects caused by climate change. The necessary actions are mainly aimed at rising temperatures and loss of biodiversity(6). This urgency is underlined by the IPPC report of 2022(7).

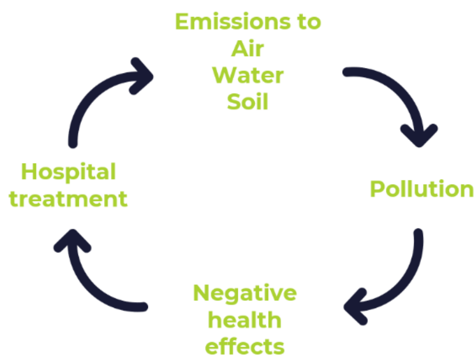


Figure 4: Visualization of a health care paradox

Hippocrates, the father of medicine, said: 'First, do no harm'. However, the large environmental impact of the current healthcare sector creates a health paradox. Hospital treatments lead to emissions to air, water and soil which causes pollution. This results in negative health effects on humans, causing more hospital treatments(3,8).

To avoid this paradox and to decrease the share of environmental impact causing climate change, the green deal 3.0 for the health care sector has been launched(8). One of the goals is to decrease the CO_2 emissions, with a reduction of 30% in 2026 compared to 1990. Besides this, the aim is to be climate neutral in 2050 for properties and transport. Another goal is to reduce the primary resource use, with a goal to have 25% less residual waste in 2026 and maximal circular health in 2050(8). To achieve this goal, the R-ladder can be followed. This ladder contains several words starting with an 'R' in order to decrease the environmental impact. The best option is to refuse using a medical device when it is not necessary. The other 9 Rs are rethink, reduce, reuse, repair, refurbish, remanufacture, repurpose, recycle and recover. Refuse has the highest impact reduction, and recover has the lowest impact(9). Therefore, healthcare providers are advised to choose reusable products instead of disposable variants where possible. In this way the sector can contribute to the limitation of the increasing demand for care(8). Redesigning a medical device can also be helpful to decrease the environmental impact.

1.2 Absorbent underpads

1.2.1 Use

Absorbent underpads are frequently used medical products inside the hospitals. This product is a rectangular/square shaped mat and is mostly used to protect the hospital bed from human fluids. In literature these kind of incontinence products are also called bed liners or bed pads.

The ErasmusMC in Rotterdam discovered that the ICU uses an average of 8 disposable bedliners for one patient per day(10). The absorbent underpads are used in other departments inside the hospital as well, for instance the delivery department and the gastrointestinal liver department. In the UMCG this resulted in the use of 325 000 bedliners a year(11).

The underpads are not only used for patients with incontinence, but also for a wide range of other applications. The hair of patients on the ICU is washed three times a week, with the use of disposable underpads. In addition, they are used to absorb wound fluid or to protect the arm- and leg rest during small operations, e.g. at the dermatology department. At the gynaecology department underpads are mainly used to catch fluids and gel used during echoes, and at the delivery department to absorb blood and amniotic fluid. The reusable variant is used to absorb urine and defecation, sometimes in combination with incontinence material (diaper), po or catheter(12). The use of (disposable) underpads in combination with a diaper is not preferred, since this increases the chance on decubitus. Decubitus is damage to the skin and underlaying tissue originated by pressure and shear forces. This is a common problem for bedridden, incontinent patients(13). Poor dissipation of heat and moisture causes incontinence-associated dermatitis (IAD)(14). One study suggest that disposable mats decrease the chance on hospital-acquired pressure injuries (HAPI's) compared to reusable mats(14). However, in new designs of reusable underpads efforts are being made to prevent this problem(15).

Absorbent pads are also used outside the hospital, at home or in nursing homes. However, this study will focus on hospital use.

1.2.2 Environmental impact

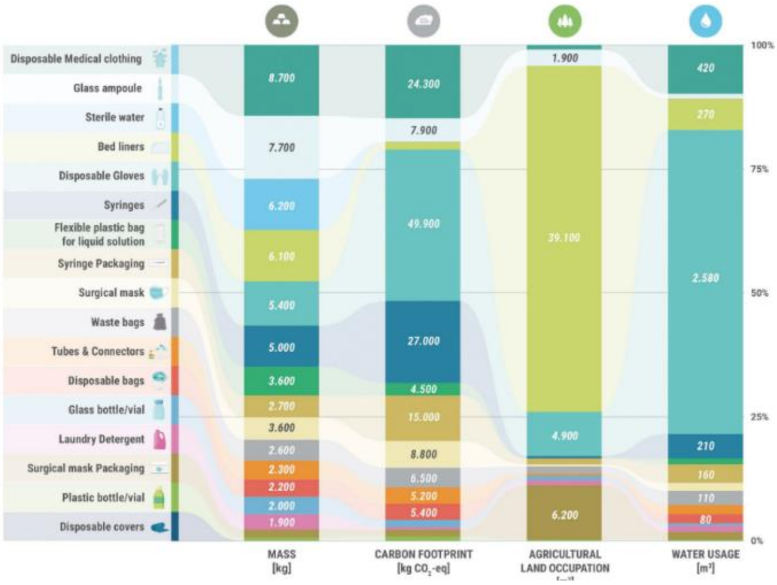


Figure 5: Impact of medical products (10)

Based on a material flow analysis (MFA) on the ICU of the ErasmusMC, an environmental footprint analysis and environmental hotspot identification were performed. The results, showed in Figure 5, were expressed in several environmental impacts; carbon footprint, agricultural land occupation and water usage. The highest impact on agricultural land occupation of the materials was caused by the use of disposable bedliners. In addition, based on the impact and the frequency of use on the ICU, bedliners were identified as one of the five hotspots on the ICU. The impact on agricultural land occupation of disposable bedliners is extraordinary in comparison to the other disposables(10). The researchers of the ErasmusMC advise to change towards a circular economy, beginning with the hotspots(10).

Moreover, an analysis of the UMC Utrecht showed that the impact of the use of disposables is estimated on 11 kton CO_2-equivalents(16). This is 7% of the total impact of this hospital. A lot of disposables are made from PUR, silicon, PC, medical PVC and non-woven materials. For the production of these (primarily plastic) disposables a lot of fossil resources are used, resulting in a high impact on climate change and fossil resource depletion(16).

1.2.3 Two variants

Nowadays, two types of underpads are used in hospitals in the Netherlands; a disposable and reusable variant. The reusable variant is washed by a cleaning company. To compare the differences between the product systems, the Life Cycle Assessment (LCA) method was used. An LCA is based on bottom-up data and is able to cover multiple impact categories(1). The whole life cycle of these products are covered.

The following products are taken into account in this study. The first one is a disposable underpad, the second one is a reusable variant.

1. Tena Bed Plus 60 x 60 cm.
2. Underpad, ABENA Abri-Soft Washable, 85 x75 cm, light blue.

Studying the environmental hotspots of the currently used absorbent underpads can help to provide guidelines for the design of an underpad with a lower environmental impact in the future. This redesign will be described at the end of this LCA-report.

2 Methods

To conduct this Life Cycle Assessment (LCA) the ISO guidelines (ISO 14040/14044) are used as a framework. This method includes four components: Goal and Scope definition, Life Cycle Inventory (LCI), Life Cycle Impact Assessment and the Interpretation of the results(17). All four components are described in this report. However, due to the time limit of this study, not all steps of the ISO guidelines are implemented. Furthermore, guidelines from the general Product Environmental Footprint (PEF) method will be used. PEF is an LCA based method and is able to quantify the environmental impacts of goods or services. The results will be expressed in a maximum of 16 environmental impact categories. To be able to make a better comparison between LCA's, the Product Environmental Footprint Category Rules (PEFCR) have been established. Unfortunately, at the moment of the research there is no fitting category for absorbent underpads(18). Based on the materials, the PEFCR for apparel and footwear comes closest and is used to select the calculation method, system boundaries and the most relevant impact categories(19).

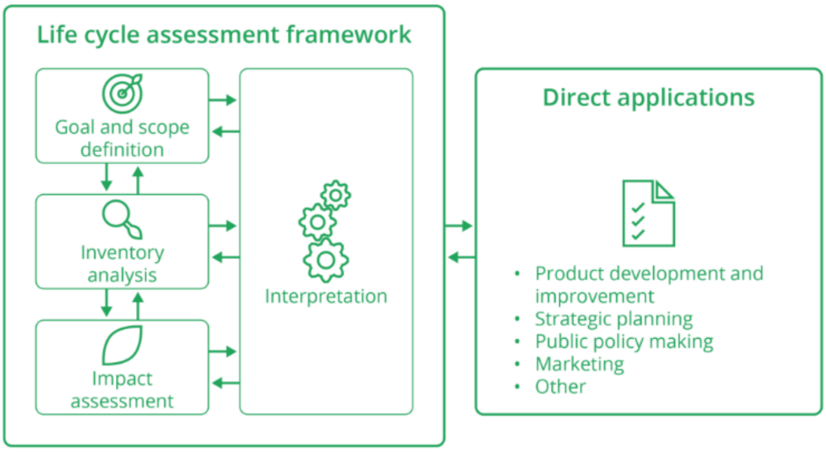


Figure 6: LCA framework based on the ISO 14040/14044 guidelines(17)

In the Figure 7 the different ways to express the environmental impact are showed; Characterization, Normalisation and Weighting. With characterization, all the impact categories are described. With normalisation all these impacts are scaled to the average impact of a person in Europe. Weighting scales impact according to the significance of impact. In addition, these values can be expressed in micro Points (mPts) resulting in one single score.

The calculation method used in this study is the (adapted) EF 3.1 LCIA calculation method.

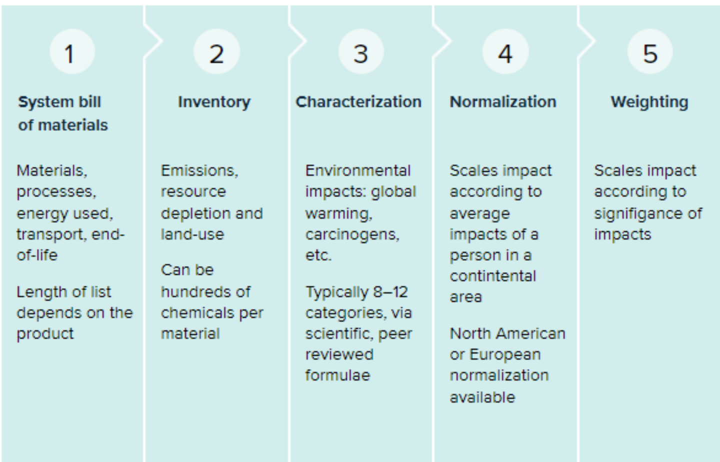


Figure 7: Steps in LCA data progression(20)

2.1 Goal and scope definition

The goal of this LCA is to analyse the environmental hotspots of the disposable and reusable underpad and to make a comparison on different environmental impact categories. The results of the comparison can provide information for health care organisations to make a more sustainable choice while purchasing underpads. The analysis of the environmental hotspots can help to provide focus points to design an new absorbent underpad.

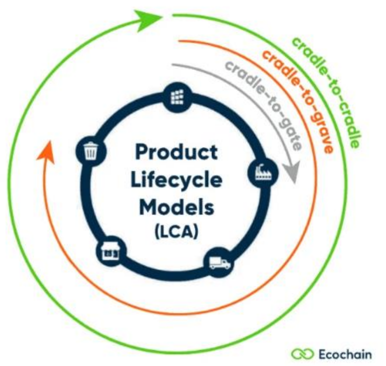


Figure 8: Visualisation of the different scopes of an LCA(38)

The scope of the study is a cradle to grave assessment of two variants of absorbent underpads used in a hospital in the Netherlands. Meaning that the whole life cycle of the disposable and reusable underpad is considered. This includes the raw material extraction, manufacturing, distribution, use and the disposal/recycling. In case of the reusable underpad, cleaning is also part of the use-phase. Furthermore, the life cycle of the packaging is taken into account. The inputs include materials, water and energy (electricity and gas), the outputs include the total amount of generated waste (materials and water). Since this study focusses on hospitals in the Netherlands, the geographical scope of the datasets will be on national level. Except for the activities: material extraction, manufacturing and distribution as these are primarily performed outside of the Netherlands.

2.1.1 Function and functional unit

As described before, the absorbent underpads are used to absorb fluids in different situations. To define an appropriate functional unit, all applications of the absorbent underpads have been collected. While conducting a comparative LCA, it is important that the functional unit is well defined.

The two types of absorbent underpads differ in dimensions and absorption capacity.

- Disposable 60x60 cm, absorption capacity of 1450 ml
- Reusable 75x85 cm, absorption capacity of 2000 ml

Considering the applications, the maximum absorption capacity is not reached for most of the underpads.

Table 1: Applications of underpads

Product	**Expectation**	
	Maximal absorption is used	**Maximal absorption is not used**
Disposable	-Washing hair of patients	-Catch faecal defecation
	-Catch urine and defecation	-Catch wound fluid
	-Catch blood and amniotic fluid during deliveries	-Catch fluids and gel during echoes
		-Protecting arm- and leg rest from blood spatter
		-Muffling noise from instruments on a trolley/table
		-Cleaning up blood from the ground
Reusable	-Catch urine and defecation	-Catch defecation while using a po, catheter or incontinence material (diaper)

In conclusion, the number of underpads used in a hospital is mainly based on how many times an underpad is needed, not on the absorption capacity. To make a fair comparison, the dimensions of the reusable variant are converted to a 60x60 cm underpad. Therefore the weight is 56,5% of the original reusable underpad.

Table 2: Description of the Functional Unit

Aspect	Functional Unit	Additional information
What – functions or services provided	Absorbing body fluids of a patient.	Disposable Tena 60x60 cm = 1450 ml Reusable Abena 85x75 cm, 56,5% =1130 ml
How much – extent of the function or service provided	1000 times of use of a 60x60 cm underpad.	A reusable can be used at least 100 times. A disposable can be used 1 time.
How well – expected level of quality of the function or service	The surface underneath the underpad and the skin of the patient feel dry.	
How long – duration of the function or service / product lifetime	1 time of use can vary from 1 minute – 24 hours.	Depending on the function and the amount of fluid.
Where - location/geography of the function or service	Hospitals in the Netherlands.	
For whom – beneficiary of the function or service	All patients who currently use one.	

Resulting from this table, the following functional unit is defined:

“Absorbing body fluids 1000 times with a 60x60cm underpad to keep the surface underneath and the patient’s skin dry in hospitals in the Netherlands.”

2.1.2 Reference flow

To fulfil the functional unit, 1000 disposable underpads of 0,050 kg are needed. This results in a total amount of 50 kg. Since the reusable underpads can last at least 100 washing cycles, 10 reusable underpads are needed. The dimension of the reusable underpad are converted to a 60x60 cm underpad. One reusable underpad with these dimension will be 0,19 kg. To fulfil the functional unit, 10 x 0,19 = 1,9 kg underpad material is used.

Figure 9: Flowchart of the lifecycle of a disposable underpad

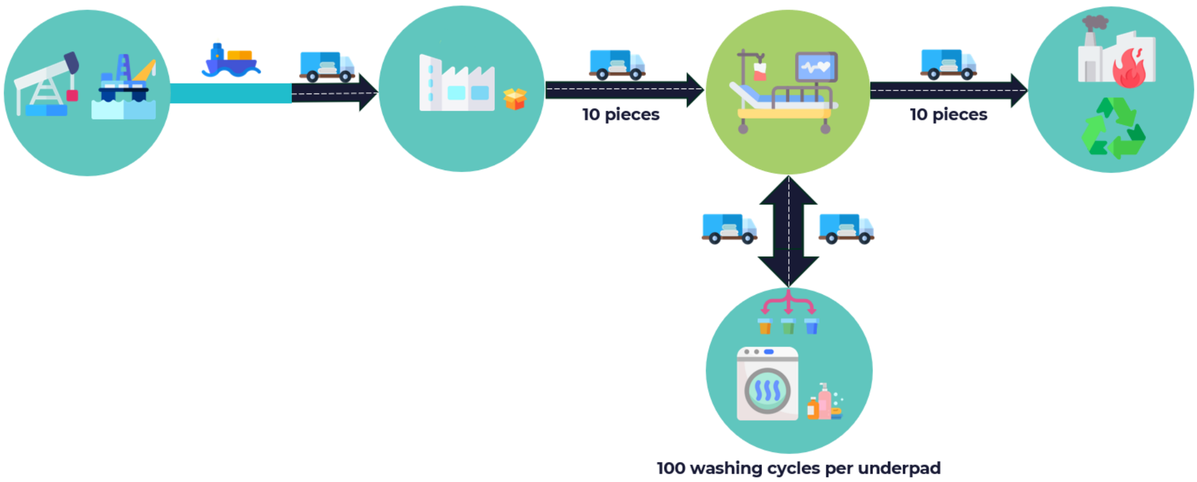


Figure 10: Flowchart of the lifecycle of a reusable underpad

2.1.3 Allocation procedures and cut-off criteria

An attributional LCA will be performed to investigate the environmental hotspots of both variants.

