

Towards a 4th Industrial Revolution of Textiles and Clothing

*A Strategic Innovation and Research Agenda
for the European Textile and Clothing Industry*

Welcome message

Dear Reader,

The present document is the result of a process involving hundreds of textile research, technology and industry experts from across Europe over a period of almost one year to identify and describe the major Strategic Innovation Themes and corresponding Research Priorities of the European textile and clothing industry for the next 10 years. This work was coordinated by the European Technology Platform for the Future of Textiles and Clothing, Europe's most comprehensive expert network for textile research and innovation.

A similar work had been carried out shortly after creation of this network in 2005-6. At this time, we singled out 3 major trends which we believed would shape the future of this industrial sector in the following 10 years. These were:

- The move from commodity to specialty products in all stages and subsectors of the textile value chain
- The extension of the use of fibres and textiles as material of choice across many new and growing application areas and end markets
- The replacement of the traditional mass production concept in favour of a more flexible, customer-driven integrated product development, production, distribution and service model

This vision was developed at a time when a significant part of Europe's textile and clothing industry was in the midst of a painful restructuring process to deal with the dramatically increased global competition in the aftermath of the full liberalisation of global textile and clothing trade in 2005. Our underlying idea was that of an inevitable shift to higher added value products. For companies, this often meant giving up production volumes and only retaining the most attractive market niches, the need to conquer new markets beyond national or European borders or even finding new applications for their materials and products in different sectors. It also meant a greater investment in research, innovation, product and business development as well as skill and competence upgrading of the workforce.

Now looking back over the last 10 years, our past analysis was 'spot-on'. The productivity of the EU textile and clothing industry increased an impressive 36% since 2004, exports have grown by 37% in value and many technical textile markets have shown compound annual growth rates of up to 5-7%. Many more textile and clothing companies are now investing regularly in research and innovation. Overall the EU textile and clothing industry has become smaller in terms of production volume and employment, but has greatly strengthened its competitiveness, resilience and diversification.

Over the next 10 years, new challenges await this industry. The constant flow of new textile materials with better performance and smart functionalities will not stop, digitisation and clean high-tech manufacturing technologies will become the norm in textile factories and value chains, resource efficiency and circularity will make the industry and its products more sustainable and new growth markets in sectors such as health and sports, sustainable transport and energy, construction and agriculture, entertainment and fashion look for innovative textile solutions.

I invite you to explore our new vision for Europe's bright textile future in the following pages and I encourage you to collaborate with the European Technology Platform for mutual benefit.



Paolo Canonico
*President of the European Technology Platform
for the Future of Textiles and Clothing*

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Executive Summary

Ten years after the publication of the first Strategic Research Agenda of the European Technology Platform in 2006, Europe's textile and clothing research and industrial innovation community has undertaken a new collective exercise to identify the most strategic innovation themes and research priorities for this sector for the next 10 years.

The key innovation trends identified ten years ago – (1) move from commodities to specialties, (2) use of textile materials in more technical end markets and (3) move from mass production to customisation and added value services – have largely played out as predicted and have led to an average higher added value creation and a better competitiveness of the industry in Europe. The sector was able to stabilise its manufacturing base and employment in Europe, has increased its research, innovation, education and training efforts, has shown steadily growing exports and more recently registered some noticeable production re-shoring trends.

4 key innovation themes will shape the textile and clothing industry of the future: Advanced Materials, Digitisation, Sustainability and New Growth Markets

While these developments are expected to continue, additional powerful innovation drivers will impact this industry in the coming years. These include (1) **digitisation** of products, processes, factories, workplaces, supply chains, distribution and retail, (2) **sustainability, circularity and resource efficiency** of materials, processes and overall business operations and (3) the proliferation of **new business and consumption models** based on sharing of productive resources and final products, servitisation, pay-per-use or subscription models.

Four strategic **Innovation Themes** have been singled out as particularly impactful for the further development of the European textile and clothing industry.

- I. Smart, high-performance materials*
- II. Advanced digitised manufacturing, value chains and business models*
- III. Circular economy and resource efficiency*
- IV. High-value added solutions for attractive growth markets*

A successful interplay of these four themes underpinned by positive end market conditions in Europe and major export destinations, the unsuitability of the prevailing offshoring logic for faster moving, small volume markets and smart support for collaborative research, innovation, education and training targeted especially at SME's on local and regional level can lead to a veritable **4th Industrial Revolution** of this sector in Europe.


The full potential of the 4 strategic Innovation Themes can only be realised if the necessary knowledge and technological capacities are developed and successfully introduced into industrial practise. **19 Research Priorities** with over 90 specific research topics have been identified and described in detail. They have also been qualified in terms of the main end markets in which they apply, the key collaboration partners for successful research and technological development work, the current Technology Readiness Levels, the expected time frame until industrial demonstration is feasible and the approximate investment level for an industry scale deployment of the technology.

In the field of **Materials Research**, priorities identified include new and improved high-performance fibres, novel 1, 2 and 3-dimensional fibre-based structures, multifunctional textile surfaces and e-textiles with embedded ICT-enabled smart functions.

Research in the field of **advanced and digitised Industrial Technologies and enabling ICT for new Business Models** must focus on new manufacturing technologies for efficient realisation of complex textile and composite structures, digitisation and flexibilisation of production processes and factories, virtual modelling and design of fibre - and textile - based materials and products, digitisation solutions for the full textile-fashion value chain and new digitally enabled business models.

Circular Economy and Eco-innovation in the sector will be enabled by research on more water and energy-efficient textile processing techniques, new recycling concepts and technologies, development of substitutes for hazardous process chemistry, the adoption of biochemistry and bio-based material solutions as well as a better exploitation of natural fibres sources of European origin.

Textile innovations for high value added growth markets addressing the key **Societal Challenges** such as health and active ageing, mobility, food and energy security, safety and sustainable construction and infrastructures, secure and inclusive societies must be developed collaboratively with suppliers and end users in these markets.



Most of these new technologies and innovative solutions will be developed by industry itself together with its main material, technology and service providers as well as industrial customers and end users. However, as some of these research priorities are currently at relatively low TRL levels and entail significant technological and financial risk, **public funding mainly directed at SME's** and their research partners is a crucial factor in the equation.

Funding should to a large extent be provided at national and regional level at which the implementation of less complex projects in well established trusted partnerships is often most effective. Here the funding opportunities need to be improved in many EU countries, also through a better leveraging of EU regional and structural funds dedicated to innovation investments. The recently launched **Regio-Text Initiative** is engaging with textile regions across Europe and their policy makers and textile innovation communities to raise awareness for this need and stimulate cross-regional peer-to-peer learning.

