DESIGNING SUSTAINABLE CLOTHING SYSTEMS

The design for environmentally sustainable textile clothes and its Product-Service Systems

Carlo Vezzoli, Giovanni Maria Conti, Luca Macrì, Martina Motta

D.I. FrancoAngeli
DESIGN INTERNATIONAL

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Table of contents

1. Clothing system design for sustainability: background knowledge

1.1. Behind the sustainable clothing system

Today the demand for a sustainable clothing care system is higher than ever due to the continuous environmental impact caused by this system. When it comes to the environment (*The State of Fashion 2020*, 2020), the fashion industry record is well documented. Fashion accounts for 20 to 35 percent of microplastic flows into the ocean and outweighs the combined carbon footprint of international flights and shopping. It is no wonder, then, that campaigners who target the industry as part of the Extinction Rebellion describe the industry's potential future impact as "catastrophic". The current generations are more careful about our planet, the scarcity of resources, and the total impacts related to the clothing care system. They care about what they wear and how and where their clothes are made.

In the critical research book on sustainability in the fashion sector, Sandy Black (Black, 2012) affirms that "the business of fashion is a complex mix of personal, cultural, economic, and social factors. The words 'fashion' and 'clothing' donate different aspects of our relationship with what we wear. 'Clothing' can be understood as our everyday basic garments, commodities purchased out of necessity; 'fashion', on the other hand, represents consumers' discretionary choices, which can be driven by all manner of personal and symbolic motivations: desire, aesthetics, novelty, conformity. […] Whether involved in the creation, production, communication, or representation of fashion or simply as its consumers, everyone is implicated in the destructive aspects of this endemically unsustainable system, where obsolescence is inbuilt. As public awareness of issues and demand for product transparency have grown, there is now an urgent imperative for change. Still, the question remains: can fashion

ever really be sustainable, or is the very term 'sustainable fashion' an oxymoron?".

Many studies affirm (Ellen MacArthur Foundation, 2013) that approximately sixty-five/seventy percent of the consumers under thirty-five worldwide affirmed that they select where and what to buy based on the ethical actions and believers the companies and fashion retailers.

They are more prepared than the previous generations about the environmental impact of what they wear. As consumers' demand for ethical and sustainable fashion products gets higher, many new brands are trying to propose solutions to avoid environmental impacts by producing and using clothes. At the same time, many historical companies and retailers have been encouraged by the request of the markets to innovate their offices, creating one specifically dedicated to the research for new sustainable strategies to be implemented in their collections.

By the expression "economically responsible behaviour", we mean an increasingly widespread tendency for consumers, and partly also for companies, to consider the consequences of their behaviour on the market, especially consumption-related behaviour, which nowadays goes beyond being just the outcome of and the reward for a given working process. It is important to note how, although in theory individuals should always act functionally to optimize costs and benefits, in practice, people buy and utilize items according to criteria that are not altogether rational, both in meeting primary needs for material survival and when satisfying other requirements. In so many everyday life situations, rationality is systematically left out of the equation: one would expect the consumer always to opt for the most economical alternative but, inexplicably, it does not always do so.

One explanation can be advanced from the observation that choosing and using commodities is not only a way of satisfying physical or psychological necessities. It also involves other dimensions, among which communication particularly stands out. Consumption is a communication device that we habitually use when building relations with other people, on par with physical appearance and language. So, consumers make a cultural move when choosing commodities, a move by which in practice they manage to define their vital world and at the same time to express both their individual and social ethos. As individuals (Corner, 2012), we consume with a personal style that clarifies our individuality. Still, this style is nevertheless linked to the group or section of society we aspire to be part of. Our garments interact with us, as individuals and as a broader society, what we need to operate on a physical level. Clothing conventions allow us to attend a party or go for a job interview.

In consumption, we measure two fundamental human needs: the desire to be accepted and the aspiration to make our uniqueness acknowledged, dynamics that are not always easy to combine. Already at the end of the nineteenth century, Georg Simmel recognized in them the recurring forms of social living and identified in fashion a fertile terrain for their combination.

It is not by chance then that clothing and its associated consumption patterns can help us understand some of the orientations emerging in contemporary society. Consumption goods increasingly represent a symbolic and communicative value and can therefore express who we are and what we want. The emergence of responsible consumption reinforces the concept of multiple criteria spurring consumers in their purchasing options, driven not only by their need for material satisfaction but also for effective and value gratification.

Responsibility in consumption can be interpreted in three possible macro directions corresponding to three different types of commodity:

- towards oneself: items for psychophysical wellbeing and personal happiness;
- towards others: fair trade products that respect worker rights and exclude child labor;
- towards the environment: low environmental impact clothes in all their life cycle phases, from material production to clothes manufacturing, distribution, wear and care, and disposal.

In responsible consumption dynamics generally, a virtuous circle is established between producer and purchaser, capable of conferring values like justice and solidarity to certain products. This synergy also allows for a particular subversion of current market logic, which is devoted to the blind pursuit of individual profit and unbridled wealth, creating a more sustainable lifestyle from a social and environmental point of view by offering environmentally sustainable clothing Products-Services Systems. This implies rendering all the transactions in the value production chain visible.

The main issue at stake here is cultural: responsible consumption seeks not only to produce economically essential facts but also to influence societies' values. It is no longer a question of selling responsible goods to a growing number of consumers but of making the consumer's ethical choice not only a necessity but much more a preferable choice. As designers, we need to rethink what we design and put on the market, removing the embedded obsolescence that comes from adopting a model made up of products focused on current trends, doing that as a responsible business but also driven by consumer demand.

Examples of responsible production and consumption have been mushrooming, making the sector particularly effervescent and suggesting that the fashion world is not insensitive to responsibility (Lunghi & Montagnini, 2007) as an expression of what is most peculiar in the human soul: respect and care for one's fellows, values which can also be expressed through the garments we wear every day. In this perspective, the expression "responsible fashion" is far from being a contradiction in terms; it acquires depth and seems to point to a new frontier in contemporary culture building. Today, sustainable fashion (*Seven Forms of Sustainable Fashion*, 2012) is a highly debated and increasingly covered topic in media and at seminars worldwide. More and more clothing companies are transforming their business models and improving their supply chains to reduce overall environmental impacts, improve social conditions in factories, and human and earth wellbeing in general. We also see a growing awareness among consumers, especially younger generations.

Fashion is nowadays subject to constant changes; every day people come into contact with a large number of textiles and clothes. It is therefore easy to understand how each consumer establishes a relationship with these objects, which offer comfort and protection and which in many cases allow people to express their individuality. It is an industry that constitutes an important sector within the global economy.

Today more than ever, it is essential to know and study the negative aspects hidden behind the design, fibre and textile production, clothes manufacturing, distribution, use & care, and disposal of clothes. And if this is true for any object, so forth is for the textile-fashion sector, also due to the large number of items that everyone keeps in closets and periodically disposes of. The downside is represented by numbers: according to the Ellen MacArthur Foundation (Ellen MacArthur Foundation, 2017), the clothing industry employs over 300 million people worldwide, and cotton production alone employs about 7% of the workers in low-income contexts.

Clothing accounts for over 60% of the total textiles produced, and the forecasts do not bring any clues to a possible turnaround. It is estimated that in the years from 2000 to 2015[1], the production of clothes doubled, thanks to the increase of people belonging to the middle class in low- and middle-income contexts. This increase in production is the consequence of a constantly growing demand, which in the last two decades has certainly been favored and facilitated by the birth of a phenomenon that has spread

1. Euromonitor International Apparel & Footwear 2016 Edition (volume sales trends 2005-2015); World Bank, World development indicators – GD (2017), in Aa.Vv. (2017), *A new textiles economy: redesigning fashion's future.*

rapidly on a global scale: fast fashion. Fast fashion immediately accustomed consumers to an ever-increasing number of collections, boasting affordable prices compared to the traditional market. To make possible what in the eyes of less attentive consumers is a simple "miracle", commercial and economic strategies such as the delocalization of production sites and the externalization of costs have been adopted. We can see in the graph in Fig. 1.1 how this growth in production goes together with a strong decrease in the use of each garment. This means that in the last two decades, more and more has been purchased and, at the same time, as a logical consequence, much less has been used of the items purchased.

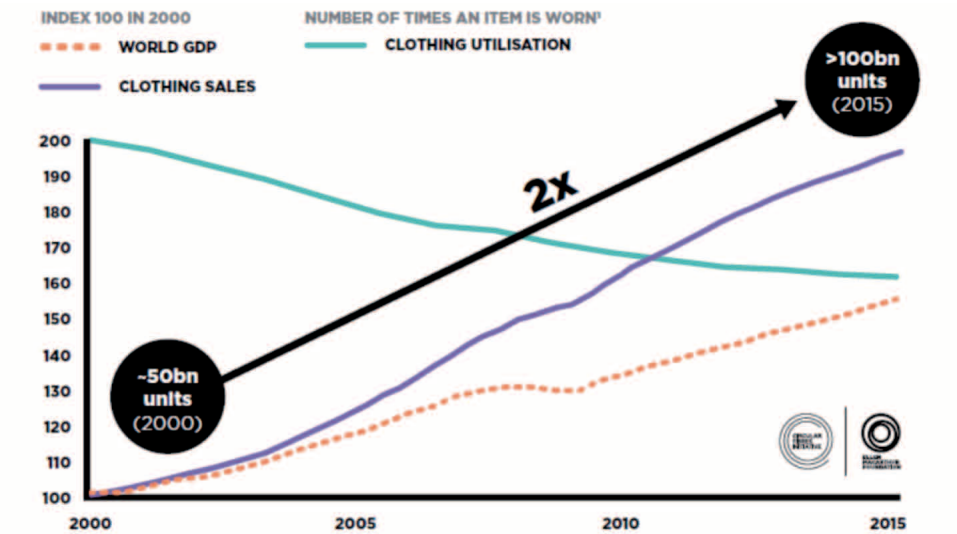

Fig. 1.1 - Growth in clothing sales and decline in usage rate, source: Euromonitor International Apparel & Footwear 2016 Edition (volume sales trends 2005-2015); World Bank, World development indicators – GD (2017)

According to Sophie Benson (Benson, 2011) we own more and more things and less and less time to enjoy them. A recent article published in the New York Times describes how some generation Z kids (born between 1995 and 2010) feel the need to continually buy new items to post new content on social media without reusing the same outfit more than once or twice. To the question: "why (do you wear the clothes) only once?" they answer: "because they are usually in the photos when I wear them and then they are posted on social media. I really don't want anyone to see me

in a dress more than once. People might think it is not stylish always to wear the same thing. The style is to change for whatever situation you are in and for different events".

Fast fashion is undoubtedly an innovation of the fashion industry and would not be possible without technological and infrastructural progress. This consumption model was induced thanks to various commercial strategies, first of all the perceived obsolescence. Going from the main collections, spring/summer and autumn/winter, to a weekly proposal for new looks has led consumers to a state of frenzy and fear that forces them to visit the shops with an ever-closer frequency. According to Lucy Siegle (Siegle, 2011) and Elizabeth Cline (Cline, 2013), if it is true that fashion has always counted on change, what is surprising today is its schizophrenic speed: the consumers who want to be fashionable must constantly update their wardrobe. However, they are no longer willing to spend this because they know that the following season, if not the following month, they will buy other items. This vicious circle has forced companies to lower the quality and the checks of products to further lower prices and continue to sell large quantities of clothes. The average final consumer does not realize the poor quality of these garments: the younger ones may have never owned a high-quality one; more generally, consumers today do not have time to realize if a garment is of quality or not since they will not use it for more than a few months.

As we know, mass production arrived at the beginning of the twentieth century with the industrial revolution, powered looms, sewing machines, and cutting machines (partly due to the need for uniforms) together with the first signs of fashion democratization.

More practical yet still fashionable, clothes became available thanks above all to the American ready-to-wear industry. In the 1940s and 1950s, the American designer Clare McCardell introduced a new informal look under the name of "sportswear". Industrial clothes became increasingly popular and reached a growing number of working people. The habit of making clothes at home gradually disappeared from the second half of the century, when the youth revolution overturned the traditional social order (top downwards) and young designers like Pierre Cardin, André Courrèges, and Mary Quant looked to a new future.

The influential stylists remained the domain of the most privileged, but high fashion became less and less influential, to such an extent that the great French Fashion Houses started to launch their first prêt-a-porter lines. The consumer society began to emerge.

In the Seventies and Eighties, fashion moved in the opposite direction, appearing as a rebellion against fashion, in the guise of youth trends like

punk and rock. These styles inspired great designers like Versace, Jean-Paul Gaultier, and Zandra Rhodes. Since the Sixties, the mass production of casual clothes (jeans, T-shirts, and baseball caps) based on the casual American look has become a sort of uniform for youth culture.

The rigid seasonal diktats from magazines like Vogue and Tatler had to leave their place to emerging publications guided by this new look. Fashion was fragmenting: the rules were overturned, and the barriers between high fashion and popular trends, great designers and everyday styles began to disappear.

In the Eighties, when consumerism reached its heights, fashion parades became the symbol of an aspirational status. A second luxury-democratizing wave spread this imprint during the Nineties, when aggressive marketing and massive expansion made brands accessible to more consumers.

Over the last 15 years, fashion has become increasingly faster and cheaper. As well as increasing competition and industrial growth, global communication and marketing have fuelled demand and consumer expectations, constantly speeding up fashion cycles. However, this position is unsustainable for fashion, both in the medium and long term. Fashion production and consumption are the ends of an extremely long, complex, fragmented chain that transforms fibres and fabrics, which in turn are mediated by designers, industries, and buyers into the clothing on sale in shops. There are problems to deal with at every stage of the process, long before the end-user chooses, wears, washes, and finally throws away the product. As Catherine Hamnett says, the way (Black, 2012) we consume "the future of the planet".

The recent interest in the relationship between fashion and sustainability is associated with the convergence of many different environmental and commercial factors, together with changing social and cultural norms. Fashion has always been a global affair, a quest for the unusual or exotic for its rarity and prestige.

The recent increase in goods arriving from abroad, especially China and India, is a direct result of the change in international trade agreements, altered in 2005, when the MFA (Multi-fibre Arrangement) and GATT (General Agreements on Trade and Tariffs) regulations, already in force, were integrated with an adjustment in international import-export quotas. Closed markets like the UK were previously protected against competition from very cheap imports (like those from China). However, now these goods can invade the market, destroying the previous equilibrium. Consequently, many low-income countries, like Bangladesh or Cambodia, have moved into the clothing market. Although some regulatory quotas are still in use concerning exportation, the new trade relations could prove

difficult. For example, the so-called "Bra war" broke out in 2005: millions of garments made in China were blocked at European Customs until China agreed not to export more pullovers, bras, and trousers that year and to include half the blocked items in the quotas for the following year. In contemporary times (*US Consumer Sentiment Survey 2019: Consumers Are Ready to Spend – but Wisely | McKinsey*, n.d.), demand for change is led by the young. Activists such as Greta Thunberg attract global headlines, bringing forward a call to action to address environmental sustainability, adding to the lexicon on the subject by using "crisis" and "emergency" over "change" and "warming". Thunberg says, "it's 2019. Can we all now call it what it is: climate breakdown, climate crisis, climate emergency, ecological breakdown, ecological crisis, and ecological emergency? […]". These activist movements are making consumers increasingly interested in the environmental impact of fashion. Some 66% of respondents to a McKinsey US cohort survey (and 75% of millennial respondents) say they consider sustainability when making a luxury purchase. Still, consumers do not always back words with actions. Only a minority is willing to pay more for sustainable products – only 31 percent of Gen-Z and 12 percent of baby boomers (*US Consumer Sentiment Survey 2019: Consumers Are Ready to Spend – but Wisely | McKinsey*, n.d.).

The global fashion industry is highly energy-consuming, polluting, and wasteful. Despite some modest progress, fashion has not yet taken its environmental responsibilities seriously enough. Next year, fashion players need to swap platitudes and promotional noise for meaningful action and regulatory compliance while facing consumer demand for transformational change.

The clothing textile sector is a highly significant economic player; as far as earnings are concerned, clothes are much cheaper now than they were a few decades ago. Clothing sales have risen by about 60% over the past ten years. According to research by McKinsey Apparel CPO Survey 2019 (Berg *et al.*, 2019), today we consume a third as many clothes again as we did four years ago and throw them away after wearing them very little, even only once. There has been an increase in the way garments and fashion are sold, with the advent of "value fashion" available in supermarkets, alongside food, and in high street chain stores, clothes that sell because of their low prices rather than for their potential to last. Cheap fashion means accessible fashion and encourages greater consumption, creating a vicious circle. More importantly, fast fashion puts pressure on the textile industries and their suppliers to raise their output, impacting those at the bottom of the production chain and those who actually make the clothes. Sustainable fashion (Berg *et al.*, 2019), is

picking up rapidly among consumers and becoming a fundamental driver of purchasing decisions and is likely to be critical for competitive success in the near future. As an indicator of growing public concern about the topic, internet searches for "sustainable fashion" tripled between 2016 and 2019. Hits on the Instagram hashtag #sustainablefashion quintupled between 2016 and 2019 in both the US and Europe. That is an indicator that sustainable fashion is becoming part of a broader movement, driven, in part, by the concern, activism, and rising spending power of Generation Z consumers.

In this context, many are the questions raised about sustainable fashion since many are the elements involved and complex the sequence of events inherent in the life cycle of our clothes and the fabrics that go to make them. According to *The Sustainable Fashion Handbook* by Sandy Black (Black, 2012), we will continue this work in the same interdisciplinary spirit, making it accessible not only to seasoned players in the industry but also to students, fashion lovers who are just embarking on the journey towards sustainability awareness.

Possible futures' strategies are needed, seeking answers to the key questions surrounding sustainable fashion:

- How can fashion become more environmentally and ethically positive?
- How can we slow down fashion?
- How can consumers make a difference?
- Can conflicting interests be reconciled in such a fast industry as fashion?
- What environmentally sustainable opportunities are available among textiles?
- What would the impact on the market be if everybody kept their clothes longer?
- Is it possible to resolve the paradox between transitoriness and sustainability?
- How can designers make a difference?

Obviously, it is a difficult process, at least as long as the clothing textile industries continue to sidestep sustainability-related issues. However, the wave of criticism from more watchful consumers and the reporting on environmental problems and ethical practices within the production chain have created a certain pressure, which has now speeded up reparatory action in many ready-to-wear companies such as the Sustainable Apparel Coalition[2].

2. Launched in 2011, it involves some of the largest global brands and retailers, including Nike, Gap Inc., H&M, Levi Strauss, Marks&Spencer, Patagonia, and Walmart, together with government agencies, NGOs, and academic institutions. The Sustainable

There has been a fundamental behavior change spurred by ethical consumption, by which consumers request more information about how, where, and in what conditions their clothes are made. Dramatically passing the buck of company social responsibility, companies that were previously seen as the primary cause of the environmental problem, as far as textile production, dyeing and manufacturing is concerned, should urgently become part of the solution. The pressure exerted by small companies and the propaganda from some organizations have taken hold, and a new way of thinking is emerging at higher and higher levels, impacting the whole value production chain. Mass media interest in working conditions in the clothing industry has grown. Numerous interviews have been published about industries in the fashion sector, and various covers have been dedicated to the problem of exploitation at work. Almost all economics magazines and newspapers, from Vanity Fair to Business Week, have been publishing a green column since 2005.

But what steers fashion? We know that fashion is full of contradictions: it is ephemeral yet runs in cycles; it looks back to the past but constantly embraces novelty; it is an expression of personal identity but also group membership; it can both be a way of drawing attention to ourselves and a collective experience, it exists for the few as a unique piece of tailoring, for the many as a mass product. On the other hand, making one's clothes or making them unique, imitating the hippie trend of the seventies, with its handmade garments, has recently captured the attention of younger generations and is steadily gaining in popularity. The desire to be fashionable, continually changing and renewing one's look, is expressed in every area of contemporary lifestyles, increasing obsolescence so forth resources consumption and environmentally impacting emissions. This paradoxically fuels the industry on which millions of people depend, in high/middle/low-income contexts: cotton farmers, textile workers, shop keepers, and many other categories. For those who live below the poverty line, working in the clothing industry is often a better alternative to subsistence agriculture, even though wages may be no greater than the local minimum. High-income contexts consumers must realize that there are serious, complex problems behind all our fashion purchases.

In the present context of growing debate on the problems of environmental protection, social equity-inclusion, and economic prosperity, there is a new sensitivity according to which this unbridled consumption

Apparel Coalition was founded with thirty-three members to focus on developing universal tools for measuring sustainability in the apparel and footwear life cycle and driving best practice and innovation through collaboration (Black, 2012, p. 324).

of faster fashion must slow down. We must remember that in any case, companies in the clothing textile sector are fundamental economic players; they have to respond to one in six of the world's workforce, from fields to factories. The desire for novelty and a credible fashion status is deep-rooted in our psyche. The constantly changing fashion cycles that steer demand and fuel the market will never disappear, and neither could they. It is, therefore, necessary to develop alternatives. Pioneer sustainable-fashion designers (Black & Eckert, 2012) such as Katharine Hammett[3] have raised the profile of organic and ethically produced clothing through meticulously sourced collections that have been widely publicized. As an independent designer, Hamnett could invest the necessary commitment and resources to ensure that every element of her collection is fully sustainable and produced as locally as possible under fair wage conditions. Buying things that have been made with more significant consideration is a choice we are preparing to embrace. However, other problems arise when entrepreneurs have to face the impact of a drop in sales and find win-win beneficial solutions.

Against this background and the numerous meanings and interpretations of fashion as a cultural, economic, and social phenomenon, the concept of sustainable fashion may look self-contradictory, in itself an oxymoron. We come to the concept of the 'fashion paradox' (Black, 2012) to encapsulate this complex web of contractionary perceptions and practices – comprising economics and employment, trade, design and manufacturing, buying and marketing, and cultural identity that collectively make up the global fashion industry.

The pioneering but brief wave of sustainable fashion in the early Nineties associated its natural and healthy image with organic products, "natural clothing" that respect the environment. Today's sustainable fashion is based on a combination of environmental protection and social inclusion principles, innovation, and a high level of aesthetic content. The clothing supply chain (Black & Eckert, 2012) is highly complex and time-sensitive, involving many components and subcontractors in different locations. Except for a few staple clothing products, fashion garments are produced by ever-changing suppliers in relatively small production runs compared to engineered products. The time invested in designing a product is, therefore, a significant part of the cost. Today the demand for clothing is changing: the clothes are designed in a different way, can be produced

3. Unofficially crowned 'queen of sustainable fashion', designer and campaigner, Katharine Hamnett was made a CBE in January 2011. Hamnett's collections span four decades, and have been sold in over 700 stores in forty countries. Her influence – from slogan T-shirts to new stonewashing – is widespread (Black, 2012).

totally with organic fibres, there are recycled fabric collections or products designed for a long life and less waste, and all this contributes to a new wave of design that is changing the way of perceiving clothes made with sustainable resources. The popularity (Morley, 2012) of approaches such as Cradle-to-Cradle and closed-loop fibre-to-fibre recycling instead of down-cycling fibres to industrial products indicates a desire in the industry for a more circular approach to design. Designing and making a more sustainable item of clothing can be both conceptually simple and frustratingly complex in practice. Life Cycle thinking tells us that extending the product's lifetime will bring substantial environmental benefits for reasonably durable products that do not consume energy (including clothes). Hence, a body of evidence supports the sustainability credentials of vintage and second-hand clothing, be it sold in domestic markets. So longer-lasting clothes, and those with multiple lives, are definitely preferable.

Recently, for the fashion industry (*The State of Fashion 2021*, 2021), 2020 was the year in which everything changed. As the coronavirus pandemic sent shockwaves worldwide, the industry suffered its worst year on record, with almost three-quarters of listed companies losing money. Consumer behavior shifted, supply chains were disrupted, and the year approached its end with many regions in the grip of the second wave of infections. A turbulent and worrying year has left us all looking for silver linings – both in life and in business – knowing full well that we will need to make the most of them in the year ahead.

The pandemic has not only accelerated a pre-existing critique of consumerism but also the increased importance of sustainability in purchasing decisions and the rise of circular business models. Consumer attitudes (*The State of Fashion 2020*, 2020) are changing in the wake of the pandemic, as many embrace a "less is more" approach that coincides with industry changes in the fashion cycle. Some 65 percent of consumers in a McKinsey survey conducted during the Covid-19 crisis said they plan to purchase more long-lasting, high-quality items. Overall, consumers considered "newness" one of the least important factors in making purchases. One promising way for fashion to reduce its environmental impact is by scaling win-win business models, through which companies employ a range of strategies to make long-lasting clothes, make more efficient use of resources, being less toxic and more renewable, and valorize waste, as well as help their customers to do so. In 2021 (*The State of Fashion 2020*, 2020), we see circularity moving from the fashion fringes towards center stage.

The way in which value is created in environmentally sustainable systems is radically different from how it is created in traditional systems.

In essence, a single garment can create value repeatedly – through sale and resale, repeated rental, or being sold, maintained (washed, dried), repaired, returned, remanufactured, or recycled, and resold again to reduce the environmental impact. "Sustainability (*The State of Fashion 2020*, 2020) is obviously more important than ever, but it is also becoming the baseline requirement for all apparel companies", Dai Wear Chief Executive Joanna Dai said. "We find increased organic engagement and followers slightly outside of our core target niche who align with our values and buy into our brand. Environmental protection is likely to be one of the key business trends of the next decade. Instead, a collective effort is required in which fashion companies, customers, and all participants in the value production chain collaborate". To date (*The State of Fashion 2020*, 2020), players that feature sustainability in the centre of their branding have been at the forefront of environmental protection practices, as well as some established luxury brands owing. More so, perhaps, to the resale value of their stock rather than their eco aspirations. However, looking forward, we expect mass-market brands to scale their efforts. In addition, aggregators are well-placed to launch resale and repair programs, combined with an enhanced in-store experience. Marketplaces can build on their size and logistical capabilities. As consumers become more engaged with sustainability issues, environmental protection will be the key that unlocks the door to a more sustainable future.

1.2. Textile, Clothing, Fashion: discussing sustainability

Talking about sustainability requires different knowledge, especially in the clothing sector, defined as one of the most polluting sectors in the world. In the textile sector, the Fashion Pact, signed in 2019 by the biggest international fashion brands, represents an important document for producing with more responsibility, cooperating in the supply chain to find shared solutions.

A distinction (Tham, 2012) can be made between clothing and fashion: clothing can be described as answering material or physiological needs, as in a coat offering warmth, whereas fashion operates primarily at a symbolic level. As we have seen, sustainability is likely to be one of the predominant themes of the fashion industry in the years ahead, but the topic is complex and multifaceted. Frequently, articles titled "What is sustainable fashion?" are published in general-interest magazines. However, these typically focus on sustainable materials options without providing sustainability measures or covering the broader and systemic issues involved.

With Alberto Saccavini, expert of sustainability in fashion, member of Blumine/sustainability-lab.net and *Fa' la Cosa Giusta*, we talked about how it is possible to focus the discussion on sustainability in fashion in a sector that is indeed complex but increasingly close to this theme.

Give us your vision on fashion today.

Today the Fashion industry has, finally, I would say, decided that sustainability is an essential aspect for both their longevity and profit.

We can identify three main aspects.

The first one is the one that revolves around the circular economy, in other words, the one that looks to the productions, including textiles, as a closed cycle and not a straight line. All the buzz created around Circular Economy, starting from Cradle to Cradle, may be the soul from which the same circular economy comes. The Ellen MacArthur Foundation and the political effort of the European Union, are pushing the entire fashion value chain to take action in this direction. Of course, there are a lot of successful examples of circularity at a different level of implementation, some at a lab level some at a full scale one, but unfortunately the industrial reality is that very few products and material streams are fully circular. To make an example, the average quantity of recycled cotton used in a new fabric is rarely above 20%.

Nevertheless, I am sure that in 5 or 10 years, because I am an eternal optimist, we will see a huge step forward in this direction, especially when chemical recycling of cellulosic fibres, starting with cotton, and of synthetics will arrive at full industrial development. One of the most significant concerns when imagining Circular Fashion is the possibility of inputting in a closed-loop system all used garments. If technically we are slowly but steadily moving in the right direction, the direct involvement of the final consumer in this equation can be an imponderable variable. In other words, if the final consumer will not send her/his used garments towards recycling, it will be difficult or even impossible to intercept them.

A second aspect is responsible chemistry that is probably the single aspect in Sustainability in Fashion that made the greater steps ahead in this past decade. The foot on the throttle was set by Greenpeace back in 2011. They clearly pointed their finger towards the fashion supply chain as one of the major contributors to water pollution. Their campaign initially targeted international brands producing in South-East Asia, which responded positively and started to commit to eliminating toxic substances from the clothes they produce. This caused a domino effect that pushed the entire industry to reconsider their chemical approach more responsibly. Another reaction to the Greenpeace Detox Campaign was the creation

of the Zero Discharge of Hazardous Chemicals – ZDHC an organization initiated by several brands that today includes all actors of the supply chain from brands to chemical producers to manufacturers. The aim of ZDHC is to help, especially those companies using chemicals in their productions, mainly dye houses, tanneries, and ennoblers, to identify and substitute those hazardous chemicals with safer ones. Even though in this field major steps have been taken, the optimum is still far ahead.

The third and very important aspect is linked to transparency and traceability. These two interlinked and mutually essential qualities of a sustainability policy or program are crucial for environmental and social responsible sourcing and production. The entire fashion value chain is today pushed by civil society, media and all stakeholders to increase their level of transparency and implement credible traceability. Of course, this is a real challenge, especially when, for example, natural materials are produced in small farms or by nomadic people, namely I refer to cotton and cashmere. Nevertheless, essential projects at all levels are being developed involving different supply chains and steps within them.

What does sustainability have to do with the macro trend of making, the makers, a phenomenon now exploded in the design scene in general?

lt surely is a popular theme because it is linked to geography and the call for shortening supply chains and protecting and passing on the know-how as an additional component of sustainability. Undoubtedly, the world of making and crafting are very interesting topics as well as the idea of going back to do things with our own hands, to regain those skills that until a couple of generations ago were typical household practices, but that we have lost in our society replacing them with consumption as a way of life. The attention to craftsmanship, the growth of makers, the tradition of 'artisanship' will help fashion and, therefore, the consumer to better understand the quality of products and push for a new awareness of garments quality. These traditional techniques, practices, and craft skills are a plus, especially in luxury production. In the textile world, there are unfortunately many cases of traditions that were being lost.

We are also witnessing the phenomenon in which many luxury brands open their own schools where they teach ways of traditional making and artisanal techniques. What do you think about it?

The luxury cannot live without the highest-level craftsmanship and its quality. Therefore, there is the need to preserve and often to internalize instead of outsourcing a certain type of work. This is another

symptom of how sustainability, in the broadest sense, has become an integral part of the structures, especially in big luxury groups. On the other hand, there is real craftsmanship, so the capacity, the need to keep alive the knowledge that these artisans have, and that can transmit to future generations.

What do you think about operations like the one H&M practices, promoting the return of the clothes to get a discount ticket? Can this practice sensitize the end customer at the moment of purchase or use?

I think there are good and bad aspects of this project simultaneously, not forgetting that the one of H&M is just one of many projects in this direction. There is real closed-loop exercise on one side, sousing those 'take back' clothes as source material for new production. As we know, this is a challenge, but actually, a certain amount of textile waste has not been used for landfilling but sent back into clothing production. Probably this is just a small percentage for now, but it exists, especially considering the huge investments H&M has made in several emerging recycling and sorting technologies essential to their project.

On the other hand, it is positive to push the consumer to consider the end of life of the clothes they own. However, the discount ticket system incentivizes overconsumption, which has been indicated by many as a major weakness in the entire fast fashion business model.

This raises many questions for the consumer: how much do we really need? Do we need a new garment that only resists a couple of washes? Or maybe we need something that will last much longer in time?

In order to let sustainability be that essential and mandatory path that big fashion brands are considering, I recall the words of Pinault, President of Kering Group, who claims that the only path to maintain the level of acceptance and interest from the consumer on their product is to focus on sustainability.

What can design do to make this aspect one of the levers young designers have in their "toolbox"?

Design is crucial for sustainability. In just a few years, arguments concerning sustainability that were only discussed among professionals today are taken for granted and are treated not as a novelty but as a fact already in the first years of design education. Nevertheless, educating the next generation of designers in all sustainability fields from environmental to social and economical, and in subjects like zero-waste design, upcycling, and disassembly, so that they can grow with the idea of designing not just one generation of products.

1.3. Designing sustainable clothing

Designers play a significant role in the development of new fashion products, and they can lead the selection of materials and services used within the production process (Gwilt & Rissanen, 2011). In the nowadays production system, designers do not directly connect with resources extraction and material production, making, distribution, and disposal of garments. They are thus unaware of all phases that a garment requires, from its design to disposal. That is because, conventionally, the design and the making of a product are separate. Design for sustainability has key challenges to face. Design (Black, 2012) has a big role in the industry because it is the stage where you have all the choices – specifying materials and shape. That is where to bring in sustainability aspects, at the beginning. All life cycle stages should be considered when designing; this would consider the overall environmental impact required. Each life cycle phase of a product should be addressed at the time of the design stage to evaluate each specific case with the aim to reduce environmental impacts.

Within this framework, overconsumption is a key problem to solve. Both referring to social inclusion and environmental protection, new design challenges are spreading, and studies address the necessity of a shift in the production and consumption system.

The fashion business is often totally unpredictable: months ahead of sales, designers and buyers must predict and interpret consumer trends. The traditional clothing textile chain includes many levels: transforming fibre and fabric (including dyeing and finishing), designing, acquiring raw materials, sample production, purchasing by buyers, production, shipping, marketing, and end sales.

Fashion buyers play a hidden but fundamental role in selecting and directing the styles that appear in the shops. Industrial products must be ordered in advance, and the very nature of fashion makes this operation speculative. Actual sales are uncertain, with massive fluctuations due to fashion cycles, trends' influence, and even the volatile seasonal factor. On top of this, buyers are subject to commercial pressures and try to keep their sales as near as possible to their seasonal needs while responding to last-minute trends.

The industry provides seasonal work, which may not be offered the following season because those dealing with supplies usually look around for the best price and delivery times for each order. In this way, it is not possible to guarantee workers continual employment from season to

season. Decisions made at high levels may also affect production, an issue now recognized by multinational sportswear brands.

Beyond this volatility, fashion lifecycles are intrinsically impacting the environment. For example, many items remain unsold even after being put into the sales at a cut-price. Waste is produced both before and after product consumption, and what remains in stock is sold through minor sales channels (outlets or discount stores), sold off in developing countries through charity organizations, burned, and taken to landfills. E.g., over a million tonnes of clothing and fabric (including furnishing material) are eliminated annually in Great Britain, 70% of which are thrown into landfills even though at least half of it could be reused.

A more sustainable approach to fashion design must consider the entire life cycle of clothes, including every stage from pre-production, to production, distribution, use, and disposal.

Over the past couple of decades, issues like green design, design for sustainability, design for the environment, eco-design, and product Life Cycle design have been discussed and investigated, focusing on the product dimension of fashion. We understood that design for sustainable fashion should consider even promising radical innovation and win-win new offer models that have been studied since the end of the ’90, namely Sustainable Product-Service System. Design (Black, 2012) is more than just creating a nice product, a fashionable product. Design involves responsibility: you can no longer just use a nice color, spot the right trend and make a new collection. […] designers today cannot only be designers; they have to be something of a philosopher: The consumer will be more educated in the future, so a designer has to convey a message that is true and authentic. By contrast, the aim must be to highlight the interdependence of the various aspects of the fashion sector that includes clothes, shoes, and accessories but also incorporates aesthetics, lifestyles, and the artificial environment.

1.4. Redesigning fashion

Design (Black, 2012) has a huge role, and when we talk about design, we do not just think about the sketch artist, the pattern cutter, or the production machinist. Design is every decision made along the whole process, from the original concept right through to the way we are wearing them. The designers who create the original concepts play an important role because they impact everybody else further along with life. If we think about any product design, the initial decisions are the ones that indicate all of the other decisions. So it is a huge responsibility, but also an

incredible opportunity. Product design determines how everything around us works, appears, and seems, from the humblest of objects to highly engineered tools. Redesigning changes the relationship of an object with a person. In the fashion sector, the revolutionary concept of A Piece of Clothes (APOC), launched for the first time by Issey Miyake and Dai Fujiwara in 1999, creates clothes that are practically finished when they come off the loom or knitting machine. Designed to reduce fabric waste, the garments require minimal sewing and finishing. This process eliminates the need to use trial fabric, and clothes can be made to order, thus reducing warehouse space. This concept is unique in the fashion industry and represents a rethinking of fashion through the creative development of manufacturing technology. Moreover, it also represents a rethinking of the relationship between designer and consumer.

Over the past few decades, sustainable propositions (longer-lasting commodities, less energy wastage, recycled materials) have gradually become part of contemporary architecture and design. Despite this, the same approach has not yet been automatically and fully applied to the fashion field, which, though a form of product development, has to reckon with constant change. Generally, when we thought of clothes, we considered them functional, suitable for their market and purpose, available in a wide range of sizes, washable or dry cleanable, and must also remain in a cost range determined by the market. At the same time, the novelty and originality of fashion must continue to give pleasure and trigger desire. There is an infinite variety of styles, sizes, shapes, and fabrics and no absolute values, just a few timeless "classics" that remain constant despite the periodic stimuli that drive fashion ahead.

There is a distinct polarity between the more influential, radical fashion designers and the companies pioneering in sustainability. Avant-garde designers like Miyake, Comme des Garcons, Yamamoto, Margiela, and Hussein Chalayan create the main thrust towards rethinking fashion, inventing new body proportions, often using new materials, technologies, processes. On the other hand, small innovative companies are generally less interested in changing fashion and are keener on ecology or ethical production, especially using organic fibres. Many global labels and chain stores are now starting to propose ethical products for the mass market. However, numerous companies still do not yet see sustainability as a problem to be dealt with.

Given the convergence of environmental problems with those of social justice, it is no longer possible to ignore the need to completely rethink our relationship with clothes and how we can design fashion. Many companies are beginning to wonder what they could do. There are huge barriers

to overcome, especially the cost involved in setting up new plants and a supply chain for new materials, closer production chain monitoring, continuous updating and closer contact between all players in the chain. All this lays the base for new challenges in the fashion field and helps to resolve the paradox of fast fashion and sustainability. The role of design (Carbonaro, 2012) for a sustainable fashion system is similar to what we now call design thinking in other areas of design. It is a holistic approach to product development that is not only based on product lifecycle design but also focused on wider anthropological shifts, promoting new meanings and new styles of thought, not just a new sustainable lifestyle (Fletcher, 2014). In that sense, the real work of redesigning design.

1.5. The role of design and designers

In recent years (Manzini, 2015), the terms "design" and "designer" have been successfully applied to notions, activities, and people well beyond those found in the community traditionally acknowledged by these terms. The result is that an increasing number of people recognizes today design as a way of thinking and behaving that is applicable to many situations. On the other hand, for this very reason, its meaning has become less clear to those in the field than in the past. The capacity to turn out new ideas and better approaches to things is ultimately what increases productivity and, therefore, standards of living. We have (Carbonaro, 2012) come from a model of modern design that was mainly driven by the "form follows function" diktat, to postmodern design that seemed to be oriented around the slogan "form follows fiction", ad are now moving towards a new intellectually engaged "form follows sense" approach.

Many design theorists, whether innovative collaborators in design or responsible consumers, have proposed radical ideas about how we must rethink design with a more holistic approach, bearing in mind the entire context in which design works. Ezio Manzini supports the conception of an emerging design network in which "everybody designs"[4] including single individuals, businesses, non-profit organizations, and local and global institutions.

Today, both consumers and the new generation of designers will have to commit to being catalysts of new stimuli and implementing different

4. "This means putting their design capability into action: a way of thinking and doing things that entails reflection and strategic sense", in Manzini, 2015, p. 1.

design approaches. The crisis we find ourselves in is not simply a series of problems with a single answer. The circumstances are extremely complex, and many different strategies can simultaneously lead to a solution. Some of the ways fashion can do its part have already been put in motion, but this is only the beginning of what must become conventional behavior. This time, ecological fashion cannot merely be a transitory stage.

Production and economic processes have become essential for survival since they are fundamental drivers in consumer and designer behavior, though this could be a difficult path.

A new model of behavior means there is no going back. Emotional involvement may help: there are many advocates of new approaches to human progress, other than the capitalist-Fordist industrial growth economy, which holds happiness, personal satisfaction, and sustainability to be part of the final result of economic accounting.

Creative people also play an emerging role in recognizing new opportunities by looking at things from a new approach. Design is becoming increasingly important for business and has been significantly repositioned within organizations. Could a better design induce more consumers to buy ethical and ecological products? Can sustainable fashion be conciliated with the economic reality of the sector's traditional commerce, or is it destined to serve only a niche market, itself subject to the whimsies of fashion? People (Carbonaro, 2012) are pushing even the big corporations to change, and they are changing. This is happening in fashion, in food production, and in the construction of our built environment, and we see this reflected in the way that these and other fields are being taught.

I think that (Carbonaro, 2012) the breakthrough innovations will not emerge from inside the industrial mass-market production and retail system. The real transformation of the fashion industry will be wrought by the majority-minority and will arise out of the vast, diffuse creativity of the many individuals who are courageous enough to attempt to construct the future we thought we had lost. It is a cultural issue: designers can change the mental attitude of consumers and the market, which sees the economic problem as a limit rather than an opportunity.

1.6. An increasing role in designing a sustainable clothing system

Historically, the reaction of humankind to environmental degradation, especially since the second half of the last century, has moved from an end-of-pipe approach to actions increasingly aimed at prevention.

Essentially this has meant that actions and research focused exclusively on the de-pollution of systems have shifted towards research and innovation efforts to reduce the cause of pollution at source. In other words, the changes have been from: (a) intervention after process caused damages to (b) intervention in processes (e.g., so-called clean technologies), to (c) intervention in products and services (e.g., design of low environmental impact product and services), to (d) intervention in consumption patterns (e.g., so-called sustainable consumption).

Due to the characteristics of this progress, the role of design in this context has expanded over time. This increasing role is due to the fact that: the emphasis shifts from end-of-pipe controls and remedial actions to prevention; the emphasis expands from isolated parts of the product life cycle (i.e., only production) to a holistic life cycle perspective; the emphasis passes further into the sociocultural dimension, into territory where the designer becomes a "hinge" or link between the world of production and that of the user and the social/societal surroundings in which these processes take place; and the emphasis widens towards enabling users' alternative and more sustainable lifestyles.

Within this framework, the discipline of **Design for Sustainability** has emerged and enlarged its scope and field of action over time, as observed by various authors (*Seven Forms of Sustainable Fashion*, 2012). The focus has expanded from the *selection of* ***resources*** *with low environmental impact* to the *design of* ***products*** *for environmental sustainability*, to ***System*** *Design for Sustainability (aiming at environmental protection, social equity and inclusion, and economic prosperity).*

Moreover, Design for Sustainability has been recently recognized within the international institutional context as one of the key disciplines to foster sustainability, as reported within the "Circular Economy Action Plan" published by the European Community (European Commission, 2020):

> Up to 80% of products' environmental impacts are determined at the design phase. [The core of this legislative initiative will be to […] make the Ecodesign framework applicable to the broadest possible range of products. […] "Priority will be given to addressing product groups identified in the context of the value chains featuring in this Action Plan, such as electronics, ICT, and textiles but also furniture and high impact intermediary products such as steel, cement, and chemicals". […] "In the light of the complexity of the textile value chain, to respond to these challenges, the Commission will propose a comprehensive EU Strategy for Textiles, based on input from industry and other stakeholders. The strategy will aim to strengthen industrial competitiveness and innovation in the sector, boost the EU market for sustainable and circular textiles, including the textile reuse market, address fast fashion, and drive new business models".

In fact:

> This will be achieved by a comprehensive set of measures, including applying the new sustainable product framework, improving the business and regulatory environment for sustainable and circular textiles in the EU, providing guidance to achieve high levels of separate collection of textile waste, and boosting the sorting, reuse, and recycling of textiles (European Commission, 2020).

This is to say that even up to the top level of Political commitments, the fundamental role **of design is clear to promote a sustainable fashion System**.

Indeed, it is since the 90s that a new knowledge-base and know-how started to be developed to design products with low environmental impact. This attention was initially focused on redesigning specific qualities of individual products (e.g., reducing the amount of material used in a product, facilitating disassembly, etc.). It was in the second half of the 90s that this design approach broadened to systematically address the entire product life cycle to reduce the environmental impact, from the extraction of resources to the material production (pre-production), the distribution, the product manufacturing (production) and its disposal. This started to be referred to "as Product Life Cycle Design, Eco-design, or product Design for Environmental Sustainability and other approaches, including Cradle to Cradle design, biomimetics, emotionally durable design, and design for sustainable behavior, Circular design" (Vezzoli *et al.*, 2021). In those years, the environmental effects of the pre-production, production, distribution, use, and disposal of a product and how to assess them became clearer. New methods of assessing the environmental impact of products (the damaging effects of all input and output of all of the processes along the product Life Cycle) were developed; the most accepted is Life Cycle Assessment (LCA). In particular, two main approaches were introduced.

First, the concept of life cycle approach – from designing a product to designing the product life cycle stages, i.e., all the activities needed to produce the materials and then the product, to distribute it, to use it and finally to dispose of it – are considered with a system approach.

Second, the functional approach was reconceptualized from an environmental point of view, i.e., designing and evaluating a product's environmental sustainability, beginning from its function rather than from the physical embodiment of the product itself. It has been understood that environmental assessment, and therefore also design, must have as its reference the function provided by a given product. The design must thus consider the product less than the ‹service/result' procured by the product.

How this has been specified and articulated concerning the clothing system, it is described in chapter 5 "The clothes Life Cycle Design" in relation to the clothes design environmental requirements, the clothing product Life Cycle Design approaches and skills, and finally, the clothing product Life Cycle Design strategies, guidelines and examples. the method and tools for clothes life cycle design are described in chapter 7 "Methods and tools for sustainable product-service system design".

Again, the new EU action plan for the circular economy also mentions some models as win-win opportunities to enable the diffusion of design for sustainability (European Commission, 2020):

> Incentivising product-as-a-service or other models where producers keep the ownership of the product or the responsibility for its performance throughout its lifecycle.

This is indeed what, since the end of the 90s, has been defined as the Sustainable Product-Service System win-win offer model. In fact, from the end of the 90s, we started to realize that a more stringent interpretation of sustainability requires radical changes in production and consumption models. For this reason, attention has partially moved to design for Sustainable Product-Service Systems, a wider dimension than designing individual products alone. From among several converging definitions, the one given at that times by the United Nations Environment Programme (UNEP, 2002) states that a Product-Service System (PSS) is «the result of an innovative strategy that shifts the centre of business from the design and sale of (physical) products alone, to the offer a system of (ownerless) product and/or (all-inclusive life cycle) service, that are together able to satisfy a particular demand». In this context, it has therefore been argued that the design conceptualization process needs to expand from a purely functional approach to a satisfaction approach, in order to emphasise and to be more coherent with the enlargement of the design scope from a single product to a wider system, fulfilling a given demand related to needs and desires, i.e., a unit of satisfaction.

Other authors (Vezzoli *et al.*, 2021) more recently developed new knowledge about Sustainable Product-Service Systems (S.PSS) design coupling economic and environmental benefits with social equity and cohesion: this new role was shortly named System Design for Sustainability. Indeed, a system approach to design for sustainability may be referred to other studied approaches, i.e., Distributed Economies (DE) design for sustainability, design for (sustainable) social innovation, systemic design and design for sustainability transition (Ceschin & Gaziulusoy, 2016).

How S.PSS design has been specified and articulated in relation to the clothing system, it is described in chapter 6 "Sustainable Clothing Product-Service System Design" concerning the win-win sustainable clothing product-service system types, the sustainable clothing product-service win-win benefits, a scenario for sustainable clothing product-service system, sustainable clothing product-service systems, limits and barriers, designing sustainable clothing product-service system, approaches and skills, and sustainable clothing PSS design, strategies, guidelines and examples. The method and tools for sustainable clothing product-service system are described in chapter 7 "Methods and tools for sustainable clothing product-service system design".

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2. Towards a sustainable supply chain: interviews with stakeholders

One of the many ways to describe fashion, and the one that is probably the closest to the description of the Italian fashion system, is the one that defines it as the action and interaction of people in the process of making. This means that people are at the very center of this system. In their actions and in the exchanges of raw matters, artifacts, knowledge, expertise relies on the essence and the engine of the entire fashion industry, that is based on what Tartaglione and Gallante (Tartaglione & Gallante, 2010) define as "collective creativity", a special kind of creativity that has always been linked and exchanged with a myriad of productive realities, in a close relationship that goes far from the veneration of the one-of-a-kind or from the excess of the catwalks. Designers are part of this system, and the more they are involved in and familiar with the dynamics that regulate it, the more they can intervene to bring change and innovation.

As we have read, sustainability is a widely discussed issue for fashion, still searching for a definition not just in terms of words to describe it but also in terms of actions and decisions to be taken and professional competencies to shape. The above-mentioned process of making can be positively considered as a great expression of human creativity and artisanal expertise, but it is also the reason why the fashion industry has become responsible of big wastage and unsustainable practices. A business so full of contradictions – craftmanship against high volumes – that the notion of sustainable fashion itself "seems to be paradoxical, an oxymoron – how can fashion ever be sustainable, with its focus on novelty and inbuilt obsolescence?" (Black, 2012b).

In the attempt of solving this paradox, the concepts of transparency, environmental, and social responsibility are becoming requirements in the time being, pushed from the broad public on one side and from big brand's policies on the other.

If design, in its broadest meaning, consists in the understanding of the existing situation and the creation of new ones (Simon, 1988; Simonsen *et al*., 2014), it comes that today, being a fashion designer cannot be separated from the ongoing spreading and the rising need for sustainability. Fashion designers today are in charge, whenever they design, to face such complexity, to be aware of what sustainability is, what they can do to operate more consciously in a sustainable way, and how each design decision and action impacts people, the fashion system, and the planet. This process of understanding the existing can – and should – be supported by numbers, data, audits, and analyses but cannot stand without the people, without the knowledge that comes from the experience on the supply chain. This knowledge opens up perspectives for designers, highlighting the mutual impact that design decisions have on the supply chain and that the actions of each one of the stakeholders along it have on the work of designers. This makes evident the need to connect objects, environment and meaning (Walker, 2011) and to re-design not just the relations in the system, but also of the rules and goals of the system (Williams, 2020).

The fashion system is, indeed, made of farmers, raw material processors, artisans, garment makers, manufacturers, retailers, and they all have the chance to contribute with their work for a better and sustainable future. They are not just suppliers to be controlled with audits and inspections; they became, with their decades-long efforts, resources to learn from and thus have to be known and deeply understood as the places where sustainability happens. Fashion producers are taking the role – together with designers and users – of primary actors of a change towards what Rissanen envisions as a "community of fashion producers and users who eliminate waste at every instance of fiber generation, yarn spinning and processing, fabric design manufacture, garment design and manufacture, storage and transport, sales, garment use, and the cycling back of resources at the end of the first use life of the garment" (Rissanen, 2013).

The interviews in this chapter shed light on the commitment that the whole supply chain belonging to the Italian fashion system is undertaking and report the multiple voices of privileged witnesses belonging to a variety of people and professionals that fashion designers encounter along their way.

They should be read with an eye on the importance of a reliable relationship with suppliers and clients, at any level of the chain, in any role that might be taken: the will, or the need, to work together as a system towards the objective of a more sustainable future recur in every interview and emerge as the key asset to act for a concrete change.

Among the voices, there are textile and yarn Italian companies with a long history and firm belongings to the Italian industrial clusters; fashion

brands; innovative start-ups with a focus on sustainability; a certificatory body; the country coordinator of Fashion Revolution Italy.

Their words touch all the phases that will be outlined in the following chapters of the book, from pre-production to production, retail, use, and end of life.

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- Sara Francesca Lisot, founder of VIC – Very Important Choice;
- Marina Spadafora, sustainability consultant and Country Coordinator for Fashion Revolution Italia.

The first contributions, from the upstream companies on the supply chain, give an overview of the first steps of the fashion process, framing the importance of the commitment of those companies that deal with the raw materials, their sourcing, and their processing. They make the evidence of the opportunity for designers to rely on people's expertise and hard work. They prove that sustainability is a journey that has been recently given a name, but that used to happen even decades ago, driven by the individual consciousness of enlightened entrepreneurs. The interview with the Woolmark Company offers the privileged perspective not just on the auditing process but also on the wider commission that they have dealing with farmers, raw material processers, brands, and designers. The words of Margherita Missoni shed light on how a creative director and his/her team of designers can review the traditional way of doing fashion to pursue sustainable directions and on how these new ways are going to change the way of thinking of buyers, suppliers, final customers. The innovative start-ups interviewed stress the evidence that design for sustainability does not just belong to the product but can re-design the processes, the circularity, the relationship pf fashion with other productive areas, the interaction with customers, the act of purchasing. Marina Spadafora then explains, with a wide-open view on fashion as one of the higher human

employing industries in the world, how the end customers can pull the significant paradigm change.

All of these are tools of knowledge for designers who are approaching sustainability. To navigate the chapter, here are orientation charts with the topics touched in each interview.

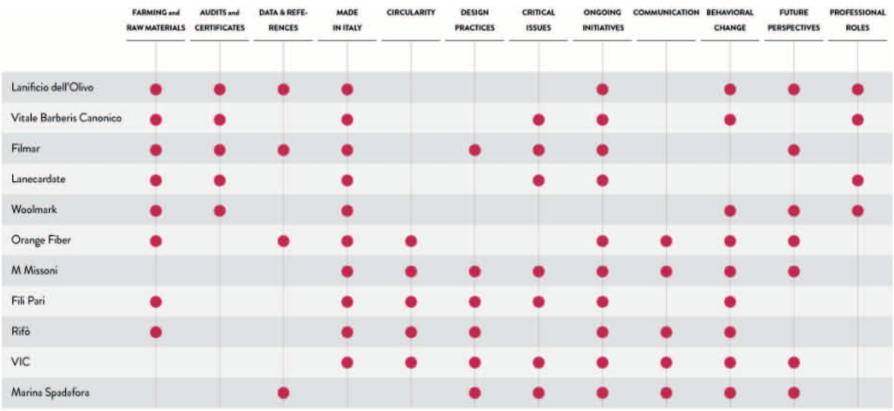

Chart 1 - How contributors/companies are located on the supply chain of fashion. The red dots indicate which of the steps they operate or with which their work is related

Chart 2 - Recurrent issues in the interviews. Red dots indicate in which interview each issue has been covered or touched

From the analysis on the recurrent issues outlined in Chart 2 the author identified seven emerging areas of intervention that recur in the first-hand experience reported by the interviewees. The seven areas, listed here below, represent relevant topics to work with in the near future as levers to activate the paradigm shift towards sustainability.

Lever 1: A long-term commitment
Lever 2: The emerging of a sustainable geography
Lever 3: A demanding audience
Lever 4: New professional figures
Lever 5: The sustainable utopia
Lever 6: In search of common language and practices
Lever 7: The future of design

Taking into account the seven emerging areas as the groundwork for future intervention, the following part of the chapter reports relevant extracts from each interview that are related to one or more areas. The interviews order follows the sequential role of each interviewee along the supply chain (see Chart 1).

Chart 3 reports the areas emerged in each interview and that can be found in the extracts.

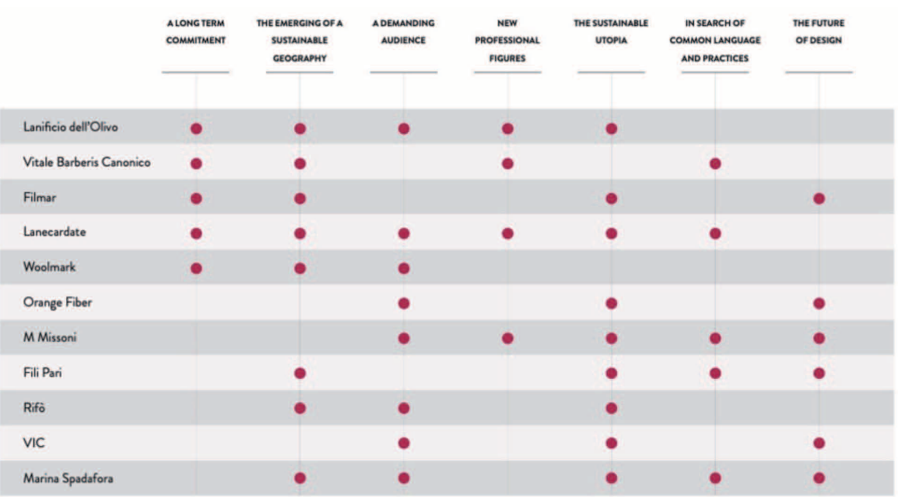

Chart 3 - The seven levers to activate the paradigm shift towards sustainability as they recur in the interviews

2.1. Fabio Campana, Chief Executive Officer and Pierluigi Biagini, Chief Operations Officer at Lanificio dell'Olivo

Lanificio dell'Olivo has been one of the leading spinning mills in the Prato textile district in Tuscany for 70 years. They are specialized in making innovative and 100% Made in Italy fancy yarns, and with the integrated Italian production site, they control production, innovation, quality, and service. Their clients are national and international fashion brands, and about two-thirds of the production is sold abroad, with Europe, the United States, and the Far East as primary markets. Their added value is the research on fibers, colors and stitches, and the care of all value chain stages. They show, with products and actions, a total commitment to being responsible and sustainable (*Lanificio Dell'Olivo*, n.d.).

The interview touches 5 out of 7 levers:

Lever 1: A long-term commitment
Lever 2: The emerging of a sustainable geography
Lever 3: A demanding audience
Lever 4: New professional figures
Lever 5: The sustainable utopia

What does it mean for a yarn to be sustainable?

PB: *We need to define what sustainability is. Sustainable is that set of operations, processes, use of resources brought to a standard that can be kept unchanged over time. That is, they are not going to impact on the environment and to constantly impoverish it. This is a generic definition: with regard to yarns, we obviously start with raw materials, which can have plant, animal, artificial or synthetic origin. A certain degree of sustainability can be obtained for each of these raw materials.*

For the plant fibers we act trying to make the best use of water and soil resources, with attention to the use of chemical fertilizers for crops […]; or animal-derived fibers, sustainability concerns the animal welfare, therefore it goes from avoiding cruel practices in shearing and breeding the animal (for example mulesing) to avoid pesticides on the animals themselves, which is common in farms. In concrete terms and despite the certifications, however, sustainability starts a long time earlier: no one can improvise itself in being able to carry out operations of this kind, a company must know the product in depth.

The certification is in fact issued by third parties, but it is the company, not the body that takes the responsibility for the product, and for the safeguard of its supply chain, […] starting from the washing of

the greasy wool, the dyes, up to the spinning processes and to the final product that we deliver to the knitwear factory, in charge to continue with the chain of custody.

Lanificio dell'Olivo is part of the Prato cluster, traditionally linked to the recovery and regeneration of the textile product.

PB: *This city started working the rags to regenerate them in 1860 and to this day it has continued to recycle millions of tons of clothes. There was a collapse in the 1980s due to some laws that favored the prices of virgin raw materials and that made the recycled product lose its attractiveness. For thirty years, hundreds of millions of kilos of garments every year have gone to landfills. Today we are back in trend thanks to the widespread interest in sustainable practices.*

Being part of this cluster is also advantageous for the use of energy and water resources in the production processes. Prato has always had a textile connotation, and started to deal with these problems very early, so much so that, in 1981, the city built an industrial water purifier for all the companies in the area. Here the companies use 97% of recycled water without having to build private plants, that is one of the greatest costs for textile companies.