This study will focus on the environmental impact of the 1000x use of both underpads. The product system collects all the processes required to perform this function. The positive impact due to recycling of plastic and cardboard packaging will not be granted in this study. This is due to the fact that this is a cradle to grave study, instead of a cradle to cradle study. The benefits of recycling are allocated to the next life cycle and it cannot be verified that the recycling of this packaging will result in new packaging for the underpads. This study does not focus on the whole plastic and cardboard market in the Netherlands.

In addition, inputs expected to contribute less than 1% are excluded from this study. There was no information available about by-products from the production systems, it is assumed that the impact of this will be less than 1%.

2.1.4 System boundaries

In Figure 11 on the next page, the system and system boundaries are defined. This figure shows which processes are included. This graph is based on the system boundaries from the PEFCR apparel and footwear. Some aspects are excluded from this impact assessment. This is due to the fact that the information was not available, and it was not possible to make accurate assumptions at this moment.

Aspects included in this impact assessment:

- The production of raw materials and packaging materials
- The transportation of these materials
- The manufacturing of the underpads
- The distribution to the hospital
- Washing, cleaning and drying of the reusable underpad
- Distribution between hospital and laundry service, including packaging
- Transportation to end of life
- End of life processes of product and packaging

Aspects excluded in this impact assessment:

- Distribution to a distribution location (between factory and hospital) – *Information was not available and can differ a lot between hospitals and brands. Therefore, the direct transportation distance between the factory and hospital is assumed.*
- Transport weight of the metal shelves during transport of the reusable underpad from the hospital to the cleaning service and back – *Information was not available and the weight of the truck itself was generalised. This can vary as well.*
- Packaging of the soap to wash the reusable – *Information was not available and was assumed to have an insignificant impact.*
- Infrastructure to wash the reusable (the machine itself and the maintenance of it) – *Information was not available and it was not possible to make an appropriate assumption.*

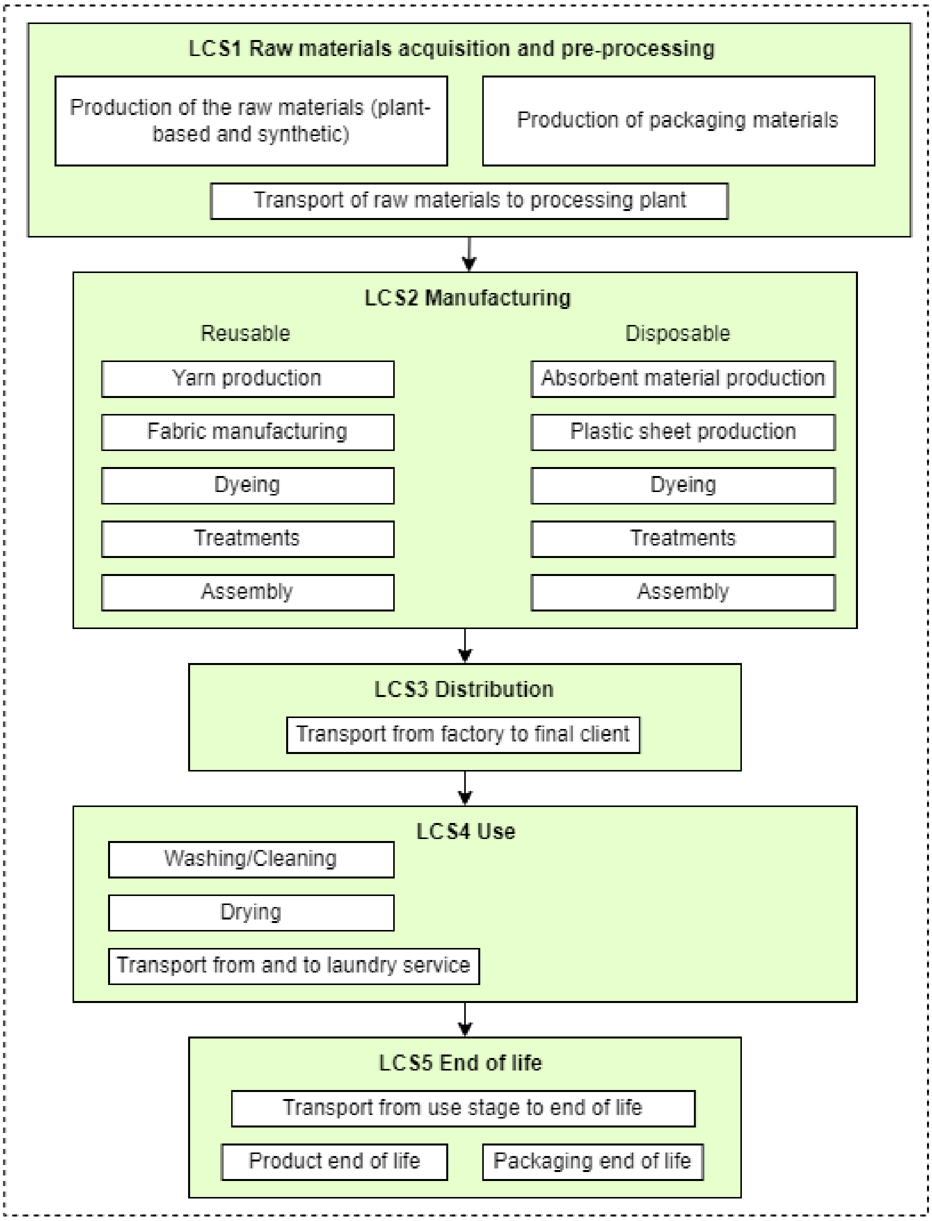


Figure 11: System boundaries of the cradle-to-grave LCA about absorbent underpads

2.1.5 Data gathering and quality

During the LCI the following production data need to be obtained(21).

1. Raw resources and intermediate products (=part of the finished product)
2. Ancillary materials (=materials used in manufacturing process but not part of finished product)
3. Packaging leaving the factory gate with the product.
4. Energy consumption: e.g. electricity, thermal energy and/or fuels used in the manufacturing process (incl. internal transport)
5. Manufacturing waste, including wastewater treatment (e.g. final resides and packaging not leaving the factory gate with the product)
6. Process emissions (e.g. the emissions that are part of an environmental permit of the manufacturing location)

To complete the LCI for this cradle to grave analysis, more data is needed.

7. Transportation during the life cycle: e.g. locations of material extraction, factories, distribution centra, washing companies and waste processors.
8. Energy consumption during washing: e.g. electricity (by fossil fuels or renewable sources) and gas usage
9. Material consumption during washing: e.g. soap (including its composition) and water use, packaging
10. Waste treatment: e.g. incineration (incl temperature)/landfill/recycling
11. Packaging for waste treatment

To acquire information for this study, several companies and organisations have been contacted; Most of the companies needed to be contacted several times, to receive as much detailed/specific information as possible.

- *Tena*, brand of disposable underpads, used in Treant hospitals and several other hospitals in the Netherlands, customer service and product developer.
- *Absorin*, brand of disposable underpads, used in Radboudumc, customer service.
- *Green It Out*, brand of disposable biodegradable underpads, co-owner (This information is confidential.)
- *Nedlin*, underpad leasing and cleaning company, cleans underpads for Radboudumc and several other washing companies, Business Development Manager Healthcare
- *Dumoulin*, manufacturer of reusable underpads in Belgium, supplies to Nedlin, customer service.
- *Abena*, producer of disposable and reusable underpads in Denmark, Senior Product Manager
- *Cleanlease*, underpad leasing and cleaning company, several locations in the Netherlands, supplies to several hospitals in the Netherlands, Manager Sales and Business Development
- *Zorgmatras*, supplier of underpads, customer service
- *Dintex*, manufacturer of underpads, customer service
- *Hebo Van Dijk*, manufacturer of underpads, Adjunct director
- *Christeyns*, soap supplier, managing director BE

The following hospitals were approached:

- *RadboudUMC*, Sustainability researcher ICU
- *MCL*, Policy adviser sustainability (This information is confidential.)
- *UMCG*, Sustainability research and medical doctor (This information is confidential.)
- *LUMC*, PhD Sustainability research
- *Santeon Group,* Project leader Santeon facility (procurement) projects

The Ecoinvent (version 3.8) database was used. *Searates.com* was used to determine the transport per ship and truck. Internet was used to locate the largest used harbours of a country.

Each activity presented in the Ecoinvent database has a geographical location. Geographical locations are reported using an internationally accepted set of abbreviations. For example, The Netherlands has the abbreviation NL. Besides, the most activities are also represented at the global level (GLO). When the desired location is not present, Rest of World (RoW) can be chosen as well. When an activity takes place somewhere in Europe, RER can be chosen. Sometimes, only a few of the geographical locations are available. Then it is key to choose the best fit.

Assumptions and material choices that are made regarding the LCI inputs for SimaPro can have a large effect on the overall impact results. Therefore, a set of assumptions and different dataset choices are analysed. This data quality and sensitivity analysis can be found in the Appendix.

2.2 Life Cycle Inventory (LCI)

In this section the collected LCI data is outlined. To give an overview of all the aspects, the life cycle of the disposable underpad is described in Figure 12. Furthermore, the structure of the system boundaries is used to describe this data clearly. Starting with the raw materials acquisition and pre-processing, followed by the packaging materials, the manufacturing, distribution through the whole life cycle and the end of life of the underpads. The life cycle of the reusable underpad is described in Figure 14. The same structure is hold, with an addition of the use phase, where the washing of the underpads is described.

Since it was not possible to collect all the required information from companies and hospitals, some assumptions needed to be made based on literature. These assumptions will be described and justified in this section as well.

2.2.1 Disposable underpad:

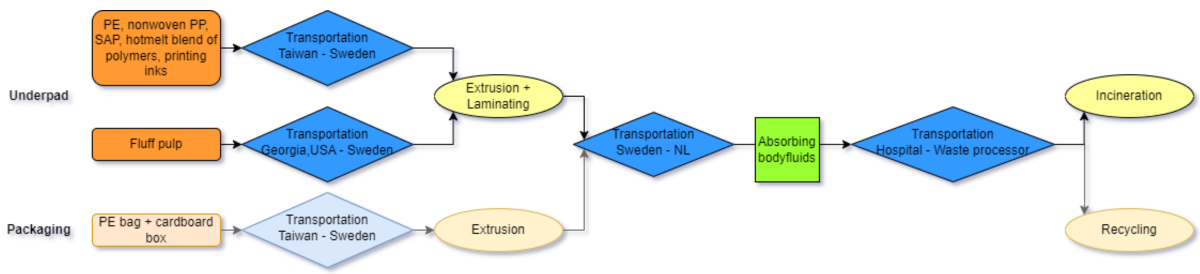


Figure 12: Life cycle of the disposable underpad of Tena

-Raw materials acquisition and pre-processing- production and transportation

Tena provided a list with all the materials used to produce the Tena Bed Plus 60x60 cm underpad. The top layer is made from nonwoven polypropylene. The middle layer needs to absorb the fluids and is made from fluff pulp and a super absorbent polymer (SAP). The SAP used in this product is cross-linked polyacrylate salt. This material can be made from ammonium peroxide sulphate, acrylic acid, NaOH, water and electricity. Ammonium peroxide sulphate is made from sulphuric acid, ammonium sulphate and electricity. The bottom layer is made from PE film and is printed with inks, to show which brand it made. The sides of the 60x60cm underpad have a 1cm wide strip for gluing the three layers together. This is done with adhesives, which is a hotmelt blend of polymers. The polymers used are mainly polyolefin or styrene block-copolymers and hydrocarbon resins (only of synthetic origin). Therefore, there is assumed that this hotmelt is made from a combination of polyolefin and hydrocarbon resins.

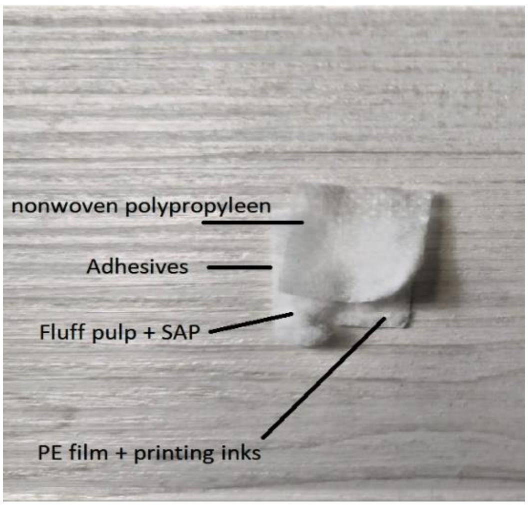


Figure 13: Picture of the different layers of the disposable underpad of Tena

Despite several attempts addressed to different people, it has not been possible to receive the exact weight percentages of these materials. Therefore, the weights needed to be estimated based on several assumptions. The declaration is described in this section. The result can be found in table 6.

Table 3: Composition for the Tena Bed articles in 2015(22)

Composition for TENA Bed (all articles) Specific data is used in all calculations.	
Pulp	61 - 79 %
Polymers	2 - 4 %
Plastics	19 - 36 %

Table 4: Review of average weights of incontinence bed pads(23)

	Layer Weights (grams / m²) Reusable Pad	Disposable Pads
Layer		
Topsheet	130 - 220	20 – 40
Soaker	240 - 380	120 – 140
Barrier	150 - 350	(included in backsheet)
Backsheet	60 - 90	30 – 40
(indicative) Total Weight	575 - 890	190 – 210

Table 5: Weight percentages from an EPD of the Italian brand Farmex(24)

SVAS BIOSANA EPD®

Product	Code	Component	Medium gewicht¹ (g)	% in gewicht
Absorberende wegwerpstang 60x60	03JOL5003020		50	
		Cellulose pluis		75,34
		Polypropyleen		7,26
		Polyethyleen		14,40
		Lijm		3,00

In the Environmental Product Declaration (EPD) of the TENA Bed articles of 2015, Table 3 was found. It is assumed that ‘polymers’ means the amount of Super Absorbent Polymers (SAP). In addition, it is assumed that ‘plastics’ means the nonwoven PP and PE film used for the top and bottom layer. There are various products of TENA Bed. In order of absorption capacity; Tena Bed Original, Normal, Plus and Super. The original and normal variant are almost the same. In this research the Tena Plus variant is studied. This variant has the mean absorbance capacity of the TENA Bed products. Therefore, it is assumed that this variant contains 70% of fluff pulp and 3% of SAP. This leaves 26.6% to be distributed among the other materials.

Table 4 shows that previous research has found that the back sheet of a disposable underpad (PE film) contains in general a bit more weight than the top sheet (nonwoven PP)(23).

No SAP is used in this absorbent underpad of Farmex(24). However, it assumes that 3% of the weight is accounted to the glue. Besides, this source states as well that there is more PE used than PP. Therefore, in this study is assumed that 3% of the weight of the underpad are adhesives.

For the use of printing inks, another calculation is made. Based on sales websites for printing inks, 6 ml ink is needed to print 250 papers with A4 format (20x30 cm). Therefore, printing one underpad is the same as 6 A4 papers. 6/250 = 1,4 ml = 1,44 cm^3. The density of inks is 1,40 g/cm^3. Therefore, 1,44 cm^3 x 1,40 g/cm^3 = 2,02 g = 0,0002 kg.