More effective research and innovation support for SME's is needed - from HORIZON 2020 to the regional level

Still not all knowledge and technological capacities needed for the realisation of international market leading innovation are necessarily available at regional or national level. In these cases, **European funding for collaborative textile research and innovation is crucial**. The **HORIZON 2020 Programme** has so far shown mixed results for the textile and clothing sector. Some high-potential projects in cross-sectoral key innovation areas such as circular economy and resource efficiency, digitisation and new business models have been launched. However, heavy project preparation efforts and average low success rates, have discouraged many sectoral key research and industry players. **The European textile research community therefore calls for improvements in HORIZON 2020** such as a reduction of average project sizes and funding levels with more funding allocated to smaller, shorter term projects, more economic impact related project selection criteria and the introduction of an **SME-dedicated funding instrument based on cascading funding**, enabling representative organisations of thematic or sectoral SME research and innovation communities to allocate very rapidly small-scale grants to SME-led small consortia based on a simplified application, evaluation and reporting system.

An important emphasis must also be put on the **development of a highly skilled and appropriately qualified workforce** for Europe's textile and clothing sector. Some 600,000 job openings are expected in this industry until 2025. An important generational shift must be accomplished, preserving specialised traditional skills and know-how and acquiring the correct qualifications for the textile business of the future. For this to succeed, Europe must support and further develop its **world-leading textile education and training infrastructure**.

In the coming months and years, the European textile and clothing research and innovation community organised in the European Technology Platform will intensively engage with EU research and innovation policy makers, programme managers and partners from related industrial sectors and technology domains to further improve the situation for textile-related collaborative research and innovation in Europe.

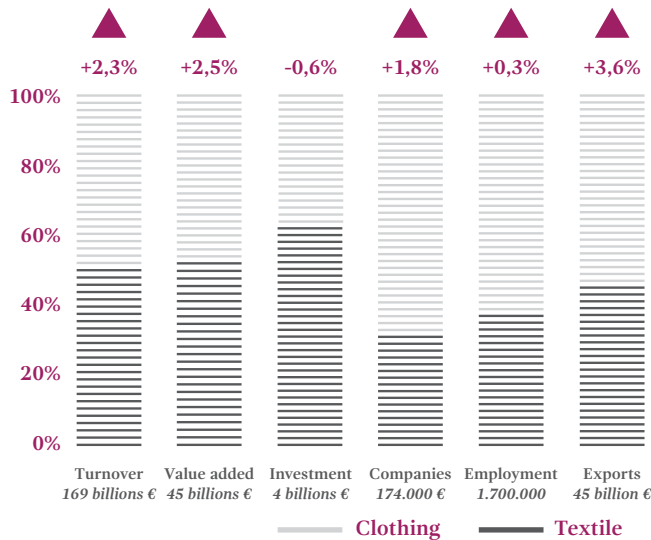
It will also work towards a better general understanding of the great economic and societal potential of an innovative and thriving textile and clothing industry in Europe. The times of struggle and regress are over. **The industry and its research community look forward with confidence to a textile future full of opportunities.**

1. The European Textile and Clothing Industry Today and Tomorrow

Smaller volumes – higher values

Over the last two decades the European textile and clothing sector, today representing a turnover of about € 170 billion and employing some 1.7 million people across 175,000 companies, has undergone a profound transformation. The industry, massively dominated by small and medium-sized companies, largely abandoned low value added mass production and commodity markets and opened a broad spectrum of new application areas for textile materials across virtually all industrial and consumer sectors. The European industry has successfully maintained the higher value-adding positions in the supply chain. Those that are typically linked to knowledge, advanced technological capabilities and highly specialised skills.

In the **textile sector** these include research, development, testing and highly flexible, strictly quality controlled manufacturing of functional, performance targeted fibres and textile materials and their assembly into complex high-value components or products. It also includes design, efficient made-to-order manufacturing and rapid delivery of textiles with a high fashion content or an outstanding sustainability profile for the higher value clothing and interior markets.



Positive key figures of the EU textile and clothing industry in 2015

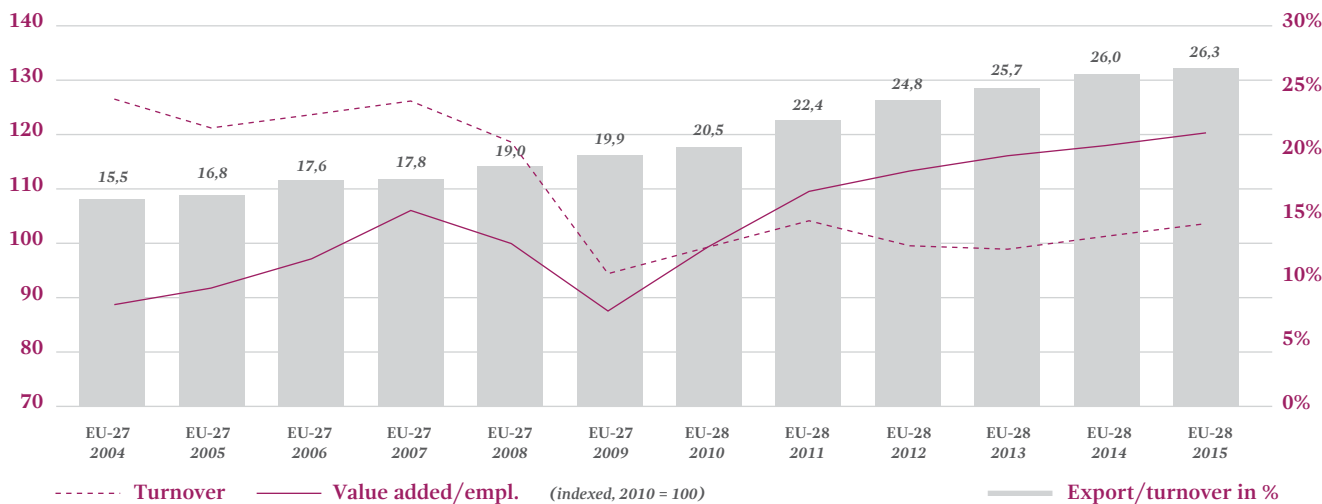


Fig. 1: Evolution of industry turnover, exports and labour productivity between 2004 and 2015 (source: Euratex)

Also in the clothing and fashion sector Europe retained the essential creative value creation functions. These include design and prototyping of fashionable and functional wear as well as branding, merchandising and retail operations to position these products in the most attractive segments of the European and global consumer markets. Southern and Eastern Europe in addition retained a significant manufacturing capacity for premium and luxury clothing and fashion products based on a highly skilled, specialised workforce combined with strict quality insurance, flexible operations and rapid delivery. Highly automated manufacturing operations of interior textiles including carpets are also still solidly present in Europe.