When did you start seeing a positive response in customers for "sustainable" products?

FC: *The tendency of customers to request a sustainable product has differed greatly from geographies. Initially the requests came from Japan and the United States, mainly regarding the toxicological aspects of the substances used in production; recently the strongest push comes from the countries of northern Europe, which have a great sensitivity in this sense. Germany is demanding, Italy started the process quite late and for a long time talking about sustainability here almost meant scaring the customer towards the possible increase in costs. This gap then recovered and today there is a good alignment of requests from customers.*

Most of the requests are for certified products, because our customers' brands want the absolute certainty of the truthfulness of each sustainable aspect. They are increasingly exposed to the judgment of the communities, especially from the younger audience, therefore they need to tell true stories about products, materials and processes. If within a brand's followers the suspicion that there are no real elements behind sustainability arises, the brand itself has a big issue to deal with.

It is interesting how today next to the buyer and the designer we find the new figure of those who follow sustainability full-time and 360-degree:

it has become essential to dedicate a person to this, as the time of greenwashing, where we told ourselves how "green" we were, is already over; today we have to tell it and prove it.

Where do you think this change comes from?

FC: *Both from the public and from brands. There is a growing sensitivity among the brands, albeit with great contradictions, because careful brands often coexist in the same large group with other brands that still live on a continuous launch of collections at increasingly competitive prices.*

At the final consumer level, the growing sensitivity involves all segments. […] Compared to a few years ago when the trend was accumulating for every single season, today we are more and more looking for quality and extension of the life of the product.

Is a 100% sustainable product portfolio a utopia?

PB: *If by 100% sustainable we mean achieving zero impact, I would say it's a utopia. However, the degree of sustainability of the products will certainly grow over the years, not only because of the actual need and request from the consumer but precisely because more and more companies are aware of the need to better maintain our environment. Unfortunately, in some countries is still difficult to achieve high environmental and social standards.*

FC: *To say if there is an ideal point where zero impact will be achieved is difficult, but it is certainly a question of always choosing the best direction.*

2.2. Lucia Bianchi Maiocchi, CSR Manager at Vitale Barberis Canonico

Vitale Barberis Canonico is the oldest woolen mill in the world. Founded in 1663, with headquarters in Prativero in Biella, Piedmont, it is renowned for its pure wool flannel and wool and mohair blend fabrics, favored by the world's most celebrated tailors. Today, the company is still run by the Barberis Canonico family, benefiting from the experience of 13 generations.

During its long history of more than 350 years creating fabrics for formal men's clothing, Vitale Barberis Canonico has always been committed to sustainability and has searched for quality in three fundamental pillars: People, Environment and Product. Sustainability for VBC starts with its close ties to the region, from which it takes its principal

resources and to which it is devoted, to returning economic growth and support to the community while always keeping an eye on environmental issues. In 2019, Vitale Barberis Canonico adopted a voluntary **integrated QSE System (Quality, Safety, Environment)** formalized and certified by a third party (*Vitale Barberis Canonico*, n.d.).

The interview touches 4 out of 7 levers:

Lever 1: A long-term commitment
Lever 2: The emerging of a sustainable geography
Lever 4: New professional figures
Lever 6: In search of common language and practices

What does it mean to be a CSR Manager, and how did you come to play this role in Vitale Barberis Canonico?

I can answer the second question. For the first, I'd take a few more years. I'm learning, because it's a new role that still has no frame. In the history of VBC, since we are a family business rooted in a specific area, sustainability has always existed and has been a way of living with work, with the company and with the local community in which both the company and the family resides. What I did was collect and formalize a story that spontaneously existed over the decades […].

What are the duties of a CSR manager?

There is a big problem at the moment which removes the tasks of a CSR manager from concrete actions for sustainability: it is the time that must be dedicated to the many bureaucratic needs of our customers. Each customer has different sustainability tenders that cover a wide range of topics concerning the production management of a company. Therefore, an important part of our commitment is to give answers to customers, while another is to find a common language […] It is such a new theme that there is still no effective and cohesive communication between the parties.

[…] Customers ask us to make our third suppliers sign the same tenders, and this is another big problem. We try to keep the district alive, use external skills as much as possible, and be flexible, as more than everywhere else craftsmanship, quality, and the combination of different skills have an important meaning. However, the small businesses that we rely on do not have staff or skills suitable for dealing with documentation of dozens of pages, almost always in English. We need a sustainability of the supply chain, so that everyone can gradually conform to that.

Does being part of a district economy help you in this regard?

The district of Biella is a very particular reality, where competitors are fair competitors, always ready to cooperate. Sustainability is a competitive asset, but it is also a common interest factor, and here I see a great collaboration. […] We try together to spread a culture of sustainability that includes and helps the whole district. Sustainability is a great potential for the territory because here we have always done things well and it is a card that the district must play.

Going back to the CSR manager. Who are the figures you surround yourself with?

In addition to the chemical engineer and someone with economic skills, I would very much like a lawyer. I would take an environmental engineer. And then someone who can speak to customers.

We always return to the problem of language: if a common language were found, the figure of the lawyer would disappear because an interpreter would not be needed.

This would be the ideal sustainability office for giving the answers that customers ask for. I believe, however, that we need a task force made up of those who deal with production, those who manage the water, those who deal with communication, personnel, safety… every branch of the company should have its own responsible for sustainability, who works in the company and knows the company's practices.

When did the role of CSR manager in the company and the presence of a task force dedicated to sustainability become necessary?

In 2018, when we decided to formalize and begin to tell what we do. Vitale Barberis Canonico did not use sustainability as a lever to communicate […] In the 1980s my uncle invented these "bells" that are used to cover the looms to reduce noise in the departments. That operation had no economic, communicative, or strategic purpose but had the only aim of improving the environmental conditions for workers. This is sustainability, and until 2018 we didn't tell it but it doesn't mean we were not doing it. Setting up the CSR unit helped us put together all the information, coordinate and plan investments, understand how to narrate the company to be transparent. […] A dedicated CRS unit allows you to better investigate and pay attention to aspects that are overlooked in everyday life in favor of productivity. You have time to stop and understand where and how to put order.

What do you foresee for future job positions that will deal with sustainability?

When I looked for people to hire, I could not look for them in the "sector" of sustainability because it doesn't exist; I just found people who had a personal interest in these issues. I myself would need to be trained in some more specific way, but still the possibilities are few.

2.3. Pierfrancesca Solinas, CSR Manager and Michelle Marzoli, Marketing Communication Manager at Filmar

Filmar produces and sells high-quality cotton yarns since 1958. Filmar deals only with the most valuable variety of cotton, which is the 100% Egyptian one, cultivated in the farms acquired by the company directly in Egypt. Cutting edge machinery ensures an annual production of 7 million kilos of dyed yarn, controlled in an equipped laboratory to perform tests and prepare samples. Processes and products are certified, managed and implemented to protect the environment, as well as the health and safety of both employees and consumers (*Filmar*, n.d.).

The interview touches 4 out of 7 levers:

Lever 1: A long-term commitment
Lever 2: The emerging of a sustainable geography
Lever 5: The sustainable utopia
Lever 7: The future of design

What does it mean for a yarn to be sustainable?

Yarns that are fit for the future and go beyond certifications. *This is our motto. Filmar is at the forefront of sustainability by being directly involved in the activities we launch and promote. A sustainable yarn is, in our view, a product made by adopting all needed changes today to guarantee that it can be fit for the future. Fit for the environment's future, by adopting raw materials and processes that preserve precious resources, decrease negative impacts and promote regenerative procedures. Fit for the people's future by ensuring that persons involved in all our processes are respected, nurtured, and given the possibility of developing knowledge and skills through continuous improvement. Fit for a shared economic growth by enhancing and guaranteeing that our firm's success fosters social progress, besides providing economic returns to stakeholders, starting from the most vulnerable ones, such as the farmers who cultivate the cotton we use for our products.*

What does it mean for a company to be sustainable, going beyond the product and thinking about environmental, social and economic sustainability?

Now more than ever consumers, hit hard by a global recession brought by the Covid 19 pandemic, will be more cost-conscious. Sustainability, therefore, will need to be grounded in authentic behavior and internal practices that integrate the dimensions of people, planet, and shared prosperity. At Filmar we focus on protecting and valorizing our human resources more and more through knowledge and skills development to equip them with all that is needed for working safely and for the implementation of eco-friendly processes and that can save precious resources. Moreover, we believe that sustainability cannot just be practiced at the company. It needs to become a new normal even in personal lives.

Sustainability is not a trend anymore but a given. When did you start working on this? What was the spark that pushed you at the beginning?

Since the day of our foundation, quality and technological innovation, combined with sustainable development and ethics, have been the cornerstones of Filmar's business. Therefore, promoting sustainable fashion through a fully transparent, eco-friendly, and socially responsible production chain is the mission we pursue. At Filmar, we think that a sustainable business does not simply mean respecting and protecting the environment. Our core beliefs and priorities are the respect of human rights, workers' and consumers' health. […] Intending to minimize cotton's environmental impacts, Filmar committed to implementing a set of actions enclosed in the innovative CSR program, Cottonforlife*, launched in 2015 and realized by Filmar SpA with the participation of Alexbank of Intesa San Paolo Group. The Initiative intends to promote a fully transparent, eco-friendly, and socially responsible cotton value chain. […]*

Sustainable choices: how much have customer requests influenced them?

Along with customers' requests, which are certainly a driving factor for every company's production strategy, there are global challenges that we need to consider for the sustainability of our operations. Among these are climate changes and population growth that need to be taken into consideration specially when cotton is the main raw material used. Therefore, we have started business partnerships with our customers to share concerns and define joint action plans to maximize our positive impact.

How do customers perceive sustainable and certified products? Which types of customers are most attentive and demanding in terms of sustainable products?

Certifications for customers are important as they define the standards of raw materials used, chemicals adopted, and how operations are conducted. Many certifications also make sure social standards are respected along the supply chain. True is that we need to go beyond certifications by engaging ourselves in defining and evaluating our value chains. This means that we cannot just put a label with certification on our products without knowing exactly what is behind it. Remember what happened in Rana Plaza and how many people died? Well, as we all know, garments produced there were then sold in our main cities shops where certifications are a must.

The textile sector is a complex system, where a 360° sustainability still seems utopian, due to the large consumption of water, the chemical agents used for cultivation, the process and the finishing, the difficulties in tracing those processing steps that are entrusted to third parties. What efforts does the commitment in this sense entail for the company? Do you think it is possible to reach high sustainability standards? How?

As said, sustainability is the integration of environmental, social, and economic dimensions. When we assess the environmental impact of cotton cultivation and its industrial transformation, we should balance it with its social and economic impact. Cotton-Textile industry involves millions of people all over the world and this should be kept under due consideration. This means that we need to improve the way we do things, starting from supporting sustainable cotton production by procuring cotton that has a reduced environmental footprint while ensuring social and economic positive impacts. Filmar directly supports organic and Better Cotton *cultivation by engaging with value chain stakeholders and investing in cotton plantations that follow such standards.*

How can the work of designers in your customers' brands push the entire system towards more sustainable choices?

Nowadays, designers' role goes far beyond their classic role of designing collections: their role can be instrumental for the real advent of sustainability. They select raw materials, design shapes, define colours, etc. If they could operate their choices in the light of the environmental, social, and business impact of each step they deal with, I believe things would really change. […]

2.4. Chiara Bianchi Maiocchi, Chairwoman at Lanecardate

Lanecardate started in 1987 as support of Vitale Barberis Canonico: the woolen spinning department of VBC had been closed in the 40s, but when in the 70s the woolen flannel – which is still a very important product for Vitale Barberis Canonico – was catching on again, Chiara's uncles asked her mother and father, engineer, to move to Biella and to found the company. They started to produce yarn for knitting, and from being a woolen spinning department for textile, Lanecardate became an independent spinner.

Today they produce just 3-4% of their turnover for VBC; all the rest is for third clients. Customers are mainly luxury brands or knitwear manufacturers who work for these same brands, in particular Italian, French, English, and American for the high end of their product.

The interview touches 6 out of 7 levers:

Lever 1: A long-term commitment
Lever 2: The emerging of a sustainable geography
Lever 3: A demanding audience
Lever 4: New professional figures
Lever 5: The sustainable utopia
Lever 6: In search of common language and practices

What does it mean for a company like yours to be committed to sustainability, from the product's point of view, and the environmental, social, and economic impact?

I remember a customer who, one day, when sustainability was still not a widespread theme, but we at Lanecardate were starting to talk about it, asked me "Well, but what does sustainability mean?". If on the one hand this question would no longer be conceivable nowadays, I think on the other it is still very current, because the topic is so rich that it is a question that you can and must always ask yourself, finding in each answer a new point of view to work on to improve.

We started to deal with sustainability without calling it that, since 2004, for a distinctive character of my father who can't tell lies. In 2004, in times when it was not yet discussed, he tried to convince the spinners of the Union [Unione Industriale Biellese] *to make a voluntary declaration of traceability. At that time, he convinced very few of them because everyone wanted to somehow keep the "secrets of production", something that today would no longer be understandable or acceptable.*

He was a precursor of the times: in 2004 Lanecardate made his first voluntary declaration of traceability, declaring for each phase of our production where and how it was made and where the raw materials came from. This already included the tracing of farms, which was not yet driven by the animal welfare but by quality: my father understood that, since we are one of the very few spinners of woolen yarn that directly buy greasy wool in its country of origin, some farms had a much better product than others, and by knowing the farm from which each batch of wool came, he could indicate to the Australian buyer which farms to stock from by choosing them personally.

This has now allowed us to do a similar thing for animal welfare.

I am mentioning times and dates to highlight the competitive advantage we got by having traced everything by ourselves, and for a long time: to start today with the intent to reconstruct the traceability from scratch, from downstream to upstream of the process, is complicated, sometimes impossible without "buying" it packed by some service suppliers […].

How have your customers' perception and demand for sustainable products changed?

It is an exclusively growing trend. In the beginning, more than ten years ago, it was a voluntary action, today every customer asks us "What are your sustainable products?". I find it a strange question, somehow open and incomplete, as it seems they leave the exclusive responsibility of sustainable actions to us.

What are the most difficult challenges for a textile company on the path towards sustainability?

At the moment the biggest difficulty is to extricate yourself in the jungle of certifications. There are many, very bureaucratic, all very similar and it is difficult to identify which one customers will ask us for in the near future. […]

Is the Italian context a context that favors the sustainable choices of the companies that operate there?

I think it is easier to be in Italy than elsewhere. Here the commitment comes at a district level, at a chain level, it is very collective and shared. […] Being part of the district of Biella is good for the proximity and commonality of approach, but I am also happy to relate to our Italian customer knitwear factories, who are ready for this topic and deal with it as we do, with a concrete commitment that is not necessarily dictated by the bureaucracy of certifications.

Do you see a future with a product portfolio entirely made of sustainable yarns, and when products that are not declared as sustainable will disappear?

I have to say that the frequently heard question of clients, "Do you have sustainable products?" never made sense to me because it's the company that must be sustainable. It makes no sense to choose a sustainable product among others because it ends up just being a marketing operation, it must be a whole sustainable process. In this way, companies will progressively reach 100% of sustainable products, and products that will not be that will progressively lose their sense of existence.

Do you see sustainability as a future perspective for design education?

Education should start to work on sustainability by considering the whole supply chain. […] We need new experts working with us or with our client brands, that are able to understand the supply chain and the great efforts we are making.

2.5. Francesco Magri, Regional Manager Continental Europe at The Woolmark Company

The Woolmark Company is the global authority for promoting the Australian Merino wool. Operating worldwide through an extensive network of relationships spanning the international textile and fashion industries, they highlight Australian wool's position as the ultimate natural fibre and premier ingredient in luxury apparel. They are also committed to the sustainable aspects of wool and its impact on the environment, starting from farmers until the finished product (*The Woolmark Company*, n.d.).

The interview touches 3 out of 7 levers:

Lever 1: A long-term commitment
Lever 2: The emerging of a sustainable geography
Lever 3: A demanding audience

How can Woolmark define its idea of sustainability, from an environmental, social, and economical viewpoint?

For The Woolmark Company, the idea of sustainability is mainly linked to fiber and its natural origin.

Our woolgrowers are the keepers of the territory who manage, most of the time, of immense spaces and dimensions. The conservation and

defense of the territory is a necessary condition for the sheep breeding that feed on air, water, and grass, and these elements can coexist only in a natural and original environment.

There can be no concept of environmental sustainability if it does not start from the beginning, in reference to fashion, it is therefore intended to start from the fiber used.

As a certificatory body, how is Woolmark taking the challenge of sustainability?

The Woolmark Company certifies the fiber quality in fabrics and yarns of wool garments, our challenge for sustainability is to be able to support a traceability path originating from the farms that allows brands to choose the product they consider most suitable as sustainable for their customers. Our challenge is to help brands to understand the supply chain and how they act on it as much clear as possible.

What are the main issues to consider concerning wool environmental footprint?

The Woolmark Company is supporting woolgrowers for the adoption of best practices, such as regenerative agriculture and become more than an owner, a "custodian" of the land. That's our first priority.

How important are all the phases of the lifecycle of products for the environmental impact of wool?
What is Woolmark doing in this direction?

Wool itself is a solution for making fashion a more sustainable market and not an issue, what comes after – as dying or treatments as happen for all fibers – can become an issue and that's why we are investing 25% of our total budget in supporting the research for innovative techniques for the use of more natural treatments on the fiber. This is why we activate numerous partnerships with key players in the supply chain to support them in finding new techniques in the direction of greater sustainability.

Wool is much more versatile than any other fiber; a wool garment can be handed down over generations, upcycled for other use in other sectors thanks to its qualities (soundproofing, thermal insulation etc.) or disposed of in a natural way thanks to its natural biodegradability. A full sustainable lifecycle.

Woolmark Italy has a privileged perspective on emerging trends and innovations as a certificatory body that works with many different

textile and fashion companies. What is the role of sustainability in this very moment*?*

Since it is inevitable for man to interact with nature in whatever activity is carried out, today the real concept of sustainability is understood by us, as consumers, in "damaging the environment as little as possible, reducing our impact and feeling good in taking care".

The absolute concept of sustainability is obviously utopian for humans, so today it is not only a matter of just using natural fibers – that is a must –, but to reduce waste: for this reason, garments must also be versatile and long-lasting, and performance and functionality mixed with natural fibers is the biggest trend textiles companies and brands are now riding.

Moreover, sports, well-being, and sustainability are the new pillars in lifestyle, and that's why wool – the most versatile and performative natural fiber – is living now a golden period and is regaining large areas in sportswear. It is not a novelty, as until the diffusion of low-cost synthetics in the 70s all sports – soccer, tennis, running, skiing – were practiced wearing wool garments!

What kind of evolution do you envision for the future*?*

More and more natural fibers will be used, quality will be synonymous with new luxury, and more and more people will be aware of the impact of their purchases on pollution. This logically will lead to fewer products but higher quality and more natural fibers.

Man has been dressing since he was born and always will; fashion will never end but we, as consumers, will be able to buy less and better, and the companies will adapt to it by reducing the collections and increasing the quality of the offer.

In your opinion, is the Italian context a context that favors the sustainable choices of the designers and the companies that operate here?

The Italian context is perhaps the most advanced in the concept of sustainability, as the sustainability of a product is the result of a process and of many steps that must be all "sustainable". In Italy, we have the most important districts of fashion fabrics and yarns in the world, and the work that weavers and spinners are pursuing in the sign of sustainability is the cornerstone of the whole fashion process.

Without a fiber and a fabric/yarn worked with the chrism of sustainability we can exclude a priori that a piece of clothing can be considered sustainable itself.

Do you see the perception of sustainable messages, brands and products has changed in recent years?

The global concept of sustainability has evolved by embracing the life cycle of a finished garment (while only a few ago we stopped only at production) and social and work sustainability. These are all elements that today play an equal role in being able to define a sustainable product. It is not an easy game anymore; I would say that it is not a game at all as today sustainability is a proper job requiring high profile professionals and expertise.

2.6. Enrica Arena, CEO & Co-Founder at Orange Fiber

Orange Fiber is an Italian company that ideated and patented a sustainable material made from citrus juice by-products, pioneering an innovative process to extract cellulose and to transform it into a refined and high-quality fabric well appreciated by national and international fashion brands (*Orange Fiber*, n.d.).

The interview touches 3 out of 7 levers:

Lever 3: A demanding audience
Lever 5: The sustainable utopia
Lever 7: The future of design

How did the idea of Orange Fiber rise and what has it become today?

Our adventure started at the end of 2011 in Milan, when we were finishing our studies and sharing a flat.

Adriana Santanocito was studying fashion design and she was focusing on innovative and sustainable products while I wanted to get a job in line with my idea of sustainable development and social entrepreneurship.

We had different backgrounds, but we shared the dream of changing the world starting from our country – Italy – and region – Sicily – using our skills and passion.

Adriana with her background in design, while writing her thesis, asked the crazy question: what if we could turn citrus juice by-products into an innovative fabric, contributing to solving two problems – the environmental and economic impact of citrus juice leftover disposal and the need for sustainable materials in the Fashion Industry – at a time? She brought me on board, and together we started our journey through sustainability and innovation that in 2014 led us to found Orange Fiber: the world's first and only company to produce sustainable fabrics for fashion from citrus juice by-product.

How did you go from the – idea of using waste resources to generate a new material – to its industrialization? How did you manage to transform a concept strongly linked to sustainability into a sustainable production process?

Following a collaboration with Politecnico di Milano University, we developed an innovative process that allows to turn virtually more than 700.000 tones of by-product that the citrus processing industry produces every year in Italy. […] The innovative process was patented in Italy in 2013 and extended to International PCT the following year. Registered as innovative start-ups, the company was established in February 2014 […] and we presented the first prototypes of our fabrics the same year. On December 2015 – thanks to the funding by Smart & Start Invitalia (Ministero Sviluppo Economico) – we opened our first pilot plant to extract pulp from citrus juice by-products in Sicily. In 2016, thanks to the Global Change Award by H&M Foundation we significantly moved forward with our R&D, implementing our team and deploying our first ever pilot production of more than 10.000 thousand meters of fabric. This first-ever production was pre-booked by the famous fashion brand Salvatore Ferragamo who has used it to create the first-ever citrus clothes collection, the Ferragamo Orange Fiber Collection. This important milestone marked the official entry of our products on the market and the first step of our history as a company.

Do you think the Italian territory is a context that feeds the sustainable choices of the designers and the companies that operate on it?

In recent years, attention to issues related to environmental sustainability has grown considerably in our country, paving the way for eco-friendly products and projects based on the circular economy model. We believe that the context is rich and favorable to sustainable designers and companies and that there is an ample market space and credibility with consumers and institutions. In this scenario, bold actions need to be facilitated and accelerated through financial support, industrial investments, strategic partnerships, and collaborations between changemakers, universities, private and public sector, and research centers.

How important is the role of independent designers and innovative companies like yours to push the entire fashion system towards more sustainable choices?

We believe that independent designers, innovative start-ups, and SMEs have a crucial role in widespread awareness of sustainable fashion, accelerating changes and pushing the entire Fashion Industry to move rapidly

from words to more concrete actions.The collaboration between emergent designer/start-ups and top fashion brands could be the key to accelerating changes in the Fashion Industry, facilitating the adoption of innovative materials, solutions, and business models.

Let's talk about communication: how and to whom a sustainable company is operating upstream of the supply chain told? How much effort does it take and what are the most difficult messages to convey?

[…] Communicating effectively on social media and traditional media, our dedicated team works every day to make sustainability "fashionable" to mass-market consumers. And pushing fashion brands and other important supply chain actors to move from words to deeds, really implementing innovation and sustainability in their business models. This is probably the most difficult message to convey.

Do you find that the perception of sustainable messages, brands, and products has changed by the end consumer in the last few years? If so, what consequences does this change have on the choices made upstream of the supply chain?

According to Lyst, in 2018, there was a 66% increase in web searches concerning sustainable fashion and sustainable materials, such as organic cotton and vegan leather. This number demonstrates a strong interest in sustainable fashion products among consumers. Researches show that this trend is destined to increase, and, in a bottom-up effect, this will involve essential changes in the entire Fashion Industry […].

2.7. Margherita Missoni, Creative Director at M Missoni

Missoni is the second line of the Italian brand Missoni, recently redesigned by Margherita Missoni that took the lead as creative director. In the new definition of the brand image and values, Margherita Missoni took sustainability and social responsibility as pillars of the new M aesthetic, with the claim "REMIX REUSE RESPECT". The brand works to improve and move forward with sustainability in many ways: it builds projects that respect communities, workers, and animals, it geographically relocated part of the production to collaborate with companies that share the same values, it created a network of suppliers to control the impact on the environment, it works in line with the DNA of M at the origins by repurposing disregarded materials and objects to give ulterior life to physical and conceptual scraps (*Missoni*, n.d.).

The interview touches 5 out of 7 levers:

Lever 3: A demanding audience
Lever 4: New professional figures
Lever 5: The sustainable utopia
Lever 6: In search of common language and practices
Lever 7: The future of design

What does it mean for a fashion brand to be committed to sustainability? From the point of view of the product and the environmental and social impact of the company itself, up to the economic aspects.

Sustainability has been a priority and a pillar of M since we relaunched the label. I think it would be inconceivable to launch or start a brand nowadays without considering that aspect. […] Sustainability obviously crosses all the aspects of the brand, from the product development to communication, to the choice of materials, to the presentation and distribution, so every time we start with a new project, we ask ourselves how can we make it more sustainable, what's the ethical impact, what's the ecological impact.

To design sustainable it is clearly a bit more expensive, especially because it is not yet a common practice, but I think the more people and the more brands will embrace it and the less expensive it will be. Every single collection we develop at M, we find more possibilities in terms of yarns, fabrics, treatments that were not available even six months before.

Raw materials, yarns, and textiles: you started to use for M collections materials that were in stock inside the warehouse of Missoni. How did you end up with this decision? What are the technical limits that this entails?

The knowledge that we had a lot of stocks of yarns and fabrics in our warehouses was always in my head. I knew that even when I was not working on M or even in Missoni, and I kept thinking about how we could put that to good use. As they are special yarns, namely space-dyed, the idea they could be sold for a lower value really upset me – and in fact we never did, that's why we have the warehouses, and we never burned anything not to waste them –, so when I took over M I thought maybe this was the place where I could give new life to that. The limits are clearly numbers: we often have small productions, but that requires just a different set of minds, from everyone in the chain, to adapt to it. People who develop need to know that whatever color they combine with the stock yarns needs to go well, at least with four different space-dyed yarns, because that yarn will change through the production. The people who produce need to be aware that maybe you will distribute different

yarns to different continents, so it's easier for people who are going to sell to understand they will sell different things. Once you adapt, it gets even better because everything is a limited edition, and it becomes an upcycling in the sense of giving a higher value to something, but it takes a while for everyone to oil well in this new mechanism.

How does this affect the way of designing the collection?

Usually, we design without thinking if we are going to use some upcycled yarns in that specific design; and once we approve all the sketches and all the groups, we look at them, and think of where we could use solid yarns or space-dyed yarns we have on stock. In every collection, we have some recurring items where we know we are going to use stock yarns. […] We started doing for a few seasons stripes fully done with the upcycled solid yarns, and we are re-developing and re-introducing them in every collection.

How does the way of telling the collection to buyers change? What do you need to insist on most?

On the whole process, everybody in the chain needs to adapt to the mentality. Once buyers start to understand that those are limited edition garments that are more valuable than other items, they start to appreciate them. Some are more prone to that than others, the more fashion-forward clients only buy the sustainable part of our collection, whether it is upcycled, recycled, or ethically produced.

For the textile-clothing industry, sustainability is a complex issue, full of contrasts, and true sustainability seems at times utopian. What are the most difficult challenges for a brand?

True. Consumerism and sustainability contradict each other. My husband, a man of extremes, always says to me that the most sustainable thing I could do would be to stop making clothes at all. But it's a challenging compromise, and we are always leaving on edge. I think we have to choose our side and work in an ethical way, and I think the same will happen with ecological values: in a few years, there will be enough laws to make fashion stop being the second most impactive business on the planet.

How important is to communicate the brand's sustainable commitment and actions with the end customers? What are today the most effective channels to do it?

In general, the rules of communication have been disrupted, and I think the Covid situation will push forward many changes in fashion, especially in communication and distribution. Fashion shows, which are very

impactful from a polluting point of view but also from a financial one, are probably going to change a lot; […] people will start questioning who are those fashion shows for, who are they trying to speak to. Those events are hybrid; if they were originally created for buyers, now they do not respond to the need of buyers anymore; they are more of an event for the press and for the final clients. So we started from the beginning wondering what our means and our tools are, and how we can use them at their best.

For the message that we've been trying to communicate from the beginning, our hashtag #reuseremixrespect *has been very helpful in communicating the brand's DNA in all aspects, including sustainability.*

Do you think the Italian context favors the sustainable choices of the companies – brands and manufacturers – that work in it?

Italian production, in general, is much more sustainable than production in any other part of the world, and even if it is more expensive, a higher price means better working conditions, more ecological materials, and practices […].

Do you imagine a future in which "normal" products will disappear from the collections and it will no longer make sense to design without doing it in a sustainable way?

Yes. […] I think this is what we fight for in fashion, and we need to communicate to people that there is a difference, there is a reason why something costs more and it is the dedication of people who worked on it. I believe we will achieve that, and people will buy consciously and accept spending more on something produced following certain criteria.

What can fashion designers do to push the whole system towards more sustainable choices?

The most important thing we could do is to get together, create a system that decides to work in the same way, pushing the same concept, following the same rules, in order for the general public to start understanding and become aware of what's behind fashion.

2.8. Alice Zantedeschi and Francesca Pievani, founders of Fili Pari

Fili Pari is an innovative start-up focused on the research and development of unconventional materials for the textile industry, respecting the territory and the environment. They develop cutting-edge technologies to enhance

marble powders, protect the land and valleys from the mountains dismemberment, and encourage by-products as a raw material (*Fili Pari*, n.d.)[1].

The interview touches 4 out of 7 levers:

Lever 2: The emerging of a sustainable geography
Lever 5: The sustainable utopia
Lever 6: In search of common language and practices
Lever 7: The future of design

How can Fili Pari define its idea of sustainability, from an environmental, social, and economic viewpoint?

Our project is based on the desire to enhance the Italian territory through the use of natural materials, typical of our country, to develop highly innovative fabrics. Our MARM/MORE material is made with both waste and production marble powder, depending on the type. The research started by inserting 10% of marble, then rising to 20% and 30%. Today we are able to use up to 50% of marble in the product, reaching a higher impact on the final composition. […] For us, sustainability is respect for the territory and circular economy: with our product we recover the waste of a district to transform it into opportunity and raw material in the textile sector, putting the fashion sector in communication with the stone sector, in full respect of the circular economy. We have developed a local supply chain located in northern Italy, optimizing transport and reducing the impact on the environment to enhance the business realities that our country offers.

Fili Pari was born with a powerful concept. How the intuition come?

Marble is a natural element, an excellence of Made in Italy, which communicates the territory, its history, and its evolutions. The project was born at Politecnico di Milano, during the master's degree course in Design for the Fashion System, by transforming a graduation thesis into an entrepreneurial project with the desire to create a connection between the Italian territory and the textile world: marble, a typical element of our peninsula, has been used since ancient times in art, architecture and is a symbol of the Italian culture and knowledge that are recognized worldwide. It is widely used in the form of powder in the chemical, agri-food, and pharmaceutical sectors, but in textiles, it had never been used except as pure aesthetic inspiration through prints that imitated its

1. All the interviews were made during the emergency for Covid-19 pandemic. Some of them thus contain references to the ongoing changes and overviews on the incoming perspectives and consequences for the fashion system.

grain. Continuous experimentation has given rise to a patented membrane containing marble dust […]

Fili Pari has a vision that goes beyond the fashion sector and the fashion product. How does the synergy between different sectors act with a view to sustainability?

The circular economy, understood as reuse, efficiency in production processes, and longer life of products or materials, is one of the pillars of our project. This perspective is applied transversely from upstream of the supply chain and working on the reuse of waste material from the stone industry to introduce marble dust into the textile sector. […] With the development of the MARM/MORE material we have activated a synergy between the textile and stone sectors, two sectors apparently very distant from each other, but which can create a value proposition, connecting and activating a cross-fertilization that allows the transfer of technologies, by-products and know-how between different industrial districts.

Sustainability is not a trend anymore, but a given. How important is the role of independent designers and small brands like yours to push the entire fashion system towards more sustainable choices?

In recent years, sustainability has become a very important element in all sectors, especially in the textile and fashion sector, one of the most polluting industries in the world. Emerging designers and small brands are more predisposed and reactive in bringing sustainable products to the market, to offer the end customer a more ethical and innovative fashion. The big challenge is that of the big luxury and fast fashion brands, which will have to try more and more to think about the impact that their product can bring to the ecosystem, rather than continuing to carry out mass production. The numbers of these industries are linked to price logic, and the vicious circle between this kind of offer and the final consumers who prefer these products does not allow a real change of course. However, we feel a change downstream; customers are becoming more aware of the products they buy and have developed a greater sensitivity for all that is sustainability and respect for the environment. We therefore believe that it must be a collective movement involving young brands, important fashion houses, and end consumers.

How can they do this?

Based on our experience, we have noticed how the collaboration between different actors can generate interesting results. An example of this is the Open Innovation operation that we carried out with the Limonta Spa group: on the one hand, a young sustainable-oriented start-

up and on the other a historic Italian textile company that for years has been committed to optimizing production processes in a green perspective. The result was surprising: we managed to use marble as a natural dye, replacing the chemical agents normally used in dyeing processes. The sharing of experiences, know-how and intentions is certainly an interesting key to aspire to an increasingly greener world.

In the same way, the end consumer will also have to enter into the same perspective and become more responsible in purchasing decisions. The customer has the power to direct the market differently, with small steps, this path has already begun.

In your opinion, is the Italian context a context that favors the sustainable choices of the designers and the companies that operate here?

The Italian context is full of companies and artisanal realities that have made their belief in the optimization of processes, an ecosystem of virtuous companies in which sustainability has its weight. This type of context facilitates the finding of raw materials and production in general, which have higher costs than foreign productions. The problem is to make people perceive the green orientation on the final product; consumers are very attentive to sustainability in sectors like food and related products, preferring organic products, buying directly from farms, reducing the purchase of special plastic and packaging and so on. The fashion sector is still perceived in a less intense way.

Do you see the perception of sustainable messages, brands, and products has changed in recent years?

Certainly yes, the sensitivity towards sustainability issues has changed a lot, thanks to the communication that is made. In January 2020, the first "WSM Fashion Reboot" fair was held, the first event in conjunction with White and the men's fashion week in Milan. It was "The first event dedicated to sustainable innovation and fashion design, to bridge the culture of sustainability, the market, and the public. […] Being part of initiatives like these is a source of great pride for us and talking about sustainability and innovation is very important to enter more and more into people's daily lives.

2.9. Niccolò Cipriani, founder of Rifò

Rifò started as a social and sustainable project, with the idea to create a line of garments made in the textile cluster of Prato, with recycled materials, and to give a part of the profit to local NGOs.

We were born as a project, and we are progressively shifting towards a more design-oriented fashion brand, with the intent to propose products at an affordable price, with a good design development, and with values behind them, cultivating both the social and environmental aspects.

The interview touches 3 out of 7 levers:

Lever 2: The emerging of a sustainable geography
Lever 3: A demanding audience
Lever 5: The sustainable utopia

You were born in Prato, which is a very particular environment where the recycling of textiles was a common practice even before the idea of sustainability started to be widespread. What does it mean to be part of this reality?

I always say that Rifò couldn't exist if it wasn't in Prato. What we do is exactly to take the tradition and all the know-how held in this cluster. For us is crucial to be here, we can follow the production on a daily basis, we can test new products when we have an idea, we can be easily updated regarding all the steps of the supply chain even in terms of sustainability and be well informed of all the innovations on sustainability that the cluster provide to its companies.

Recycling has been in the DNA of Prato for more than a century. Did you perceive any change in the latest years, with sustainability becoming one of the major topics of the contemporary?

Well, once no one was used to say that something recycled means something sustainable, and they were even used to hide the thing, selling yarns as fabrics as they were virgin fibers. Now, everyone is happy to declare that that yarn and fabric are recycled and make circular economy or green economy. It changed, actually, but just in the last two or three years, when they realized that there is an added value in something that pays attention to the environment.

Rifò was born as a stat-up and is now groeing as a brand. What is the most difficult thing to be communicated to the public?

The most difficult thing for us is still to overcome the idea that if something is recycled, it should be very cheap. Many people think that when you recycle the raw material comes at zero cost, so the final garment should be cheaper than one made with virgin fibers. But there are many manual processes all the way through the value chain that make the cost rise, especially if you are supposed to pay them at a fair wage.

How much attention do you find in your buyers and in the end customer on the topic of product sustainability?

There is a lot of attention and interest in the process and the benefits, even if the end customers are always looking for something well done but at an affordable price. The attention of the final customers is growing faster than the buyers' one; I feel buyers are still traditional in a certain way, they buy sustainable pieces just for a small percentage of their purchases and mainly for a communication strategy.

Can you retrace the making process of a Rifò garment?

We collect old clothes and sort them by color and quality. We can rely on local organizations that do the collection, we collect them also from other businesses that give us their production wasted or directly from the customers through our website. With cashmere, we have at least one-two contact each week from people who want to donate their old clothes in exchange for a small discount on our new products. Once divided by color and quality, the old clothes are shredded to become fiber and the fiber is twisted to spin the yarn. With that yarn, you can make knitwear or fabrics for tailoring.

What are the technical limits when you work with regenerated fibers?

Well, you can regenerate fibers for a maximum of three times depending on the kind of fiber. Then since regenerated fibers are shorter, you can spin them into medium gauge yarns, avoiding thinner gauges to reach good quality standards. For example, a 100% recycled cotton yarn will not last, it must be strengthen with virgin fiber or to blended with a synthetic one. For cashmere, the properties of the fiber remain the same but the fibers are a bit shorter, this increases the risk of pilling so it's better to avoid thin fabrics or knits.

How do you think the role of small independent realities like yours can push the whole fashion system towards more sustainable choices?

I think that together we can create an alternative. I would say that changes start from small movements, so I encourage all designers and everyone who has an idea about products or services for sustainable fashion.

2.10. Sara Francesca List, founder of VIC – Very Important Choice

VIC is an innovative start up that works for social innovation in fashion, with the mission to make sustainable fashion available to all and to propose a new way of purchasing. They have created a selection of the

best sustainable brands that clients can wear for some time and give back, or buy at specific conditions.

The interview touches 3 out of 7 levers:

Lever 3: A demanding audience
Lever 5: The sustainable utopia
Lever 7: The future of design

Sustainability is a very complex and wide theme, quite difficult to define it. What does it mean to you?

To me, sustainability is a container with many different themes in itself. […] When I founded VIC, it was very clear to me that the impact is not only on one level, not only to create wealth for everybody involved but also to create a positive impact for the environment. I mean having a new business model that saves tones of CO_2 on the environment and has an impact on people's habits because that's what impacts the most on the planet and that's where social innovation comes from.

You created a network that includes artisans, workshops, social innovation projects, and you are also into the reuse of textile waste. How do you deal with all of these aspects?

VIC commits on many levels to sustainability. The first is to create a new model for consuming fashion: you have an option not to buy and own everything but to use a piece of cloth and give it back, and this is very important as it eliminates the production of waste. […] The second is to pay attention to how and where things are done: with VIC we decided to collaborate exclusively with the artisans on a different supply chain, completely held in Italy, traceable. The third level is our commitment to transparency: we are an innovative start-up, and we created a software that can help the consumer to understand what is shown in the blockchain label.

Can you retrace step by step how VIC works?

For the sharing platform, it is very easy: the person just goes on the website and sees our catalog to purchase a service. With that ticket you have the option to buy three, four, five items for a different number of days, so you can decide how many items you want and for how many days you want to own them. Depending on that you have a different price, that covers the costs of the service that includes the shipment – back and forth –, the insurance, the repairing if needed, the cleaning and disinfection of the items which is also done naturally, and all our logistics that are zero-impact on the environment.

Then you receive the items at home, in an upcycled and zero-waste packaging, and will wear and enjoy them before giving them back. […] We are implementing the system to minimize the CO_2 impact of the shipment that would cut our footprint exponentially.

It seems that a strong commitment has also to come from the final customer. What kind of response from the public did you get at the beginning and is it rising with time?

Our question as a start-up was: "is sustainability enough to create attraction?", and with sustainability, I also mean the selection of our artisans and brands with criteria based on good design, traceability, ethical production and transparency of their supply chain. These are the values that we had to communicate at the beginning, and when we started, in October 2017, they were not really well perceived. Now things have changed and the interest is raising a lot. Today we communicate a lot on this mental approach to fashion that is using rather than owning*, and I have to say that is difficult, but I see an increasing interest in these topics, even if it still doesn't translate automatically in the will to purchase. There is still a long way to go.*

Do you think the Italian context is helping the sustainable choices of designers and businesses? Do you find fertile ground for VIC?

Well, it depends. On the market side, the Italian consumers still suffer a lack of culture on sustainability if compared to the Nordic areas of Europe; on the other hand, the vantage is that here, in Italy, we still have a lot of production sites and real artisans. When VIC selects the brands that are all based in Italy, we can visit their workshops, physically go there, and have videos showing how everything is done. This is the better transparency you can hope for and is a value that can happen only by staying here.

Do you feel consumers are becoming more demanding about that?

This is another battle we have to bring more mindful shopping to the general public, make them question everything, and make them ready to question products. […] Every single item you see is not just that item, it has a story behind it. This is something that consumers are not really asking yet, but in the future if we give them this option they will answer.

2.11. Marina Spadafora, sustainability consultant and Country Coordinator for Fashion Revolution Italia

Marina Spadafora is a Fair Fashion Ambassador and the Country Coordinator of Fashion Revolution Italia. Her work is widely known for her experimental knitwear brand and for her role as Senior Design Consultant for Prada, Miu Miu, Salvatore Ferragamo, and Marni.

Since 2007 she has been involved with ethical fashion projects, from Banque to Cangiari, to initiatives of development for Africa with Franca Sozzani. She has also been Creative Director of "Auteurs du Monde", the ethical fashion brand of Altromercato, and she worked with the United Nations to bring development to emerging economies through fashion. In 2015, she received the United Nations "Women Together Award" in New York for her work with handcrafted textiles in the world.

Author of a TED Talk on the theme of "Consumer Power", she also teaches Ethical Fashion in fashion academies, in Italy and abroad.

The interview touches 3 out of 7 levers:

Lever 2: The emerging of a sustainable geography
Lever 3: A demanding audience
Lever 5: The sustainable utopia
Lever 6: In search of common language and practices
Lever 7: The future of design

What is Fashion Revolution, and what are the key topics that you pursue with the organization?

I have been involved in sustainability for about thirteen years, and sustainability in fashion is something that I believe in very strongly. Each of us, in whatever career or job we find ourselves, we have a responsibility to do the best that we can to turn whatever we do into a more responsible practice.

I became the country coordinator of Fashion Revolution in 2013, when the Rana Plaza complex collapsed in Dhaka, in Bangladesh, killing 1138 people and injuring 2500.

Since then, Orsola De Castro and Carry Somers founded this movement in London that is very much consumer-oriented: our hashtag is #whomademyclothes*, so with a simple question we make people think about the fact that the textile industry is still a very manual industry with a lot of people involved. In the fashion industry alone, we have more than 70 million people working, and in the textile industry in general, we have 300 million people. It's a lot of people and if we pay attention*

to our consumption and to where we spend our clothes doing a due-diligence research before we do shopping, at least we can give our money to companies that behave properly and are trying to do something – as far as corporate social responsibility – at least starting to move the first steps towards being responsible and transparent.

Saying that, not everybody is absolutely honest about this, we see a lot of companies that are doing little projects, little drops as we call them in the industry, and then they don't do anything more, so they get a lot of press, they get a lot of people thinking that they are sustainable and they are not. This is called greenwashing*, and we have to be very aware of this phenomenon as well.*

As you said, the revolution starts from the consumers, from people. Do you see a raising awareness in them in the latest years? And what can people actually do from the bottom of the supply chain to activate this change?

I see a lot more awareness, especially in the younger generation. If we think for a minute about the generation of Greta Thunberg, there is a really big movement around the world right now. Moreover, I think the current Covid-19 crisis has proven that our world is completely out of balance: it took only a few months of non-activity on a global scale for the rates of pollution to drop drastically, so nature has the power to regenerate itself, and that is comforting I think.

It is important to go towards a more circular way of production, where everything that is produced and designed is meant to return to its cradle, to design having in mind that that piece of clothing at the end of its life cycle will be regenerated into a new one instead of being thrown away.

Things have to change, and the consumers have the power to do it in their wallet: if we decide we do not want to spend money on certain brands because they are not behaving the way they should, then we take away the oxygen – which is money, our money – from the brand. That is how the consumer is vital to this process.

Is the dialogue between consumers and brands evolving somehow?

It's becoming more and more active. Fashion Revolution has the Transparency Index, a list of companies and brands to whom we ask questions. These brands answer the questions about their impact on the environment and they get a rating. The transparency is online on fashrev.org and with that, consumers can evaluate the commitment and the transparency of that particular brand.

For how long will it still make sense to talk about purchase and consumption?

Well, consumers consume, don't they? I think we still need the economy to move, otherwise, a lot of jobs are going to be lost, so we can't advocate the stop of purchases and the act of consuming: it has to be done more consciously, that's all.

Do you think there is a need to redesign places, times, and ways of purchasing fashion?

Yes, I think that online and digital selling will become more and more important. There are companies and technologies now that can digitally represent a product that literally looks real, and also for fashion shows and selling campaigns we might move towards that. […] Companies will have to come up with different strategies and sell the clothes in a different way.

There are also some emerging phenomena like renting, what is your opinion on the evolution of those practices?

I think they are very good practices. Rent the Runway *for example, has become one of the biggest clients of a lot of fashion brands, because these rental services still purchase the clothes from the designers in order to have them on their websites, so now a lot of designers are counting on the orders coming in from these rental services. It can be a way not to stop the industry while pushing the customer to a more conscious consumption.*

2.12. Conclusions

The reported interviews outline sustainability as a very complex and multifaceted theme, rich of contrasts and deserving a serious commitment and actions at all the levels of the supply chain, from manufacturers to design, selling, and distribution. What is also clear is that a paradigm shift happening in the set of minds of whoever operates on the value chain as well as in the public. The seven key aspects recurring in the interviews can indeed be defined as the levers that are driving the paradigm shift towards sustainability.

There is a **geography of sustainability (lever 2)** where some countries emerge more than others, in terms of **demanding end customers (lever 3)** as well as in terms of regulations and demands from clients and suppliers along the chain. In a global industry as the fashion one, the connections between stakeholders are making the more committed areas driving the others, in a step-by-step progression towards sustainable practices.

From the particular perspective of the Italian manufacturers the seed of sustainability emerges as already spread by a **long-term commitment (lever 1)** in doing things well and entrusting reliable suppliers and clients. The Italian context is frequently declared here as a privileged one, with its clusters that own long-lasting relationships among stakeholders, a common belief in the optimization of processes, virtuous companies that are often willing to open themselves in the name of transparency, a deep knowledge of products and of the value chain. By these stakeholders, sustainability is pursued with progressive actions and changes and is seen as a very concrete way of working rather than as **a utopistic ideal (lever 5)** to be immediately realised.

In this progression, sustainability is becoming such wide, pervasive, and detailed that companies are more and more in need to hire people that take a full-time care of every aspect of it. These **new professional figures (lever 4)** are in charge not only to bring new knowledge, but to make order in the background that was already there, made of actions and decisions taken during decades without going under the name of sustainability, but being that. Designers themselves become part of a whole system where a sustainable product does not make sense if the companies that work on its supply chain do not operate in a sustainable way. From a designer's perspective, the main task is not to design a product anymore: the **future of design (lever 7)** is to control all the aspects, from the choice of materials to the product development, from communication to the presentation and distribution, until the delivery of values that can bring new habits in purchasing and behavioral changes of the public.

One other big issue is communication: talking about sustainability is still confusing, ineffective, with a lack of common language and clarity inside companies, between companies, between the value chain and the public. In this regard, given sustainability as an issue that concerns the fashion system as a whole, it comes as a shared feeling the need to create synergies – confirming the cited Williams words (Williams, 2020, p. 2) – towards a system that works with **common practices and languages (lever 6)**, pushes the same concepts, follows the same rules, to make the public aware of what's behind fashion.

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3. Sustainable development and system innovation

3.1. An Introduction to sustainable development

During the last three decades, the concept of sustainable development has entered the international scene on various levels and in relation to different competencies, calling for a systemic and interdisciplinary approach. The sustainable development refers to systemic conditions where on a planetary and regional level both social and productive development takes place:

- within the limits of environmental *resilience*[1], i.e. within its capacity to absorb the effects of human impact without causing any irreversible degradation;
- without compromising the ability of future generations to meet their own needs, i.e. preserving resources, or *natural capital*[2], which will be passed on to future generations;
- on the grounds of equal redistribution of resources following the principle that everyone has the same rights to *environmental space*[3], i.e. the same access to global natural resources.

1. Resilience is the capacity of an ecosystem to overcome certain disturbances without losing irrevocably the conditions for its equilibrium. This concept, extended planet-wise, introduces the idea that the ecosphere used for human activities has limits on its resilience, that, when surpassed, give way to irreversible phenomena of deterioration.

2. Natural capital is the sum of non-renewable resources and the environmental capacity to reproduce the renewable ones. But it also refers to natural diversity, to the amount of living species on this planet.

3. Environmental space is the quantity of energy, territory and primary non-reproducible resources that can be exploited in a sustainable way. It indicates the amount of environment available for every person, nation or continent to live with, produce or consume without surpassing the environmental resilience level.

Let us see briefly how this concept has emerged and spread over time. In coherence with most updated overviews (Vezzoli *et al*., 2022).

The environmental issue, understood as the impact of the production-consumption system on ecological equilibrium began to rise in the second half of the 1960s, because of the acceleration and expansion of industrialisation. The first scientific studies handling these problems were published at the beginning of the 1970s. International studies and debates considered the deterioration and exhaustion of natural resources as an undesirable effect of industrial development. The natural limits of our planet were connected to the technological and productive development and the increase of the world's population.

The international debate about environmental issues intensified and spread further during the 1980s. The pressure from public opinion escalated, and institutions took their stand with a series of ecological norms and policies examining productive activities based on the Polluter Pays Principle. The watchword of the United Nations Environment Programme (UNEP), and other institutions, then became *cleaner production*, defined as the continual redesigning of industrial processes and products to prevent pollution and the generation of waste, and risk for mankind and the environment.

In 1987, an important study was drafted by the UN World Commission on Environment and Development to provide indicators regarding the future of humanity. This report was called *Our Common Future* (World Commission on Environment and Development, 1987) and was the first to define sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs".

During the 1990s, environmental issues reached the phase of maturity. The *Caring for the Earth: A Strategy for Sustainable Living* (UNEP *et al*., 1991) publication for The International Union for Conservation of Nature (IUCN) by the United Nations Environment Programme (UNEP) and World Wide Fund For Nature (WWF) had a competing definition of sustainable development: "improving the quality of human life while living within the carrying capacity of supporting ecosystems". This accentuates the possibility to actually improve human life conditions while safeguarding the Earth's capacity to regenerate its resources. These two definitions considered together describe sustainable development as a practice that delivers benefits to human beings and ecosystems at the same time.

Another historical event of those years was the United Nations Conference on Environment and Development (UNCED) held in Rio de Janeiro in 1992. This and other initiatives have provided a persistent integration of the concept of sustainable development into the documents of all international organisations as a model for a reorientation of social and

productive development. Since 1994, sustainable development and environmental sustainability have formed a fundamental benchmark in the Action Programme of the European Commission.

Onwards from the 2000s (following the Johannesburg Conference and ten years after Rio de Janeiro) the necessity of awareness and active engagement of all social participants involved in the production-consumption circuit is even more present and pronounced. Particularly significant was the setting up of UNEP's Sustainable Consumption Unit in May 2000. The initial assumption was that "in spite of the progress made by the industrial world and enterprise during the last decade […] the extent to which consumption exceeds the Earth's capacity to supply resources and absorb waste and emissions is still dramatically evident" (Geyer-Allély, 2002).

In June 2006, the European Council adopted a comprehensive Sustainable Development Strategy (SDS) for an enlarged EU (Council of the European Union, 2006). It builds on the Gothenburg strategy of 2001 and is the result of an extensive review process that began in 2004. The renewed EU SDS sets out a single, coherent strategy on how the EU will more effectively live up to its long-standing commitment to meet the challenges of sustainable development. It recognises the need to gradually change current unsustainable consumption and production patterns and move towards a better integrated approach of policymaking. It reaffirms the need for global solidarity and recognises the importance of strengthening work with partners outside the EU, including rapidly developing countries that will have a significant impact on global sustainable development.

The European Council confirmed in December 2009 that "sustainable development remains a fundamental objective of the European Union under the Lisbon Treaty". As emphasised in the Presidency's 2009 review of the Union's Sustainable Development Strategy, the strategy continued to provide a long-term vision and constitute the overarching policy framework for all Union policies and strategies (Council of the European Union, 2009).

The diversity of countries and their economic and social systems, especially considering the disparity of environmental impact produced by high, middle and low-income contexts and the pressing needs for social inclusion and the fulfilment of the basic needs for all, has been an important parameter for sustainable development and the Sustainable Consumption and Production (SCP) approach throughout the UN's directives and policy orientation. The positive assertion is that the necessary shift towards sustainability is presented as an opportunity for emerging and low-income contexts rather than yet another burden to be borne. For emerging economies, this entails leapfrogging to sustainable structures of consumption and production without repeating the mistakes of the Industrialized contexts,

and for low-income contexts, developing dedicated solutions as the basis for sustainable growth.

At the educational level, in 2005, the United Nations Educational, Scientific and Cultural Organization (UNESCO) established a *Decade on Education for Sustainable Development* (UNESCO, 2015). The decade was aimed at integrating the values inherent in sustainable development into all aspects of learning, to encourage changes in behaviour to enable a more viable and fairer society for everyone. During this decade, education for sustainable development contributed to citizens becoming better equipped to face the challenges of the present and the future, allowing decision-makers to act more responsibly to create a viable world.

In 2015, the *Agenda 2030 for Sustainable Development* was approved by the United Nations as a mutual commitment to global development, in favour of human well-being and to preserve the environment. The main outputs of the Agenda are the 17 Sustainable Development Goals (SDGs), which gather the main challenges to be achieved by 2030 in relation to the three dimensions of sustainable development. Hereafter, the 17 goals (United Nations, 2015) are listed:

- Goal 1: No poverty – end poverty in all its forms everywhere;
- Goal 2: Zero hunger – end hunger, achieve food security and improved nutrition and promote sustainable agriculture;
- Goal 3: Good health and wellbeing – ensure healthy lives and promote well-being for all at all ages;
- Goal 4: Quality education – ensure inclusive and equitable quality education and promote lifelong learning opportunities for all;
- Goal 5: Gender equality – achieve gender equality and empower all women and girls;
- Goal 6: Clean water and sanitation – Ensure availability and sustainable management of water and sanitation for all;
- Goal 7: Affordable and clean energy – ensure access to affordable, reliable, sustainable and modern energy for all;
- Goal 8: Decent work and economic growth – promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all;
- Goal 9: Industry, innovation and infrastructure – build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation;
- Goal 10: Reduced inequalities – reduce inequality within and among countries;
- Goal 11: Sustainable cities and communities – make cities and human settlements inclusive, safe, resilient and sustainable;

- Goal 12: Responsible consumption and production – ensure sustainable consumption and production patterns;
- Goal 13: Climate action – take urgent action to combat climate change and its impacts;
- Goal 14: Life below water – conserve and sustainably use the oceans, seas and marine resources for sustainable development;
- Goal 15: Life on land – protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss;
- Goal 16: Peace, justice and strong institutions – promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels;
- Goal 17: Partnerships for the goals – strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development (Fig. 3.1).

Fig. 3.1 - The 17 sustainable development Goals (SDGs) by the United Nations (United Nations, 2015)

Alongside the 17 SDG's set out but the United Nations, the European Commission outlined their own strategies under the European Green Deal (EGD) (European Commission, 2021). The EGD is aimed at developing Europe into becoming the first climate-neutral continent. The deal provides

an action plan to boost the efficient use of resources by moving to a clean, circular economy and to restore biodiversity while cutting pollution.

3.2. The sustainability dimensions

For a better understanding of sustainability and its implications, it is common to schematise it as three interlinked dimensions (United Nations, 2015):

- the *environmental protection (Environmental dimension)*: not to exceed the "resilience" of the biosphere-geosphere, that is, its ability to absorb anthropic perturbations without provoking irreversible phenomena of degradation such as climate change, acidification, and land use;
- the *social equity and inclusion (Socioethical dimension)*: the ability of future generations to meet their own needs and the achievement of social equity and cohesion, where a key issue is equal redistribution of resources following the principle that everyone has the same access to global natural resources;
- the *economic prosperity (Economic dimension)*: promote inclusive and sustainable economic growth, employment, and decent work for all.

These dimensions have significant and characterising features that are described in the following paragraphs.

The Environmental Dimension

In the 1960s, industrialised countries saw a strong acceleration in the development of consumption and production systems, but it was soon realised that this did not produce only advantages. In those years we can recall the pollution of the Great Lakes in North America; the winter smog in London at the end of the 1950s, which led to the death of thousands of people; and the ecological disasters caused by the washing of cargo tanks from oil tankers into the open seas.

In 1972, the book *Limits to Growth* was published, reporting the first computerised simulation of the effects of the ongoing system of production and consumption on nature; it was the first scientific forecast of a possible global ecosystem collapse. Hence why these were the years of the discovery of environmental limits (and irreversible harmful effects).

Today we have more information and scientific data testifying humankind's responsibility on the deterioration of the eco-system and how damaging and dangerous the effects are.

The *Intergovernmental Panel on Climate Change* (IPCC) established by the United Nations in 1988 to study and report on global warming, estimated that global mean sea level will rise from a minimum of 0.28 m (best-case scenario) to a maximum of 1.01m (worst case scenario) within

the end of the century. As a consequence, several areas of land would be submerged below water level (Seneviratne *et al*., 2021).

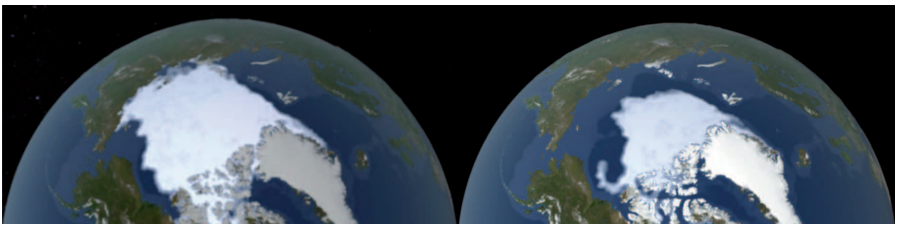

Fig. 3.2 - The reduction of Arctic Sea ice minimum form 1979 and 2020 (NASA) is shown and gives a clear idea of the consequences of global warming

This visualisation shows the annual Arctic Sea ice minimum in 1979 and in 2019. The area of the perennial ice has been steadily decreasing since the satellite record began in 1979.

