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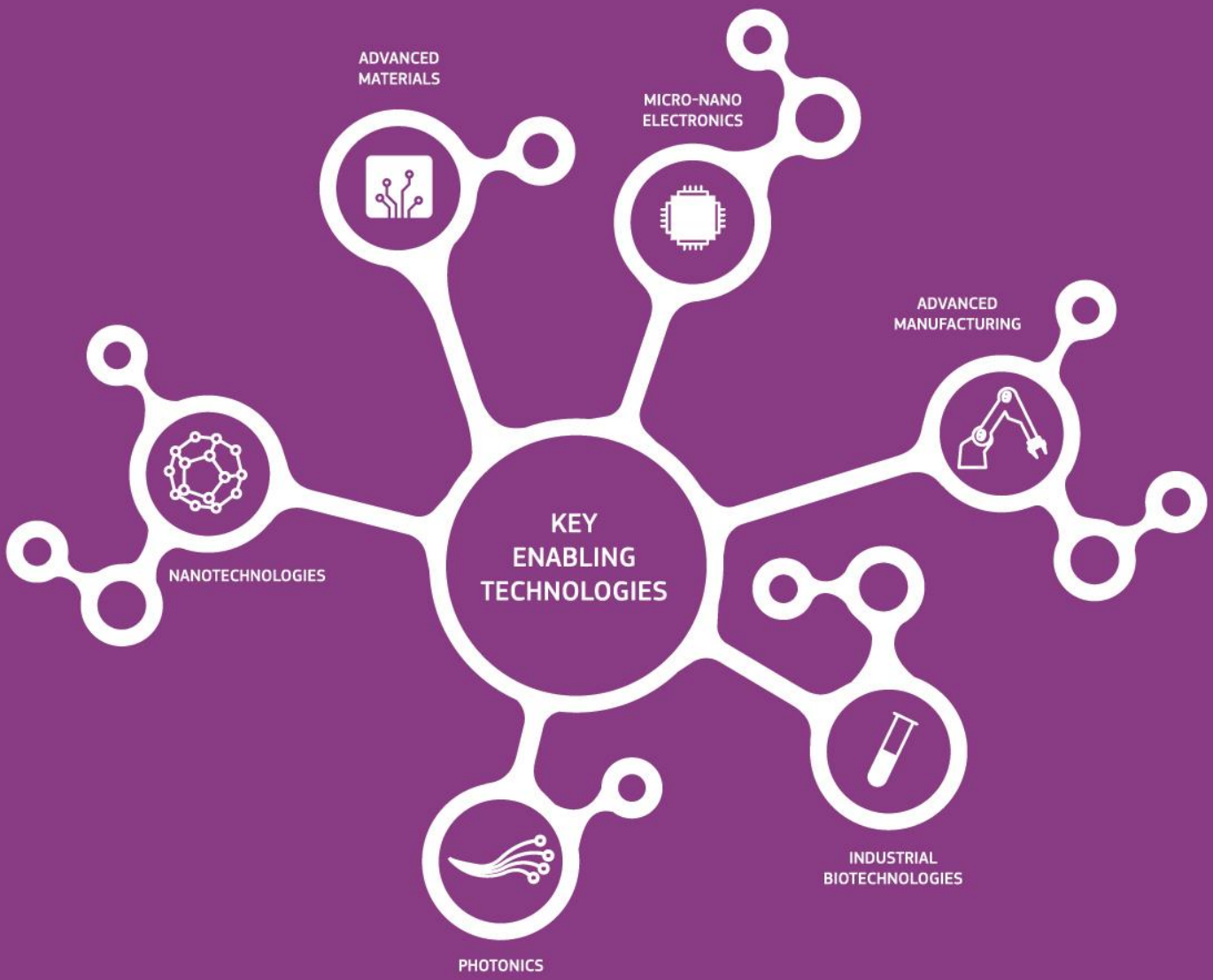
KETs OBSERVATORY PHASE II



SMART TEXTILES FOR SPORTS

Report on promising KETs-based products nr. 1

Contract nr EASME/COSME/2015/026

Internal Market, Industry, Entrepreneurship and SMEs

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SMART TEXTILES FOR SPORTS
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Executive summary

The current report aims to provide stakeholders with an analytical base helping to strengthen cross-regional cooperation mechanisms to boost the deployment of KETs in Europe. The report specifically aims to highlight the value chain structure, key players and constraints for the domain of *smart textiles for sports* in Europe. It also addresses the key strengths and potential of the EU regions, as well as promising business opportunities and key risks and challenges. Finally, the report elaborates on specific policy recommendations with both immediate focus and longer-term orientation.

Smart textiles for sports have a potential to bring a dramatic change in the way athletes at all levels train. Most major sports already started taking advantage of the growing use of technology. Although it is still an emerging area, several products have already been introduced to the market, and the number of those is growing. In this domain, Europe is reported to be particularly strong in research, product development and prototyping, including the integration of electronics into textiles. When it comes to manufacturing, at this point, it is still at a small scale in Europe, as it is also in other world regions.

Smart textiles for sports operate in the value chain comprising multiple actors from four distinctive industries (namely electronics, textile, clothing and software) spread across different parts of Europe. The latter underlines the need for cross-regional partnerships. The value chain for smart textiles in sports can still be considered immature and emerging. The community is dominated by SMEs, working in flexible networks and alliances. Key constraints of the value chain stem from product development being driven predominantly by technology push, many products only reaching the prototype stage, absence of large-scale manufacturing and challenges related to connecting multiple highly diverse value chain players.

There are only few manufacturers in Europe that could take on large production volumes. The smart textiles for sports domain currently exhibits a small market demand. A rapid growth in demand could, however, signify an increased attention also from manufacturers from the United States and Asia. Stakeholders suggest that there is a high chance that large-scale production for mass consumers will not take place in Europe, especially at the level of garment production on a large scale. Europe, however, has a high potential for leading the manufacturing of more advanced custom-made products. The latter refer to smart sportswear for professional athletes and for higher-end customer segment.

The value chain activities currently are organised not at the level of specific regions, but as activities of individual actors spread across diverse EU regions. The key risks and challenges include high production costs, limited consumer acceptance, regulatory gaps, limited investment opportunities of European manufacturers, skills mismatches and lack of a pan-European approach towards addressing the abovementioned challenges.