The move up the value ladder is strongly visible in the economic figures of this sector across all of Europe and bodes well for the future of this industry. Since 2004, the EU textile and clothing industry increased its labour productivity by 36% and its exports to markets outside the EU by a cumulative 37%, not missing a single year of improvement. The low value-added mass production of standard fibres, textiles and clothing has largely left Europe, which resulted in a decrease in total turnover and employment. However, the remaining industry has greatly improved its competitiveness.

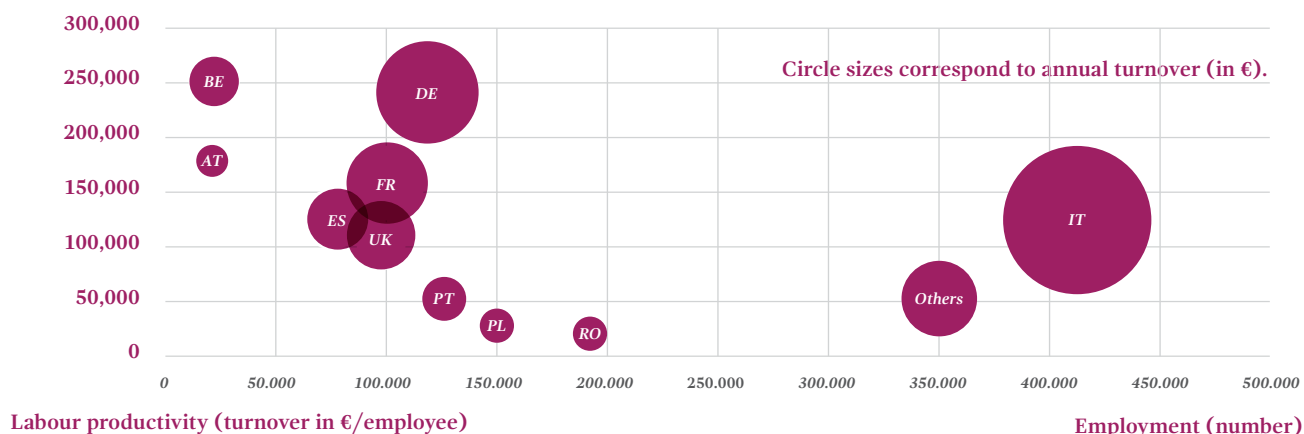


Fig. 2: Turnover, employment, labour productivity of the 10 biggest textile and clothing producer countries in the EU (source: Euratex)

A further transfer away from Europe of highly skill-dependent and knowledge-based manufacturing as well as the market-facing section of this industry doesn't make much economic sense. Quite to the opposite, increasing trends of customisation, less-but-better consumption, faster time to market and sustainability offer real **opportunities to re-shore** some highly efficient small-scale manufacturing units for both textiles and clothing.

Conquering new markets in Europe and the world

Some 20 years ago the fate of the European textile and clothing industry almost entirely depended on the final consumption of clothing and home textiles of the European consumer. In the last two decades both the international market and the non-conventional, i.e. non-clothing and non-interior, applications of textiles have grown into very sizeable drivers of the industry, leading to a very healthy market diversification.

European fashion and interior textile design and product quality are in high demand among sophisticated and aspiring consumers around the globe, especially in the rapidly growing emerging markets. Exports have grown steadily over the last decade and the sector now ships almost 28% of its output to non-EU countries. Provided free and fair global trade is further strengthened in coming years, this trend is unlikely to stop anytime soon. It will provide further attractive market opportunities also for SME's and maintains quality manufacturing, service and management jobs in Europe.

A similarly impressive success story is being written by the **technical textiles sector**. This part of the industry provides materials, components or final products often of high added value to many end markets - from airplanes to smartphones, from race cars to

medical implants, from bridges to deep sea platforms, from fire-fighting gear to clean room equipment, from high-tech greenhouses to food processing plants. This was achieved through a strong push into research and innovation, including specialty chemistry, fibre and textile machinery developments. It often takes place in close collaboration with research centres and universities and with supplier and customer sectors from outside the conventional textile value chains. Many of these large sectors such as transport, construction, energy, food and agriculture, personal protection or healthcare constantly look for new material solutions that are more sustainable, lighter-weight, more functional, safer or more affordable. As a result, most of the technical textile markets are in growth mode in Europe and worldwide. A recent EC study confirmed attractive market opportunities for the EU technical textile industry, including its many SME's, in major global growth markets.

Continuous change to meet future challenges

The main structural adjustment due to the strong globalisation and market liberalisation push of the early 2000's has now been achieved by the sector. The challenge and opportunity set for the coming years is much more diversified.

The constant need to strive for greater cost-efficiency in all business operations, the need to explore and defend profitable market niches, to closely follow or even anticipate the needs of the end market while reacting to constantly evolving political, regulatory and financial market developments – all this will remain an everyday reality for the European textile and clothing company. However, some newer very broad and potentially far-reaching challenges will also need to be dealt with.

Consumption patterns are constantly shifting and some truly disruptive models such as subscription or pay-per-use systems for a broad range of consumer products may eventually also impact the textile and clothing sector. The rise of the **collaborative or sharing economy** enabled by collaboration platforms represents both challenges and opportunities for textile and clothing businesses.

Digitisation of design, manufacturing, distribution, consumer/end user interaction or even the product itself has the potential to upend established business models or turn traditional supply chains on their head. While a change as dramatic as in the media industry is not expected for the textile and clothing sector in the near future, some significant challenges and opportunities start to emerge. Online distribution and direct virtual channels to the consumer reduce the need for middlemen (agents, wholesalers, shop assistants etc.) and enable designers and producers to collect direct feedback from end users and provide value-adding services around their products. However, it also requires the capacity to do this professionally and efficiently.

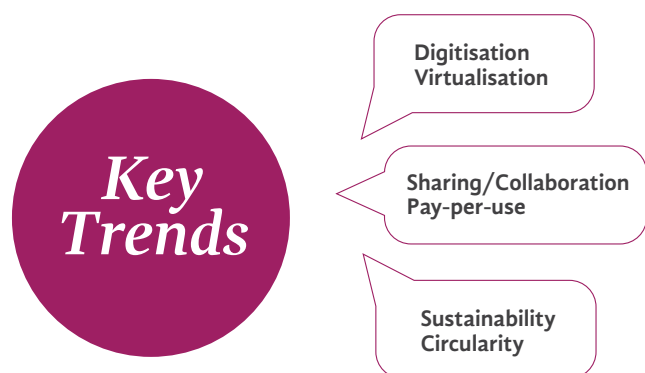
Sustainability, with its economic, environmental and social dimensions, challenges many of today's operations in the textile and clothing industry. Greater efficiency and responsibility in the use of resources whether they are materials, water or energy will have

to be managed and proven by companies of all sizes. Transparent supply chains which demonstrate compliance with environmental, health and social legislation, standards and best practices will have to become the norm. Circularity and excellent corporate governance will have to be integrated into business practices of every company to ensure they remain a welcome and respected actor in their local community.