Arctic sea ice reaches its minimum each September. September Arctic sea ice is now declining at a rate of 12.85 per cent each decade, relative to the 1981 to 2010 average.

The current ecosystem equilibrium would be disrupted by global warming. Today the number of extreme climate-related disasters, such as. droughts, extreme temperature, floods, landslides, storms and wild-fires, has more than doubled since the early 1990s (World Meteorological Organization – WMO, 2021) – see Fig. 3.3.

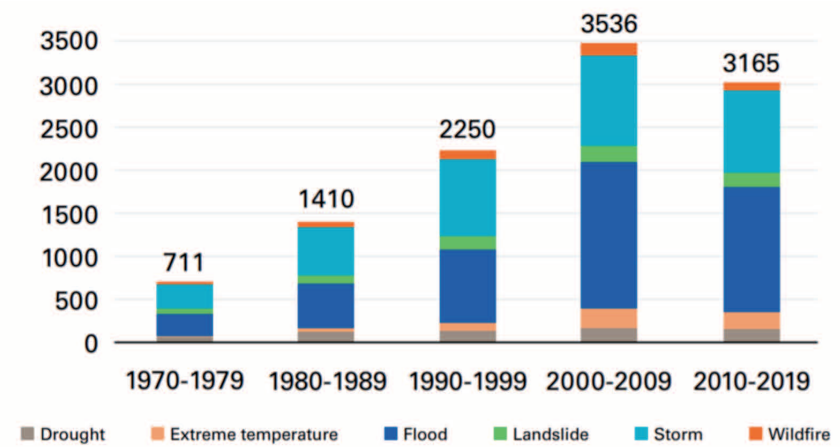

Fig. 3.3 - Number of extreme climate-related disasters that took place in the past decades (WMO, 2021)

Moreover, recent projections by IPCC (Intergovernmental Panel on Climate Change) show that such events are likely to keep increasing their frequency in the next century, depending on different scenarios related to climate change (Masson-Delmotte *et al.*, 2021).

There is also a rise in air pollution (fine particles, O_3, NO_2, SO_2, CO, etc.) the World Health Organisation has estimated that this is the cause of 7 million premature deaths worldwide (World Health Organization, 2021).

Human activity is also having a large impact on the extinction of various species. The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) reported in 2019 that the health of ecosystems in which we, and all other species depend on, is deteriorating more rapidly than ever. It is estimated that 1 million animal and plant species are now threatened with extinction, more than ever before in human history (IPBES, 2019). Current global response is insufficient, transformative changes are needed to restore the nature (see Fig. 3.4).

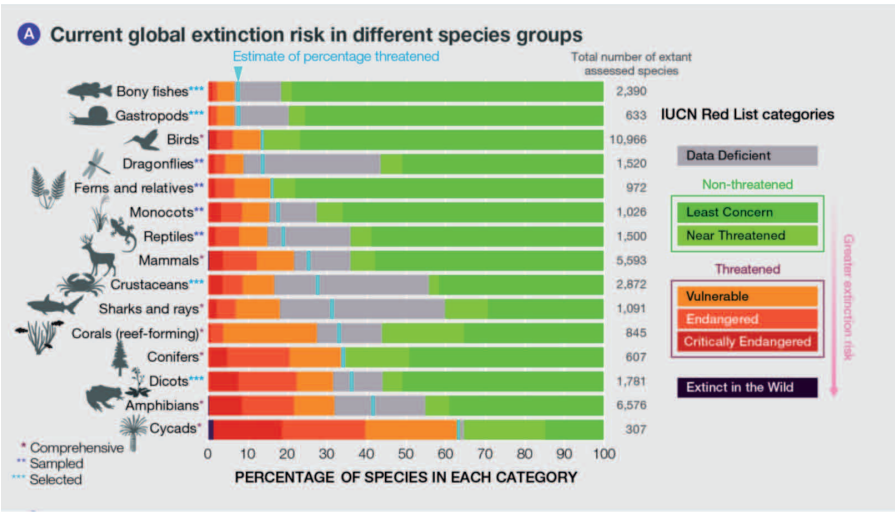

Fig. 3.4 - Current global extinction risk in different species groups (IPBES, 2019)

As regards waste, the quantity generated by human activities goes at an increasing rate. As of 2016, it was found that 2.1 billion tons of municipal waste were generated worldwide (Kaza *et al.*, 2018). This equates to 0.74 kg on average per person, per day. Without any change, by 2025, this is expected to increase to 0.95 kg per person per day with a total of 3.4 billion tons of waste produced worldwide.

A consequence of this increase in waste is the build-up of discarded plastic that can be found in the ocean. Looking at the ratio of plastic in the ocean to fish (by weight) today (2014) there is 1kg of plastic (World Economic Forum & Ellen MacArthur Foundation, 2016) for every 5 kg of fish. By 2025, is a business-as-usual scenario this will increase to 1kg of plastic for every 3kg of fish and if there is still no change by 2050 the mass of plastic in the ocean will outweigh that of the fish.

The Global Footprint Network calculated that in 2021, the *Earth Overshoot Day* fell on July 29th (Global Footprint Network, 2021), i.e., the date on which humanity's resource consumption for the year exceeds Earth's capacity to regenerate those resources that year. For the remainder of the year, the world is working within an ecological deficit by drawing on more local resources and stocks than is naturally available. The Overshoot Day has trended closer since it began being recorded in 1970. Even though this is not a linear trend each year there is an overall difference between 1970 and 2020 of 153 days. While this is accumulated as a worldwide effort, some countries have a greater contribution than others; Fig. 3.5 shows when Earth Overshoot Day would occur if the world population lived like in many representative countries.

Fig. 3.5 - Different Earth Overshoot Days in some world countries (Global Footprint Network, 2021)

We have had an overview of some of the damaging effects caused by the production and consumption system. If we now examine the exact meaning of these environmental effects, we see that each environmental effect is based on an impact when exchanging substances between nature/the environment and the production and consumption system[4]. These effects can occur in two directions:

- as an input, namely extracting substances from the environment;
- as an output, namely emitting substances into the environment.

Which effects, then, must be considered in relation to environmental requirements?

Regarding input, we consider the use (extraction) of resources and in particular the exhaustion of these resources such as water, minerals, and fossils, including those of which are both non-renewable and renewable. Exhausting non-renewable resources has a negative impact on the socio-ethical dimension of sustainability in that it compromises the ability of future generations to meet their needs.

Furthermore, the extraction of these resources is altering the balance of the ecosystem. For regarding fossil extraction, coal mining in particular causes often issues with ecosystems local to the extraction site since excess rock and soil is placed in nearby streams. This diverts the natural flow of the stream and pollutes the water, affecting the species which can survive in it. Another example is the deforestation is a consequence extracting timber, a renewable resource, for use within construction or in heating systems, has made the land more vulnerable to erosion over the course of time and caused the extinction of several species.

Finally, there are the harmful effects connected to extraction processes, e.g. oil leaks during extraction and transportation processes. Below, these issues are discussed further, together with environmental impact related to the outputs.

When considering the outputs of processes and therefore, the emission of resources, damaging effects can be categorised in one of two ways. The first, *ecological damage*, the detrimental effects of these resources on the environment such as climate change (global warming), acidification and ecotoxicity. The second category is related to the *human damage* of the resource emission, including phenomena such as smog, stratospheric ozone depletion and several other toxic emissions for humans. These main impacts alongside others are listed together with their main environmental effects in Table 3.1.

4. Obviously not all impacts are equally damaging if they are damaging at all. The release of 1 kg of water into the environment differs greatly from releasing 1 kg of asbestos powder in high concentration.

Table 3.1 - The main environmental impacts and their environmental effects

Type of Environmental impact	**Environmental impact**	**Environmental damaging effects**
Resources exhaustion *(input-related)*	Water resources exhaustion	Resources exhaustion (water, mineral, fossil & renewable resource depletion) Alteration of habitat/ecosystems' balance
	Mineral resources exhaustion	
	Fossil & renewable resource depletion	
Ecological damage *(output-related)*	Climate change (global warming)	Artic ice sheet melting of polar icecaps, rising seawater levels, inundated lowlands Ocean temperature increasing Extreme climate-related disasters (droughts, extreme temperature, floods, landslides, storms and wildfires) Desertification Migration of pathogens
	Acidification (terrestrial acid rain, ocean acidification)	Limited regrowth of forests Limited regrowth of trees in urban zones Corrosion of monuments and buildings Contamination of groundwater Loss of aquatic fauna Sanitary risks (respiratory problems) Depressing metabolic rates and immune responses in some organisms and causing coral bleaching
	Eutrophication (terrestrial, freshwater, marine)	Loss of aquatic fauna due to oxygen depletion Contamination of groundwater and lakes, e.g. resulting in non-drinkable water Obstacles to swimming
	Ecotoxicity (freshwater, marine, terrestrial, ionizing radiation)	Mortality, reduced mobility, reduced growth or reproduction rate, mutations, behavioural changes, of species Changes in ability to perform photosynthesis
	Land use (alteration of habitat, e.g. deforestation, urban development, agriculture, waste)	Land occupation and its quality deterioration

Table 3.1 - continued

Type of Environmental impact	Environmental impact	Environmental damaging effects
Human damage *(output-related)*	Human toxicity (cancer effects, non-cancer effects, ionizing radiation)	Intake of taxic substances by human being. For example: dioxin (TCDD) provokes chloracne and soft tissue cancer, inhaling pyrene and benzopyrene is highly carcinogenic, lead poisoning (saturnism) may cause irreversible neurological damage
	Winter smog (particulate matter and inorganics air pollution)	Respiration problems potentially fatal
	Summer smog (photochemical ozone formation, etc.)	Some organic compounds (e.g. aldehydes) provoke lacrimation and irritate respiration Some compounds (e.g. PAN) can have toxic effects on plants
	Stratospheric ozone depletion	Damage to flora and fauna Elevated skin cancer risk Immune system weakening
	Others	Olfactory pollution Acoustic pollution Electromagnetic pollution

The Environmental protection

Observing the relations between the anthropic world and nature altogether, we can distinguish two fundamental actions to reduce the environmental impact:

- concerning the *input* from nature we must preserve resources, using fewer resources and preferably more renewable ones;
- concerning the *output*, we must prevent the pollution (of resources), reducing emissions and increasing their biocompatibility.

These actions can be further elaborated into three scenarios.

First, there is **biocompatibility**, the scenario of the ***biological cycles*** where the resource flows to produce goods and services are compatible with the natural system: using renewable resources and disposing of biodegradable and biocompatible emissions and waste. Food and organic-based materials (such as cotton or wood) are designed to feed back into the

system through processes like composting and anaerobic digestion. These cycles regenerate living systems, such as soil.

In industrialised economies, this scenario has several limits that must be faced, for which the following scenario can be highlighted.

Secondly, there is **non-interference**, the scenario of the ***technical cycles*** where resources are no longer drawn from nature, but products, components, and materials are recovered and restored through reuse, repair, remanufacture or (as a last resort) materials are recycled or energy is recovered.

This scenario also has its limits, at minimum, those given by the laws of thermodynamics, for which we know always have an increase in entropy during any process of transformation.

The two above together describe what started to be defined in the last few years as the **Circular Economy**, i.e. "an industrial economy that is restorative or regenerative by intention and design" (Ellen MacArthur Foundation, 2013) and acknowledged by the European Union (since 2014), as an economic system that "aims to maintain the value of products, materials and resources for as long as possible by returning them into the product cycle at the end of their use, while minimising the generation of waste" (European Comission, 2020).

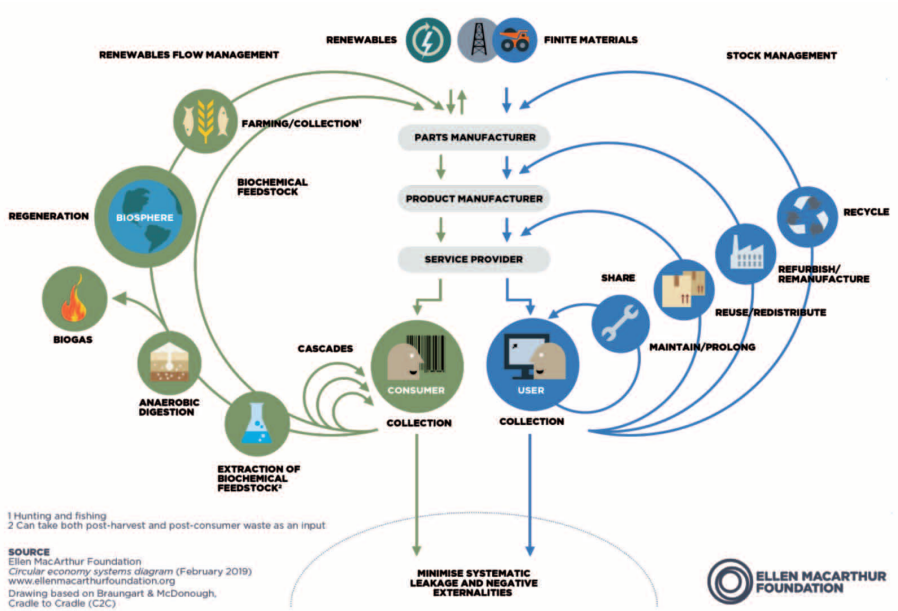

Fig. 3.6 - The "butterfly diagram", representing biological and technical cycles within Circular Economy (Ellen MacArthur Foundation, 2021b)

Finally, we can imagine a third scenario of **dematerialising** how we satisfy the demand for well-being (i.e. "dematerialising demand for satisfaction"), where both input and output flows of resource would be quantitatively diminished in relation to a given social demand for needs and wants, satisfied by a mix of products and/or services.

The transition towards sustainable development will consist of a mix of these scenarios depending on the various conditions in different contexts.

The Socio-ethical Dimension

Promoting socio-ethical sustainability primarily means taking into account (according to the assumptions of the concept of sustainable development) the so-called equity principle, whereby every person, in a fair distribution of resources, has a right to the same environmental space. For example, to the same availability of global natural resources or better, to the same level of satisfaction that can be reached from these. When the issue of sustainable consumption crosses that of socio-ethical sustainability, the spectrum of implications and responsibilities, extends to several different issues (related to some of the SDGs) such as:

- eradicating poverty and hunger in all its forms everywhere (see SDG 1, 2);
- ensure healthy lives and promote well-being for all at all ages (see SDG 3);
- ensure inclusive and equitable quality education for all (see SDG 4);
- achieve gender equality and empower all women and girls (see SDG 5);
- ensure access to energy, water and sanitation for all (see SDG 6, 7);
- reduce inequality within and among countries (see SDG 10);
- promote just, peaceful and inclusive societies (see SDG 16).

When talking about the socio-ethical dimension of sustainability a dominant issue is that of **eradicating poverty and hunger**.

In 1996, a summit organised by the UN's Food and Agriculture Organisation (FAO) was held in Rome, where 185 countries agreed and committed to cut the number of undernourished people by half. Four years later, on 8 September 2000, following a three-day Millennium Summit of world leaders at the UN headquarters, the General Assembly adopted the Millennium Declaration signed by 191 member states. In that declaration we can read:

> Eradicate poverty by 2015: a) reduce by half, from 1990 to 2015, the percentage of persons living in extreme poverty; b) grant a full and productive employment and a dignified job for all, including women and youngsters; c) reduce by half, from 1990 to 2015, the percentage of undernourished persons (United Nations, 2005).

Within the last UN action plan (Agenda 2030) on sustainable development and its sustainable development goals, the new target regarding poverty is now to "end extreme poverty in all forms by 2030" since the original goal of halving the number of people living in extreme poverty was achieved. Reviewing their initial aims of ending hunger they found that in the past 20 years hunger has dropped by almost a half and that countries that used to suffer from famine are now able to meet the nutritional needs of their most vulnerable people. The SDG of "Zero Hunger" is based on the aim of ensuring that everyone, worldwide has access to nutritious food all year round by 2030.

The State of Food Insecurity in the World 2020 (FAO *et al.*, 2021) reports the most recent estimate: "Between 720 and 811 million people in the world faced hunger in 2020. Considering the middle of the projected range (768 million), 118 million more people were facing hunger in 2020 than in 2019 – or as many as 161 million, considering the upper bound of the range".

With 720 to 811 million people chronically undernourished in 2020, the number of hungry people in the world is unacceptably high. The vast majority live in low-income and emerging countries. As shown in Fig. 3.8, undernourishment increased the most in very low-income contexts, i.e. in Asia, Africa and Latin America. "[…] with less than a decade to 2030, we are not on track to ending world hunger and malnutrition – in fact, we are moving in the wrong direction" (FAO *et al.*, 2021).

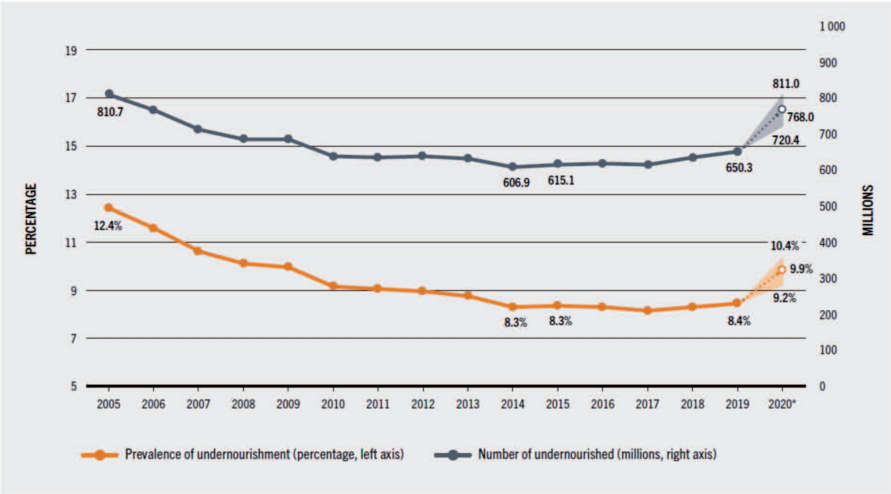

Fig. 3.7 - Undernourishment in the World from 2005 and estimated rates for 2020 (FAO et al., 2021)

Furthermore "moderate or severe food insecurity has been climbing slowly for six years and now affects more than 30 percent of the world population" (FAO *et al.*, 2021). Over half of the population in Africa, more than one-third in Latin America and in the Caribbean and more than one-fourth in Asia are food insecure. An individual is considered to be living with food insecurity if they do not have reliable access to sufficient, safe, and nutritious foods that meet their dietary requirements and preferences.

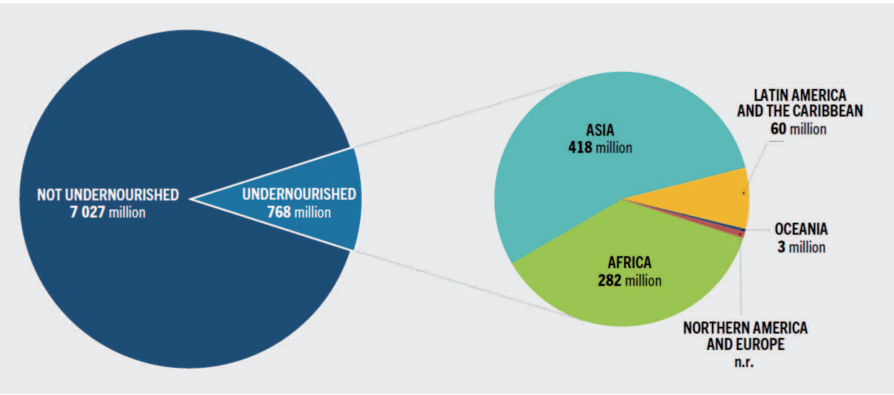

Fig. 3.8 - Global undernourished population by different continent of the world (FAO et al., 2021)

After all this, it is worth noting that social equity and inclusion is not only a matter of eradicating poverty, but more widely a matter of facilitating an improvement in quality of life and social cohesion, by "Fostering a high-employment economy delivering economic, social and territorial cohesion. Empowering people through high levels of employment, investing in skills, fighting poverty and modernising labour markets, training and social protection systems so as to help people anticipate and manage change, and build a cohesive society" (European Commission, 2010).

The Economic Dimension

Promoting economic sustainability means fostering economic prosperity, i.e. an inclusive and sustainable economic growth, granting employment and decent work for all. In other terms, the economic dimension of sustainability engages us in promoting environmentally and socio-ethically sustainable models of production and consumption, while being economically feasible.

Three main strategies could be drawn regarding this dimension: *internalisation of costs, orientating the main ongoing transitions*

towards sustainable solutions, and *enhancing promising niche economic models.*

We can observe that in industrialised contexts many natural resources have low costs which do not correspond to the cost of their actual use. This can be seen within the dyeing process of textiles. Almost 200 tonnes of water are required to dye 1 tonne of fabric, this includes the water required to be mixed with the dye but also the several stages of washing that occur once the dye has been applied. Furthermore, indirect costs appear when resources are embedded in products, generating life cycle environmental and economic costs. Clothing producers and consumers pay very little towards the indirect costs of the garment, such as health costs incurred by society. This is particularly prominent in communities near cotton-growing plantations where inhabitants are developing cancer from constant ingestion of pesticides after they have infiltrated soil and water sources. The producer and the user pay very little of the indirect costs of the car, such as health costs incurred by society when people contract illnesses. The **internalisation of costs** would entail embedding in the purchase cost of a good or service all direct and indirect costs, in order to encourage the minimisation of environmental impacts. In other words, we should move towards a proper attribution (or internalisation) of resource costs, which is mainly a political and legislative issue.

Another strategy is to **orientate the main ongoing transitions** towards sustainable solutions, i.e. transitions regarding interconnection, globalisation, and localisation (referred together as *glocalisation*), information, services, etc. An example which can illustrate this is the move towards cloud-based sharing of information between stakeholders within a clothing design process using specialised software to design and collaborate without generating wasted material an example of this is ShareCloth. In such cases it can be seen that reorientating can produce considerably more effective results than, say, attempting to go back in time and return to former production-consumption model.

Finally, it is important to promote and **enhance promising economic models** even if they are currently with **niche market value**. Some promising models fitting into the frame of environmental and socio-ethical sustainability with economic benefits have been studied, such as, *Sustainable Product-Service Systems* (models where producers keep the ownership of the product or the responsibility for its performance throughout its lifecycle), and *Distributed Economies* (small-scale production units, shifting the control on essential activities towards the end-user)[5].

5. These promising models are described in chapter 6.

3.3. Call for a radical change

During the second half of the 1990s, a series of studies and analyses led to a clearer understanding of the dimension of change necessary to achieve a society that is effectively sustainable for all (Stahel, 1997). It was then realised that conditions for sustainability can only be achieved by drastically reducing: the extraction of environmental resources and the emissions released back to the geosphere and biosphere of the (average) production and consumption systems of mature industrialised societies.

Those studies – taking into account demographic growth forecasts and hypothesising an increase in the demand for well-being in currently disadvantaged contexts and contexts – have staggering findings: in 50 years, conditions for sustainability are achievable only by increasing the eco-efficiency of the production-consumption system by a factor of ten. In other words, we can only consider sustainable those socio-technical systems whose use of environmental resources per unit of satisfaction/ service rendered is at least 90% below what is currently to be seen in mature industrial societies[6].

If in the 1970s, the goal was to slow down before hitting the limits, the goal must now be to get back down below the limits without severe damage to the earth. For example, if the current trends of overfishing and pollution continue, all seafood faces collapse by 2048. By the middle of the 21st century, 7 billion people in 60 countries may be faced with water scarcity. All these considering we see why some authors (Diamond, 2004) star to say that the global society is close to the collapse of the eco-systems.

These estimates (even though still under scientific discussion) are valid enough to indicate the scale of the change that should take place. A profound, radical transformation in our development model is necessary, and the production and consumption system in this sustainable society will be significantly different from what we have been taking for granted up to now. In other words, the transition towards sustainability requires radical changes in the way we produce, consume and more in general, in the way we live. The prospect of sustainability necessarily places the same model of development under discussion. Over the next few decades

6. On this issue see works by the Wuppertal Institut fur Klima, Umwelt, Energy; by the Advisory Council for Research on Nature and Environment (in particular: The Ecocapacity as a challenge to technological development, a study funded by a group of Dutch ministries); by the Working group on eco-efficiency sponsored by the World Business Council for Sustainable Development (see particularly the final report "Eco-efficient Leadership for Improved Economic and Environmental Performance" by WBCSD, 1996).

we must enable ourselves to move from a society where well-being and economic health are measured in terms of growth in production and material consumption, to a context where economic growth cannot be seen as the ultimate goal and where, freedom is the initial means by which to achieve a development that must be orientated towards improving life (Sen, 1999). Freedom as a guarantee that people are the protagonists of their own destiny and not the passive beneficiaries of a development programme. How this may happen is at present difficult to foresee. It is, however, certain that there will have to be a discontinuity that will affect all facets of the societies. In other words, given the nature and the dimension of this change, we have to see transition towards sustainability (and, in particular, towards sustainable ways of living) as a wide-reaching social learning process in which system discontinuity is needed. In fact, the debate on more sustainable consumption patterns has been included in the agenda of major international governmental institutions in recent years (the United Nations, for instance, already set up the Sustainable Consumption Unit in May 2000).

This complex debate can be summarised in the following question: how can we adopt a new outlook to separate the social demand for well-being from a relationship that is directly proportional to the increase in consumption of resources and environmentally impacting emissions, so that it is no longer a characteristic of high-income industrialised societies?

3.4. The Need for system innovation

Keeping in mind that there are great differences between contexts, it has been argued above that if we are to take the concept of a sustainable society seriously, we need a wide-reaching social learning process in which a system discontinuity is catalysed. Therefore, when taking this to the implementation level, it is clear that what is requested is a system innovation approach. By system innovation we usually refer to a transformation which takes place at the wider societal context, with fundamental structural changes. It covers changes in user practices, markets, policy, regulations, culture, infrastructure, lifestyle, company and organisations structures. As well as their interactions within the various production and consumption systems (Kemp & Rotmans, 2004; Geels, 2006; Frantzeskaki & Haan, 2009; Vezzoli *et al.*, 2014; Ceschin & Gaziulusoy, 2019).

At a system innovation level not only products, services and production systems are optimised with new ways of satisfying consumer needs are found within existing institutional frameworks and infrastructures, but new

infrastructures, spatial planning and incentive systems are developed and implemented that promote more sustainable lifestyles.

System innovations refer to major shifts in dominant "socio-technical regimes"[7] and the way in which societal functions are fulfilled. They are complex processes between the social, economic, technological and policy domains.

Within the wide debate on how to approach and foster system innovation, the offer model of Sustainable Product-Service Systems (S.PSS)[8] appears a promising one to decouple resource consumption and environmentally impacting emissions, from value creation.

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7. The socio-technical regime can be defined as the dominant way of innovating, producing, distributing, consuming etc. It is made up of different socio-economic stakeholders, practices, shared rules and ways of doing related to a specific field (mobility, energy, etc.).

8. This type of innovation is described in the chapter 6.

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4. The environmental impact of the clothing system

4.1. The clothing: a heavily unsustainable system

This chapter focuses on the clothing system and in particular on environmental impact of textile clothes. The value chain of textiles has been identified as one of the most overriding in terms of transition towards sustainable production (European Commission, 2020). Indeed, the impact of the textile sector on the environment is particularly relevant (Manshoven *et al.*, 2019): it is the fourth sector as regards the use of raw primary materials (after food, housing fuels and transport), the fifth in terms of Greenhouse Gases emissions (after food, recreation and culture, beverages, restaurants and hotels) and the second for land use (after the food sector). Moreover, the value chain of textiles involves the use and release of hazardous chemicals – both for human beings and the environment – along the whole life cycle. Finally, less than 1% of textiles is recycled into new fibres (Ellen MacArthur Foundation, 2017) and the market of reused textiles is very low; all the rest is landfilled. Just in the European context reused textiles are below 5%, an amount of 5.8 million tonnes of textiles every year, which means 11.3 kg per person is landfilled (Beasley *et al.*, 2014).

Focusing on clothes, mainly due to the continuous chasing of cost optimisation during the production processes – and a consequent loss of products' quality – the lifespan of clothes has progressively decreased. For instance, the average lifespan in Europe is between 2.2 and 5 years, which is half as long as it was fifteen years ago (Manshoven *et al.*, 2019). Although awareness about environmental issues has increasingly spread among customers all around Europe, the relevance of the sustainability factor on production and consumption is still secondary in relation to others like price, fit, comfort or quality (Manshoven *et al.*, 2019).

4.2. The analysis of the clothing system environmental impacts

The environmental impacts related to clothes are determined by all of the inputs and outputs directly and indirectly associated with a clothing system. The *inputs* are the extraction/acquisition of natural resources, and the *outputs* are the emission to air, water and soil that affect the biosphere and the geosphere.

To properly study and understand the environmental impact of clothes we need to define both the so-called *functional unit* and the *system boundaries.* Indeed, to analyse the environmental impact of any type of product system, it is necessary to define a quantified description of the performance requirements that the product system fulfils. This quantified description is called the ***functional unit*** of the product system. The functional unit provides the reference to which all other data in the product systems are normalised. When analysing clothing system, the *functional unit* should be defined as the ***use of a garment for a given period of time***. One year is a good time reference since it takes into consideration all seasons that may affect the use of clothes.

The ***system boundaries***, instead, define all those activities (processes) directly or indirectly related to the clothing system, before, during and after its use.

In other terms, we have to look at the clothes life cycle, which identifies the journey of a clothing product from the extraction of the raw materials until its disposal. More precisely the clothing system life cycle phases:

- pre-production;
- production;
- distribution;
- use;
- disposal.

Pre-production

The **pre-production** phase (see Fig. 4.1) incorporates all impacts associated with the acquisition of necessary resources (raw materials) as well as their transformation into materials to be used into the different manufacturing options for clothing products. Within the clothing value chain, these can be distinguished in *fibres production processes*, and *textiles production processes.*

Fibres' production processes

We all know that clothes are made with different types of fibres coming from different types of resources and processed till the fabric is made, throughout different processes. This means that the environmental impact of the pre-production phase is different form fibre to fibre and from fabric to fabric that can be obtained. In fact, it is evaluated in relation to all of the processes that characterise each specific type of fabric and fibre of a given clothes. In other terms, we have to evaluate the specific processes for the extraction/acquisition of the raw material needed for the production of a given fibre, all of the processes needed for the production of a specific yarn from that fibre, and finally all of the processes for the production and finishing of a given fabric. In light of this, it is useful here to remind the different types of fibres and so forth the main possible alternative processes related the pre-production phase.

A first distinction is usually made, and it is useful for this introductory discourse, between *natural fibres* production and *man-made* fibres production.

Natural fibres come from two main sources:

a) ***plants*** (cellulose), the main fibres being cotton, flax, hemp, jute, coir, sisal (agave);
b) ***animal*** (protein) such us wool (sheep), silk (silkworms), cashmere (goat hair), mohair (goat hair), camel hair, alpaca hair.

Man-made (chemical) **fibres** come from two main sources:

a) ***oil*** form which we can produce some *synthetic polymeric fibres* such us polyester, nylon (polyamide), Lycra (elastane), acrylic and polypropylene;
b) ***cellulose*** form which we can produce some *natural polymeric fibres* such as viscose (rayon), cupro (rayon), acetate (rayon).

When analysing the environmental impact of *plants-based natural fibres production* we have to take into account all processes related to their c*ultivation and farming*, i.e. all agricultural stages related to the planting, growth, and harvest of plants. So forth, different environmental impacts are caused by the use of land, pesticides, herbicides, water, energy, etc. (Fig. 4.2), generating resources exhaustion (water, energy), alteration of habitat/ecosystems' balance, climate change, eutrophication, ecotoxicity, land use, winter smog and, human toxicity.

When analysing the environmental impact of *animal-based natural fibres production* we have to take into account all processes related to their breeding (included the feeding), clipping and processing of fur. Actually, some processes could be valuable for the production of meat, dairy products, etc., so forth only a value-related share should be allocated to the fibre production.

Even with an appropriate attribution all those processes may cause resources exhaustion (water, energy), alteration of habitat/ecosystems' balance, climate change, eutrophication, ecotoxicity, land use, winter smog and human toxicity.

When analysing the environmental impact *of man-made oil-based fibres* we have to take into account all processes from oil extraction (exploration and drilling) to transportation and successively polymerization, as well as the preparation of materials to be extruded and spun into yarn. These processes determine several environmental impacts such as fossil resources exhaustion, climate change, ecotoxicity, land use and winter smog.

When analysing the environmental impact *of man-made cellulose-based fibres* we have to take into account all processes from cellulose extraction to its chemical treatment toward the viscose solution that is functional to be extruded as a yarn. These processes determine several environmental impacts such as renewable resources exhaustion, climate change, eutrophication, ecotoxicity, land use and winter smog.

Fibre production is followed by *spinning* processes to obtain the yarn, and even in this case the set of specific operations changes in relation to the different type of spun fibres. For example, in the case of natural fibres, from pre-arranged parallel clean fibres, a set of stretching and strengthening operations occur to reach a compact thread with radically thinner diameter. Differently, man-made fibres require the initial polymeric extrusion through tiny holes, producing thin twines that are successively stretched, combined and strengthened through different machines. These processes relate to inputs and outputs (e.g. energy consumption) that determine several environmental impacts, such as resources exhaustion (energy), climate change, and winter smog.

The production of fibres includes also the *Pre-treatment*, a set of processes that helps to prepare the fibres or the yarn for successive specific operations, depending on the type of fibre, yarn and future requirements. Some examples are washing, scouring, carbonizing, etc. The pre-treatment could take place even before spinning processes, e.g. through dying operations applied directly on cleaned fibres. Environmental impacts related to this stage are mainly resources exhaustion (water, energy), eutrophication, ecotoxicity and toxic effects on humans.

Textiles' production processes

After the yarn has been manufactured, a set of operations is put in place to assemble and process yarns to obtain textiles. *Knitting, weaving or non-woven production* are the main methods to make textiles. As it is known, knitting is based on the bind of successive rows if yarns, weaving consists

of the intersection of two different sets of yarns, crossed with fixed angles, non-woven production is based on alternative ways of bonding fibres, with either chemical, mechanical or heat processes. Any input and output of those processes (e.g. energy consumption) has to be considered to determine different environmental impacts (e.g. resources exhaustion).

Part of textile production are also *Wet processes*, a set of operations aimed at improving a textile's properties, e.g. aesthetics, comfort of function. Typical wet processes are dying, printing, bleaching, and finishing. These processes usually consume water, energy, chemicals and determine emissions, such as the release of toxic substances and microfibres due to the discharge of wastewater. The main environmental impacts of these processes are toxic effects on humans and ecosystems, eutrophication, climate change, resources exhaustion (energy, water) and winter smog.

Pre-production of non-textile materials

Apart from textile materials, garments are made by other complementary components such as buttons, zips, and laces. Each of these products is based on different raw materials which extraction and transformation must be considered as part of the pre-production phase of a given clothing system.

Production

The following stage is the clothing **production**, and it is referred to all the garment manufacturing processes, including *cutting*, *sewing*, *trimming* – the so-called "make-up" process (Khan & Islam, 2015; Moazzem *et al.*, 2018) – and in some cases ironing. The environmental impact in this phase is generally much lower than in the pre-production phase, nevertheless inputs and outputs of those processes (e.g. energy consumption) has to be considered to determine the negative impact of the environment. Moreover, also the production of non-textile products should be taken in a count within this phase, e.g. the injection moulding of polymeric buttons, the weaving of laces, the manufacturing of zips as well as their assembly on garment.

As a whole, production processes include inputs and outputs generating several environmental impacts, e.g. the depletion of fossil or renewable resources, climate change, ecotoxicity, land use (generated waste) and winter smog.

Distribution

The **distribution** stage evaluates the environmental impact of the transportation (from the factory to the user), the packaging, as well as all the retail and storage activities. Indeed, about packaging we have to

consider both primary, secondary and tertiary packaging and all those need to be considered in all of their life cycle stages.

So forth, the main resources and natural capital inputs are related to the consumption of energy resources for transportation as well as their emission. In particular, the environmental impact of transportation could be different in relation to both the distance of travel as well as the means of transport, which differs in terms of fuel types and related emissions. Other impacts are related to waste generation from primary, secondary and tertiary packaging.

All this considered, environmental burdens caused in this phase are the exhaustion of fossil resources, climate change, human toxicity (air pollution) and winter smog.

Use

The **use** phase considers the impacts associated with clothes wearing, and clothing care activities, i.e. washing, drying and ironing, but even repair or upgrade. Particularly relevant are the impact of washing due to the consumption of energy, detergents, and water. Indeed, detergents need to be considered in all their life cycle stages, resulting in a relevant environmental impact.

In this phase main resources and natural capital inputs involved are energy and water, while main environmental impacts are climate change, resources exhaustion (water, energy), human toxicity and ecotoxicity.

Actually, in the hypothesis of considering a complete system for the evaluation of its environmental impact, also the pre-production, production and distribution of side-products like washing machine or iron should be considered.

Disposal

Finally, the **disposal** phase rates the impact of the activities associated with the end-of-life of the item, in particular landfilling, incineration, or recycling.

In this phase, main resources and natural capital inputs involved are related to the consumption of energy and the consequent exhaustion of fossil and renewable resources, while main environmental impacts are climate change, land use (waste), human toxicity and ecotoxicity. However, part of the negative impact can be avoided due to the recovery of fibres through recycling, energy recovery (through incineration, if arranged through systems that do not generate toxic emissions).

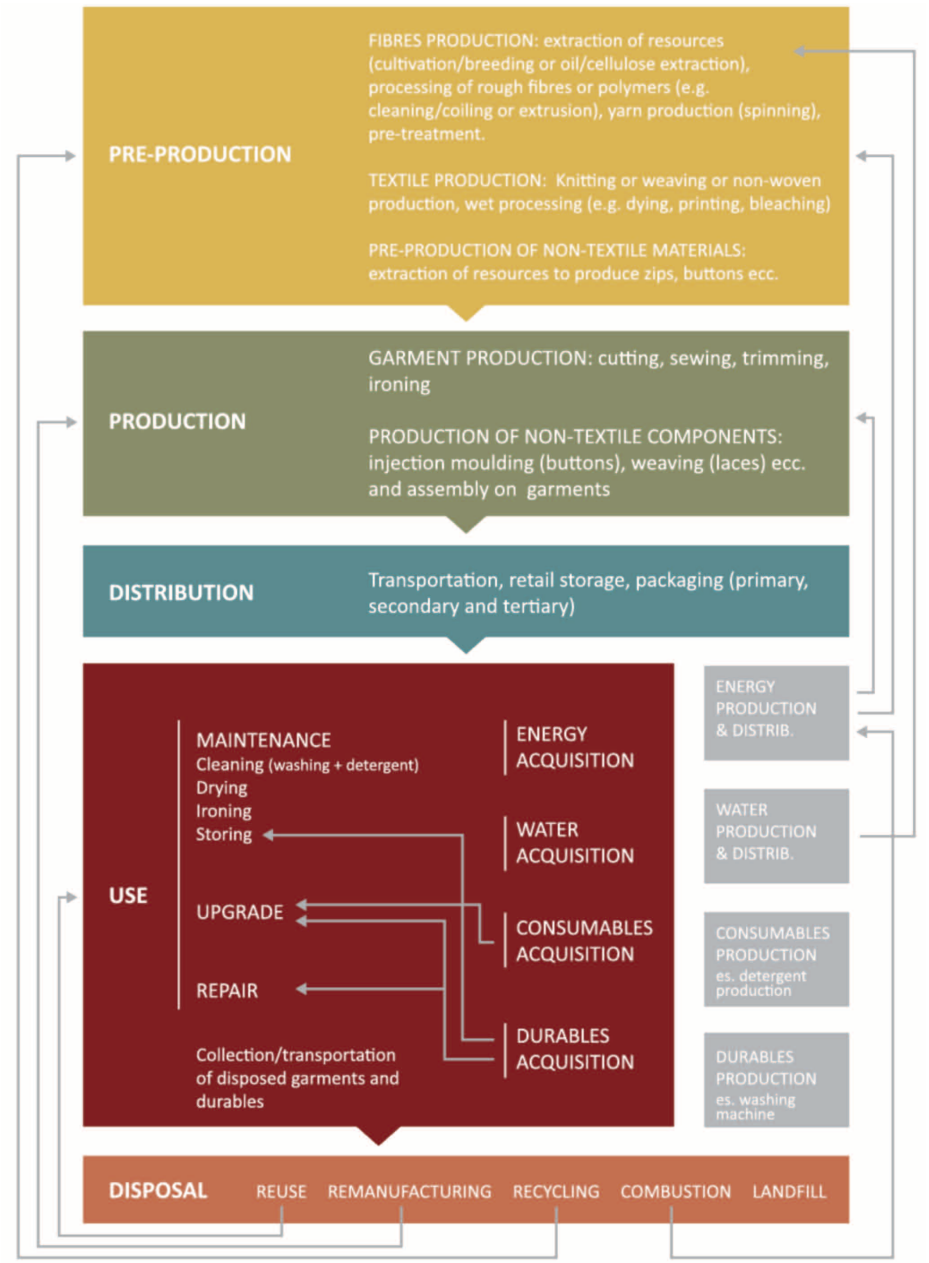

Fig. 4.1 - The system boundaries: the clothing system life cycle (elaboration by Macrì, L. & Vezzoli, C.)

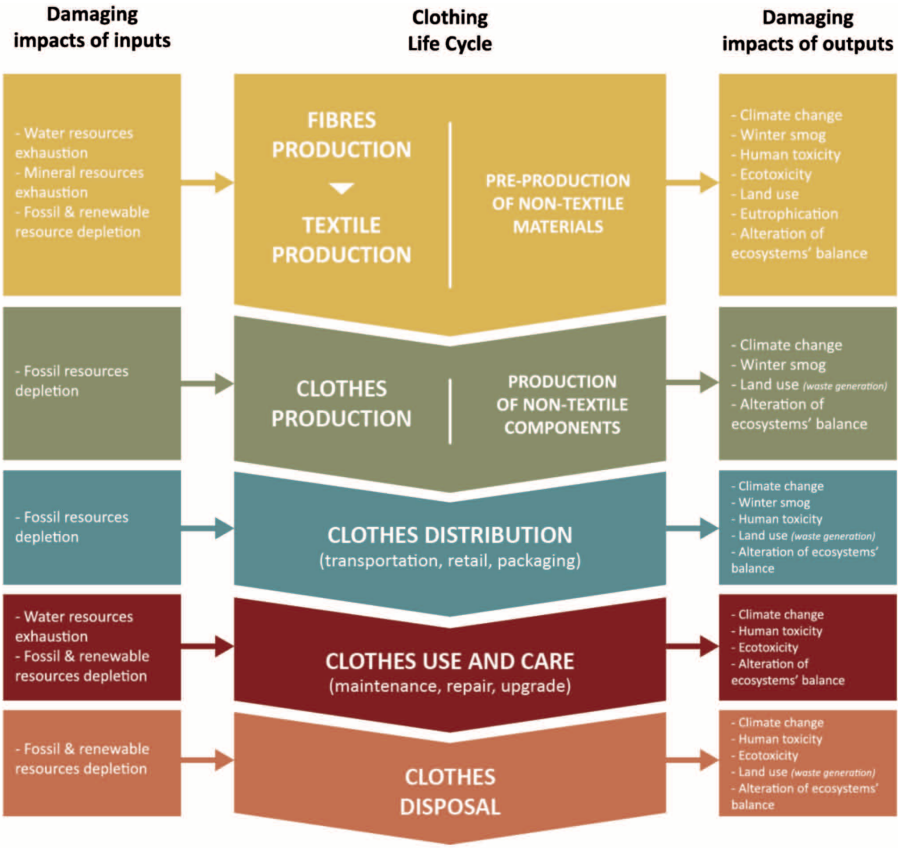

Fig. 4.2 - Main damaging environmental impacts generated by inputs and outputs related to the life cycle of clothes (elaboration by Macrì, L. & Vezzoli, C.)

All this considered, which stages and processes have the highest environmental impact along the clothing life cycle? How could different process alternatives (e.g. which fibres, which manufacturing processes, which clothing care operations) affect the environmental impact of the clothing system?

The following paragraphs try to give a comprehensive answer, through an analysis based on existing knowledge on environmental impacts in the clothing sector. In particular, most of the considered studies are based on Life Cycle Assessment (LCA), which is the most popular and reliable method for making environmental assessments. Detailed information about LCA can be found within chapter 5 (description box after section 5.2).

4.3. The life cycle environmental impact profile of clothes

In general, the pre-production and use phases have the highest environmental impacts (Beton *et al.*, 2014), as also highlighted by Fig. 4.3. In pre-production, the environmental impact obviously depends on the type of fibre and confrontations of such impacts are presented in the next section (5.4). Moreover, it depends even on the type of textile production processes like dyeing, printing, bleaching, wet treatment and finishing.

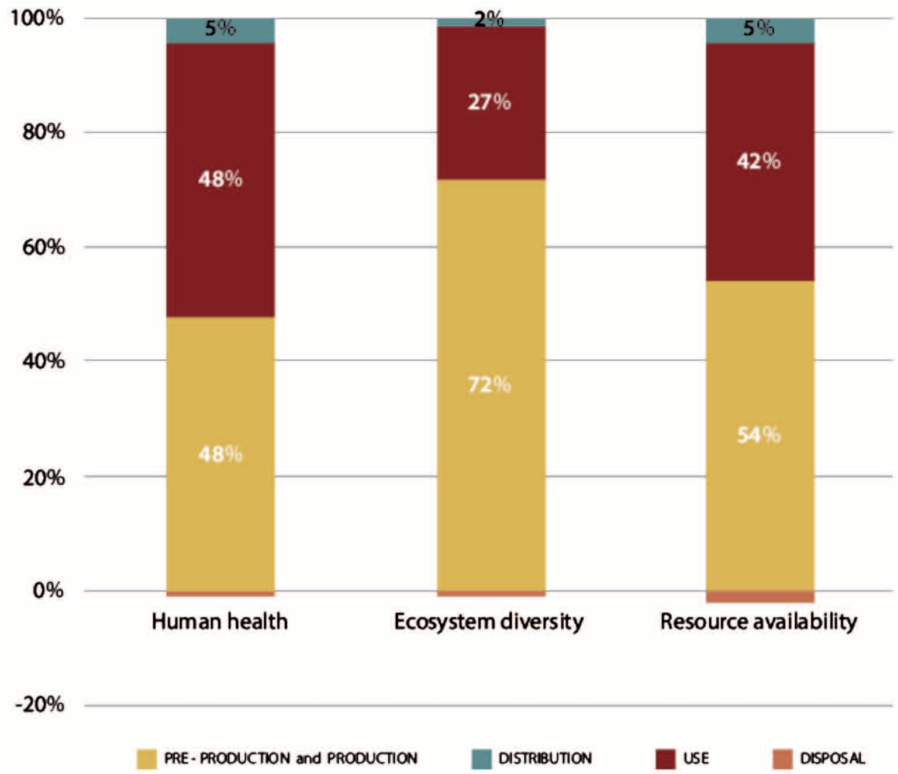

Fig. 4.3 - Impacts[1] *of textiles consumed in Europe in 2007 (19,1 kg/ citizen), according to ReCiPe's endpoint indicators, re-elaborated by Giannone, D., Macrì, L., Vezzoli, C. & Conti, G. from Beton et al., 2014.*

1. The diagram reports negative impacts for the disposal phase. Indeed, according to the reference study, this is due to credits for energy and material recovery. This does not include reuse, that has been considered as a discount in the environmental impact of the production stage.

The use is the other high impacting phase – as we saw – due to the consumption of detergents (considered in their pre-production, production, use, distribution, and disposal), energy and water during the clothing care and their related environmental impacts. In the following chapters we will see that the impact could be different in this phase even in relation to the type of fabric and different caring behaviours.

A less relevant impact compared to the pre-production and use phase occurs in the distribution phase – as mentioned previously – due to energy resource consumption and emissions during transportation, retail activities as well as the impact of primary, secondary and tertiary packaging.

A significantly lower impact occurs during the production phase (minimal compared to the impact of the whole life cycle), as we saw mainly related to energy consumption for the manufacturing of clothes and waste generation during operations like cutting, sewing, trimming and finishing.

Finally, a significantly lower impact occurs even in the disposal phase, although differences are related to whether the garment is landfilled (impacting in terms of land use,), incinerated, with or without energy recovery (with burdens like winter smog, etc.) or recycled (impacting on resource depletion and climate change).

The environmental impacts related with each lifecycle phase are analysed in detail throughout the following paragraphs.

4.4. The environmental impact of pre-production

As anticipated in the description of the clothing life cycle profile, in the pre-production phase we include fibres production and textile production, which take place before garments manufacturing (considered as the production phase). In this sense, pre-production involves different processes, depending on the fibre and fabric typology, which determine specific environmental impacts. The following paragraphs go through a deeper analysis of fibres' burden in pre-production, as well as some specific focus on different type of fibres.

4.4.1. *Comparison between different fibres in the pre-production phase*

Focusing on the environmental impact of the pre-production phase within the clothes life cycle, the most influencing factors are related to the extraction and processing of raw materials, which in the textiles

industry are mainly represented by the type of fibres and the technological approaches to process them. As anticipated, the fibres are usually divided in two main categories: *natural* ones, which come from plants, animals or minerals, and *man-made* ones, which are mostly synthetic – made by synthetic macromolecular compounds – but include also regenerated fibres – that use regenerated cellulose (Houck, 2009). Consequently, pre-production could involve different stages according to the type of fibre, i.e. natural fibres involve cultivation or breeding while man-made fibres are connected to oil extraction and processes for chemical synthesis (Fig. 4.4).

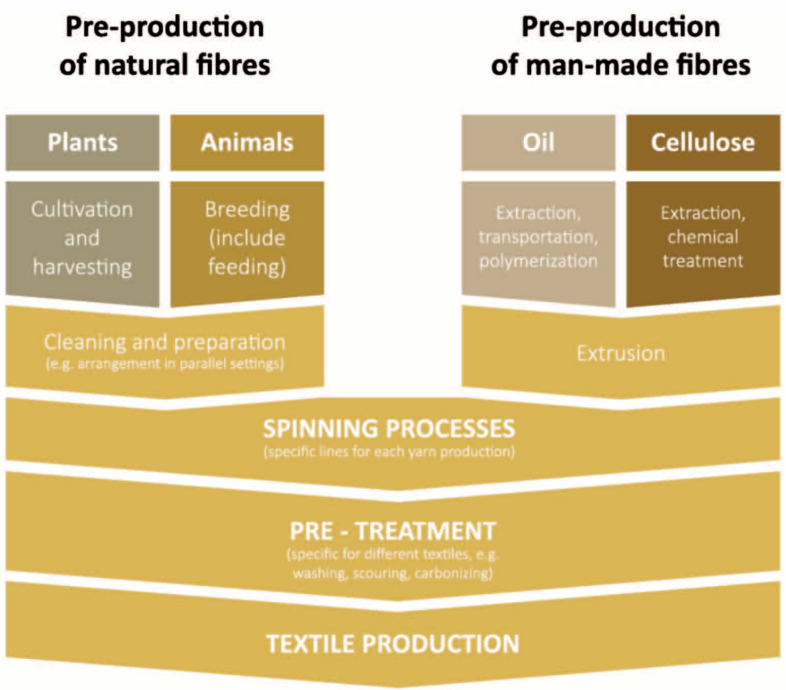

Fig. 4.4 - Different pre-production processes for natural and man-made fibres (elaborated by Macrì, L. & Vezzoli, C.)

Natural fibres

Focusing on the pre-production phase of *natural* fibres, a first impact occurs during agricultural and breeding processes. Indeed, all the operations involved in the growth of plants that are used as raw materials for the production of fibres as well as all the processes related to

animals breeding generate various types of environmental impacts. An example of different types of inputs and outputs related to specific agricultural processes in the pre-production of natural fibres is provided in the following table[2].

Agricultural Process	Included inputs
Transport	Fuel used to transport seed cotton from field to gin
Field Fuel Use	All field operations such as: planting, cultivation, fertilizer application, and harvest
Seed Production	Production of planting seeds
Post-harvest	All ginning operations and materials (cleaning, ginning, baling, ties, bags)
Pesticide manufacture	Pesticide production, including potential impacts associated with raw materials
Irrigation	Water used for irrigation as well as energy associated with its application and conveyance
Fertilizer	Fertilizer production, including potential impacts associated with raw materials
Field emission	Impacts associated with the estimated loss of fertilizer and pesticides to the air, water or soil outside the root zone
Reference system	Accounts for emissions that would occur in the natural environment if cotton were not produced
Crop Rotation	Primarily associated with fertilizer credit of unused nutrients

Fig. 4.5 - Definition inputs related to agricultural processes involved in the production of 1.000 kg of Cotton Fibre (Cotton Incorporated, 2012)

Complete Life Cycle Assessment (LCA) have been made considering a few types of natural fibres, cotton, jute and kenaf (La Rosa & Grammatikos, 2019). Indeed, Fig. 4.6 shows the comparison between these three typologies of textiles, revealing how the environmental impact of jute and kenaf is way lower than cotton.

2. These tables are part of the Life Cycle Assessment of a hypothetical knit short and a woven pant, conducted by Cotton Incorporated (2012).

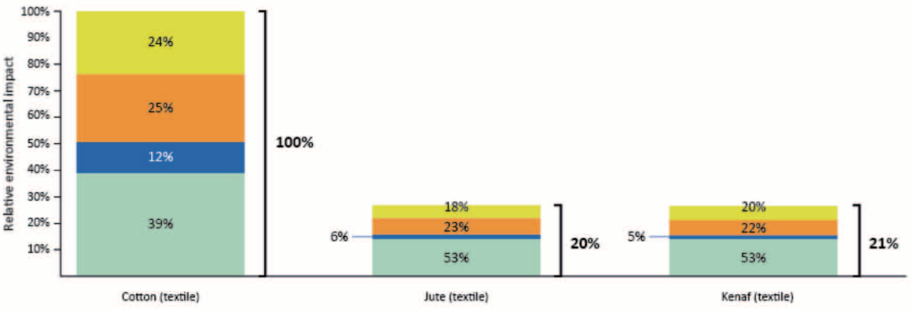

Fig. 4.6 - Comparison between the environmental impact of jute and kenaf textiles in relation to cotton – single score indicator obtained using through the CML-V3.02 method (Re-elaborated by Macrì, L. & Vezzoli, C. from La Rosa & Grammatikos, 2019)

The higher environmental impact of cotton is influenced by a variety of factors, first of which is the toxicity output that affects the human health indicator. Since cotton is a plant grown fibre, there are a range of pesticides used to assist its growth including herbicides, insecticides, and fungicides. These pesticides are used in intensive cotton growth procedures in large volumes. For example, herbicides which target weeds are being applied to 93% of planted cotton crops (National Agricultural Statistics Service, 2019) which could be reduced with preventative measures such as hand hoeing. Unfortunately preventive measures are often not adopted as they are expensive and labour intensive (Roberts *et al.*, 2013).

Another output in which cotton scores highly is within water use/consumption, affecting the resource depletion indicator. Irrigation, like the pesticides, is often carried out across the entire land without identification of areas that need it. Differently, jute and kenaf have a way lower single indicator and are very similar between themselves in terms of environmental impact. When considering their energy demand for their production, for Jute is slightly lower compared to kenaf (La Rosa & Grammatikos, 2019).

Man-made fibres

On the other side, *man-made* fibres (not involving agricultural processes) have their relevant impact due to the extraction and processing of raw materials. Indeed, most of them (except for viscose, cupro and acetate) are derived from oil, which is a non-renewable resource that impact on the environment in different ways:

- oil extraction – exploration and drilling – may affects land ecosystems with deforestation and can be harmful for marine flora and fauna,

e.g. due to loud noises and vibrations caused by seismic techniques (Science for Environmental Policy, 2012; EIA, 2021);

- oil transportation is dangerous for accidental spillages in the ocean during loading, sailing, or unloading, which have highly dangerous consequences on sea ecosystems (ISPRA, 2011; Science for Environmental Policy, 2012; EIA, 2021). An amount of almost 10.000 spilling accidents have been counted from 1970 to 2009 on a global scale (ISPRA, 2011); last but not least, the disaster happened to the Wakashio ship in August 2020, with more than 1.000 tonnes released in the ocean;
- the industrial processes involved to turn oil into polymers are energy-consuming and release polluting emissions like volatile organic compounds, particulate matter, and acid gases (Claudio, 2007).

The abovementioned inputs and outputs, related to the raw materials of man-made fibres, partly explain the higher energy consumption of synthetic fibres production in relation to others. Indeed, as shown by Fig. 4.7, the phase of raw material feedstock contributes to make Polyester, Acrylic and Nylon much more energy-consuming than cotton, linen, wool, and viscose.

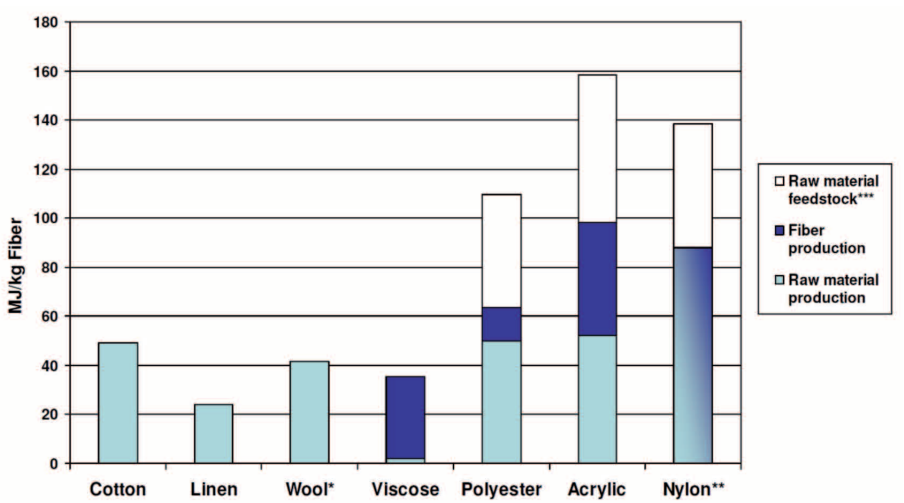

Fig. 4.7 - Comparative Energy Use in Fibre Production (BSR, 2009)

Focusing of Global Warming potential (carbon footprint), large part of the impact comes from emissions during the production of fibres derived from the combustion of fossil fuels to generate energy (BSR, 2009). For this reason, the comparison between different fibres (Fig 4.8) is coherent

with the energy consumption trend and shows how oil-based man-made fibres impact more than plant-based and natural ones. In particular, linen lower emissions in the fibre production phase are related to its low need for pesticides, fertilizers and irrigation. Again, the component of raw materials production – i.e. oil – makes the difference between the impact of different types of fibres. However, a peculiar exception is represented by wool (Fig. 4.8), that have a much higher Global Warming potential in relation to all the other fibres – due to methane emissions from sheep farming (BSR, 2009; Moazzem *et al.*, 2018).