There is a need to build on strong points of each region rather than trying to develop full value chains at the regional level. The specific identified measures with immediate focus include developing the EU standards for smart textiles for clothes; providing better regulatory guidance for companies active in the domain; advancing the requirements of Horizon 2020 calls to cover the whole value chain beyond prototyping; and enhancing the pan-European platforms bringing all key actors together. The identified measures with a longer-term orientation imply addressing the key skills-related challenges, namely training multidisciplinary professionals with a practical orientation and work experience during education; as well as facilitating the development of a large-scale manufacturing facility.

1. Introduction

The current report has been developed in the context of the second phase of the KETs Observatory initiative. The KETs Observatory represents an online monitoring platform that aims to provide quantitative and qualitative information on the deployment of Key Enabling Technologies[1] (hereafter "KETs") both within the EU-28 and in comparison with other world regions. Specifically, the KETs Observatory represents a practical tool for the elaboration and implementation of Smart Specialisation Strategies in the EU regions.

1.1 Background

A key challenge for the EU competitiveness policy is to enable European industry to move to the higher end of the value chain and position itself on a competitive path that rests on more innovative and complex products. For many KETs, this implies a focus on more integrated technologies with the potential of connecting several KETs.

To this end, one of the key tasks of the KETs Observatory implies identifying and describing "promising KETs-based products" and their value chains, and recommending specific policy actions to help the EU industry stay ahead of global competition. Promising KETs-based products here can be defined as emerging or fast-growing KETs-based products with a strong potential to enhance manufacturing capacities in Europe. Such products correspond to KETs areas where Europe has the potential to maintain or establish global industrial leadership - leading to potentially significant impacts in terms of growth and jobs.

1.2 Objectives of this report

In the context of the second phase of the KETs Observatory, in total, 12 promising KETs-based products have been selected for an in-depth analysis of their value chain, the associated EU competitive position and the corresponding policy implications. The selection of the topics stems from a bottom-up approach based on active engagement of regional, national and EU stakeholders through the S3 Platform for Industrial Modernisation[2].

This report presents the results of the abovementioned in-depth analysis for one of the selected top-priority topics, namely **smart textiles in sports**. The analysis is based on desk-research and in-depth interviews with key stakeholders. The report aims to provide relevant stakeholders with an analytical base helping to establish or strengthen cross-regional cooperation mechanisms to boost the deployment of KETs in Europe.

1.3 Target audience

The report aims to provide key market insights for smart textiles in sports and identify key directions for action in order to maintain Europe's competitive position on the global market. The report specifically targets the EU, national and regional policy makers and business stakeholders who are currently involved in or consider engaging in cross-

[1] Namely Nanotechnology, Micro-/Nanoelectronics, Photonics, Industrial Biotechnology, Advanced Materials and Advanced Manufacturing Technologies
[2] http://s3platform.jrc.ec.europa.eu/industrial-modernisation

regional cooperation mechanisms. The report may also be relevant for other key stakeholder groups including academia, as well as different support structures such as cluster organisations, industry associations and funding providers.

2. Key product facts

In the current section, we provide a brief introduction to smart textiles for sports. We also elaborate on the market potential and the importance of this product for the EU competitiveness.

2.1 Introduction to the product

Source: Ohmatex

Smart textiles here refer to fabrics that enable digital components and electronics to be embedded in them. Smart textiles are distinct from wearables because emphasis is placed on the seamless integration of textiles with electronic elements like microcontrollers, sensors, and actuators. The focus of the current report is on the application of smart textiles in sportswear.

Smart sportswear promises to offer effective solutions for wearers who seek more detailed data about their fitness and performance. Smart fabrics can also increase the comfort level of the user and eliminate the use of bulky equipment such as chest straps. Since athletes and major league players constantly strive to improve their performance, an opportunity of storing data for analysis by lightweight devices that can be embedded in their sportswear offers a high potential for further performance enhancement[3].

Specifically, technology-enhanced sportswear, including compression garments designed to aid circulation and muscle recovery, can provide an appropriate medium for carrying large numbers of sensors close enough to the wearer's skin, to pick up the weak electrical signals generated by physical effort. Multiple extra data types, in addition to heart-rate electrocardiogram (ECG) signals, can be collected today, including electromyography (EMG) for analysing muscle activity. Furthermore, accurate body-temperature monitoring can be useful for monitoring fitness and can also protect the wearer against the dangers of over-exercising[4].

Scientists are also working on the opportunities for measuring Galvanic Skin Response (GSR) using electrodes placed against the skin to assess athletes' emotional responses to training routines. However the use of GSR in sports training currently is at the very initial level (a reference design for a wearable, mobile Galvanic Skin Response (GSR) system already exists[5]).

Close-fitting sportswear represents an ideal base for embedding sensors such as MEMS inertial modules, to accurately monitor the wearer's movements. Smart fabrics allow accurate sensing by helping eliminate noise that looser-fitting garments could introduce by moving relative to the wearer's body. Sensing motion enables applications allowing to identify areas where technique could be improved, such as running stride or

[3] Mordor Intelligence (2016) "Analysis of Europe Smart Textiles Market - Growth, Trends, Competition, Analysis (2016 - 2021)", published in December 2016, available at: https://www.mordorintelligence.com/industry-reports/analysis-of-europe-smart-textiles-market

[4] Digi-Key (2016) "Technical Sports Clothes Get Smart", published on 28 April 2016, available at: https://www.digikey.com/en/articles/techzone/2016/apr/technical-sports-clothes-get-smart

[5] Produced by Maxim, source: Digi-Key (2016) "Technical Sports Clothes Get Smart", published on 28 April 2016, available at: https://www.digikey.com/en/articles/techzone/2016/apr/technical-sports-clothes-get-smart

arm action. A number of products with the motion sensing functions are already on the market[6]. Another development refers to smart heating and cooling systems that allow sustaining an optimal body temperature[7].

Finally, smart clothing products for sports have the potential to reduce or eliminate most of the preventable injuries. Furthermore, applications having big data capabilities might be able to predict injuries before they happen, based on predictive analytics[8].