The total weight of an underpad is 0,05 kg, so 0,05 kg/0,0002 kg = 0,0004. This results in the assumption that 0,4% of the weight of the underpad is ink. Lastly it is assumed that 9% is PP and 14,5% is PE. The weight percentages of table 6 are multiplied by the total weight of one disposable underpad. The result is showed in Table 7.

Table 6 : Assumption of the weight percentages of the materials from the Tena Bed underpad

Disposable Tena 60x60 cm	Weight percentage
Fluff pulp	70%
SAP→cross-linked polyacrylate salt	3%
Non-woven PP	9%
PE film	14,6%
Hotmelt blend of polymers (adhesives), mainly polyolefin or styrene block-copolymers and hydrocarbon resins (only of synthetic origin)	3%
Printing inks, pigments (without metals)	0,4%

Table 7: LCI data of the disposable underpad imported in Simapro. This table is split up in several sections.

Produced resources					
Product	**Resource**			**Weight per disposable**	**Data source**
Disposable 60x60 cm Tena				0,05	
Materials product	Fluff pulp			0,035	Sulfate pulp, bleached {RoW}| market for sulfate pulp, bleached | Cut-off, S
	SAP=cross-linked polyacrylate salt:			0,0015	
		Ammonium peroxide sulphate:		0,0000075	
			Sulphuric acid	0,000004335	Sulfuric acid {RoW} market for sulfuric acid
			Ammonium sulphate	3,2175E-06	Ammonium sulfate {RoW} market for ammonium sulfate
			Electricity	0,000054	Electricity, high voltage {GLO}| market group for | Cut-off, S [MJ]
		Acrylic acid		0,001173	Acrylic acid {RoW}| market for acrylic acid | Cut-off, S
		NaOH		0,000702	Sodium hydroxide, without water, in 50% solution state {GLO}| market for | Cut-off, S
		Water		0,0026295	Tap water {GLO}| market group for | Cut-off, S
		Electricity		0,011745	Electricity, high voltage {GLO}| market group for | Cut-off, S [MJ]
	Non-woven PP			0,0045	Textile, nonwoven polypropylene {GLO}| market for textile, nonwoven polypropylene | Cut-off, S
	PE-film			0,0073	Polyethylene, low density, granulate {GLO}| market for | Cut-off, S
	Hotmelt blend of polymers (adhesives), mainly polyolefin or styrene block-copolymers and			0,0015	

	hydrocarbon resins (only of synthetic origin):				
		Polyolefins		0,0005	N-olefins {GLO}| market for | Cut-off, S
		Hydrocarbon resins		0,001	C3 hydrocarbon mixture {GLO}| market for C3 hydrocarbon mixture | Cut-off, S
	Printing inks, pigmets (without metals)			0,0002	Printing ink, offset, without solvent, in 47.5% solution state {RER}| market for printing ink, offset, without solvent, in 47.5% solution state | Cut-off, S

Transportation is showed in the table below. The unit used for transport is kgkm. Fluff pulp is often grown in Georgia (USA) and plastic are mostly made in Asia; therefore Taiwan is assumed. The factory of Tena is located in Gothenberg (Sweden). *Searates.com* is used to measure the relative distance the truck or container ship has to travel. From Georgia (USA) to Gothenberg (Sweden) a distance of 5862 km needs to be covered. This distance is multiplied by the weight of the fluff pulp. The distance from Taiwan to Gothenberg (Sweden) is 19252 km over sea. This is multiplied by the weight of all the plastics together.

Transport			
		Distance [kgkm]	**Locations**
Ship	Fluff pulp	205,17	Georgia, USA – Gothenberg, Sweden
	Plastics	284,9296	Taiwan – Gothenberg, Sweden
Source		*Transport, freight, sea, container ship {GLO}| market for transport, freight, sea, container ship | Cut-off, S*	

-Raw materials acquisition and pre-processing of packaging materials - production

This underpad is transported in a plastic bag and a cardboard box. 40 underpads fit inside one bag, and 4 bags have been packed in one cardboard box. Therefore, 160 underpads are transported in one cardboard box.

Based on desk research, a PE bag of 20x30x0,10 cm =1210 cm^2, which is 0,02 kg PE film. However, for 40 underpads a bigger bag is needed. When one underpad is folded the dimensions are 20x30x1 cm. Therefore, a bag for 40 underpads needs to be 20x30x40 cm. In Table 8 can be seen that there is 0,09 kg PE film needed for 40 underpads.

Table 8: Surface and weight of a PE bag for 40 disposable underpads

	One standard bag	Bag for 40 underpads
Surface	1210 cm^2	5200 cm^2
Weight	0,02 kg	→0,09 kg

So, 0,09/40 = 0,002 kg PE film is needed for one underpad.

Another calculation is made for the amount of cardboard. Based on desk research, the specific weight of carton board is 180-600 grams per m^2. Since disposable underpads are not heavy, the required carton board is assumed to be of a lower gram/m^2, therefore a value of 300 grams per m^2 is assumed. Four plastic bags fit in one carton board box. Therefore, the dimensions are 40 x 60 x 80 cm. This results in a surface of 2,08 m^2. Then, 2,08 m^2 x 300 g/ m^2 = 624 gram = 0,62 kg per carton board box. This results in 0,62/160 = 0,0039 kg cardboard per underpad.

Product	Resource	Weight per disposable	Data source
Materials packaging	PE	0,00215	Packaging film, low density polyethylene {GLO}| market for | Cut-off, S
	Cardboard	0,0039	Corrugated board box {RoW}| market for corrugated board box | Cut-off, S

-Manufacturing

As described before, manufacturing of this underpad is done in Gothenburg (Sweden). The processes considered are extrusion of plastic film and a laminating service. Lamination of the materials is only applied at the edges of the underpad, with a width of 1 centimetre. Manufacturing of the plastic bag is also performed via an extrusion process.

Production Product		
	Weight per underpad	**Data source**
Product	0,0118	Extrusion, plastic film {GLO}| market for extrusion, plastic film | Cut-off, S
	0,024	Laminating service, foil, with acrylic binder {RER}| processing | Cut-off, S

Production Packaging		
	Weight per underpad	**Data source**
Packaging	0,00215	Extrusion, plastic film {GLO}| market for extrusion, plastic film | Cut-off, S

-Distribution – factory to final client

The unit used for transport is kgkm. *Searates.com* is used to measure the relative distance the truck or container ship has to travel. The distance by road from the factory in Gothenberg (Sweden) to Ede (middle of the Netherlands) is 748 km. This is multiplied by the weight of the underpad, and by the weight of the packaging.

Transport Product			
		Distance [kgkm]	**Locations**
Truck	Underpad	37,4	Gothenberg, Sweden – Hospital in NL
Source		*Transport, freight, lorry 16-32 metric ton, euro6 {RER}| market for transport, freight, lorry 16-32 metric ton, EURO6 | Cut-off, S*	

Transport Packaging			
		Distance [kgkm]	**Locations**
Truck	Packaging	4,5254	Gothenberg, Sweden – Hospital in NL
Source		*Transport, freight, lorry 16-32 metric ton, euro6 {RER}| market for transport, freight, lorry 16-32 metric ton, EURO6 | Cut-off, S*	

-End of Life – Waste treatment and transportation

In some departments within the hospital, plastic and paper are separate waste streams. The underpad packaging is part of these waste streams and is therefore recycled.

Furthermore, there are two different residual flows, the specific hospital waste and the not specific hospital waste.

- **Specific hospital waste**
  When the underpads are not leak-free of blood (*Euralcode 180103*), or when the patient is treated with cytostatic drugs (*Euralcode 180108*), they belong to the specific hospital waste and need to be incinerated in a specifically incinerator licensed for that purpose (higher temperature). In the Netherlands is ZAVIN (Ziekenhuis Afval Verwerking Installatie Nederland) in Dordrecht the only incinerator with this permission(25).

  Euralcode 180103: including undried blood and all undried excreta (e.g. sputum) regardless of origin or type of infection;

  Euralcode 180108: Cytotoxic and cytostatic medicines. However, the description 'cytotoxic and cytostatic drug' should be interpreted broadly. Incontinence materials from patients treated with cytostatic drugs should also be considered 180108 waste.

- **Not specific hospital waste**
  When the underpads are leak-free of blood (*Euralcode 180104*), they can be transported to the ordinary waste incinerator (in Dutch: AVI). Higher-value forms of processing are also permitted(25).

  Euralcode 180104: Waste whose collection and disposal are not subject to special guidelines in order to prevent infection (e.g. dressings, plaster casts, linen, disposable clothing, nappies) or waste which has been decontaminated in accordance with the relevant provisions.

These are the rules of the ministry of IenW, who wrote the beleidstekst sectorplan LAP3(25). However, these are not the only regulations about hospital waste.

Other regulations:

- **ADR** (Accord relatif au **transport** international de marchandises Dangereuses par Route)→ ADR is the pan-European treaty for the transport of dangerous goods by road. The ADR describes requirements on criteria for hazard classification of dangerous goods, conditions for carriage, requirements for packaging and tanks and procedures for shipment. The ADR works following the UN (United Nations) numbers. Each UN number is classified in the ADR and the corresponding conditions for carriage are described(26).
- **ILT** (inspectie leefomgeving en **transport**) → The Environment and Transport Inspectorate (ILT) carries out administration inspections at hospitals and clinics, for compliance with the Transport of Dangerous Goods Act. These inspections focus on the (offering for) transport of medical or hospital waste and diagnostic samples(27).

The ministry is vague about the interpretation of the different rules.

For this reason, some hospitals currently dispose of the underpads with the specific hospital waste in order to avoid risks. This is due to the fact that inspectors test the safety of non-specific hospital waste. They do not test what is in the specific hospital waste.

In reality, in some places the underpads are discarded with the specific hospital waste and in some places, they are discarded with the non-specific hospital waste.

For this study, the rules from the ministry IenW LAP3 are followed. Therefore, the impact of incineration of non-specific hospital waste is taken into account. In addition, no specific packaging for waste distribution in considered.

In the Netherlands there are 12 modern ordinary waste incinerators (AVI's) who are allowed to process non-specific hospital waste (in Dutch: NSZA). The average distance between a hospital and an ordinary waste incinerator will be around 50 km(28). For this reason, the weights are multiplied by 50 km in order to calculate the impact of transportation.

Waste treatment Product		
	Weight per underpad	**Data source**
Product	0,05	Municipal solid waste {NL}| treatment of, incineration | Cut-off, S

Waste treatment Packaging		
	Weight per underpad	**Data source**
Packaging	0,00215	PE (waste treatment) {GLO}| recycling of PE | Cut-off, S
	0,0039	Core board (waste treatment) {GLO}| recycling of core board | Cut-off, S

Transport Product			
		Distance [kg]	**Locations**
Truck	Underpad	2,5	Hospital – Waste processor
Source		*Transport, freight, lorry 16-32 metric ton, euro6 {RER}| market for transport, freight, lorry 16-32 metric ton, EURO6 | Cut-off, S*	

Transport Packaging			
		Distance [kg]	**Locations**
Truck	Packaging	0,3025	Hospital – Waste processor
Source		*Transport, freight, lorry 16-32 metric ton, euro6 {RER}| market for transport, freight, lorry 16-32 metric ton, EURO6 | Cut-off, S*	

2.2.2 Reusable underpad:

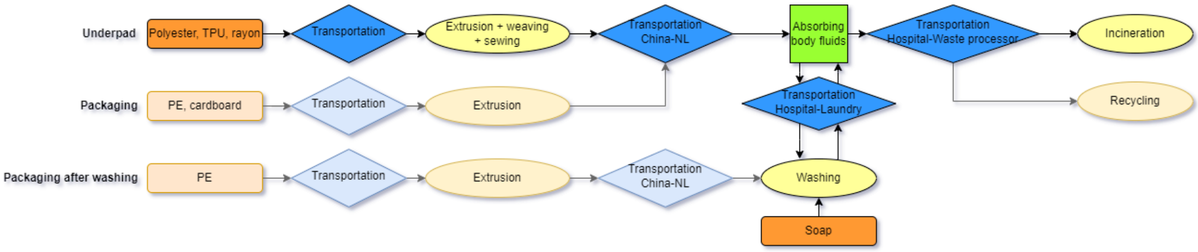


Figure 13: Life cycle of the reusable underpad of Abena

It is important to note that to fulfil the functional unit, 10 underpads are used and 1000 washing cycles are taken into account.

-Raw materials acquisition and pre-processing – production

The reusable underpad of Abena also consists of three stacked layers. The upper layer is made of woven polyester. The middle layer is made of nonwoven polyester mixed with rayon. This is the absorbent part of the underpad. The bottom layer is made from woven polyester. On the top side of this, a thin transparent layer of TPU is applied. The different layers are sticked together with yarn made of polyester.

Similarly with the disposable underpad, it was (during this phase of the study) not possible to obtain the exact weight percentages of the materials. Besides, for the reusable not enough accurate data was found in previous research to make sufficient assumptions. Therefore, the three layers of a 2x2 cm piece of the reusable underpad were taken apart and weighed individually. These weights have been converted to the dimensions of a 60x60 cm underpad, presented in Table 9.

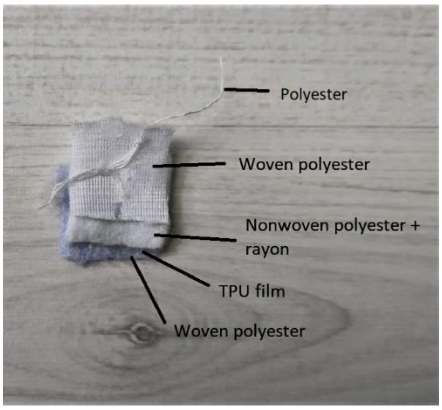


Figure 14: Picture of the different layers of the reusable underpad of Abena

Table 9: Weight percentages of the reusable underpad of Abena

	Weight 4cm^2 (g)	**Percentage**	**Assumption**
Yarn	0,0045	1,90%	Polyester
Woven upperlayer	0,042	17,76%	Woven Polyester
Nonwoven middlelayer	0,101	42,71%	95% Nonwoven polyester + 5% Rayon
Blue bottomlayer	0,089	37,63%	5% TPU coating + 95% Woven polyester
Total	0,2365	100,00%	

After weighing the three layers, an assumption is made about the amount of material per layer. According to the Radboudumc, the absorbent middle layer contains 95% polyester and 5% rayon(29). For the blue bottom layer an assumption is made. It can be seen that this bottom layer contains a thin transparent layer, it is assumed that this will be 5% of the weight of the bottom layer in total. These assumptions led to the weight percentages for a reusable underpad.

After this, the weight per underpad for each material is calculated. This is the number of materials required to produce a 60x60 reusable underpad. The calculations can be found in Table 10. The total weight of a 60x60 underpad is 0,19 grams. This is multiplied by the percentage of the layer of Table 9. And this is multiplied by the percentage of that material in that layer.

Table 10: Weight of the materials for a 60x60 cm reusable underpad

Materials	**Weight per 60x60 underpad [kg]**
TPU (thermo-plastic-polyurethaan)	=0,189275*0,3763*0,05
Woven polyester	=0,189275*0,1776+0,189275*0,3763*0,95+0,189275*0,019
Nonwoven polyester	=0,189275*0,4271*0,95
Rayon	=0,189275*0,4271*0,05

Table 11: LCI data of the reusable underpad imported in Simapro. This table is split up in several sections.

Produced resources			
Product	**Resource**	**Weight per 1 underpad [kg]**	**Data source**
Reusable 85x75 cm Abena		1 underpad van 60x60 cm	
		0,189275	
Materials product	TPU (thermo-plastic-polyurethaan)	0,003561209	Polyurethane adhesive {GLO}| market for polyurethane adhesive | Cut-off, S
	Woven polyester	0,104874438	Fibre, polyester {GLO}| market for fibre, polyester | Cut-off, S
	Nonwoven polyester	0,076797385	Textile, nonwoven polyester {GLO}| market for textile, nonwoven polyester | Cut-off, S
	Rayon	0,004041968	Fibre, viscose {GLO}| market for fibre, viscose | Cut-off, S

In this section the transportation is neglected, since the plastics are produced in Asia (exact location unknown) and the factory is located in China.