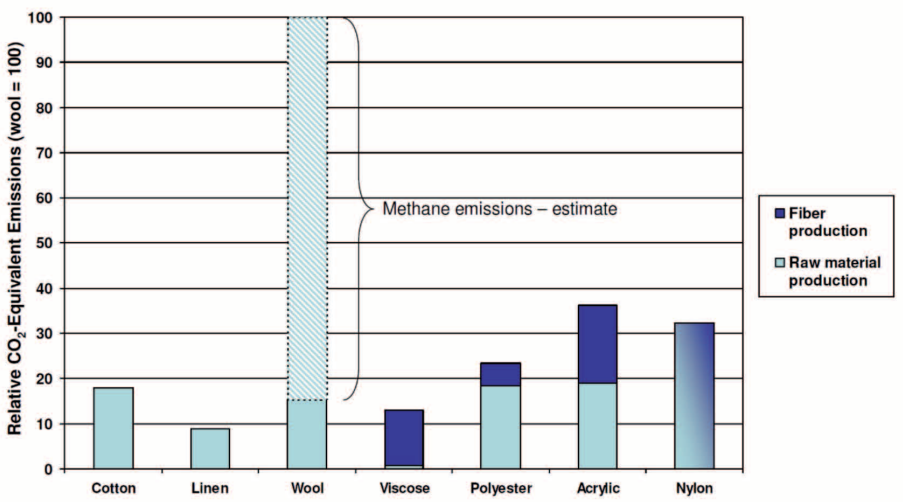

Fig. 4.8 - Comparative Global warming potential from Fibre Production in relation to Wool (BSR, 2009)

4.4.2. *Comparison between conventional and low impact cotton*

Within the clothing pre-production phase, as regards cotton, there are evident differences between conventional and low impact one (also known as *preferred cotton*), which is defined as environmentally and/or socially more sustainable than conventional alternatives, based on specific sustainability criteria and peer reviewed LCA analysis (Textile Exchange, 2018). Nowadays, the term *preferred cotton* identifies fifteen types of cotton[3],

3. ABRAPA, BASF e3, Better Cotton Initiative (BCI), Cleaner Cotton, Cotton made in Africa (CmiA), Fairtrade, Fairtrade Organic, Field to Market, In-Conversion Cotton

that together represent the 30% – it was 5% in 2012 – of the total cotton production and that keep growing in relation to conventional alternatives (Textile Exchange, 2021).

To give an idea of the reduced environmental impact of low-impact cotton fibres within the pre-production phase, the following diagram shows a comparison between organic – an example of low-impact solutions – and conventional cotton (Fig. 4.9). A consistent impact reduction can be seen in terms of global warming, acidification, eutrophication, blue water consumption and on primary energy demand. Indeed, organic cotton has significant benefits, like the almost exclusive (95%) use of green water – rainwater that is stored in the soil – instead of blue water – surface water and from reservoirs – (Textile Exchange, 2014) and the avoid use of toxic pesticides and synthetic fertilizers (Textile Exchange, 2021). Other environmental impacts of organic cotton are compared in relation to conventional cotton's ones in Fig. 4.9, showing better performances of the former one also in terms of global warming, acidification, eutrophication and energy demand. However, why organic cotton is not leading the market in terms or production and consumption? It is mainly due to the required financial difficulties related to the achievement of certifications, as well as overlooked transition expenses (from conventional to organic), the reduced yields and overall time-consuming process (Fess & Benedito, 2018).

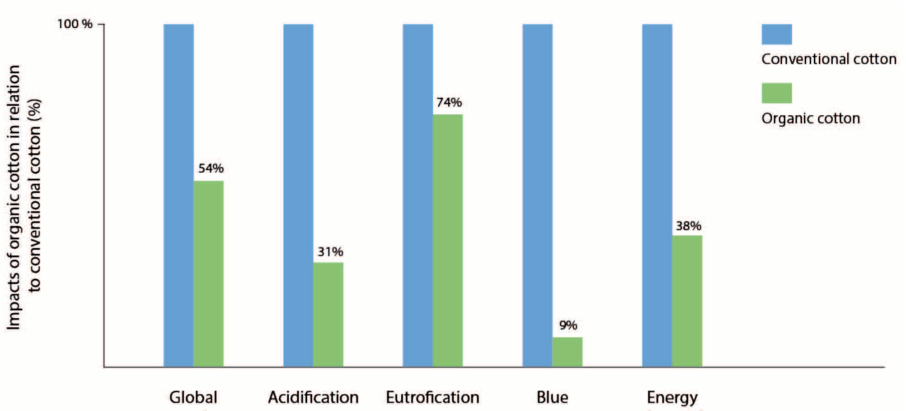

Fig. 4.9 - Impacts of organic cotton in relation to conventional cotton (re-elaborated by Macrì, L. & Vezzoli, C. from Textile Exchange, 2014)

(Transitional in USA), ISCC, myBMP, Organic, REEL Cotton, Regenerative Organic Certified (ROC), United States Cotton Trust Protocol (USCTP).

4.4.3. *Comparison between virgin and recycled polyester*

For what concern polyester, relevant differences in terms of environmental impact can be identified between virgin and recycled solutions. In terms of consumption, virgin polyester is the most used fibre in the world, around the 52% of the global overall fibre market (Textile Exchange, 2021). It is a man-made synthetic fibre obtained by chemical reactions that produce a fibre-forming polymer. We know that the production of polyester involves a high quantity of chemicals (e.g. dyes, pigments, catalysts, stabilizers) that could release dangerous substances for human health and cause high environmental impact (e.g. formaldehyde, PVC remains, acids), in particular for what concern water and air pollution (Saxena *et al.*, 2017).

An alternative solution could be recycled polyester (rPET), which is currently achieved mainly from non-clothing dismissed products, e.g. PET plastic bottles and PET ocean waste (Textile Exchange, 2021). In lower quantity, it is also obtained from the recycling of textile fibres, both from pre-consumer waste – generated during the fibre production – or post-consumer waste – generated after its disposal. The reason behind this disparity is that recycling non-clothing products into rPET fibres requires mechanical technologies that are largely available, while clothes-to-fibre process needs chemical recycling, more complex and expansive (Greenblue, 2018). Indeed, this latter process requires a 70-80% of PET purity, and the technology is still difficult to scale up. Looking at key suppliers and innovators presented by the Textile Exchange (2019), chemical recyclers are less than half of the ones that imply mechanical processes.

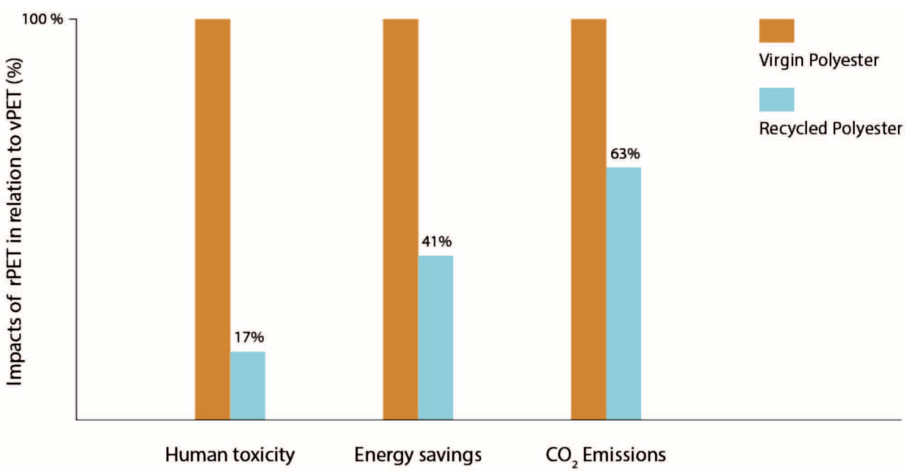

Fig. 4.10 - Reductions on impact categories for recycled polyester in relation to virgin polyester (re-elaborated by Macrì, L. & Vezzoli, C. from Textile Exchange, 2017)

Comparing PET and rPET fibres (Fig. 4.10) in terms of environmental impact, the latter allows to reduce the categories of human toxicity, energy consumption and CO_2 emissions (Textile Exchange, 2017). Other benefits from the use of rPET are the reduction of oil consumption as a raw material, the reduction of energy used, the decrease of waste addressed to landfills and a decrease of air and water pollution.

4.4.4. *Comparison between cotton and polyester*

Analysing the differences between cotton and polyester fibres in terms of environmental impact within the pre-production phase, it is crucial to specify that a meaningful comparison can be made only with coherence in terms of yarn thickness, which is a fundamental factor in quantifying the burden related to a fibre in pre-production (van der Velden *et al*., 2014). In this sense, considering the so-called "cradle-to-gate" part of the clothing value chain[4] and a yarn thickness of 70 dtex[5], the impact of cotton in the pre-production stage results to be around 20% higher than polyester, evaluated with an LCA study – Fig. 4.11 (van der Velden *et al*., 2014).

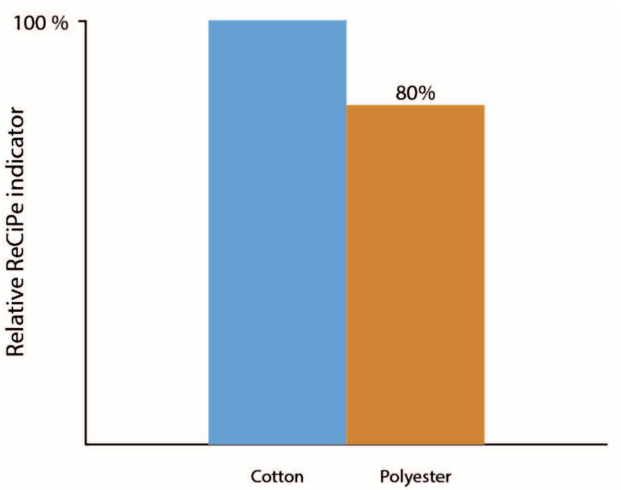

Fig. 4.11 - Relative impact of polyester in relation to cotton, based on LCA study adopting Recipe Europe H/A method (re-elaborated by Macrì, L. & Vezzoli, C. from Textile Exchange, 2017)

4. The study includes raw material extraction, spinning weaving and knitting. Dyeing and finishing are excluded.

5. Dtex means decitex, i.e. the mass in grams per 10.000 m of fabric.

The highest difference in terms of environmental burden between the two fibres is related to the consumption of water during their production: polyester consumes around 0,1% of water in relation to cotton (Kalliala & Nousiainen, 1999). The difference is obviously attributable to the high quantity of water required during the cultivation of cotton plantations.

Finally, it is important to remind that abovementioned data refer just to the pre-production stage and are not sufficient to determine a design choice between a clothing solution or another, which would need the analysis of the complete life cycle of the garment. For example, as described in detail by the next chapters, the analysis of use phase reveals the opposite: although cotton consumes more energy than polyester (due to the need of higher washing temperature), the latter needs to be washed more frequently and release microplastics, so forth making necessary to conduct a complete LCA on a clothing product.

4.4.5. *Toxicity in pre-production*

Considering natural fibres, toxicity in the pre-production is in general due to the fertilizers and pesticides that are used for instance in cotton crop during the fibre production. Indeed, fertilizers contains nitrates, which can be poisonous if inhaled or ingested by humans (Gupta *et al.*, 2017) and can alter ecosystems through eutrophication; pesticides may contain endocrine disruptors – dangerous for growth and reproductivity – carcinogenic substances and may cause dangerous combined effects with other chemicals (Calaf *et al.*, 2020); from an environmental point of view, pesticides can affect non-targeted species, damaging ecosystems and entering the food chain.

The comparison between the toxicity burden of different materials (Fig. 4.12) partly confirms the outlined framework on the use of fertilizers and pesticides, in fact it shows how cotton is undeniably the fibre with the highest impact in terms of freshwater ecotoxicity.

As a general consideration about toxicity in the pre-production stage, Fig. 4.12 suggests that silk is the fibre with the lowest environmental impact in terms of human and freshwater ecotoxicity, followed by polyester, wool, viscose and acrylic[6].

6. Cotton is not reported in the ranked list, since the discrepancy between human and freshwater ecotoxicity doesn't allow a direct comparison with fibres other than silk.

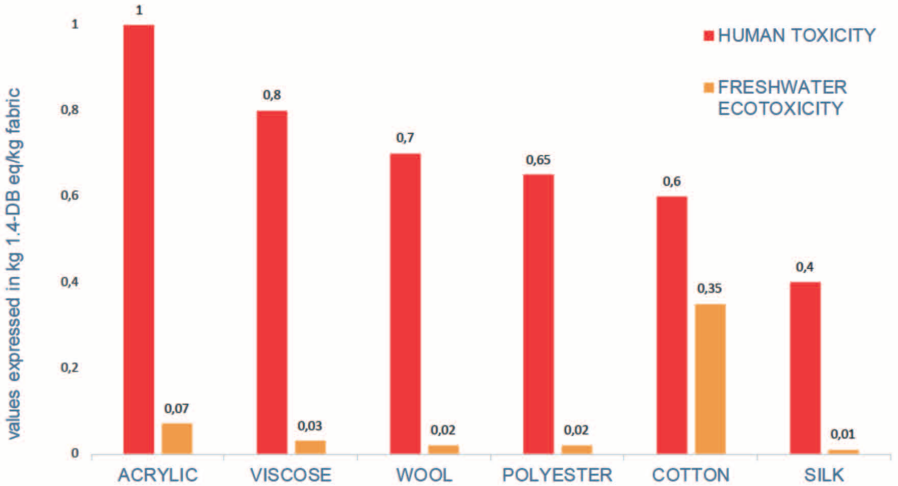

Fig. 4.12 - Human toxicity and freshwater ecotoxicity by fibre types in pre-production (re-elaborated by Giannone, D., Conti, G., Vezzoli, C. & Macrì, L. from Beton et al., 2014)

Another considerably relevant impact – for both synthetic and natural fibres – in terms of harmfulness for people and the environment is related to chemicals that are required within wet processing, and that are drained in wastewater. The term wet processing identifies a stage of the pre-production phase in which textiles added with substances that improve their original properties, e.g. aesthetics, comfort, or functionality. Examples of such processes are dyeing and printing, as well as different types of finishing procedures aimed at combining auxiliaries like softeners or fixing agents. In terms of toxicity impact, the problem related to wet processing is the high difficulty in treating wastewater, that leads to the release of unfixed chemicals into effluent water and land. An example is unfixed dye, which affects aquatic ecosystems reducing light infiltration and thus photosynthetic capability. Moreover, some toxic non-biodegradable chemicals (e.g. formaldehyde, PVC remains) can enter the food chain, becoming dangerous for animals and humans (Saxena *et al.*, 2017).

4.5. The environmental impact of production

As already mentioned, in the context of this book we consider as part of the production phase all the stages of the make-up process of clothing, i.e. cutting, sewing, trimming, garment finishing and ironing (Khan & Islam, 2015;

Moazzem *et al.*, 2018). The environmental impact of the clothing make-up process is currently less explored than other stages, however it is possible to gather insights from studies that focus on specific garments and fibres.

Considering cotton garments, a Life Cycle Assessment (LCA) by (Sule, 2012) highlights that sewing is the most impactful process within the production phase. Indeed, Fig. 4.13 shows that sewing has the highest relative burden for all the mentioned indicators, except for the ozone layer depletion and the photochemical oxidation, in which the impact of packaging – that in this case includes also ironing – is the most relevant.

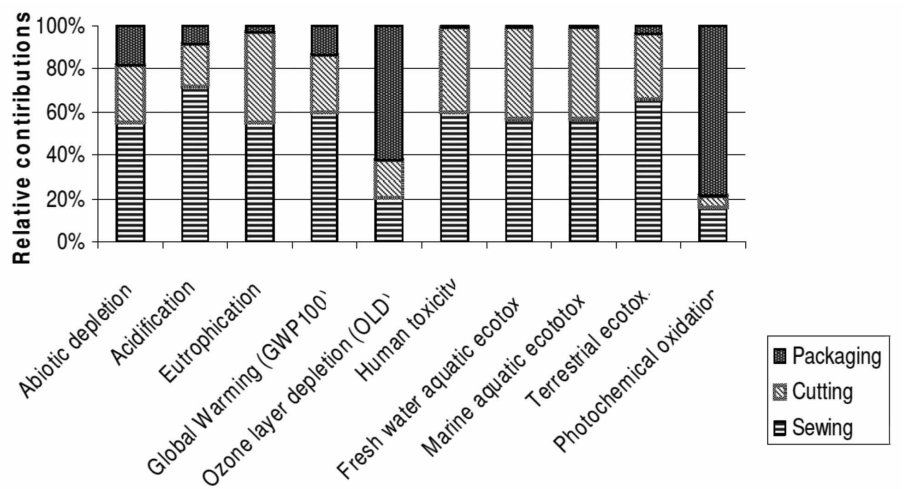

Fig. 4.13 - Relative contributions of different production processes in relation to different impact categories (Sule, 2012)

Particularly important is also the potential impact of the clothing cutting phase, which is considered by the European Parliamentary Research Service (EPRS) to be responsible for the 20% of wasted fabric from the industry (EPRS, 2019). However, the waste from cutting is often downcycled into products that have lower quality requirements (Khan & Islam, 2015).

4.6. The environmental impact of distribution

Distribution phase considers transportation from the production site to the end-user (from manufacturers of textiles to clothing producers, as well as from producers to retailers and from them to the end users), as well as packaging and storing. In fact, transportation occurs even during pre-

production, production, use and disposal stages, but usually we consider those as part of those phases. However, what is important is that those processes are, in one way or another, counted. Indeed, clothing companies move pre-production and production processes to countries with a cheaper labour cost, e.g. like Bangladesh, Vietnam and Philippines, shipping from countries like India and China the raw materials needed. When the garments are ready, they are sent to retail by rail, ships and trucks in shipping container. Though the designer has not that much influence on this aspect, it is good to know the impact of different transportation means in order to reduce the environmental impact not only minimizing transports (e.g. trying to work as much as possible with local companies), but even through conscious decisions like the adoption of transport solutions with minimum pollution, e.g. avoiding transportation by aircrafts and trucks.

For a complete evaluation, packaging, retail operations and distribution processes within other lifecycle phases should be included in the lifecycle analysis. However, as already mentioned in the description of the life cycle profile, the distribution has a relatively lower environmental impact, in particular compared to, the use and pre-production phases. In distribution phase retail and packaging impacts should be also considered according to their own life cycle processes.

4.7. The environmental impact of use

The use phase is related to all processes of clothing care, since the wearing in itself has not an impact (if not in the case of toxicity caused by the clothes when it is dressed; but toxic or harmful clothes are indeed phased out by the lows). Some of the most important are: washing, dry-cleaning, drying, ironing, storing, repairing and upgrading. As anticipated, each of these actions is characterized by specific inputs and outputs that make the use phase highly responsible in terms of environmental impact within the clothing life cycle (Beton *et al.*, 2014; Gray, 2017).

In particular, Fig. 4.14 shows the burden associated with different clothing care actions in relation to human health, ecosystem diversity and resource availability, considering all the fibres associated with clothing consumption in EU-27 in relation to their market share (Beton *et al.*, 2014). It can be observed how the process of washing has the highest impact covering approximately the 60% in relation to all the three indicators. In the figure are highlighted the impacts of the detergents (necessarily connected to the washing practice) This makes clear how much the practice of washing is relevant in terms of clothing eco-efficiency.

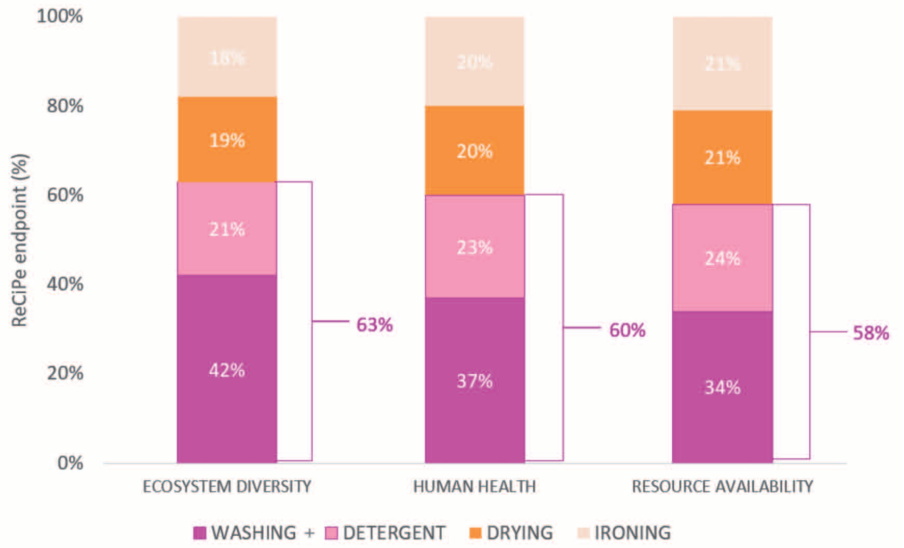

Fig. 4.14 - Impacts of use phase of textile consumed in Europe in 2014, based on LCA ReCiPe endpoint (re-elaborated by Giannone, D., Vezzoli, C., Conti, G. & Macrì, L. from Beton et al., 2014)

To carefully analyse the impact of clothing during the use phase, it necessary to point out that relevant differences occur in relation to the type of fibre, type of clothing, user behaviours as well as aesthetical and functional properties. Indeed, they correspond to different ways of using and taking care of clothes, resulting in variable lifespan durability and the consequent environmental impact. The following paragraphs give an overview on different clothing care variables and their impact from an environmental point of view.

As well as in the pre-production stage, the environmental impact of clothes in the use phase is dependent from the types of fibre, which require different treatments. For example, different required washing temperatures and frequencies can be associated to different levels of resources and chemicals consumption, as well as different quantities of waste produced (Laitala *et al.*, 2018).

It is often sufficient to read washing machine manuals or clothing labels to see such differences: for instance, comparing wool and cotton, the former needs to be washed less frequently and with lower temperatures, which results into a save of energy, water and use of detergents; cotton is also more inclined to wrinkles, that requires ironing and related energy consumption. Differently, synthetic fibres require more frequent washing

and are characterized by the peculiarity of releasing microplastics in the water (Laitala *et al.*, 2018).

Focusing on a comparison between two of the most spread materials – cotton and polyester, it is interesting to observe Table 4.1, that represents product parameters and ratio of product lifetime according to fibre type. In this case it is analysed a 100% cotton fibre, a 100% polyester fibre and a blended fibre (50% cotton and 50% polyester). As we can see, the 100% polyester product and the blended one are washed at a lower temperature, 40 °C compared to 45,8 °C[7] for cotton. On the other hand, products made with polyester fibres need to be washed more frequently during their lifetime than cotton-based ones; this is due to inherent fibre properties like the oleophilic nature of polyester (easy impressible by oily stains) and its inclination to increase strong odours (Laitala *et al.*, 2018).

FIBRE TYPE	WASHING TEMPERATURE (°C)	TUMBLE DRYING	LIFETIME RATIO IN YEARS
100% COTTON	45,8°	YES	1
100% POLYESTER	40°	NO ONE	1,9
50% COTTON AND 50% POLYESTER	40°	YES	1,6

Table 4.1 - Product parameters and ratio of product lifetime according to fibre type (re-elaborated by Giannone, D., Vezzoli, C., Conti, G. & Macrì, L. from Beton et al., 2014)

Another aspect that differentiates the two fibres in terms of environmental impact within the use phase – specifically during the washing process – is the release of microplastics, which are defined as (any) plastic

7. Average wash temperature of clothes in Europe considered by Beton *et al.*, 2014 based on data from Presutto *et al.*, 2007. It has to be noted that average temperatures for both cotton and polyester may have slightly varied in the last fifteen years.

scraps under five millimetres of length (NOAA, 2016; ECHA, 2017). As Laitala *et al.* has noted from the analysis of different studies, the dispersion of microplastics in the water – and thus in the sea – is exclusively associated with polyester and depends on different clothes and washing treatments: a fleece garment can generate more than 1.900 microplastics per wash (Browne *et al.*, 2011) while a 100% polyester jumper has a release of 500.000 ones during a full load wash (Napper & Thompson, 2016). It has also been observed that top-load machines release almost seven times more microplastics than front-load ones, due to the presence of a central agitator that moves clothes more vigorously (Hartline *et al.*, 2016). Moreover, it is not just a matter of washing: the release of microplastics due to tumble drying is approximately 3,5 times more than washing (Pirc *et al.*, 2016).

When discharged, microplastics enter in marine ecosystems through the food chain and are consequently consumed as food also by humans; health risks connected to microplastics are currently under observation by the European Food Safety Authority in 2021 (ECHA, 2017).

All this considered, even though it is not possible to make a comprehensive statement on which is the fibre – between cotton and polyester – with the lowest environmental impact in relation to their inherent properties of use, some studies have highlighted some data related to single indicators, like global warming.

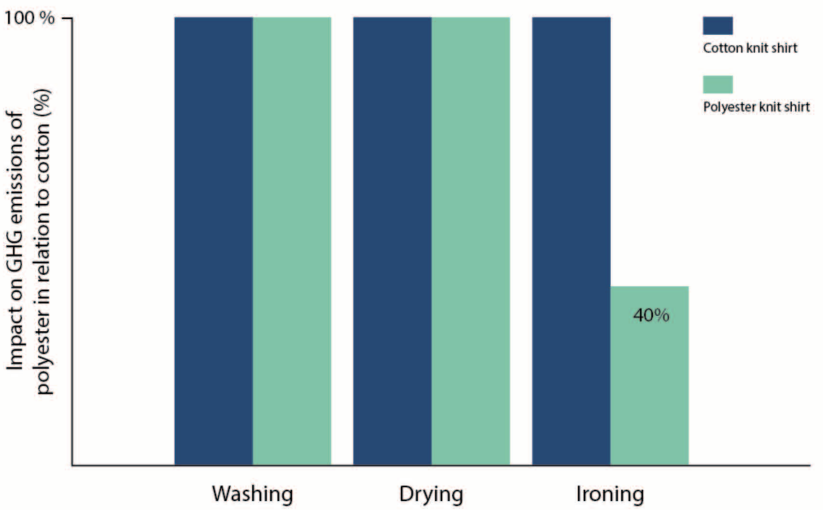

Fig. 4.15 - Impact (percentage ratio) related to GHG emissions (CO_2-e/kg) within use phase of a cotton and a polyester knit shirt (re-elaborated by Macrì, L. & Vezzoli, C. from Moazzem et al. (2018)

Indeed, within the Life Cycle Assessment made by Moazzem *et al.* (2018) – taking into consideration a cotton and a polyester knit shirt from the Australian market – it is highlighted (Fig. 4.15) that cotton is slightly more impactful than polyester in terms of Global warming potential during the use phase. This is due to the lower need of ironing that synthetic clothes have in relation to cotton. However, as already mentioned, inherent fibre properties are not the only factor to be considered as an impact variable in the use phase, as shown by the following paragraphs.

The environmental impact of the use phase is also largely influenced by users' habits, e.g. most of the time they wash their garments too often and at higher temperatures than those needed, so forth increasing the overall environmental impact of the use phase. As shown in a study about greenhouse gasses emissions from one year of care of a pair of blue jeans – Fig 4.16, the impact can significantly vary according to user choices in terms of wash frequency, temperature, type of washing machine and drying process (Levi Strauss & Co., 2015). In particular, the study compares the impact related to the use of a conventional and an efficient washing machine, including also two setting variables (warm and cold wash) and different drying processes (using dryer or line drying).

All this considered, the study shows that the habit with the lowest burden (washing in cold every month and using an efficient washing machine without the dryer) is twenty-four times less impactful than the worst habit (washing in warm every week using a conventional machine and a dryer). Moreover, besides improvements of washing/drying appliances efficiency, reducing temperature of washing (use cold washing when possible), number of washing and the use of line dry (use air drying of garments) are the best practice to reduce the impact of the use phase.

As regards the choice of clothing care facilities, comparing domestic washing machines and tumble dryers with communal laundries' ones (see Fig. 4.17), the former consumes 60% more energy than the latter (Menon *et al.*, 2010). This is known to be due to scale dimensions and more efficient methods used within communal laundries (Vezzoli, 2000).

Apart from washing behaviours, choices related to detergents are also particularly important since they are highly contributing to the environmental impact of the use phase. Indeed, LCA studies related to the outlining of Ecolabel Certification[8] observed that the use of compact

8. Ecolabel is a certification of environmental excellence that is released to products and services meeting high environmental requirements throughout their life-cycle https://ec.europa.eu/environment/ecolabel/.

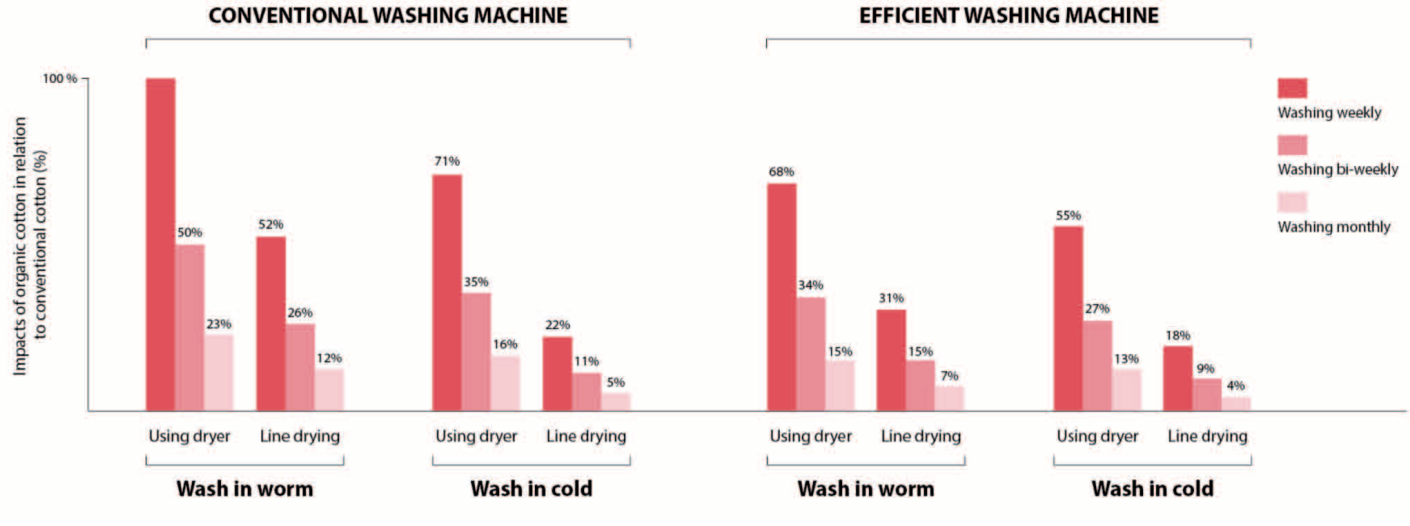

Fig. 4.16 - Carbon footprint from one year of care of 1 pair of blue jeans Levi's 501' (re-elaborated by Macrì, L., Giannone, D., Vezzoli, C. & Conti, G. from LEVI's, 2015)

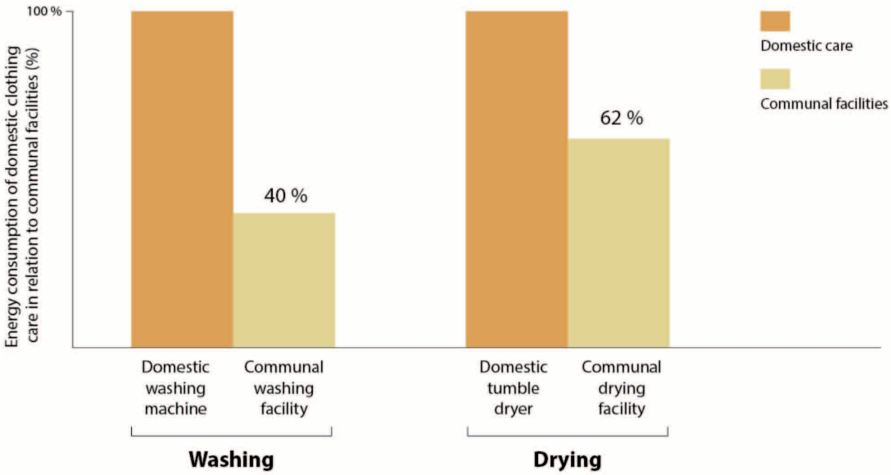

Fig. 4.17 - Energy consumption by communal washing and drying facilities in relation to domestic ones for clothing care (re-elaborated by Giannone, D., Macrì, L., Vezzoli, C. & Conti, G. from Menon et al., 2010)

detergents may reduce the environmental impact by up to 50% in relation to conventional powders (Ecolabelling Danemark, 2011; Medyna *et al*., 2015).

Detergent fabrication requires sodium compounds, as well as surfactants, which are potentially harmful for human health, water and terrestrial ecosystems. Indeed, detergents have high impact on human toxicity, as well as on marine, freshwater and terrestrial ecotoxicity.

4.8. The environmental impact of disposal

Disposal options for clothes are reuse, remanufacturing, recycling, incineration (with or without energy recovery) or landfill. As reported by Ellen MacArthur Foundation (2017), in 2015 the 73% of clothing materials worldwide were landfilled or incinerated after its end of life. Only around the 25% of clothes was collected for reuse or recycling and, during this process, about the 2% got lost. The 13% of the total material input was recycled after clothing use, mainly (12%) through a cascaded recycling process, which means that materials are used into lower-value applications, as wiping clothes, insulation materials and mattress stuffing. Finally, less than 1% of clothing material is recycled into new garments. Indeed, clothes made with natural fibres are very rarely recycled due to the remarkable

loss of fibre quality (Beton *et al.*, 2014), while the recycling of synthetic ones is currently difficult to implement, because it needs to be made using chemical processes that require high purity and are not available on a large scale (Textile Exchange, 2021).

As regards after use disposal processes, it should be considered that their amount highly varies among countries. For example, in Western Europe countries the amount of clothing collected after use is around 30-50% as a whole (ECAP, 2020), while it has been estimated to be 11% Italy and 75% in Germany. The differences in post-consumer collection percentages depend on several factors including cultural differences, the intensity of activities of charities and other collectors, policy and implementing measures (Watson *et al.*, 2018). In fact, even the calculation's methods[9] may determine a part of the variation.

For what concern the environmental benefits of some after use disposal scenarios, the Waste and Resources Action Programme (WRAP) has developed a specific methodology for quantifying the benefits of reusing products. For example, analysing the reuse of 120 million T-shirts (ca 30.000 tonnes) in the UK every year, it is possible to avoid 450.000 tonnes CO_2-eq per year. Moreover, textile reuse, recycling and remanufacture have the potential to offer large environmental benefits mainly from the decrease in the production of new textile fibres (WRAP, 2012).

The effect of increased collection of clothing waste on clothes life cycle impacts is shown in Fig. 4.18 (Beton *et al.*, 2014). Starting from the environmental impact of a scenario where 20% of textile clothing waste is collected (the current one), there is around 20-25% reduction on both Human health, Ecosystem Toxicity and Resource availability categories when the scenario changes to 40% or to 70% collection of clothing waste.

In this sense, an increasing tendency of reusing clothing in UK has been observed through the data gathered with a survey directed to final users (WRAP, 2017). In Fig. 4.19, the different disposal routes chosen by final users for their garments in 2016 are shown. The largest amount of clothing is taken to charity shops (39%) and collected in charity bags (18%). A relevant amount is downcycled and/or reused through bring backs policies (13%), while the 7% is sold as second-hand clothes. The 6% is instead disposed in general rubbish landfill, which means an additional environmental impact with its value to gets lost.

9. The variation related on calculations methods, can either include or exclude shoes and bags and general or specific collection methods, e.g. only via containers or including school and sports club collections.

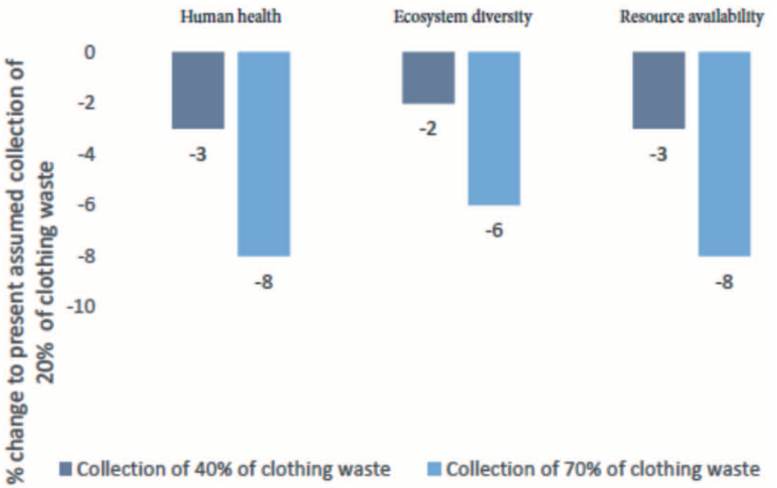

Fig. 4.18 - Changes in life cycle impacts of textile (assessed with LCA – ReCiPe method, Ecoinvent 2.0 database) from increased collection of clothing waste (re-elaborated by Giannone, D., Conti, G., Vezzoli, C. & Macrì, L. from Beton et al., 2014)

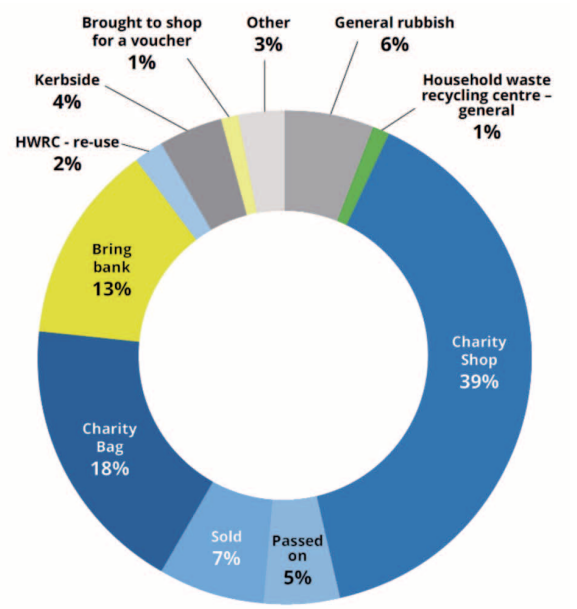

Fig. 4.19 - Disposal routes for garments, on average, in 2016 (UK), reported by respondents to a survey question (re-elaborated by Giannone, D., Conti, G., Vezzoli, C. & Macrì, L. from WRAP, 2017)

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5. The clothes Life Cycle Design

5.1. The clothing Life Cycle Design: an introduction

The role of design to innovate clothing products toward sustainability is increasingly recognized as a key leverage. The Circular Economy Action Plan adopted by the European Union in 2020 (EU, 2020) puts at the very first place the key role of design for sustainability as well as textile products – fundamental part of the clothing system – as a major issue related to the environmental impact.

Indeed, the concern about environmental requirements in the early stages of the design process is recognised as a more efficient practice than retrospective actions, since it allows to avoid expensive and dangerous operations to reverse or limit the damages. Although disciplines like environmentally sustainable product design or better Life Cycle Design (LCD) are nowadays widely studied, their application within of the clothing system is still limited. The following paragraphs present an overview on the concept of clothes Life Cycle Design.

The *clothes Life Cycle Design* could be defined as the:

> design of the clothes life cycle stages that, while considering all requirements, aims at minimising the overall environmental impact of all the life cycle processes in relation to the functional unit.

Particularly two main approaches need to be introduced.

Firstly, the designer is asked to adopt a *life cycle thinking* approach – that means to move from clothes design to the design of the clothing system life cycle stages, i.e. all the processes needed to produce the materials and then the clothes itself, to distribute them, to use and care about them and finally to dispose them, are considered as a single unit. In fact,

all those processes have been already described in the previous chapter on the Environmental impact of the clothing system when describing the system boundaries[1].

Secondly, the designer is asked to adopt a *functional thinking* approach with an environmental perspective i.e. design clothes for environmental sustainability (and evaluating them), considering its *function*, or better still its *functional unit* (even this already introduced in the chapter Environmental impact of the clothing system) rather than from the mere physical clothing perspective.

In this chapter we briefly bring up the main notions of clothing product Life Cycle Design (LCD). First defining the *Environmental Requirements*, then introducing the *Life Cycle* and *functional unit* design approaches.

Finally, we see the following main clothes *Life Cycle Design strategies*, with a set of related design *guidelines*:

- clothes use extension/intensification;
- resources conservation/biocompatibility for clothes;
- minimise resources toxicity and harmfulness for clothes;
- minimise energy consumption for clothing care;
- minimise material consumption for clothing care;
- design for clothes materials recycling;
- design for clothes disassembly.

5.2. Clothes design environmental requirements

As in clothing product design processes we might have requirements related to performance, technology, ergonomics, costs, legislation, culture and aesthetics, as well we have the *environmental requirements*. Those are related to the environmental impacts we can associate to an existing product or a redesigned one. To understand how resource extractions and emissions are connected with different clothing system, it is useful to recall the main environmental impacts[2]: climate change (global warming), stratospheric ozone depletion, eutrophication, acidification (acid rain terrestrial and fresh water), ocean acidification, winter smog (suspended particulate matter, etc.), summer smog (photochemical ozone formation), human toxicity (air, water and ground pollution) as well as resources consumption.

1. See section 4.2 of the previous chapter (The environmental impact of the clothing system).

2. See chapter 4, introducing such environmental impact and effects.

Without going any deeper now into complex details, it is important to keep in mind that clothes Life Cycle Design aims to reduce the overall clothing system environmental impacts. At this stage, clearly a query emerges: can we relate, or better still evaluate and calculate the amount of the different type of environmental impacts – we just recalled – to a given clothes, e.g. a pair of trousers being used in given way for a given period of time. The answer is yes and has already been presented in the previous chapter "The environmental impact of the clothing system". Coherently with what already introduced in order to design (and evaluate) clothes to minimise their environmental impacts two main design approaches need to be adopted:

- the product life cycle;
- the functional unit.

So, we must fully understand and clarify these concepts in a design perspective, to assess the environmental impact of a clothing product to be redesigned and when redesigned to compare it with the existing one. To evaluate (hopefully) how much and where the environmental impacts have been reduced. As already mentioned in the previous chapter, the most reliable method for making these assessments is called Life Cycle Assessment (LCA). A brief description of this method is given in the box below, since it is an important tool within a Life Cycle Design process.

Clothing product environmental impact assessment: Life Cycle Assessment (LCA)

Among other developed methods, one of the most popular and reliable for making environmental impact assessment is called *Life Cycle Assessment* (LCA)[3]. Alongside the description of this method given here, it is important to keep in mind that such tools can and should always be used as an aid into design processes. Indeed, they can help us to define environmental priorities and at the end of the design stage LCA might reveal whether or not we have managed to reduce environmental impact of the clothing product we have designed, and how much.

LCA (*Life Cycle Assessment)* enable us to make an environmental impacts estimation of product's lifecycle. The latter refers here to the set of interactions between a product and the environment, including acquisition and refinement of the raw materials, manu-

3. The acronym LCA has also been used to define Life Cycle Analysis, but lately the latter has been renamed as Life Cycle Inventory (LCI).

facturing supplies and the clothing product's distribution, use, and finally the disposal processes.

Since the '90 LCA has found official recognition in international standards being introduced to ISO (International Standardisation Organisation) normative. According to the ISO14040 definition the LCA *is a technique estimating the environmental aspects and potential longterm impacts of the whole lifecycle of products or services*, namely:

- compiling and inventorying the system's inputs and outputs of all the processes of all of the life cycle phases;
- evaluating the environmental impacts regarding these inputs and outputs;
- interpreting the results of inventory and evaluation phases according to given scope and objectives.

LCA considers the environmental impacts of an examined system, particularly in the light of environmental and human health and depletion of natural resources, but does not observe its economic and social character. Furthermore, one has to bear in mind, that this methodology is working with models and therefore is a simplification of the real world and does not pretend to handle environmental interactions in absolute and unerring manner.

General objectives elaborating LCA are:

- define the frame of interactions between a given activity and environment, as integrally as possible;
- contribute towards further understanding of the complexities occurring in environmental impacts of such activities;
- provide with information all interested sides, who have any power on further decisions[4] about impacts of such activities on environment and about opportunities to improve environmental conditions.

Stages of LCA

The elaboration process of a LCA is divided into four phases:

- Goal and scope definition

This stage is focused on defining the main reasons behind the LCA development and its expected results, as well as system boundaries and the functional unit. Indeed, as anticipated, a crucial step for a valuable LCA is a proper definition of functions that should be fulfilled, since that is the object of the assessment. Finally, the quality of data to collect is defined[5].

4. Referring to either authorities who define the regulations or who attribute the ecolabel, or to those who during different stages of product development are in position to make decisions, among other the designer: Indeed the book discusses the use of the tool by this latter actor.

5. If data needs to be precisely retrieved or can be average ones.

- Life Cycle Inventory

Data about system environmental inputs and outputs are collected in this stage, referring to the functional unit all along the life cycle. Data about different life cycle processes are collected, elaborated toward an inventory table and the results are evaluated in their sensibility, variability and uncertainty.

- Life Cycle Impact Assessment[6]

Four sub-stages define this phase: classification, characterisation, normalization and evaluation. During the *classification*, inputs and outputs are grouped into one or more impact categories (e.g. the water consumption input is assigned to the resource depletion category). Within the *characterisation* stage, the different impacts are clustered into one impact class through a proportional calculation and successively *normalized* through a common factor. Lastly, in the *evaluation* sub-stage, different normalized values are further aggregated toward a single indicator of the environmental impact (e.g. Fig. 5.1).

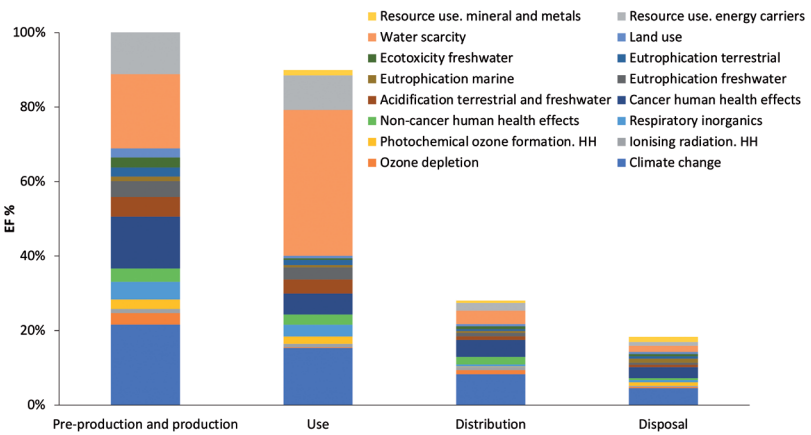

Fig. 5.1 - Aggregated results that could be obtained in doing an LCA over a clothing product (Method EF Method / Global, 2010)

6. For a detailed description of calculations, check Vezzoli (2018).

- Results Interpretation

The results of the assessment and of the inventory are finally interpreted in this stage, in relation to LCA objectives defined in the first stage. Apart from insights and suggestions for decision making, interpreted results could also lead to a redefinition of initial goals. Finally, other design requirements (performance, costs etc.), can be integrated with environmental ones.

As an example, let's look at the results that could be obtained in doing an LCA over a product, where it is evident which of the life cycle stages is the most impacting one. The environmental impacts seen in the Fig. 5.1 are aggregated and calculated in relation to different life cycle phases.

5.3. The clothing product life cycle

In environmental terms, the expression "life cycle" means the consideration of every relation that a clothing product and its system have with the biosphere and geosphere.

Furthermore, in the clothing product life cycle all the processes related to all the life cycle phases are considered simultaneously as a single unit. Better still, thus described life cycle can hereafter be defined in environmental terms, in order to consider the inputs and outputs, in relation to the geosphere and biosphere, in every process of all of the stages, and assess the effects of these processes on the environment.

As already outlined in the previous chapter, five life cycle phases are identified (see Fig 5.2):

- **pre-production**, compasses the raw material/resources/supplies acquisition and refinement processes;
- **production**, the components processing, assembling and finishing processes of clothing product;
- **distribution**, the packing, transport and storage of the clothing product;
- **use,** the wearing of the clothing product, and all clothing care (e.g. maintenance) processes like;
- **disposal** of the product, which may follow a number of different paths after its end-of-life. In fact, after the product is collected it can be either landfilled, incinerated, converted into compost recycled remanufactured or reuse (the entire clothes or some of its parts).

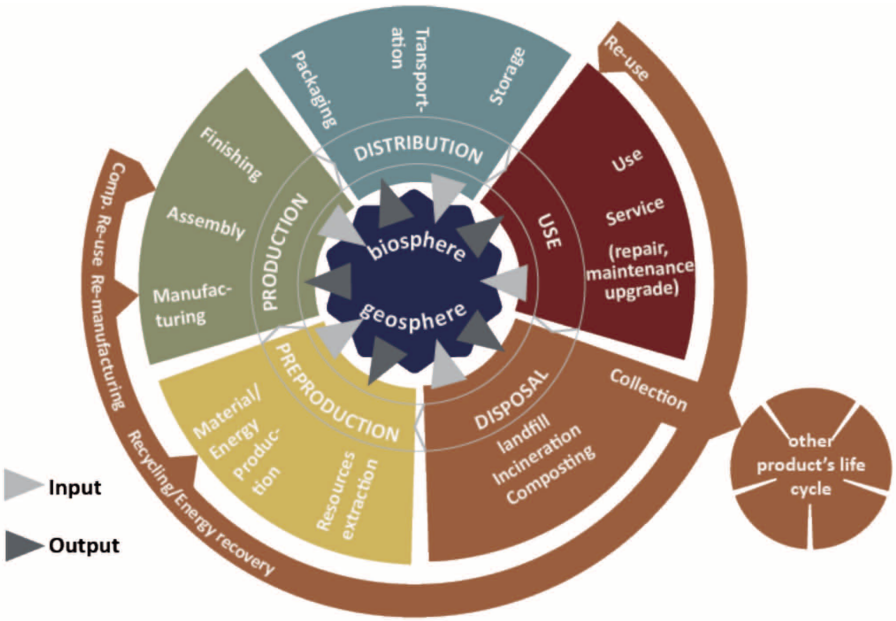

Fig. 5.2 - The clothing life cycle phases and main processes

5.4. The clothing functional unit

The second key design approach is the clothing product *functional unit*. The environmental assessment, and therefore also design, must have as its reference the function provided by a given clothing product, i.e. the clothing *functional unit*. The functional unit is defined as the "*quantified performance of a product system for use as a reference unit*" (ISO, 2006)[7]. That means the function or service supplied by the clothes has to be studied, not the physical clothes itself. Therefore, to compare the existing clothes with the one that has been designed, we have to compare clothes that are functionally equivalent. As already proposed in chapter three, when the product we are designing is clothes, the functional unit could be defined as follow:

The use of a garment for a given period of time, e.g. one year is a good time reference since it takes into consideration all seasons that may affect the use of clothes.

7. LCA is defined by the ISO 14040 and successively detailed within ISO 14041:1998, 14042:2000 and 14043:2006.

In this framework, it become far clear how important is the life span of clothes. Let us take the example of two t-shirts, that may be use in the same set of situations by a given person. Let us assume as well that one of the two last for one year and the other one for five years. Assuming the functional unit above defined, the consequence on the evaluation is the following. All of the environmental impacts of all of the processes of all of the life cycle stages of the five-year lasting t-shirt has to be compared with the life cycle impacts of the one years lasting t-shirt multiplied per five.

This fundamental criterion set the base of clothing designing over the function that the clothes have to supply rather than the clothes in itself: it is not the clothing product to be designed, but all processes associated with the fulfilment of a given function.

It is a basic approach of design for environmentally sustainable clothing system, which means that design-wise it is a step back from the clothes product, starting with its *function*, in other words with the satisfaction it is supposed to bring to the user.

5.5. Clothing product Life Cycle Design

Finally, the discipline integrating environmental requirements within the design process it is called clothing product Life Cycle Design (LCD). Other terminology may be found such as Design for environmentally sustainable clothing product, clothes eco-design or design for eco-compatible clothes. The environmental aim of clothing product Life Cycle Design is to reduce the input of materials and energy, as well as the impact of all emissions and waste, both quantitatively and qualitatively; that also means to assess the harm done (with LCA or other tools) by the processes at every stage of the clothing product's *life cycle*, in relation to a given *functional unit.*

The environmental as well as economic presuppositions of a life cycle design approach attempts to intervene upstream in order to prevent dangerous emissions and reduce consumption (depletion) of resources. As anticipated in previous chapters, it has been estimated that taking action at design phase may reduce up to 80% of the environmental impact (EU, 2020).

Furthermore, it is more effective and potentially economically beneficial to prevent harm to the environment at the design stage than to try to remedy things once the product is on the market. The importance of an LCD approach is therefore to identify and bring together the environmental advantages with the economic and competitive ones, i.e., to intervene upstream identifying all the opportunities.

As a consequence of what described in the previous chapters, there are two keys approaches to clothing product LCD:

- Life Cycle approach: adopt an extended design horizon moving from clothes product design to the design of the clothing product life cycle stages.
- Functional (unit) approach: the design "reference" that has moved from designing the clothing product's function instead of clothes product itself.

In other words, the LCD adopt a system approach to product design, in which resource inputs as well as emissions are reduced at the lowest level possible. Besides, this embraces the principles of, most recently introduced, Circular Economy (CE), which has recently been redefined as "A system approach to economic development […] that is regenerative by design and aims to gradually decouple growth from the consumption of finite resources […] and based on three approaches: design out waste and pollution; keep products and materials in use; regenerate natural systems" (Ellen MacArthur Foundation, 2021a).

Indeed, Life Cycle Design (even though older as an approach) covers all principled introduced by Circular Economy, furthermore, embracing a more complete set of strategies to reduce the environmental impact. Alongside with technocycles and biocycles used to describe the CE: in fact, LCD encompasses even the functional approach and the scenario of the dematerialisation of the demand of wellbeing, i.e. it concerns more clearly the reduction of resource consumption along all of the processes of life cycle and in relation to the functional unit.

To speak about clothing product LCD does not mean to focus on only environmental requirements, it is intended to be a more general approach to design that take into consideration all other design requirements such, functional, ergonomic, aesthetical, etc. Nevertheless, when we do consider, as it is our interest in this book, the environmental requirements, then the objective is to minimize the inputs and the outputs both quantitatively and qualitatively. Obviously in relation to life cycle and functional unit.

To design for an environmentally sustainable clothing product it is crucial to evaluate its environmental impacts, or better still its reduction in the new designed products as compared to the existing ones. Said this, it is not enough to make an environmental assessment; a designer needs a knowledge-base and know-how on how to design low environmental impact products. It is in this framework that also LCD strategies and guidelines to design low environmental impact clothes, has been developed. In the following paragraph, an articulated set of clothes-related LCD strategies and guidelines is presented, alongside with some examples.

5.6. Clothing product Life Cycle Design strategies, guidelines and examples

This chapter introduces seven strategies specifically developed to design clothes with low environmental impact, each followed by a set of guidelines and sub-guidelines to support the designer in their development[8]. Each strategy contains a description together with a set of case studies following one or more of the guidelines.

It is evident that designing good clothes cannot be based solely on fulfilling environmental requirements. The following strategies and guidelines take for granted the necessity to satisfy all other requirements for a good clothes design, i.e. performance, technological, economic, legislative, cultural and aesthetic requirements.

The strategies to design clothes with low environmental impact are the following.

Design for:

- clothing use extension/intensification;
- resources conservation/biocompatibility of clothing;
- avoid/minimise resources toxicity and harmfulness of clothing;
- minimise energy consumption of clothing care;
- minimise material consumption of clothing products;
- clothing materials recycling;
- facilitate clothes disassembly.

5.6.1. *Clothes use extension/intensification*

The focus of this design strategy is to design durable and intensively usable clothes. Indeed, as already anticipated in previous chapters, the clothing product lifespan has been halved in the last 15 years (Manshoven *et al*., 2019), while the annual discard of textiles – the majority of which is clothing – is around 11 kg per person just in Europe.

The strategy of clothes use extension/intensification aims towards an overall reduction in the environmental impact during the following

8. The LCD strategies to design clothes with low environmental impact that are presented in the following section have been specifically developed by LeNSlab Polimi within the research project *The Circular Economy for the competitiveness of Made in Italy industry – GIOTTO*, funded by the Italian Ministry of Education and Research (MIUR), gathering eleven national partner organizations with the aim of developing and disseminating innovative design tools to foster and implement a sustainable and circular economy within competitive value chains of Made in Italy i.e. furniture, food and fashion.

stages of the clothing lifecycle: pre-production, production, distribution and disposal). Let us consider first clothes use extension. A garment (or some of its components) – lasting longer than another one (i.e. having a more extended lifespan) that has the same function generates a lower environmental impact in those phases for the following reasons. The less the cloth lasts, the earlier it is disposed of (usually landfilled). Moreover, it generates other impacts due to the replacement needed to fulfil the same function; that is to say that pre-production, production and distribution of a new garment that has the same function lead to consumption of new resources and generation of new emissions, i.e. new environmental impacts. Finally, we avoid the impact the environmental impact of the processes during the stages of pre-production, production, distribution and disposal. Fig. 5.3 gives a graphical representation of the phases in which we avoid the impact comparing a long-lasting (2) with a short-lasting (1) clothing product (in the figure, lasting half of the time).

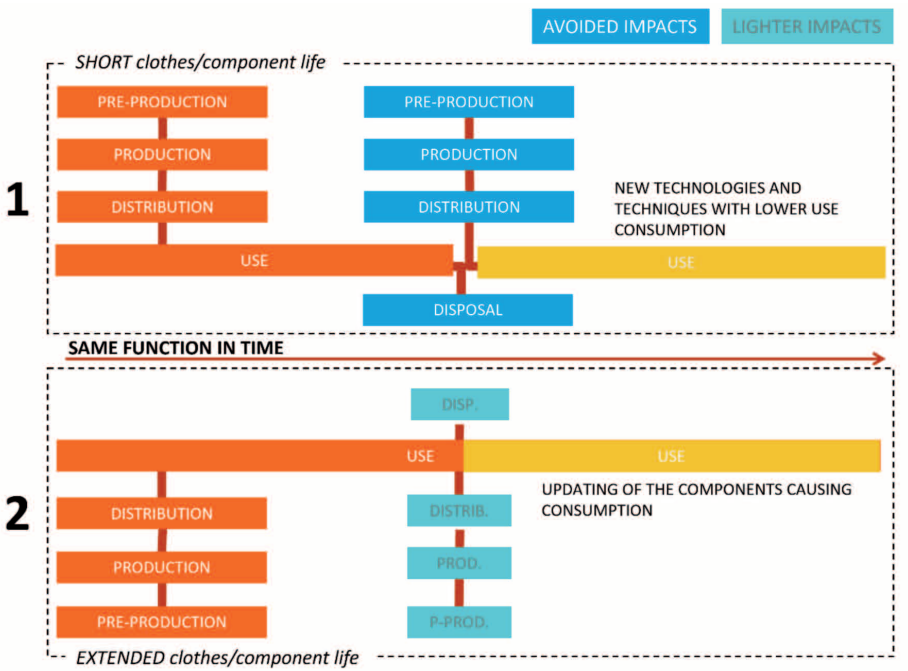

Fig. 5.3 - Comparison between the life cycle avoided impacts of long-lasting clothing products compared with short-lasting one (adapted from Vezzoli, 2018 and elaborated by the authors)

However, regarding to the given clothing product in use, the extension of its lifespan might not always determine a reduction in the overall environmental impact. In fact, continuing to use an old product can even cause an increase in impact, when technological development offers the opportunity to have new clothing products with lower environmental impact in the use phase (e.g. lower impacting clothing care operations or reductions in microplastic emissions during washing). In other words, providing the same service, a sooner replacement of the clothing product (with the need to pre-produce, produce, distribute the new product, as well as dispose the old one), may be over-compensated – in terms of balancing environmental impact – by the improved performance in use. For example, if an old polyester t-shirt that needs to be washed after every use because of its inclination to increase strong odours, it could be more eco-efficient to replace it with another that doesn't need so much care. Indeed, it would avoid the corresponding water/energy/detergent consumption and the emission of microplastics.