To summarise, smart textiles for sports could potentially bring a dramatic change in the way athletes at all levels train. They promise to transform sportswear into smart garments that can take on the role of personal coach[9].

2.2 Relevance to grand societal challenges

The current product contributes to tackling the grand societal challenge related to health, demographic change and wellbeing.

2.3 Market potential

Most major sports already started taking advantage of the growing use of technology[10]. Although the application of sensors, actuators and computer systems in sportswear is still an emerging area, several products have already been introduced to the market, and the number of those is growing[11]. The sports & fitness industry forms the second largest market segment of smart textiles (following military & defence industry)[12].

While the sector is still at the early stages of development, rapid advancements in textile technologies, nanotechnology, biosensors, new materials, and miniaturised electronics lead to a major change to the overall growth dynamics of the global market for smart textiles in sports[13]. The demand in sports and fitness applications is anticipated to witness a significant growth, namely 33% from 2015 till 2023[14]. This area benefits from increasing attention of the major sportswear brands and rapidly emerging start-ups.

Stakeholders report that initially, the development of smart textiles domain was driven by technology push. However, this approach often proved to be impractical, not taking

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[6] such as the PIQ multisport sensor that also incorporates GPS to provide extra functions for golfers, such as course information including distance to the hole; source: source: Digi-Key (2016) “Technical Sports Clothes Get Smart”, published on 28 April 2016, available at: https://www.digikey.com/en/articles/techzone/2016/apr/technical-sports-clothes-get-smart.

[7] https://www.newscientist.com/article/2074964-smart-clothes-adapt-so-you-are-always-the-right-temperature/

[8] Hanuska A. et al. (2016) “Berkeley ELPP: Smart Clothing Market Analysis”

[9] Digi-Key (2016) “Technical Sports Clothes Get Smart”, published on 28 April 2016, available at: https://www.digikey.com/en/articles/techzone/2016/apr/technical-sports-clothes-get-smart

[10] Salako T. (2015) “Smart textile ready to boost performance sportswear market”, published on Euronews on 26 March 2015, available at: http://www.euronews.com/2015/03/26/smart-textile-ready-to-boost-performance-sports-wear-market

[11] Sawh M. (2017) “The best smart clothing: From biometric shirts to contactless payment jackets”, published on Wearable on 9 January 2017, available at: https://www.wareable.com/smart-clothing/best-smart-clothing

[12] Mordor Intelligence (2016) “Analysis of Europe Smart Textiles Market - Growth, Trends, Competition, Analysis (2016 - 2021)”, published in December 2016, available at: https://www.mordorintelligence.com/industry-reports/analysis-of-europe-smart-textiles-market

[13] TMR (2016) “Smart Textile Market - Global Industry (will reach US$7.73 billion by 2023) Analysis, Size, Share, Growth, Trends and Forecast 2015 - 2023: TMR”, published on 29 September 2016, available at: https://globenewswire.com/news-release/2016/09/29/875784/0/en/Smart-Textile-Market-Global-Industry-will-reach-US-7-73-bn-by-2023-Analysis-Size-Share-Growth-Trends-and-Forecast-2015-2023-TMR.html

[14] *Ibid.*

into account the actual needs of the market. With the integration of big data analysis into the value chain, more user-driven applications begin to emerge. The profit is reported to come mainly from software selling rather than from the clothing itself[15].

2.4 Importance for the EU competitiveness

In 2014, the global smart textile market was worth 700 million USD (about 622 million EUR)[16]. Europe is the second largest regional market for smart textiles, accounting for a share of over 30% in the global market in 2014[17]. North America is currently leading, with more than 40% of the global market in the same time period[18]. These shares, however, correspond to the overall market shares for smart textiles, rather than specifically for the sports domain.

In the domain of smart textiles for sports, Europe is reported to be particularly strong in research, product development and prototyping, including the integration of electronics into textiles. When it comes to manufacturing, at this point, it is still at a small scale, as it is also in other world regions.

[15] Kirstein, T. (Ed.). (2013). Multidisciplinary Know-How for Smart-Textiles Developers. Elsevier.

[16] TMR (2016) "Smart Textile Market - Global Industry (will reach US$7.73 billion by 2023) Analysis, Size, Share, Growth, Trends and Forecast 2015 - 2023: TMR", published on 29 September 2016, available at: https://globenewswire.com/news-release/2016/09/29/875784/0/en/Smart-Textile-Market-Global-Industry-will-reach-US-7-73-bn-by-2023-Analysis-Size-Share-Growth-Trends-and-Forecast-2015-2023-TMR.html

[17] TMR (2016) "Smart Textile Market - Global Industry (will reach US$7.73 billion by 2023) Analysis, Size, Share, Growth, Trends and Forecast 2015 - 2023: TMR", published on 29 September 2016, available at: https://globenewswire.com/news-release/2016/09/29/875784/0/en/Smart-Textile-Market-Global-Industry-will-reach-US-7-73-bn-by-2023-Analysis-Size-Share-Growth-Trends-and-Forecast-2015-2023-TMR.html

[18] *Ibid.*

3. Value chain analysis

The current section addresses the value chain structure, key players, as well as the key identified constraints. The value chain for smart sportswear can be considered a *hybrid value chain* as it brings together the (sports) clothing, electronics, textile and software industries. In the context of smart textiles for sports, one needs to refer to the *European* value chain or the value chain comprising multiple elements and actors spread across different parts of Europe (rather than concentrated in specific regions or countries). The results of the analysis presented below illustrate the importance of the European dimension for smart textiles in sports, and underline the need for cross-regional partnerships. The value chain for smart textiles in sports can still be considered immature and emerging.

3.1 Value chain structure

Figure 3-1 presents the reconstructed value chain structure for smart textiles in sports, and encompasses three dimensions: (1) value-adding activities; (2) supply chain; and (3) supporting environment.

Six key value-adding activities can be identified, ranging from research & development to the provision of after-sales services such as, for example, online training logs, data analysis, benchmarking to other users etc. Although these activities are presented as a linear chain, in practice, however, they often are intertwined, with multiple feedback loops embedded into the innovation trajectory (e.g. with input from market intelligence and/or services feeding back to R&D, design and production). The value adding activities are thus organised in a non-linear fashion as a cluster of multiple interrelated and partially parallel activities.