In 2015, the European Commission's Joint Research Centre brought together over 50 experts from all domains related to textile research, education, technology, industry, trade and policy from across Europe to map out an industry vision with a target horizon of 2025. A broad range of external agents of change emanating from society, economy, technology, policy and environment as well as drivers and constraints of development was taken into account. As a result of a series of workshops the below Industry Vision 2025 was developed.

It captures many of the underlying concepts on which this present Strategic Innovation and Research Agenda is based. Many of the Innovation Themes and Research Priorities detailed in the following chapters will form the strategies and tools with which this future vision will be realised.

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FUTURE VISION 2025

By 2025 the textiles and clothing industry, including fibre-based materials, clothing, home and technical textiles, will be a strategic EU industry sector providing innovative and competitive products enabling personalised, adaptable and attractive solutions, integrating services for very diverse, informed and demanding consumers and business.

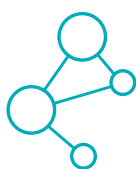
It will operate according to a globalised and efficient circular economic model that maximises the use of local resources, exploits advanced manufacturing techniques and engages in cross-sectorial collaborations and strategic clusters. It will implement profitable and inclusive business models and attract skilled and talented entrepreneurs and employees.

*European Commission – Joint Research Centre
Industrial Landscape Vision Study 2025, January 2016*

2. The Strategic Innovation Themes and Research Priorities

In a process involving hundreds of textile research, technology and industry experts from across Europe over a period of almost one year, the major **Strategic Innovation Themes** and corresponding **Research Priorities** for the next 10 years have been identified, structured and described in detail. All research topics have further been qualified in terms of the major end markets they address, the additional knowledge providers or co-developers they require, their Technology Readiness Levels and time horizons until early industry adoption as well as the approximate scale of investment for an industry-scale pilot system or prototype.

Significant technological progress, successful pilot demonstration and subsequent rapid industrial adoption across this broad field of innovation themes and research topics will enable the European textile and clothing industry to unleash a product, process, service and management innovation boost and lead to a veritable **4th Industrial Revolution** for this sector in Europe.



Innovation Theme I

Smart, high-performance materials

- Research Priority 1.1 High-performance fibres and textile materials for technical applications
- Research Priority 1.2 Novel 1, 2 or 3-dimensional fibre based structures for technical applications
- Research Priority 1.3 Multifunctional textile surfaces and related processing technologies
- Research Priority 1.4 E-textiles for smart structures, functional interiors or smart wearable systems



Innovation Theme II

Advanced digitised manufacturing, value chains and business models

- Research Priority 2.1 New manufacturing technologies for efficient realisation of complex textile and composite structures
- Research Priority 2.2 Digitisation and flexibilisation of production processes and factories
- Research Priority 2.3 Virtual modelling and design of fibre- and textile-based materials and products
- Research Priority 2.4 Digitisation of the full textile-fashion value chain
- Research Priority 2.5 New digitally-enabled business models



Innovation Theme III

Circular Economy and Resource Efficiency

- Research Priority 3.1 Novel flexible process technologies to save water, energy and chemicals
- Research Priority 3.2 High-tech textile recycling for circular economy concepts
- Research Priority 3.3 Sustainable substitutes for hazardous or restricted textile processing chemicals or bio-chemistry based textile processing
- Research Priority 3.4 Bio-refinery concepts using European biomass or waste for textile fibres
- Research Priority 3.5 Greater use of EU-origin natural fibres



Innovation Theme IV

High-value added solutions for attractive growth markets

- Research Priority 4.1 Functional and smart textile solutions for health, sports and personal protection
- Research Priority 4.2 Textile solutions to resource and protect a growing global population
- Research Priority 4.3 Textile solutions for safe, energy-efficient buildings and smart interiors
- Research Priority 4.4 Textile solutions for light-weight, clean and safe transport systems
- Research Priority 4.5 Personalised fashion and functional wear products

Innovation Theme I

Smart, high-performance materials

High-performance material solutions

In analogy to the spider web, man-made fibres and filaments as well as 2D or 3D materials made out of them can exhibit astonishing strength and durability despite their rather fragile appearance, flexibility and light weight. This very fact has allowed the textile industry to bring their material and manufacturing competences to many sectors which traditionally relied on heavier, bulkier materials such as metals, ceramics, concrete etc.

High-performance fibres made of polymers, carbon, glass, basalt, ceramics or metals have been invented many decades ago and have been used since then primarily in niche applications in the aerospace, defence, construction, protection and sports markets. However, lack of knowledge about the characteristics of these materials as well as more complex manufacturing processes which made these fibre-based materials typically more expensive than traditional materials often limited their broad adoption.

The trifecta of **better material knowledge, more efficient manufacturing and increasing end market demand for lighter performance material solutions** is changing this situation rapidly. Worldwide demand for carbon fibres has more than tripled over the last 15 years on the back of strong demand from the aerospace sector, but even stronger growth is expected for the coming years based on growing demand from the high volume automotive and construction markets.

For the coming years, research and technology development in the more established performance fibre classes such as high-tenacity polymers, carbon or glass must focus on **further increasing the productivity and efficiency of their production** and further **processing into 2D sheets and 3D components, mainly composites**, to raise their competitiveness against traditional materials.

For the more “exotic” fibre classes such as ceramics, basalt or niche polymer-based fibres including nano-fibres, research needs to focus on the **exploration of applications** that truly require their specific performance characteristics. There is also a need to **establish pilot plants** for their manufacturing at scale to make them reliably and affordably available to downstream industry users in Europe.

Also the **exploration of bio-based high performance fibres** or fibre precursors, whether from cellulosic or other biological origins, can yield interesting solutions for certain niches of the high-performance materials market.

Functional solutions for very specific challenges

The potential for processing fibres and textiles in specific ways so as to reach a highly purpose-targeted material property is practically endless. It can start at the fibre level where the use of different **additives and finishes** during fibre or filament production can lead to widely differing properties for the same base fibre.

Another option for polymer-based man-made fibres is the realisation of **multicomponent fibres** or filaments through the combination of two (or more) different polymers during the extrusion process. It is also possible to give a fibre a specific geometry in its diameter and thereby change its properties.