Considering the use intensification of clothes, we may reduce the impact of the processes along the pre-production, production, distribution and disposal phase. Intensifying usage means that a (greater) number of people use the same clothes (or a component of it) at different times, instead of everyone using its own clothing product. Thus, clothing product used more intensely than others lead to a reduction in the quantity of products present at a given time or in a given place in order to meet a given/the same demand (same functional unit).

This is exemplified by Fig. 5.4, that compares the intense (1) and not-intense (2) use of a clothing product by: User A, that uses the clothing product in the moments A1, A2 and A3; User B, that employs it in B1, B2 and B3; User C, that uses it in the moments C1, C2 and C3.

In the first scenario (1), the three users employ the same clothing product at different times. Differently, in the second scenario (2) they have their own clothes to satisfy the same functional unit, thus generating an additional environmental impact caused by the pre-production, production, distribution and disposal of clothes addressed to multiple users individually. Thus, the intense use of clothing products avoids these additional impacts.

However, this is true just when the usage of clothes is not affecting its life span, since otherwise the intense use would lead to a shorter durability of the garment. It is the case of aesthetical or technological obsolescence: for such clothes that tend to get rapidly old-fashioned, the intense use allows to maximize its effective usage. The same applies to clothes that are inherently used with low frequency: the intense use of the same clothing product by multiple users (in different times) instead of a single individual allows to maximise the use effectiveness (Vezzoli, 2018).

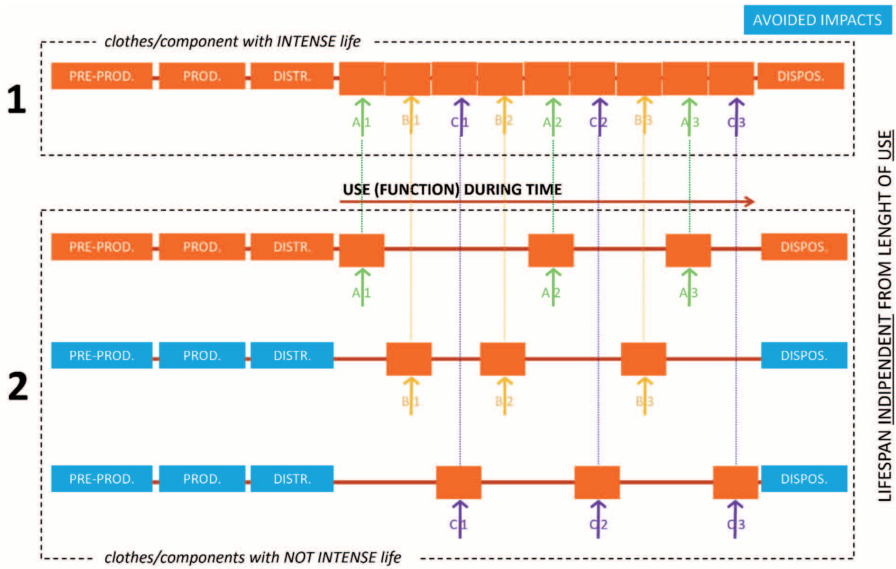

Fig. 5.4 - Comparison between the life cycle avoided environmental impacts of intensely used clothing products as compared low-intensely used one, when the life span is independent form the length of use (re-elaborated by Macrì, L. & Vezzoli, C. from Vezzoli, 2018)

As far as durability is a key strategy, it is useful to recall the main reasons that lead to the disposal of clothes:

- aesthetic or cultural obsolescence;
- performance and structural degradation due to normal usage;
- degradation due to environmental or chemical causes;
- damage caused by accidents or improper usage.

To design for the extension of a product's lifespan, it is important to facilitate its reliability (i.e. assuring a satisfying performance without the need of frequent repair or substitution), maintenance (i.e. precautionary interventions made periodically), upgrade/adaptability (i.e. changing minor parts of clothes to conform them to changing conditions), repair (i.e. fixing clothes malfunctions or damages), re-use (i.e. second use of the clothing product after disposal) and remanufacturing (i.e. bringing used products to as-new conditions through industrial interventions). In chapter 6 it is described how could be important to complement the product offered by the provider with a service to contribute and help with its lifespan extension.

Guidelines to design for extending the lifespan of clothes and their components

- ***Design clothing for reliability.***
- ***Facilitate clothing maintenance*** **(example 1).**
- ***Facilitate clothing upgrading, extension and adaptation*** **(examples 2.1, 2.2 and 2.3).**
- ***Facilitate/enable clothing re-use*** **(example 3).**
- ***Facilitate/enable clothing remanufacturing.***
- ***Intensify clothing use*** **(example 4).**

5.6.1.1. *Design clothing for reliability*

Assuring the design of reliable clothes is particularly important to avoid untimely disposal, which could be caused by the need of frequent repair interventions that lay on user's shoulders. Reliability is usually connected with a low number of components and solid assembly solutions.

Guidelines for Design clothing for reliability

- Reduce the number of clothes parts.
- Simplify the clothes as much as possible.
- Avoid weak connections, such as Velcro for shoes.

5.6.1.2. *Facilitate clothing maintenance*

Designing to facilitate precautionary adjustments through maintenance allows to avoid costs and environmental impacts related to clothing repair or substitution (which cause untimely disposal). Indeed, maintenance operations are often crucial to assure clothes proper durability (e.g. proper protection, cleaning, etc.).

Guidelines to facilitate clothing maintenance

- Facilitate the replacement of easy to wear out parts of clothes, such as shirt collar and cuffs, by easing their disassembly and providing additional parts.
- Facilitate the reparation of single parts of the product, such as using buttons instead of zippers.
- Facilitate the access to parts to simplify cleaning, avoiding slots and narrow holes, e.g. in shoe soles.
- Design for maintenance that can be done by the user at home or at work.

- Provide a website and/or an app with suggestions and tools to enable the user to carry-out maintenance procedures, such as dedicated brushes to clean narrow holes, air-based cleaning tools.
- Design to reduce maintenance operations/procedures, e.g. by using repellent fabrics or applying finishing on fabrics to repel fluids and dirt.

5.6.1.3. *Facilitate clothing upgrading, extension and adaptation*

The easy upgrade or adaptation of clothes is particularly important in terms of environmental sustainability because allows to extend their lifespan even in case of changing conditions (technological, cultural, geographical, etc.). In particular, speaking about eco-efficient upgrade we refer to interventions in which a significant part of clothes stays unaltered. Differently, designing for adaptation is meant as making clothes suitable to be continuously used in relation to environments that are changing.

Guidelines to facilitate clothing upgrading, extension and adaptation
- Design modular and reconfigurable clothes that can adapt to different spaces/climatic conditions, such as multilayer jackets and/or pants that enable the placement of internal layers for colder environments and/or an external waterproof layer for the rainy season.
- Design reconfigurable clothes that can adapt to changes in bodies sizes, such as elastic wrist and ankles adjustments for trousers, adjustable elastic embedded belt, pants extensions, e.g. by using appropriate zippers.
- Design clothes for on-site adaptation, by easing their disassembly and providing additional parts, such as different shirt collar and cuff colours, shoelaces, etc.
- Provide a website and/or an app and tools to enable the user to upgrade/adapt the clothes.

5.6.1.4. *Facilitate/enable clothing re-use*

To design for a clothing re-use means to preserve its conditions and facilitate the transition toward a second end-user, which include all the maintenance and repair operations to assure clothes' integrity.

Guidelines to facilitate/enable clothing re-use
- Facilitate the access to and the removal of clothes parts and components that can be re-used, e.g. by using buttons instead of sewing, preferring removable two-way clips.

- Design clothes that can adapt to different ways of re-use.
- Design modular and interchangeable clothes parts and components, such as shirt collar and cuffs.
- Design/use standard parts and components, such as buttons, zippers, etc.
- Improve the resistance of easy to wear out or easy to damage parts such as shirt collar and cuffs.
- Design packaging that can be re-used, e.g. shoebox that can be used as a storage container.
- Design for "second use", e.g. by facilitating the reparation/replacement of single parts of the product by using buttons instead of zippers, for example.

5.6.1.5. *Facilitate/enable clothing remanufacturing*

Enabling re-manufacturing means to design in order to facilitate the re-collection of used clothes as well as to make them suitable for storage, since they will be reintroduced into a structured industrial process. In this sense, design interventions related to easy disassembly operations would be appropriated.

Guidelines to facilitate/enable clothing remanufacturing
- Facilitate the removal and replacement of easy to wear out parts.
- Design structural parts that can be easily separated from external/visible parts, e.g. removable padding for jackets.
- Facilitate the access to parts to be remanufactured.
- Increase the amount of material used on clothes parts more subject to deterioration.
- Increase the amount of material used on surfaces that tend to rapidly deteriorate, e.g. finishing/coating materials.

5.6.1.6. *Intensify clothing use*

To design for intensifying clothing use entails that clothes are more frequently used, by the same person (e.g with multiple functions clothing that can be used in different situations) or by sharing between different persons, so forth minimising the time of non-usage).

Guidelines to intensify clothing use

Design multifunctional clothes with common components that can be replaced.

The following examples are cases of clothes designed for use extension/intensification that show one or more of the presented guidelines.

Examples

1. Layer

Fig. 5.5 - Layer shoes

The Layer shoe design by Evan Stuart focuses on repairability, personalisation and modularity. No glues are used in bonding major shoe components in place, allowing all parts to be replaced or repaired. If one of the components wears out, users can replace just that part thanks to its lacing system. Users can select different parts in their desired colour and finish to create their own desired look. A single shoe can be assembled or disassembled in under 15 minutes. Shoes are made with natural hemp linen, recycled polystyrene heel counters, recycled polyester fabric uppers, biodegradable bio plastic soles and natural dyed leather heel tab.

2.1. The Shoe That Grows

Fig. 5.6 - Shoe that grows

Kenton Lee created sandals that can accompany the growth of a child's foot. Made with compressed-rubber sole and leather body, sandals are adjustable thanks to side buckles and metal clips which enable them to expand up to 5 sizes, to be modelled on the width of the foot and to have a duration of a few years.

2.2. Petit Pli

Petit Pli designs clothes for babies, from new-born to 12 months, and for toddlers, from 9 months to 4 years. Clothes grow with the child thanks to shells that are pleated in such a way that they can grow bi-directionally to custom fit a range of sizes. They can grow up to 7 sizes and are made from recycled fabrics with a mono-fibre construction to facilitate recycling at the end of their use. Additionally, garments have a rainproof coating that can be re-applied when necessary and a reinforcement grid within the fabric to provide added strength for longer durability.

2.3. OMDANNE collection by Solve Studio

Fig. 5.7 - Omdanne multifunctional clothes

The OMDANNE capsule collection by Solve Studio presents three pieces of clothing (T, R and E) that can each transform into over 10 different styles. With a multifunctional design, one piece can become jumpsuits, dresses, blouses, cape, jacket, trousers or boleros, inviting the user to co-create diverse styles. Each garment is designed with a scenario in mind. The T garment is thought to adapt to the user's daily needs, the R garment is more focused on traveling and the E garment offers several skirt styles, dresses and boleros for different activities, from going out to sports. All three pieces are made of 100% woven lyocell TENCEL® fibres, a material that is 100% biodegradable and compostable.

3. ACBC Zipshoe™

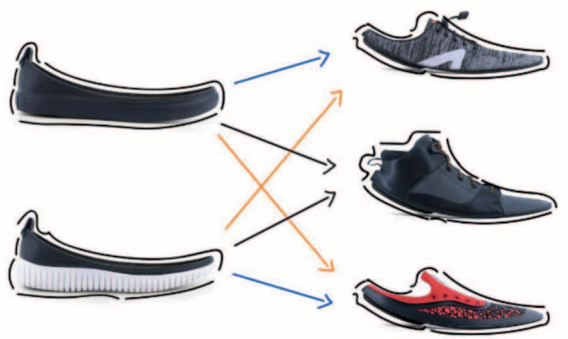

Fig. 5.8 - Zipshoe combinations

ACBC, Anything Can Be Changed, an Italian company designed Zipshoe™, a modular system that allows the creation of different shoes with one sole. Sole and upper are joined by a zipper, a closure system that makes it possible to create different shoes by assembling various “skins” on a single sole. By purchasing a single sole, it is then possible to combine many uppers, creating different combinations.

4. Flavialarocca

Fig. 5.9 - Flavialarocca clothes

Adopting a modular concept approach, the designer Flavialarocca designs pieces that can be zipped into different combinations. Garments are made of interchangeable modules that can be detached and assembled again through hidden zippers. Since pieces are built on a modular concept with zipper connections, modules from different collections can be combined to create new pieces.

5.6.2. *Resource conservation/biocompatibility for clothing systems*

To design for resources conservation and biocompatibility in the clothing system means to design to save resources (material and energy) for the future generations, both in terms of extraction, i.e. choosing renewable or non-exhaustible ones, as well as preferring biocompatible outputs. More precisely, a resource is called renewable if in a specific context, the anthropogenic rate of the resource consumption is lower than the natural rate of regeneration of the resource itself (Vezzoli, 2018). As regards biocompatibility, the term identifies the condition in which outputs emitted in the geosphere are not affecting the equilibrium of ecosystems or damaging the quality of the natural capital (Vezzoli, 2018).

To facilitate the understanding of the different selection steps, the guidelines are divided into two parts one for each resource type:

- select renewable/non-exhaustible and/or biocompatible materials for clothes;
- select renewable/non-exhaustible and/or biocompatible energy resources for clothing systems.

Although the consumption of resources in relation to clothes could be directly associated with just a limited number of examples (e.g. highly technical garments with energy powered light or heating systems), the same cannot be said considering the overall clothing system. Indeed, this includes several life cycle processes that rely on the consumption of resources, from pre-production to disposal, e.g. consumption of raw materials, energy for spinning yarns, water for dyeing, detergent for clothing care etc.

5.6.2.1. *Select renewable/non-exhaustible and biocompatible materials for clothes*

It is important to understand that some natural material resources are more limited than others and that, at the same time, there are some materials that are more renewable than others. In addition, some renewable materials are also biodegradable. This can be a significant benefit when considering the disposal phase thanks to their decomposition process, even though they have to be considered in relation to the functional unit and the whole life cycle, i.e. the biodegradable materials when disposed can be become compost or can be a real environmental benefit, as well

they do not cause a reduction of the clothes lifespan. The main fabrics originated from renewable materials are Tencel (also known as lyocell), hemp, jute, linen, cotton and silk. Also, the acetate, the triacetate and the viscose, which are man-made produced from the tree's cellulose or from other production chain waste. Indeed, all the above-mentioned textiles are also biodegradable, although attention should be paid to treatments (e.g. dyeing) that could compromise such feature. Non-renewable are man-made fibres coming from oil, like polyester, nylon, acrylic (polyamide), polypropylene and spandex (most known with one of its commercial name lycra). Furthermore, these fabrics have also a very low biodegradability rates. Renewability and biocompatibility of materials are not only related with the typology of fibres, but have to be considered in relation to the whole clothing system, e.g the detergent used for washing during clothing care of typology of dyes used in the production of textiles.

Guidelines to select renewable and/or biocompatible materials for clothing systems

- ***Consider the use of rapidly renewable materials, like plant-based fibres or animal-based fibres*** **(example 1).**
- ***Avoid materials from exhaustible sources, such as polyester, nylon and acrylic*** **(made from fossil fuels).**
- ***Use materials derived from other production processes*** **(example 2).**
- ***Use components from disposed products, e.g. hinges, zippers and buttons from disposed accessories (purses, bags, suitcases)*** **(example 3).**
- ***Use recycled materials only or recycled materials combined with new materials*** **(examples 4.1 and 4.2).**
- ***Consider using biodegradable materials*** **(example 5).**

Examples

1. Rothy's

Fig. 5.10 - Rothy's shoes

Rothy's designs and produces shoes and bags using a wide spectrum of renewable and biocompatible materials within different components. For some products, yarns based on hemp blending and other natural fibres are preferred to man-made oil-based ones. In the case of strobel boards and footbeds, an algae-based foam is used, while outsoles are either made through a composite based on 9 to 31% of natural rubber or with a bio-based thermoplastic polyurethane (TPU) derived from corn. Furthermore, as regards yarns, a first option used by Rothy's is a thread made from 100% post-consumer plastic water bottles, which are hot washed, sterilized, then fused into a fibre that is then spinned into yarn. Through a similar process, the company uses a yarn derived from recovered ocean plastic to manufacture bags (indeed, this makes Rothy's a valuable example for other guidelines, i.e. use materials derived from other production processes).

2. Orange Fiber

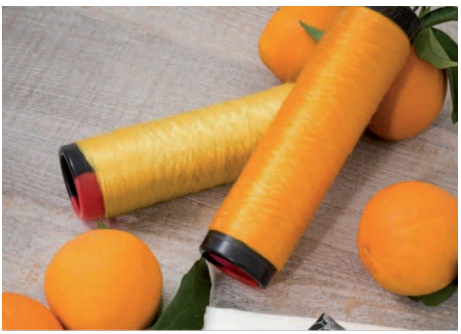

Fig. 5.11 - Orange Fiber yarn

Orange Fiber is an Italian company that produces fabrics made from citrus juice by-product, i.e. waste from industrial squeezing of citrus fruits. The company absorbs a part of the by-product of some companies that deal with the pressing of citrus fruits in Sicily and provides Italian brands and fashion houses with a soft and silky hand-feel, light weight, opaque or shiny fabric. The collected waste (i.e. a renewable material) is transformed into cellulose for textiles.
Thanks to the partnership with other producers, this material takes the shape of the staple – as happens with cotton – or of the yarn and, together with some companies in the Como area, the fabric is created.

3. Freitag bags and accessories

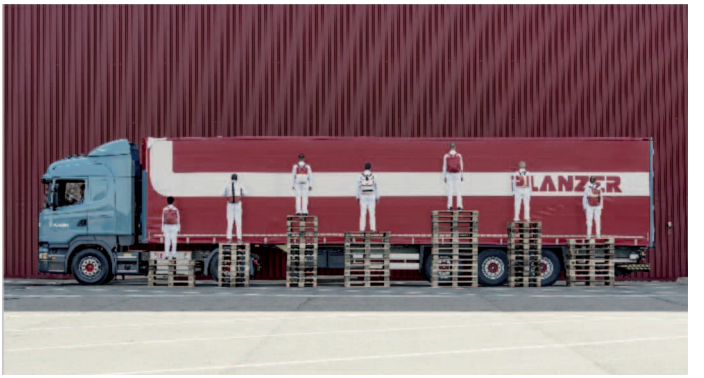

Fig. 5.12 - Freitag bags

Since 1993 Freitag has been producing bags and accessories made from disposed components which can be found, for example, in old vehicles and trucks like: old truck tarps tanned by exhaust fumes, bicycle inner tubes and used car seat belts. Furthermore, the truck tarps are washed using rainwater collected on the roof of the production plant Nœrd F-actory in Zurich. The water is stored in tanks under the building and heated with the energy produced by a waste-recycling plant.

4.1. ECONYL® by Aquafil

Fig. 5.13 - ECONYL® yarn and examples of waste recycled to produce it (fishing nets, industrial plastics and old carpets)

ECONYL® regenerated nylon, created by Italian firm Aquafil, comes from synthetic waste such as industrial plastic, waste fabric, and fishing nets that are recycled into a new nylon yarn, through an innovative purification process that can extract nylon's original raw material. It is declared to have the same quality as virgin standard nylon.
This regeneration system has four main steps. Once the plastic waste is collected through an established worldwide network, it is sent on to be sorted and clean to recover all of the nylon possible. Through a radical regeneration and purification process, the nylon waste is recycled right back to its original purity. ECONYL® regenerated nylon is then processed into yarns for the fashion industries. This process can be repeated infinitely – with no loss of quality in the yarn.

4.2. Ecoalf

Ecoalf is a fashion brand creating clothing and accessories made with a high content of recycled fibres. What makes Ecoalf quite unique is the use of recycled cotton and recycled wool. Indeed, although the mechanical recycling of such natural fibres usually

lowers the textile quality, Ecoalf managed to implement a regeneration process that overcome the obstacle, based on high quality primary materials and finishing. Other particular materials used by Ecoalf are recycled tires to make flip flops and coffee powder made from post-consumer coffee grounds, that gets mixed with recycled PET or nylon to be turned into fabrics.
Furthermore, the company works with recycled polyester made out from recycled plastic water bottles (PET), and from recycled PET collected from the oceans. Thanks to the partnership with Econyl, Ecoalf also uses recycled nylon, which can be recycled again when the garments reach the end of their lifecycle. The recycled nylon yarn is made from discarded fishing nets, scrapped carpeting and pre-consumer nylon waste.

5. Wolford: Aurora Collection

Founded in Austria in 1950, Wolford produces luxury legwear and bodywear for women. Within a high number of available fibres, Wolford uses a biodegradable alternative to elastane (ROICA textile[9]) and a compostable polymeric fibre (Vinatur by Inogema). Furthermore, in general clothes from Aurora collections are designed using recycled or rapidly renewable textiles like Aquafil's Econyl® (made from recycled fishing nets and other nylon waste) and Tencel Modal, a fibre made from responsibly managed forests (FSC Certified[10]). In 2018 they launched Aurora, a Cradle to Cradle Certified™ (a certification mark licensed by the cradle-to-cradle Products Innovation Institute[11]) collection made with yarns that fits the both the regeneration loops of technological and biological cycles. This means that products can be either depolymerized and spun into a new polyamide fibre without reducing the quality of the material or composted to produce biogas that is used to fuel production facilities.

9. Details on ROICA textile available at www.asahi-kasei.co.jp/fibers/en/roica/sustainability/index.html.
10. Details on FSC Certification available at https://fsc.org/en.
11. Details on Cradle-to-Cradle certification: www.c2ccertified.org/.

5.6.2.2. *Select renewable/non-exhaustible and biocompatible energy resources for clothing systems*

As the concern for material resources conservation and biocompatibility, it is inherently important in terms of sustainability to take care of the remaining energy resources for future generations. First of all, it is important to remind the main energy sources considered renewable: solar energy, wind energy, hydroelectric energy, geothermal energy, biomass, wave and tidal energies. Moreover, in terms of energy management, it is recommended to use a *cascade approach* in order to minimise energy losses during its transformation. This strategy implies – for example – that during a transformation from heat to mechanical energy, if the heat is provided with sufficient temperature, the residual heat can be used – under certain conditions – as an energy source for other processes.

As for materials, it is useful to remind the renewability and biocompatibility of energy resources have to be considered in relation to the overall clothing life cycle. So forth, although clothes are very rarely based on resource consumption during their use phase, the selection of renewable/non-exhaustible and biocompatible energy resources becomes important e.g. for clothing care operations like washing, drying, ironing.

All this considered, designing with renewable and biocompatible energy resources means selecting types of energy that are not exhaustible and making natural ecosystems able to use these resources at their maximum, avoiding any type of waste and damage. When possible, it is also important to use energy sources that best fit the local environment conditions, e.g. wind energy in windy places.

Guidelines to select renewable/non-exhaustible and/or biocompatible energy resources for clothing system

- ***Select renewable energy resources for clothing system*.**
- ***Adopt the cascade approach for clothing system*** **(example 1).**

The following examples show cases of clothes designed to select renewable and/or biocompatible energy resources for clothes that contain one or more of the presented guidelines.

Examples

1. Saitex

Saitex is a certified B Corp[12] denim manufacturer deploying an aerial drying system, recapturing heat, using natural lighting, and investing into solar energy as alternative energy resources. The company reduced its energy usage by 13 million kilowatt-hours per year – and reduced CO_2 emissions by nearly 80%. It also uses an ETP (Effluent Treatment Plant) system for cleaning the water that passes through its jeans manufacturing facilities. The system combines reverse osmosis, bacteria nanofiltration and evaporation that cleans water so thoroughly that it can be totally reused in a closed-loop system. Saitex also uses wood pellets made from recycled shipping pallets or pistachio shells, usually waste by the nut industry, to generate power. The company also invested in Atelier & Repairs, a brand focused on upcycling clothing (i.e. collect leftover garments and re-design them into new clothes) to extend the life of any garment that the company produces.

5.6.3. *Minimise resources toxicity and harmfulness of clothing system*

To design for the minimisation of toxicity and harmfulness means to choose clothing fibres, additives, as well as production, distribution, use and disposal processes that allow to avoid or reduce at the minimum the emissions of harmful substances along the whole life cycle and in relation to the functional unit.

In general, as analysed in chapter 4, toxicity or harmfulness during pre-production is caused by the use of chemical fertilizers and pesticides in the cultivation of natural fibres, as well as by wet processing, which involve pre-treatments, bleaching, dyeing and printing. As regards the use phase toxicity or harmfulness is determined by detergents, which fabrication often requires sodium compounds, as well as surfactants, which are potentially harmful for human health, water and terrestrial ecosystems. In terms of design choices, it is important to foresee and avoid the dependency of clothing products from such detergent.

12. The title of B Corporation is a certification provided by B Lab, an independent and international certification body (https://bcorporation.eu/certification).

Considering pre-production, it is useful to know that organic cotton is produced avoiding chemical pesticides and fertilizers and that hemp and flax crops do not need pesticides, since their fibres are not made from the plant flower but from the plant wood.

Said this, in order to properly choose the least toxic or harmful solution in a specific clothing system, it is important to understand that except for clothing toxic materials (like formaldehyde, which should be avoided anyway) the environmental impact depends on both *the material-specific characteristics* and *the product-specific ones*. Let's take a sport garment as an example, focusing on the toxicity impact: even though fibre A would be generating more harmful outputs then fibre B because of the need of chemical pesticides and fertilizers in pre-production, due to the high frequency of washing needed by a sport garment fibre B could be much worse in releasing microplastics. Thus, it would be misleading to propose scaled environmental impact ranking of different materials.

Guidelines to design for minimising resources toxicity and harmfulness of clothing system

- ***Select nontoxic and harmless materials for the clothing system* (example 1).**
- ***Select nontoxic and harmless energy resources for the clothing system.***

5.6.3.1. *Select nontoxic and harmless materials for the clothing system*

The design of clothes with nontoxic and harmless materials has to be considered in relation to all the life cycle processes involved in the clothing system (e.g. including dying substances, non-textile products and materials, microplastics etc.), and can be facilitated by the following guidelines.

Guidelines to design selecting nontoxic and harmless materials for the clothing system

- Avoid the use of toxic and harmful materials for clothes components.
- Avoid dyeing processes, when possible, in particular heavy metals mordants and wetting agents; when necessary, select dyeing processes with the lowest toxicity and harmfulness potential.
- Avoid the use of additives and finishing materials for operations like desizing and scouring, e.g. fixing agents, pH regulators, wetting and

dispersing agents. When necessary, select those without or with the lowest toxicity and harmfulness potential.
- For the finishing of knitwear, replace the exhaust dyeing processes by continuous processes.
- Use a one-step bleaching with high add-on impregnation.
- Design to avoid the dispersion of toxic and harmful residues during use and disposal, e.g. prevent the dispersion of microplastics during washing or avoid clothes that are processed using mercury or chromium.
- Select the least hazardous chemical suitable for use, e.g. replacement of chemicals with enzymes for desizing and scouring of textiles.

5.6.3.2. *Select nontoxic and harmless energy resources for the clothing system*

If simply considered during the wearing phase, clothes are very rarely based on energy consumption. However, the selection of nontoxic and harmless energy resources becomes important considering the overall life cycle, e.g. for running machineries or dyeing processes.

Guidelines to design selecting nontoxic and harmless energy resources for the clothing system
- Select energy resources that minimise toxic/harmful emissions during pre-production and production, such as shifting from fossil fuels to solar energy to run machineries, e.g. sewing machines in textile factories.
- For the finishing of knitwear, replace the exhaust dyeing processes by continuous processes.

The following example represent a case of design intervention based selecting nontoxic and harmless energy resources for the clothing system.

Examples

1. Flavia Aranha

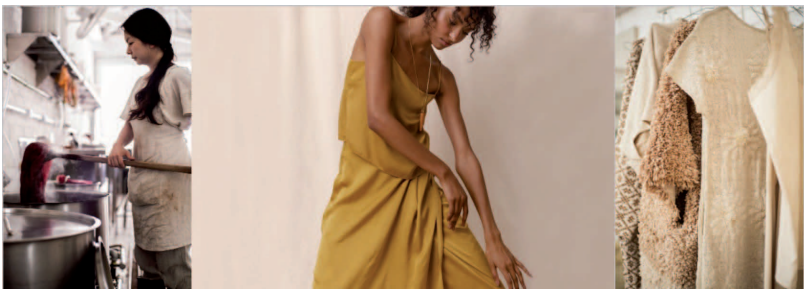

Fig. 5.14 - Dyeing operations by Flavia Aranha

Founded in 2009 in Brazil, Flavia Aranha designs clothes with natural fibres dyed with Brazilian nontoxic colourings resources such as tree bark, fruits, leaves and roots, avoiding any type of heavy metal. Materials that are usually discarded are incorporated in the creation of new products and colours through dyeing techniques. Another example is the use of vegetable latex on fabrics such as linen that results in an impermeable material that can be a substitute for leather and synthetic fabrics.

5.6.4. *Minimise energy consumption in the clothing system*

The guidelines for minimising energy consumption of clothing refer to all the processes that consume energy along the clothes life cycle, e.g. for fibre production in pre-production phase, garments components production, assembly and finishing during the production phase as well as energy consumption during distribution, use (washing, drying, ironing) and disposal. In particular, since clothing design choices could have a direct and strong impact on energy consumption use clothing phase, especially as concern clothing care practices and behaviours. The outlined guidelines focus on this latter most relevant aspect.

5.6.4.1. *Minimise energy consumption during clothes use and care*

Practical decisions to respect the guidelines could be to design with the use of materials that can be washed at low temperatures (wool, cashmere and polyester) or washing with enzymes (at lower temperatures). It could be useful as well to design with new materials, which doesn't have to be washed and/or allow to avoid using the iron. Another idea is to co-design with washing machines companies the washing of clothes at a medium/low temperature, like twenty-five degrees, and place a QR code on the care label, which could be read from the washing machine and automatically select the lowest and most effective temperature for that product. To facilitate the cleaning, it is not only important to write instructions on the care label but also to think of other ways to provide more information, like a little printed manual or a mobile application developed by the brand.

Guidelines to design for minimising energy consumption of clothing use and care

- ***Choose materials that do not need to be washed frequently, e.g. that are fluid-repellent*** **(examples 1 and 2).**
- ***Prefer colours or textures that hide stains or dirt to reduce washing frequency.***
- ***Co-design systems that can benefit from the passive use of energies, e.g. washing/ironing tools based on shower steam or drying tools to maximise the outdoor drying processes.***
- ***Design systems or provides instructions about energy saving for washing to support users to save energy during washing and maintenance more in general, e.g. manual, app, website, label, QR-code.***
- ***Design with materials that can be washed either at low temperatures, with enzymes or using a mechanic system that doesn't need electricity or fuel.***
- ***Design to enable the separate washing of just single easy-to-dirty parts of the clothes.***
- ***Design products with anti-crease fabrics to avoid/minimise ironing.***
- ***Co-design with washing machines companies a QR-code on the care label that enable the selection of most efficient washing method/cycle.***

Examples

1. Filium and Ably

Ably apparel line is made in partnership with Filium technology, that *activates* hydrophobic properties in natural fabrics such as cotton, wool, linen, or silk using a patented process without synthetic or nanotechnology materials. It enables fabrics repel liquid and resist odour, reducing washing and drying cycles, which leads to less energy consumption. Since it repels liquid, the perspiration can evaporate through the breathable fabric leaving clothes smelling fresh even after a hard workout and drying up to 40% faster than regular clothing.

2. Patagonia and HeiQ

Patagonia uses HeiQ® Fresh, a silver-ion-based odour-control additive, on selected styles such as base layers and other next-to-skin applications (e.g. the internal surface of a T-shirt). The anti-odour treatment application is intended to keep garments smelling fresh for longer and to prevent the build-up of persistent odour over time, allowing users to increase the number of wears between washes and to extend the overall lifetime of the garment.

5.6.5. *Minimise material consumption of clothing*

The reduction of material consumption contributes to reduce the environmental impact of all the stages along the clothes life cycle: less resources need to be extracted, fewer processes are used, and less material has to be transported and disposed (Vezzoli, 2018). Materials used in clothing products are often not completely necessary for their function so, when possible, it is important to reduce them. Using fewer materials brings as well economic benefits for the company by saving costs and, at the same time.

This strategy embraces also the practice which aims to create clothing patterns that leave as few scraps of fabric as possible during the cutting process, in order to minimise fabric consumption. Alternatively, the scraps parts can be used as decoration of the garment. Designing to minimise material consumption may also converge with aesthetical choices, for example, when possible preferring solid colour fabrics instead of striped

and checked ones: indeed, solid colour fabrics are easier to work with because they do not need to follow a pattern, helping to optimize/reduce the use of material.

Guidelines to design for minimising material consumption of clothing

- ***Minimise the material content of clothes.***
- ***Minimise scraps and discards* (examples 1 and 2).**
- ***Minimise or avoid clothes packaging.***
- ***Minimise material consumption during clothes use.***

5.6.5.1. *Minimise the material content of clothes*

In coherence with the function that needs to be performed by the clothing product, the minimisation of the material content aims at reducing the overall quantity of material applying alternative solutions regarding for example thicknesses, geometries, overall dimensions but also yarn replacement in favour of weight-optimised ones.

Guidelines to design for minimising the material content of clothes

- Reduce the thicknesses of clothes components where not necessary, e.g. use air to fill shoes' soles or make fabric thickness variable according to heating needs of different parts of the body.
- Use ribbed structures to improve structures stiffness, such as knitwear weaves that reduce the need of elastic polymer or ribbed shoe soles.

5.6.5.2. *Minimise scraps and discards*

Within the overall clothing life cycle, other materials than the one contained in the final product are processed and involved at different levels. Through the guidelines above, design interventions can be facilitated to reduce any waste of materials in this sense.

Guidelines to design for minimising the scraps and discards

- Select processes that reduce scraps and discarded materials during production, such as 3D printing and CNC (Computer Numerical Control) cutting.
- Design cutting paths to minimise scraps and waste during clothes production, e.g. use software that optimise the use of available material.

- Try to incorporate the tiniest pieces of offcut fabrics in the design of the product as a decoration part or use those parts as padding.
- When possible, prefer solid colour instead of patterns, stripes and checks fabrics.

5.6.5.3. *Minimise or avoid clothes packaging*

Since packaging can be considered as a product itself, it can be designed to contribute in the reduction of the overall environmental impact (without compromising the need of keeping clothes untouched in the stages of transportation and storage); here some guidelines proposed accordingly.

Guidelines to design for minimising or avoiding clothes packaging
- Minimise or avoid clothes packaging when possible.
- Design multifunctional packaging, e.g. with handles to avoid single-use bags and/or coupled with information on website/app to avoid additional printed materials.
- Design the packaging as a part (to become a part) of the garment itself, such as reversable pockets.
- Design reusable packaging such as biodegradable bags to be used at home for waste collection.

5.6.5.4. *Minimise material consumption during clothes use*

It has been already clarified that referring to clothes use is not only about the act of wearing, but also about clothing care; in this sense, designing to minimise the material consumption means to deal for example with reduced detergent for washing or to prevent the consumption of unnecessary other materials.

Guidelines to design for minimising the material consumption during clothes use
- Design systems that allow different consumption modes of materials according to different functioning conditions/needs, such as double-face clothing design in order to avoid new fibres consumption for different clothes.

Examples

1. Son of a tailor

Fig. 5.15 - Son of a tailor custom-made pullover

Son of a tailor is a clothing-tech company making custom fitted garments using innovative processes to eliminate waste in clothing production. In 2019, the company launched its first pullover using 3D knitting to make a one whole piece garment with no cut-offs, which reduced production scraps from 20% to less than 1%. All products are made to order, and custom fitted for each customer, eliminating over-production and avoiding unsold items from ending up in landfills.
They also produce custom fitted T-shirts with individual patterns generated automatically and placed like a puzzle in a file optimising the placement of every piece to minimize waste. The patterns are cut with laser for optimal precision.

2. House of Sunny

The UK-based brand House of Sunny decided to not use the usual technique of “print placements”, in which pattern prints are designed to be precisely positioned in a specific garments shape. This usually creates a lot of fabric excess and waste, since each garment cut has to be made in a precise position to make exactly identical clothes. Differently, the brand uses only “repeat prints” that make each piece of clothing unique as the print placement results different each time (the whole textile surface can be used). Furthermore, the company produces two collections a year, contrary to the trend of fast fashion that constantly releases new items.

5.6.6. *Design for clothing materials life span extension*

To design for clothing materials lifespan extension means making them last longer than the clothes they are part of. This can take place through the main following processes: clothes material recycling, composting or as, a secondary possibility, energy recovery trough combustion. Apart from avoiding the environmental impact of more materials disposed in landfills (Fig. 5.16), this strategy helps also to prevent the consumption of resources to produce virgin materials or energy for a new life cycle (Vezzoli, 2018).

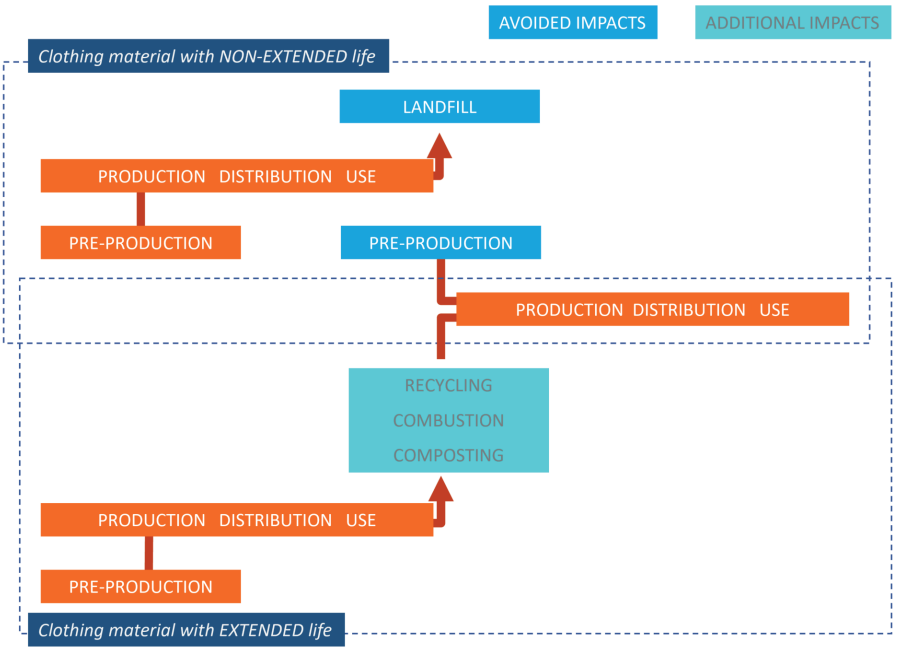

Fig. 5.16 - Environmental advantages of extending the lifespan of clothing materials

Indeed, the clothing materials recycling is a crucial theme for the sector, since the 87% is landfilled, or incinerated and only 1% is recycled into new garments (Ellen Mac Arthur Foundation, 2017), which is indeed most of the times the preferrable option in terms of environmental impact reduction. The remaining 12% is downscaled through a cascade approach, i.e. recycling textiles' components into clothes' components that can be used with progressively lower functional/aesthetic requirements. To foster

the environmental benefits associated with material lifespan extension, it has to be foreseen in advance how materials can be reprocessed as much as possible to obtain new materials through recycling, composting or (low impact) energy recovery. Unfortunately, recycled materials form disposed textile clothes often cannot be used to make new textiles with similar performances/qualities than the materials they come from, since the original quality is difficult to be obtained with mechanical recycling processes. Chemical recycling could be an alternative, but the available technology is still complex to implement and difficult to be scaled up. In most of the cases, the only available strategy is to be farsighted and adopt a cascade approach.

Moreover, another clarification is needed about recyclability, since it depends not only on inherent fibres' characteristics, namely the performances recovery potential and the relative costs, e.g. highly pure fibres have a better recovery than rough ones. Indeed, recyclability depends also on the way clothes' textiles and fibres are made easy to be separated, which is affected by a clothes' assembly. Even though a fibre is capable of an excellent performance recovery, it cannot be considered recyclable if it is hard and inconvenient to be separated from others.

Similarly, recyclability depends on every recycling phase, beginning from collection and transportation: even though a fibre is capable of well recovering its performances and easy to be separated from the others, if it's too much costly to be collected and transported to the recycling sites, it is not considered as a recyclable material.

Guidelines to design for facilitating clothing materials recycling

- ***Adopt the cascade approach for clothing*.**
- ***Select clothing materials with the most efficient recycling technologies* (example 1).**
- ***Facilitate collection and transportation of disposed clothes*.**
- ***Identify clothing materials*.**
- ***Minimise the number of non-compatible clothing materials and/or facilitate their separation* (example 2).**
- ***Facilitate disposed clothes cleaning*.**

5.6.6.1. *Adopt the cascade approach for clothing*

To design adopting a clothing cascade approach means to plan in advance the recycling of clothing materials (both textiles and non-textiles) toward applications with progressively lower functional requirements.

Guidelines to design for a cascade approach for clothing

- Facilitate and foresee the recycling of materials into clothes components with lower aesthetic/formal requirements, such as recycling jacket coating fibres into jacket paddings.
- Facilitate and foresee the recycling of materials into components with lower mechanical requirements, such as recycling external fabric into pockets.
- Facilitate and foresee energy recovery from materials through environmentally safe combustion.

5.6.6.2. *Select clothing materials with the most efficient recycling technologies*

When designing to facilitate clothing recycling, the choice of easy recyclable materials is both related to the highest predisposition to available recycling technologies and their value on the market as recycled materials, as well as the environmental impact of their life cycle.

Guidelines to design for clothing materials with the most efficient recycling technologies

- Select materials that recover more easily their original performance characteristics after recycling.
- Adopt ribbed structures (or similar) to improve the stiffness of polymers instead of using reinforcing fibres.
- Prefer thermoplastic polymers instead of thermosetting.
- Avoid composite materials (if necessary, choose those with the most efficient recycling technologies).
- Avoid the use of fireproof additives by selecting thermoplastics that resist to high temperatures.
- Design clothes considering how materials will be recycled for the production of a new garment.

5.6.6.3. *Facilitate collection and transportation of disposed clothes*

The suitability of clothing materials for recycling is also strictly related to the possibility for them to fit in the recycling system, either if it is already existing or has to be designed on purpose. This means to consider

both the collection system of materials and the successive employment of secondary materials.

Guidelines to design for the collection and transportation of disposed clothes

- Design clothes considering the existing (third parties) recycling systems, e.g. provide instructions about recycling specifications and different fabrics separation.
- Design for easy stocking of disposed clothing products, e.g. using vacuum-sealed packaging for collection.
- Inform users about how to dispose clothes or their parts.

5.6.6.4. *Identify clothing materials*

Clothing materials can be designed to facilitate even the process of classification in relation to a specific recycling route, especially when they are not well-known in relation to current/designed recycling systems.

Guidelines to design for the identification of clothing materials

- Codify materials according to their type.
- Add information on material age, conducted recycling processes and additives used.
- Indicate the presence of toxic residues and contaminant materials.
- Apply identification codes in visible places.
- Use standard identification systems, especially when open loop recycling may occur.

5.6.6.5. *Minimise the number of non-compatible clothing materials and/or facilitate their separation*

It can be environmentally and economically convenient to design clothes that have a low/absent number of non-compatible materials or that ease their separation for recycling purposes; indeed, processes and costs related to disassembly can be avoided.

Guidelines to design for the minimisation of non-compatible clothing materials and/or to facilitate their separation

- Use one single material within a clothing product or part, if possible, i.e. mono-material strategy.

- Use compatible materials that could be recycled together within the garment or a sub-assembly, designing mono-fabric clothes or sub-assemblies made of the same fibres.
- Integrate functions to minimise the quantity of materials and components to be used, e.g. integrate zipper with hood or combine sleeves and coat.
- Use the same material but processed with different technologies in sandwich structures of clothes.
- Facilitate the separation of non-compatible materials for recycling or energy recovery trough combustion, e.g. through reversible sewing junctions or/and pre-determined paths for tearing.

5.6.6.6. *Facilitate disposed clothes cleaning*

One of the necessary processes to enable a proper recycling is cleaning, that allows to remove impurities and contaminations. The operation can be often facilitated by upstream design choices, here listed.

Guidelines to design for facilitating the cleaning of disposed clothes
- Avoid unnecessary surface finishing, such as prints or patches made of different fabrics.
- Avoid the use of contaminant materials.
- Facilitate the removal of contaminant materials.
- Use surface treatments compatible with the (treated) material.
- Avoid adhesives; if needed, prefer those which are compatible with the material to be recycled.
- Prefer internal polymers dying rather than surface painting.
- Use a higher quantity of material in the most overuse-affected parts.

Examples

1. Rapanui

Fig. 5.17 - Rapanui recycled clothes

Rapanui garments are designed to be remade, using a mono-material strategy that facilitate recycling. Products are all made from organic cotton and/or post-consumer remanufactured organic cotton and are designed to be sent back at the end of their lifespan to be recycled and redesigned into new items of clothing. To reduce waste, printed t-shirts are made one at a time only after they are ordered, which means there is no inventory of printed t-shirts to avoid unsold pieces and wastage. It manages this on-demand production through a platform called Teemill, where customers can upload their own designs to print on the T-shirt.

2. Wear2go: Wear2™ Thread (sewing thread)

Fig. 5.18 - Wear2go disassembly concept

Wear2go offers a seam separation solution thanks to the microwave technology *Wear2 Ecostitching Technology* in combination with a specially developed sewing thread called *Wear2™ Thread.*

The use of *Wear2 Ecostitching Technology* at the manufacturing stage enables all kinds of mixed textile materials, such as zippers, buttons, fastenings and linings, to be easily removed prior to garment recycling, allowing the recovery of pure fibre from disassembled garments. The *Wear2 Thread*, made from recycled polyester with a core composition partly consisting of Copper Sulfide, breaks down when exposed to a microwave radiation allowing an easy disassembly of all components of the microwaved garment. Buttons, metal zippers and other solid trims are resistant to the transmitted energy. The Wear2 Ecostitching Technology allows the de- or rebrand of new unsold clothing items or old stocks, which is a way to avoid the shredder, landfill or incinerator and for the implementation of new business models.

5.6.7. *Design for clothes Disassembly*

The design of easy to disassemble clothes (Design For Disassembly, DFD) is useful to make the separation of either parts or materials easier and more convenient. The facilitation of parts separation makes clothes maintenance, repair, updating and remanufacturing easier. On the other side, the facilitation of materials separation is positive both for recycling (in case of assemblies made of incompatible materials) and for special treatment (in case of assemblies that include toxic or harmful materials). Therefore, what is shown in this section can be useful also for both clothes and components life span extension and clothes material life span extension.

In the recycling process, it can happen that the system becomes economically not profitable if runtime and expenses of separation of incompatible materials are too high. In other words, the disassembly of incompatible materials (along with disposed clothing product collection and recover) has to be facilitated; otherwise, there is the risk of not balancing the recovery expenses with the value of secondary material. The same can be said for the recovery of parts for maintenance, reparation, updating and remanufacturing. Usually technologies/features for destructive disassembly are useful if there is no design intervention on the component that compromises the capacity and performance of the part. Separation after shattering can be done by dedicated companies/institutions. In such case, it is useful to know which technologies are used and to design accordingly.

Guidelines to design for clothes disassembly

- ***Reduce and facilitate operations of clothing disassembly and separation*** **(examples 1 and 2).**
- ***Design and/or co-designing special technologies and features for of clothing crushing separation.***

5.6.7.1. *Reduce and facilitate operations of clothing disassembly and separation*

In coherence with specific requirements of clothing products, designing to simplify disassembly operations means to work on their overall architecture and connections with the aim of minimising the number and the complexity of processes. Concepts like modularity, minimisation/reversibility of joints (sews) as well as linearity of procedures are key approaches and are considered by the following guidelines.

Guidelines to design for reducing and facilitating operations of clothing disassembly and separation

- Prioritize the disassembly of components or materials with higher economic value, such as decorations made with precious fabrics or metals.
- Prioritize the disassembly of more easily damageable or consumable components and materials, such as jackets covering, shoes soles or movable mechanisms like buttons and zippers.
- Prefer modular structures, such as skirts or trousers with zipped extension.
- Construct the product into easily separable and manipulatable subassemblies, such as jackets with waterproof cover connected to the internal warm layer by buttons or zippers.
- Facilitate the removal of other components like zippers and buttons.
- Minimise the overall dimensions of clothing item.
- Minimise the quantity of different fabrics.
- Minimise hierarchically dependent connections among components, such as different layers in shoe soles or jacket.

5.6.7.2. *Design and/or co-designing special technologies and features for clothing crushing separation*

Although crushing is not properly functional for disassembly aimed at clothing lifespan extension, specific technologies can be rather designed to separate components toward different recycling routes. However, such

technologies should not affect clothes durability and performance during the use phase.

Guidelines to design for clothing crushing separation

- Co-design cutting or breaking paths with appropriate separation technologies for separating incompatible materials.
- Suggest to the users how and with what device they could separate incompatible materials.
- Provide information to the user together with the clothes about the characteristics of crushing separation, such as providing video resources online (website, app).
- Use materials that are easily separable after being crushed, such as fibres with different density, e.g. cotton and polyester or EVA and PU for shoe soles.
- Use additional parts that are easily separable after crushing of materials.

Examples

1. Voronoi Runners

Fig. 5.19 - Voronoi shoes and soles

Designer Rik Olthuis from the Massey University of New Zealand created the Voronoi Runners, shoes made from 100-percent biodegradable materials, each of which can be separated at end of life to be composted. To avoid adhesives, the upper (based on a blending of Merino wool and Nylon knitted fabric) is stitched, and tied using organic cotton thread onto a strong, flexible, 3D-printed structured sole into which the foam (gelatine and glycerine-based recipe) is poured to shape the midsole. 3D printing of the sole and midsole

allows to adapt each shoe to the individual wearer. The toe and heel caps are 3D printed from plant fibres and the upper made from Merino wool fabric with 3D printed details. The heel and toe caps are inserted with a plant fibre reinforcement and sewn shut before stitching onto the edge of the sole.

2. Patagonia Sugar & Spice

Patagonia designs their products to ensure they will last as long as possible, also offering product care guidelines to shoppers. Sugar & Spice modular shoes were designed for disassembly and are completely seamless. The leather upper can be separated from the durable TPU foot frame and the shoes can be worn as ballerina shoes. The shoe construction does not require any glue in principle, facilitating disassembly. Although the model is now out of production, it represents a great example of shoes designed to ease the separation of components.

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6. Sustainable Clothing Product-Service System Design

6.1. Sustainable Clothing Product-Service Systems: introduction

As introduced by chapter one, given the dimension and the nature of the change required to achieve sustainability, the transition should embrace a wide-reaching social learning process in which a system discontinuity is needed. Therefore, other than a clothing Life Cycle Design approach (described in the previous chapter), a system approach is important in order to seriously tackle the transition towards sustainability, i.e. a so-called system innovations should take place.

Furthermore, a first key contemporary query is the following: are clothing system manufacturers or providers economically incentivized in designing, producing, selling low environmental impact clothes and clothing care products increasing accessibility to all, even to low and middle-income people? Actually, clothes and clothing care products manufacturers might not always be economically incentivised in adopting strategies to reduce their products environmental impact, i.e. adopting product Life Cycle Design approach. Indeed, they are sometimes interested in accelerating replacement, to sell more clothes and/or clothing care products to increase the profits, thought increasing the environmental impact.

Consequently, a second query emerges: within the environmental and economic crisis, which are the opportunities for the clothing system? Do we know any system offer/business models capable of creating (new) value decoupling it from the materials and energy consumption and environmental impact increase, while enhancing even social equity and cohesion by extending the access to goods and services to low and middle-income contexts? Within the wide debate just introduced (design) researchers have

more and more converged towards a model usually referred as Sustainable Product-Service System. More recently, S.PSS has been demonstrated to be a clearly promising offer model to extend the access to good and services even to low- and middle-income contexts, thus enhancing social equity and cohesion as well. Among the several converging definitions, one of the most updated and agreed by a wide international community of researchers – belonging to the LeNS network – (Vezzoli *et al.*, 2021) has been adapted to the clothing sector and runs as follow:

An offer model providing a system of clothes and/or clothing care products and services that are together able to deliver a "unit of satisfaction" (wear clean clothes for a given period of time), based on innovative interactions between the stakeholders of the clothes and clothing care value production&satisfaction system, where the ownership of the clothes and/or clothing care product/s and/or the life cycle services costs/responsibilities remain by the provider/s, so that the economic interest of the provider/s continuously seeks environmentally (and socio-ethically) beneficial new solutions.

Sustainable Clothing Product-Service System (S.PSS) are value propositions introducing relevant innovation on different levels (see Fig 6.1):

- they shift the business focus from selling (only) clothes, clothing care and fashion products to offering so-called "unit of satisfaction", i.e. a combination of clothing wear and care products and services jointly capable of achieving a final user satisfaction;
- they shift the primary innovation from a technological one to an innovation on a stakeholder interaction level, i.e. they are based on three main types of innovative stakeholder configurations: clothes or clothing care offer combined with product life cycle services to customer; offer as enabling clothing care platform for customers; clothing wear & care full service offer to customers;
- they shift the value perceived by the customer from individual ownership to access to goods and services.

Fig. 6.1 - Clothing S.PSS: a paradigm shift from traditional product offer

Finally, clothing S.PSSs are offer models with a win-win sustainability potential, i.e. they are offer/business models capable of creating (new) value decoupling it from resources consumption and environmental impact increase, while extending access to good and services to low and middle-income people enhancing social equity and cohesion. This is described in the following chapters.

6.1.1. *Sustainable Clothing Product-Service System Types*

It is possible to identify three main **types** of Sustainable clothing Product-Service Systems (S.PSS):

- ***Clothing product-oriented S.PSS***: S.PSS providing added value to clothes and/or clothing care products life cycle;
- ***Clothing care-oriented S.PSS***: S.PSS enabling clothing care platforms for customers;
- ***Clothing result-oriented S.PSS***: services providing clothing wear and care full services to customers.

6.1.1.1. *Clothing product-oriented S.PSS*

A **Clothing product-oriented S.PSS innovation** adding value to the product life cycle is defined as:

A company/organisation (alliance of companies/organisations) provides all-inclusive additional services – maintenance, repair, upgrading, substitution, take back of clothes and/or clothing care products – to guarantee life cycle performance of the clothes and/or clothing care, which is sold to the customer.

The customer owns the clothes and/or clothing care products and her/his responsibility is reduced in the use. She/he pays all-inclusive the clothes and/or clothing care products with (some of) its life cycle services. The innovative interaction between the company and the customer drives the company's economic interest in continuously seeking environmentally beneficial new solutions, i.e. the economic interest becomes something other than only selling a larger amount of clothes or clothing-care products.

Example

Nudie Jeans

Fig. 6.2 - Nudie Jeans

Nudie jeans offers a guarantee of free repairs forever, no matter when or where the customer purchased them. Although their jeans are meant to be worn a lot, they are made using only high-quality fabrics and with reinforced sewing to be long-lasting. The company, also take care of jeans through the Nudie Jeans Repair Shops, where they repair any damage to the jeans restoring them to their original condition. If the customer does not have a repair shop nearby, they can order a repair kit free of charge. Indeed, Nudie offers to customers a Product-Oriented Clothing S.PSS since their repair services are included in the product warranty.
In 2019 they repaired 63,281 pairs of jeans, which means they prolonged the life of 50.000 kg of clothing, an increase of 15% up on 2018. They estimate that if each person who repaired their jeans with them had decided to buy a new pair, the production of these jeans would demand 443.000 tons of water, an amount that would fill 177 Olympic swimming pools.

6.1.1.2. *Clothing care-oriented S.PSS*

A **Clothing care-oriented S.PSS innovation** offering an enabling platform to customers is defined as:

a company/organisation (alliance of companies/organisations) provides access to clothes and/or clothing care products, enabling customer to clothing ware and care, e.g. customer are enabled to care for maintenance, repair, up-grading, etc.

The customer does not own the clothes and/or clothing care product but operates on them to obtain a specific clothing wear and care "satisfaction". She/he pays only per use of the clothes and/or clothing care product.

Depending on the contract agreement, the user could have the right to hold the clothes or clothing care products for a given period of time (several continuous uses) or per number of uses. Commercial structures for providing such services include rental, leasing, pooling or sharing of certain goods for a specific use.

Again, in this case the innovative interaction between the company and the client drives the company's economic and competitive interest to continuously seek environmentally beneficial new solutions, e.g. to design highly efficient, long-lasting, re-usable and recyclable clothes or clothing care products.

Pay x wash by Bundles

Bundles is a Dutch company that offer a bunch of products in the form of services, keeping their ownership and getting paid on a monthly basis with a Pay x Use mode. Among the others, Bundles offers washing machines and tumble dryers for clothes. Customers can subscribe on the website to different packages based on different washing and drying functions, paying a fixed amount per month and an additional price per wash cycle. Moreover, customers have always included the maintenance and repair services, as well as the delivery and the take back of old appliances. Being the ownership retained by Bundles, the company is interested in providing long-lasting and reliable washing machines and dryers, which are provided by a selected manufacturing partner (Miele). In this way, the client demand of having clean clothes is satisfied, and the provider is economically motivated to design long-lasting clothing care products (i.e. beneficial in terms of environmental sustainability).

6.1.1.3. *Clothing result-oriented S.PSS*

A **Clothing result-oriented S.PSS innovation** offering final results to customers can be defined as:

a company/organisation (alliance of companies/organisations) provides access to clothes, with all-inclusive life cycle services, e.g. maintenance, repair, up-grading, substitution. take back of clothes.

The customer does not own the clothes and/or clothing care products, and the provider carries out life cycle services, being paid per wear of the clothes, i.e. the client pays the company to provide the agreed wearing results. The customer benefits by being freed from the problems and costs involved in the acquisition, use, and maintenance of clothes and/or clothing care products. The innovative interaction between the company and the client drives the company's economic and competitive interest to continuously seek environmentally beneficial new solutions, e.g. long-lasting, re-usable and recyclable clothes (and clothing care products).

Moreover, if properly conceived, such a clothing S.PSS can offer to low and middle-income (all) people the possibility to have access to services that traditional clothes or clothing care product sales models would not allow. In fact, it has been argued that in low and middle-income contexts a clothing "S.PSS innovation may act as a business opportunity to facilitate the process of a socio-economic development by jumping over the stage characterised by individual consumption/ownership of mass-produced goods towards a 'satisfaction-based' and 'low resource-intensity' advanced service-economy" (UNEP, 2002).