-Raw materials acquisition and pre-processing of packaging materials - production
This underpad is packed per piece in a plastic bag. Furthermore, 36 underpads are transported in one cardboard box.

Based on the internet, a PE bag of 20x3x0,10 cm =1210 cm^2, which is 0,02 kg PE film. One folded reusable underpad is 20 x 30 x 1 cm. This makes a surface of 1300 cm^2.

Table 12: Surface and weight of a PE bag for 1 reusable underpad

	One standard bag	**Bag for 1 underpad**
Surface	1210 cm^2	1300 cm^2
Weight	0,02 kg	→0,022 kg

It can be seen that there is 0,022 kg PE film needed for 1 underpad.

Another calculation is made for the amount of cardboard. Based on internet, the specific weight of carton board is 180-600 grams per m^2. Since underpads are not heavy, the carton board does not have to be really strong, therefore a value of 300 grams per m^2 is assumed. 36 underpads need to fit in one cardboard box. This results in the dimensions of 20 x 30 x 36 cm. Calculating the surface of the cardboard needed for this box, it comes down to 4800 cm^2 = 0,48 m^2. Therefore, 0,48 m^2 x 300 g/m^2 = 144 gram = 0,14 kg per carton board box. This results in 0,144/36 = 0,004 kg cardboard per underpad.

Produced resources			
Product	**Resource**	**Weight per 1 underpad [kg]**	**Data source**
Reusable 85x75 cm Abena		1 underpad van 60x60 cm 0,189275	
Materials packaging	PE	0,0215	Packaging film, low density polyethylene {GLO}| market for | Cut-off, S
	Cardboard	0,004	Corrugated board box {RoW}| market for corrugated board box | Cut-off, S

-Manufacturing

This underpad in manufactured in China. The processes considered are extrusion of plastic film, weaving and dyeing. For extrusion, the weight of the nonwoven polyester is taken. The weaving is only done for the woven polyester. Only the woven polyester part of the bottom layer is dyed in a blue colour. After this, the three layers are sticked together. The Ecoinvent database does not contain a sufficient process for sewing, therefore the electricity for this process is considered. The calculation for the amount of electricity needed for this process is based on literature. It is estimated that a commercial sewing machine uses 4 kWh(30). Sewing a menstruation pad (around 50cm) takes 0,1 minute. To sew an underpad the sides need to be stitched, this is approximately 60 x 4 = 240 cm. To stitch the pattern on the underpad, 60 x 8 = 480 cm. The calculation below shows that is takes 1,5 minute to sew an underpad. It will take 0,1 kWh to do this.

Table 13: Calculation of the time needed for sewing one reusable underpad.

	Length which needs to be stitched	**Time needed for sewing**
Reusable underpad	720 cm	→1,5 minute
Menstruation pad	50cm	0,1 minute

Table 14: Calculation of the electricity needed for sewing one reusable underpad.

	Standard ratio	**One underpad**
Electricity	4 kWh	→0,1 kWh
Time	60 min	1,5 min

Production Underpad		
	Weight per underpad [kg]	**Data source**
Extrusion	0,076797385	Extrusion, plastic film {GLO}| market for extrusion, plastic film | Cut-off, S
Weaving	0,104874438	Weaving, synthetic fibre {GLO}| market for weaving, synthetic fibre | Cut-off, S
Sewing [kWh]	0,1 [kWh]	Electricity, high voltage {NL}| market for | Cut-off, S
Dyeing	0,067662973	Continuous dyeing, fibre, cotton {GLO}| continuous dyeing, fibre, cotton | Cut-off, S

Production Packaging		
	Weight per underpad	**Data source**
Extrusion	0,0215	Extrusion, plastic film {GLO}| market for extrusion, plastic film | Cut-off, S

-Distribution - factory to final client

The unit used for transport is kgkm. The factory of Abena for the production of reusable underpads is located in China. *Searates.com* is used to measure the relative distance the truck or container ship has to travel. The distance over sea from China to Rotterdam is 21543 km. The distance by road from Rotterdam to Ede (middle of the Netherlands) is 82 km. These are both multiplied by the weight of the underpad, and by the weight of the packaging.

Transport Underpad		
	Distance [kgkm]	**Locations**
Truck	15,52055	Rotterdam – Hospital in the middle of NL
Source	Transport, freight, lorry 16-32 metric ton, euro6 {RER}| market for transport, freight, lorry 16-32 metric ton, EURO6 | Cut-off, S	
Ship	4077,551325	China - Rotterdam
Source	Transport, freight, sea, container ship {GLO}| market for transport, freight, sea, container ship | Cut-off, S	

Transport Packaging		
	Distance [kgkm]	**Locations**
Truck	2,091	Rotterdam – Hospital in the middle of NL
Source	Transport, freight, lorry 16-32 metric ton, euro6 {RER}| market for transport, freight, lorry 16-32 metric ton, EURO6 | Cut-off, S	
Ship	549,3465	China - Rotterdam
Source	Transport, freight, sea, container ship {GLO}| market for transport, freight, sea, container ship | Cut-off, S	

-Use, washing and drying

Figure 15: Pictures taken at the washing location of Cleanlease in Eindhoven

The usage of electricity, gas, water, soap and packaging can differ between washing companies. Besides, it varies also between different locations of the same company. As this data is confidential, this report gives a range without naming the companies. At the right column, the average of the given values is given.

Table 15: Energy and materials used for the washing process.

Company	**1**	**2**	**Averages based on the exact values**
Electricity [kWh per kg laundry]	0,10-0,12	0,07-0,15	0,10
Gas [M^3 per kg laundry]	0,08-0,10	0,06-0,12	0,085
Water [L per kg laundry]	2,2-2,4	4,5	3,4
Soap [kg per kg laundry]	-	0,0075	0,0075
Packaging [kg per kg laundry]	0,004-0,005	-	0,0045

The average values are used to calculate the amount needed for 1 washing cycle of 1 underpad. However, the value of water use is multiplied by 1,25 to compensate an error in this version of the Ecoinvent database.

Figure 17: Picture of packaging after washing

In the Netherlands, most companies use soap from Chrysteyns, following a cool chemistry washing process. 7,5 kg soap is used for 1000 kg laundry.

After washing, the laundry is collected on a trolley. Plastic film is put around the trolley to keep the items clean during transportation.

Transport distances between hospitals and laundry services can vary widely. A few examples can be found in the Appendix. It is assumed that 80 km will be the average value in the Netherlands. This is verified by an expert of Cleanlease. Therefore, 80 is multiplied by 2 (back and forth), which is multiplied by the weight of an underpad. The same is done for the packaging.

In this use section, two different scenarios will be studied. In the first scenario the normal electricity mix for the Netherlands will be taken. In the second scenario, green energy will be chosen. In this case solar energy is chosen. However, the environmental impact of solar panels is almost the same as energy generated by wind turbines.

Cleaning (for 1 cycle of 1 underpad)		
	Amount per underpad	**Data source**
	0,018721285	Electricity, medium voltage {NL}| market for | Cut-off, S Or Electricity, high voltage {RoW}|electricity production, solar thermal parabolic trough, 50 MW| Cut-off, S
	0,80441875	Tap water {Europe without Switzerland}| market for tap water | Cut-off, S
	0,0164656	Natural gas, high pressure {NL}| market for | Cut-off, S
	0,001419563	Soap {GLO}| market for | Cut-off, S
Packaging after cleaning	0,000846816	Packaging film, low density polyethylene {GLO}| market for | Cut-off, S
Transport		
	Distance [kg]	**Locations**
Product	37,855	Hospital– Cleaning service
Packaging after cleaning	0,084681635	Hospital– Cleaning service

-End of life – waste treatment and transportation

The same rules as for the disposable version can be applied, since the underpads which are thrown away inside the hospital, will be incinerated as well. In addition, some reusable underpads will be thrown away by the laundry service. The plastic packaging around the transportation trolley after washing is recycled as well.

During the time of the Inventory Analysis, one of the washing companies assumed that part of the 4,5-litre water per kg laundry was used again. Therefore, 2,5 litre wastewater per kg laundry was assumed.

Waste treatment Underpad		
	Weight per underpad [kg]	**Data source**
	0,189275	Waste plastic, mixture {CH}| treatment of waste | Cut-off, S

Waste treatment Packaging		
	Weight per underpad [kg]	**Data source**
	0,0215	PE (waste treatment) {GLO}| recycling of PE | Cut-off, S
	0,004	Core board (waste treatment) {GLO}| recycling of core board | Cut-off, S
Packaging after cleaning	0,000846816	PE (waste treatment) {GLO}| recycling of PE | Cut-off, S

Waste treatment Water		
	Weight per underpad [m^3]	**Data source**
	0,00035	Wastewater, average {Europe without Switzerland}|market for wastewater, average | Cut-off, S

The same values as for the disposable are used for transport to the waste processor. This means a distance of 50 km multiplied by the weight of one underpad and the packaging.

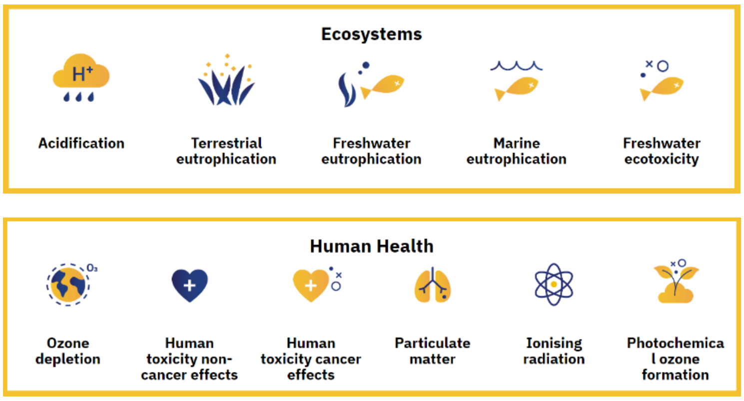
Transport Underpad		
	Distance [kgkm]	**Locations**
Truck	9,46375	Hospital - Waste processor
Source	Transport, freight, lorry 16-32 metric ton, euro6 {RER}| market for transport, freight, lorry 16-32 metric ton, EURO6 | Cut-off, S	

Transport Packaging		
	Distance [kgkm]	**Locations**
Truck	1,275	Hospital - Waste processor
Source	Transport, freight, lorry 16-32 metric ton, euro6 {RER}| market for transport, freight, lorry 16-32 metric ton, EURO6 | Cut-off, S	

2.3 Life Cycle Impact Assessment (LCIA)

The LCA software SimaPro (version 9.5) was used to perform the assessment. The (adapted) EF 3.1 LCIA Method was selected to calculate the impact on different categories. In addition, the EF 3.1 normalization and weighting factors are used.

The PEFCR Apparel and Footwear is used to select the most relevant impact categories. Based on the thickness of the material of the underpad, it is assumed that the category for sweaters and midlayers (RP3) best matches(19). The environmental impact indicators of this category are Climate change, Acidification, Particulate matter, Land use, Water use and Resource use, fossil. The various impact indicators have influence on different domains, described in Figure 18. These domains are Ecosystems, Human Health, Climate Change, Natural Resources and Water.



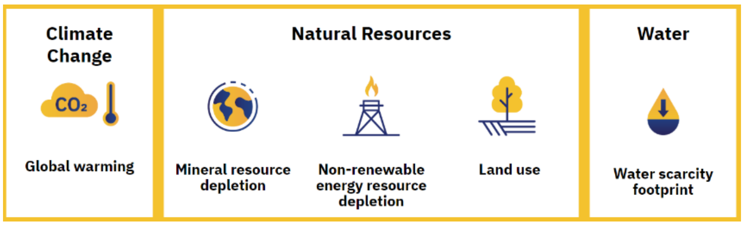


Figure 18: The impact indicators of the PEF method (19)

EF impact category	Impact indicator	Unit	Characterization model
Climate change - Climate change – fossil - Climate change- biogenic - Climate change – land use and land use change	Radiative forcing as Global Warming Potential (GWP100)	kg CO_2-eq	Baseline model of 100 years of the Intergovernmental Panel on Climate Change (IPCC) (based on IPCC 2013)
Ozone depletion	Ozone Depletion Potential (ODP)	kg CFC-11-eq	Steady-state ODPs as in (WMO 2014 + integrations)
Human toxicity, cancer	Comparative Toxic Unit for humans (CTUh)	CTUh	USEtox model 2.1 (Fankte et al, 2017)
Human toxicity, non-cancer	Comparative Toxic Unit for humans (CTUh)	CTUh	USEtox model 2.1 (Fankte et al, 2017)
Particulate matter	Impact on human health	disease incidence	PM method recommended by UNEP (UNEP, 2016)
Ionising radiation, human health	Human exposure efficiency relative to U235	kBq U^{235} -eq	Human health effect model as developed by Dreicer et al., 1995 (Frischknecht et al, 2000)

EF impact category	Impact indicator	Unit	Characterization model
Photochemical ozone formation, human health	Tropospheric ozone concentration increase	kg NMVOC -eq	LOTOS-EUROS model (Van Zelm et al, 2008) as implemented in ReCiPe 2008
Acidification	Accumulated Exceedance (AE)	mol H^+ -eq	Accumulated Exceedance (Seppälä et al. 2006, Posch et al, 2008)
Eutrophication, terrestrial	Accumulated Exceedance (AE)	mol N -eq	Accumulated Exceedance (Seppälä et al., 2006, Posch et al, 2008)
Eutrophication, freshwater	Fraction of nutrients reaching freshwater end compartment (P)	kg P -eq	EUTREND model (Struijs et al, 2009) as implemented in ReCiPe
Eutrophication, marine	Fraction of nutrients reaching marine end compartment (N)	kg N -eq	EUTREND model (Struijs et al, 2009) as implemented in ReCiPe
Ecotoxicity, freshwater	Comparative Toxic Unit for ecosystems (CTUe)	CTUe	USEtox model 2.1 (Fankte et al, 2017)
Land use	• Soil quality index (dimensionless) • Biotic production (kg biotic production) • Erosion resistance (kg soil) • Mechanical filtration (m^3 water) • Groundwater replenishment (m^3 groundwater)	Dimensionless (pt)	Soil quality index based on LANCA (Beck et al. 2010 and Bos et al. 2016)
Water use	User deprivation potential (deprivation-weighted consumption)	m^3 world -eq	Available WAter REmaining (AWARE) as recommended by UNEP, 2016
Resource use[2], minerals and metals	Abiotic resource depletion (ADP ultimate reserves)	kg Sb -eq	CML 2002 (Guinée et al., 2002) and (van Oers et al., 2002).
Resource use, fossils	biotic resource depletion – fossil fuels (ADP-fossil)	MJ	CML 2002 (Guinée et al., 2002) and (van Oers et al., 2002)

Figure 19: Impact categories for the PEF-profile (19)

3 Interpretation

In this chapter, the results from the Life Cycle Impact Assessment are presented. First, the impact of 1000 times use of disposable underpads are described. This is done by showing the impact in CO_2 equivalents in a (network)tree. This visualization provides a traceable overview of the impact contribution of the different parts within the life cycle of the underpad. The impact is also expressed in a graph showing the Single score per component of the life cycle. Another graph shows the impact in the specific impact categories from the PEFCR, described before. The same is presented for the reusable variant, where the impact of using 10 underpads with each 100 washing cycles is shown. In the last section, the two variants of underpads are compared. They are compared based on the characterization impact on climate change and based on the single score.

3.1 LCA results

3.1.1 Disposable underpad

Figure 20 shows the impact tree on climate change of a disposable underpad expressed in CO_2 equivalents. In this graph a cut off of 6% is utilized to enhance the readability and to identify impact hotspots. This cut off means that only the components within the life cycle with an impact of 6% of more of the total impact of the product are shown. The whole tree can be found in the Appendix. It can be seen that the use of 1000 disposable underpads contribute to an impact of 117 kg CO_{2e}. The use of fluff pulp (19,7 kg CO_{2e}) and the incineration of the underpads (26,5 kg CO_{2e}) contribute the most to this impact category. In addition, the use of polyethylene (18,1 kg CO_{2e}) and polypropylene (13,7 kg CO_{2e}) have large effects as well.