Once fibres and filaments are processed into yarns or fabrics a further vast array of functionalisation options exist through chemical, mechanical and many other ways of **altering the material surface** or by adding **additional material layers**.



Such functionalisation can increase the value of a fibre or textile many-fold and make it suitable for the most specific and unexpected applications. Functionalised fibres and textiles are in strong demand in high value growth markets such as health care, personal protection, sports, functional interiors or filtration.



Insertion of a conductive thread into a textile layer (source: STFI)

Laboratory research has proven the technical feasibility of many new fibre or fabric functionalisation processes over the last decade. Some of these new technologies have reached industrial maturity and show interesting market adoption. Many others still struggle with industrial scale-up, cost and market demand problems. Research and technological development must focus on these problems to give the European industry additional options for realising high-added value performance targeted textile solutions at competitive cost. Pilot installations at industrial scale or semi-industrial test-beds at technology centres or cluster facilities with easy access for potential industrial users and in close collaboration with technology developers and providers of processing chemicals are needed.

Smarting up materials and products

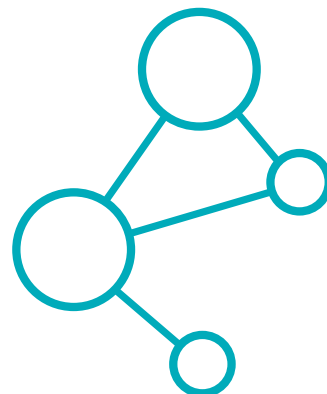
The addition of smartness or intelligence to a textile-based product can start at the smallest material building block, the fibre, but can equally happen at any subsequent stage of processing, manufacturing or assembly of the final system, may it be a medical device, a firefighter suit or a smart car or home interior. **Sensing, actuation, power generation or storage, communication** and a host of other functions have already been successfully integrated into many textile materials and products at least in a prototype setting or in some cases such as wearable heart rate sensors, smart floor coverings, seismic “wallpaper” or smart filters up to market maturity. With the advent of the **smart wearables revolution** and the Internet of Things, the interest and concrete value-adding potential for such

materials and products has grown dramatically. Textiles can bring advantages especially for applications where large surface areas or flexible covers are required or where light weight, comfort and soft touch are desirable. In addition to electronic or digital capabilities, engineered textiles can also smartly respond to temperature, moisture, photochromic, (bio)chemical or physical stimuli offering interesting innovation potential for smart medical solutions, sports and work wear, clothing for the elderly or other people with special needs for functional interiors.

Research and technological development must find perfect combinations of textile material and smart components focussing on end user functionality, durability, manufacturing cost and efficiency as well as ease of use and maintenance including where necessary washability. **Standardisation and certification** as well as end user awareness and education are further important hurdles to be overcome.

A specific challenge valid for all types of high-performance, functional or smart textiles is the aspect of **re-use or recycling** for which technologically feasible and economically sound solutions need to be developed in parallel to the growing introduction of such materials in many sectors.

Europe has a unique leadership position in the high-performance, functional and smart textile material sector, but many other world regions are catching up quickly with the increasing economic importance of such materials. More research and innovation to maintain and further improve Europe’s position is therefore highly strategic as strong material production and processing competences and capacities are at the origin of strong global market positions in many key future markets from mobility and energy, to health and safety.



Innovation Theme II

Advanced digitised manufacturing, value chains and business models

Textile manufacturing - from revolution to revolution

It is well known that the textile industry was the linchpin of the **1st industrial revolution** which started with the invention of the flying shuttle weaving loom and the spinning jenny, the first multi-spindle spinning frame, in England in the middle of the 18th century and quickly swept across Europe and the world. It is generally less well appreciated that the textile and clothing industry was also a massive beneficiary of the **2nd industrial revolution** during which first steam-powered and later electrified manufacturing equipment led to another massive surge of textile and clothing productivity giving rise in the late 19th century to the first truly industry-scale mass-production factories. The **3rd industrial revolution** in the 1960-80's enabled by the introduction of electronic systems and computer technologies was another game changer for the textile industry. Computer numerically controlled (CNC) machine tools and computer-integrated manufacturing (CIM) concepts leading to the next jump of textile productivity based on previously impossible automation, production speed, precision and quality.

Now that **digitisation and interconnection** of every factory, every machine, every technology component and virtually every piece of material that runs through the production process promises the next paradigm shift in industrial manufacturing, the industry again stands ready to embrace the change and reap the benefits in terms of massive gains in speed, productivity, flexibility and quality. The first seeds of this **4th Industrial Revolution** are currently being sown in the European textile and clothing industry, but significant investments in research and development, industry demonstration and worker education will be necessary in the coming years to make the vision of a truly smart textile or clothing factory a reality.



High-tech material manufacturing in every dimension

In the past manufacturing of a textile product mainly consisted of weaving or knitting yarn into a 2-dimensional fabric, put on a roll to be later spread and cut into patterns that would be sewn together into a final product, typically a garment. With the vast extension of the textile sector into a broad range of fibre-based materials processed through a wide spectrum of different processing steps and technologies and made into components or final products for virtually every industrial or consumer sector, this traditional image does not apply anymore to a large part of the industry.

Today the textile industry is **at the forefront of high-tech material manufacturing** using complex material property and process parameter simulation, advanced mechatronics and robotics, machine vision, self-adjusting or self-learning technology to enable efficient one-step or integrated production of complex, multi-layered, 3D shaped or multi-material/hybrid textile and composite structures. **Reliable, precise and fault-free processes** are a must when supplying materials and components to demanding end users such as aerospace, automotive, civil engineering or the life sciences and medical sector.

The experience gained from **processing, handling and assembling complex 3D-shaped components** from flexible materials for high-tech niche applications such as aerospace composites can also over time create spill-over effects into larger volume textile manufacturing such as furniture or automotive structural or interior parts. In combination with digital printing and finishing or later 3D printing even the so far elusive goal of **automated individualised garment making** may one day become reality.



Virtual textile reality

Textile materials are among the most intrinsically complex materials and their **realistic simulation and rendering in 3D** or even in movement has occupied researchers for decades. While most processes in the industry were analogue and customers typically came to see and touch the products in reality before making purchase decisions, textile virtualisation did not offer sufficient added value in relation to its cost and difficulty.

During the last decade however, CAD systems initially only in 2D but more recently also in full 3D, have started to populate textile and clothing design studios and development departments and significant gains in speed and efficiency due to **reduction of physical prototype** making have been achieved.

Now that manufacturing and retail goes more and more digital, the case of virtual textile materials and products that are only manufactured once a customer has expressed a clear interest or even commitment to purchase it, becomes extremely compelling.