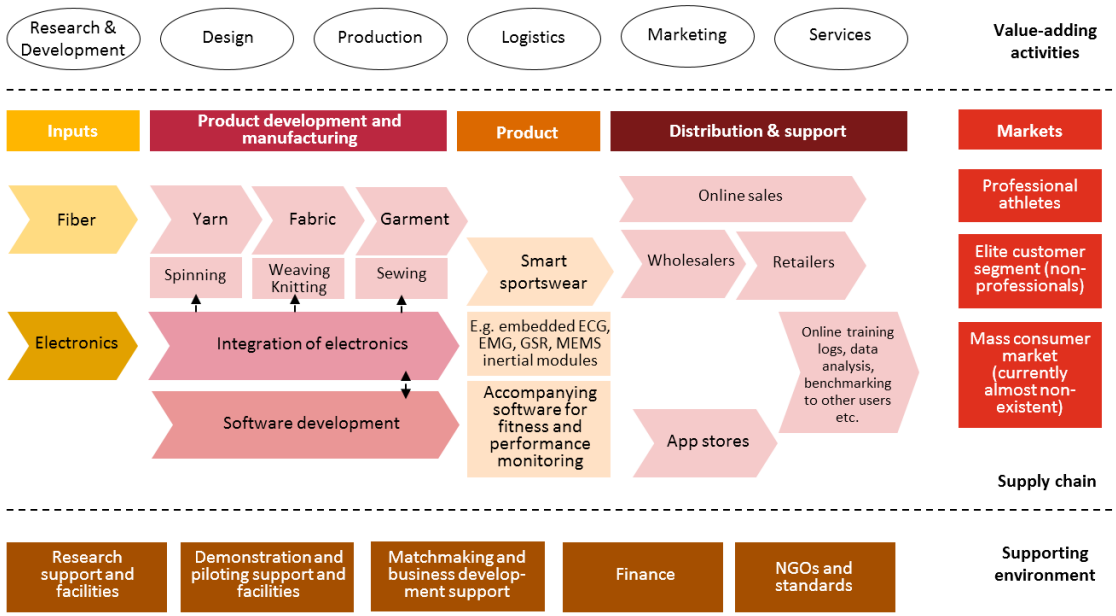
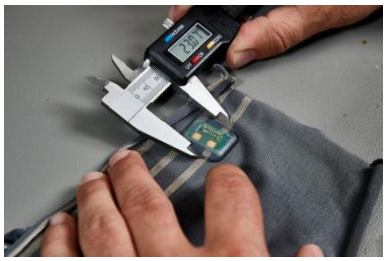


FIGURE 3-1: Value chain model for smart textiles in sports (source: PwC[19])

[19] Partially based on Roberts M. "Making it in the USA" Blog Series- Resources for Manufacturing Textiles & Apparel in the USA", available at: https://technicalts.com/blog/part-1-making-it-in-the-usa-blog-series/

The supply chain dimension highlights the key steps of the supply chain from the input/output point of view. The main inputs of the supply chain come from two distinctive industries, namely textile and electronics industries. The inputs of the textile industries can take the form of fiber, yarn, fabric or actual garments. The inputs of the electronics industry imply specific electronic elements like microcontrollers, sensors, and actuators. Existing technologies allow to perform the integration of electronics into textiles at different stages (i.e. at the level of yarn, fabric or garment). Furthermore, since the added value of embedding electronics into textiles stems from the potential of generating and analysing data, the abovementioned activities are accompanied by software development and testing.

The product development and manufacturing stage results into smart sportswear with embedded electronics elements in it such as ECG, EMG, GSR, MEMS inertial modules etc. (as highlighted in sub-section 2.1). This smart sportswear is accompanied with a software for specific fitness and performance monitoring. The product distribution is organised mainly through online sales by both big sports brands and smaller niche companies, as well as through customised sales to elite clients (i.e. big brands serving specific professional athletes) and, in some cases, also through traditional retailers.



Source: Ohmatex

Due to high costs of production and the corresponding high price of the smart sportswear products, the focus of developers and producers is currently on the professional athletes and increasingly on the high-end consumer market. Further development of technology and introduction of large-scale manufacturing is likely to lead to lower costs and thus paves the way for targeting also broader mass consumer segments in the future.

Finally, the supporting environment consists of a wide range of organisations that influence and support the supply chain, including R&D institutions, organisations offering support with demonstration and piloting, as well as matchmaking and business development support, financial institutions (investors), and NGOs. Based on the inputs of consulted stakeholders, also these supporting organisations have a pan-European orientation and have a tendency to work in a cross-border fashion, in the context of the European-level value chain.

3.2 Key players

The key actors of the value chain of smart textiles for sports can be clustered into the following main groups:

- **Research organisations and service centres**: these organisations are involved in research related to, for example, new fiber development, advancing functionalities, interactivity and connectivity etc. They typically also offer testing and prototyping services. Additional services of such organisations may also be related to matchmaking with the relevant business partners and assistance with business development (e.g. assessment of market feasibility).

- **Niche application-oriented companies** (SMEs, medium-large scale companies): these companies typically work on specific applications at early stages of product development. They elaborate on the specific functional requirements of the product (e.g. comfort, interactivity, connectivity). In the last

3-5 years, multiple application-oriented SMEs emerged on the smart textiles market. However, the creation of these companies is reported to often be driven by technology push rather than a clear market need.