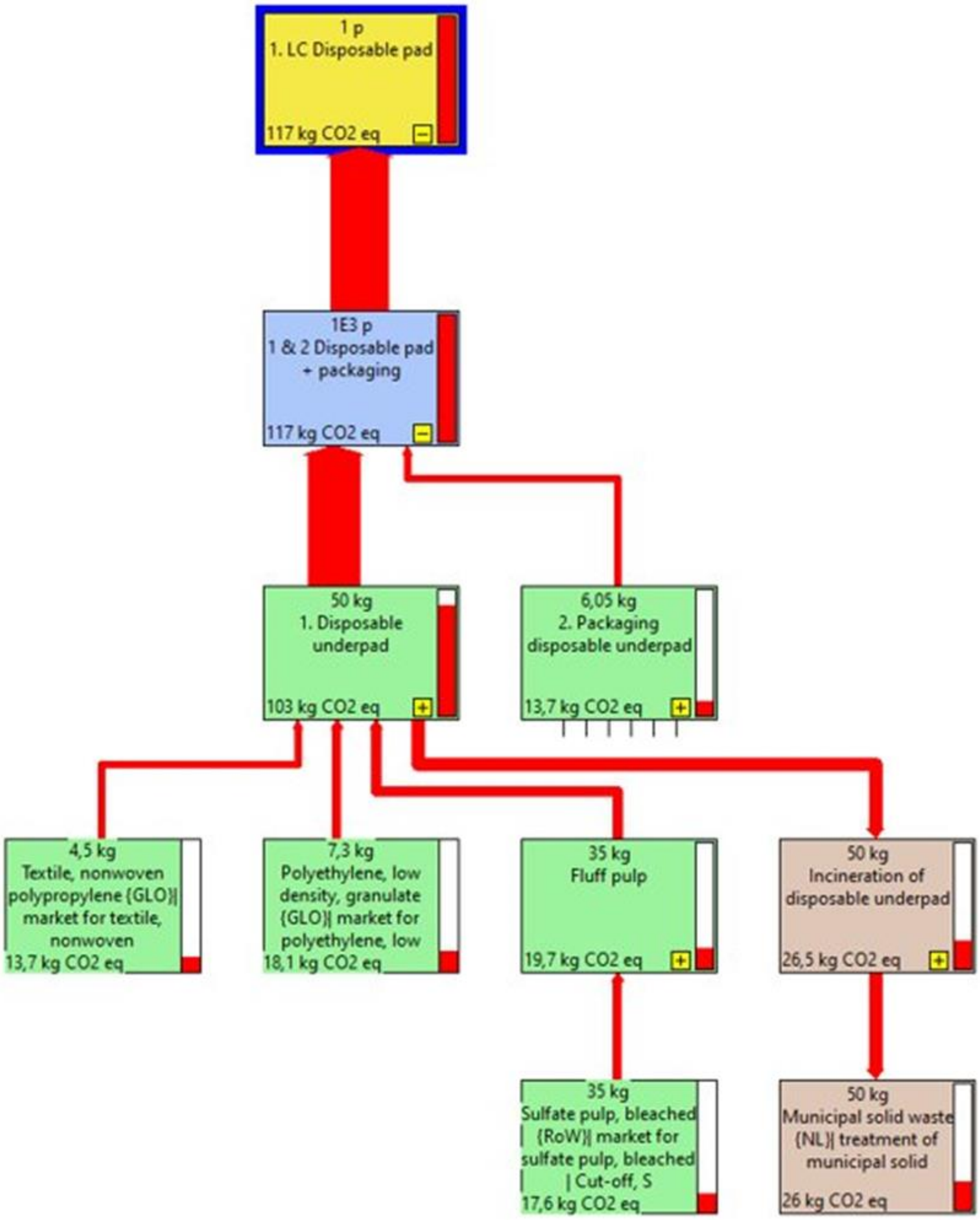


Figure 20: Tree of disposable underpad, impact in CO_2 equivalents, calculated with EF 3.1, cut off 6%

In Figure 21 the total impact is divided over the different components of the life cycle. Moreover, the impact is not only expressed in climate change. As described in the method section, six impact categories are taken into account. The impact of all the categories is combined into one single score, expressed in micro points (mPt). First of all, it shows that the materials needed for the production of the underpad have a high impact score. Another interesting finding is that the end of life of the underpads has a high contribution to climate change, but does not contribute much to the impact on the other five impact categories.

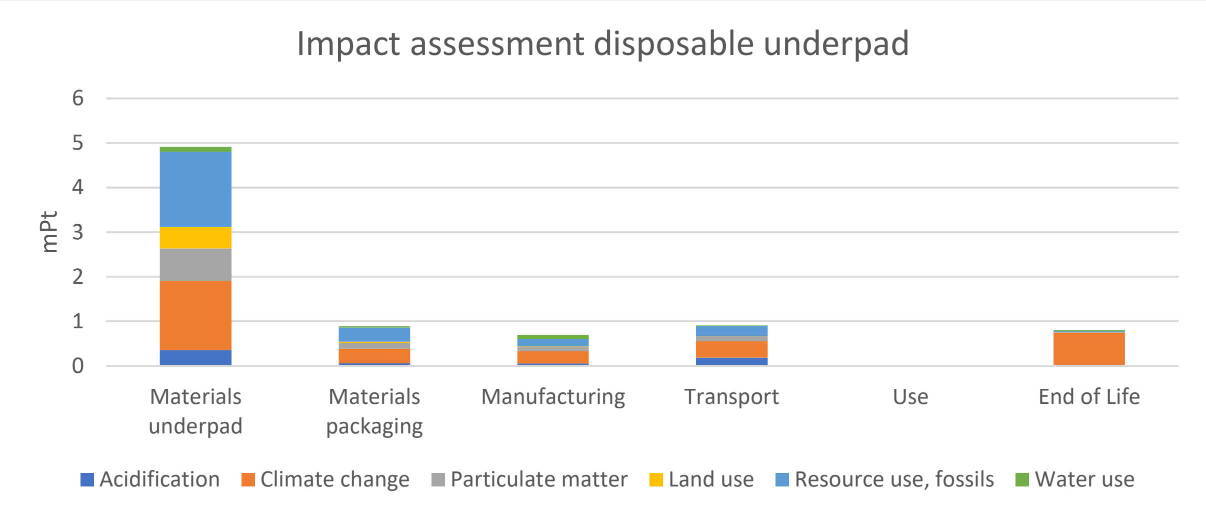


Figure 21: Impact of the different parts of the disposable underpad calculated with EF 3.1, expressed in a single score

Since materials of the underpad have the highest contribution in the life cycle, it is important to gain insights into which materials cause this high single score. In Figure 22 can be seen that the bleached fluff pulp has the highest impact, together with polyethylene and the nonwoven polypropylene. However, only 3% of the underpad consists of Super Absorbent Polymers (SAP's), and this small amount leads to 5% of the total impact of the whole life cycle.

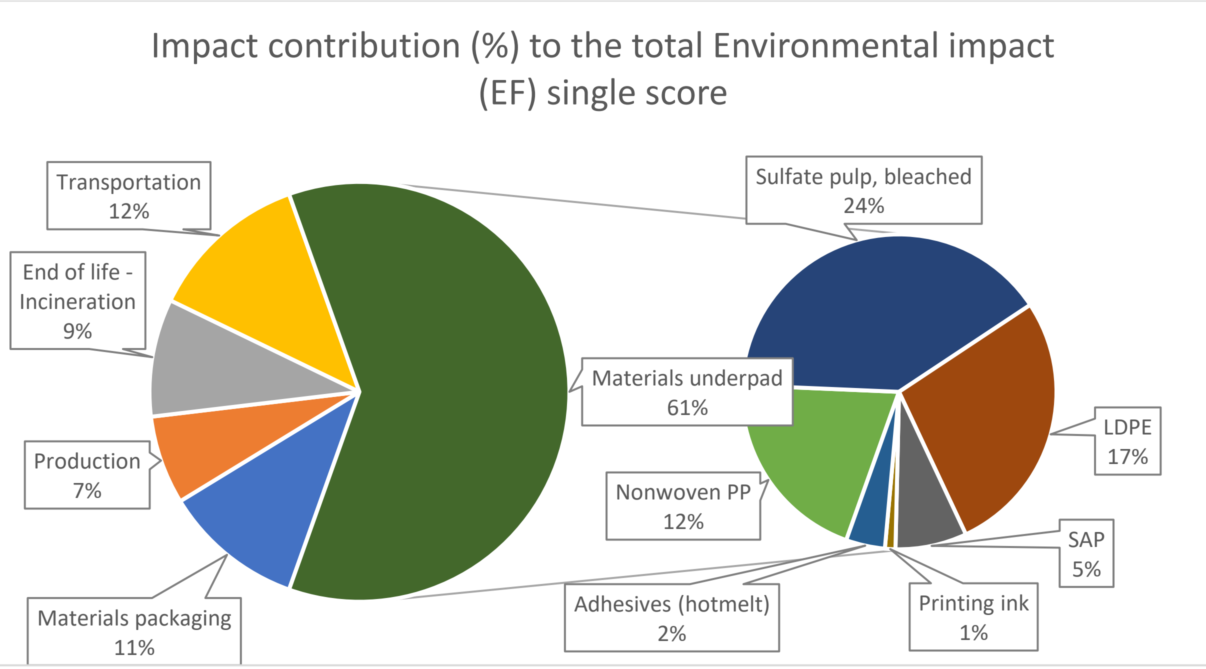


Figure 22: Impact of the disposable underpad calculated with EF 3.1, expressed in a single score. Especially zoomed in on the impact of the materials.

In Figure 23 the same data is displayed as in Figure 21. However, in this graph it is more clear which part of the life cycle contributes to which impact category.

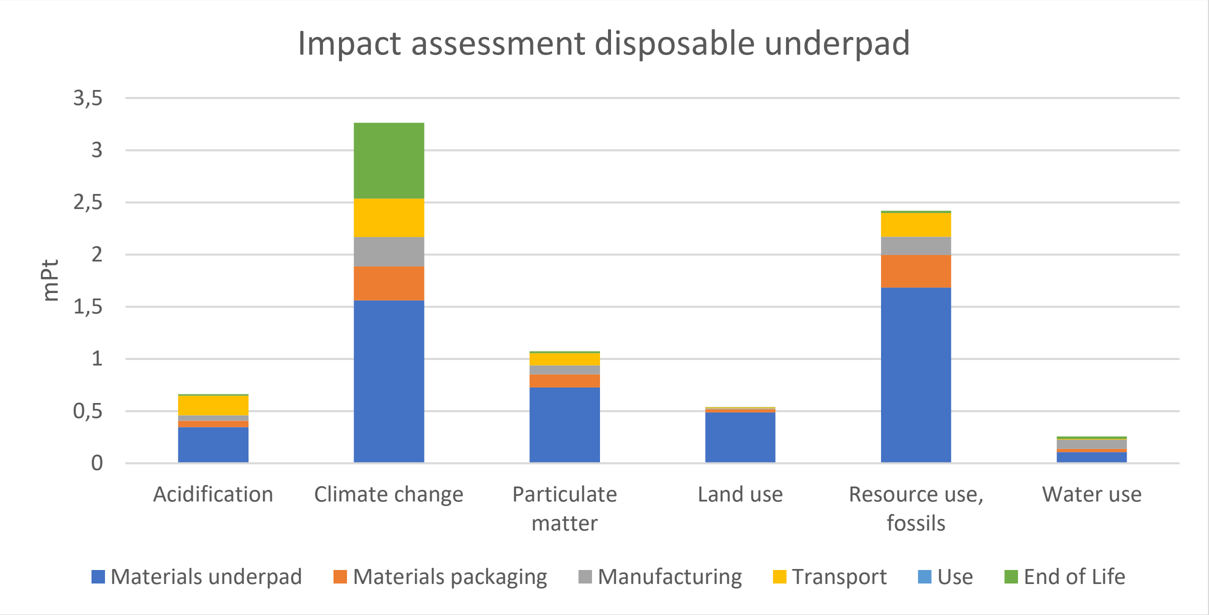


Figure 23: Impact of the different parts of the disposable underpad calculated with EF 3.1 expressed in six impact categories

Acidification

There are two components contributing the most to this impact category. These are the materials of the underpad and the transportation during the life cycle.

Climate change

Again, the materials of the underpad have a high impact on this impact category. Secondly, the end of life, the incineration of the underpads have the highest contribution.

Particulate matter

The materials of the underpad have the highest contribution on particulate matter. In depth research shows that this is mainly caused by the use of bleached fluff pulp.

Land use

The materials of the underpad causes almost the total impact on this impact category. Bleached fluff contributes the most.

Resource use, fossils

The impact on fossil resource use is the second highest peak. This is mainly due to the materials used for the underpad and materials used for packaging. A deeper insight show that this is due to the use of polyethylene and polypropylene.

Water use

All life cycle phases have a small contribution to the impact on water use. The materials of the underpad and the manufacturing the most.

3.1.2 Reusable underpad

Figure 24 shows the tree of the impact on climate change of the reusable underpad with a cut off of 6%. 1000 use times of a reusable underpad result in 49,4 kg CO_2 equivalents. It can be seen that the most impact is created by the washing process. Soap (7,45 kg CO_{2e}), electricity (9,45 kg CO_{2e}) use have the highest impact. Besides, the transportation back and forth the washing company (5,6 kg CO_{2e}), contributes as well.

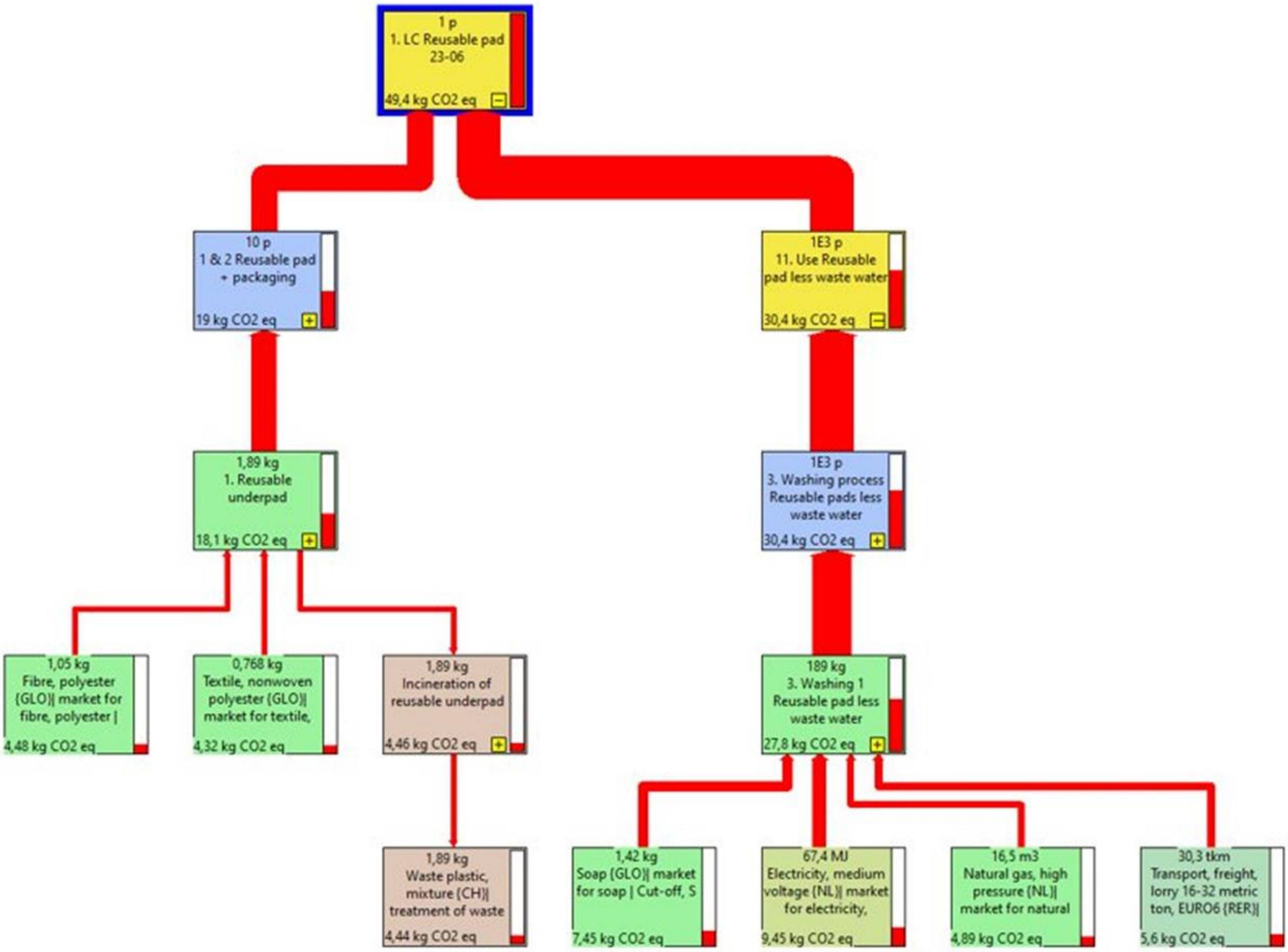


Figure 24: Tree of reusable underpad, impact in CO_2 equivalents, cut off 6%

Figure 25 shows the impact in single score based on the six impact categories per component of the life cycle. It can be seen that the impact of the use phase, the washing and drying process, it the highest. This is mainly due to the impact on fossil research use, and secondly to the impact on climate change.

