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The Outlook of Current Sustainable Business Models for Single-use Nonwovens

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ABSTRACT

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Resource scarcity, biodiversity loss and climate change are disruptors of today and impose great risks to businesses. Regulation and stakeholder demands are driving sustainable transformation, but businesses need to take sustainability into their core, not only to mitigate the risks these disruptors pose, but also to find competitive advantage and business opportunities from sustainability.

This study aimed to bring clarity to the concept of sustainable business model and give an outlook to the current sustainable business models in use by the nonwoven industry. The scope of the study was narrowed to single-use nonwoven products, moreover to diapers and wipes. Firstly, a literature review was performed, then a company website search was performed to draw an outlook of the current sustainable practises and business models in use within the value chains of the studied nonwoven products. The findings from the literature and company review were used as a basis for semi-structured interviews to get more insights and validation. A questionnaire was also sent out to nonwoven industry representatives to understand better different drivers and barriers guiding the sustainable transformation within the nonwoven industry.

It was concluded that sustainable business model creates value not only from the economic point of view, but also to the environment and society, without the expense of each category. As a result, currently most sustainable business models in use by the industry within the scope are related to raw material choices, features, product safety and sustainable production practises. However, businesses need to consider their businesses' sustainability throughout the life cycle of their product to call their business model sustainable.

Key words: sustainable business model, nonwoven, diaper, wipes

CONTENTS

ABBREVIATIONS AND TERMS

AHP	Absorbent hygiene product
BM	Business model
CR	Corporate responsibility
CSR	Corporate social responsibility
GWP	Global warming potential
EDANA	European Disposables and Nonwovens Association
EoL	End-of-Life
FSC	Forest Stewardship Council
ISCC	International Sustainability & Carbon Certification
LCA	Life Cycle Assessment
PE	Polyethylene
PET	Polyethylene Terephthalate
PLA	Polylactic acid
PP	Polypropylene
SAP	Superabsorbent polymer
SBM	Sustainable business model
SBMI	Sustainable business model innovation
SUP Directive	Single Used Plastics Directive (EU) 2019/904
SUSTAFIT	Sustainable fit-for-purpose research project
TBL	Triple Bottom Line

1 INTRODUCTION

Global disruptors such as biodiversity crisis, resource depletion and climate change bring great risks to businesses faster than ever. We have already gone beyond safe operating space at least in six of the nine planetary boundaries (Stockholm Resilience Centre 2022). In connection to the disruptors, rising stakeholder demands and tightening regulations are giving a boost for companies to transform their operations sustainable. And currently, companies are doing many actions to reduce their impact on the environment and societies by creating for example sustainability strategies. However, to reduce the risks, meet the demands and make the sustainable transformation, separate sustainability strategies aren't enough. Sustainability needs to be at the core of any business model.

Textiles are recognized as one of the most polluting industries in the world and hence in the centre of many upcoming sustainability policies (European Commission, Textiles n.d.). Nonwoven fabric is an important product group to focus on when talking about the sustainability of textiles, they are used in many kinds of applications due their adaptability and characteristics, but they are mostly still produced from fossil-based raw materials (Edana 2019). Advantages of nonwovens compared to knitted or woven fabrics are for example higher production rate and automation of the production system, thus offering both environmental and monetary benefits. (Karthik et al. 2016) Nonwovens can be divided into several product categories each with their unique features. In 2019 the largest markets by volume in Europe were hygiene (28,7 %), personal care wipes (12,3 %), construction (9,8 %) and automotive (6,2 %) segments. Thus, most of the nonwoven products are used in the single-use markets, such as hygiene. In 2019, the total production volume of nonwovens in Europe was 2 783 tons which equals to 76,90 million square meters. Most of Europe's nonwovens are produced in Germany, followed by Turkey and Italy. (EDANA n.d.)

The goal of this study is to provide information for the nonwoven industry regarding the concept of sustainable business model and case examples of existing ones in use globally. As the concept of sustainable business model isn't clearly specified in the literature, this study aims to gather information on the current

scientific literature on the topic and clarify it using two single-used nonwoven product examples: wipes and diapers.

Research questions of this study are:

- What is the definition of sustainable business model and are what kind of concepts, if any, exists in the scientific literature?
- What kind of sustainable business models and practises, if any, exists internationally regarding the chosen segments' value chain?
- What or who drives sustainability in the nonwoven industry regarding the studied products?

As a starting point, it is expected that:

- there isn't a clear definition regarding sustainable business models
- sustainable business models can't be categorized into a universal concept
- most of the sustainable business models in use globally regarding wipes and diapers are based on the use or renewable raw materials
- As the studied products are consumer goods, it is expected that consumers play one of the biggest drivers for sustainability

This thesis is done as a part of a research project, sustainable fit-for-purpose nonwovens (SUSTAFIT). The research project is led by Tampere University of Applied Sciences, Aalto University and VTT together with companies. The aim of SUSTAFIT project is to boost the use of sustainable fibres in nonwoven applications.

Chapter 2 of this study defines sustainable business model and related key definitions. Chapter 3 presents the life cycle of a nonwoven product and discusses different sustainability related viewpoints of each life cycle stage. Methodology of the study are presented in chapter 4. Results from the qualitative research are presented and analyzed in chapter 5. Discussion regarding the results and recommendations for future steps in chapter 6. Chapter 7 summarizes the conclusions of the study. All illustrations are done by the author if not otherwise stated.

2 SUSTAINABLE BUSINESS PRACTISES AND MODELS

Businesses shape the world in a way that affects society and the environment, both positively and negatively. On the other hand, societies and the environment affect businesses. The definition and shape of this relationship creates foundation for sustainability in businesses.

2.1 Sustainability in business

A famous definition of sustainable development was written in 1987 by the World Commission on Environment and Development as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs” in a publication called “Our Common Future”. Thus, sustainability as a concept has been around for decades, however until recently, it has been more of a niche concept in the business world. Today, sustainable development and practises in businesses are skyrocketing among all organization. Drivers for this are such as increasing stakeholder demands, tightening regulations, competitive advantage through sustainability and general awareness to fight climate change and preserve resources.

Concept of sustainability for businesses is multidimensional. It is traditionally portrayed as a balance between the economic, social and environmental impacts, a system called the Tiple Bottom Line (TBL) (Figure 1) created by John Elkington. The same concept is often referred also as the three pillars (people, planet, profit). TBL refers to the long-term health of ecological systems (environmental sustainability), people and community (social sustainability) and secure resources (economic sustainability). (Aalto University n.d.)

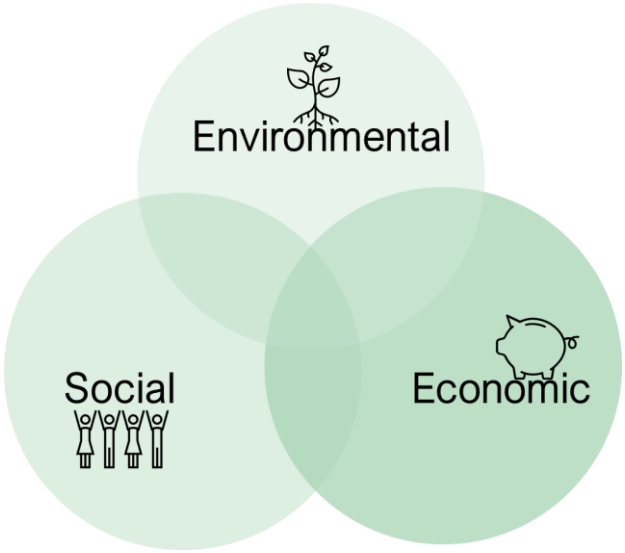


Figure 1. TBL portraying sustainability in business (Modified from Aalto University n.d.).

In the traditional model for sustainability (Figure 1), the three elements of TBL are equal, fairly independent entities with some interconnections. However, when talking about sustainable business, the business isn't centred only around financial key figures, but the environment and society have to be taken account as well creating an interlinked entity, rather than silos. Therefore, another way to portray three elements of sustainability is presented in Figure 2. In the nested circle model, dependencies of TBL are shown as subsystems of each other.

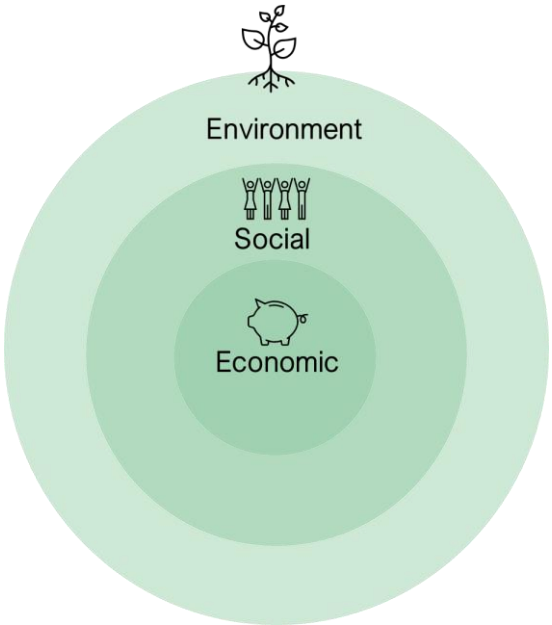


Figure 2. Sustainability portrayed as nested circles between elements of TBL (Modified from Aalto University n.d.).

When talking about sustainability in business, corporate responsibility (CR), or corporate responsibility (CSR) is a common buzzword used. CR refers to actions made by the organization that exceed the minimum requirements set by regulations aiming to improve the welfare of society as well as protect nature (Liappis et al. 2019). There are different levels of CR implementation in organizations and the magnitude of impacts of the CR actions differ. It is important to understand that in addition to TBL, there are several other elements that need to be included when taking sustainability at the core of business (Figure 3).

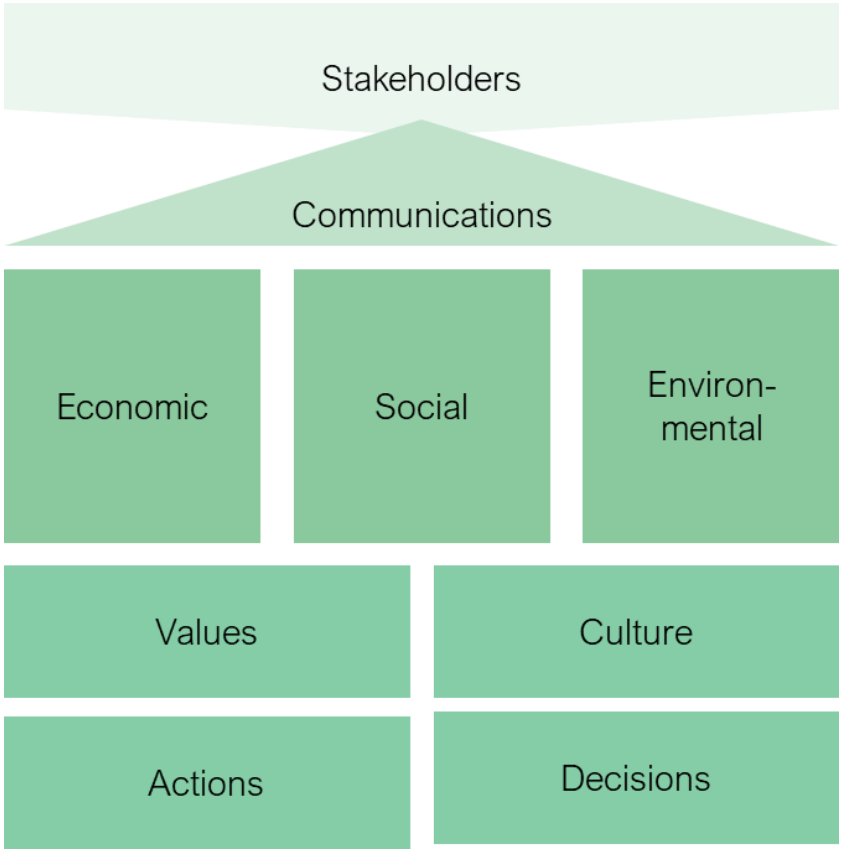


Figure 3. Corporate responsibility big picture (Modified from Liappis et al. 2019).