7 Abiti per 7 Giorni (7 outfits for 7 days), e.G.o[1]

Fig. 6.3 - e.G.o main system value proposition and offer

e.G.o is a brand based on the shared wardrobe principle, providing a result-oriented fashion S.PSS. Each year, it presents two exclusive collections, one spring-summer collection and one fall-winter collection. Each of them includes 120 models and it is divided into eight styles (classic, casual, folk, romantic, dandy, glam, future and sport). Available models include skirts, trousers, blouses, and dresses.
Customers can become e.G.o members by purchasing a yearly fidelity card and paying a monthly fee. After they became members, they go to the e.G.o atelier once a week and choose seven outfits, one for each day of the following week. In this occasion, they also return the seven outfits of the previous week in a dedicated envelope. E.G.o takes care of washing and ironing them.
Bags and shoes are not available in the 7 outfits for 7 days formula since they cannot be properly sanitized.
The outfits ownership remains to the atelier, which provides both the outfits and the washing and ironing service, as well as style consultation service. Thanks to these services, customers obtain their final satisfaction without operating on the rented fashion products.

1. Rota (2012).

6.2. Sustainable Clothing Product-Service: win-win benefits

When is a clothing S.PSS eco-efficient? Better still, when is an S.PSS decoupling the economic interests from both an increase in resource consumption and a decrease of damaging environmental impacts? In other words, why and when is a clothing S.PSS producer/provider is economically interested in designing clothes and/or clothing care products for environmental sustainability? The following S.PSS environmental and economic win-win benefits could be highlighted (adapted from Vezzoli *et al.*, 2021):

a) *Clothing and/or clothing product lifetime extension*: as far as the S.PSS provider is offering clothes and/or clothing care products retaining the ownership and being paid per unit of satisfaction, or offering them all-inclusive with its maintenance, repair, upgrade and substitution, the longer the clothes/clothing care product and its components last (environmental benefits), and the more the producer/provider avoids or postpones the disposal costs plus the costs of pre-production, production and distribution of a new product substituting the one disposed off (economic benefits). Hence the producer/providers are driven by economic interests to design (offer) for lifespan extension of clothes and/or clothing care products (with eco-efficient product Life Cycle Design – LCD implications) – see an example in Fig. 6.4.

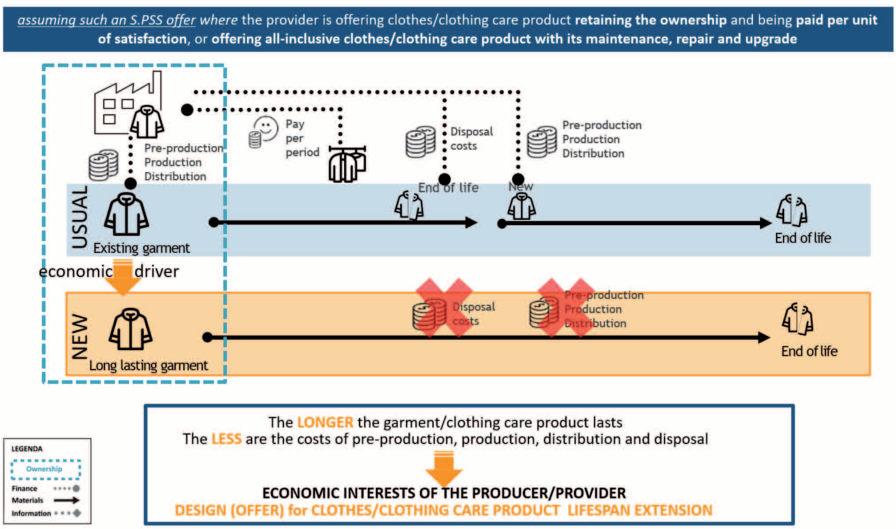

Fig. 6.4 - S.PSS model fostering the design (offer) for clothes and/or clothing care product lifespan extension, adapted from Vezzoli et al. (2021)

b) *Intensive use of clothes and/or clothing care products:* as far as the S.PSS provider is selling a shared use of clothes and/or clothing care products (or their components) to various users, the more intensively the clothes and/or clothing care products (or some components) are used, i.e. the more time (environmental benefits), the higher the profit; proportionally to the overall use time (economic benefits). Hence, the producer/providers are driven by economic interests to design for intensive use of clothes and/or clothing care products (eco-efficient product LCD implications) – see an example in Fig. 6.5.

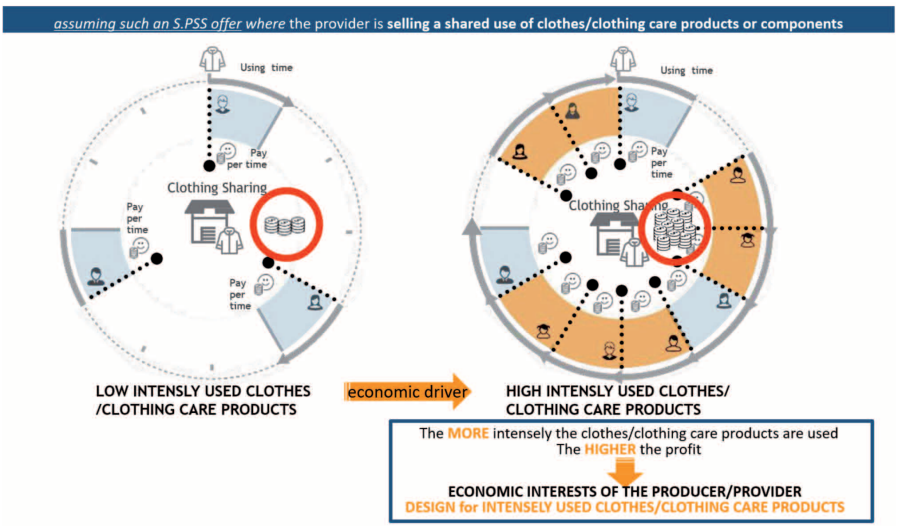

Fig. 6.5 - S.PSS model fostering the design (offer) for intensely used clothes/ clothing care products, adapted from Vezzoli et al. (2021)

c) *Minimisation of the resource consumption of clothes/clothing care products in the use phase*: as far as the S.PSS provider is selling all-inclusive the access to clothes and/or clothing care products and the resources they consume in use, with payment based on unit of satisfaction (the ownership of clothes and/or clothing care products remains by the producer/provider), the higher the clothes and/or clothing care products' resource efficiency in use is (environmental benefits), and the higher the profit, i.e. the payment minus (among others) the costs of resources in use (economic benefits). Hence, the producer/provider is driven by economic interests to design/offer clothes and/or clothing

care products minimizing resource consumption[2] in use (eco-efficient product LCD implications) – see an example in Fig. 6.6.

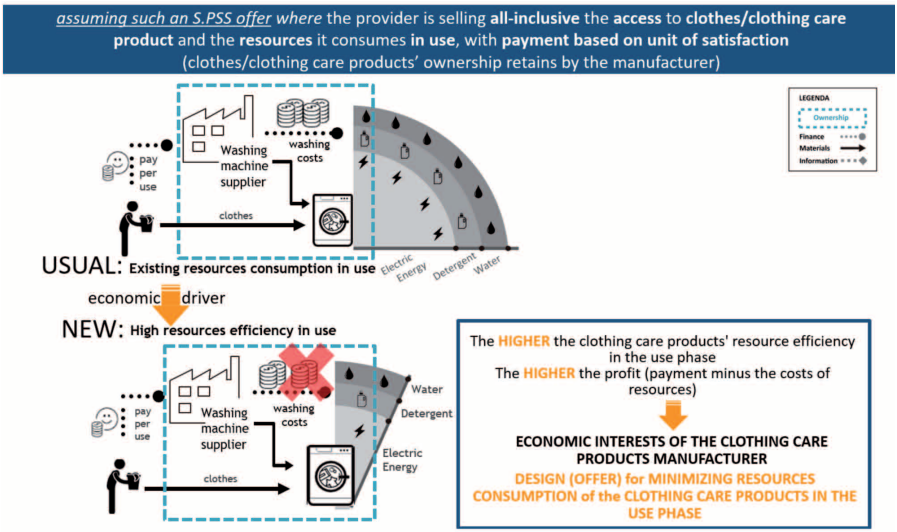

Fig. 6.6 - S.PSS model fostering the design (offer) for minimizing resources consumption of clothing care products in the use phase, adapted from Vezzoli et al. (2021)

d) *Resources' renewability for clothes/clothing care products*: when the S.PSS provider has an all-inclusive offer of a clothing care product, with pay per period/time/satisfaction, the higher the proportion of passive/renewable sources is in relation to non-passive/non-renewable (environmental benefits), and the higher the profit, i.e. the payment minus (among others) the costs of non-passive/non-renewable sources (economic benefits). Hence, the producer/provider is driven by economic interests to design (offer) for passive/renewable resource optimization (eco-efficient product LCD implications) – see an example in Fig. 6.7.

2. When referring to "resource consumption in use" for clothes, it is important to recall that the use of a garment is not limited to wearing, but includes care operations (wash, dry, iron, etc.). In this sense, the win-win benefits include the interest of the provider to design clothes themselves with the aim of saving resources, e.g. using fibres with lower washing-frequency requirements.

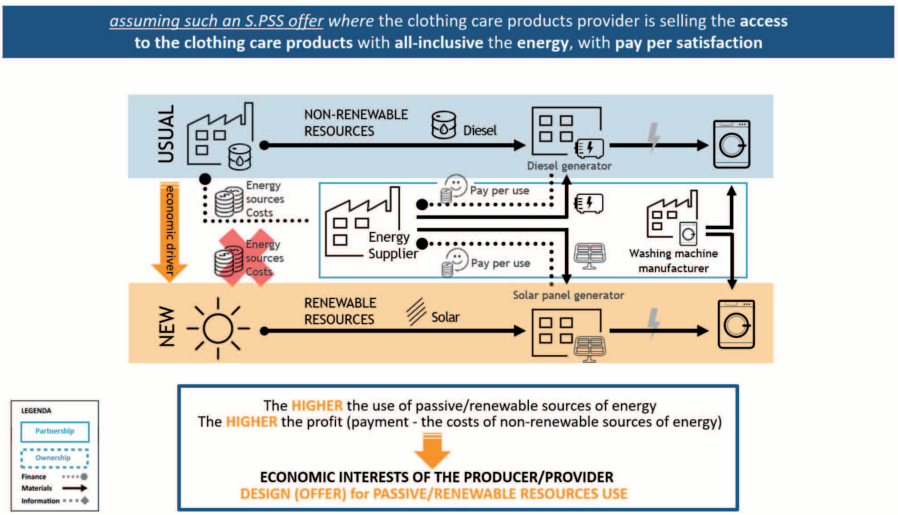

Fig. 6.7 - S.PSS model fostering the design (offer) for passive/renewable resource optimization of clothing care products, adapted from Vezzoli et al. (2021)

e) *Clothing material life extension:* as far as the S.PSS provider is selling clothes and/or clothing care products with all-inclusive end-of-life treatment/s, the more the materials are either recycled, incinerated with energy recovery or composted (environmental benefits), the more costs are avoided of both landfilling and either the purchase of new primary material, energy or compost (economic benefits). Hence, the producer/provider is driven by economic interests to design for material life extension, i.e. recycling, energy recovery or composting (eco-efficient product LCD implications) – see an example in Fig. 6.8.

f) *Minimization of toxicity and harmfulness of fibres production equipment or clothing care products*[3]*:* as far as the S.PSS provider is offering *fibres production equipment* or clothing care products that are potentially toxic/harmful (e.g. traditional dying equipment or washing machine using traditional detergent) with all-inclusive the use and/or end-of-life toxicity/harm management services, the lower the potential toxic or harmful emissions are in use and/or at the end-of-life (environmental benefits), the more costs are avoided of both toxic/harmful treatments in use and/or at the end-of-life. Hence, the producer/provider is driven by

3. Indeed, more than an offer for final users, this could be appropriate for Business-to-Business situations, e.g. washing machines manufacturers and laundry service providers.

economic interests to design (offer) for toxicity/harm minimization (eco-efficient product LCD implications) – see an example in Fig. 6.9.

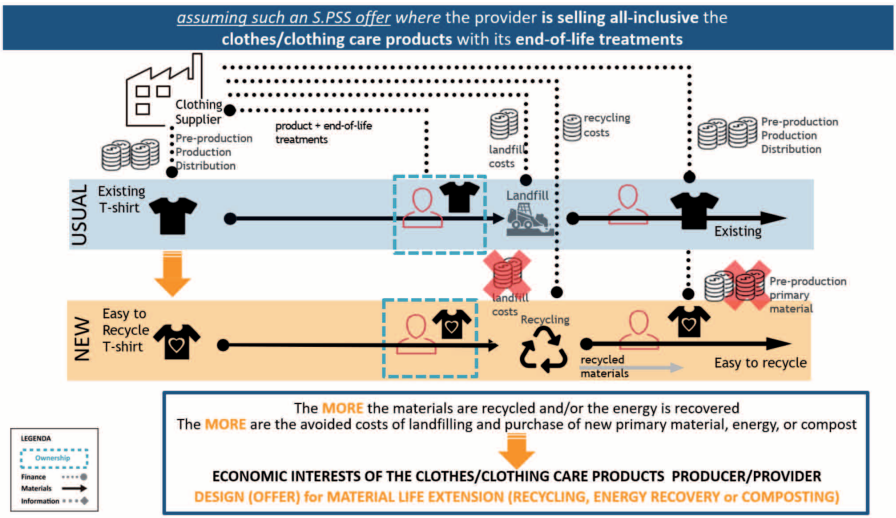

Fig. 6.8 - S.PSS model fostering the design (offer) for material life extension (recycling, energy recovery or composting), adapted from Vezzoli et al. (2021)

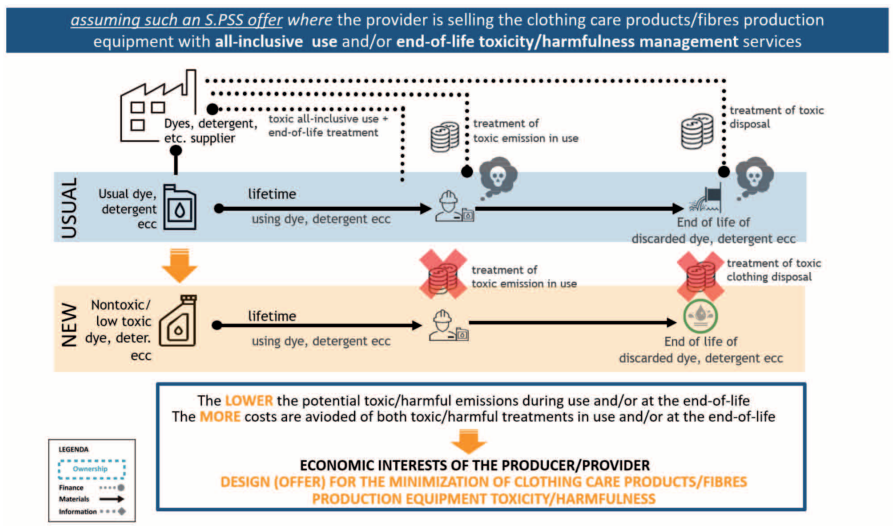

Fig. 6.9 - S.PSS model fostering the design (offer) for toxicity/harm minimization of clothes/fibres production equipment and/or clothing care products, adapted from Vezzoli et al. (2021)

To conclude, when is an S.PSS eco-efficient, i.e. environmentally promising because of economic interest of the producer/provider? When the product ownership and/or the economic responsibility for its life cycle performance remains with the producers/providers who are selling a unit of satisfaction rather than (only) the product. And why does this happen? Because in this way, we shift or allocate the direct economic and competitive interest to reduce the products' and/or the services' environmental impacts, onto the stakeholder responsible for their design and development. Consequently, within an S.PSS model, a product LCD/ eco-design is eco-efficient.

In other words, an S.PSS producer/provider is economically incentivized in design for:

- clothing system life optimisation;
- reduce transportation/distribution in the clothing system;
- minimise resources consumption in the clothing system;
- minimisation or valorisation of waste from the clothing system;
- resources conservation/biocompatibility in the clothing system;
- reduce the toxicity in the clothing system.

Fig. 6.10 - The shift from traditional sale of products to an S.PSS offer model and its implication in product Life Cycle Design, adapted from Vezzoli et al. (2021)

6.3. A scenario for Sustainable clothing Product-Service System

Sustainable clothing Product-Service Systems can vary according to the kind of service offered, more specifically, whether it is a Clothing care-oriented S.PSS (i.e. a **do-it-yourself** kind of service) or a Clothing result-oriented S.PSS (i.e. a **full-service** model). Furthermore, Sustainable clothing Product-Service Systems vary also according to their sharing level, which means, if the system has an **individual** or **collective** dimension.

In relation to these two polarities and their possible sustainable combinations, a Sustainable Design Orienting Scenario (SDOS)[4] for clothing S.PSS has been designed to show a new picture of sustainable clothes and clothing care products' production and consumption systems.

More precisely, the scenario is composed by a polarity diagram with four visions, for each of the four quadrants drawn by the same diagram. Each vision represents a Sustainable clothing Product-Service win-win configuration, combining cultural, organization and technological factors, fostering solutions with a low environmental impact as well as economic benefits.

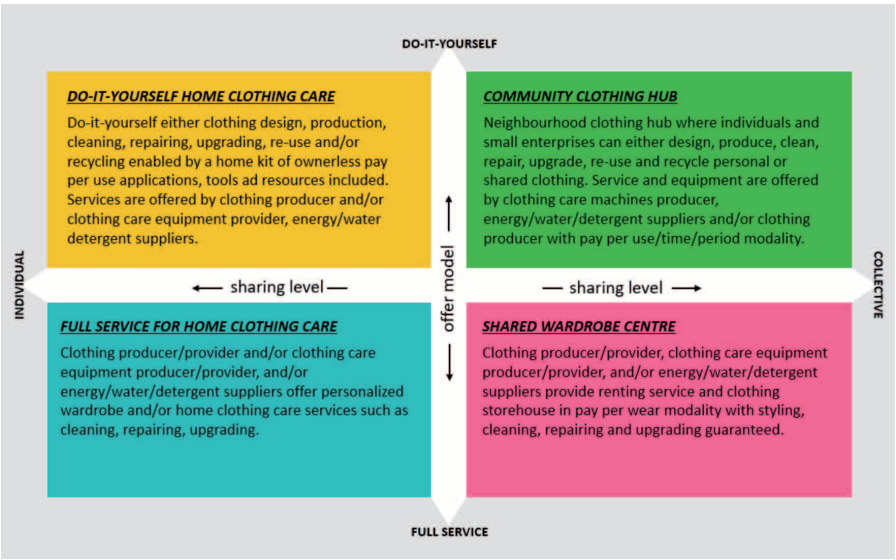

Fig. 6.11 - Clothing S.PSS SDOScenario diagram: visions and polarities

4. The SDOScenario x Clothing S.PSS is described in detail within Chapter 7.

The scenario is polarised on the vertical axis by the service model – do-it-yourself or full service – and on the horizontal axis on the sharing level – individual or collective.

The crossing of these two polarities produced the following four visions (see Fig. 6.11), relative to the four quadrants:

- do-it-yourself home clothing care;
- full service for home clothing care;
- shared wardrobe centre;
- community clothing hub.

The four generated visions are explained in detail in the following paragraphs.

6.3.1. *Do-it-yourself home clothing care*

The first promising vision can be defined as "do-it-yourself home clothing care" and it is based on an individual sharing level and on the do-it-yourself service model. Customers can exploit the do-it-yourself principle for clothing design, repairing, upgrading, re-use and/or recycling, enabled by a home kit. This home kit is paid per use and may include applications, tools and resources. Customers do not purchase the home kit and therefore do not own it. This kind of services may be offered by clothing producer, clothing care equipment providers eventually in partnership with energy, water and detergent suppliers. Examples of this vision are the pay per use services for washing machines and energy and the sewing machines rentals.

Example of do-it-yourself home clothing care vision

Ravelli Service

Ravelli Service is an Italian company which sells machines and semi-finished products for the textile and clothing industry. Their catalogue includes sewing machines, iron and laser cutting machines, both new and second-hand, as well as string reels.
One of their services is sewing machines renting, especially thought for privates or companies who need a specific kind of sewing machine for a limited period of time. This service is an example of "do-it-yourself home clothing care", since customers can exploit a home kit – the sewing machine –, which is paid per use, without purchasing and owning it, in order to obtain the satisfaction of one or more need/s.

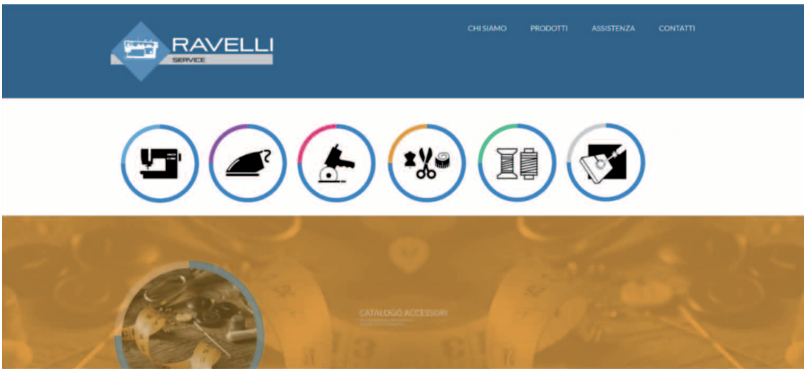

Fig. 6.12 - Ravelli service rental offer: sewing machines, irons, cutting equipment and other accessories

6.3.2. *Full service for home clothing care*

The second promising vision can be defined as "full service for home clothing care", which is also based on the individual sharing level with a full-service model. In this case, clothing producers or providers, clothing care equipment producers or providers, energy suppliers, water suppliers or detergent suppliers offer personalized wardrobe and/or home clothing care services as cleaning, repairing and upgrading.

Example of full service for home clothing care vision

Mama Clean

Mama Clean provides a delivery laundry service in Milan and other 30 municipalities in the north of Italy. Customers can request the service on the app or on the website, by choosing the date and place of collection and the needed services. There is a list of garments and clothes, so that customers simply need to select what they would like to give. Mama Clean offers different kinds of services, which can include only washing, washing and folding, washing and ironing or all the three of them. Moreover, customers can choose between rush or flexi service. Rush service ensures the one-day delivery and is more expensive, while flexi service ensures the delivery in two days. Garments are collected at home, 7 days per week, from 7 a.m. to 11 p.m. by Mama Clean and delivered,

cleaned and ironed, after one or two days in the same location of the collection or in a second one – as home and office.
The fashion S.PSS offered by Mama Clean is an example of "full service for home clothing care" since it provides clothing care services for garments owned by customers.

Fig. 6.13 - Mama Clean service overview

6.3.3. *Shared wardrobe centre*

The third promising vision can be defined as "shared wardrobe centre" and it is based on a full-service model and on a collective sharing level. In this case, clothing producers or providers, clothing care equipment producers or providers, energy suppliers, water suppliers or detergent suppliers provide renting services and clothing storehouses in pay per wear modality. These services guarantee styling, cleaning, repairing and upgrading services.

Example of shared wardrobe centre vision

Dress You Can

Dress You Can offers an online service for clothing rental. It is an example of use-oriented clothing S.PSS and of the "shared wardrobe centre" vision. Dress You Can provides access to their online platform, where customers can choose clothes and fashion accessories from an online catalogue. Customers can rent maximum three items per order, whose ownership remains to Dress You Can.

Fig. 6.14 - Dress You Can clothing rental

In this way, customers do not need to purchase clothes and Dress You Can takes care of clothes cleaning and repairing. This S.PSS is particularly convenient for customers, since the available clothes and accessories also include high fashion products, whose purchasing costs would be high, especially if customers need them just for one special occasion.
The available items are divided into four categories: clothes, shoes, accessories and wedding dresses. Customers pay per wear and if they order but not use a garment, they receive a refund.
Clothes are delivered inside dedicated envelopes, which are then used by customers to send back the rented products after four days.

6.3.4. *Community clothing hub*

The fourth promising vision can be defined as "community clothing hub" and it is based on a do-it-yourself service model and on a collective sharing level. These services provide neighbourhood clothing hubs where individuals and small enterprises can design, produce, clean, repair, upgrade, re-use and recycle personal or shared clothing. Service and equip-

ment are offered by producers of clothing care products, by suppliers of energy, water or detergent or by clothing manufacturers. The pay modality can be either pay per time, pay per use or pay per period.

Example of community clothing hub vision

Neighbourhood Laundromat Café

Neighbourhood Laundromat Café is an example of cafés with additional laundry services, located in London (Canada). It is an example of use-oriented fashion S.PSS where customers can spend time relaxing and having a coffee or snack while waiting for the washing machine to finish its cycle. The café provides machines maintenance, store cleanliness and manages a courteous staff in order to both provide a clothing care service and build a community among customers. This fashion S.PSS can be therefore considered an example of "community clothing hub", since it is based on a do-it-yourself model – customers use the washing machines by themselves – with a collective sharing level.

6.4. Sustainable Clothing Product-Service Systems: limits and barriers

Barriers to overcome in Sustainable Clothing Product-Service Systems may include a lack of external infrastructure and technologies, e.g. for clothes or clothing care products collection, remanufacturing or recycling. Per stakeholder type, barriers for the eco-efficient clothing PSS diffusion in industrialised contexts are summarised as follows (Ceschin, 2013a, 2013b).

For *clothing and clothing care product companies*, the adoption of an S.PSS strategy is more complex to be managed than the existing way of delivering products, as far as there is a need to implement changes in corporate culture and organisation to support a more systemic innovation and service-oriented business (UNEP, 2002). There is indeed resistance by companies to extend involvement with a product beyond point-of-sale (Mont, 2002). Extended involvement requires new design and management knowledge and approaches. It requires medium-to-long-term investments and is therefore connected with uncertainties about cash flows

(Mont, 2004). Moreover, a further obstacle is the difficulty of quantifying the savings arising from S.PSS in economic and environmental terms, in order to market the innovation to stakeholders both inside and outside the company, or to the company's strategic partners (UNEP, 2002). Finally, the significant change in the system of earning profit could deter producers from employing the concept, first through limited experience in pricing such an offering, and second through fear of absorbing risks that were previously assumed by customers (Baines *et al.*, 2007).

For *clothing wear and care product customers or users*, the main barrier is the cultural shift necessary to value an ownerless way of having a satisfaction fulfilled, as opposed to owning a product (Goedkopp *et al.*, 1999; Manzini *et al.*, 2001; Mont, 2002; UNEP, 2002). Solutions based on sharing and access contradict the dominant and well-established norm of ownership (Behrendt *et al.*, 2003). This is especially true in the B2C market, while in the B2B sector numerous examples of eco-efficient PSS concepts can be identified (Stahel, 1997). Clothes and clothing care product ownership not only provides a function to private users but also status, image and a sense of control (James & Hopkinson, 2002). Another obstacle is the lack of knowledge about life cycle costs (White *et al.*, 1999), which makes it difficult for a user to understand the economic advantages of ownerless solutions.

For *governments*, on the regulatory and policy side, actual laws may not favour S.PSS-oriented solutions. Environmental innovation is often not rewarded at the company level due to lack of internalisation of environmental impacts (Mont & Lindhqvist, 2003). In addition, there are difficulties in implementing policies to create corporate drivers to facilitate the promotion and diffusion of this kind of innovation (Ceschin & Vezzoli, 2010; Mont & Lindhqvist, 2003).

6.5. Designing Sustainable Clothing Product-Service System: new approaches and skills

Sustainable clothing Product-Service Systems introduce a new role for designers, who is taken to design a system of clothes and/or clothing care products and services that are together able to deliver a "unit of satisfaction" (wear a clothes for a given period of time), based on innovative interactions between the stakeholders of the clothes and clothing care value production (satisfaction) system, where the ownership of the clothes and/or clothing care product/s and/or the costs/responsibilities of life cycle services remain by the provider/s, so that the economic interest of the

provider/s continuously seeks environmentally (and socio-ethically) beneficial new solutions.

Moreover, the introduction of S.PSS into design has led researchers to work on defining new skills for a more systemic approach, which aims at sustainability through a strategic convergence of interests coherent with a "satisfaction-based" approach. "Strategic" here also refers to the necessary acknowledgement of cultural contexts and inherent opportunities and barriers built into the social context. In synthesis, the main approaches and skills of Sustainable clothing Product-Service System Design are:

- ***a "satisfaction-system" approach***, i.e. the design of the satisfaction of a particular demand (a "satisfaction unit") and hence all its related clothing wear and care products and services;
- ***a "stakeholder configuration" approach***, i.e. the design of the interactions of the stakeholder of a specific clothing satisfaction-system;
- ***a "system sustainability" approach***, i.e. the design of such stakeholder interactions (offer model) making the providers economically interested to continuously seek after both environmentally (and socio-ethical) new beneficial clothing wear and care solutions.

6.5.1. *The "satisfaction-system" approach*

In the words of Ehrenfeld (2008), a satisfaction approach in design "is to think more on being (satisfied), rather on having (products to be satisfied)". The first key point lies in the satisfaction-based approach where the focus is no longer on a single clothing wear or care product. It is thus inadequate to merely design or assess a single product, but instead we consider the whole process of every clothing wear and care product and service associated with satisfying certain needs and/or desires.

To clarify this concept, we can recall the example of e.G.o.[5] where the unit of satisfaction was 'having access to clean clothes', a unit based on having ready-to-wear clothes without the need of taking care of washing, drying, ironing as well as maintenance, repair and disposal. The term satisfaction is proposed to emphasise the enlargement of the design scope from a single product to the system of products and services (and related stakeholders) that together meet a given demand of needs and desires: in fact, a particular demand for satisfaction.

5. "e.G.o, Ecologico Guardaroba Organizzato (Organized Ecologiacal Wardrobe)", available as a case study on www.lens-international.org/.

Finally, in parallel with the introduction of the concept of the *functional unit* for product Life Cycle Design, *a satisfaction unit* could be introduced. And could be defined as follow (adapted from Vezzoli *et al.*, 2021):

A defined (quantified) clothing wear and care satisfaction of a customer that could be fulfilled by a mix of products and services used as a reference unit to design and to evaluate the sustainability benefits and impacts.

6.5.2. *The "stakeholder configuration" approach*

The second key task is to introduce a *stakeholder configuration* approach. If we want to design the *stakeholder interactions*, the system design approach should project and promote innovative types of interactions and partnerships between appropriate socio-economic stakeholders in the clothing sector, while responding to the particular social demand for clothes wearing satisfaction.

To clarify this approach, we can again recall the example of ready-to-wear clothes, where the innovation involves all the different socio-economic stakeholders in this satisfaction system: the clothing manufacturers, the user and those responsible for maintenance and disposal. To visualise the mode of approach it may be useful to think of and draw a parallel with the design questions that more typically concern a traditional designer, who in designing a clothing wear or care product defines the technical, performance and aesthetic characteristics of its components and its connections, in order to describe the configuration of the product components that are not characterised by materials (with specific performance functions) and by their connection systems (joining elements). In this way a designer of sustainable clothing systems must imagine and promote innovative types of *connections* – interaction/partnership – between appropriate *components* – socio-economic stakeholders – of a system responding to a particular social demand for satisfaction. In other words, the components of a satisfaction system are the socio-economic stakeholders (with their characteristics, skills and abilities) and by the interaction occurring between them, i.e. material, financial, information, labour flows. Therefore, designing the configuration of a clothing system means understanding who the best stakeholders (*components*) are and what the best interrelationships (*connections*) are.

6.5.3. *The "system sustainability" approach*

Not all system innovations are eco-efficient (and/or socially equitable and cohesive). We must remain critical and reflective, in order to avoid the intuitive assumption that any obtainable clothing PSS innovation naturally carries the potential for sustainable development.

For this reason, in terms of the development of new systems it is expedient to operate and adopt appropriate strategies and guidelines. This brings up the great importance to study cases, methods and tools to manage and orientate the design process towards sustainable stakeholder interactions/relationships.

In the e.G.o example, the new stakeholder system configuration could be e.g. towards a pay per use system (unit satisfaction) and include maintenance, repair and end-of-life collection. The innovative interaction between the companies and the client drives the companies' interest to design and provide highly efficient (for energy, water and detergent), long-lasting, re-usable and recyclable washing machines.

From this perspective on design, which takes into account all simultaneously active socio-economic stakeholders, designers must likewise equip themselves with the necessary skills to operate in a participatory design context (i.e. among various entrepreneurs, institutions, NGOs, associations and services) for system development that includes the offer (clothing wear and care products and services).

As far as design practice is concerned, the first design methods and tools described here have been developed since the beginning of the 2000s, thanks to a series of EU-funded research projects, such as tools for the development of sustainability design-orienting scenarios, for the strategic convergence of different stakeholders, for interaction designing and for the generation of highly sustainable systems ideas.

6.6. Sustainable clothing PSS design: strategies, guidelines and examples

It has been already observed that not every clothing Product-Service System is environmentally sustainable, or better still driven by economic interests towards environmentally beneficial solutions, i.e. eco-efficient. Accordingly, it is crucially important to adopt appropriate methods and tools, when designing new Product-Service Systems (with the potentialities to be radically innovative toward sustainability), that would steer

toward sustainable solutions. For this reason, in terms of the development of new systems, it is expedient to operate and adopt appropriate strategies and guidelines.

This chapter focuses on the strategies and guidelines for environmentally Sustainable Product-Service System design for the clothing system. As adopted by the LeNS network, six strategies can be listed according to their orientation towards environmental sustainability:

- clothing system life optimisation;
- reduce transportation/distribution in the clothing system;
- minimise resources consumption in the clothing system;
- minimisation or valorisation of waste from the clothing system;
- resources conservation/biocompatibility in the clothing system;
- reduce the toxicity in the clothing system.

There are interrelations between such environmentally sustainable strategies (and related guidelines), meaning that for a given satisfaction system, some strategies (and related guidelines) have higher relevance than others. Therefore, in a decision-making process (designing) it is important to identify the environmentally sustainable design priorities, namely the relevance of the strategy in relation to the system that need to be re-designed, i.e. the most promising strategy and related stakeholders' interactions guidelines.

Though similar to product guidelines, a clear shift from "functional" to "satisfactory" design reference appears, that emphasises the enlargement of design scope, i.e. from single clothing to the whole clothing Product-Service System and its participants, the system that provides satisfaction for given needs and desires. From here on, the perspective stays on a satisfaction systems level. Next paragraphs present the abovementioned strategies together with guidelines and case studies and respective examples.

6.6.1. *Clothing system life optimisation*

To optimise a clothing system's life means to design such interactions between system stakeholders that lead to the lifespan extension or the use intensification of offered clothes and/or clothing care products.

As previously discussed in chapter four, a clothing product with a longer lifespan than another – with similar functions – has (generally) a lower environmental impact. A clothing product that wears down rapidly will not only generate untimely waste but will also determine further impact due to the need to replace it (see Fig. 5.3). Pre-production, production and distribution of a new garment to replace its function involves the

consumption of new resources and new emissions, with an increase of the overall environmental impact.

The duration of clothing products can be planned by increasing their reliability and facilitating proper maintenance, repair, re-use and re-manufacturing.

However, regarding to the given clothing product in use, the extension of its lifespan might not determine a reduction in impact; continuing to use an old product can even cause an increase in impact. When technological development offers the opportunity to have new products with better environmental effectiveness (e.g. lower need of clothing care operations or reductions in microplastic emissions during washing) providing the same exact service, then soon the need to manufacture, distribute and dispose the new product is compensated, in terms of balancing environmental impact, by improved performance in use.

As regards the use intensification of the sum of products within a system – as described in chapter 5 (Fig. 5.4) – a set of clothes or clothing care products that is intensely-used (i.e. the same set is used by a greater number of users at different times) allows to avoid impacts related to the life cycle stages of multiple sets of clothing products that would be otherwise needed to achieve the same satisfaction unit for the same group of users.

In qualitative terms to understand whether an existing clothing system presents problems related to life optimisation, the following key questions should be asked:

- Are disposable systems used?
- Are disposable clothing packaging or support products used?
- Do parts of the system tend to be technologically obsolete?
- Do parts of the system tend to be culturally/aesthetically obsolete?
- Do some parts of the system tend to wear out more easily (than others)?

Guidelines for clothing system life optimisation

- ***Complement clothing products with all-inclusive services for maintenance and/or repair, as well as temporary replacement in the meanwhile*** **(example 1).**
- ***Complement clothing products with services for aesthetical/cultural upgrade.***
- ***Complement clothing products with services for technological upgrade.***
- ***Complement clothing products with services that enable their reconfigurability, e.g. adaptation in new location.***

- ***Complement clothing offer with all-inclusive take-back services aimed at re-using or re-manufacturing.***
- ***Offer services for shared use of ownerless clothing, e.g. pay per period, pay per use* (examples 2.1 and 2.2).**
- ***Offer services for shared ownership of clothing collection, e.g. collective purchase and use of clothing by multiple users.***
- ***Offer services for sharing and/or exchange of clothing* (example 3).**
- ***Offer services for reuse and second hand selling of clothing, by providing infrastructures (e.g. collection points, clothing cleaning) or platforms (e.g. online marketplace of used clothing).***

Examples

1. Lease a Jean – MUD Jeans

MUD Jeans is a jeans brand that allows customers to lease Jeans for € 9,95/month for one year, with a free repair service included in case of damage during the lease. Once the lease is complete the user has 3 options: keep the jeans and terminate the lease, lease a second pair of jeans for a reduced price of € 8,95/month or swap them and start a new lease at € 7,99/month.
Furthermore, users are encouraged to send their old jeans to MUD – even if they are not made by them – in return for a one-month discount on their lease. Indeed, since jeans are mostly designed by MUD, they are economically interested in re-using and re-manufacturing old jeans instead of relying on virgin resources. Finally, by creating jeans that last longer and can be repaired they save money on disposal as well as pre-production, production, and distribution of new pairs.

2.1. Bundlee

Bundlee is a UK based clothing rental company for parents of babies aged 0-24months. The idea was generated by Eve Kekeh after she realised how quickly children outgrow clothing during their early years. Between birth and 2 years old babies are expected to go through 7 different sizes of clothing leaving parents with masses of unusable baby clothes. The clothing is made to be durable to withstand all activities with the child from playing, sleeping, and eating. The service allows parents to pay a monthly subscription in return for clothing delivered to their door, when the child has grown out of the clothing the parent return can it with all delivery and return fees included in the subscription. These clothes are then swapped for new ones from Bundlee in the next size up. When the clothes

are back at Bundlee they are sanitised in an Ozone Sanitisation Chamber, a zero-waste process that leaves the clothes cleaner than those found in shops. To maximise the clothing lifespan Bundlee produces their garments with high-quality cotton, utilising renewable energy sources to provide the power required.
The key aspect here is that Bundlee is not offering an almost single use/owner product like many clothing companies but is providing a service. This service of swap and reuse of clothes intensifies the clothes usage and significantly extends their lifespan. The users will not actually own the clothing and therefore will not be responsible for their disposal, this role lies with the service provider Bundlee. Bundlee will decide which clothes are fit to be reused and any which are not will be broken down and recycled. It is largely in Bundlee's interest that the clothes they produce and care for are robust and well made, since the longer the lifespan of their clothing is, the less are the costs required to produce new ones.

2.2. HURR Collective

Fig. 6.15 - HURR clothes for rent

HURR collective was set up in 2018 as an online rental and leasing platform. Unlike other clothing rental companies, the majority of the clothing rented from HURR is not managed by the company itself. Instead, they have created a platform to encourage other users to rent their clothes allowing them to monetise their wardrobes. This encourages users to share their wardrobe, making use of items they currently do not have a use for but also are not ready to let them go.

The platform gives access to clothing items, accessories, bags, and shoes, usually those of which are branded and therefore considerably higher in price than typical items. Giving individuals all across the country chance to rent their own clothes rather than holding them in a warehouse encourages local sharing, reducing costs in warehouse storage and transportation.

3. SWAP by Freitag

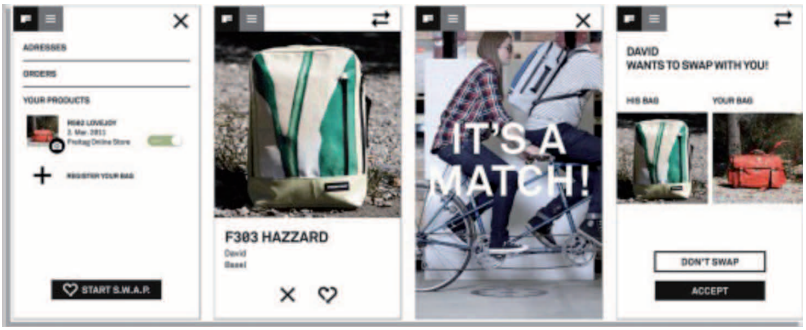

Fig. 6.16 - Freitag SWAP online platform

Freitag is a company from Switzerland that specialises in reusing truck tarpaulin to create a range of bags and other accessories. In 2019 they launched a new initiative, SWAP standing for “Shopping Without Any Payment”. To take part the users have to register their bag by taking a photo and uploading it to the mobile platform. Once the product is activated for swapping, they will be able to view other swappable bags. While viewing other swappable bags they can swipe right if they like it or left if they do not. If the owner of the bag you like also likes your bag you will get a “match”. You and the other owner will decide if you want to exchange bags, once complete Freitag asks that the swap is confirmed with them. This process allows users who are no longer using their bags to get a theoretically new one without additional costs and without generating waste. This service offering an exchange of items prologues the lifespan of the product and increases the usage of what ordinarily would be a single owner product.

6.6.2. *Reduce the transportation/distribution in the clothing system*

Reducing transportation/distribution in the clothing system means to design such interactions between stakeholders of the system that could lead to a decrease of the overall number of transfers and related packaging (which has to be considered as an inherent component of transportation). This includes the transportation of raw materials, components or semi-finished clothing system products during pre-production and production stages, as well as all their transfers and packaging from the factory to the customer, including retail operations. Designing to reduce transportation means also to consider either primary, secondary and tertiary packaging, e.g. stock containers, pallets etc.

To understand in qualitative terms whether an existing system presents problems related to transportation/distribution in the clothing system, the following key questions should be asked:

- Is there any excessive transportation of goods?
- Is there any excessive transportation of semi-finished clothing products or by-products?
- Is there any excessive transportation of people? Are the transportation means in service fully used?

Guidelines to reduce transportation/distribution in the clothing system

- ***Clothing producer/provider uses digital channels to offer information/guidance services for clothing purchase and care, e.g. virtual fitting rooms, repair and care instructions*** **(example 1).**
- ***Clothing producer/provider creates partnerships with locally-based clothing care service providers, with all-inclusive maintenance, repair, upgrade, end-of-life collection/valorisation etc.***
- ***Clothing producer/provider creates partnerships with locally-based acknowledged suppliers of resources for the clothing pre-production, production and care, e.g. local material and energy suppliers.***
- ***Clothing developer/designer creates partnerships with clothing manufacturers for local delivery (e.g. a decentralised manufacturers network)*** **(example 2).**
- ***Clothing producer/provider creates partnerships with clothes retailers and other stakeholders to reduce/avoid clothing packaging, either tertiary, secondary or primary.***
- ***Clothing producer/provider creates partnerships to reduce or avoid transportation/packaging of semi-finished clothing products, e.g. partnerships with textile suppliers and manufacturers.***

- ***Offer clothing products with reusable/returnable packaging.***
- ***Offer remote support and status monitoring of activities and interventions to be carried out on-site by the user related to clothing care, e.g. maintenance, repair, upgrade, end-of-life collection/valorisation.***

Examples

1. Patagonia repair & Worn Wear services

Fig. 6.17 - Patagonia's Worn Wear repair station

If a Patagonia product rips or tears, alternatively to the option where customers return products to Patagonia repair station (America) where a staff member will fix it, customers can follow repair tutorials available on the website to mend it themselves, with a consequent reduction in transportation.
Furthermore, customers could return broken products to Patagonia repair station where a staff member will fix it or send it to their garment repair facility, which is said to be the largest in North America conducting over 40.000 individual repairs a year. The brand also offers trade-in service and second-hand options. The trade-in service available at stores or by mail consists of the exchange of used Patagonia clothing in good condition for credit towards

purchases in Patagonia retail stores, on WornWear.com or at Patagonia.com. Items that are repairable and resalable will be sold in the company's Worn Wear stores. Worn Wear is Patagonia's "hub to keep gear in play", offering a Recrafted collection made of products that Patagonia received back that are beyond repair or that cannot be recycled. Creating long-lasting products and encouraging users to return them for a reward becomes economically beneficial for Patagonia as they are making an additional profit on items that have previously been sold and generated a profit once before.

2. Artknit Studios

Fig. 6.18 - Artknit logistic model, based on the delivery directly from manufacturers

Artknit Studios are paving the path for a direct to customer business model. All products are shipped directly from the makers bypassing middlemen and intermediaries, reducing costs and CO_2 emissions, something which is then reflected in the price customers pay. To ensure the high quality of their products they produce items in small batches. Keeping with maintaining quality, Artknit use locally sourced fibres from hand-picked supplies and also only work with locally based artisans to create each garment. Within their website they are aiming to operate on a transparent production system, customers are able to find details of the material and the manufacturer of their items. Since the quality of Artknit products is so high they also produce on demand garments, to ensure they do not have excess

stock which can lead to waste. To prolong the life of their garments after sale they provide information regarding how to store and care for each item. With Artknit committing to minimising resource consumption they are gaining an economical advantage since they are not purchasing unnecessary volumes of fibres, producing large volume of clothing, or needing to store clothing which cannot be sold.

6.6.3. *Minimise resources consumption in the clothing system*

Reducing the consumption of energy in the clothing system means to design to enable system stakeholders' interactions that reduce the sum of the resources used by all products and services of the clothing system.

Materials and energy, albeit with different intensity for different products, are used throughout the entire clothing life cycle. For this reason, the design approach must aim at reducing consumption of resources at all stages, including design and management activities. Obviously, a reduction in the use of resources determines removal of environmental impacts regarding what is no longer consumed. Using less material diminishes impact, not just because fewer materials are manufactured, but also due to avoiding their conversion, transport and disposal.

In the same way, lower energy use diminishes impact, thanks to smaller amount of energy that has to be produced and transported.

Finally, on a system perspective we have to consider the overall and interlinked material and energy reduction of the whole of the products or support products needed for the satisfaction of a certain demand of needs and desires.

To understand whether an existing system presents problems in qualitative terms related to resources reduction, the following key questions should be asked:

- Is the system consuming high quantities of energy?
- Is the system consuming high quantities of natural resources?
- Is the system absorbing high quantities of consumables?
- Are products, packaging or support products highly material intensive?

Guidelines to minimise resources consumption in the clothing system

- ***Complement the supply of resources/semi-finished products/consumables related to the clothing system (energy, detergents, dying substances, etc.) with services for their optimal use.***

- ***Offer access to clothing products or related infrastructures (enabling platform) through payment based on the unit of satisfaction, e.g. the use of a garment for a number of times/specific occasion, as well as manufacturing facilities*** **(example 1).**
- ***Offer access to clothing products or clothing care infrastructures (enabling platform) through payment based on a fixed fee per given period of time.***
- ***Offer access to clothing along with clothing care services to client/final user through payment based on the unit of satisfaction.***
- ***Provide resource saving technologies and practices to upgrade existing clothing related equipment where the investment is financed through subsequent resource savings.***
- ***Offer collective use of clothing care infrastructures*** **(example 2).**
- ***Outsource and/or offer activities when higher specialisation and technological efficiency of clothing products/infrastructures are available.***
- ***Create partnerships to use/integrate/complement existing clothing system infrastructures, e.g. sewing or dyeing facilities.***
- ***Outsource activities when higher scale economies are feasible along the clothing system.***
- ***Complement the clothing system offer with services designed for their adaptation in the context of use aimed at resource optimisation for clothing production and care e.g. custom-designed drying solutions depending on local weather conditions.***
- ***Complement clothing production and care with services designed for their adaptation to use in variations of resource requirements e.g. adaptive drying solutions depending on variable atmospheric conditions.***
- ***Offer clothing products/accessories based on demand aimed at avoiding unsold inventory and/or surplus production*** **(example 3).**

Examples

1. The Loft

The Loft works on the same idea of co-working. Ariane Arnad – passionate and professional sewer created her own space in Lisbon to produce clothing along with other designers. The spaces offer access in a pay-per-use mode, to a range of equipment from specialised sewing machines, textiles and cutting tables. In this way,

users (designers) that access the labs are interested in making the most efficient use of infrastructures, and at the same time The Loft – which is responsible for the spaces' resource consumption – are economically interested in selecting the most efficient solutions in terms of resource consumption.
Furthermore, spaces offer classes to those that want it as well as spaces for those who wish to share ideas and receive help from like-minded individuals. In this way, those without the funds to purchase their own equipment outright now have no barriers to creating garments. This also intensifies the usage of specialised equipment which instead of being used once every few weeks is required daily.

2. Self-service laundry – Ondablu di Millebolle Srl

Fig. 6.19 - Left: Ondablu washing machines; Middle: the Ondablu hall; Right: the interface

Ondablu is the first and largest franchise chain of self-service laundries with more than 60 facilities throughout Italy. They offer the shared use of last generation washing machines and dryers that wash and dry all types of laundry, always respectful of the fabrics: underwear, jeans, shirts, work overalls, but also duvets, curtains etc. To ensure maximum hygiene, a medical and surgical device disinfects the machines with every wash.
The service consists of the following steps: after choosing the machine, the client inserts their items to be washed, they choose the relevant program, dosage and detergent (provided by the shop); finally, they turn to the control board that works with either notes or coins (more practical and convenient than tokens), choose the correct washing machine and the rest is automatic. Payment per wash encourages the client to maximise the load, which consequently reduces energy, detergent and water consumption per weight of the laundry. The shared use of the washing machines also reduces production materials and waste and intensifies usage of a machine which can be used all day every day as opposed to a few

times per week if there is one per household. Finally, as Millebolle is responsible for the payment of resource consumption (electricity, detergent etc.), they select the most efficient technologies/product for both washing and drying.

3. Gustin

Fig. 6.20 - Gustin value proposition based on crowdsourcing

Gustin is focused on Crowdsourced fashion. This means that rather than encouraging customers to purchase what they have already manufactured, they design a clothing range and ask what the customers would like, tailoring their production line to the customer's needs. This is done by customers per-paying for items that they like then when the demand is reached Gustin begins production. If the demand is not met within a designated timeframe, the garment is not produced and any customers who showed interest receive a refund. They originally started as a traditional clothing producer company creating jeans that they would sell to a wholesaler for a specified price, with the wholesaler marking up the price for a profit and selling them on to the customer. Other than cutting the number of consumed resources, Gustin's new initiative of selling directly to the customer has cut out the middleman reducing clothes' transportation costs and providing a better price for the end-user.

6.6.4. *Minimisation or valorisation of waste from the clothing system*

Waste minimization or valorisation entails the design for system stakeholders' interactions improving the sum of the system recycling, energy recovery and composting and reducing the sum of the landfill produced in the clothing system.

As we introduced in previous chapters, we use the term recycling when secondary raw textiles are used to manufacture new industrial products and composting when secondary raw textiles are made into compost.

In all these cases the environmental advantage concerns the avoidance of disposing textiles in landfills, as well as avoiding the impact from the extraction and processing of raw fibres and energy from virgin resources. The impact of these avoided processes can be considered as an indirect environmental advantage.

Finally, on a system perspective we have to consider the overall and interlinked avoided (or eventually added) environmental impacts of the whole of clothes and/or clothing care products or support products needed for the satisfaction of a certain demand of needs and desires.

As anticipated in chapter 5, it is useful to recall that – even from a system perspective – recyclability depends not only on inherent materials' characteristics, but also on the way a material is made easy to be separated as well as on the feasibility of each recycling phase.

All this considered, to understand whether an existing system presents problems in qualitative terms that are related to resources reduction, the following key questions should be asked.

- Does all clothing system waste end up in landfills?
- Does the system produce high quantities of landfill waste at the end of service-life?
- Do the clothing production, packaging and support products produce big quantities of landfill waste?

Guidelines for the minimisation or valorisation of waste from the clothing system

- ***Complement clothing offer with all-inclusive take-back services aimed at recycling*** **(example 1).**
- ***Complement clothing offer with all-inclusive take-back services aimed at (low-impact) energy recovery, i.e. incineration for energy generation.***

- ***Complement clothing offer with all-inclusive take-back services aimed at composting.***
- ***Complement clothing care equipment with all-inclusive take-back services aimed at recycling/energy recovery.***
- ***Create local partnerships aimed at symbiotic/cascade approach for recycling/composting of disposed clothes into products with lower requirements within other sectors, e.g. textile recycling as "soft" filling for other products*** **(example 2).**

Examples

1. On Running – Cyclon

Fig. 6.21 - The Cyclon running shoe

Cyclon is a recyclable running shoe developed by On Running. Runners are usually encouraged to change their trainers frequently to maintain the support of the foot and keep them running at optimal performance, this can be as often as every six months. The continual upgrading leads to millions of shoes in landfill each year. On Running has developed a subscription service to their new Cyclon shoe where users pay € 25 per month for the high-performance Cyclon trainer. When the trainers begin to reach the end of their life the users are encouraged to contact On Running who will post out a new pair. They then ask that in the same box, the old trainers are returned. On Running will then reuse 100% of the returned shoes to create new Cyclon shoes. A major cost saver is that On Running do not need to resource the yarn needed for the shoes as they can reuse that from

original products, saving material costs as well as not being required to pay for landfill costs.
Moreover, in coherence with this offer, the Cyclon trainer itself is a made from mono-material weave cut from a single piece of fabric. It is only available in white since this is the original material colour and therefore does not require dyes, reducing toxins. Finally, the actual material is a high-performance polyamide derived from beans. The beans are able to be grown in dry, remote places so they are not compromising the ability to crow crops. The nature of this material makes the shoes biodegradable and fully recyclable.

2. Eileen Fisher – Renew program

Fig. 6.22 - Eileen Fisher Renew factory

Eileen fisher, an American clothing company founded in 1984, runs the Renew program to extend the lifecycle of the clothes and materials by cleaning and reselling or recycling them toward new markets.
Items purchased from Eileen Fisher online or instore which are no longer fit for purpose can be returned to an Eileen Fisher clothes store, a Renew store or by shipping items directly to one of their recycling centres, regardless of their condition. For each item returned the customer will receive € 5 in renew rewards. The Eileen Fisher recycling centres receive around 800 returned garments each day, totalling over 1.4 million items of clothing in the last 10 years. Each item is checked by hand to assess its quality and condition. The clothing items are then sorted into three categories (first quality,

not quite perfect and damages). Items that are deemed to be lightly worn, are given a deep clean and resold at the Eileen Fisher renew shops. Items that are damaged and are beyond repair are transferred onto the "Waste No More" team who transform them into one-of-a-kind artworks, pillows and wall hangings using a custom felting method. With this method, the company avoid pre-production of primary material and avoid landfill and disposal costs even of materials that cannot be reproduced as clothing items. By utilising unusable textiles within other sectors such as artwork, they are adding another stage before disposal however, in this case, artwork is significant in that it does not wear or age like other products, in theory giving it a limitless lifespan.

6.6.5. *Resources conservation/biocompatibility in the clothing system*

Conservation and biocompatibility entail the design for system stakeholders' interactions that improves the overall amount of the system's resources conservation/renewability.

An explanation is needed on resources (both materials and energy) renewability. As an example, timber is considered a renewable material, but the same type of wood can be procured from areas with planned and controlled exploitation or from unverified ones, leading to deforestation. Thus, the very same material can qualify as renewable in the first case, and not renewable/non-reproducible in the other case. It can be summarised that the renewability depends upon specific re-growing speed and extraction frequency. Therefore, we can define that: *a material or energy resource is renewable when its consumption rate is smaller than the natural re-growing rate.*

Finally, on a system perspective it has to be considered the overall and interlinked level of renewability of the whole of the materials of the whole of the products or support products needed for the satisfaction of a certain demand of needs and desires. To understand whether an existing system presents problems in qualitative terms related to conservation and biocompatibility, the following key questions should be asked.

- Is all the energy produced from exhausting resources (e.g. fossil fuels)?
- Does the system use mainly depleting and/or non-renewable materials for products, support products, packaging, and infrastructure?

Guidelines for resources conservation/bio-compatibility in the clothing system

- ***Engage energy suppliers offering renewable energy or renewable energy systems (eventually locally installed) for the functioning of the various phases of the clothing system.***
- ***Engage a material supplier to use renewable and biodegradable materials in the clothing system.***
- ***Engage energy suppliers offering the design, installation, maintenance, repair, etc. of on-site passive energy systems for the functioning of the clothing system's various phases.***
- ***Create partnerships that enable/increase the use of recycled materials in the clothing system from disposed products of other sectors.*** **(example 1).**

Examples

1. Rifò Lab

Fig. 6.23 - Organization of retrieved materials according to alike colors. In small: a sample product made with discarded textiles from other products

Rifò Lab is an Italian company based in Tuscany that produces and sells clothes using fibres regenerated from the clothing manufacturing district of Prato.
Indeed, the production is based on different methods that allow to regenerate discards into new valuable fibres mechanically. Cashmere can rely on regenerated fibres for its 95%, Jeans up yo 85%.
In this way, Rifò's production is minimally based on virgin resources, since it works through the collaboration with suppliers to use materials that are disposed from other sectors.

6.6.6. *Reduce the toxicity in the clothing system*

Reduction of toxic emissions in the clothing system entails the design for system stakeholders' interactions that reduce/avoid the gross total of toxicity and harmfulness among the resources utilised or emitted by the clothing system.

In this sense, it is important to remember that a properly effective approach must always refer to the entire clothing life cycle and to every concurring process of the whole of the clothing products and the support products of a particular system of satisfaction. This means that various technologies for transforming and treating clothing materials (some of them might entail toxic or noxious emissions, others equally effective might not) have to be considered, as well as the distribution systems that cause even the least harm to the environment. Finally, the choice of materials (and additives) must be oriented also towards the minimisation of toxic emissions that occur during disposal.

Furthermore, it is important to recall – from chapter 5 – that the least toxic or harmful system solution is not just a matter of material, but it relates to the overall system satisfaction provided (e.g. fibres with the same level of general microplastic release during washing may be differently toxic due to the use of a highly seeping washing machine provided by a collective laundry option).

Finally, on a system perspective it must be considered the overall and interlinked toxicity of all the materials and processes within the whole of clothing products and support products needed for the satisfaction of demanded needs and desires.

To understand whether an existing clothing system presents problems in qualitative terms related to toxic and harmful resources, the following key questions should be asked.

- Are the processed resources toxic or potentially toxic for the workers?
- Are the processed resources toxic or potentially toxic in during distribution?
- Are the processed resources toxic or potentially toxic for the user?
- Are the clothing products, support products, packaging or infrastructure toxic or potentially toxic during after service time treatments?