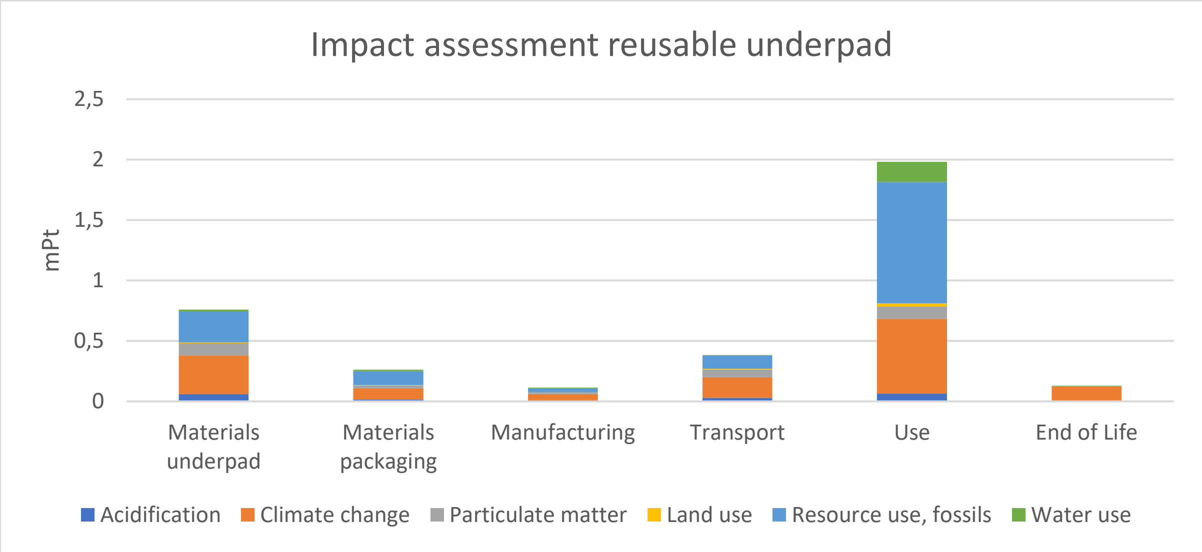


Figure 25: Impact of the different parts of the reusable underpad calculated with EF 3.1, expressed in a single score

In Figure 26 the same data is used as in Figure 17, but this graph gains inside in which part of the life cycle contributes the most to an impact category.

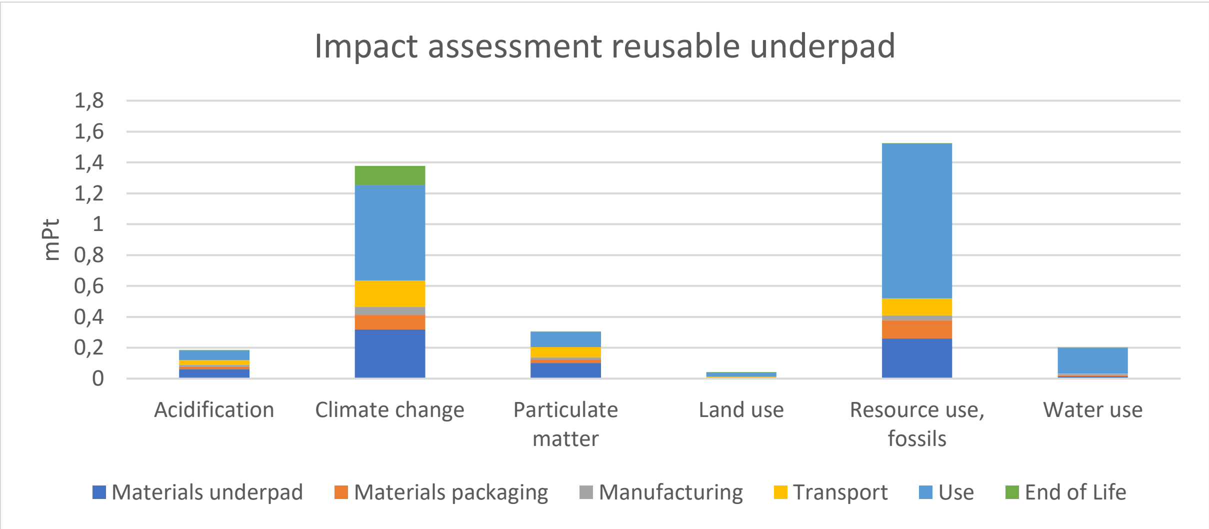


Figure 26: Impact of the different parts of the reusable underpad calculated with EF 3.1, expressed in six impact categories

Acidification

The use phase (washing and drying) and the materials of the underpad have the highest contribution to this impact category. In depth research shows that de impact of the use phase, is mainly caused by the use of soap.

Climate change

The use phase turns out to have the highest contribution to this impact as well. The rest of the impact is mainly caused by the materials of the underpad.

Particulate matter

Again, the use phase and the materials of the underpad have the highest contribution to this impact. Transportation during the life cycle contributes as well. Detailed research shows that the impact of the use phase is mainly caused by the use of soap.

Land use

This variant underpad has a really small impact on land use. The impact created is almost totally due to the use phase. More in depth research shows that this is mainly caused by the use of soap.

Resource use, fossils

The impact in this category is mainly caused by the use phase. In depth research shows that this is due to the use of gas during the washing process.

Water use

The impact on water use is almost totally created by the use phase.

3.2 Comparison

In this graph a comparison on all six impact categories between the disposable and reusable underpad is made.

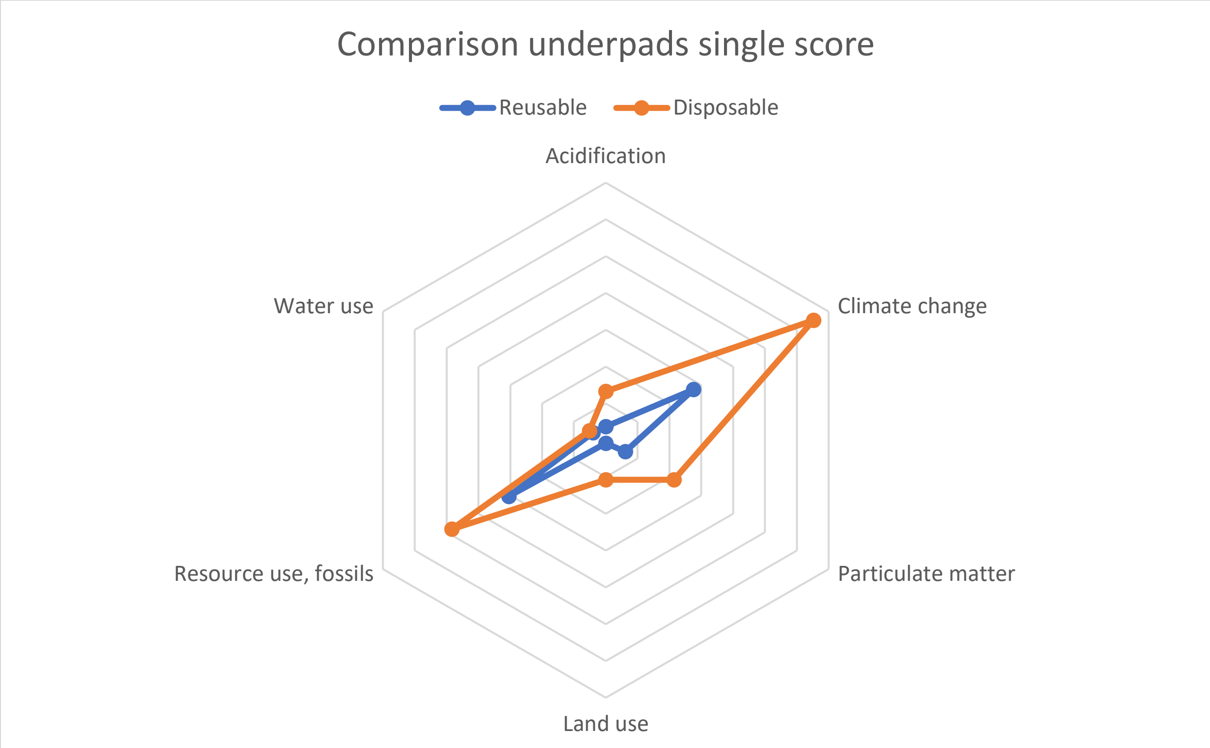


Figure 27: Comparison between the reusable and disposable variant on the six impact categories, calculated with EF 3.1

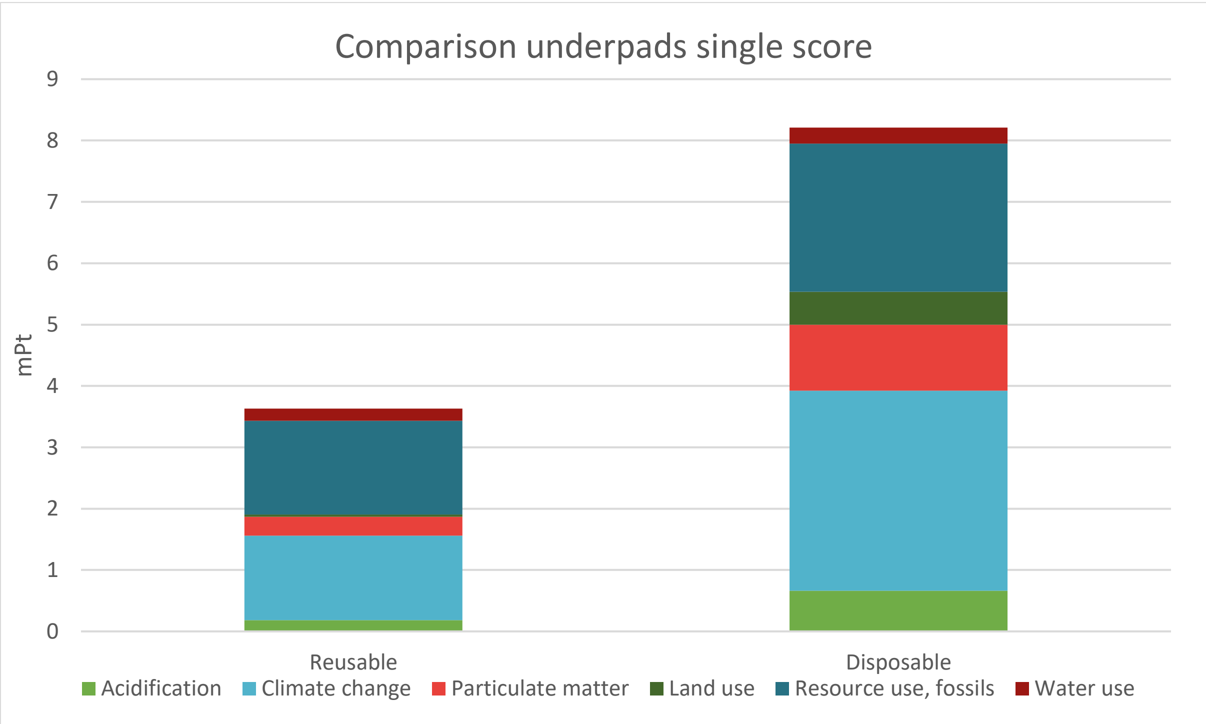


Figure 28: Comparison of the reusable and disposable underpad expressed in a single score, calculated with EF 3.1

In this graph the underpads are compared based on the single score. All six impacts categories are combined and expressed in mPts. With the combination of all the impact categories, the disposable has an impact of 8.1 mPts. The reusable as an impact of 3.7 mPts. In the graph underneath is showed where in the life cycle this impact is created.

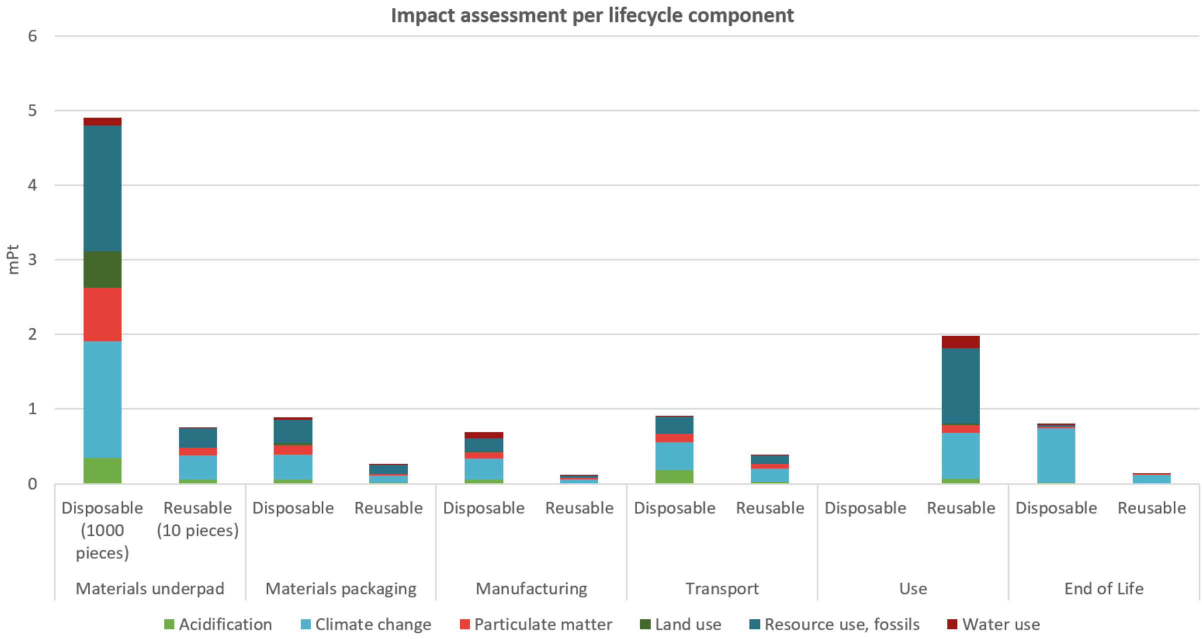


Figure 29: Comparison of the reusable and disposable underpad per life cycle, calculated with EF 3.1

Extra findings:

- When the 12+ impact categories of the PEF-profile, showed in Figure 19, are taken into account, the reusable variant scores better on almost every category. There is only one category in which the disposable underpad has a lower impact. This is freshwater eutrophication. This is due to the use of soap during the washing process.
- The electricity required for the washing and drying process of the reusable underpad is generated using an average electricity production mix of the Netherlands. In a second scenario, solar energy is used to wash the reusables. In this case, the impact of electricity use will be almost zero. The impact on climate change of 1000 times use of the reusable underpad will then be approximately 40 kg of CO_2 equivalents. Besides the impact category 'Climate change', there are no big differences compared to scenario 1. In most of the other impact categories, the impact is slightly smaller.