In order for businesses to create value while considering all aspects of sustainability, they need to apply sustainable business thinking. The concept of sustainable business thinking is linked to sustainable business models, innovations and value creation. Bocken et al. (2015) determined, that sustainable business thinking is “a way of thinking in which business is viewed as a positive force, which contributes to society and the environment, while still generating profit”.

2.2 Sustainable business models

Business model (BM) as a concept can be defined many ways, simply it is the way companies do business. In general, companies exist to create value and a business model relates to how that value is created. Value refers capital, such as financial or human. Additionally, business model relates to how the organization is designed and how it functions. Combined, business model is the organizational design which exploits opportunities and creates value. Desired features of great business model are for example meeting customer needs, build value to the company, differentiation of the company, is effective and is sustainable beyond near future. It is also important to remember that a specific business model that is good for that industry or market, may not work for others. (Bock & Gerard 2017) Boons & Lüdeke-Freund (2013) defines traditional business model as a concept that includes

- value offered by the business, *value proposition*
- managing of upstream relationships with suppliers, *supply chain*
- managing of downstream relationships with customers, *customer interface*
- costs and benefits from above mentioned, *financial model*

The challenge today is to either incorporate sustainability into the current business models or create new sustainable ones. The following chapters discusses the complex surroundings of the topic of sustainable business models by summarizing the reviewed literature on the definition, different concepts and frameworks created around it, target groups and levels to implement sustainable business models.

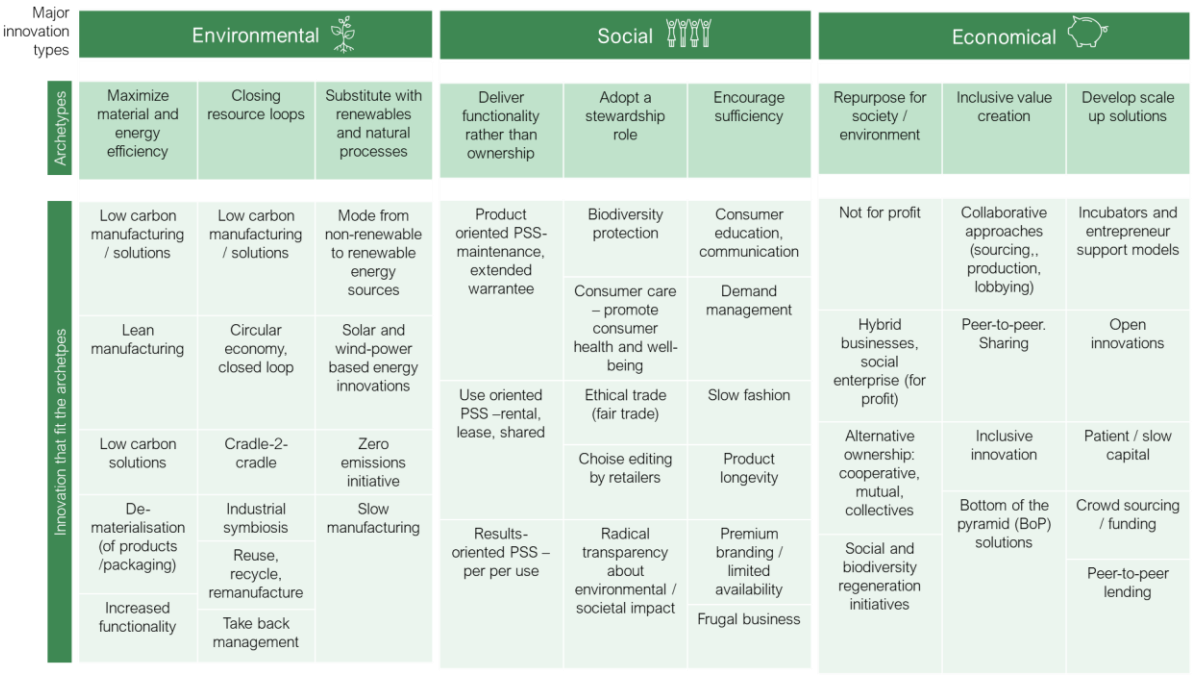
There isn't any unified approach to defining sustainable business models (SBM). Firstly, there are different terms used in addition SBM in the literature, for example *business model for sustainability*, *sustainability-oriented business models* and *more sustainable business models*. (Lozano 2018) However SBM seems to be the most used term and hence used in this study as well. The general understanding is that SBMs are a modification of traditional business models, which are rethought and designed to preserve and benefit the environment and society. Most studies on SBMs bases their definition on a business-oriented perspective similar to traditional BMs, where the economic value is the main point of view.

The challenge is to look at sustainable business models covering all aspects of sustainability and how to create value to the environment and society as well. (Lozano 2018)

Sustainable business models are difficult to describe and conceptualize in a universal way, as they depend on a lot of the field, they are applied in. As an exception, circular economy business models which are a subsection of SBMs types, are universally conceptualized and discussed further in chapter 2.2.1.

One of the most used models to describe different kinds of sustainable business models was developed by Bocken et al. (2014). Their model describes SBMs through archetypes. These SBM archetypes are grouped into technology, social and organizational groups. However, later the model has been updated by Bocken et al. (2016) to describe SBMs through innovation and the triple bottom line perspective (Figure 4). The created innovation types are for each category: environment, social and economic. Each type then has several archetypes that are meant to describe solutions and mechanisms which can help to create SBM, thus they can be seen as a guiding framework for businesses to use in their research and practices.

Environmental business models refer to BM that close resource loops, substitute fossil raw materials with renewable ones and maximize resource efficiency. Social business models encourage sufficiency, adopt a stewardship role and deliver functionality rather than ownership. Economical business models develop scale up solutions, inclusive value creation and repurpose for society and environment. Bocken et al. (2014; 2016) model has been criticized of having a too narrow view on archetypes which bring value to social aspects. In addition, the model is from 2016 and as the knowledge and field of sustainability has grown drastically in recent years, the model might not represent the latest knowledge on sustainable business models. However, the model serves as a good starting point to visualize what SBM could mean.



Major innovation types	Environmental			Social			Economical		
Archetypes	Maximize material and energy efficiency	Closing resource loops	Substitute with renewables and natural processes	Deliver functionality rather than ownership	Adopt a stewardship role	Encourage sufficiency	Repurpose for society / environment	Inclusive value creation	Develop scale up solutions
Innovation that fit the archetypes	Low carbon manufacturing / solutions	Low carbon manufacturing / solutions	Mode from non-renewable to renewable energy sources	Product oriented PSS-maintenance, extended warrantee	Biodiversity protection	Consumer education, communication	Not for profit	Collaborative approaches (sourcing,, production, lobbying)	Incubators and entrepreneur support models
	Lean manufacturing	Circular economy, closed loop	Solar and wind-power based energy innovations		Consumer care – promote consumer health and well-being	Demand management	Hybrid businesses, social enterprise (for profit)	Peer-to-peer. Sharing	Open innovations
	Low carbon solutions	Cradle-2-cradle	Zero emissions initiative	Use oriented PSS –rental, lease, shared	Ethical trade (fair trade)	Slow fashion	Alternative ownership: cooperative, mutual, collectives	Inclusive innovation	Patient / slow capital
	De-materialisation (of products /packaging)	Industrial symbiosis	Slow manufacturing		Choise editing by retailers	Product longevity		Bottom of the pyramid (BoP) solutions	Crowd sourcing / funding
		Reuse, recycle, remanufacture		Results-oriented PSS – per per use	Radical transparency about environmental / societal impact	Premium branding / limited availability	Social and biodiversity regeneration initiatives		Peer-to-peer lending
	Increased functionality	Take back management				Frugal business			

Figure 4. Examples of sustainable business models (modified from Bocken et al. 2016)

Another example to represent SBM archetypes by Geissdoerfer et al. (2018) is to divide SBM types as:

- Circular business models
- Social enterprises
- Bottom of the pyramid solutions
- Product-service systems

Sommer (2012) studied how existing companies can transform their business models into sustainable ones by developing examples of prototypical business models with green potential. Study also defines a scale of 0-3 and a formula to estimate what is the impact of the business model to the environment and can it be classified as “green” or not. However, the scale should be used an indicative model as it doesn’t count all aspects affecting the environmental impacts of the business model. The study defines type 3 business models as “strong sustainability” which describes that the business doesn’t impact negatively to the environment. As the study is relatively old, it should be noted that calculation methods and related knowledge for environmental impacts have evolved in the past few

years. It would be interesting to see if Sommer (2012) methods could be incorporated with today's current environmental calculation methods, such as life cycle assessment (LCA).

Goni et al. (2021) concluded from their literature review on SBMs that key features of SBM concepts developed are: sustainability, value chain, core values, value creation, organizational values, circular economy, performance management, information technology and stakeholder engagement.

2.2.1 Circular business models

Circular economy as a concept has many definitions, but in general, it is described as an opposite model to linear economy (take-make-dispose model). Sitra (n.d.) defines circular economy as a model which instead of producing more goods, consumption is based on using services instead of owning. In addition, materials are not discarded without exploitation, but are used to make new products time and again. Circular business models are one type of example of sustainable business models (Figure 5) which furthers the transition from linear economy to circular economy.