A further driver for textile virtualisation comes from the growing end markets for technical textiles such as aerospace, automotive and medical device manufacturing or civil engineering where virtual product development including **simulation of material performance characteristics** during production and use has been commonplace for a long time. Still a lot of research is required for realistic modelling of complex, functionalised or smart textile materials and the integration of such models into industry-ready design and product development systems.

Value chains at the service of the connected smart consumer

Mass production and distribution models in which collection developers, wholesalers, sourcing agents or retailers take decisions on what type of textile and fashion products their target consumer segments are most likely to purchase and place production orders many months before the consumer will ever see the product, are still largely the norm in the textile and clothing business – even in the so-called “fast fashion”. They are the source of much consumer frustration when products in the desired designs or sizes are unavailable. They also result in enormous costs for businesses when their forecasts prove wrong and their ordered product miss the fickle fashion zeitgeist or hit an unexpected weather pattern. They are also a burden on the environment when unsold or heav-

ily marked-down products quickly land in waste streams or when large quantities of mass-produced materials and finished goods sit in stocks or transportation systems around the globe.

Today's new consumer generation fully digitally connected, sophisticated, used to **personalised goods and services** or in search for authentic and sustainable consumption experiences will gradually drive the emergence of a different paradigm. A paradigm in which full personalisation of products is expected, in which sellers must be capable of delivering products to the consumer's doorstep virtually the next day, in which regularly consumed products arrive automatically when needed in a subscription-like way, in which products may be rented for a limited period of time or shared in a community or in which products need to tell an authentic and transparent story about their making.

Such a paradigm will turn today's textile and fashion business upside down. It will require new technologies for **consumer-driven design** and product development, new production technologies for flexible efficient and **local on-demand production** down to lot size 1, new business models facilitating **deep consumer interaction**, servitisation, easy product return or sharing options and seamless networks of designers, producers and service providers sharing resources, data and common business cultures.



Learning to make more with less

The Textile and Clothing industry like any other manufacturing sector is in the business of transforming resources – materials, energy, water, chemicals – into value added products for professional or private end users. Several textile production processes, such as dyeing and finishing, are indeed very resource-intensive. As the consumption of these resources is not free, companies have a natural incentive to use them as efficiently as possible. In addition, tightening legislation on energy efficiency, CO₂ emission, water use, waste water quality or air pollution makes the industry seek better technology to combine economic with ecological benefits while complying with the law. Finally, better environmental performance in production also starts to be more and more rewarded in the marketplace by increasing consumer interest in more sustainable textile products.

To reach tougher resource efficiency targets, the textile industry pursues incremental as well as radical innovation approaches. Incremental approaches include regular production technology upgrade, employment of better monitoring and control systems, use of energy-saving or energy recovery installations, water or chemical re-use systems, better waste water treatment facilities or a generally more resource efficiency driven production planning and worker education.

Radical technological innovation approaches involve the move from wet to dry textile processing replacing conventional dyeing, printing or finishing by digital printing, dyeing with supercritical CO₂, plasma, laser or coating processes. Also material waste can be radically reduced by move from cut-and-sew assembly to seamless manufacturing for instance in knitwear or direct joint-free 3D production of technical textile or composite parts.

Making a chain move in circles

When discussing innovation and market potential, “the Circular Economy” is rapidly becoming one of the most used terms in the European textile and clothing industry. It provides a guideline for the industry, when making investments in production technology (cleaner and less resource-consuming), product development (more sustainable products, focus on recyclability) and in respect to the selection of textile materials (more focus on the use of sustainable fibres). However, the industry still faces tough challenges in the transition from a traditional linear production and consumption model (take – make – dispose) to a circular model. In a circular model it is essential to cooperate with all stakeholders in production, retail and waste processing. Due to its fragmented, SME-dominated structure, the industry lacks the authority to enforce such a corporation with other essential stakeholders in the value chain. Therefore, essential innovations are not yet implemented on a large scale, due to uncer-

tainties in the required investments and long-term economic viability of circular business models and the absence of long term commitments with retail and waste processors. Also the European legislative framework is not (yet) favourable for circular systems, although the circular economy roadmap of the EU might trigger changes with respect to green procurement and legislation (product liability). The use of recycled textile materials can be promoted by these changes.



However, there are also important barriers still to be overcome for an effective recycling of post-use textiles through new technologies for sorting and recycling of textile waste, better used textile collection systems in Europe, better consumer education and easier access for designers and product developers to high-quality, cost-competitive recycled textile materials.

Natural solutions to protect the environment

Approximately 70% of all textile fibres produced in the world today as well as most textile processing chemicals are fossil-based. And while the use of a barrel of oil for textile products that may be in use for years or even decades is a much higher value use than to burn it for energy or transportation, this heavy reliance on a fundamentally non-renewable resource raises viability questions, at least in the long term. Natural fibres, while clearly renewable, are not automatically the more sustainable solution as the case of conventional cotton demonstrates much of which is grown with heavy use of water and pesticides in some of the world's most environmentally challenged regions.

Market interest in EU-grown natural fibres such as flax, hemp as well as European wool and cotton is rising due to an appreciation of their favourable sustainability profiles and interesting potential of their application in growing textile fibre end markets such as

composites for the construction or automotive sector, functional clothing and interiors for allergy sufferers or generally health-conscious consumers or naturally flame-retardant material (i.e. wool) for protective clothing.

As agricultural products, natural fibres typically find themselves at a production efficiency disadvantage compared to man-made fibres which are produced in large-scale controlled industrial processes. They also suffer from greater variability due to impact of changing weather and other natural conditions beyond the control of the producer.

Rapid agricultural productivity progress and new biomass processing technologies represent a strong two-pronged approach to improve the competitive position of European bio-based textile fibres. European forest-based and agricultural waste resources are an abundant, sustainable and economic feedstock for textile fibres as well as bio-chemistry used in textile processing and functionalisation. Apart from being fully renewable these bio-economy routes to textile and clothing products also help to reduce hazardous and toxic chemicals from the textile industry and facilitate circular economy concepts through better recycling or biodegradation of material waste and easier treatment of wastewaters.



Innovation Theme IV

High value added solutions for attractive growth markets

Safe work and play, active ageing and affordable healthcare

Humans are surrounded and touched by textiles virtually every minute of their life from cradle to grave. Textiles support and protect us when we are active – doing work, engaging in sport and play. Textiles are also there to sooth and comfort us when we are tired, sick or immobilised.

Workwear and protective clothing is saving health and lives of millions of workers and professionals being exposed to hazardous situations every day in Europe. They have to strike a delicate balance between being protective while being light and comfortable to be worn for hours without impact on work performance. While previous generations of such products were merely passively protective like a second skin, future generation will be smart and pro-active, reacting and adapting to changing physical conditions of the wearer as well as the surrounding environment.