- **Textile producers**: these are typically large companies manufacturing textile structures (including activities like fiber spinning, yarn spinning, weaving and knitting) that need to satisfy specific technical requirements to enable integration of electronics. However, these companies usually lack specific knowledge of electronics. Textile producers are, in general, not yet actively involved in upscaling smart textiles manufacturing.
    - There is also a group of **smaller (niche) textiles producers** that specialise in specific types of smart textiles (e.g. heated textiles for sportswear). These companies typically have limited production capacity and perform manufacturing also at a small scale.
- **Electronics companies/Electronics Manufacturing Service companies (EMS):** these companies design, manufacture, test, distribute, and provide return/repair services for electronic components. These companies typically do not have specific knowledge of textiles.
- **'System integrators'** putting textiles and electronics components together and producing the actual garments. These companies typically bridge textile and electronics companies, by providing electronics-related expertise to textile companies and textile-related expertise to electronics companies. These companies cover the manufacturing part of the value chain, where textiles and electronics come together. Being typically SMEs, these companies produce garments at a smaller scale (often hundreds – up to a thousand of pieces). For the manufacturing of larger volumes, the production process needs to be outsourced to the large apparel companies. System integrator companies often use the services of support manufacturing companies (e.g. laser cutting; mounting connectors etc.).
    - Garment manufacturers: some companies (typically small) are involved exclusively in producing garments.
- **Big sports brand companies**: these companies are involved in market analysis and technology scouting, design, logistics, promotion, and distribution. They typically outsource manufacturing activities to other players (both within and outside the EU). Sometimes these companies also have their own electronics division (like Adidas). If they find a certain technological area strategically important for their company, they typically integrate it into their own R&D departments. If they do not find a certain area strategically important, then they often find a niche company (often an SME) and an R&D organisation, and sponsor a project.
- **Software developers**: these companies (often start-ups) represent interface/software producers specialising in software development for big data analysis for specific applications. There is a vast community of companies developing sports-related apps, and many of them offer generic interfaces for devices of different kind. This community is increasingly growing. Such companies often have better access to finance than manufacturing companies due to the nature of their activities (less capital-intensive).

The smart textiles community is dominated by SMEs, working in flexible networks and alliances[20].

The Table below presents some illustrative names of relevant companies. Some of the listed companies have headquarters outside the EU; nevertheless, these companies were also included due to their active presence on the European market. The list should by no means be considered exhaustive.

TABLE 3-1: Mapping of key market players[21]

Organisation types/Value-adding activities	Research & development	Design & prototyping	Production	Logistics	Marketing	Services
Research institutes and service centres	Centexbel (Belgium) CSEM (Switzerland) Fraunhofer IIS (Germany) TITV (Germany)	Centexbel (Belgium) CSEM (Switzerland) Fraunhofer IIS (Germany) TITV (Germany)				Centexbel (Belgium) CSEM (Switzerland) Fraunhofer IIS (Germany) TITV (Germany)
Niche application-oriented companies	Applycon (Czech Republic) TITERA (Slovenia)	Applycon (Czech Republic) Ambiotex (Germany) IMBUT (Germany) Sensing Tex (Spain)	Applycon (Czech Republic) Ambiotex (Germany) IMBUT (Germany)		Applycon (Czech Republic)	
Textile producers		Kufner (Germany) P&R – Têxteis (Portugal) Getzner22 (Austria) Liebaert23 (Belgium) Sympatex (Germany) Gore (Unites States24)	Kufner (Germany) P&R – Têxteis (Portugal) Getzner25 (Austria) Liebaert26 (Belgium) Sympatex (Germany) Gore (Unites States27)		Kufner (Germany)	
Electronics producers (EMS)		Flextronics (United States[28]) Gore (Unites States[29])	Flextronics (United States[30]) Gore (Unites States[31])			

[20] Kirstein, T. (Ed.). (2013). Multidisciplinary Know-How for Smart-Textiles Developers. Elsevier.

[21] The list of organisations presented in this table should not be considered exhaustive. It is rather an illustrative representation of organisations currently active in the value chain of smart textiles for sports in Europe

[22] Is reported by stakeholders to be close to the introduction of large-scale manufacturing

[23] *Ibid*.

[24] With facilities also in the United Kingdom, Germany, France, Spain and Italy

[25] *Ibid*.

[26] *Ibid*.

[27] With facilities also in the United Kingdom, Germany, France, Spain and Italy

[28] With production facilities also in Europe

Organisation types/Value-adding activities	Research & development	Design & prototyping	Production	Logistics	Marketing	Services
'System integrators' and garment manufacturers	Cityzen Sciences (France)	Ohmatex (Denmark) Cityzen Sciences (France) Clothing+ (Finland)	Ohmatex (Denmark) Clothing+ (Finland) 30seven (Belgium)		Clothing+ (Finland)	Cityzen Sciences (France) Clothing+ (Finland)
Big sports brand companies	Adidas (Germany) Nike (United States) Decathlon (France) Polar (United States)	Adidas (Germany) Nike (United States) Decathlon (France) Polar (United States)		Adidas (Germany) Nike (United States) Decathlon (France) Polar (United States)	Adidas (Germany) Nike (United States) Decathlon (France) Polar (United States)	Adidas miCoach (Germany) Nike (United States) Polar (United States)
Software developers		Runtastic (Austria) Google Fit (United States) Strava (United States) Nike+ (United States) Endomondo (Denmark) Adidas miCoach (Germany)	Runtastic (acquired by Adidas) (Austria) Google Fit (United States) Strava (United States) Nike+ (United States) Endomondo (Denmark)		Runtastic (acquired by Adidas) (Austria) Google Fit (United States) Strava (United States) Nike+ (United States) Endomondo (Denmark)	Runtastic (acquired by Adidas) (Austria) Google Fit (United States) Strava (United States) Nike+ (United States) Endomondo (Denmark)

Below we illustrate an *example* of possible relationships of the involved players of the value chain. A big sports brand company decides to support a certain elite team or a sportsman. They then approach a textile company, which, in turn, does not have an electronics expertise. This textile company would then approach a 'system integrator' company. It would, in turn, integrate textiles and electronics, and develop the actual garments (at a small scale). The big sports brand company is the owner of the end product and takes care of logistics, promotion and distribution.

The value chain players are often connected to each other through networks/platforms of researchers, developers and manufacturers, such as, for example, Smarttex Netzwerk[32] in Germany, Smart Textiles Cluster in Sweden[33] and Smart Textiles Plattform in Austria[34]. However, stakeholders expressed a concern that these platforms often are of regional/national orientation, while the value chain operates at the European level. Therefore, there is a clear need for cross-regional pan-European platforms. This point will be further addressed in the recommendations session.

[29] With facilities also in the United Kingdom, Germany, France, Spain and Italy
[30] With production facilities also in Europe
[31] With facilities also in the United Kingdom, Germany, France, Spain and Italy
[32] http://smarttex-netzwerk.de/en/
[33] http://smarttextiles.se/en/background/
[34] http://www.smart-textiles.com/

3.3 Key constraints

Several key constraints have been identified in the value chain for smart textiles for sports.