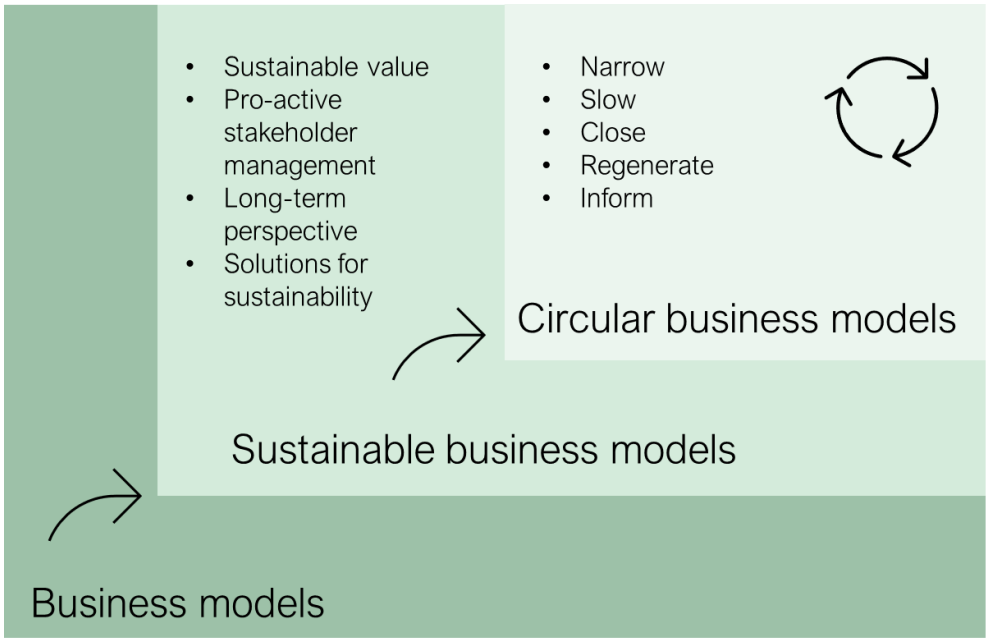


Figure 5. Interconnections of business models, sustainable business models and circular business models (Modified from Geissdoerfer et al 2018; Fräki 2021).

The concept of circular economy business models is defined quite similar in literature, as rest of the sustainable business models aren't. Circular business models are usually divided into 5 categories: resource efficiency and recycling, renewability, product life extension, product as a service and sharing platforms. (Sitra 2022)

In the resource efficiency and recycling business models, value is sought from all material streams of operations. In other words, by-products and waste streams are optimized. Renewability as a business model offers access to renewable, recyclable or biodegradable inputs. Product life extension is about manufacturing long-lasting products, which requires design that ensures quality and durability but also enables maintenance and repairing. Companies doing business by offering services, products are being rented or leased instead of selling. In such case, ownership responsibilities regarding for example maintenance stays with the product manufacturer/owner. Sharing platforms refer to service compensation models in which the owner sells access to assets. Owners are responsible for maintenance and service quality. One of the main differences with product as a service and sharing platforms is that the typical time of usage for sharing platforms is much shorter and the number of users in a sharing platform is much higher. (Sitra 2022)

2.2.2 Implementation of sustainable business models

The way sustainable business models are created and implemented can be divided into four categories. Firstly, there are the startups which have integrated sustainability into the core of their business, thus creating value solely from sustainable business models. Second group contains established organizations where they are aiming to change their current business models to sustainable ones. This kind of approach is called the sustainability transformation or sustainable transformation journey. Third group is similar to group two, except that these companies are adding sustainable business models next to their current existing business models without major changes. Fourth group gains sustainable business models through acquisition where and an additional sustainable business

model is integrated into the organisation through acquisition. (Geissdoerfer et al. 2018)

Organization where SBM can be implemented are diverse, such as traditional, for-profit businesses, but also for social enterprises and nonprofits. They way SBMs are used in these organization differs a bit. For-profit organizations seek to make profit but not at the expense of environmental and social aspects. Social enterprises' priority is not to make profit, but to advance social programs. Social enterprises usually make profit while maximizing benefits regarding environmental and social aspects and the profit is usually directed to social funds. Non-profit organizations in contrast do not seek to make profit and all possible revenues are directed to the cause it represents. (Aalto University n.d.)

2.3 Sustainability based value

At the core of any business model is the concept of value. Value is usually determined through three elements: value creation and delivery, value proposition and value capture. Traditionally, value creation and delivery refer to making money, the business' capability to produce value from its resources. Value proposition is the value offered to the customer by the business. Sometimes value proposition is defined also as the customers' perception of value. Value captured refers to the value generated for the business by the value proposition. (Abdelkafi & Täuscher 2015)

However, as value has been measured through economic indicators before, today system-level challenges, such as climate change and resource scarcity, in addition stakeholder demands and tightening regulation are rapidly pushing towards sustainable operations, and thus environmental and social impacts need to be part of the concept of value. Businesses need to think how they would create sustainable value, i.e., environmental, social and economic value not only to the organisation itself and its customers, but to the entire entity it exists in.

The dimensions of sustainable value can be divided into four categories: economic, environment, society, network and customers. Economic sustainability re-

fers to wider economic performance, where the economic impact affects company's stakeholders. (Aalto University n.d) For example, companies can invest in reducing their impact on climate change, which in long-term is vital in terms of business continuity, but also benefits the society and the environment, also in short-term for example through employer branding.

Environmental value creation refers to recusing the environmental impact through the company's sustainable business model (for example see Bocken et al. 2016 archetypes). Environmental value goes beyond only being compliant with environmental regulations and is an essential part of the business. Social value in turn can be created for example increasing wellbeing of employees or local communities. In addition, many companies are still focusing on reaching the compliance level of social aspects in the entire value chain, for example regarding human rights and fair labor practices. Social value creation is not easily measurable as environmental and economic values are. (Aalto University n.d)

Prior to traditional way of doing business individually and seeing other companies as rivals, systemic change to sustainable business practices requires companies to build networks with stakeholders and see rivals more as partners. (Aalto University n.d) For example, circular ecosystems are not built alone, but extensive ecosystems are needed and thus, value is created through the network.

2.4 Sustainable innovations

Innovations are vitally important for businesses to survive and stay ahead of competition. To transform the traditional way of doing business into sustainable business, innovations are needed. Sustainable development requires innovations that transform current systems and not just small adjustments. In general, sustainable innovations defer from traditional innovations as future-oriented innovations that take into account improvement of ecological and social aspects while creating economic profits. Sustainable innovations don't only refer to creating novel products or services, but also changing of current processes, products, and services more sustainable.

For companies to start innovating, they need to decide on their innovation strategy. According to Adams et al. (2015), sustainable innovations can be approached through three categories shown in Figure 6.

Figure 6. Three types of sustainable innovations (Modified from Adams et al. 2015).

In operational optimization, environmental and social impacts are reduced (e.g. using renewable energy in operations). This means that current way to operate is tweaked and done a bit better. Second category, organizational transformation refers to finding new opportunities and markets. Here innovations are seen as novel products or services, or as new business models. The impact of the innovation is more incremental and has a greater impact to society and/or environment than in the first category. In this category, sustainability is seen as a business opportunity and requires fundamental shift in the business. Third category, systems building, is similar to second category, but in this most advance form of sustainable innovations, companies collaborate with stakeholders to create net positive impact. Here companies strive for systemic chance and see themselves as part of a larger ecosystem. The important factor here is that companies understand that sustainability cannot be achieved alone. (Adams et al. 2015) To conclude, to fully consider social and environmental impacts on a long-term and wide enough scope, businesses need systems thinking.

In addition to the three levels of sustainable innovation strategies presented, companies need capabilities to succeed in their innovation strategy. Sustainable business model innovation (SBMI) is an example of a concept used to describe what is needed for the sustainable transformation. SBMI process recognizes that busi-

nesses need dynamic capabilities to transform their business models sustainable, but also organization design to nurture these capabilities. (Bocken & Geradts 2020)

2.5 Sustainable business model design tools

Several tools have been created to support the innovation or transformation journey of sustainable business models. Most presented tools in the literature are related to business model canvases and value mapping tools.

Business model canvas helps to map out important aspects of a viable business idea where value proposition for the customer is at the core of the tool. However, the traditional business model canvas by Osterwalder and Pigneur doesn't address sustainability, thus several versions of sustainable business model canvases have been created (Attachment 1).

Value mapping tool was developed by Bocken et al. (2015) to assist in the design of sustainable business models (Attachment 1). It is mostly recommended as a qualitative evaluation tool and could be used to supplement LCA studies for example. The tool can also be used to compare different sustainable business models. The value a mapping tool uses a multi-stakeholder perspective and considers positive and negative aspects of value creation (**Error! Reference source not found.**). In the tool, value creation is considered from the following viewpoints: value captured, value missed, value destroyed and value opportunities. Value missed refers to the failure of capitalizing existing assets and resources for example and operations are below best practices. Value destroyed refers to negative outcomes of the business, including environmental and social outcomes as well, such as destruction of local biodiversity. Opportunities to create value means that businesses need to seek and create novel solution to go pass managing risks to address sustainability challenges outright. (Bocken et al. 2015)

Other tools which support sustainable business thinking are such as life cycle assessment (LCA) and eco-design. LCA is a tool which helps to quantify environ-

mental impact of a product or service which is essentially a tool for product design. Eco-design helps to select sustainable materials for the product, appropriate design for recycle, reuse, and remanufacture.

2.6 Regulation and stakeholders

Market drivers for sustainability refer to for example stakeholders, suppliers and competitors. Stakeholder refers to any group or individual who are impacted by businesses, such as consumers, investors, NGOs, local community, suppliers and employees. Involvement of stakeholder in the development of sustainable business models for the organization is universally recognised as an important factor. Involvement of stakeholders into the sustainability journey stems from the assumption that value creation is dependent on stakeholder needs. (Samant & Sangle 2016)

Government actions through regulation are needed as well to fight environmental crisis and enforce for example circular economy. The following chapters discuss interesting regulatory developments from the nonwoven industry's point of view focusing on European Union.

The current European Commission has taken rapid steps towards sustainable transformation in the Member States. For example, the European Green deal aims to establish roadmap to achieve climate neutrality target by 2050 in all sectors, create mechanisms to monitor the progress and furthermore, decouple economic growth from resource use. The European Green Deal affects nearly all private organizations and sectors of economy, operating in the Member States. Related to the Green Deal, EU has published for example EU Climate Law (and related Fit for 55 package), Circular Economy Action Plan and the European Green Deal Investment Plan. (A European Green Deal n.d.) In addition, as part of the Green Deal, EU Commission is currently developing an Initiative on substantiating green claims. This green claim initiative will tackle for example green washing and will target all "green" claims that aren't unsubstantiated (Euractiv 2023).

For textiles the Circular Economy Action Plan, related Plastics Strategy and Sustainable and Circular Textiles Strategy can be seen as drivers for incorporating sustainability into nonwovens. The upcoming Ecodesign for Sustainable Products Regulation (ESPR) will target textiles as one of the most important sectors to be addressed.

EU's Plastic Strategy aims to reduce plastic waste through different actions. As part of EU's Plastic Strategy, Single Used Plastics Directive 2019/904 (SUP Directive) was published in 2019. Nonwoven product groups addressed in the SUP Directive are certain feminine hygiene products and wet wipes (excl. industrial wet wipes). The SUP Directive aims to reduce plastic pollution and marine litter through actions such as increasing awareness and reducing consumption, labelling requirements, design requirements, and extended producer schemes. Plastic under the scope of the SUP Directive is defined as material which consists of polymers that might contain additives. However natural polymers resulting from a polymerisation process which has taken place in the nature and haven't been chemically modified, don't fall under the scope of SUP Directive. For the addressed nonwovens, the SUP Directive sets an obligation to mark the product with a label which tells the consumer that the product contains plastic. Other interesting policies from the nonwoven point of view which are being discussed by the EU are policy on bio-based, biodegradable and compostable plastics and policy on microplastics (European Commission, Plastics n.d.).