Guidelines to reduce the toxicity in the clothing system

- ***Create partnerships with other producers to reuse or recycle toxic/harmful by-products from the clothing system.***
- ***Complement substances/semi-finished products or clothes with services that minimise/treat toxic or harmful emissions of processes***

along the clothing pre-production, production and use stages, e.g. full management service to monitor and treat ecotoxic outputs from washing processes **(example 1).**

- *Complement toxic or harmful substances/semi-finished products for the clothing system with all-inclusive end-of-life treatments.*
- *Offer toxic management services to stakeholders of the clothing value production chain, through payment based on the unit of satisfaction, e.g. full management of pesticides* **(example 2).**

Examples

1. Zyosh

Fig. 6.24 - Microparticles released per wash

As clothes are subjected to repetitive washing, they start to release a larger quantity of microplastics. Zyosh has developed innovative technology in the form of a clothing label that is attached to clothes like a regular sewn-in tag in order to inform the user of the "optimal time to recycle" to prevent the weakening of the textile and minimizing the emissions of microplastics. Zyosh creates the tag for companies tailored specifically to the composition of their

clothing. They take this information, encrypt it, and transform it into a QR code. When it is sewn into a garment the QR code is invisible. As the user washes their clothing the code appears. When scanned QR code provides information on where to recycle the item, whether the retailer offers a take-back service, or whether to contact Zyosh to arrange a collection. Finally, the label explains recycling best practices that can be used across all clothing items, not just those with the Zyosh label, such as, removing buttons and labels at home.
A key point here is that Zysoh does not directly reduce toxins within the clothing system. They do, however, provide vital information (in partnership with clothing manufacturers) to the customer who can then make an active decision as to whether to recycle the garment or not.

2. Cleaning cloth rental service – MEWA Wiesbaden

MEWA hires out rags made of recycled cotton to engineering companies, printing plants, repair shops and to the German railway company Deutsche Bahn. The rags are delivered in containers to the customers, used and then thrown back into the containers to be collected by MEWA. They are then returned to the MEWA facility where they are cleaned and hired out again. Each rag completes this cycle up to 50 times.
From a company's perspective, MEWA offer, aside from being a more sustainable option companies, can choose their rags tailored to their specific needs. This allows them to be more efficient in collecting oil or gentler on sensitive surfaces.
In fact, MEWA has not only improved its rental service but also the material cycles involved. Solvents contained in the returned rags are used in the cleaning process, water and energy are re-used several times and cascade through the washing and drying stages. The oil contained in sewage is recycled and used for energy production in the MEWA plant allowing the company's plant in Vienna to become energetically self-sufficient. After treatment in the MEWA plant, the sewage is sufficiently clean to be accepted by normal municipal sewage treatment plants without any problems. Furthermore, compared to other washing machines the wash process in the "giant" washing machines of MEWA proves to be much more efficient.

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7. Methods and tools for sustainable clothing product-service system design

7.1. Method for environmentally sustainable clothing system design

In help of designers to develop environmentally sustainable clothing systems, support methods and tools are helpful and needed in order to adopt strategies and decisions based on reliable priorities and opportunities. Indeed, including the environmental requirements into the design process makes this process more complex. Within this framework the designer needs proper knowledge/information and decision support tools, in relation to three main aims:

Assessing the environmental impact of the existing clothing system and identifying the priorities for the design interventions;

Orientating the design innovations and decisions towards lower environmental impact solutions;

Evaluating the potential environmental improvements of ongoing development.

Among different approaches that have been developed in the years, the one visualized in Fig. 7.1 has been adopted as a reference, connecting design for sustainability methods and tools with the typical development stages for products, services and systems (adapted from Vezzoli *et al.*, 2021 and Vezzoli, 2018).

The proposed method is defined along the following four stages of product and/or product-service system design:

- *Strategic analysis*
  Stage aimed at collecting information to understand the existing context and processing them into insights to steer the exploration of promising solutions.

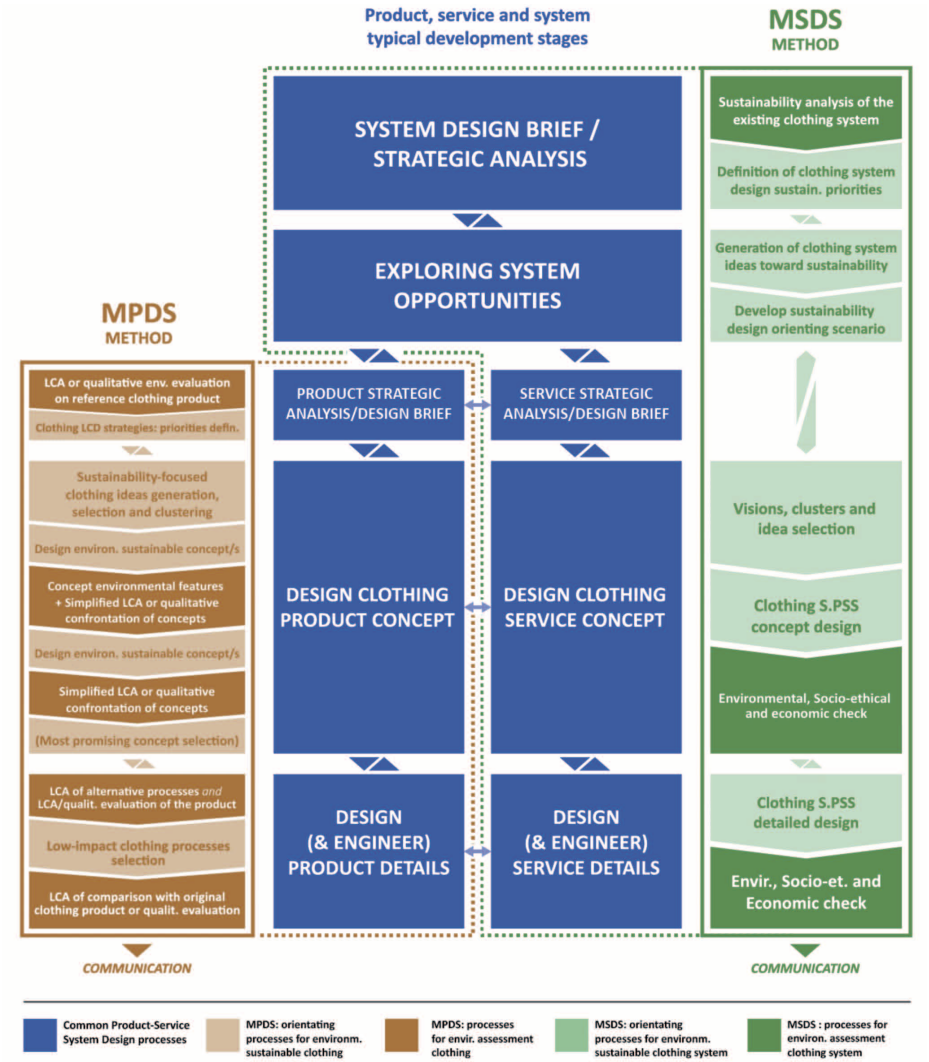


Fig. 7.1 - Integration of the processes of the method for sustainable clothing system design (including both the MPDS and MSDS methods), with typical design phases, aimed at either assessing or orientating it towards sustainable solutions

- *Exploring system opportunities*
  Identification of innovative potential directions for the development of valuable solutions, through a system approach considering/involving all the value production chain stakeholders.

- *Product and/or service concept design*
  This stage aims at developing and selecting the most promising product and/or service concepts.
- *Product and/or service detailed design*
  Stage aimed at developing the details of the project to enable the implementation of the solution.

A further stage can be added, across the others, of drawing up documents to report on the sustainability characteristics of the solution designed, i.e. the *Communication* stage.

Along the abovementioned phases, the proposed method for environmentally sustainable clothing system design presents processes and tools for both the product-service system level (based on the Method for System Design for Sustainability, MSDS, Vezzoli *et al*., 2021) and the clothes product level (based on the Method for Product Design for environmental Sustainability, MPDS, Vezzoli, 2008).

As highlighted within Fig. 7.1, the presented method combines processes to be adopted along both the product-service system and the product design to address three main goals: support the designer to analyse the context of intervention and identify product and product-service system design priorities; help in the orientation of innovation and choices toward most promising sustainable solutions; evaluate the potential improvements in terms of environmental sustainability in relation to the existing context.

7.1.1. *Method for clothing Product Design for environmental Sustainability*

When a designer or a design team is engaged at the level of clothing products design, the following method is presented with the goal of integrating and supporting a design process toward the development of an environmentally sustainable clothing product. The proposed method is an adaptation and specification of the Method for Product Design for Environmental Sustainability (MPDS)[1] to the clothing system. It is addressed to individual designers, design studios or designers in design departments of companies/organisations.

1. The MPDS Method has been developed by LeNSlab Polimi (Research Lab at the Design Department of Politecnico di Milano) as a result of more than 20 years of research, didactics and consultancies. Extended information can be retrieved from Vezzoli (2018).

The MPDS for clothing it is characterized by a flexible modular structure so that it can easily be adapted to specific design requirements, diverse design contexts and conditions and usable in existing design procedures/practices. It is meant to be integrated since the early stage of *clothing product brief* and *clothing concept design*, if and when most promising Sustainable Product-Service System ideas have been developed and selected. Most of the tools related to MPDS are open access and free to download at www.lens-international.org.

The clothing MPDS processes and tools can be integrated within typical stages of clothing design:

- clothing strategic analysis and brief;
- clothing concept design;
- clothing product detailed design (and engineering).

Specific clothing Product Design for environmental Sustainability processes, aims and tools related to each design stage, are described in detail within the following table.

Table 7.1 - The MPDS for clothing aims, processes and tools, in relation with the typical product design stages

Clothing product design stages	**Method for clothing Product Design for environmental Sustainability**		
	Aim	**Processes**	**Tools**
Clothing product strategic analysis and brief	To evaluate the environmentally critical areas and the LCD strategies with the greatest potential for reducing the environmental impact of the clothing product (functional unit) to be designed	• LCA for a standard existing clothing product [or] • Qualitative evaluation of environmental impact of a standard existing clothing product • Definition of the environmental design properties across the LCD strategies • Synthetic visualisation of the environmental design properties	• LCA software (e.g. Open LCA, SimaPro, GaBi) [or] • Checklist (ICSxClothing toolkit) • Functional unit & priorities/ improvement form & Radar (ICSxClothing toolkit)
Clothing concept design	To orient the generation of ideas towards environmentally sustainable solutions	• Environmentally sustainable focused ideas generation • Environmentally sustainable ideas check, selection and clustering	• Eco-idea boards (ICSxClothing toolkit) • Radar (ICSxClothing toolkit)

Table 7.1 - continued

Clothing product design stages	Method for clothing Product Design for environmental Sustainability		
	Aim	**Processes**	**Tools**
	To design promising concept/s in terms of environmental sustainability	• Design environmentally sustainable concept/s • Highlight concept/s environmentally sustainable Life Cycle profile and features • Concept simplified LCA [or] • Concept qualitative environmental evaluation	• Life Cycle Exploded Diagram • LCA software (e.g. OpenLCA, SimaPro, GaBi) [or] • LCD strategies pursuing Evaluation (ICSxClothing toolkit)
	To select the most promising concept in terms of environmental impact reduction	• Design environmentally sustainable concept/s • Simplified LCA concepts confrontation [or] • Concepts' qualitative confrontation in terms of LCD strategies pursuit level	• LCA software (e.g. Open LCA, SimaPro, GaBi) • ESPI Form & Radar (ICSxClothing toolkit)
Clothing product detailed design (and engineering)	To orient the design of project details towards most environmentally sustainable solutions	• LCA as comparison evaluation between alternative processes to select the one with the lowest environmental impact (e.g. alternative materials, manufacturing processes, etc.)	• LCA software (e.g. OpenLCA, SimaPro, GaBi) and LCD Evaluation (ICSxClothing toolkit) • LCA software (e.g. SimaPro, GaBi, Open LCA)
Communi-cation	To communicate the environmentally sustainable benefits and characteristics of the new designed clothing product	• LCA as comparison evaluation between the new designed and the standard clothing product aimed at quantitative supports for communication • Documentation drafting of the communication of the clothing product environmental quality	• LCA software (e.g. Open LCA, SimaPro, GaBi)

Furthermore, the method is defined as a modular approach for three main reasons:

- the possibility to start the process at each design stage, choosing the processes according to the project needs;
- the possibility to adopt a selection of processes and tools;
- the possibility to integrate of other tools and design activities, in accordance with the project requirements;
- the following paragraphs analyze on a deeper level the integration of sustainability objectives and processes within each design stage.

7.1.1.1. *Clothing product strategic analysis and brief*

The strategic analysis for clothing products has the general goal of understanding which Life Cycle Design strategies have the highest potential to reduce the environmental impact of a clothes, in relation to its functional unit (that could be specified in relation to the type of clothes and the context of use, through the Functional unit & priorities/improvement form within the ICS×Clothing toolkit[2]). The process begins with a Life Cycle Assessment of an existing standard clothing which function can be considered the same of the one to be designed, and that best represents trends and opportunities in the clothing market.

If a quantitative (LCA) evaluation is not feasible, a qualitative alternative through checklists can represent a possibility to estimate the environmental impact of an existing standard clothing product, e.g. with the Checklist of the ICS×Clothing toolkit[3] (the toolkit is described in detail within section 7.2.1.4 – A).

Successively, either starting from LCA results or qualitative evaluations, priorities of intervention can be identified with the help of specific environmental indicators (e.g. the Functional unit & priorities/improvement form within the ICS×Clothing toolkit), useful to define the most effective strategies toward the highest potential reduction of the garment's environmental impact.

2. *Functional unit & priorities/improvement form* is a tool of the ICSxClothing toolkit, available at www.lens-international.org, developed within the GIOTTO MIUR funded project, and described in detail within Vezzoli (2018).

3. ICS×Clothing is a toolkit for the application of Life Cycle Design approaches to clothes products, available at www.lens-international.org and based on the ICS Toolkit, presented in detail within Vezzoli (2018).

Finally, a synthetic visualization of environmental design priorities is suggested to be generated, e.g. through the *multi-strategy radar*, which can be directly connected to environmental indicators defined previously, within the ICS×Clothing toolkit.

Reference tools

- LCA software (e.g. OpenLCA, SimaPro, GaBi) [or];
- Checklist (ICS×Clothing toolkit), described within section 7.2.1.4 – A;
- Functional unit & priorities/improvement form & Radar (ICS×Clothing toolkit), described within section 7.2.1.4 – B.

7.1.1.2. *Clothing product concept design*

The general aim of this phase is to facilitate the generation of environmentally sustainable clothing ideas finalised to the definition of the most promising concept/s, as well as to evaluate the potential environmental improvement reached by the concept/s, in relation to the existing standard product analysed in the strategic analysis.

A first step is the brainstorming aimed at generating environmentally sustainable clothing product ideas through a dedicated workshop activity, in which identified environmental priorities can be kept as a supporting reference. Successively, ideas produced during the workshop are clustered, re-elaborated (combined, improved, etc.) and selected according to their potentiality to be the insights to design a concept.

As soon as one or more clothing concepts are developed, a sustainability check has to be undertaken in order to understand if and how the generated clothing solutions bring improvements in relation to the existing product. This can be done through a quantitative method (through a complete or simplified LCA on each concept) or a qualitative approach (evaluating the level of achievement for each strategy). In particular, the clothing concept must be firstly described in relation to its whole life cycle, in order to properly assess its environmental features. At this stage, thanks to LCA or qualitative results, it is possible to compare and visualize the improvement of concepts in relation to each other and to the existing product.

Reference tools

- Eco-idea boards (ICS×Clothing toolkit), described within section 7.2.1.4 – C;
- Life Cycle Exploded Diagram;
- LCA software (e.g. OpenLCA SimaPro, GaBi) [or];

- LCD strategies pursuit Evaluation (ICS×Clothing toolkit), described within section 7.2.1.4 – D;
- Multi-strategy Radar (ICS×Clothing toolkit), described within section 7.2.1.4 – E.

7.1.1.3. *Clothing product detailed design (and engineering)*

In the last stages of the design process, in which we get to the design detailing and engineering, the method implies the process of "the selection of the lowest environmental impact processes and project details", which can indeed be iterated several times.

While the project details start to be defined, until you get to the execution drawings, it is still possible to make environmental impact evaluations to select, among viable alternatives, the best material, the best production process, the best finishing, the best disposal treatment, etc.

The selection requires an environmental impact evaluation, typically and LCA, even simplified, giving results about alternative options.

Reference tools

- LCA software (e.g. OpenLCA, SimaPro, GaBi);
- LCD strategies pursuit Evaluation (ICS×Clothing toolkit), described within section 7.2.1.4 – D.

7.1.2. *Method for clothing System Design for Sustainability*

When a designer or a design team is engaged at the level of clothing Product-Service System design a method is here proposed with the aims of supporting and orienting the clothing system innovation development process towards win-win sustainability solutions. The proposed method is an adaptation and specification of the Method for System Design for Sustainability (MSDS)[4] to the clothing system. It is conceived for clothing/fashion designers and companies, but is also appropriate for public institutions, NGOs and other type of organisations. It can be used by an individual designer, by a wider design team or by a multidisci-

4. The MSDS Method is a result of more than 20 years of international research and didactics by the Learning Network on Sustainability (LeNS Network). Extended information can be retrieved from: Vezzoli *et al.* (2014).

plinary team facilitated by a designer. In all cases special attention has been paid to facilitating co-designing processes both within the organization itself (between people from different disciplinary backgrounds) and outside, bringing different socio-economic actors and end-users into design process.

The scope of the presented method is to support design processes for the development of clothing Sustainable Product-Service System (S.PSS). As the clothing MPDS, MSDS is characterized by a flexible modular structure so that it can easily be adapted to specific design requirements, diverse design contexts and conditions and usable in existing design procedures/practices. The users could be designers, design offices, designers within a company or organisation. All tools are open access and free to download at www.lens-international.org.

The clothing MSDS processes and tools can be integrated within typical stages of clothing Product-Service System design:

- clothing system strategic analysis;
- exploring clothing system opportunities;
- clothing system concept design;
- clothing system detailed design (and engineering).

Specific clothing System Design for Sustainability processes and aims related to each design stage, are described in detail within the following table:

Table 7.2 - The MSDS for clothing aims, processes and tools, in relation with the typical Product-Service System design stages

Clothing system design stages	**Method for clothing System Design for Sustainability**		
	Aims	**Processes**	**Tools**
Clothing system strategic analysis	To obtain the information necessary to facilitate the generation of sustainable clothing system innovation ideas	• Analysis of project proposers and outline the intervention context • Analysis of the context of reference • Analysis of the carrying structure of the system • An Analysis of cases of sustainable best practice • Analysis of sustainability of existing system and determine priorities for the design intervention in view of sustainability	• Checklist for the analysis of the existing system and priority set (SDOxClothing toolkit) • S.PSS Innovation Diagram x Clothing

Table 7.2 - continued

Clothing system design stages	Method for clothing System Design for Sustainability		
	Aims	**Processes**	**Tools**
Exploring clothing system opportunities	To make a "catalogue" of sustainability promising strategic possibilities for the clothing system	• Generation of sustainability-oriented ideas • Outline a design-oriented sustainability scenario	• Sustainable idea boards (SDO×Clothing toolkit) • SDOScenario Polarities× Clothing
Clothing system concept design	To design one or more clothing system concepts oriented towards sustainability	• Select clusters and single ideas • Develop clothing system concepts • Environmental, socio-ethical and economic qualitative check assessment	• S.PSS Innovation Diagram× Clothing • S.PSS Concept description form • Checklist for the system sustainability improvement evaluation (SDO×Clothing toolkit)
Clothing system detailed design (and engineering)	To develop the most sustainability promising system concept into the detailed version necessary for its implementation	• Detailed sustainability system design • Environmental, socio-ethical and economic qualitative check and visualisation	• System map for S.PSS • Stakeholders motivation and sustainability table • Interaction table • Stakeholders interaction storyboard • Satisfaction offering diagram • Checklist for the system sustainability improvement evaluation (SDO×Clothing toolkit) • Radar (SDO×Clothing toolkit)

Table 7.2 - continued

Clothing system design stages	Method for clothing System Design for Sustainability		
	Aims	**Processes**	**Tools**
Communi-cation	To draw up reports to communicate the sustainable characteristics of the system designed	• Draw up the documentation for communications of sustainability	• Animatic for S.PSS

7.1.2.1. *Clothing system strategic analysis*

The aim of this stage is twofold: on the one hand, it is to understand the existing situation and find out more about the project proposers, the socio-economic context of the clothing system in which they operate and the dynamics (socio-economic, technological, and cultural macro-trends) that influence that context and last but not least to analyse the unsustainability profile and critical areas of the existing clothing system; on the other hand, to process information by which to steer the designing process towards the generation of clothing system win-win sustainable promising solutions.

In particular, specific processes that characterise this stage are the following:

- analysis of project proposers and outline the intervention context;
- analysis of the context of reference;
- analysis of the carrying structure of the system;
- analysis of cases of sustainable best practice;
- analysis of sustainability of existing system and determine priorities for the design intervention in view of sustainability.

- ***Analysis of project proposers and outline of the intervention context***

The aim of the activity is to define the overall scope of the design intervention, or better the demand for well-being to be met (e.g. having clean clothes for the whole week or having the proper garment for a special occasion). This includes the definition of project proposers' characteristics in relation to the design intervention, i.e. their mission, expertise, value chain structure, strengths/weaknesses and opportunities/threads.

- ***Analysis of the reference context***

This process has the objective of analysing the socio-technical regime of which the designed solution will be part of. This means to define all the actors that belong to the reference production and consumption system, together with the relationships between them and the specific dynamics of the clothing system itself (e.g. regulations, technologies, culture etc.).

- ***Analysis of the carrying structure of the system***

It consists of the identification and analysis of macro-trends (social, economic and technological) that lie behind the reference clothing system context.

- ***Analysis of sustainable best practices***

The objective of this activity is to conduct a detailed analysis of clothing system cases of excellence that could represent a stimulus during the generation of ideas, although don't necessarily have to concern the area of intervention.

- ***Sustainability analysis of the existing system and definition of priorities for the design intervention***

This process aims at analysing the existing clothing system context from an environmental, socio-ethical and economic point of view, in order to identify design priorities, i.e. which are the most relevant areas of intervention to reduce the overall environmental impact, to improve social equity and inclusion and improve economic prosperity.

Reference tools for the overall clothing system strategic analysis

- Checklist for the analysis of the existing system (SDO×Clothing toolkit), described within section 7.2.1.1 – A;
- S.PSS Innovation Diagram×Clothing, described within section 7.2.1.2.

7.1.2.2. *Exploring clothing system opportunities*

Subsequently to the strategic analysis, the goal of this stage is to identify potential orientation for the development of promising clothing system solutions, through a process in which different system stakeholders could be involved to generate sustainable system ideas. Crucial matter at this stage is the adoption of a system innovation approach that is oriented toward radical improvements from an environmental, socio-ethical, and economic point of view. Two different processes characterize the exploring opportunities stage and are described below.

- ***Generation of sustainability-oriented ideas***

This process consists of a workshop session involving the one or more clothing system stakeholders, with the goal of generating sustainability-oriented system ideas. Fundamental elements should be considered in the planning and management of the workshop: i) As a very first step, the unit of satisfaction[5] to be met by the design intervention should be defined; ii) Ideas should be on a system level, i.e. defining an innovative offer model and the relative configuration of actors able to produce/deliver that offer; iii) Design guidelines toward sustainable system solutions and best practices should be adopted in the activity, to respectively steer the system idea generation process and provide additional stimulus to the activity.

- ***Outline a design-oriented sustainability scenario***

Ideas generated in the previous activity could be mapped out through a purpose-designed polarity diagram, which outlines a set of visions on how a context could evolve due to the occurrence of certain conditions (economical, regulatory and socio-cultural), i.e. a sustainability design-orienting scenario suggesting potential promising design orientation. In fact, a general clothing sustainability design-orienting scenario has been developed and is available as an operative tool[6]. Nevertheless, a context and clothing type specific scenario could be developed.

Reference tools for the overall stage of exploring clothing system opportunities

- Sustainable idea boards (SDOxClothing toolkit), described within section 7.2.1.1 – B;
- SDOScenario Polarities x Clothing, described within section 7.2.1.3.

7.1.2.3. *Clothing system concept design*

Given the set of ideas and clusters that emerges from the exploration of opportunities (as well as the general available scenario or a specific one developed), the goal of this stage is to select the most promising ones through a process that may involve one or more clothing system stakeholders (in a participatory design process) and to develop them into clothing

5. The unit of satisfaction is the combination of clothing wear and care, i.e. the system of products and services jointly capable of achieving such a final user satisfaction (see chapter 6).

6. See section 6.3 chapter 6 (developed scenario) and section 7.2.1.3 of this chapter (tool description).

system concepts. This means to define – for each cluster or idea – the set of products and services concepts that makes the offer up, as well as to define the actors and their mutual interactions in relation to the innovative production and use innovation.

The developed draft system concepts are then assessed in relation to their potential improvement from an environmental, socio-ethical and economic point of view, in order to solve possible issues in advance to a detailed design or to analyse which is the most promising, using proper evaluation tools (check table 7.1).

Reference tools

- S.PSS Innovation Diagram x Clothing, described within section 7.2.1.2;
- S.PSS Concept description form, described within section 7.2.2.1;
- Checklist for the system sustainability improvement evaluation (SDO×Clothing toolkit), described within section 7.2.1.1 – C.

7.1.2.4. *Clothing system detailed design (and engineering)*

This stage has the goal of detailing the clothing system concept at the point of enabling its actual implementation. Other than precisely defining the set of products and services that makes up the offer as well as all the actors involved in the clothing system with their mutual interactions, this stage requires: i) the outlining of all the interactions between actors and client/end users that occur during delivery of the offer; ii) all the elements (both material and non-material) required for delivery of the offer and who will design/produce/deliver them.

Reference tools

- System map for S.PSS, described within section 7.2.2.2;
- Stakeholders motivation and sustainability table, described within section 7.2.2.3;
- Interaction Table, described within section 7.2.2.4;
- Stakeholders interaction storyboard, described within section 7.2.2.5;
- Satisfaction offering diagram, described within section 7.2.2.6;
- Checklist for the system sustainability improvement evaluation (SDO×Clothing toolkit), described within section 7.2.1.1 – C;
- Radar (SDOxClothing toolkit), described within section 7.2.1.1 – D.

The following paragraphs provide a detailed description of general and specific tools that have been developed to support the designer along the

clothing product and the clothing Product-Service System design process that has been described so far.

7.2. Tools for clothing product and PSS design

This section describes several tools that may be used to support the various stages of the presented methods, i.e. to design environmentally sustainable clothing products and/or Product-Service Systems (S.PSS).

In particular, the following paragraph (7.2.1) goes through a detailed description of tools specifically developed for the clothing sector to support the design of more sustainable product and/or product-service system. Other useful general tools that may be openly adapted to the clothing sector are introduced as well in the last section of this chapter (7.2.2).

7.2.1. *Specific tools for clothing system design for sustainability*

The tools presented in the following section have been specifically developed in relation to the clothing system throughout a set of different research projects carried out by LeNSlab Polimi[7].

Therefore, this section of the book is to help potential fashion designers and students, fashion companies, NGO, or interested organizations to apply in practice the tools to support the design for environmentally sustainable clothing system. Each tool is described using the following structure:

- the aim;
- the components of the tool (what it consists of);
- tool's integration into the method for sustainable clothing system design;
- how to use the tool in the design process;
- availability and resources required to use the tool.

Four clothing-specific tools are presented in the following sub-paragraphs.

7. Particularly relevant has been the research project *The Circular Economy for the competitiveness of Made in Italy industry – GIOTTO*, funded by the Italian Ministry of Education and Research (MIUR), gathering eleven national partner organizations with the aim of developing and disseminating innovative design tools to foster and implement a sustainable and circular economy within competitive value chains of Made in Italy i.e. furniture, food and fashion.

7.2.1.1. *Sustainability Design Orienting (SDO)×Clothing Toolkit*

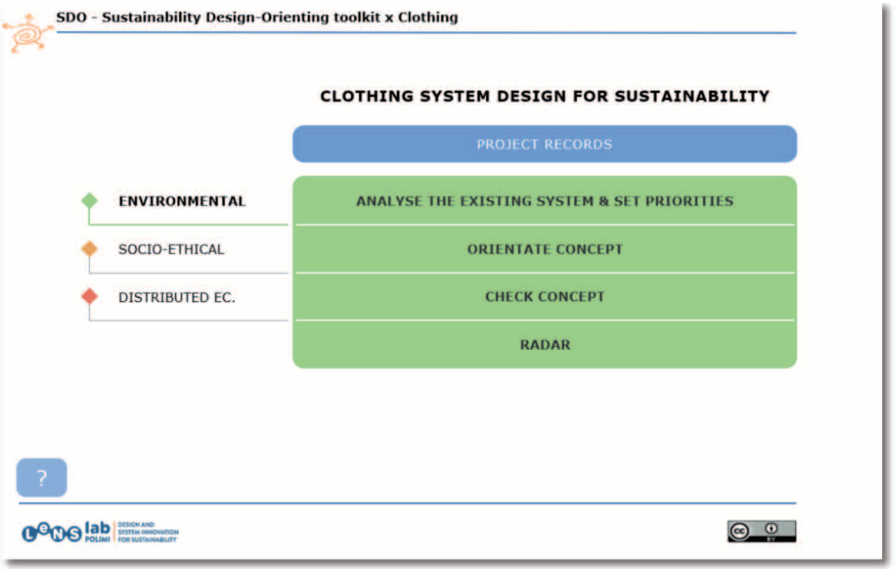


Fig. 7.2 - Main menu of the SDOxClothing Toolkit

Aims

The toolkit aims at guiding the system design process towards clothing S.PSS solutions from an environmental point of view with the possibility of exploring also the socio-ethical dimension of sustainability and potential distributed offer configurations (indeed, these two latter parts of the tool have not been made specific for the clothing system, although they may be openly adapted).

This happens thanks to the different functions within the toolkit, which is made to support designers in: qualitatively analysing the existing system unsustainability and setting sustainability design priorities; using sustainable idea generation boards with design-orienting guidelines and related best practices; checking and visualising the potential sustainability improvements in relation to an existing reference system.

In fact, the SDO toolkit is able to support several design processes, by having a modular structure so that it can be used in all its tools or just with some of them, according to the special needs and circumstances of each design project.

The specific aims of the tool are here explained in detail:

- to analyse qualitatively the unsustainability of the existing (reference) system and then to define the design priorities for both of the envi-

ronmental and the socio ethical sustainability dimensions (e.g. for the environmental dimension, to ascertain whether it is more important to optimise the life of the system, or to reduce resources, etc.). This is done by using a set of checklists to analyse the existing system (SDO section: "Analyse the existing system & Set Priorities");

- to stimulate the generation of ideas for potentially sustainable systems. This is done by using a set of idea generation boards with design strategies, guidelines and best practices oriented towards sustainability (SDO section: "Orientate Concept"). In particular, the specific strategies to generate clothing system ideas for the environmental dimension are the following (described in detail within Chapter 6):
  - clothing system life optimisation;
  - reduce the transportation/distribution in the clothing system;
  - minimise resource consumption in the clothing system;
  - minimisation/valorisation of waste from the clothing system;
  - resource conservation/biocompatibility in the clothing system;
  - reduce the toxicity in the clothing system;
- to assess potential improvements, or any worsening, associated with both the environmental and the socio-ethical dimensions of sustainability compared to the existing system. This is done by using a set of checklists per each of the strategy to compare the designed solution and the existing system, and radar diagrams to visualise the results of the analysis (SDO section: "Check Concept" and "Radar").

What it consists of

The SDO is based on a spreadsheet file that integrates different tools and allow to navigate through them. In particular, for both the environmental and the socio-ethical dimensions of sustainability (although socio-ethical tools are not specifically adapted for the clothing system), the toolkit includes:

- six boards (one per each strategy) with checklists for the existing system qualitative sustainability analysis and the successive prioritisation of sustainability strategies;
- six boards (one per each strategy) to generate sustainability-focused system ideas with the support of best practices;
- six boards (one per each strategy) with checklists to assess the sustainability improvement/worsening of developed system concept/s;
- a single summary board to visualise the sustainability improvement/worsening of developed system concept/s, as well as to report.

As previously mentioned, the toolkit allows to explore also potential distributed offer configurations, through a set of six boards (one per each distributed offer strategy) to generate sustainability-focused system ideas.

Integration of the SDOxClothing toolkit within the MSDS method

The toolkit can be integrated within multiple stages of the MSDS method: a) during the system strategic analysis, to evaluate the system unsustainability and define sustainability priorities; b) within the exploration of system opportunities, to facilitate the generation of sustainability-focused ideas; c) when designing the system concept, in order to cluster, refine and select most promising ideas; d) during both the system concept and detailed design, to qualitatively evaluate and visualise the improvement in terms of sustainability.

How to use the SDOxClothing Toolkit

The following describes how to use the toolkit, with reference to the stages of the MSDS methodology.

- **Setup**

Firstly, login into www.lens-international.org and download the "SDO×Clothing" toolkit from the "Tools" section. When opening the downloaded file, the homepage interface is visualized. As a preliminary step, click on the 'Project record' button and fill-in your project data (Fig. 7.3).

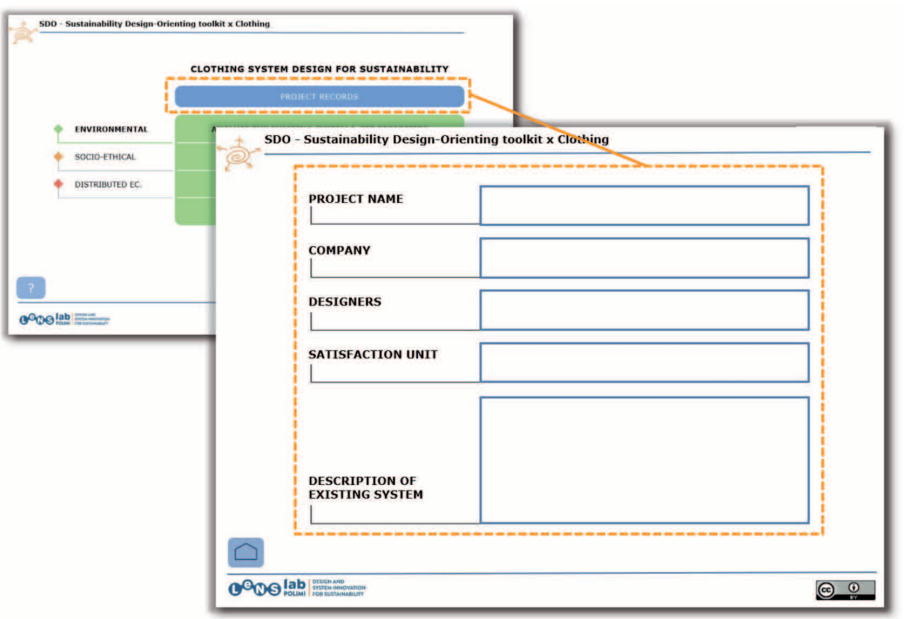


Fig. 7.3 - The SDO×Clothing Toolkit's first page after opening

The use of the SDOxClothing Toolkit in relation to different processes is described below:

- A: existing system qualitative sustainability analysis and prioritisation of sustainability strategies;
- B: generate sustainability-focused idea with the support of existing best practices;
- C: check/visualise sustainability improvement/worsening of developed concept/s.

A: existing system qualitative sustainability analysis + prioritisation of sustainability criteria/guidelines

Select the sustainability dimension to work on and click, e.g. environment (Fig. 7.4). Successively, start from "analyse & set priorities".

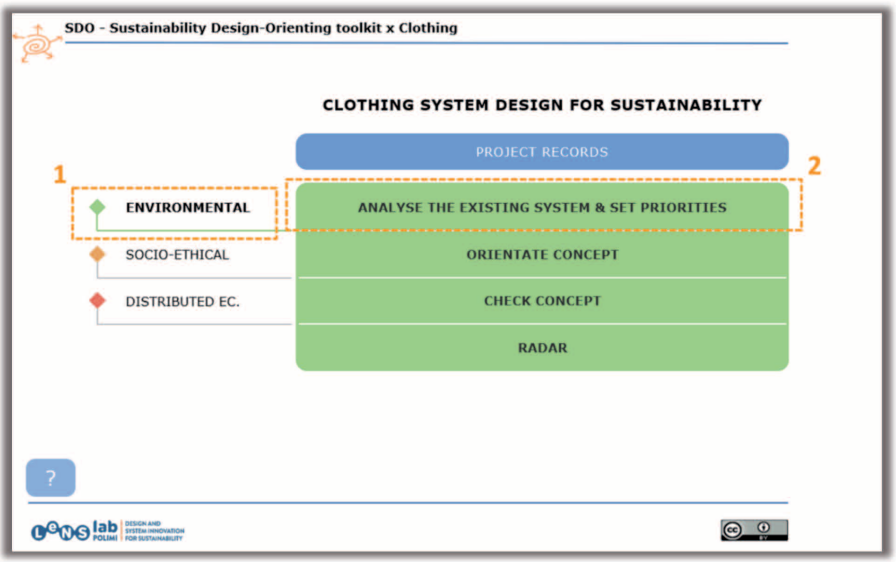


Fig. 7.4 - Selection of the sustainability dimension to work on (1) and start from the analysis of the existing system (2) (SDO×Clothing Toolkit)

For each strategy (Fig. 7.5), visualize one by one the evaluation checklist (1) and give respective answers (2), in order to evaluate the existing clothing system. When this evaluation is made for all of the six strategies it is possible to define the relative priorities among them: no, low, medium or high. This is made by using the pop-up window above the text box (3).

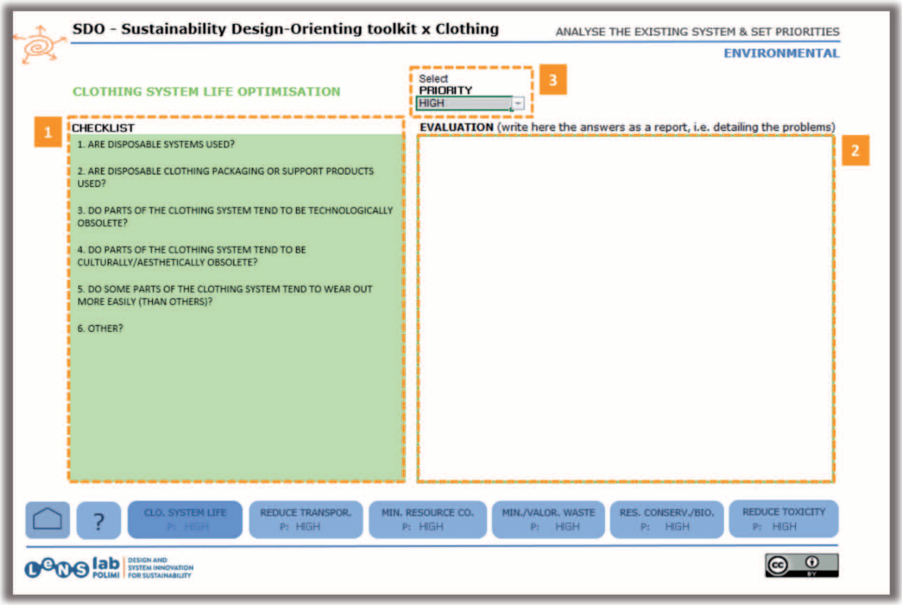


Fig. 7.5 - Existing system (environmental) analysis and priorities setting (SDO×Clothing Toolkit)

B: generate sustainability-focused system ideas

The objective of clothing S.PSS Idea Boards (Fig. 7.6) is to support designers in generating system ideas.

To do so, a series of design guidelines can be used for each strategy, as a support and stimulus. Within the SDO×Clothing, in the menu on the left, select a sustainability dimension (i.e. environmental, socio-ethical and distributed economy) and click on "Orientate Concept". As previously mentioned, strategies and guidelines for the environmental dimension are specifically adapted for the clothing system, while socio-ethical and distributed economy ones are generally referred to any system typology (and may be adapted by the user).

At the lower menu, six design strategies appear in six blue boxes where it is possible to see the priorities assigned during the analysis of the existing system (only for the environmental and socio-ethical dimensions[8]),

8. Indeed, the Distributed Economy dimension is supposed to be functional to other ones, without direct connection with specific sustainability impacts to be assessed.

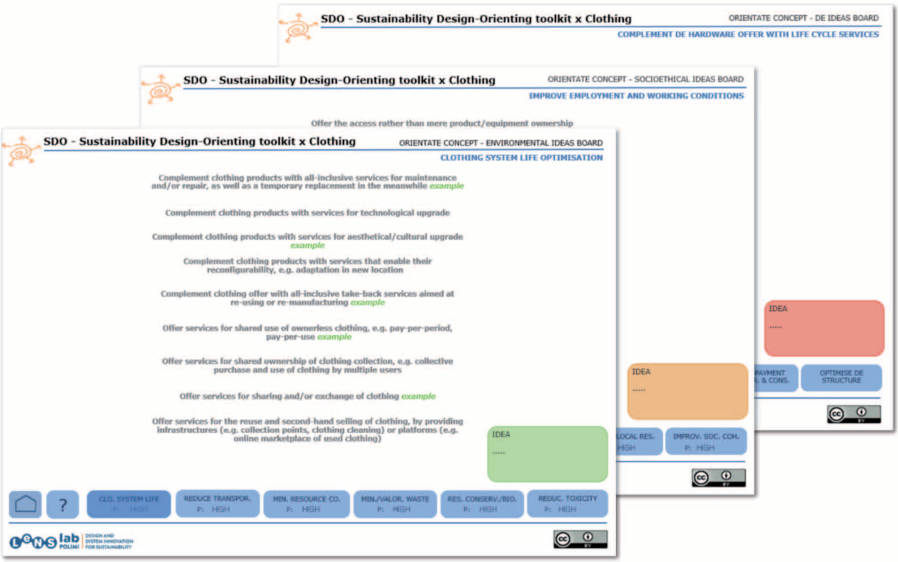


Fig. 7.6 - Idea Boards for clothing S.PSS (SDO×Clothing toolkit)

with a set of corresponding guidelines and links to some inspirational real case examples. These guidelines stimulate the generation of clothing system ideas, which can be noted on the digital 'post-its' to be found at the sides of the screen. Obviously, as mentioned, the idea generation session must give more attention/time to the strategies with the highest priorities. For example, if "resource reduction" is a high priority, the designer should start with the idea board referring to this strategy, getting inspiration from the related guidelines and examples. At the same time, if "transportation/distribution reduction" has a low priority, less attention will be given to it.

In practice (Fig. 7.7), select one by one the idea boards (one for each strategy) (1). Then, read the clothing-specific guidelines (a set for each strategy) (2) and check guideline's links to examples available on lens-international.org to have further inspiration (3). Additional info on the case related to the specific guideline can be accessed directly on lens-international.org (4). Finally, digital post-its can be used to describe emerged system ideas (for each criterion) (5).

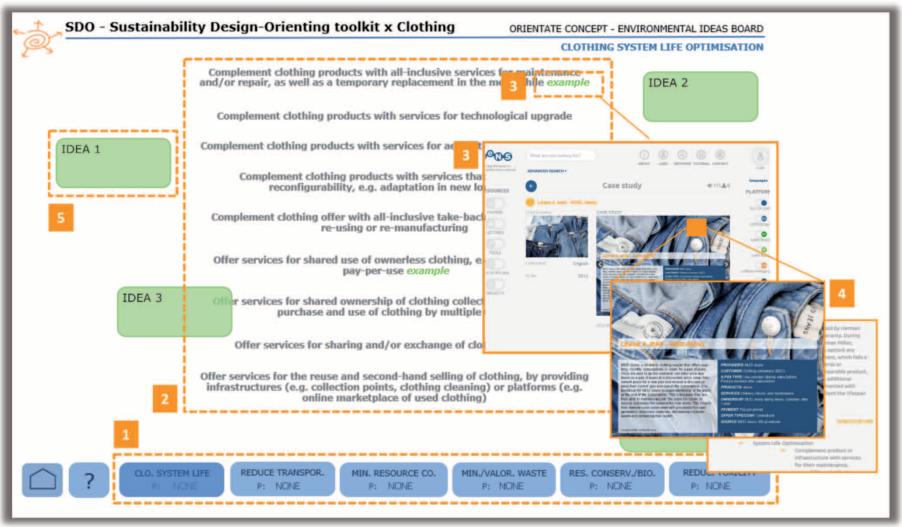


Fig. 7.7 - Orientation and generation of sustainable clothing system ideas using the Idea boards (SDO×Clothing Toolkit)

C: check/visualise sustainability improvement/worsening of the concept/s

The aim is to analyse the clothing system concept to identify its potential improvements over the existing system. Select a sustainability dimension (e.g. environment) and click on "Check Concept". In reference to the provided checklist for each strategy (Fig. 7.8), answer the questions (1) through the specific text box (2). Answering the checklists helps to identify the improvements offered by the designed clothing system solution over the existing one. For each strategy it is possible to select (3): radical improvement (++), incremental improvement (+), no significant change (=), or worse (–). The selected improvement rate is then automatically visible on each strategy button.

By opening the "Radars" section (Fig. 7.9) on the home menu and selecting the desired sustainability dimension (1) it is possible to visualise the potential improvements of the concept in relation to the initial system, for each strategy. Again, the key elements of the solution can be written in the text boxes (2).

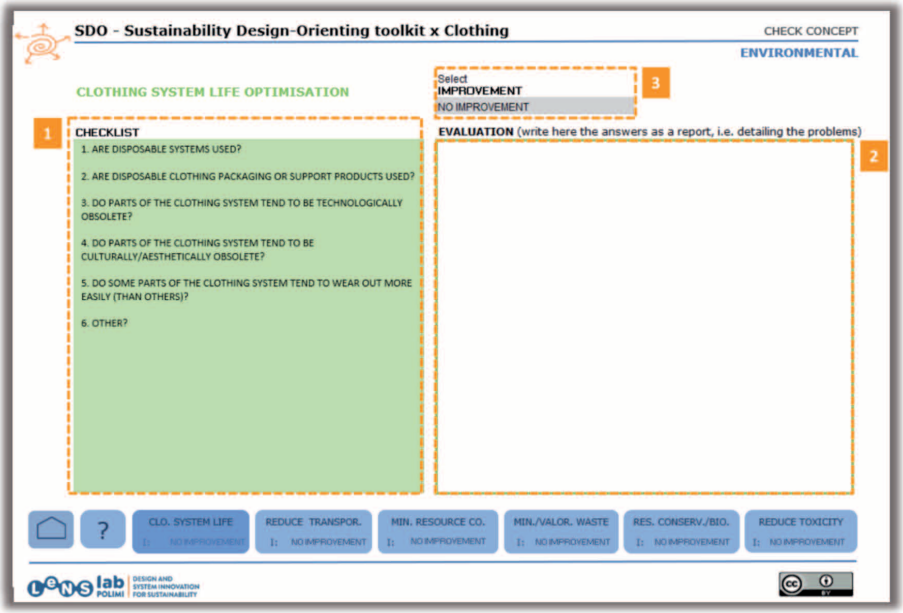


Fig. 7.8 - Checklist to evaluate the sustainability improvement/worsening of the concept/s (SDO×Clothing Toolkit)

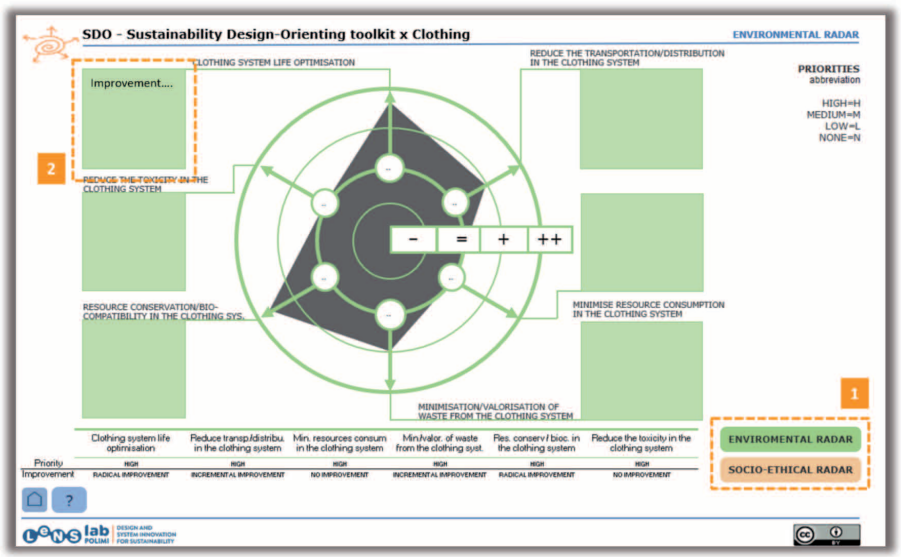


Fig. 7.9 - Environmental Radar diagram (SDO×Clothing Toolkit)

Availability and requested resources for the SDO×Clothing Toolkit

The SDO×Clothing Toolkit is open access and can be downloaded for free from www.lens-international.org ("Tools" section). A spreadsheet reader is needed to use the tool. As regards timing, the sustainability evaluation activity can take from 45 to 90 minutes; Idea Boards are required from 60 to 180 to complete. The check of progress can take from 30 to 60 minutes.

7.2.1.2. *Innovation Diagram×Clothing S.PSS*

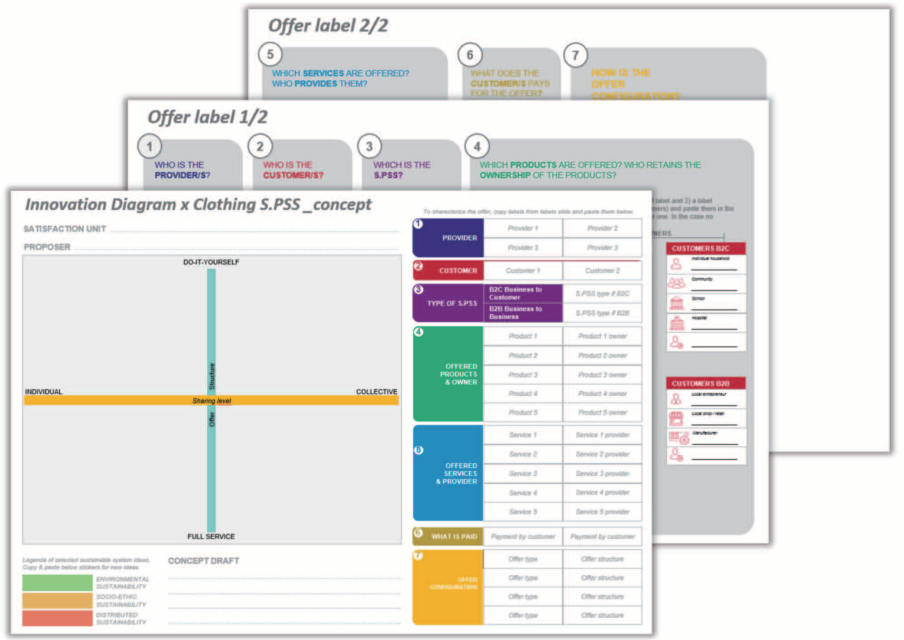


Fig. 7.10 - Innovation Diagram×Clothing S.PSS

Aims

The objective of the *Innovation Diagram×Clothing S.PSS* (Fig. 7.10) is to: a) position and characterize existing offers; b) map the strategic positioning of competitors; c) select promising clothing system sustainability ideas and help achieve a new concepts profiling.

What it consists of

The diagram consists of:

- polarity diagram concept profile;

- digital post-it;
- repository of labels.

Integration into the MSDS design process

The Innovation Diagram×Clothing S.PSS can be used at various stages of the clothing design process.

- In the "**Analysis of the project promoters and the reference context**" (part of the system strategic analysis stage) it can be used to analyse the current offer and the related competitors' offers to orientate promising ideas.
- In the "**Visions, clusters and ideas selection and System concept development**" (part of the system concept design stage) it can used to select, map, and cluster most promising ideas and create the profile and the clothing S.PSS concept.

How to use the Innovation Diagram×Clothing S.PSS

After opening the tool (based on a slideshow file), the first step is to open the "Innovation Diagram×Clothing S.PSS_existing offer" slide. Here the designer can work to position an existing offer (Fig. 7.11). From

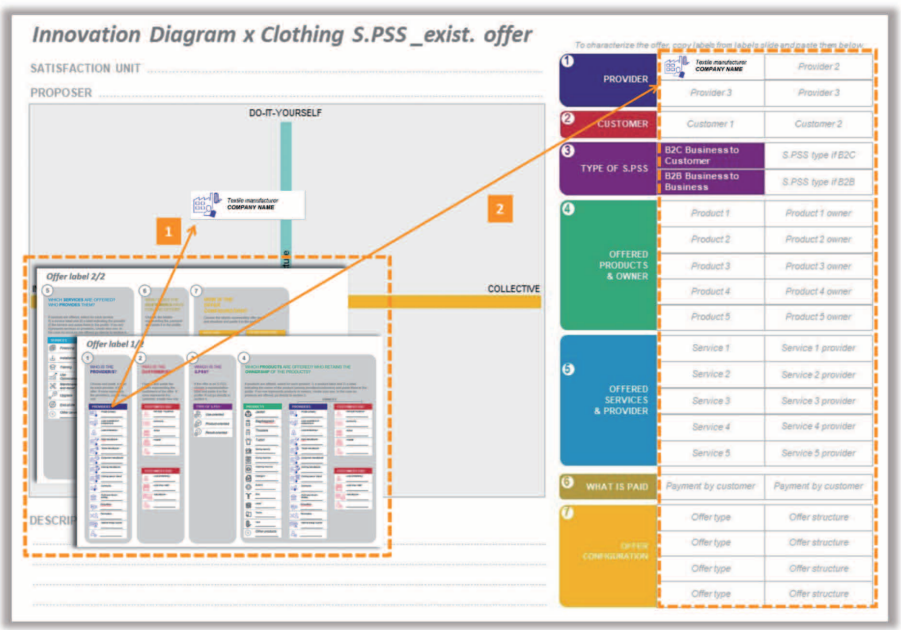


Fig. 7.11 - The clothing existing offer slide of the Innovation Diagram×Clothing S.PSS

the repository slides, select the company/organisation icon (1) and add the specific company name to adapt the general one. Successively, paste the label in the diagram and in the characterisation table on the right (2).

The following step is to characterize the existing offer by specifying all of the following (Fig. 7.11 – 2):

- **type of provider (1).** Select the company/organisation icon and write the specific name to adapt the general one. Place in the provided section and write the company name in the free space on the label;
- **type of customer (2).** Select customer/s (B2B – B2C) icon/s and add a specific name to adapt the general one; then place it in the customer section;
- **type of PSS (3).** Select the S.PSS type of the offer (if any): PRODUCT-ORIENTED, USE-ORIENTED, RESULT-ORIENTED and place it in the S.PSS type section (remembering that not all offers are already S.PSS).
- **products/ownership (4).** Select the product icon the company offers and paste in the products section. Select who retains the clothing product OWNERSHIP (provider or customer) and place the label in the provider/customer label;
- **services/providers (5).** Select the service icon the company offers and paste in the service section. Select who provides the service and place the label in the provider label;
- **what is paid (6).** Select the icon describing what is paid by the customer/s and place the label in the payment section;
- **offer configuration (7).** Select the offer type icon and paste it in the Offer type space. Select its structure icon and place it in the nearby space.

The same process made to characterize the existing offer, could be done in relation to competitors, by moving to the "Competitors" slide.

The Innovation diagram×Clothing S.PSS is also meant to be used in combination with other tools. Indeed, in the "Concept" section (Fig. 7.12), it can be used in order to select and position promising ideas designed with Idea Boards from the SDO toolkit[9].

9. Check the tool in the previous section (7.2.2).

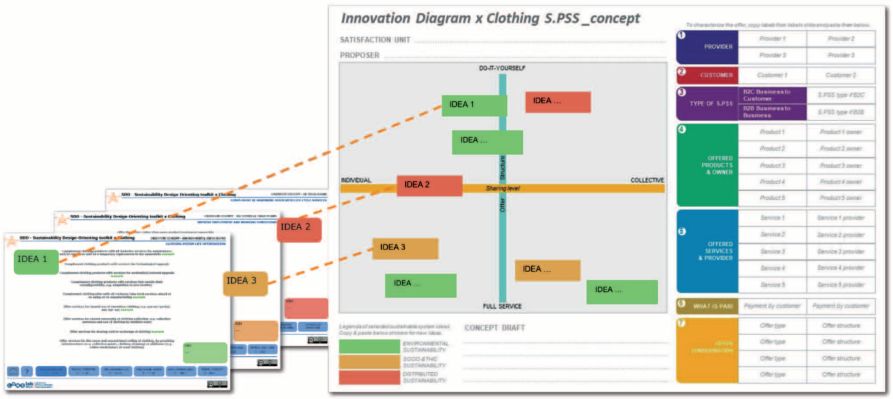


Fig. 7.12 - Concept section: positioning of ideas generated through the idea tables within the S.PSS Innovation Diagram×Clothing

Then, the following steps (Fig. 7.13) are: the generation of new ideas spotting the areas that are left empty (1), the identification and clustering of those ideas that can be combined to draft the system concept (2) and the writing of a text (max 200 characters) drafting the preliminary system concept (3).

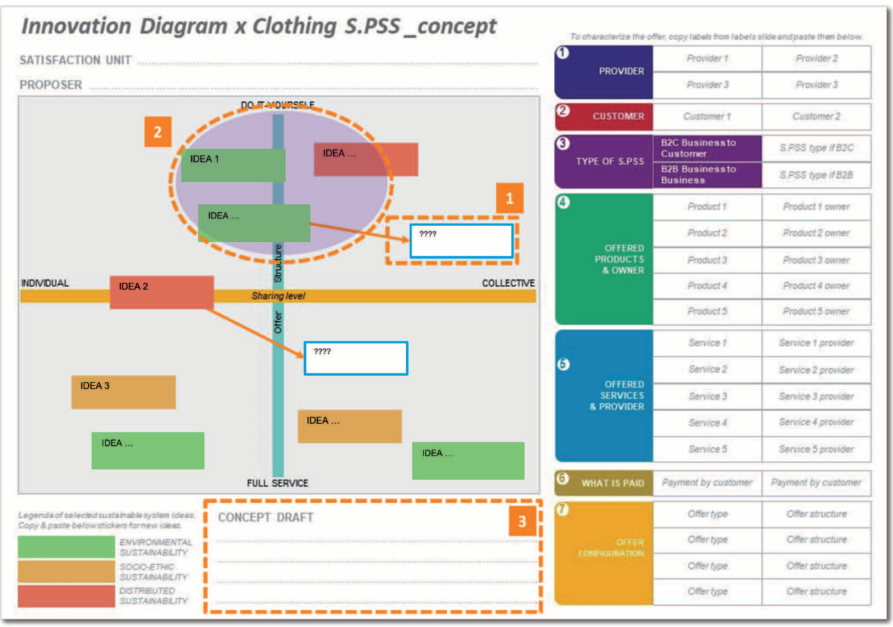


Fig. 7.13 - Idea generation, idea clustering, and system concept drafting through the concept slide of the Innovation Diagram×Clothing S.PSS

Finally, the clothing S.PSS draft concept can be profiled in its offer (provider, customer, etc.) by copying and pasting characterizing icons from the tool repository (Fig 7.14).