Europe's rapidly ageing society requires new solutions for **better and more affordable healthcare**, active and independent living of the elderly or other persons with special needs. Textiles have been applied for centuries to treat surface wounds or sooth skin conditions. Today textiles are everywhere in the medical and elderly care environments, they are implanted into the body as sutures, artificial tissues or medical devices, they fulfil advanced wound care functions, they help keeping patients and hospital environments free from microbial contaminations or provide support as orthoses and bandages to treat musculoskeletal disorders. They are also indispensable materials for infant's and woman's hygiene or for disease or age-related incontinence.

An ever growing part of the population, from the very young to the very old, regularly engages in **sport and outdoor activities**. There is virtually no sport that doesn't make use of textile-based equipment or specialised functional clothing to keep the person warm, cool or dry, to protect from environmental impact and injury, or to raise performance. Due to the ever-growing types of sport activities and the search for better equipment there is a virtually endless opportunity to develop innovative smart and functional textile-based products for this rapidly growing global market.

Buildings, infrastructures and resources for the world of tomorrow

From mega-cities to the smallest village in the country-side, people are looking for houses and homes that are safe, comfortable, functional, energy-efficient and affordable. Apart from tents, textiles have not been a dominating material used in building and construc-

tion. But this is about to change. **Light-weight textile-reinforced walls and façade elements** give architects new options to more freely design living spaces. Textile roofs and sails help to regulate light and temperature. Smart textile surfaces create interiors that are comfortable and highly functional at the same time.



Civil engineering uses a broad range of textile materials for infrastructures such as tunnels (linings), pipelines (reinforcement), bridges (repair and reinforcement), roads, embankments and dikes (geotextiles), green walls and roofs.

Important sectors that provide vital resources such as energy, food and water to the globally growing population discover smart textile based solutions. These include growth support and protection of plants, crops and animals in **agriculture**, ropes and nets for **fishing and aquaculture**, fibre and textile reinforcements for turbines and rotor blades in the **energy sector**, flexible solar cells, flexible tanks, nets and filters for water and beverages, foods oils, grains, fruits and vegetables in the **food production** and distribution sector.

Textile solutions in these areas also have the great benefit of being light-weight, flexible, foldable, inflatable and generally quickly to deploy which is critical in situations when natural or man-made disasters such as earth-quakes, floods, storms, landslides, oil spills or large-scale industrial or transportation accidents endanger lives, valuable goods and infrastructures.

Safety, energy-efficiency and comfort on the move

Modern industrial societies are built on the concept that people as well as goods are mobile and can be transported quickly, efficiently and safely over short and long distances on land, on water, on air or even into outer space. The safe and efficient movement of people and goods enables economic growth and raises the quality of life, but also comes with at a high cost and generates many undesirable secondary effects. These include the consumption of resources (transportation accounts for about 50% of fossil energy consumption) and an important contribution to climate change, the loss of life and damage of health and goods in transportation accidents, the pollution of air, water and land, the generation of noise, the loss of natural habitat to transport infrastructures etc.

The **transportation sector** and the industries supplying transport systems and services constantly strive to reduce the cost and negative impacts of transport and coming up with smarter, more efficient solutions. Important large-scale initiatives in this direction include **light-weighting of transport systems** to reduce energy consumption, shift from fossil to renewable energy use (e.g. bio-fuels and electromobility), reduction of emissions from combustion engine based transport systems (e.g. filters and catalysts), addition of **safety features** to secure passengers and goods (e.g. safety belts and nets, airbags, protective packaging etc.).



In most of these areas textile solutions have and will continue to make important contributions. Research and innovation has to focus on developing appropriate textile materials and their processing and manufacturing technologies that meet the requirements of the transport sector in terms of performance and cost. Fibre-based technical textiles and composites can lead a dramatic reduction of

weight and thereby energy consumption of cars, trucks, ships and airplanes replacing **structural and functional** components currently made of heavier materials. For this to be implemented at large scale, a very close collaboration between the textile sector, the transportation equipment manufacturers and end user sectors such as airlines, shipping, road and rail companies is necessary.

Textiles also play an important role in making the interiors of transport systems safer and more comfortable for users. **Functional and smart textile surfaces** can prevent soiling and staining, provide abrasion and fire resistance, can contribute to a better indoor climate or illumination, provide more flexibility through foldable or inflatable equipment. Smart textiles enable integration of sensors, switches, heating or cooling systems or other functionalities into seats.

The growth markets for innovative textiles outside the conventional clothing and interiors textiles are virtually endless. The additional value that can be created by use of textiles instead of other materials is often large and unexpected to manufacturers and end users in these sectors. They are initially unfamiliar with textile materials and processes. Also the replacement of one material by another in a complex system such an airplane, a car, a building or a medical implant has often far-reaching consequences for other materials and components used in the system, with the way its manufactured, assembled, used, maintained and recycled. For this reason, research, demonstration, pilot testing as well as standardisation and certification work must always be undertaken collaboratively between textile material and production experts and specialists from the targeted sectors.



3. Cross-cutting Innovation Drivers

3.1 Skills and education

The European textile and clothing industry currently employs some 1.7 million people. This large human resource pool is in need of constant development and renewal. **Until 2025, an estimated 600,000 job openings will need to be filled** with appropriately qualified young talent across the entire range of occupations, from operational to technical, managerial, creative and scientific. In addition to the industry's own needs, employees with textile-related skills and qualifications will also be in demand in related industries such as textile machinery, chemistry and services, in customer sectors of technical textiles and in textile research, testing, education and training institutions.

The restructuring of the industry and accompanying reduction of employment over the last decades had a negative impact on the general image of this sector as an attractive employer leading to a decreasing interest of young people to seek career opportunities in textiles – with the exception of design and distribution related job profiles. This decreasing demand, in quantitative and qualitative terms, for textile education also negatively impacted the sectoral education and training infrastructure, across all levels. Vocational schools were closed or downsized, textile and clothing departments at colleges and universities were often combined with other departments or faculties and lost their focussed identity and significant resources in terms of teaching and research staff and budgets.

Still Europe hosts the most diversified and world-leading textile higher education infrastructure and attracts top students and researchers from around the globe. And with the stabilisation of the industrial base and the much stronger focus on knowledge-intensive products, processes and services for niche end markets in the sector, the tide has started to turn in a very powerful way. In Northern and Western European countries in which the higher added value transformation of the industry has advanced the most, **student numbers have started to increase again**, recreating a virtuous circle of higher education and training demand leading to strengthening of the institutions providing it. This trend is further fuelled by industry-supported initiatives to attract high potential young talent to the sector, such as the *Go Textile* campaign in Germany.