Sustainable finance has become an important sector for companies to understand and comply with to secure funding. For example, EU taxonomy regulation (2020/852), referring to classification system establishing sustainable economic activities entered into force in July 2020. EU taxonomy was created to boost EU's climate and environmental objectives and aims to steer funding to sustainable activities and transparent operations. In addition, upcoming Corporate Sustainability Reporting Directive (CSRD) supports EU Taxonomy and amends the current Non-Financial Reporting Directive (NFRD). CSRD will widen the scope of organizations required to disclose information regarding environmental, social and governance issues.

There are also other interesting regulatory examples outside EU that clearly state that governments are aiming to reduce the number of single-use plastic products on the market. However, besides the SUP Directive, other regulations don’t seem to address nonwoven products yet. (The mills fabrika n.d.)

3 SUSTAINABILITY OF NONWOVENS

The history of nonwovens stretches back into the 19th century England, where textile engineer Mr. Garnett developed a machine which turns waste material back into fibrous form and machinery manufacturers started binding fibers with mechanical and chemical methods into webs. Since the nonwoven industry has developed into a crucial part of the textile markets, offering various end-use applications from hygiene products to automotive industry to construction materials. (Karthik et al. 2016)

Nonwoven is a fabric that isn't knitted or weaved as are conventional fabrics thus, the fibers are directly manufactured into *nonwoven* fabrics. ISO 9092:2019 standard defines nonwovens as "an engineered fibrous assembly, primarily planar, which has been given a designed level of structural integrity by physical and/or chemical means, excluding weaving, knitting or paper making." Nonwovens have a wide variety of properties, such as absorbency, biodegradability, breathability, density, durability, stiffness, liquid repellence, mouldability, washability, lightness and softness (Karthik et al. 2016).

Typical life cycle of a nonwoven product consists of production of raw materials, production of intermediate, nonwoven fabric and rolled goods, manufacturing of the end product, distribution and use an end-of-life scenarios (EDANA 2019). The following chapters discuss most important life cycle stages of a nonwoven product emphasizing resent studies on sustainability of the life cycle stages.

3.1 Raw materials in nonwovens

Nonwoven fabric is produced from three main components which are fibers, binders and additives, fibers being the main component. The selection of the raw materials depends on the desired properties for the end-product, costs and ease of processability. The selected materials also affect the products recyclability. From sustainability point of view, selection of the raw material plays an integral part in the sustainability of the nonwoven product (see chapters 3.3.1 and 3.3.2).

Raw materials used to produce fibers or filaments can be classified based on different viewpoints, such as source, polymer, botanical, zoological or chemical name, utility, thermoplasticity and ability absorb moisture. In this study, classification based on source is used (Figure 7).

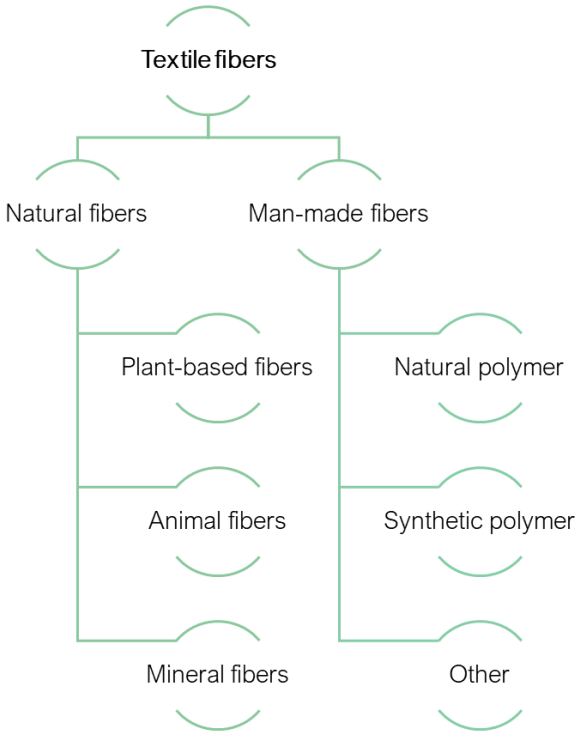


Figure 7. High-level categorization of textile fibers (Modified from Textilelearner n.d.)

Around 30% of raw materials used in nonwovens are from renewable-based materials which can be either from natural fibers or natural man-made polymers. (EDANA 2019). The use of renewable fibers in nonwovens is expected to grow drastically due to tightening regulations on plastics and stakeholder demands. Especially companies in the hygiene sector are actively replacing petroleum-based synthetic fibers into renewable ones. (McIntyre 2021)

Plant-based fibers are part of natural fibers. Plant-based fibers used in the hygiene segment include for example cotton, hemp, flax, corn, pineapple and bamboo. Use of natural fibers, such as plant-based fibers in nonwovens from sustainability point of view, is often justified due to their features such as biodegradability. However, sustainability benefits depend on the raw material used and natural fibers aren't necessarily always the best option. For example, production of cotton

fibers can include many negative environmental and social impacts as the cultivation of cotton uses high volumes of irrigation water and pesticides and use a lot of arable land. Most of cotton is also cultivated in the Global South were issues with human rights and fair labor conditions aren't always met (STJM 2021). Each material choice should always be assessed case by case in terms of their sustainability.

Synthetic polymers are widely used in nonwovens, mostly due to their good qualities and price. Typical materials used in nonwovens are usually petroleum-based fibers, for example polypropylene (PP), polyethylene (PE), polyester, polyamide and polycarbonate. (Karthik et al. 2016) Petroleum-based virgin polymers have significant environmental impacts related to for example resource use, energy use and microplastics. Synthetic polymers can also be manufactured from renewable sources. For example, polylactic acid (PLA) is manufactured by fermenting naturally occurring sugars (e.g., corn or sugar beets) into lactic acid and further processed into fibers. Regarding its features, PLA is similar to petroleum-based fibers, but biodegradable. PLA is used for example in wipes and diapers. (STJM 2021)

In addition, also **modified, cellulosic fibers** are part of the manmade fibers category. For example, viscose is a type of modified, cellulosic fiber that is use in nonwoven applications. Viscose however isn't the most sustainable option from the modified, cellulosic fiber group. Manufacturing of viscose uses a lot of harmful chemicals, water and energy. The magnitude of these negative environmental impacts is also depended on the manufacturing facility, some facilities, especially in Europe, use water in a closed loop system and the hazardous chemicals have been replaced with less harmful ones. (STJM 2021) Nevertheless, there are several innovations developed, especially in Finland, that are based on the modified cellulosic fibers which offer more sustainable alternatives. For example, Kuura® by Metsä Spring, Infinna™ by Infiniter Fiber Company, Spinnova® by Spinnova and Ioncell® by Aalto University and University of Helsinki and Norratex by Nordic Bioproudcts Group.

Motivation to replace fossil-based raw materials in nonwovens is high and one option is to use **recycled materials**. Recycled materials for nonwovens can be

taken for example from plastics streams and textile streams. Using collected textile waste to replace fossil-based plastics is one of the key factors in sustainable textiles and nonwovens. When the discarded textile is processed into a product, value is created from the waste material. EU has set a requirement that by 2025, the Member States are required to start collecting textile waste and in Finland, this requirement came already in force 1.1.2023 (Waste Framework Directive 05/07/2018; Ministry of the Environment of Finland 2021). Textile waste refers to textiles that can't be reused again (such as dirty or broken) and are usually discarded as mixed waste. Reusable textiles are both textiles that can be reused again (clean, unbroken) as well as textile waste. (STJM 2022)

Fibers in nonwovens are held together by **binders and finished with finishing materials**. Binders is a film-forming part of a coating or adhesive in the nonwoven product. Binding material can also be manufactured from biobased materials or synthetic materials. The choice of binder and finishing materials is an important part of designing sustainable products as it effects the product's ability to be recycled or degraded for example at the end of its life for example.

3.2 Manufacturing of nonwoven fabric

As the selection of nonwovens is very broad, a variety of different production techniques and structure types exists as well. Therefore, nonwovens can be classified either based on the production technique or structure (Figure 8).

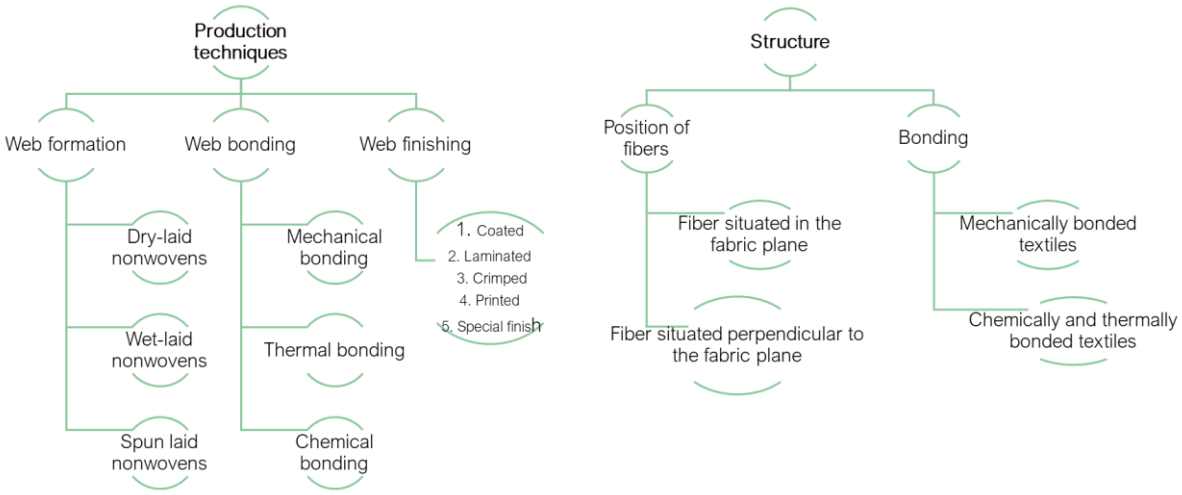


Figure 8. Different production techniques and structure types of nonwovens (Modified from Karthik et al. 2016).

Nonwovens are typically manufactured in three stages, which can be performed orderly or simultaneously. These stages are web formation, web bonding and finishing treatment. As seen from Figure 8, there are several different techniques within these main manufacturing stages and the chosen ones depend on the desired characteristics, thus it should be noted that all techniques aren't suitable for all end uses when discussing their sustainability performance. In general, the manufacturing of nonwoven fabric isn't the biggest contributor to environmental impacts during the life cycle of nonwoven products compared to for example raw material phase (e.g., Zhang et al. 2021).

3.3 Examples of nonwoven end products

Each nonwoven-based end-product has its own unique features which affect to its sustainability performance. Single-used products especially are widely discussed in terms of their impact on the environment. Within the scope of this study, the following chapters discuss and compare single-used nonwoven products to reusable ones through two examples: diapers and wipes.