Product development driven predominantly by technology push

Stakeholders report that the current smart sportswear products stem predominantly from technology push rather than from the actual needs of the market. The consumers still need to be convinced that the benefits offered by the product outweigh the high costs and the associated risks and challenges. The latter refer, for example, to the washability of the product, its possible effects on other clothes/skin, feeling of comfort etc. So far, the field is, in general, reported to be not well developed in terms of having a clear elaborated justification for the use of the smart sportswear products. The involved organisations are suggested to be typically more concerned about technology rather than the actual demand. Furthermore, there is also a direct competition from wearables (removable gadgets that can be placed on the clothes and then removed) offering similar functionality.

Many products only reach the prototype stage

Europe currently has a leading position in terms of developing and prototyping smart textile products. However, although much work has been done in this field in the last ten years, many developments still remain at a prototype stage. That can partially be explained by the fact that the organisations involved in development and prototyping activities typically are technology- rather than market-driven. Many of them have been involved in relevant initiatives through the Seventh Framework Programme (FP7) and Horizon 2020 calls. The latter often imply the development of a prototype in a few years' time, with no explicit requirement to go beyond the prototype stage and introduce the product to the actual market.

As a result, multiple different prototypes exist today. These prototypes differ in terms of the way they collect and process measurements, the way of transferring data etc. There is, however, no common standard. The prototype developments hardly go beyond the prototyping stage, and the involved organisations are reported to often lack knowledge on how to continue.

Absence of large-scale manufacturing

Occasional products already are available on the market, but only at a small scale (often hundreds – up to a thousand of pieces). Traditional textile producers are typically not yet involved in upscaling smart textiles manufacturing. For setting up large-scale manufacturing, there is a need for significant investments, design of new production processes, new machinery etc. However, stakeholders report that these factors are solvable and do not represent the main reason for lack of large-scale manufacturing. **It is rather limited demand from the market that is reported to be the key cause of low production volumes**. More efforts thus need to be invested into market research and promotion activities, with a transition from technology-driven towards more market-driven products.

In the long-term, the integration into the value chain of traditional large-scale textile manufacturers is crucial, in order to ensure sufficient scale of production. Nevertheless, there are already large textile producers that are actively working on it (e.g. Kufner (Germany)). These are evolving textile companies that try to keep up with the latest

developments (e.g. nanocoatings, sensors, sweat absorption etc.). However, there are only very few of them in Europe.

Value chain players need to be connected

The smart textiles for sports domain implies a so called hybrid value chain with multiple industries involved in it, and one of its key challenges refers to bringing all the key actors together. The value chain actors are geographically dispersed across different EU regions, often with a limited awareness of each other's activities. There is no proximity relationship between the key actors. **It is a European cluster**. In order to have a complete value chain, there is a need to link multiple regions/clusters together. A pan-European approach towards the value chain is needed instead of a predominantly regional orientation. A prominent example in this respect refers to the RegioTex[35] platform aiming to link regional competences and infrastructures that are key to SME innovation in the textile & clothing sector. Stakeholders report a need for raising awareness of the activities of such platforms among the value chain actors, and for attracting to such platforms large-scale manufacturers.

Furthermore, value chain actors often lack knowledge of other involved industries (e.g. textile companies are reported to have generally poor knowledge of electronics; similarly, electronics companies are reported to have generally poor knowledge of textiles), which further complicates collaboration. A central role in tackling this challenge belongs to the system integrator companies, dedicated service centres and multi-stakeholder networks/platforms. We have already briefly elaborated on these types of actors in the previous sub-section.

Finally, stakeholders report that the most innovative textile companies consider expanding their skills base beyond traditional textile-related expertise, and specifically hiring people with electronics background (electronics engineers). These electronics experts would make the relevant electronics expertise readily available in-house and facilitate further expansion of smart textiles business. At this point, textile companies typically rely on the services of external partners active in the domain of electronics.

[35] http://www.textile-platform.eu/regiotex-regional-investment/

4. Analysis of the EU competitive positioning

The current section elaborates on the strengths and potential of the EU regions, key risks and challenges, as well as the opportunities for the EU regions. The consulted stakeholders report that **the whole value chain for smart textiles in sports can be covered by European players**. Europe is particularly strong in research, product development and prototyping, including the integration of electronics into textiles. When it comes to manufacturing, at this point, it is still at a small scale, as it is also in other world regions.

4.1 Strengths and potential of the EU regions

In this sub-section, we address the potential for developing large-scale manufacturing in Europe, expected Europe's global position in 2030, key competitive advantages of Europe, as well as regions that could be in the lead.

Potential for developing large-scale manufacturing in Europe

According to stakeholders, **there are very few manufacturers in Europe that could take on large production volumes**. That can be explained by several reasons. First, in the last decades, many European textile manufacturers moved their production facilities to non-European regions. Among the manufacturers that did stay in Europe, many are small in size and are focussing exclusively on traditional (non-technical) textiles. These companies typically do not show interest in the smart textiles domain. There are also multiple small companies specialising exclusively in technical textiles. Additionally, there are several larger textile manufacturers with a clear interest in this domain. They report having technical capacity for large-scale volumes and readiness to invest. However, they may not form a critical mass large enough to claim a strong global position, if large-scale manufacturing of smart textiles for sports will ever become mainstream. Stakeholders suggest that the chance to create new large-scale manufacturers in Europe is rather low.

Source: Ohmatex

The smart textiles for sports domain currently exhibits a small market demand[36] which may partially explain limited interest in it from, for example, East Asian manufacturers. A rapid growth in demand could, however, signify an increased attention in this domain also from manufacturers from the United States and Asia. **The presence of large-scale manufacturing potential for this product therefore does not yet imply that large-scale manufacturing will be concentrated in Europe**. Multiple initiatives already emerge in the United States (including the development of dedicated standards for the smart textiles domain and Google Jacquard Project[37]). The competitive advantages of the Unites States are related to the strong military deployment of smart textiles there. When it comes to electronics, the key producers are located in Asia, including Taiwan, Korea, Japan, China.