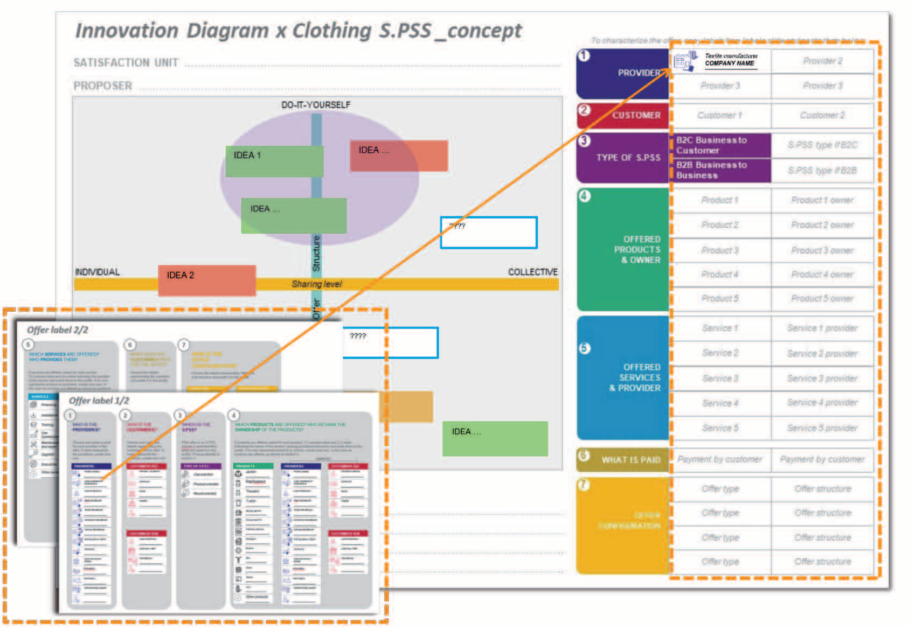


Fig. 7.14 - Profiling clothing S.PSS draft concept

Availability and requested resources

The Innovation Diagram×Clothing S.PSS is an opensource file that can be downloaded for free from www.lens-international.org, "Tools" section. A computer and a slideshow reader are needed to access the tool. This tool requires at least:

- 15 minutes to position an existing offer;
- 30 minutes to characterize the existing offer;
- 45 minutes to generate, cluster and describe ideas.

7.2.1.3. *Sustainability Design-Orienting Scenarios (SDOS)× Clothing S.PSS*

Fig. 7.15 - SDOS×Clothing S.PSS

Aims

The objective of *Sustainability Design-Orienting Scenarios (SDOS)× Clothing S.PSS* (Fig. 7.15) is to orient the design process towards sustainable clothing system solutions by using immersive and inspiring scenario videos to stimulate the generation of clothing S.PSS ideas.

What it consists of

The *Sustainability Design-Orienting Scenarios×Clothing S.PSS* consists of a polarity diagram that outlines four visions, each of which is described by a video.

Integration into the MSDS design process

The *SDOS×Clothing S.PSS* is used in "Ideas generation oriented to sustainability" to stimulate the generation of clothing S.PSS ideas.

How to use the SDOS×Clothing S.PSS

The tool is used in two simple steps.

Firstly, after downloading the *SDOS×Clothing S.PSS* from www.lens-international.org, open it and play the four videos of the four visions, to get design inputs through sample stories (Fig. 7.16).

Fig. 7.16 - The main page of the SDOS x Clothing S.PSS tool (top) and 4 visions

Availability and requested resources

The *SDOS×Clothing S.PSS* tool is an open-source tool that can be downloaded for free from www.lens-international.org, "Tools" section. A computer, a PDF reader, and Internet connection are required to access the tool. The tool may be used by a single designer, though the support of a multi-disciplinary team is preferable. It requires at least 15 min. to explore and get inspired by the proposed visions.

7.2.1.4. *ICS×Clothing Toolkit*

Aim of the ICS×Clothing Toolkit

The main objective of the ICS×Clothing Toolkit is to guide the design process from the early stages of clothing product development toward environmentally sustainable choices.

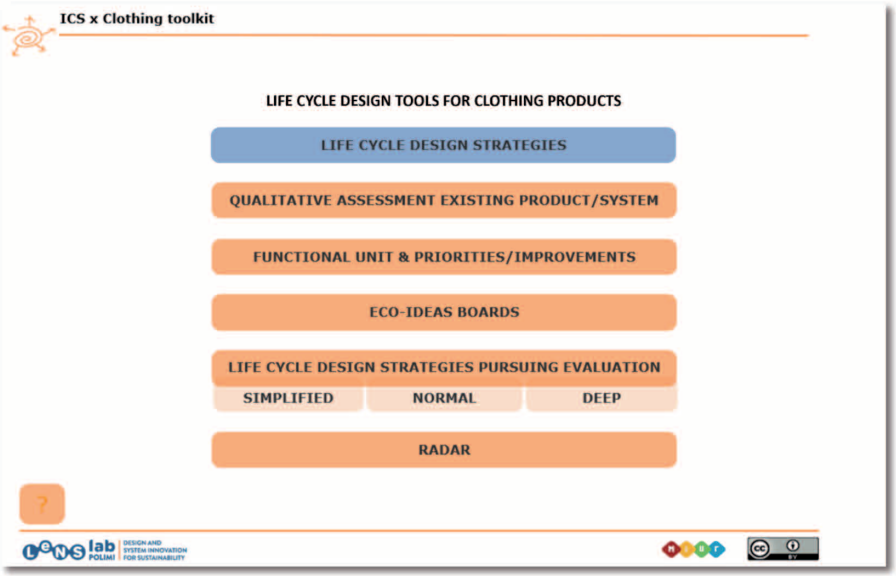


Fig. 7.17 - The ICS×Clothing toolkit homepage

What it consists of

The toolkit consists of a single navigable spreadsheet file that embeds the following six tools, namely **checklist for existing product evaluation; Functional unit & priorities/improvement form; eco-ideas boards (guidelines); checklist for LCD strategies pursuit evaluation; multi-strategy radars**.

The tools have specific objectives and characteristics, depending on the design stage in which they are meant to be integrated. In the following paragraphs, tools are described in relation to their aim and use mode, as well as the way in which they can be integrated in the design process.

A – Checklist for the existing clothing product evaluation

Aim

The tool aims at evaluating the environmental impact of an existing clothing product, using a qualitative approach based on the support of a set of checklists. Consequently, the final goal is to identify the level of priority to assign to each of the six clothing Life Cycle Design strategies.

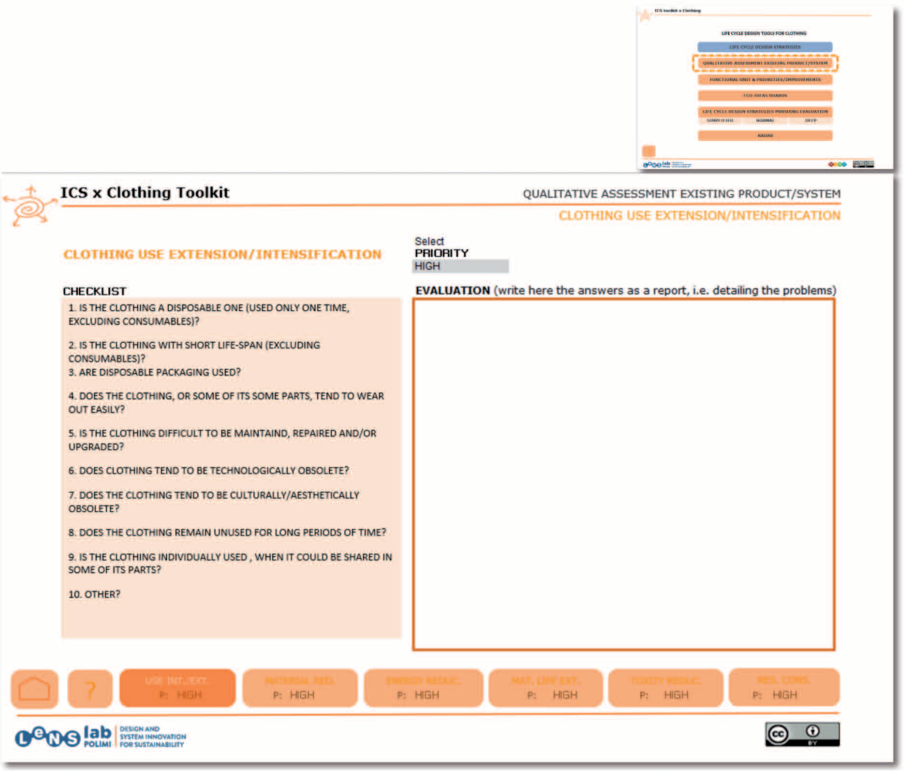


Fig. 7.18 - Access to the checklist for the existing clothing product evaluation (ICS×Clothing toolkit)

How to use it

After accessing the tool through the first button on the main menu, a first step to use it is a list of questions (Fig. 7.19) – i.e. the checklist (1) – to be answered for each of the LCD strategy using the writing area. This aims at identifying environmental problems and enabling a comprehensive detailed overview on how the impact is allocated. Consequently, the evaluation can be carried out for each strategy and the level of priority can be defined (3) through a pre-determined scale: High, Medium, Low or No priority.

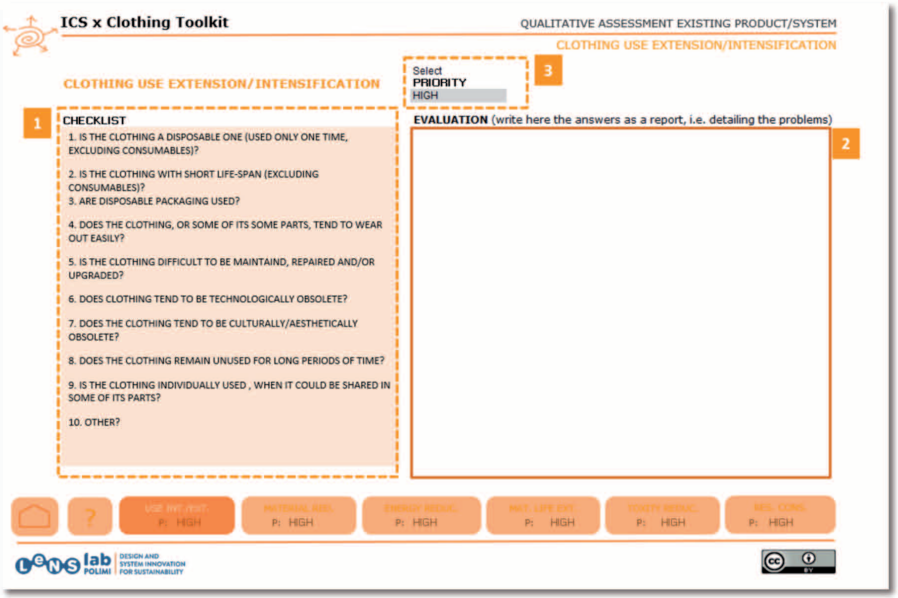


Fig. 7.19 - Checklist for the existing clothing product evaluation (ICS×Clothing toolkit)

Integration into the MPDS design process

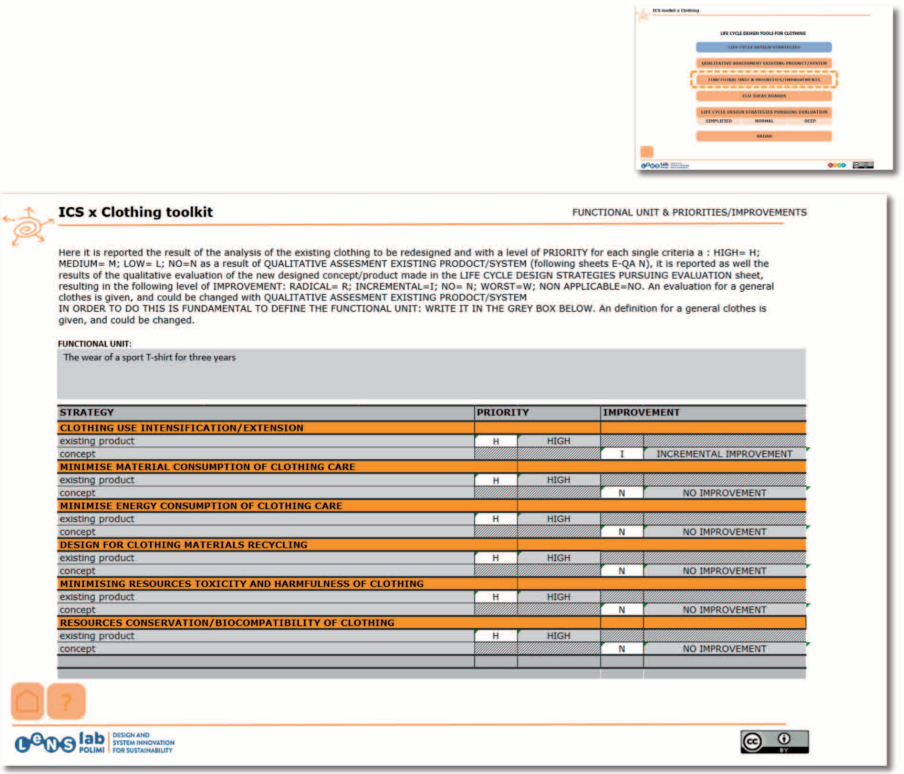
The checklist is supposed to be applied in the early stages of the clothing product design process, as part of the product strategic analysis. In particular, it applies in the definition of the environmental design properties.

B – Functional unit & priorities/improvement form

Aim

A first objective of the *functional unit & priorities/ improvement form* is to define the functional unit of the clothing product to be designed. In fact, the given general functional unit "The clothing wear for one year" could be specified in relation to the type of clothes and the context of use. A second aim is to show which LCD strategies are mostly relevant for clothing product to be designed, visualizing the priority indicators that have been defined in the "Checklist for Existing Product Evaluation". In fact, the given general clothing LCD priorities could be specified in relation to the functional unit, i.e. the specific type of clothing product to be designed. Finally, the tool aims at visualizing the levels of improvement introduced by the developed concept in relation to the existing garment for

each LCD strategy, that are defined by using the "checklist for LCD strategies pursuit evaluation".



ICS x Clothing toolkit FUNCTIONAL UNIT & PRIORITIES/IMPROVEMENTS

Here it is reported the result of the analysis of the existing clothing to be redesigned and with a level of PRIORITY for each single criteria a : HIGH= H; MEDIUM= M; LOW= L; NO=N as a result of QUALITATIVE ASSESMENT EXISTING PRODOCT/SYSTEM (following sheets E-QA N), it is reported as well the results of the qualitative evaluation of the new designed concept/product made in the LIFE CYCLE DESIGN STRATEGIES PURSUING EVALUATION sheet, resulting in the following level of IMPROVEMENT: RADICAL= R; INCREMENTAL=I; NO= N; WORST=W; NON APPLICABLE=NO. An evaluation for a general clothes is given, and could be changed with QUALITATIVE ASSESMENT EXISTING PRODOCT/SYSTEM
IN ORDER TO DO THIS IS FUNDAMENTAL TO DEFINE THE FUNCTIONAL UNIT: WRITE IT IN THE GREY BOX BELOW. An definition for a general clothes is given, and could be changed.

FUNCTIONAL UNIT:
The wear of a sport T-shirt for three years

STRATEGY	PRIORITY		IMPROVEMENT	
CLOTHING USE INTENSIFICATION/EXTENSION				
existing product	H	HIGH		
concept			I	INCREMENTAL IMPROVEMENT
MINIMISE MATERIAL CONSUMPTION OF CLOTHING CARE				
existing product	H	HIGH		
concept			N	NO IMPROVEMENT
MINIMISE ENERGY CONSUMPTION OF CLOTHING CARE				
existing product	H	HIGH		
concept			N	NO IMPROVEMENT
DESIGN FOR CLOTHING MATERIALS RECYCLING				
existing product	H	HIGH		
concept			N	NO IMPROVEMENT
MINIMISING RESOURCES TOXICITY AND HARMFULNESS OF CLOTHING				
existing product	H	HIGH		
concept			N	NO IMPROVEMENT
RESOURCES CONSERVATION/BIOCOMPATIBILITY OF CLOTHING				
existing product	H	HIGH		
concept			N	NO IMPROVEMENT

Fig. 7.20 - Access to the functional unit & priorities/ improvement form (ICS×Clothing toolkit)

How to use it

In other words, the *functional unit & priorities/ improvement form* (Fig. 7.21) is supposed to be used as the place where the functional unit can be defined (1) and as a consultation board, placing automatically side by side the environmental priorities (2) defined in the early stages of the design process (High, Medium, Low or No) and the levels of potential improvement (Radical, Incremental, None or Worsen) brought by the clothing concept in relation to each LCD strategy (3). The visualized rate of improvement depends also on the adopted level of accuracy that has been chosen for the concept evaluation (simplified, normal or deep), which is defined in the radar page (check paragraph D).

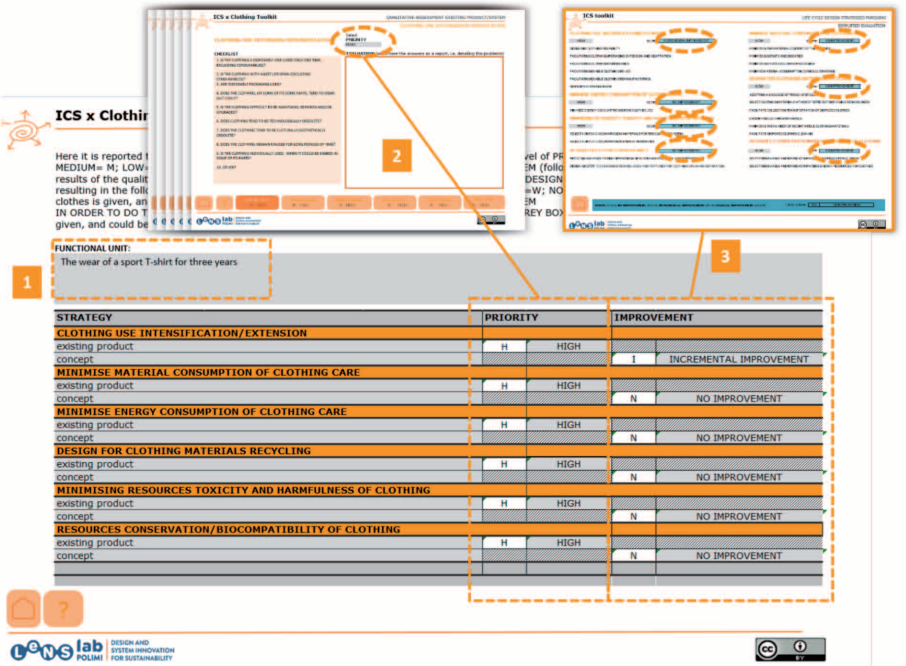


Fig. 7.21 - The main parts of the functional unit and priorities/ improvement form (ICS×Clothing toolkit)

Integration into the MPDS design process

The *functional unit and priorities/improvement form* is meant to be used both in the early stages (strategic analysis/design brief) within the process of environmental priorities definition or during the clothing concept development, to check the environmental improvement of the concept in relation to priorities and eventually engage a new stage of idea generation focused on those LCD strategies showing a worsening or without a satisfying improvement level (with the "eco-idea boards").

C – Eco-idea boards (containing clothing LCD guidelines)

Aim

The eco-idea boards aim at facilitating the generation and collection of ideas focused on clothing environmental sustainability. The tool consists of seven tables – one for each LCD strategy – containing an indication of the previously appointed priorities as well as specific guide-

lines and examples related to the strategy, to stimulate and guide the generation of environmentally sustainable ideas.

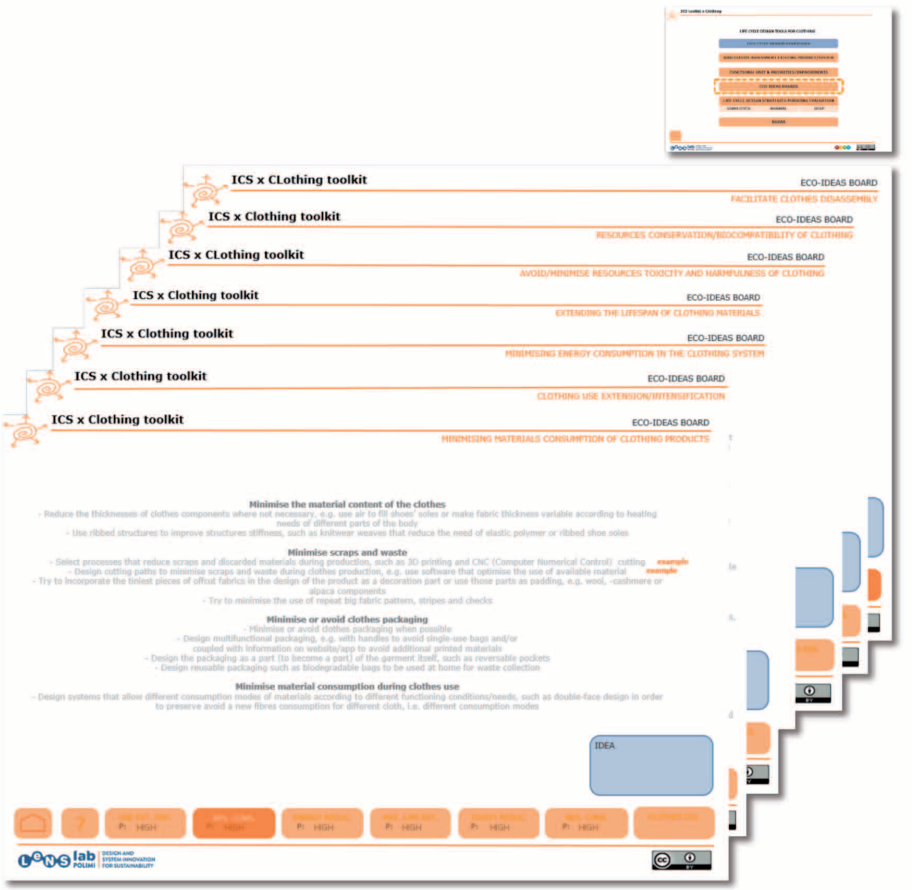


Fig. 7.22 - Access to the Eco-idea boards (ICS×Clothing toolkit)

How to use it

To properly use the idea boards (Fig 7.23), a first step is to set and read the available clothing design guidelines for a selected strategy (1). Successively, available "digital post-its" can be used to write down ideas oriented toward environmental sustainability (2). Links to examples from the repository on lens-international.org are also available, in order to take further inspiration (3). Detailed information on the case related to the specific guideline can be accessed directly on lens-international.org (4).

The process is supposed to be repeated for all the available seven LCD strategies, having always displayed the priority allocated with the checklist for the existing product evaluation (5).

As can be imagined, eco-idea boards can be use by both individual designers or teams, as long as the tool is accessible from multiple users.

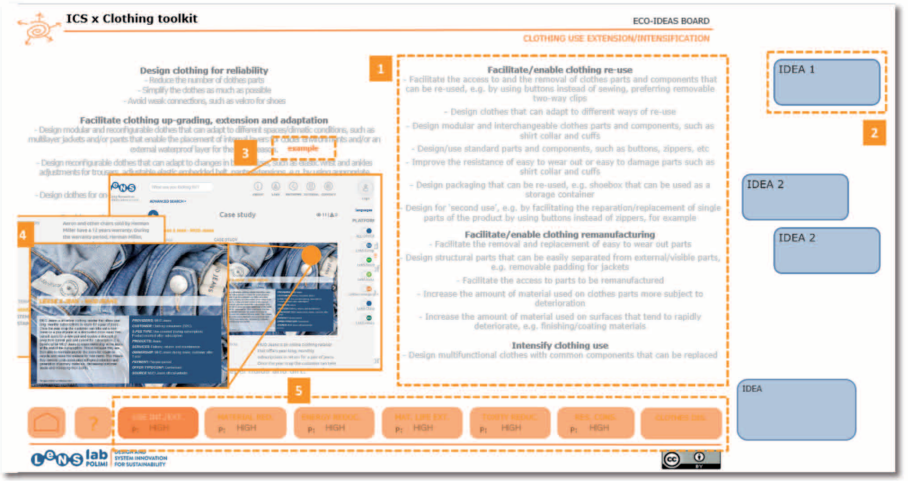


Fig. 7.23 - How to use the Eco-idea boards (ICSxClothing toolkit)

Integration into the MPDS design process

The eco-idea boards can be considered as a tool to facilitate brain-storming and thus suitable for the idea generation process within the clothing concept design stage.

D – Checklist for LCD strategies pursuit evaluation (simplified / normal / deep)

Aim

The aim of the tool is to have a qualitative assessment of the environmental sustainability of the developed concept/s throughout an evaluation on the pursuit of the LCD strategies and relative guidelines.

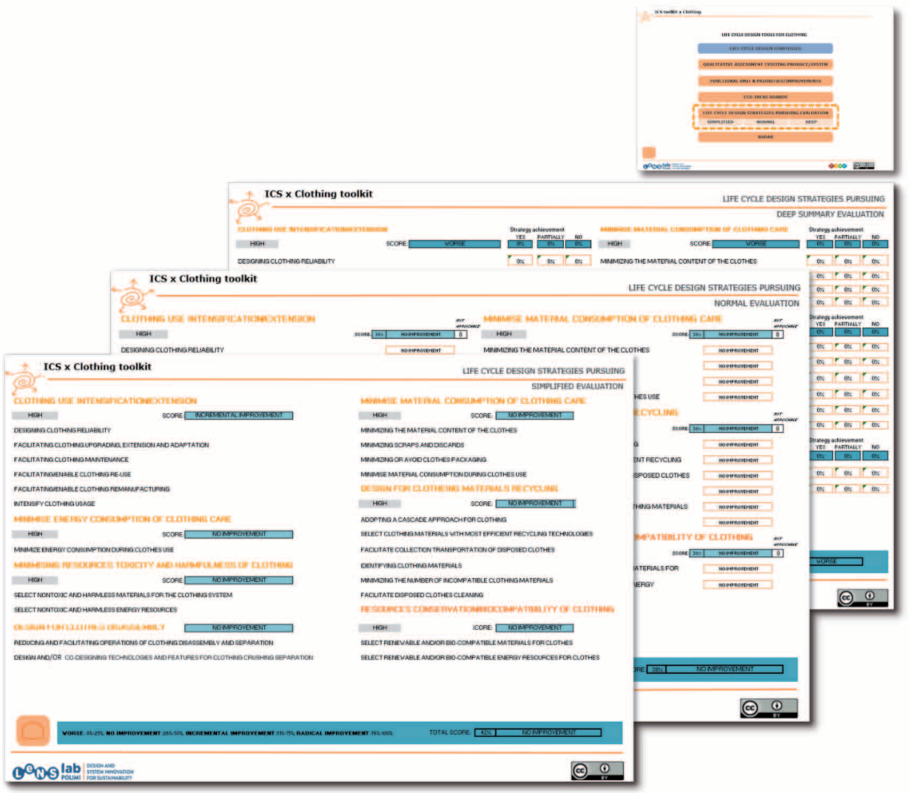


Fig. 7.24 - Checklist for LCD strategies pursuit evaluation: simplified / normal / deep (ICS×Clothing toolkit)

How to use it

The tool is based on the compilation of a checklist that helps to inquire the level of improvement for each clothing LCD strategy through a pre-determined scale (radical, incremental, none, worsen or not applicable). It is possible to choose different levels of detail for the analysis: simplified, normal or deep.

On a "simplified" mode (Fig. 7.25), the level of pursuit is assessed per each of the six LCD strategies through the above-mentioned scale (1). The evaluation is automatically weighted with the priorities given for each LCD strategy (2), providing an overall evaluation of improvement, which is summarized into an overall total score (3).

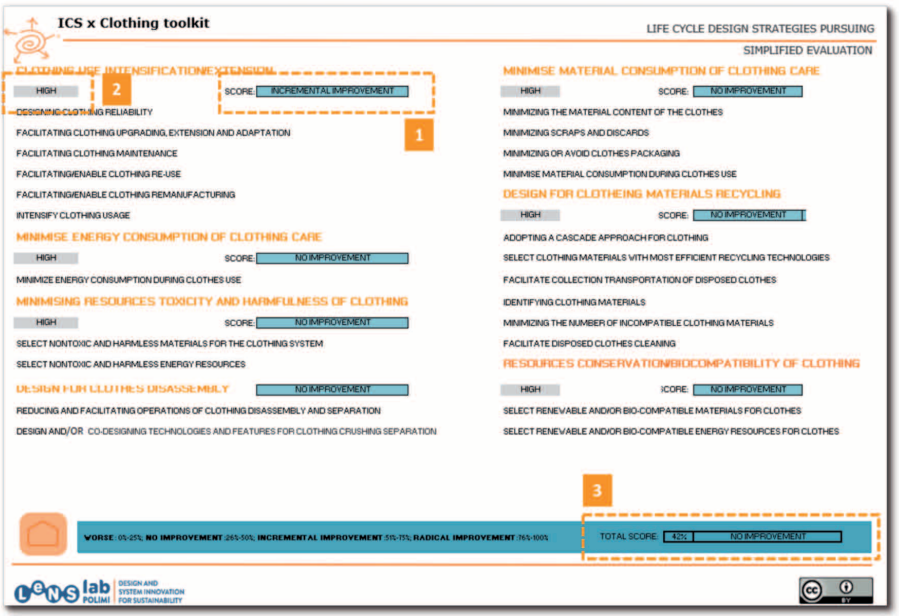


Fig. 7.25 - How to use the checklist for LCD strategies pursuit evaluation in a simplified mode (ICS×Clothing toolkit)

The "normal" mode (Fig. 7.26) allows to evaluate the pursuit of strategies through the assessment of each guideline's improvement (1), which are then summed up to determine the level of improvement for each the strategy (2). Finally, the score is weighted with each LCD priority (3) and is summarized into an overall total score (4).

Through the "deep" mode analysis (Fig. 7.27), the assessment is applied to the level of pursuit of the sub-guidelines for each guideline of each strategy. The inquires provided by the checklist (1) can be evaluated by pre-determined options ("yes", "partially", no", "not applicable") that are automatically converted into percentages and summed up to determine the level of pursuit of each guideline (radical, incremental, none or worsen). After repeating the operation for each sub-guideline of each guideline of each of the 7 strategies (2), the results are summed up to determine the level of pursuit of each strategy, that is finally weighted in relation to each strategy's priority, defining its overall improvement level summarized into an overall total score into the summary board (Fig. 7.28).

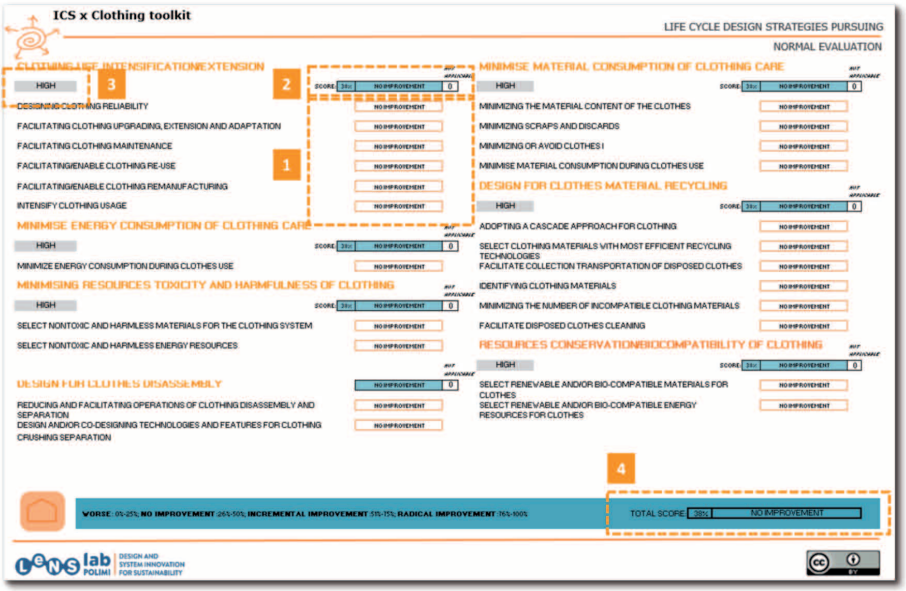


Fig. 7.26 - How to use the checklist for LCD strategies pursuit evaluation in a normal mode (ICS×Clothing toolkit)

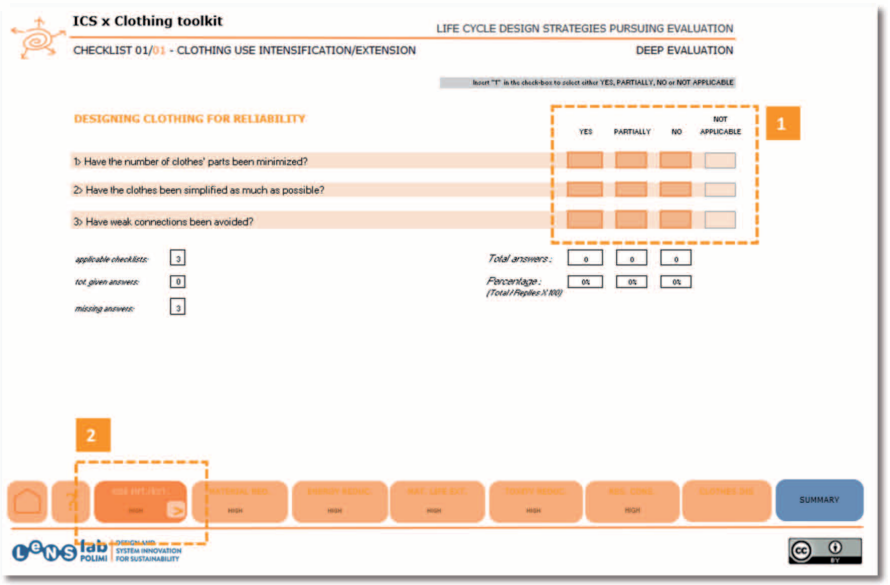


Fig. 7.27 - How to use the checklist for LCD strategies pursuit evaluation in a deep mode (ICS×Clothing toolkit)

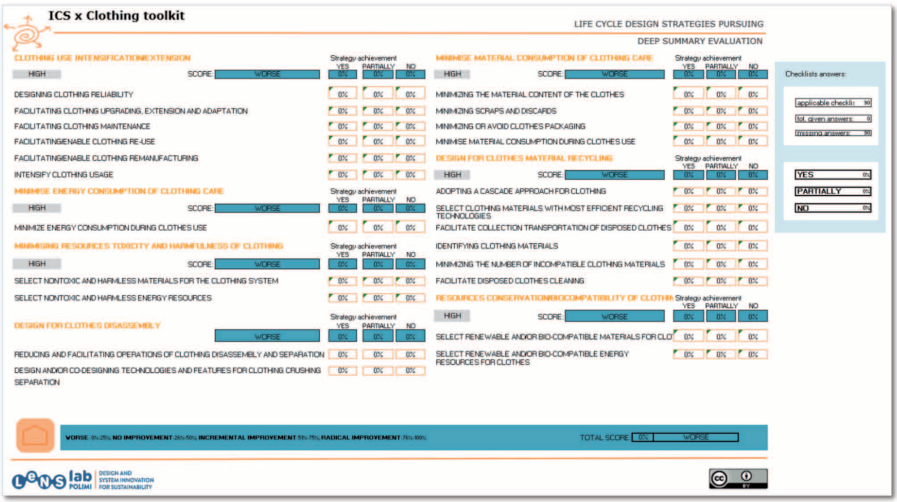


Fig. 7.28 - Summary dashboard of the "deep" evaluation of LCD strategies pursuing (ICS×Clothing toolkit)

Integration into the MPDS design process

The checklist for LCD strategies pursuit evaluation is meant to be integrated into the design process at the point of checking the environmental sustainability of the clothing product concept and could be followed by the engagement of a new session of eco-idea generation where the evaluation doesn't shows positive or meaningful results.

In fact, it can be used until the detailed clothing design and engineering stage (deep is necessarily suggested), in order to evaluate the environmental performance of the designed clothing product as a comparison to a standard product for communication purposes. The outcome of this evaluation could be effectively used as input for the communication contents.

E – Multi-strategy radar

Aim

The radar has the objective of visually summarizing evaluations and ideas elaborated through the design tools described so far, more specifically: the priorities of intervention allocated to each LCD strategy in relation to the existing product; the potential improvement determined by the concept (radical, incremental, none, worsen); the main clothing characteristics that determine such an improvement in the concept. The radar is used as well as a collector of the most interesting and promising eco-ideas among those generated.

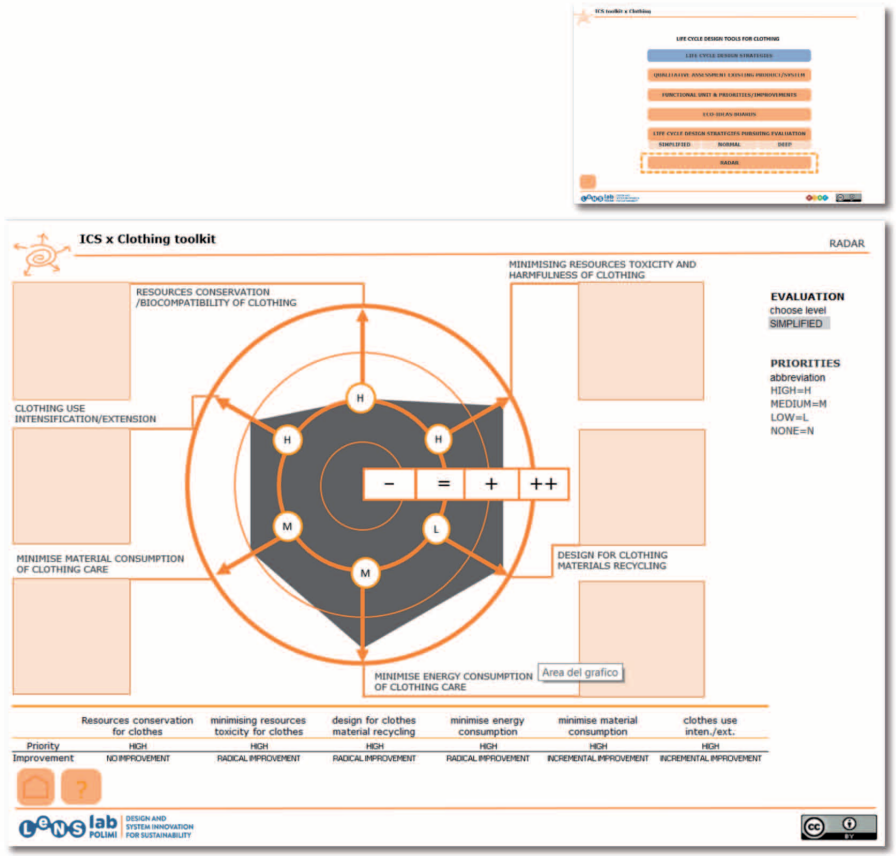


Fig. 7.29 - Multi-strategy radar (ICS×Clothing toolkit)

How to use it

The multi-strategy radar is graphically conceived as a diagram based on set of concentric circles (Fig. 7.30), with six radial arrows arising from the centre corresponding to each Life Cycle Design strategies. The first function of the diagram is to visualize the synthesis of assigned priorities, that must be reported through an abbreviation (initial letter) in the specific rounds on strategy arrows (1). A second function is to select and visualize the most promising ideas that emerged from the eco-idea generation stage: "digital post-its" produced within eco-idea boards for each strategy can be transferred into the multi-strategy radar through a simple copy-paste action and placed nearby the arrow corresponding to the specific strategy the eco-ideas were extracted from (2). The last function of the radar is to provide a graphical overview of the potential environmental improvement achiev-

able by the clothing concept for each LCD strategy (3); so forth it can be used to compare the improvements of two or more concepts developed, so to facilitate the selection of the most promising. The function is automatically performed by the tool as long as a "Checklist for LCD strategies pursuit evaluation" has been carried out, either with a simplified, normal or deep assessment. Indeed, as soon as the assessment level is selected on the screen (4), the vertexes of the hexagonal shape move on radial coordinates depending on the different level of strategies' improvements. This helps to visualize a clear and immediate feedback between the previously identified environmental priorities and the potential benefit achievable through a given concept. Moreover, a summary description of the improvements can be reported in the specific text boxes, in order to summarize the most valuable environmental characteristics that would allow the benefits (5).

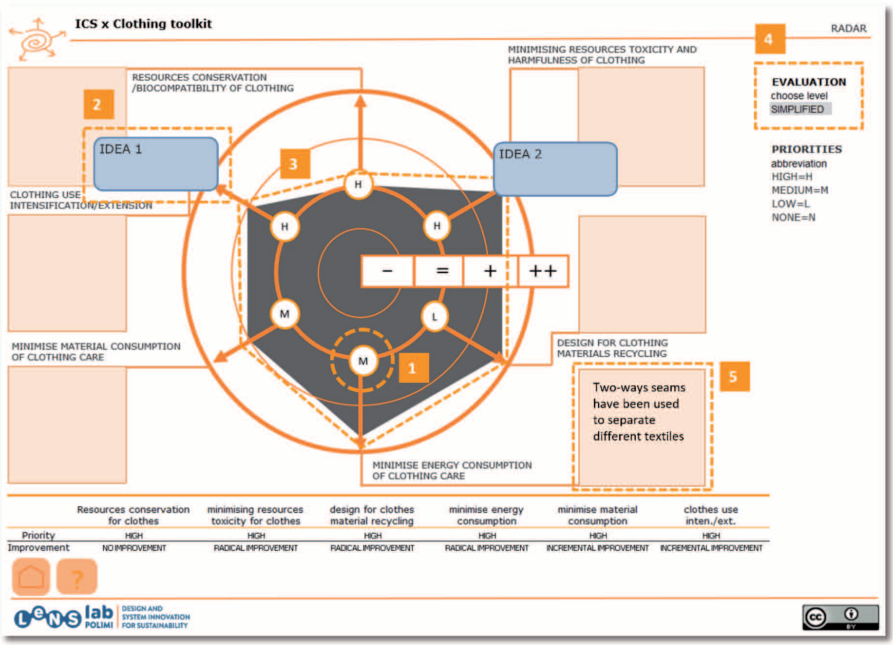


Fig. 7.30 - How to use the Multi-strategy radar (ICS×Clothing toolkit)

Integration into the MPDS design process

Due to its multiple ways of interaction with other tools, the multi-strategy radar can be integrated within different stages of the design process. It can be used during the strategic analysis phase to report identified environmental priorities for each strategy or used in combination

with eco-idea boards to transfer and clearly visualize the best ideas, as well as a visual synthesis of the overall potential environmental benefits of the concept.

As previously mentioned, all the tools described above are part of the ICS×Clothing Toolkit, which can be accessed in the form of an open access and opensource spreadsheet file, available to download for free at www.lens-international.org (tool section). Indeed, the toolkit is meant to be a resource to spread, implement and improve the practice of Life Cycle Design in the clothing system, e.g. by introducing additional strategies and guidelines related to other clothing-specific domains related to sustainability, like clothing ergonomics for specific contexts.

7.2.2. *Main tools for clothing system design for sustainability*

A total of seven tools are presented introduced below, in order to support the design process toward sustainability in general, and that could be integrated or adapted within any clothing system design process. All the tools are open source and can be downloaded for free – as well as the presentations on how to use them – from the "Tools" section on www.lens-international.org.

7.2.2.1. *S.PSS Concept description form*

Aims

The objective of the *S.PSS Concept description form* (Fig. 7.31) is to finalize description and characterization of a new concept of clothing S.PSS.

What it consists of

The tool consists of a sum-up of the concept with:

- concept title;
- satisfaction unit;
- concept description;
- concept profiling.

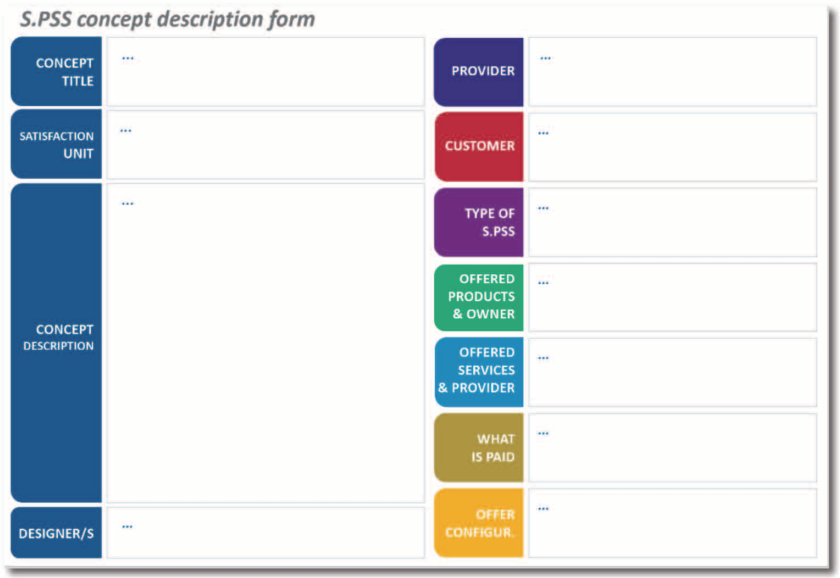


Fig. 7.31 - S.PSS Concept description form

7.2.2.2. *Stakeholders' motivation and sustainability table*

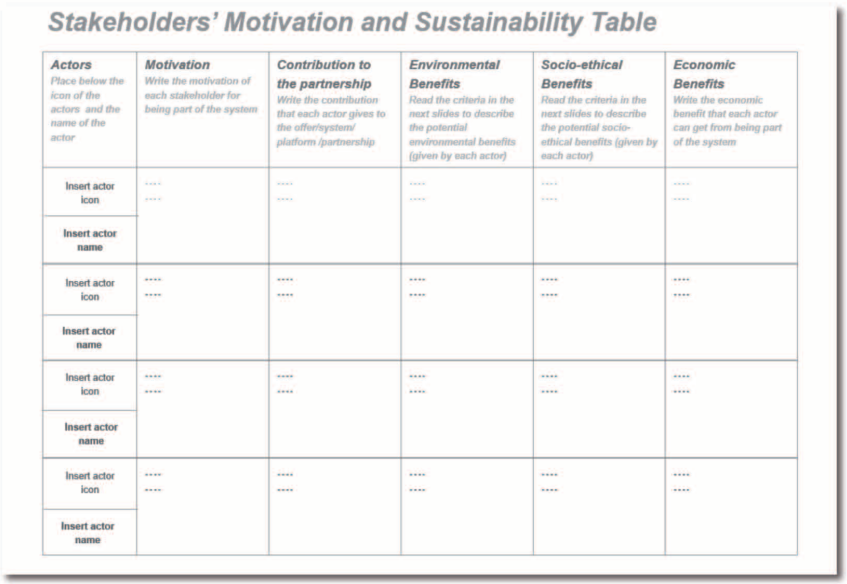


Fig. 7.32 - Stakeholders' motivation and sustainability table

Aims

The objective of the *Stakeholders motivation and sustainability Table* (Fig. 7.32) is to identify and visualize the motivations that actors have in being involved in the system, as well as environmental, socio ethical and economic benefits.

What it consists of

The tool consists of a table in which the header row is pre-filled with five voices: motivation, contribution to the partnership, environmental benefits, socio ethical benefits, economic benefits. Differently, the header column has space for different actors of the system.

7.2.2.3. *System map for S.PSS*

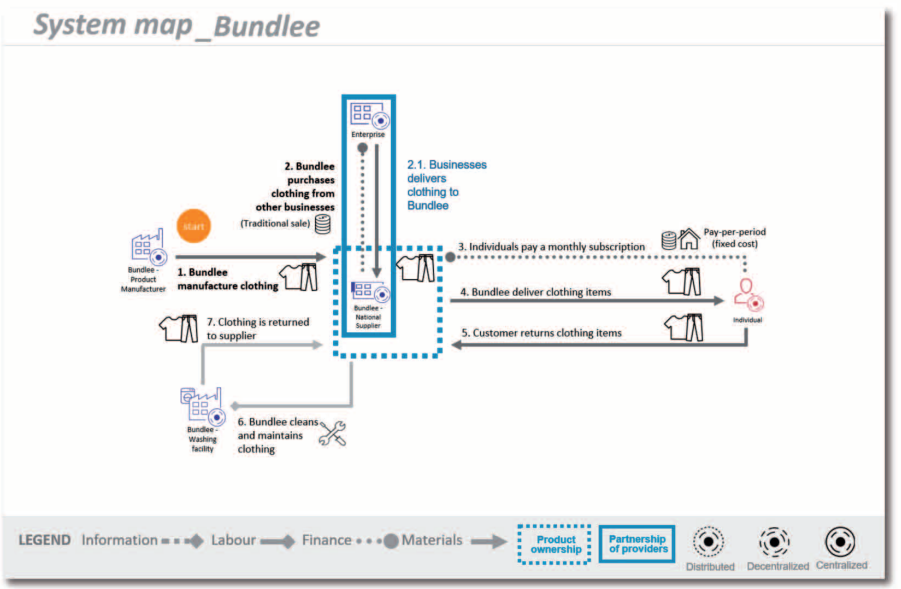


Fig. 7.33 - Overview of the System map for S.PSS

Aims

The purpose of the *System map for S.PSS* (Fig. 7.33) – is to support the co-design, visualisation and configuration of the system structure, indicating the actors involved and their interactions in the system.

What it consists of

The *System map for S.PSS* is a graphical representation of:

- stakeholders involved in the system;
- flows/interactions: physical, financial, informational, and labour performance.

7.2.2.4. *Interaction table*

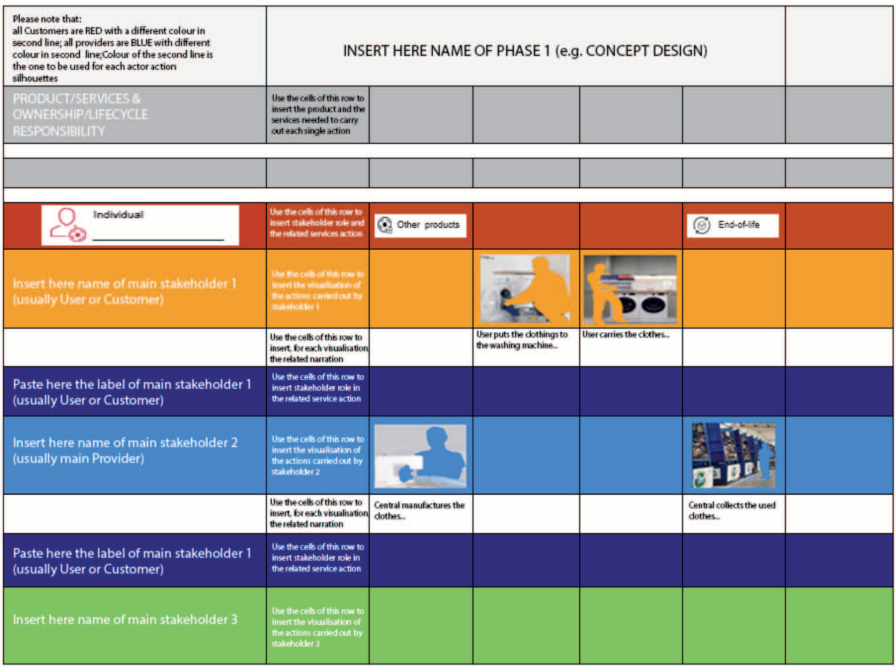


Fig. 7.34 - Overview of the interaction table

Aims

The objective of the *Interaction table* (Fig. 7.34) is to design (co-design) and visualise the functioning in time of the system as a set of narratives (one story for each stakeholder) of both the front-desk (with the clients) and back-stage interactions (between other stakeholders).

What it consists of

The tool consists of a graphical representation containing per each actor/row:

- the sequence of images with short text, representing (in time) the various actions of each stakeholder;
- a short text, describing the specific role played by each stakeholder in each single action with also a narrative of that;
- the product and services delivered in each action (highlighting ownership, Life Cycle responsibilities and provider).

7.2.2.5. *Stakeholders' interaction storyboard*

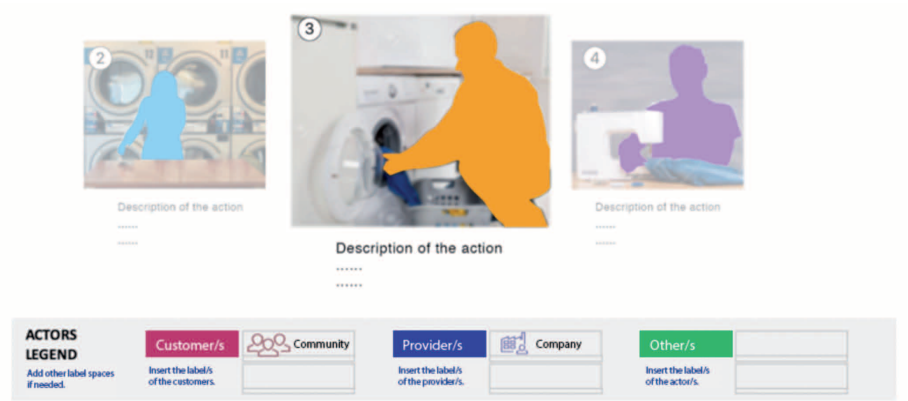


Fig. 7.35 - Stakeholders interaction storyboard

Aims

The objective of the *Stakeholders interaction storyboard* (Fig. 7.35) is to show a fluent narration of the functioning system, to the client or to the other actors involved in the project.

What it consists of

The tool consists of a graphical representation containing in one single row the sequence of images and texts, representing (in time) the main interactions of the different stakeholders.

7.2.2.6. *Satisfaction offering diagram*

Aims

The objective of the *Satisfaction offering diagram* (Fig. 7.36) is to describe in one shot the satisfaction offered to the user/customer, and how this is delivered.

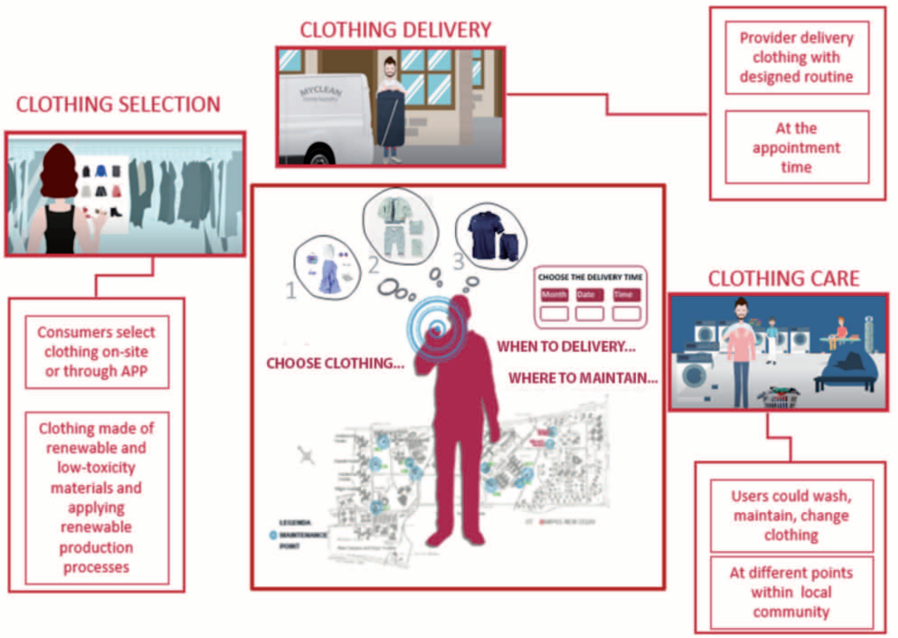


Fig. 7.36 - Satisfaction offering diagram

What it consists of

It is a graphical representation containing:

- the visualisation of the core satisfaction provided by the system;
- the visualisation of the sub-offers (through which the satisfaction is delivered);
- the description of how the sub-offers are delivered.

7.2.2.7. *Animatic for S.PSS*

Aims

The objective of the Animatic for S.PSS (Fig. 7.37) is to produce a short video to present an S.PSS concept in order to engage the discussion with other actors (involved/to be involved and internal or external to the organisation).

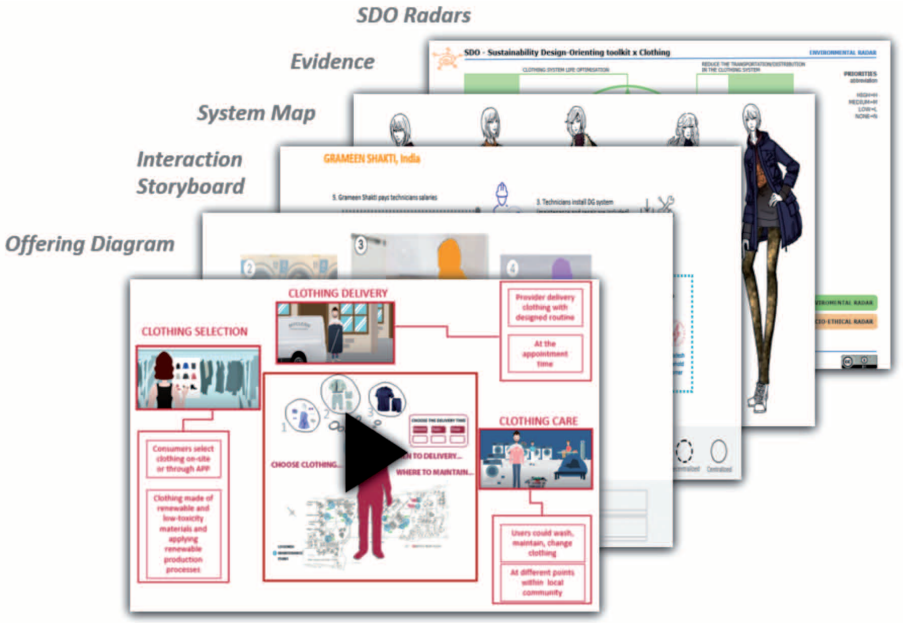


Fig. 7.37 - S.PSS Animatic

What it consists of

It is an audio-visual content based on a slideshow and made by a combination of:

- animation of static images and texts;
- audio narration.

7.3. Final considerations about tools for clothing product and PSS design

As anticipated, the presented tools are meant as resources to support fashion designers, students, fashion companies, NGO, or interested organizations in the practice of design for an environmentally sustainable clothing system, meant as a combination of clothing products and clothing Product-Service Systems.

They could be used within the framework of presented methods (paragraph 7.1) or integrated in any typical design process, due to their inherent modularity and adaptability.

Furthermore, being them open source and downloadable for free on www.lens-international.org – as well as the presentations on how to use them – they have been developed to be spread and highly adapted for specific design contexts, in order to further nurture knowledge and practices toward a sustainable clothing system.

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The Fashion System is at the center of the international debate as one of the most polluting and most impactful industries on the environment. In the last decade the fashion industry has changed, and is still modifying, its approach, aware of the fact that the attention to the environment can no longer be considered a trend: the entire system needs to find and adopt a methodological approach to the project and to the production of goods and services.

Today all the stakeholders on the supply chain follow a path from upstream to downstream: from the treatment of pollution, to the intervention on the production processes that generate a product, to the redesign of products and/or services to reach the discussion and reorientation of social behavior. This path shows the need to intervene in design terms and that the growth in responsibility and role of design, requiring reference scenarios, knowledge and new tools.

The book defines the features and scenarios of sustainable development, as well as the evolution of sustainability in research and practice of fashion design, addressing the strategies for the design and development of environmentally sustainable products. The authors describe the Life Cycle Design approach and the strategies and guidelines for integrating environmental requirements into product design for sustainable fashion. They present the so-called Systems of Sustainable Products-Services, namely the most promising scenarios and models to make design for sustainable fashion economically convenient. Finally, they provide a method and related tools to support design for sustainable fashion in the evaluation of the environmental impact of products, with particular emphasis on the LCA (Life Cycle Assessment). The text is enriched by a full-bodied review of interviews and case studies, with the dual purpose of making the design options clear and of highlighting their specificity for the different design contexts.

FrancoAngeli
La passione per le conoscenze