3.3.1 Diapers

Diapers are an essential tool in the parenting book and used everywhere. Diapers can be divided into three categories: single-use diapers, single-use biodegradable diapers and reusable diapers. Top layer of the diaper is usually made from permeable nonwoven such as PE, PP or viscose. Acquisition and distribution layer and the absorbent core of a diapers are usually manufactured from such as SAP, cellulose based fibres, polylactic acid (PLA) or protein-based fibres, the inner layer of the diaper is usually made from PE and PP (Plotka-Wasylka 2022). Although safety is the number one priority when designing and producing diapers, concerns regarding their environmental impacts are rising increasingly, hence there are many studies done concerning the environmental impacts of diapers (e.g., Somers et al. 2021; Mendoza et al. 2019; Cordella et al. 2015; Mirabella et al. 2013; Weisbrod & Van Hoof 2012).

Mirabella et al. (2013) compared the environmental performance of bioplastic based and standard commercial disposable diaper using LCA. They concluded that conventional diaper has mostly a higher environmental impact compared to bioplastic-based one. However, bioplastic-based diaper has a higher impact in natural land transformation and higher energy demand. Out of life cycle stages of a diaper, sourcing and production of raw materials used was the main contributor to the environmental impacts. When comparing different raw material compositions, their study showed that depending on the calculation method, SAP, totally chlorine-free pulp and PLA had the highest environmental impact.

Somers et al. (2021) concluded in their LCA study that production of raw materials and the manufacturing stage of diapers have the highest impact on the environment. In the manufacturing stage, production of superabsorbent polymers (SAPs) was the highest contributor to the GWP result. Environment Agency study (Aumonier et al. 2008) concluded that when comparing reusable diapers and disposable diapers, the main component affecting the environmental impact results is the washing of the reusable diaper, thus it cannot be concluded, which option is better from environmental impact assessment viewpoint.

Apart from environmental impact studies, Mendoza et al. (2019) studied the life cycle costs and eco-efficiency implications of cleaner production of disposable baby diapers. They concluded that diapers without gluing system are 7-170% more eco-efficient (€/impact, depending on the environmental impact considered). In their study, the bonding was done through thermo-mechanical and ultrasonic systems to replace glue.

3.3.2 Wipes

As covid pandemic hit the world in 2020, the market for disinfecting wipes grew exponentially. Now, when the pandemic has regressed and people aren't perhaps as manic for cleaning, manufacturers have full storages of wipes, and the market has slowed down. When moving away from the eminent crisis, consumer demands for sustainability are being prioritized. (Olivo 2022) Wipes can be divided into three main categories based on their intended use: personal care wipes, household and home cleaning wipes and industrial cleaning wipes. Wipes are usually manufactured from spunlace nonwoven fabric and typical raw materials used are synthetic polyester fibers and biobased fibers such as viscose. (Karthik et al. 2016)

According to the European commission, wet wipes are included in the top 10 of most found plastic items on European beaches (European Commission n.d.). Plastics containing wet wipes also contribute to the global microplastics problem as they are left into the environment. Environmental impacts of wipes have been studied before (e.g. Maloney et al. 2022; Zhang et al. 2021; Van Hoof et al. 2014)

Zhang et al. (2021) performed a life cycle assessment for wet wipes with different raw material compositions (1. 30% viscose fiber + 70% polyester fiber, 100 % polyester fiber and 100% viscose fiber). They concluded that biobased materials have lower environmental impact compared to the polyester fiber, except when it comes to eutrophication, where the impact is higher. Maloney et al. 2022 compared single-use wipes (PET) to reusable cloths (cotton and microfiber) used for medical purposes also focusing on different cleaning chemicals and concluded that each option has both positive and negative environmental impacts. In general, their study suggests that microfiber cloth has smallest environmental impact,

then cotton cloth and sing-use wipe has highest impact but there are many variables that affect the results.

3.4 End-of-life

End-of-life (EoL) refers to the end of the life scenario of the product and can include for example reuse and recycling of the product, or waste treatment methods such as recycling, waste to energy and landfill. EoL scenario of a nonwoven products depends highly on the product itself, the country or area where it was disposed and consumer behavior. EoL scenarios of incineration, landfill, biodegradation related processes and recycling are often most suitable for single-used products.

Recycling of nonwoven-based products is beneficial from environmental point of view (Moazzem et al. 2021). Nonwovens can be recycled through mechanical processes; however, it is not a common practice yet globally. Generally, in the mechanical recycling process of textiles, the fiber containing waste is shredded into fibre level. The process is best suited for monomaterials and blends that contain similar materials. Downside of mechanical recycling process is that it shortens the length of fibres thus possibly reducing the materials quality and strength. However, hygiene is a very important aspect affecting the possibilities of mechanical recycling. (Heikkilä et al. 2020) The nonwoven waste is usually recycled in the condition they enter the facility and hence products such as AHPs and wipes aren’t usually suitable for mechanical recycling. In addition to hygiene issue, AHPs such as diapers have a very complex composition containing for example cellulose, SAP and plastics and due to its nature, should be collected as separate waste, which makes it quite impossible to recycle mechanically. (Perez et al. 2021)

Currently there are a lot of interesting innovations developed around chemical recycling of plastic and textile waste, where the waste is processes in some cases even back into its monomer state where new polymers or fibres can be developed. Chemical processing can be done for example as depolymerization or dissolving of the waste, the exact method depends on the composition of the textile

waste recycled. (Telaketju 2020) However, chemical recycling of nonwoven products isn't that studied yet (Guo et al. 2021).

Some nonwoven materials are biodegradable, thus their EoL scenarios could be "discarded as biowaste" for example. Biodegradability is an attribute of the material which means that the material can be decomposed by living organisms, such as bacteria and it is dependent of the environment. The term "biodegradable" is often mixed with "biomaterials" and "composting", although they all mean different things. Biomaterials can be natural based, or oil based, they can biodegrade or not. Composting is a specific process where the material is degraded, and materials being composted have specific requirements. (Muovipoli n.d.) It is also important to understand that whether the product is marked as biodegradable, it doesn't mean that it can be discarded into the nature as such. Biodegradation is a means to promote circular economy and recover valuable resources through biological processes, such as anaerobic digestion or composting.

Consumer behavior and local infrastructure play an integral role when discussing EoL scenarios for nonwoven consumer products such as wipes or diapers. Although the product is marked biodegradable, it is up to the consumer to discard the product as biowaste rather than mixed waste. Or if the product could be recycled, the local waste management infrastructure most likely doesn't support recycling of the nonwoven product. When considering the sustainability performance of the product's EoL, the actual magnitude of the impact is a complex topic depending on many factors which should be kept in mind.

4 METHODOLOGY

The aim of this study was to map current sustainable business models in use in the nonwoven industry. To narrow the scope of the research for the thesis, the research questions (Chapter 1) were approached from the viewpoint of two cases: diaper and wipes product groups. These product groups were chosen as the scope since they represent the largest markets by volume in Europe. In addition, these products represent single-used product categories which contain several discussion points related to their sustainability issues.

4.1 Literature and company review

The materials used in this thesis are gathered and analysed by using qualitative methods. First a literature review was performed to understand the concept of sustainable business models in addition to nonwovens in general. Then a qualitative search was performed to get an overview of the used sustainable business models in the value chain of diapers and wipes.

Examples of sustainable business models currently used were searched through the websites of different nonwoven organizations, such as Edana and Nonwoven Industry as well as from scientific literature. Member companies of the Edana organisation who act in the value chain of diapers and wipes were selected for a closer review. In addition, examples of nonwoven companies with sustainable business models were searched through the Nonwoven Industries website.

In total, the websites of 64 companies were reviewed and searched for examples of sustainable business models. Information on the websites on companies' business models were categorized and analyzed to form an understanding of the current situation.

4.2 Questionnaire

Representatives of the nonwoven industry participating in the SUSTAFIT project were asked about the biggest barriers and drivers are to achieve sustainable nonwoven through a questionnaire. Firstly, they were asked an open-ended

question on which factors they think would serve as enablers for sustainable nonwovens introduction. Secondly, they were asked if they see that the following factors serve as challenges in the introduction of sustainable nonwovens:

- raw material price,
- lack of legislative support,
- availability of technology/production lines,
- raw material availability,
- supporting infrastructure and
- final product price

on a scale of “not a challenge”, “small challenges but can be overcome” and “clear challenge with no easy solution”. In total 12 answers were gathered and the results from the questionnaire were used as basis for questions asked in the semi-structured interviews, and analysis on the results are discussed in Chapter 6.2.

4.3 Semi-structured interviews

Findings from the literature search, company review and the questionnaire were validated and supplemented by interviewing representatives of the nonwoven value chain of diapers and wipes. Interview questions based on the observations made from the literature and company review as well as the questionnaire are presented in Table 1. In total 4 representatives of the industry were interviewed. Three of the interviewed companies operated in the nonwoven value chain and one interviewee represented a general view from the nonwoven field. All interviewed parties are kept anonymous, as some of them so requested. In addition, as the number of participants was small and hence their statements cannot be generalized.

Table 1.Observations from the literature and company search and interview questions based on the observations

Observation	Question
1. *The concept of sustainable business model has many definitions*	What sustainable business model means to you?
2. *Many of the sustainable business models today focus only on material choices and efficiency*	What kind of sustainable business models have you observed in use in the nonwoven industry, especially regarding the diaper and wipes value chains?
3. *Many of the sustainable business models today focus only on material choices and efficiency.*	Is there any "out of the box" business models that should be investigated more or have you noticed any weak signals?
4. *Nonwoven segment is feeling the demand for sustainable products and are trying to become more sustainable*	Who are the most important stakeholders to drive sustainability in the studied nonwoven segment?
5. *Studied products represent single-use nonwovens and consumer goods*	How much does consumer behaviour affect the sustainability of the studied nonwovens
6. *Studied products represent single-use nonwovens and consumer goods*	Do you see that all single-used products should be replaced with reusable ones?
7. *Nonwoven related business models seem to be mostly linear at the moment*	How could be increase circular economy in the studied value chains?
8. *Very few companies, almost none, use recycled content in diapers or wipes.*	What kind of recycled content would be possible to use in diapers or wipes?
9. *Many companies use materials in their products that are biobased.*	What are your thoughts on biomaterials, are they the future of sustainable nonwovens?
10. *Most companies use flushable and biodegradable materials as their sustainable option for the product*	Would you consider biodegradability and flushability as sustainable practises? Do you see any problems with these?
11. *There are several enablers and barriers to sustainable transformation in the nonwoven industry*	What do you see as enablers and barriers in the industry for sustainable transformation? What does the future of sustainable nonwovens look like?

5 RESULTS

Sustainable business models currently in use were studied through a company website review and additional semi-structured interviews. The following chapters go through findings and analyze the current situation of sustainability in the diaper and wipes segments regarding nonwovens. It should be noted that all the findings don't necessarily represent a sustainable business model by themselves and thus they represent more different sustainability practices or features of the product. However, in selected combinations these practices and features can be interpreted as sustainable business models that create value from the triple bottom line perspective.