[36] When it comes to the interest and involvement of large companies, it is possible to observe a higher interest in smart textiles from the automotive industry. There, the market needs and consumer preferences have been identified in a more detailed way, with a particular attention to comfort and functionality. As for the textiles/clothing companies, while large-scale producers do show an interest in smart textiles, it proves to be harder to convince consumers with regard to product benefits.

[37] https://atap.google.com/jacquard/

Europe's global position in 2030

Stakeholders suggest that there is a high chance that large-scale production for mass consumers will not take place in Europe, especially at the level of garment production at a large scale. **Europe, however, has a high potential for leading the manufacturing of specialised, more advanced custom-made products**. The latter refer to smart sportswear for professional athletes and for higher-end/elite segment customers.

Key competitive advantages of Europe

The key competitive advantages include the following:

- Access/proximity to a wide variety of relevant experts and value chain actors;
- Knowledge of and experience with research, product development and prototyping in this domain;
- Creativity and innovativeness of value chain actors;
- Trust and good collaboration among all actors of the value chain;
- Cohesive rules and regulations regarding safety, environment, functionality etc.;
- Familiar working culture;
- Good understanding of the European market:
    - in Europe, consumers tend to have a preference for customised products, tailored to personal needs. In Asia, the culture is different; it is oriented towards large volumes of the same kind of product. That makes it more difficult for Asian companies to satisfy the preferences of the EU consumers. However, for large masses of consumers, the price plays a decisive role, and that is where it would be difficult for Europe to compete with Asia.
- Some of the EU textile manufacturers report having the capacity to produce large volumes in a high-speed low-cost fashion (e.g. Kufner (Germany)).

Putting electronics and textiles together is a competence in itself. It can be done at different points of the value chain. When it is about producing sportswear and then attaching an electronics device to it, Europe can hardly compete with Asia. However, when it is about embedding electronics into textiles, then a totally different skill-set is needed, and Europe currently has a competitive position in this respect compared to Asian countries.

Regions that could be in the lead

Stakeholders report that value chain activities currently are organised not at the level of specific regions, but as **activities of individual actors spread across diverse EU regions** (i.e. as an EU cluster). Examples of key initiatives can be found in countries like Sweden, Germany, Austria, Belgium (Flanders region), Netherlands, Denmark, Czech Republic etc. Therefore, it can be too early to talk about specific leading regions (it is rather specific leading value chain actors).

There are also some developments at the level of networks/platforms, such as Smarttex Netzwerk[38] in Germany and Smart Textiles Plattform in Austria[39]. These

[38] http://smarttex-netzwerk.de/en/
[39] http://www.smart-textiles.com/

networks/platforms organise different congresses and workshops to bring key stakeholders together and exchange knowledge and experience.

4.2 Key risks and challenges

The key risks and challenges include:

- **High production costs** leading to a high price of the final product;
- **Limited consumer acceptance**: putting electronics onto textiles needs to be justified by the functionality requirements (e.g. sweat absorption, heart rate monitoring, motion sensing, force monitoring etc.). Otherwise, the benefits for consumers may not sufficient to balance out the costs, and smart textiles will not be able to win it from cheaper and more functional wearable devices/gadgets;
- **Regulatory gap** in terms of guidance to companies when it comes to compliance (e.g. testing, assessment, labelling). Some parts of the regulation are already present, but are reported to be highly fragmented; others are still missing and need to be developed. At the same time, stakeholders emphasise that there is no need for more regulatory control. For example, in Asian countries, the regulatory climate is reported to be more flexible. In Europe, there is rather a need for more clarity and systemisation.
- **Hesitance of European manufacturers to invest**: stakeholders report that limited market demand prevents them from massively investing in the area of smart textiles for sports. A significant growth in demand would make this area attractive to them from a business perspective, and necessary investments could then be justified.
- **Skills mismatch**: especially large manufacturing companies often report a considerable lack of skilled people at the level of technicians. There is a need to train multidisciplinary professionals able to combine traditional industries with emerging technological developments; for that, they need to be familiar with both fields and be able to integrate those.
    - There is a need for exposing students to work experience and real manufacturing facilities during their education. Some companies organise initiatives in this respect (e.g. Getzner in Austria, Tekstina in Slovenia, Littia in Slovenia), but it needs to be approached at a large scale.
    - There is a need for continuous upskilling of the workforce though multiple forms of formal and informal on-the-job training, including in-person training and online training (MOOCs, SPOCs, mLearning, gamification, virtual and augmented reality etc.).
    - SMEs often cannot afford significant training costs requiring long periods of absence of their staff. There, online training and collective training and apprenticeship schemes represent promising solutions.
    - Textiles sector has traditionally not been seen as attractive employer. There is a need for rebranding of the sector, in order to show that textile companies can offer creative, innovative and well-paid job opportunities.
- **A need to further strengthen a pan-European approach** towards the development of the value chain (with a key focus on regional level) and and ensure a good alignment between EU, national and regional policies.

4.3 Opportunities for the EU regions

In general, there is a need to build on strong points of each region (smart specialisation) rather than trying to develop full value chains at the regional level.

As emphasised above, it is not only a matter of technical capacity, but rather a matter of limited demand that keeps the domain of smart textiles for sports at a small scale. Therefore, **significant efforts need to be invested into analysing the actual consumer needs and developing products that are market- rather than technology-driven**. A clear statement of the benefits of such products then needs to be developed, accompanied by addressing the key consumer concerns and challenges (e.g. safety, environmental and functionality concerns). That should then serve as an input for the large-scale awareness raising and promotion campaigns. Only with a rapid growth of demand, will the large-scale manufacturing become economically feasible and reasonable.

In order for Europe to be ready for the demand growth, a cross-regional partnership needs to be established for developing a pilot large-scale manufacturing facility. This partnership would unite the efforts of multiple key players and would serve a common European interest. This facility could be a pioneer initiative to set up a large-scale production process of smart textiles. This facility could be of cross-sectoral orientation, serving multiple application domains, rather than only sports. One of the key objectives of this initiative should also be to find the ways to lower the cost of production.