4 Conclusion

In this LCA report the environmental impact of the disposable and reusable underpads used in hospitals in the Netherlands are investigated. The functional unit of this study was defined as: *"Absorbing body fluids 1000 times with a 60x60cm underpad to keep the surface underneath and the patient's skin dry in health facilities in the Netherlands."* 1000 disposable underpads were compared with 10 reusable underpads, all washed 100 times. The system was analysed from a cradle to grave scope, which includes the material extraction for the underpad and packaging, the production, the transportation during the whole life cycle, the washing process and the waste treatment.

4.1 General conclusions

Using a reusable underpad has an overall lower environmental impact compared to the use of a disposable variant. With the assumptions made in this study, 1000x use of a disposable has an impact of 117 kg CO_{2e} and 1000 times use of a reusable has an impact of 49,4 kg CO_{2e}. Therefore, using a reusable variant of 60x60 cm halves the environmental impact.

The conclusion whether one variant is more environmentally friendly cannot be drawn solely on the basis of CO_2 equivalents. However, based on the single score graph, containing several environmental impact categories, it can be concluded that the reusable variant has an overall lower environmental impact compared to the disposable variant. As shown in Figure 26, the impact categories taken into account are acidification, climate change, acidification, particulate matter, land use, water use and fossil resource use. Summed up, the disposable has an impact of 8,1 mPts, the reusable of 3,7 mPts. In this case too, the use of the disposable has more than twice the impact of the reusable underpad.

Due to these large differences between the disposable and reusable variant, in both CO_{2e} and in mPts, the conclusion would not be different if the dimensions described in the functional unit are changed to the current used designs. This is showed in the table underneath.

Table 16: Calculation of the impact of the reusable variant of 85x75 cm

	Dimensions of 60x60 cm	**Dimensions of 85x75 cm**
Cm^2	3600	6375
Kg CO_{2e}	49,4	→87,5

Fluff pulp has a high impact on all the six impact categories. The other materials, mainly polyethylene and nonwoven polypropylene have a large impact as well. For the reusable, the use of soap during the washing process has large effects on various impact categories. Gas and electricity use play an important role as well. In a second scenario, the use of solar and wind energy is assumed. This decreases the impact on climate change substantial.

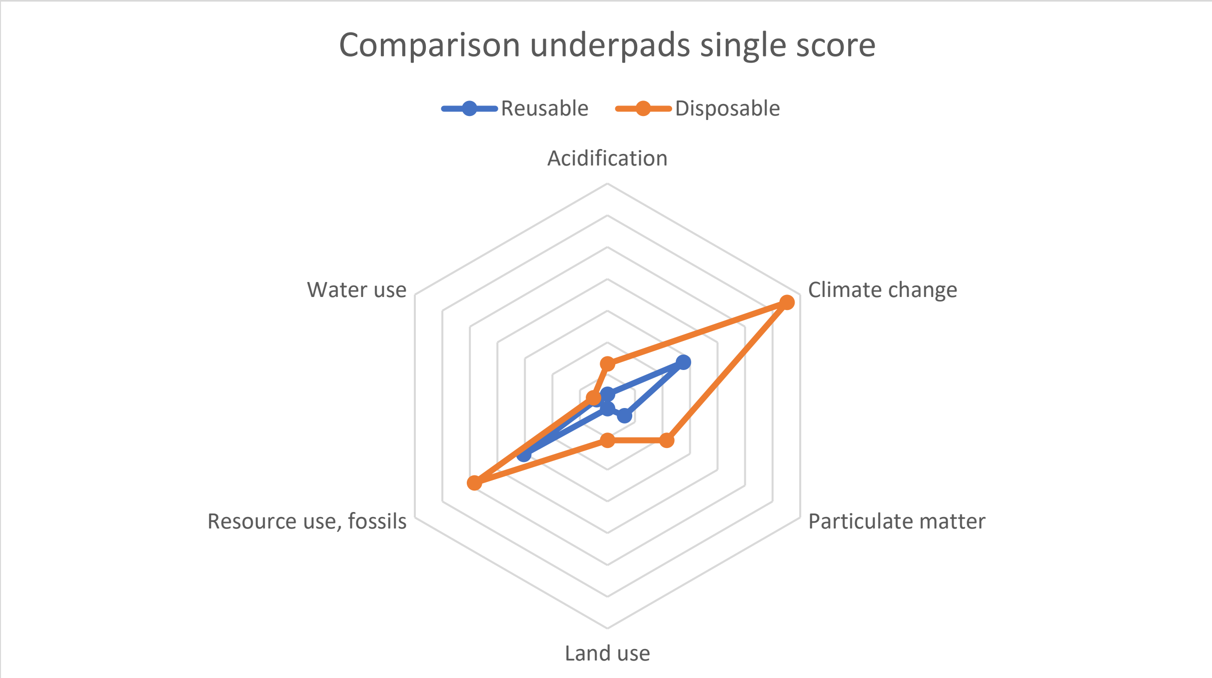


Figure 30: Comparison between reusable and disposable underpad, calculated with EF 3.1

4.2 Specific conclusions

Acidification

The impact of the disposable underpad on acidification is 3 times higher than the reusable. In both cases, the materials of the underpad have a high impact on this impact category. In case of the reusable, the use phase has a large contribution as well.

Climate change

This is the category on which the normalised and weighted impact of the disposable is the highest. The impact of the disposable underpad on climate change is almost 2,5 times higher than the reusable. In both cases, the materials of the underpad have a high impact on this impact category. The waste treatment of the disposable contributes a lot as well. For the reusable the washing process has the largest effects. Important to note is that the electricity used during the washing process contributes a lot to this result. When wind or solar energy is used, this impact can almost be neglected.

Particulate matter

The impact of the disposable underpad on particulate matter is more than 3 times higher than the reusable. In both cases, the materials of the underpad contribute to this. In case of the disposable the fluff pulp has the highest contribution. In case of the reusable the use of soap during washing has a large impact as well.

Land use

The impact of the disposable underpad on land use is more than 10 times higher than the reusable. The impact of the disposable is almost totally caused by the fluff pulp. The impact of the reusable is really small on this category.

Resource use, fossils

This is the category on which the normalised and weighted impact of the reusable is the highest. The impact of the disposable underpad on fossil resource use is approximately 1,5 times higher than the reusable.

Water use

Most water is used during the production of the disposable underpad and the material extraction of fluff pulp. In case of the reusable the washing process has influence on water use. The impact on water use for the disposable is only slightly higher than the impact of the reusable.

5 Discussion

5.1 Limitations of the study

Although many companies were contacted in the starting phase of this research project, it proved to be difficult to get in touch (with the right employee). Additionally, inventory data was not always readily available. Missing data had to be determined and estimated based on literature and expert judgement, a fairly time-intensive process. Furthermore, the absorbent underpads are used for a lot of different applications. These factors have led to several limitations of this study.

Limitations both variants

- Only two brands of underpads are considered. These are the brands who could deliver the most detailed information during the inventory analysis phase. Other brands / producers of underpads can use different materials or have different weight ratios. This will have an influence on the overall environmental impact. For example, a heavier reusable underpad would lead to a significantly higher impact. It was found that in Netherlands reusable underpads from 335 till 525 grams are used. In addition, the total weight of the disposable variant varies as well per hospital.
- During incineration and washing the weights of the dry underpads are taken into account. The weight of urine and defecation is not taken into account. This should be considered in further research.

Limitations disposable underpad

- In this study the incineration of plastic and municipal solid waste database is used, because this most closely matches the incineration of the underpads in the not specific hospital waste. However, in some hospitals the underpads are dropped in the specific hospital waste. This waste is incinerated at a higher temperature. The CO_2 emissions of hazardous waste are higher than those of non-hazardous waste(32). When the hazardous waste treatment is chosen in the Ecoinvent database, the impact is doubled. This might also be due to the chemicals and other materials which may be present in hazardous waste.

Limitations reusable underpad

- Based on the different applications it is difficult to define a comprehensive functional unit. In this study a reusable underpad of 60 x 60 cm is assumed, which is not available yet. Although, companies like Hebo van Dijk are developing a variant with these dimensions. This will be described in the recommendations →redesign section of this report.
- New information from Hebo van Dijk which was received after the inventory analysis phase showed that ratio of the soaker materials might be different than assumed in this research. This lowers the impact on climate change of the reusable underpad, as seen in the sensitivity analysis in the Appendix.
- Another factor used in this functional unit is that the reusable underpad is only used 100 times. In the prescription a use time of at least 100 times is described. In reality, the reusable underpad could have a longer lifetime of 120 uses.
- The impact of microplastics (which are released during the washing process) is not yet included in the EF 3.1 method. However, experts say the filters of keeping microplastics outside the wastewater are very good nowadays. Therefore, it is likely that this will not have a substantial impact on the amount of microplastics in nature.
- In this research the assumption was made that the reusable underpads are incinerated after 100x uses. The reusable underpads are incinerated when they are thrown away in the

hospital. While washing companies can recycle the fabric, if they decide the underpads are unusable(15). This will lower the impact of the end-of-life component of the reusable.
- The standard 'soap' process of the Ecoinvent database is used in this study. In reality, the composition of the soap is adjusted to the product which needs to be washed. Chrysteyns is the biggest soap supplier in the Netherlands. Their soap contains bleach, detergent, alkali and enzymes. The ratio of these components is unknown, but when 25% of every ingredient is taken, the impact is slightly lower. This is shown in Figure 38 in the Appendix.

This limitation can increase or decrease the impact of the disposable and reusable variant. Since the differences between the impacts of these two variants are substantial, it is unlikely that this limitation will influence the conclusion.

5.2 Data quality assessment

Some data quality is not as good as others. In this section the insecure data is described.

Disposable

- It was not possible to receive the weight percentages of the materials from Tena. Therefore, assumptions are made based on literature. One reliable source is the data from the EPD of the Tena Bed articles itself. However, this EPD is made in 2015 and therefore the percentages could have been changed. A big change in percentage in fluff pulp and SAP might have a large impact. However, it is important to note that the name and the absorption capacity of the articles are not different from now. In addition, the percentage of fluff pulp is checked with a disposable underpad currently used in an hospital in the Netherlands. This variant contains approximately the same amount of fluff pulp as assumed in this research. (Confidential information.)
- As described in the data quality analysis in the Appendix, the type of fluff pulp has a large influence. The choice in database of RER or RoW is important. Most of fluff pulp comes from Georgia, USA. Therefore RoW is chosen. However if the fluff pulp comes from Sweden, it can lower the impact.

Reusable

- The washing process has a high influence on the impact of the use of the reusable underpad. For this research, the average of data from the washing process of two companies is taken into account. It is not sure that every washing company has a sustainable washing process. Besides the washing data can differ between several locations of a company. Figure 29 shows that if the amount of gas and electricity will be 1,5 times higher, this leads to 1 mPt additional impact. Since the large difference in impact between the disposable and reusable, it is not likely that this will lead to another conclusion.
- After the results were processed, the amount of wastewater is assumed to be different. Instead of 2,5, this will be 4,5 litres water per kg laundry. This will increase the impact of water use of the reusable.
- The amount of TPU used to produce the reusable underpad is based on a rough assumption. For further research a sensitivity analysis on this material is recommended.
- The distance between the hospital and the cleaning company differs a lot. In this research 80 km is assumed. However, there are also hospitals in the Netherlands where the distance to the cleaning company is 5 km and there are hospitals where the distance is 150 km.

5.3 Comparison with literature

Not many comparable studies were found. This made it difficult to make assumptions in several cases. There are studies based on the comparison of diapers, but in a diaper a substantial higher percentage of SAP is used. Besides, most reusable diapers are used at home, which leads to a less sustainable washing process.

Only one other comparable life cycle analysis of absorbent underpads can be found(23). In this study, three types of reusable underpads are considered in comparison with two disposable underpads. The impact of the reusable variant is mainly due to the energy use of the laundry. It can be assumed that this is a combination of gas and electricity use. The materials of the soaker and the disposal of the materials (waste treatment) contribute the most to the impact of the disposable. It shows that the disposable variants have a higher impact than the reusable ones. The reusable with the lowest weight has the least impact.

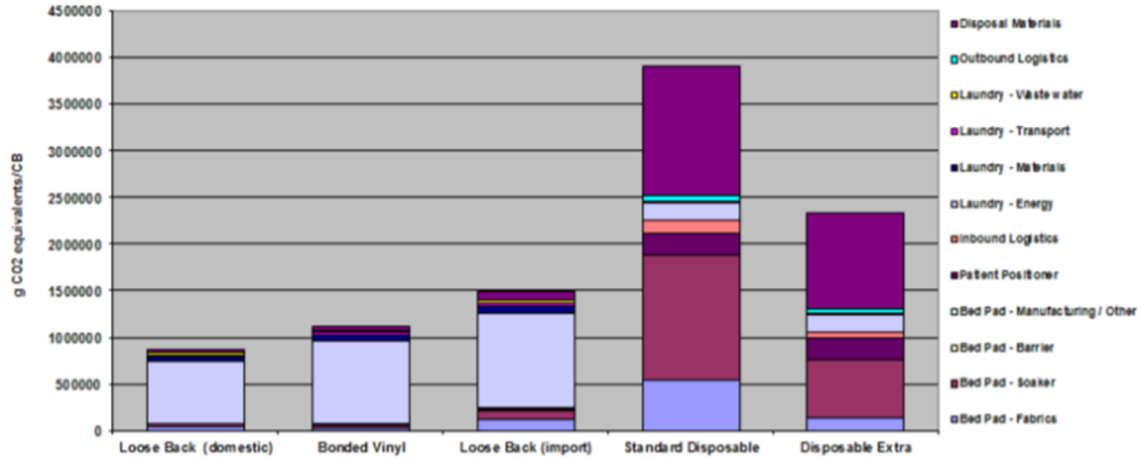


Figure 31: Results of a comparative LCA of underpads in 2012 (23)

These results correspond to the outcome of this study. However, the functional unit of this eco-efficiency research was different. A functional unit of 1000 patient days was assumed. In addition, it was assumed that there are 2 reusable, 8 normal disposable and 4 extra absorbent disposable underpads are used during one day. This assumption has a lot of influence on the results. Besides, in the publication the dimensions of the underpad are not described. Furthermore, it is important to note that the study was funded by Vintex, a manufacturer of reusable underpads.

5.4 Recommendations

5.4.1 Refuse

The most important recommendation is to **use less underpads.** Underpads are used for a lot of different applications. After multiple dialog sessions with stakeholders, it was concluded that it is not always necessary to use an underpad. Often is it done out 'ease'. To follow the ''R-ladder'', refuse and reduce strategies are generally better than reuse and recycle strategies (or, product-systems). Behavioural education of employees should therefore be a core strategy when working towards more sustainable practices within organizations that utilize underpads.

The disposable underpads are used for a lot of different applications. Besides, there are used at different departments inside the hospitals. The statistics of this, differ per hospital. In the LUMC, most underpads are used on the obstetrics department, during childbirth. In addition, they are frequently used on the Intensive Care Unit (ICU) and the gastrointestinal-liver department. Statistics of the Radboudumc show that most underpads are used on the urology department. The obstetrics department and the ICU are not part of the top 3 in this hospital. This shows that the use of absorbent underpads differs a lot between hospitals.

Figure 32: Visualization of the R-ladder(9)

The best way to change the use of (disposable) underpads is to refuse them for several applications. At this moment, they are used for(12):

- Catching urine and defecation to protect the hospital bed
- Catching wound fluid
- Catching blood and amniotic fluid during deliveries
- Washing hair of patients
- Protecting arm- and leg rest from blood splatter
- Catching (tear) fluids underneath the head of a patient
- Muffling noise from instruments on a trolley
- Cleaning up blood from the ground

It is likely that for the last four applications other solutions can be found, wherefore the use of underpads can be reduced.

Based on in practice studies, it is already found that the dermatology department can use towels instead of disposable underpads. In the UMCG, the arm and leg support are now covered with towels to catch the blood during these small operations.