In total, 64 companies globally, acting in the nonwoven industry operating either in the diaper and/or wipes value chain, were reviewed to get an understanding of the current sustainable business models in use today. In general, it was seen that out of 64 companies, around 70% had included sustainability as part of their business model in some way. To summarise, the sustainable business practises or models observed in the diaper and wipes segments were quite similar. From the company review it can be concluded that the most used SBMs in use are combinations of raw material choices, material efficiency, circular economy, and social aspects such as safety of the product. Table 2 shows what kind of sustainable practises or business models were found. Findings have been divided into different categories to bring clarity, but it should be noted that some of the properties could belong to several categories, for example recycled content can go under raw material choices and circular economy.

Table 2. Observed nonwoven related sustainable practises or business models currently in use in the value chains of diapers and wipes.

Category	Sustainable practises or business models found	Diapers	Wipes
Raw materials in the products	Natural materials	x	x
	Other renewable materials	x	x
	Recycled materials	x	x
Features of the raw materials	Biodegradability	x	x
	Compostability	x	x
	Flushability		x
	Recyclability	x	x
Societal topics	Product safety	x	x
	Other safety related topics	x	x
	Society related topics	x	x
Circular economy	Takeback system	x	x
	Product life extension	x	
	Resource efficiency	x	x
	Value from waste	x	x
Sustainable production	Renewable energy	x	x
	Closed loop processes	x	x
	Resource efficiency	x	x

The following chapters analyze and discuss specific sustainability related findings regarding diapers and wipes, then findings that are similar for both products.

5.1 Sustainability of diapers

As seen from Table 2, there are several different sustainability related aspects considered in the value chain of diapers to make the business more sustainable. When talking about the sustainability of diapers, health and safety of the product were seen as the as most important sustainability related aspects of the product.

The high requirements regarding health and safety of the product also were seen to affect other found sustainability related topics, such as raw material choices.

As the raw material choice has many limitations due to the high health and safety as well as quality requirements, most of the observed raw material used in diapers labelled as sustainable, were either natural fibers or bio-based materials, such as fluff pulp. Use of recycled content in diapers was seen as a marginal.

As explained in Chapter 3.4, mechanically recycled content doesn't necessarily provide good enough quality. Even though chemically recycled materials are more or less in pilot phase, some forerunners have emerged to the field. For example, one company that manufactures personal care nonwoven products, such as nonwoven rolled goods for diapers, is able to use chemically recycled polymers in addition to bio-based polymers in their products. Related to this, their production is the ISCC (International Sustainability & Carbon Certification) Plus certified (see Chapter 5.5). (Fibertex personal care n.d.) On the other hand, the Nordic Swan Label forbids the use of most recycled materials in sanitary nonwoven products, except for example recycled plastic that is food-grade quality, which insinuates that using recycled content in diapers is still far away. (Nordic Ecolabelling 2016).

The end-of-life scenarios of diapers is an important topic when talking about the sustainability of diapers. Firstly, use diapers cannot be discarded as biowaste or recycled due to their content in most cases, thus depending on the country, diapers are usually discarded as mixed waste, and further landfilled or incinerated as energy waste. However, the results show that many companies offer biodegradable, compostable or recyclable diapers. These features are seen as sustainability enhancing properties, even though required waste handling processes to benefit from these qualities aren't possible in most countries, as they prevent the waste diaper that is not discarded properly from staying in the environment forever. However, diapers will most likely always contain materials that don't biodegrade, for example SAP, due to their good properties.

However, as diapers, as well as wipes, are one of the biggest product groups compiling in landfills and nature, getting the waste back into the loop is very important. From the company review, one interesting example related to the diaper EoL was found, where the business model of the diaper selling company is based on takeback system. Takeback systems part of the circular economy business model group where products are sold as a service. As an example, this US based company takes back used diapers and wipes and processes the waste either by composting or pyrolysis into soil or char (Dyper n.d.). This kind of business model can be seen as a service model enabling circular economy where the resources are returned back to the cycles and value is created from the waste.

Another circular economy business model found in use, was product life extension business model, which in translates to reusable products when talking about diapers. Though, reusable counterparts or diapers aren't usually manufactured from nonwovens. However, there are also hybrid diapers on the market where the outer layer is reusable and inside layer single-use, replaceable material.

All in all, it was noted that even though the results show several sustainable practices and features, getting the entire industry go sustainable is still far away. When talking about fossil-based materials used in diapers, such as SAP, some materials have superior properties compared to many more sustainable alternatives, such as absorbency and price, that the alternative raw materials should have to match in order to be competitive. Here is where the consumers' power to affect sustainability of diapers has an integral role. When considering a product such as a diaper that is affordable and makes everyday living much easier for parents, getting these consumers to forfeit some of the properties of current diapers in order to use more sustainable alternatives is a big ask.

5.2 Sustainability of wipes

As seen from Table 2, there are several different sustainability related aspects used in the value chain of wipes. Wipes are a simple product containing a nonwoven component and often some chemical component that gives desired properties. Chemical usage isn't within the scope of this study, but it should be noted that the chemicals used in the wipes play an integral role when assessing the

sustainability of wipes as well. For example, chemicals should be safe for humans as well as the environment and need for chemicals in general should be justified (i.e., are chemicals needed or can it only use water for the intended use).

Sustainable raw material choices were the most used sustainable business model regarding the value chain of wipes. Wipes can be used in several applications and the health and safety limitations depends on the end use. Thus, the material choices in wipes in general, are wider than in diapers for example. In addition, wipes do not contain several different components which also makes the sustainable transformation a bit easier compared to complex products such as diapers. Sustainable raw material choices in wipes observed were for example natural raw materials such as cotton, biobased material such as PLA and recycled material such as recycled PET.

When considering the raw material choices in wipes in the EU, the SUP Directive was seen as one of the most important guiding instruments towards sustainability. The industry shifted away from plastic nonwoven materials in wipes after the SUP Directive entered into force, as companies didn't want to label their products as plastic containing ones.

The sustainable features of the raw materials stood out more in wipes than in diapers. Biodegradability and flushability were mentioned in almost all reviewed companies' wipe products. As wipes are one of the most found wastes in the ocean, having these properties is quite self-evident.

5.3 Sustainable production and design

Making production processes more eco-efficient is usually the first step towards sustainable business and this could be seen from the company review and the interviews. As nonwoven industry is a manufacturing industry, rather than service provider, it is crucial that the production and design choices are made as sustainable as possible. Sustainable production usually refers to both environmental and safety related topics, such as employee wellbeing and safety, using renewable energy sources and having resource efficient processes. Many companies have

closed loop production where they recycle waste raw material back into the production process. In addition to material use also, water can be used in a closed loop in production.

Furthermore, the entire supply chain should be included when talking about the sustainability performance of a company. From the company review it was seen that different sustainability actions of own operations are almost always addressed, but supply chain not as much. Supply chain sustainability is often addressed in many eco certifications (see chapter 5.5).

Sustainable production and supply chain are important factors to consider, but also product design is a central key when turning products more sustainable. Many diapers and wipes manufacturing company design these products as material efficient as possible, referring also to the reduced weight of the product. Material efficiency impacts for example carbon footprint and saves resources. Many companies also mention their product being recyclable. Designing recyclable product is essential today to get materials back into the cycle. One aspect of design for recyclability is to have as little as possible different material components in the product, so that they can be separated for appropriate recycling.

5.4 Societal topics

Societal topics refer to for example the health and safety of the product or benefits of the product as well as aspects such as human rights, fair labor conditions in the value chain and philanthropy work of the companies. Most of these topics are regulated and considered as a compliance level that the products need to fulfil. However, such as product safety can also contain business opportunities, thus it is presented on the list in Table 2. As an example, consumers might choose products to use that contain less chemicals. For example, from the company review it was observed that some companies offer safety related value to their customer by having products that are certified to different ecolabels, such as the Nordic Swan Ecolabel. These ecolabels communicate to the consumer that the product is a better choice regarding their safety and/or environmental impacts compared to other products. Another value creating societal theme presented in the value

chain of wipes especially, is the ability to provide safety of health improving features, such as disinfection and cleanliness.

5.5 Ecolabels and certifications

Diapers and wipes marketed as sustainable often obtain ecolabels or certifications that communicate to the consumer that they fulfil certain sustainability requirements. Example of known ecolables are Forest Stewardship Council (FSC) and Nordic Swan Ecolabels, but also few interesting newer and not so widely known certifications have merged in the market, such as the ISCC Plus certification.

Forest Stewardship Council (FSC) is a certification system for forests, and it ensures that forests are used responsibly from the environmental, social and economic point of view (FSC n.d.). Nonwoven products that use wood-based materials as raw materials can include the FSC certification when the forest the wood raw material is from is FSC certified.

Nordic Swan Label was founded by the Nordic Council of ministers for the Nordic countries to help companies to be more sustainable with their products or services and consumers to choose sustainable options. Circular economy is one of the key focus areas when setting new criteria for products or services. Nordic Swan Label has set criteria for the sanitary products which includes also diapers and personal care wipes and it sets sustainability requirements for companies manufacturing these products, including raw material manufacturers. (Nordic Ecolabelling n.d.)

There are also new eco certifications entering the market related to biobased and recycled content. One of these is the ISCC Plus certification that ensures chain of custody and uses a mass balance system. The mass balance system is essentially a bookkeeping approach to determine the amount of recycled or biobased content in the feedstocks of production and ensure traceability of these sustainable raw materials used in products. It also includes several other requirements for companies regarding high environmental and social standards. In the ISCC Plus certification systems, manufacturers sell certified raw material . (SCS

global services n.d.) As an example, a producer manufactures plastic products made from PP in their ISCC Plus certified facility. The raw material for the PP they use, is partially made from fossil-based polymer, recycled polymers and bi-obased polymers. All of these raw materials are chemically processed, meaning that the recycled, biobased and fossil based PP are chemically exactly the same in the granulate and impossible to separate. This producer has a client that wants to buy these PP products that are 30% made from recycled content. The mass balance method of the ISCC Plus certification system allows the producer to sell certificates to this recycled content to the customer as much as their intake to the facility has been. Hence the PP product the customer company buys might contain PP from different sources, but the producer guarantees that the volume for 30% recycled content has been used in their manufacturing processes. The example is similar to buying electricity. The customer can buy green electricity, but the electricity that comes from the grid to the customer, is still determined by the current electricity mix.

Known ecolabels and certifications are a good starting point for the sustainability transformation journey. They usually set higher requirements than legislation and communicate to the consumer that the product or service within the set terms, is sustainable.

6 DISCUSSION

6.1 Findings in terms of sustainable business models

The results categorized in Table 2 were labelled as sustainable practises and features, because many of them don't represent a sustainable business model on their own. In this study, sustainable business model was defined through theory as a traditional business model that offers value not only from the economic point of view but also to the environment and society. In addition, sustainable business model was seen to have a long-term perspective, address wider stakeholder group and offer solutions for sustainability. Furthermore, traditional business model as a concept was seen to contain value proposition, supply chain management, customer relation management and a financial model. Examples of SBM framework portrayed them through archetypes (Bocken et al. 2016) or as circular economy business models, social enterprises, bottom of the pyramid solution or product-service systems (Geissdoerfer et al. 2018) for example.