Since growth in demand will be likely to trigger the attention of large-scale manufacturers in Asia, European actors should aim for the segments where Europe is more likely to have a strong competitive position. Such segments include professional athletes and higher-end elite consumers, as well as broader consumer segments having a preference for customised/tailor-made products.

5. Policy implications

The current section aims to present specific policy recommendations on what needs to be done in order to strengthen the EU competitive position regarding this product in the coming years, and specifically on how to enable European industry to move to the higher end of the value chain. We elaborate on measures with both the immediate and longer-term focus.

5.1 Measures with immediate focus

The following measures with immediate focus have been identified:

- **Developing the EU standards for smart textiles for clothes (including sportswear)**: one of the key challenges for bringing the product to the market relates to lack of appropriate standards. The process of developing standards is reported to be unacceptably lengthy and cumbersome. According to stakeholders, there is likely to be a delay of 3-4 more years before the EU standards will become available (although the dedicated standardisation committee has already been set up). In the United States and Canada, the related developments are suggested to happen quicker than in Europe, which may jeopardise the overall competitive position of the EU on the global market.
    - The European Commission needs to set clear deadlines for drafts of the standards and facilitate the process of their development.
    - Special attention needs to be paid to the **standards for big data**. The communication of data has to occur within and between organisations. However, many current systems use proprietary data formats. The challenge is to harmonise data formats towards a preferred open data format with appropriate metadata to provide necessary context regarding the data acquisition and initial analysis. Another data challenge will be likely to arise when data systems attempt to compare data from sensors produced or calibrated differently (for example, when manufacturers use different thresholds, sample rates, or filters)[40].
- **Providing better regulatory guidance for companies active in the domain:** stakeholders report a regulatory gap in terms of guidance to companies when it comes to compliance (e.g. testing, assessment, labelling). Textile and electronic products have to comply with different norms[41]. It is currently not straightforward whether a T-shirt with electronics embedded in it should be considered a piece of electronics or a piece of clothes, and which regulations should apply to it. At this point, companies often try to position the product as electronics and provide the necessary technical documentation on it. Better guidance and systemisation here would also help the market surveillance authorities.
    - Specific aspects to be addressed include the label for washability and the label for disposal.
- **Advancing the requirements of Horizon 2020 calls** (to cover the whole value chain beyond prototyping): there is a need to introduce a new requirement to

[40] Hanuska A. et al. (2016) “Berkeley ELPP: Smart Clothing Market Analysis”

[41] Kirstein, T. (Ed.) (2013) “Multidisciplinary Know-How for Smart-Textiles Developers”, Elsevier

the Horizon 2020 calls, implying the need to go beyond the prototype stage and introduce the product to the actual market already during the project.

  - Stakeholders also report a need for more specialised product-/engineering-oriented Horizon 2020 projects instead of a more generalistic focus.
  - The evaluation periods for Horizon 2020 applications need to be shortened.

- **The need to bring all key relevant actors together**: stakeholders report a need to facilitate the connections between the multiple types of companies/other organisations involved in the value chain. A possible solution could be the development/advancement of cross-sectoral cross-regional collaboration platforms. An example of such a platform refers to the SmartPro[42] project that was funded in the region of Flanders by the Flemish government; its duration was four years. While this initiative had a regional orientation, there is a need to have similar actions on the EU scale.

  - There is a need for awareness raising among the EU companies (and specifically SMEs) on who the relevant actors of the value chain are, what they can offer and where they are located.

5.2 Measures with longer-term focus

The following measures with longer-term focus have been identified:

- **Addressing the skills-related challenges:**

  - There is a need to train multidisciplinary professionals able to combine traditional industries with emerging technological developments; for that, they need to be familiar with both fields and be able to integrate those;
  - There is a need for exposing students to work experience and real manufacturing facilities during their education. Some companies organise initiatives in this respect (e.g. Getzner), but there is a need to approach it on a large scale.
  - One way of improving the quality of (technical) education and for better preparing students for the future workplace, is to replicate real-world situations in the classroom. This principle lies at the core of a 'challenge-driven' university model (see NESTA, 2016[43]), where students work on difficult problems and challenges for which there are no established answers. This approach allows engineering students to contextualise their theoretical learning in relation to how it would be useful in the world around them[44].
  - The new education systems should focus not exclusively on providing new knowledge, but also (and particularly) on training the ability of students to constantly update their knowledge (learning to learn),

[42] http://www.smart-pro.eu/

[43] Mulgan G., Townsley O., Price A. (2016) "The challenge-driven university: how real-life problems can fuel learning", NESTA paper, available at: https://www.nesta.org.uk/sites/default/files/the_challenge-driven_university.pdf

[44] Based on the contributions of PwC NL to "Talent for Europe: Towards an agenda for 2020 and beyond", February 2017, developed together with empirica in the context of "Leadership skills for the high-tech economy" project for EASME/DG GROW of the European Commission

question existing knowledge, generate knowledge themselves and collectively, in a broader community[45].

- **Providing EU funding for the development of large-scale manufacturing facility**:
    - Europe would benefit from a pilot large-scale manufacturing facility. That could be achieved by means of a dedicated cross-regional partnership. This facility could be a pioneer initiative to set up a large-scale production process of smart textiles. This facility could be of cross-sectoral orientation, serving multiple application domains, rather than only sports. One of the key objectives of this initiative should also be to find the ways to lower the cost of production.

[45] For more detail, the reader is advised to consult the Final Report of PwC (2016) "Vision and Sectoral Pilot on Skills for Key Enabling Technologies", developed for DG GROW of the European Commission

Annex A: List of interviewees

Table A-1: Overview of the interviewed stakeholders

Nr	Name	Position	Organisation	Country	Stakeholder type
1	Christian Dalsgaard	Founder and Chief Technology Officer	Ohmatex	Denmark	System integrator company
2	Daniela Zavec Pavlinic	Director	TITERA	Slovenia	SME Technology scout
3	João Gomes	R&D Manager	CeNTI - Centre for Nanotechnology and Smart Materials	Portugal	R&D institution
4	Karin Eufinger/ Guy Buyle	Standards and Technical Regulations Manager/Manager EU Research	Centexbel	Belgium	Research and service centre
5	Karl-Heinz Maute	Head of Global Research & Development	Kufner Holding GmbH	Germany	Large textile producer

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