Figure 33: Using cotton cloth instead of underpad (Bergman clinics)

Besides, Bergman Clinics Eyes in Ede uses cotton cloths underneath the head of the patient instead of disposable underpads. These are all simple examples of refusing the use of disposable underpads.

The end-of-life component, incineration, of disposable underpads has large effects on climate change as well. When the underpads are thrown in the specific hospital waste, this impact will be even higher. The specific hospital waste needs to be incinerated in ZAVIN in Dordrecht. Due to the higher incineration temperature, the more packaging needed during transportation, and the longer transportation distance, the impact of this is higher than the impact of the normal hospital waste. Therefore, **more clear regulations around waste are needed**, **allowing the underpad thrown in the specific hospital waste only when it is necessary**.

5.4.2 Reuse

Secondly, in cases where it is necessary to use an underpad, it is recommended to **use a reusable underpad instead of a disposable** variant in hospitals in the Netherlands. The impact of the reusable variant is substantially lower in almost all the impact categories. For instance, in the UMCG 325 000 disposable underpads per year are used. By making this change a reduction of 22.000 kg CO_{2e} per year can be saved. This has the same impact as 13 000 hamburgers, which has the same impact as 85 000 vegetarian burgers. However, for specific medical reasons (like the use of cytostatics) a disposable underpad is still needed. This is only a small percentage of the total use of underpads.

Although this study does not focus on a specific hospital and is applicable for the whole country, it is important to state the main contributors of environmental impact:

- While using the reusable underpad, it is important to focus on **minimizing the use of soap, electricity and gas**. With state-of-the-art sustainable washing processes, the impact of the process can be minimized, as proven by the washing-sector.
- **Using electricity that is locally produced by solar panels and/or wind turbines** is recommended, as the emission from these energy sources is zero.

One of the biggest problems are costs. The reusable underpad seems to be more expensive than the disposable ones. The purchasing costs of reusables are way higher than those of the disposable. However, one reusable underpad can be used at least 100 times, and on an average 120 times. Previous changes show that a switch from disposable to reusable leads to less usage of the product. This might be due to the raise of awareness, because it changes the behaviour of nurses and doctors. Ruud Heeroma of Cleanlease thinks that it feels weird to use something which needs to be washed afterwards, when it does not get dirty. Therefore, it is not necessary to purchase as much reusables as expected bases on the use of disposables.

During a NEN-meeting about sustainable incontinence products, someone noted that the incineration of hospital waste costs money as well. The use of disposables results to high amount of waste. Especially the incineration of Specific Hospital Waste increases the costs due to the higher temperature, and specific packaging and transportation regulations. Afterwards, the content of the waste cannot be traced. Therefore, the costs are not allocated to the use of disposable underpads.

5.4.3 Redesign

Redesigning a medical device can help to lower the environmental impact, without negative consequences for medical doctors, nurses or patients. To conduct information for this redesign, information from the field is necessary. Contact was made by uploading a Linkedin-post, attending the Circular Textile Days in Den Bosch, and presenting a short pitch in Haren at a meeting of the Green Week from the Koninklijke Nederlandsche Maatschappij tot bevordering der Geneeskunst (KNMG). Besides, the NEN-meeting for sustainable incontinence materials was attended. Therefore, information from the Radboudumc, UMCG, LUMC, Santeon Group, ErasmusMC and Amsterdam UMC was gathered.

5.4.3.1 Reusable

At this moment, the reusable underpads used in the hospitals have dimensions of 75x85 cm or more, with an absorption capacity of at least 1500 ml. This is often more than needed for the application. The large dimensions and high absorbance capacity leads to a heavy product. Besides, when more absorbent materials are used, the drying process takes more time and uses more energy.

From the LCA it can be concluded that the washing process of a reusable underpad has the greatest impact. The heavier the product, the more electricity, gas, water and soap are needed to wash and dry the absorbent pad. Therefore, at this moment several production companies are working on a new design. For instance, Abena is working on a variant with an absorption capacity of 1000ml.

HeboVanDijk 90 years
Concept & Contract Textiles

Figure 34: Picture of the meeting about redesigning a reusable underpad

Furthermore, Hebo van Dijk produces reusable underpads used by clients from Cleanlease and Rentex. This company is working on a reusable underpad with a lower environmental product as well. To make sure that all the wishes and requirements for the redesign are fulfilled, a meeting was organised. Cleanlease and Rentex gave information about the washing process. Staff from the LUMC, UMCG and AMC have knowledge of the indications for which a reusable underpad can be used. Besides, the UMCG and LUMC performed research about staff behaviour around underpads and their requirements and wishes. The LCA described before gave inside on the environmental hotspots of the reusable underpad. Besides, the results of the LCA can be used to show that the environmental impact of reusable underpads is lower compared to disposable ones of the same size.

The conclusion from this meeting was that a lower absorption capacity and smaller dimensions (60x60 cm), will result in a more sustainable product. Also, according to Cleanlease and Rentex, it does not matter how dirty an underpad is. They are able to wash everything clean.

Figure 35: Samples of new designs from Hebo van Dijk

5.4.3.2 Disposable

When it is not possible to use a reusable variant (e.g. the use of cytostatics), a **change in the design** of a disposable can reduce the impact as well. Since the use of fluff pulp is an environmental impact hotspot, this is an important material to focus on. The content of fluff pulp and the SAP ensure the absorption capacity of a disposable underpad. However, a high absorbance is not necessary for every application. For some applications, an underpad with less fluff pulp and SAP can be used.

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Appendix

Data quality

Assumptions and material choices that are made regarding the LCI inputs for SimaPro can have a large effect on the overall impact results. Therefore, a set of assumptions and different dataset choices are analysed.

In the first graph, the impact of the geographic location and the kind of sulphate pulp is checked. When the desired location is not present, Rest of World (RoW) can be chosen. When an activity takes place somewhere in Europe, RER can be chosen.

This graph shows that sulphate pulp production in Europe has a lower impact than the production in the rest of the world. This is a difference of 4,5 kg CO_{2e}, which is more than 25% of the impact. When the sulphate pulp is made from softwood, the impact is lower as well. This makes a difference of 2-4 kg CO_{2e}. It is important to note that the first two processes are a market process, the second two are not. In a market process all the indirect impacts are taken into account as well. For instance, the infrastructure of the factory and the transport processes.

It is assumed that the fluff pulp comes from the USA, therefore the Rest of World process is chosen. A ''market process'' represents an industry & market-average process, which fits the approach in this assessment. Therefore, the ''RoW market for'' process is chosen.

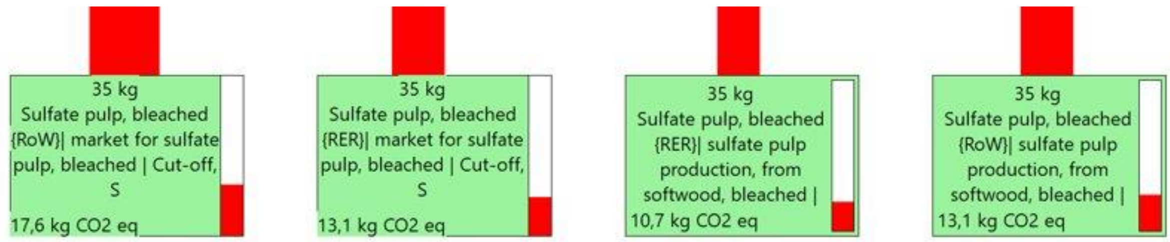


Figure 36: Different impacts of Ecoinvent databases of fluff pulp

The bottom layer of the reusable underpad has a blue colour. This layer is made of polyester, but Ecoinvent does not contain a standard process to dye this kind of material. A data quality test is done to test the impact difference of the different processes to dye. The impacts of dyeing yarn, and cotton in two different ways does not make a large difference. All the three processes are market processes. The impact for the process of continuous dyeing of cotton is in between the other ones, therefore this value is taken as an average.

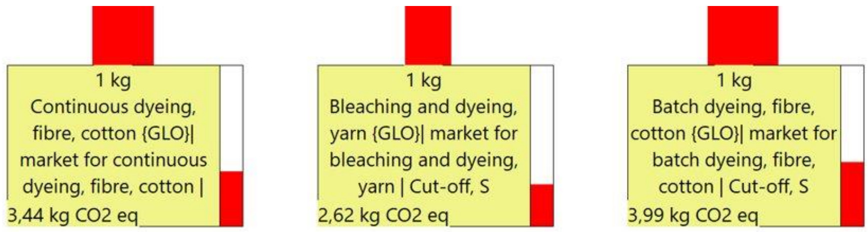


Figure 37: Different impacts of Ecoinvent databases of fabric dyeing

This last graph shows the impact difference between the waste treatments of the underpads. When NL or Europe is not available, it is common to use the database from Switzerland (CH). The two selected processes both are a kind of waste treatment in which the waste will be incinerated. For the first process it is assumed that the waste consists of plastic. In the second one a mix of materials is assumed, corresponding to average municipal solid waste of the Netherlands. Incineration of plastic has an almost 5 times higher impact than incineration of the municipal solid waste. The reusable pad is mainly made of plastic; therefore the first process is chosen. The disposable underpad is for 70% made of fluff pulp (not a plastic). Therefore, the second process is chosen.

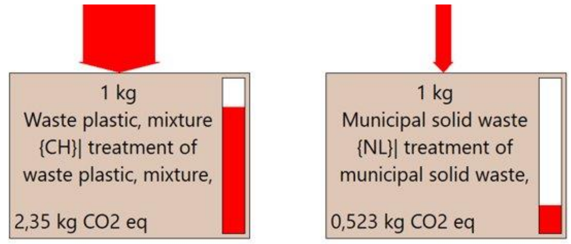


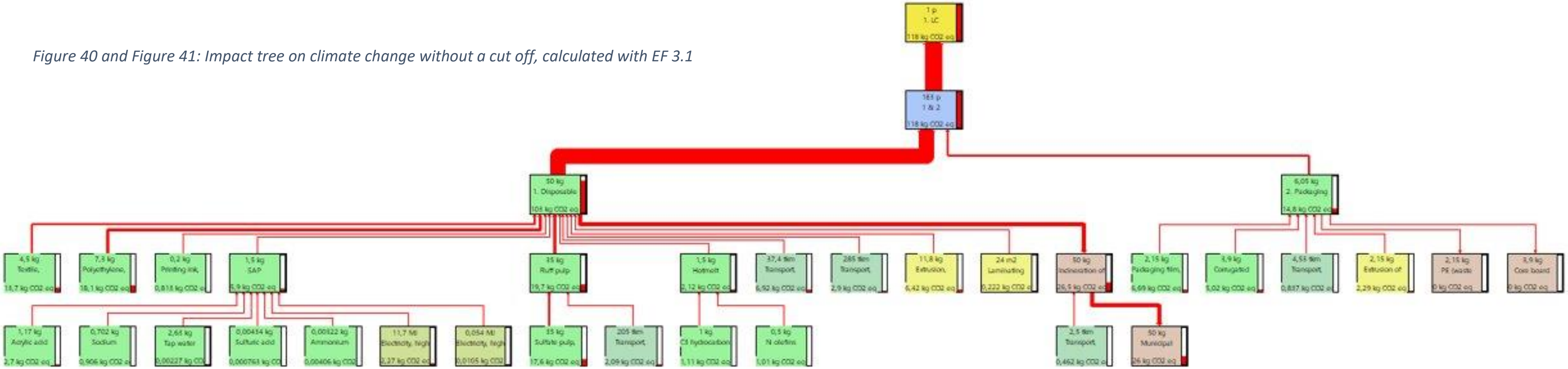
Figure 38: Different impacts of Ecoinvent databases of incineration of waste

Sensitivity analysis

A sensitivity analysis can be done to test the impact of a change in amount of a product. As described in the discussion, the reusable variant probably contains a bit more rayon (viscose) and a bit less polyester. Therefore, a sensitivity analysis is down on these two materials. Figure 35 shows that the impact of polyester on climate change is higher than the impact of rayon. So, this will lower the total impact of the reusable.

Figure 39: Impact of 1 kg polyester compared to the impact of 1 kg viscose

Figure 40 and Figure 41: Impact tree on climate change without a cut off, calculated with EF 3.1



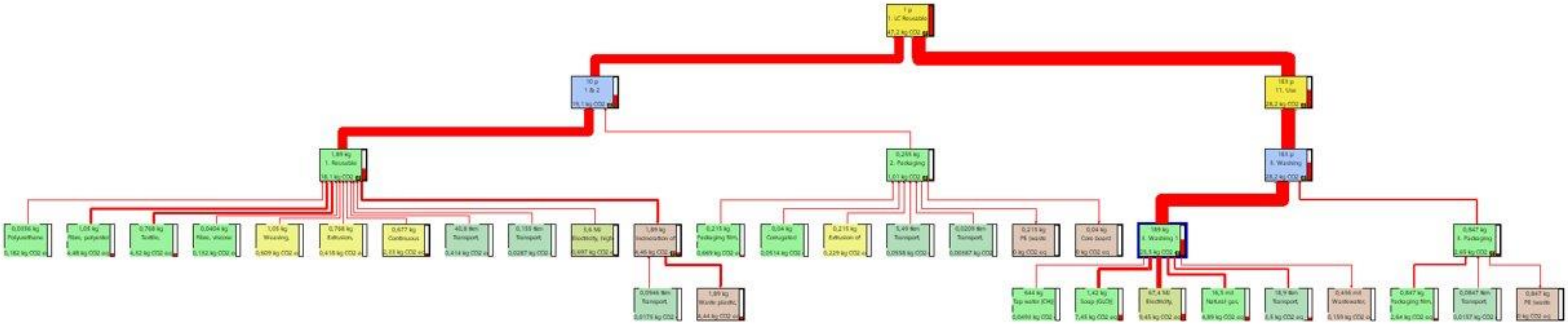


Table 17: Describing the transport distances between hospital and laundry service company

Radboud- Nedlin	118 km
UMCG- Rentex	90 km
MCL-Rentex	30 km
Emmen- Cleanlease Emmen	7 km
Leiden – Cleanlease Koudenkerk aan den Rijn	15 km

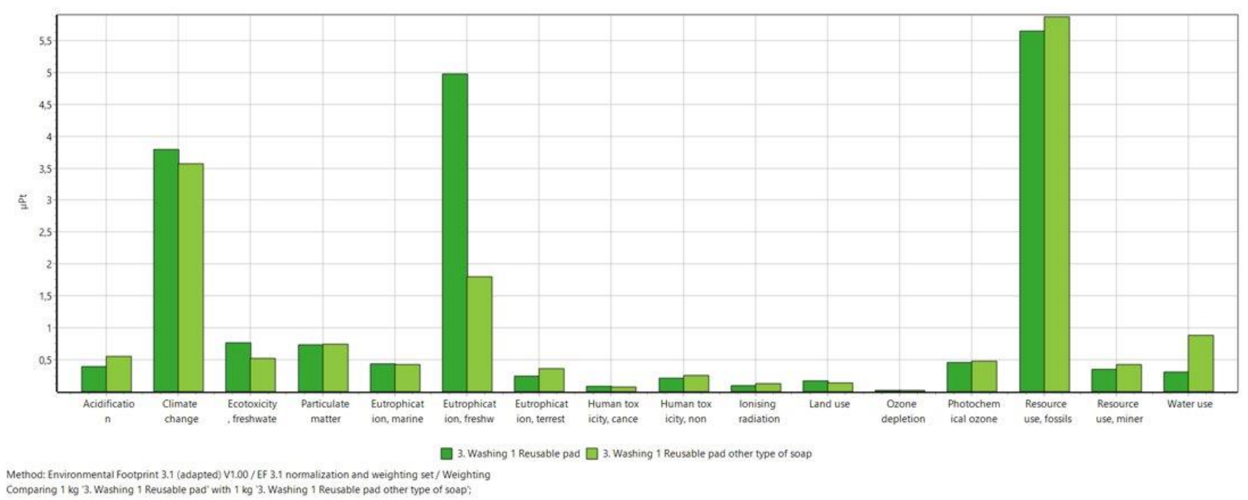


Figure 42: Dark green the database 'soap' was used. Light green, the four databases bleach, detergent, alkali and enzymes were used, each 25% of the total amount. Calculated with Ef 3.1