Discussing the innovativeness level (see Chapter 2.4) of the found sustainability features helps to see how deep in the core of business the findings of this study are. When the findings are roughly categorized according to their sustainable innovativeness, following the Adams et al. 2015 study, it can be seen, that most of them fall under categories *operational optimization* and *organizational transformation*, meaning that these aspects might require fundamental shift in the business model while collaborative actions and more thorough systemic change is required in the *systems building* category. (Table 3)

Table 3. Findings from the company review categorized by sustainable innovation type.

Operational optimization *Eco-efficiency*	**Organizational transformation** *New market opportunities*	**Systems building** *Societal change*
• Renewable energy • Closed loop manufacturing • Resource efficiency	• Natural materials • Other renewable materials • Material features (e.g. biodegradability) • Product safety	• Take back system • Product as a service • End-of-life opportunities

When considering these innovativeness levels through examples, it is easier to discuss, what could qualify as a sustainable business model from the results. For example, features that fall under the operational optimization refer mostly to sustainable production, such as use of renewable energy. However, one could argue that having sustainable production is merely over the compliance level and if the product that is manufactured itself is produced for example from fossil-based materials, can the business model then be called sustainable? On the other hand, as the definition of SBM can be interpreted as something that brings value not only from the economic point of view, but also for the environment and society, could sustainable production then be called as a sustainable business model of the company if sustainable operations in fact, produce value to the environment and society.

From another point of view, when considering take back system or product as a service that have been categorized as systems building (due to the fact that they require ecosystems), it can be discussed whether these alone represent sustainable business models. In this study one company offered diapers through a take back system, where the diaper is collected back and through processing recycled back into the biological cycle. Here value is created from the TBL point of view, but the product itself might be for example fossil-based and the model itself doesn't tell whether the product was manufactured sustainably or not. However, the innovativeness level is higher because getting the takeback system be viable,

several stakeholders are needed to create an ecosystem in addition to consumer behaviour change. It could be argued that this kind of business represents a sustainable business model.

All in all, companies define themselves if they think their business model is sustainable and value creation is probably at the core of this thinking. However, to help companies see what needs to be considered when starting their sustainable transformation journey, they can for example look at their business from the life cycle perspective and assess if have they considered sustainability throughout the life cycle, or just from one phase's perspective. Figure 9 shows how the findings from this study can be arranged into the life cycle of a nonwoven diaper of a wipe. As the life cycle model discussed is very high level, diaper and wipe life cycles haven't been separated.

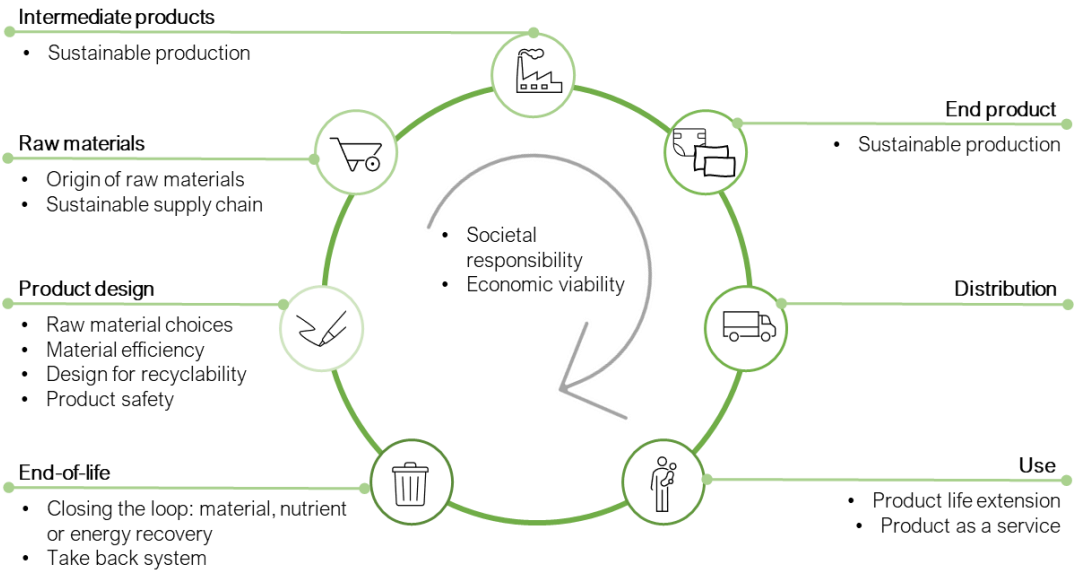


Figure 9. Results of this study displayed through life cycle approach.

When the findings of this study are combined into the life cycle model, it can be seen how existing examples address the whole life cycle quite well. This model gives a rough guideline on how companies can address sustainability throughout the life cycle of the nonwoven product. Though this model could be supplemented with sustainable distribution practises for example.

6.2 Enhancing the sustainability transformation journey

For companies to commit to sustainability, enablers and drivers are needed. Drivers can be more market based, however, when disruptors such as climate change, biodiversity crisis and depleting resources shape the world, market forces can't tackle solving these global problems alone, but governments are needed as well to show direction and lead. There are also challenges and barriers that slow down or preclude the sustainability transformation journey, that need to be tackled.

When analysing the outputs of the company review, semi-structured interviews and questionnaire answers, topics such as regulatory controls, stakeholder demands and growing awareness were brought up, in addition to competitive price, availability of sustainable raw materials and end-of-life infrastructure. It was also noticed that most of these aspects have both enabling as well as challenges or barriers attached to them. Hence, within the limits of this study, it is not possible to categorize them as only enablers, drivers, or challenges. The next chapters discuss these points of view regarding these topics.

Regulation is one tool to force sustainability in businesses and often the first step to get majority of industry to take their sustainability journey forward. In the best-case scenario, regulation enforces such as supply and demand for the sustainable raw materials, creates new innovations, technologies and competitive prices, as well as increases the awareness of stakeholders and businesses. In addition, regulation brings a certain long-term view for the market, making for example investment decisions for companies more easily justifiable. As an example of a regulation that has driven sustainability in the nonwoven field in EU is the SUP Directive. It can be seen that, for wipes the SUP Directive has had an impact on the raw material choices used in these products. Manufacturers are avoiding having to label their products as plastic containing products and thus using more and more plastic-free raw materials in wipes. However, regulation can also act as a challenging factor. The SUP Directive has been critiqued for example for the definition of "plastic", where biobased polymers might also be included under the scope of the directive in certain cases, which in turn slows down the use of more sustainable option for the petroleum-based polymers.

In addition to regulation, stakeholders are an important group to enforce sustainability. Possibly the most important stakeholder group is the consumers. Consumer awareness is rising fast regarding sustainability impact of their choices, especially in terms of carbon footprint of social impacts within the value chains. In major markets such the diaper or wipes markets, consumers have plenty to choose from. As the awareness increases, companies are forced to answer the sustainability related needs, where the impact is taken down in the value chain of the nonwoven product. Sustainably conscious consumers drive up the demand, enhancing supply, which in turn can create a ripple effect impacting for example prices, investments and innovations. should also be noted that consumers often refer to private people, but when considering wipes and diapers, public sectors as well as some private companies are also customers to these products. Especially the public sector is a big client group that should also be kept in mind when considering how to create more demand on sustainable diapers and wipes on the market.

Availability of sustainable raw material is one of the key aspects when talking about sustainable nonwovens. As many of the companies already use natural raw materials or other biobased materials in their products, it cannot be said that there is a shortage of better options to fossil-based materials. However, the interesting aspect is the availability of recycled materials and novelty biomaterials. If the industry would now decide that all material, they use for these nonwoven products is sustainable, there would not be enough raw material available. But it is seen that the availability of more sustainable raw materials is rising and availability shouldn’t be seen as a major barrier.

However, availability and properties of recycled content can be seen currently as a barrier. When discussing circular economy and closing the resource loop, it is important to understand where the recycled material comes from and is it upcycled, thus used in the same or higher value than the original one or is it downcycled into lower value products. As an example, many textile companies, including some nonwoven companies use recycled PET from bottles in their products. However, food-grade PET from bottles represents a high-quality material

which is downcycled, when used in nonwovens, especially in single-use nonwoven products. European Commission states in the EU textile strategy, that fiber-to-fiber recycling should be prioritized and not take away food-grade PET material from the PET bottle cycle. (COM 141 2022)

Nonwovens usually contain fossil-based raw materials, such as polyester and polypropylene, where the price is at a competitive level. Especially when considering light wipes, the prices are relatively low for fossil-based raw material. However, from economic point of view, the volatility of the price of crude oil creates uncertainty to the markets. Thus, this could be seen as a driver towards closing the loop and introducing more circular materials and/or biobased materials into nonwovens.

6.3 Future of sustainable nonwovens

From this study it can be concluded that the future of sustainable nonwovens is deeply focused on the raw material choices. Defining what is a sustainable raw material is a very important factor to consider, when going forward in the sustainable transformation journey in the nonwoven industry. As discussed before, sustainability means considering several factors, firstly that value is created for all TBL aspects, but the value should be also quantified. For example, environmentally friendlier raw material is a complex topic that requires different kind of impact assessment, such as an LCA study. As summarized in Chapters 3.3.1 and 3.3.2, the environmental benefits of different raw material choices in diapers and wipes depend on what environmental category is being looked at and it is no straight forward answer saying that this material is superior compared to another in terms of the environmental impact. For example, if the product is manufactured from recycled fossil-based polymers and another is manufactured from biobased polymers that are biodegradable, there is no clear answer which one is better and these need to be assessed always case by case. Recycled fossil-based polymers may have lower environmental impact compared to virgin material, but there is still the microplastic issue for example. Biodegradable bioplastic might not cause microplastics, but it affects to land use when the raw material is cultivated. Then

there are social aspects to be considered and the business should also be economically viable, hence whether something is considered to be sustainable or not, there should be science-based assessment done to back the decisions.

The results showed that there are also some more niche sustainable business models in the market that could become more mainstream in the future. Especially solving circular economy related issues regarding the studied products is something that can grow drastically in the future. One interesting observation is that currently sustainable raw materials are often divided between biobased materials and recycled materials in discussions, as in the future, there should also be innovations regarding recycled biomaterials.

Reusable products are also something to be recognized when discussing the future of single-use products such as wipes and diapers. In the future, it is possible that reusable products can take over more market space form these single-use products. However, it should be noted the power that users of these products have in this scenario. Only time will tell if consumers decide to prefer reusable diapers over single-use diapers, or decide to abandon disposable wipes. However, this kind of shift is seen very unlikely due to several factors. For example, single-use products are easier to use than reusable ones and usually cheaper, and thus sustainable options for single-use products are needed.

In addition to raw materials choices, consumers and policy makers were seen as the trailblazers that determine the direction where the nonwoven industry regarding diapers and wipes will head in terms of sustainability. Additionally, it when talking about single-use products such as diapers and wipes, the public sector and especially the healthcare sector are very important customer groups that need to be kept in mind when talking about the power of consumers. To conclude, taking sustainability forward is a joint effort accomplished through regulation, stakeholder needs and demands as well as company efforts.

7 CONCLUSIONS

The aim of this study was to define sustainable business model as a concept and use the theoretical basis to search and summarize current SBMs in use in the nonwoven industry regarding two product groups, diapers and wipes. In addition, the aim was to find out what drives for sustainability in the value chains of these studied products. As a starting point it was expected there isn't a unified definition for an SBM and that possible SBMs can't be categorized into universal concepts. In addition, it was expected that the use or renewable materials would be most used SBM regarding diapers and wipes and consumer behaviour was expected to be one of the biggest drivers for sustainability regarding the studied products.

In this study, a literature review was performed to understand SBM as a concept. As expected, there were few different kinds of definitions used in the literature, but generally it was seen that sustainable business model refers to traditional business model that creates economic value without affecting negatively to the environment and society and creates value to the environment and society as well. From the literature review, it was seen that regarding circular economy there are clear examples of circular economy business models and as a concept, circular economy business models represent one type of sustainable business model. However, there isn't a unified way to express different kind of sustainable business models, besides the circular economy ones. There are few different kind of framework examples available though, such as the Bocken et al. 2016 archetype model. However, whether these universal SBM frameworks are needed is a separate question. On the other hand, it might be a good starting point for businesses to see examples, however after analysing the results of this study it became clearer that suitable sustainable business models depend on the intended business being analysed and value to the environment and society needs to be defined and quantified case by case.

This study analysed websites of 64 nonwoven companies operating in the value chains of diapers and wipes to get an overview of different sustainable business models in use currently. In addition, findings from the literature and company review were validated through semi-structured interviews of industry representa-

tives. For both product groups and for intermediate products as well as end products, as predicted, raw material choices rose as most used topic that companies used to create sustainable value. Moreover, most used raw materials that were claimed as sustainable were from renewable sources, either natural fibers or biobased polymers. In addition, product safety was seen as one of the most important sustainability features in use, which makes sense since products such as diapers and personal care wipes are used in skin contact. Different kind production and design related sustainable features were also seen.

Regarding diapers, it was seen that although there are a lot of diapers on the market that include sustainable raw materials, they still contain most likely some fossil-based raw materials, such as SAP due to their superior properties that the current more sustainable innovations haven't been able to compete with. Here is also where the importance of consumers comes to play. Consumers were seen as one of the most important drivers for sustainability. When a product such as a diaper that is a single-use product making life much easier for parents, it would probably be very difficult to get majority of users to give up functionalities that current diaper possesses. Thus, innovations and development are needed more in this field, to downsize the major consumer power that now exists to drive sustainability.

Regarding wipes, one of the most interesting observations made was related to the power of regulation. In the EU, the SUP Directive has been able to get manufacturers to shift from plastic-based material into natural raw materials for example. However, the SUP Directive is also a good example of a regulation that has "cut corners" as it classifies very lightly raw materials as plastics, in a way slowing down innovativeness in the field of biopolymers.

From the findings it was seen that it is relative that what can be called a sustainable business model based on this type of study, but different features and practices regarding sustainability of these nonwoven products were collected and analysed and such this study can be considered successful. The results are based on a relatively large sample of the industry, however most of the reviewed companies were either an intermediate or end product producer. Hence, there can be

some gaps in the results that could have been filled if more different kind of representatives from the value chain were studied. For example, sustainable practises or models of distribution phase weren't included in the study. Moreover, as the study based its results on the findings made from company websites, there might be some gaps in the data as the websites might leave some practises out. It was also noticed that some companies might communicate heavily on their sustainability performance, but in reality, the sustainable part of their business might be quite small compared to the entire business. In addition, as only four industry representatives were interviewed, their answers could not be highlighted too much in this study. If more industry representatives were interviewed, more transparent and generalizing statements could have been presented here.

This study gathered examples of different sustainable practises and business models in use within the scope. The gathered results can be used as one of the starting points when companies are starting their sustainability journey in this field or new start-ups emerge. However, it is recommended that each company starts their sustainability journey by using the tools presented for example in Chapter 2.5, for example the sustainable business model canvas. It is important that companies see that to take sustainability at the core of their business, they should address the sustainability of the entire value chain and from the economic, environmental and social point of view.

Circular economy should be implemented more into the studied products and it is recommended that further studies focus on this topic. Especially there should be more studies on how to use recycled content in these products, that most likely would have to come from other material streams than from their own. On the other hand, there should be more focus on how recover valuable raw materials from these products when they are discarded as waste. In addition, as consumer behaviour was recognized as a very important driver, more studies could be done to understand how to help consumers become more conscious of their sustainable choices regarding the studied industry, in addition to aiding public sector procurement practises to choose more sustainable products.

To conclude, sustainable transformation is not only in the shoulders of separate businesses and a system-level change is required, which was seen in this study

as well. Different stakeholders need to come together to push companies to implement sustainable business models and push markets to offer more sustainable choices.

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APPENDICES

Appendix 1. Sustainable business model canvas

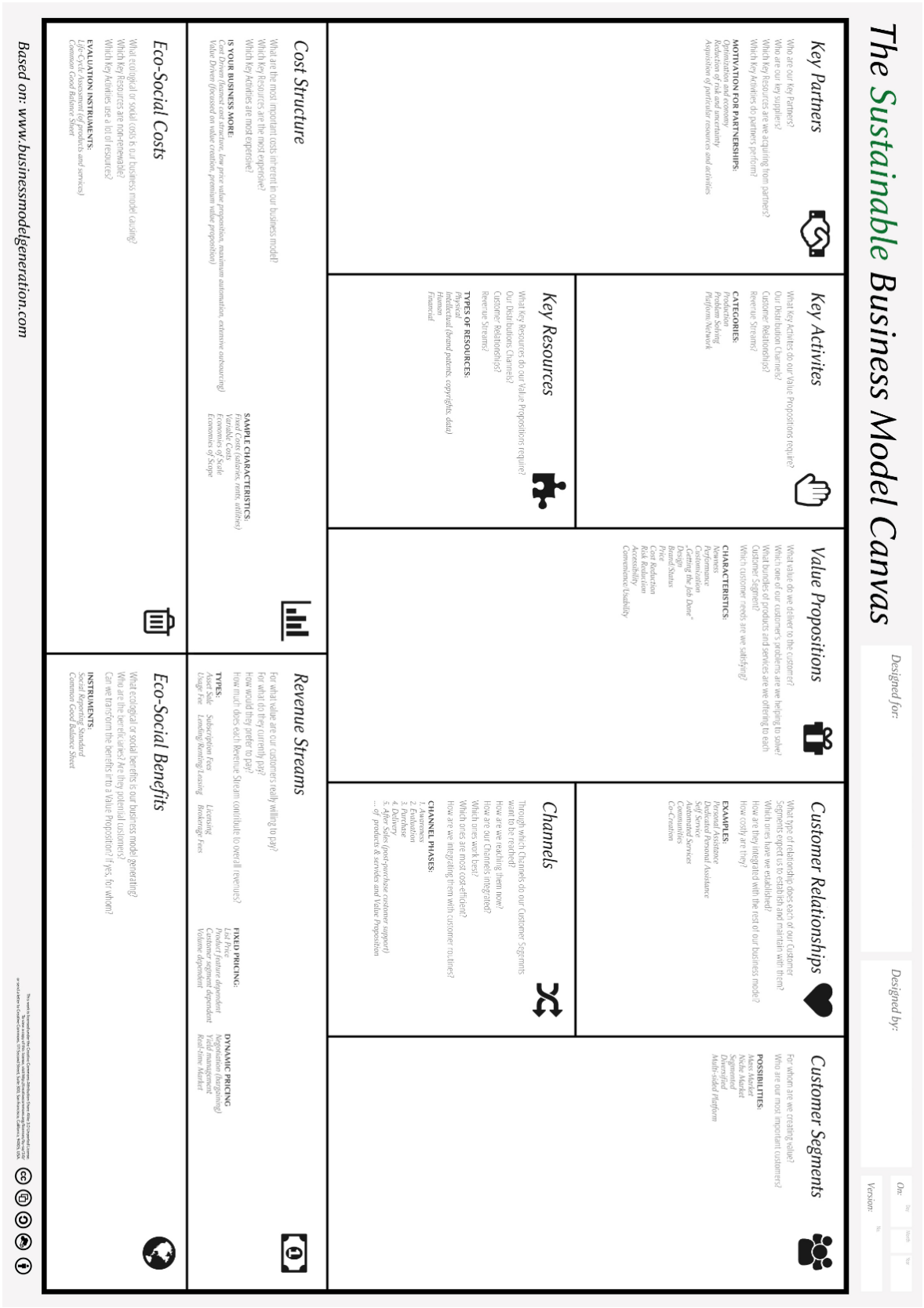

Figure 10. Sustainable business model canvas (CASE n.d.)

Appendix 2. Value mapping tool

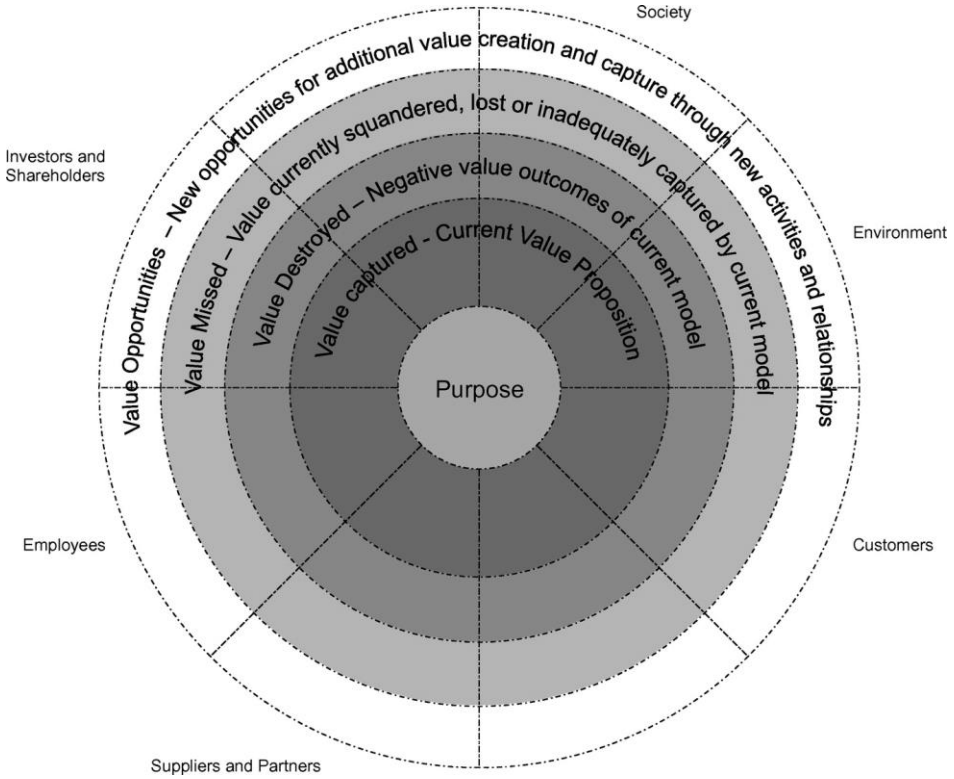

Figure 11. The value mapping tool (Bocken et al. 2015)