With the increasing need of industry to access scientific and advanced technological knowledge, the collaboration with research and higher education institutions is generally strengthening. The strong participation or even **leadership of specialised education and training establishments in regional innovation clusters** such as *Smart Textiles* in Sweden or *UP-Tex* and *Techtera* in France are good examples of truly strategic partnerships with strong mutual benefits. The *Textile Research Council FKT* in Germany has been building a collaborative system of textile research strategy development and implementation at national level for more than 50 years, resulting in a particularly strong, diversified and well-funded textile research and higher education infrastructure. In Italy, the launch of the National Technology Platform for Textiles and Clothing has set out to catalyse a similar process. In some other countries, especially the EU member states in Eastern Europe, such research-education-industry collaborations must be set up or further reinforced.

The **European Skills Council for the Textile, Clothing and Leather sectors** has done extensive work over recent years to assess the skills and qualification situation and future needs in the industry. It concludes that apart from professionals with higher education levels in technology, management and creativity disciplines, there is also acute need for correctly qualified personnel at operation and technical levels covering all functions of processing and assembly, packaging and logistics, quality assurance and maintenance as well as marketing and administrative tasks. As 93% of all textile and clothing companies in Europe employ not more than 20 people, flexibility and multiple skills are in high demand.

Apart from traditional textile-related competences, **new and transversal skills and qualifications** will need to be acquired by employees. These relate to domains such as the digitisation of factories, workplaces and supply chains, the need to implement sustainability, circularity and resource-efficiency strategies in production and value chain management, international business competences due to the growing importance of export markets, cross-sectoral knowledge to serve customers in technical textile end markets. Special attention must be given to preservation and generational transfer of **highly specialised competences and rare skills** related to traditional material and manufacturing techniques, to niche applications of textiles or unique design skills.

All such skills and qualifications must become part of initial education curricula, but must also be provided in continuous vocational training programmes. The delivery of these VET programmes must be flexibly adapted to the realities of the SME-based industry. They must be available in proximity of the companies, ideally include practical hands-on sessions at technology-equipped training facilities, at digital learning labs or directly at the workplace. They must also make use of on-line and virtual learning concepts and technologies such as massive open online courses (MOOC) or the gamification of learning.



3.2 Regional Excellence

The European textile and clothing industry has traditionally been regionally clustered typically influenced by nearby availability of raw materials (e.g. natural fibres), processing resources (mainly water) as well as human resources or relevant end markets. Over time, also sectoral technology and service providers as well as research, education and training facilities congregated around these production clusters. Typically, these **traditional production clusters** were either specialised in a particular material along its entire value chain (e.g. cotton, wool, linen, silk) or in a specific manufacturing process (e.g. knitting, garment making) or end product. Often several tens or sometimes hundreds of small companies in close proximity were producing essentially the same products and fiercely competed with each other. This situation was not conducive to collaboration or open innovation.



In successive waves of internationalisation and market liberalisation many European textile and clothing production clusters were heavily impacted leading to industry closures, to mergers of local companies to form larger, more competitive entities or a specialisation in well-defined niches. In the process, production volumes, employment and company numbers declined, but competences and technological capacities including research, education and training facilities were often preserved. This new configuration then enabled the emergence of **textile innovation clusters** all across Europe, a process that was often actively supported and facilitated by regional and national policies, for instance the *pôles de compétitivité* in France or the VINNVÄXT programme in Sweden.

The need to engage more intensively in innovation to succeed in the global market and the absence of direct competition between local companies drove a much more **open and collaborative innovation** environment. Strategy development, implementation, governance and monitoring of such open innovation clusters are jointly carried out by the Triple Helix actors – the industry, the research and education community and the public authorities. The objective is to concentrate innovation efforts and resources into knowledge, technology or market domains in which the regional cluster has a particularly strong position compared to competitors elsewhere and where attractive growth opportunities exist. This idea of **Smart**

Specialisation has also been adopted by EU Regional Policy with the objective of propagating it across Europe and facilitating it by allocating a significant share of the EU regional and structural funds towards this objective.

The results of some of the longer established textile innovation clusters in terms of competence and technological capacity development as well as industry innovation and market success, also measured in the number of textile start-ups created, is truly impressive. However, the idea of smart textile specialisation has not yet firmly taken root in all European textile regions, with particular **untapped potential remaining in parts of Southern and Eastern Europe**.

To change this situation, the **RegioTex initiative** has been launched in 2016 by Euratex and the European Technology Platform. It has been joined by many leading textile regions in Europe and remains open to welcome additional regions. Its objectives are to:

- Support regional authorities to better identify the challenges and harness the potential of textile innovation for industrial renewal, new competitive manufacturing value chains and sustainable high-quality manufacturing jobs;
- Encourage and enable “textile regions” to invest part of their EU structural funds into effective textile-related innovation support;
- Develop and strengthen regional industry innovation support structures (clusters, association, technology, education and training centres etc.);
- Build an active EU network of textile regions for peer-to-peer learning and to facilitate bilateral and multilateral business and innovation collaboration;
- Develop effective cross-regional funding instruments to support EU collaborative research, innovation or training projects by regional or national funds where EU funds are inappropriate or lacking (e.g. cross-regional SME innovation projects).

There is currently a wide gap between regions that smartly support their local or regional textile innovation communities and those who hardly recognise their existence. Consequently, there is a huge potential to be unlocked. The inhibitors for a better regional textile innovation valorisation are manifold. In some cases, the sectoral innovation community is disconnected and disorganised, research-education institutions and industry don’t engage with each other, companies are unable to organise and support an association which can effectively represent their collective interests, small local clusters in a region choose to compete rather than collaborate to increase their clout with regional policy makers. On the policy side, regional authorities sometimes prefer to copy fashionable policy approaches from elsewhere in total disregard for their regional economic reality and needs.

RegioTex will work towards triggering change among all regional textile innovation actors to ensure that the transmission mechanisms from leading edge research and technology development at European level to effective industrial take-up by SME’s at regional and local will be set into motion all across Europe.

3.3 The European Dimension

The EU internal market is the world's largest single market for textile and clothing products worth some € 500 billion per year. It is a highly sophisticated and diversified market with consumers who highly value creativity, quality and sustainability and industrial customers who demand the highest levels of innovation, reliability, product and service level.

The EU single market is also highly regulated with an extensive legal framework to guarantee free and fair competition, health and safety of consumers and workers and protection of the environment. These rules, regulations and standards and the cost and administrative burden of complying with them represent a veritable hurdle for European textile and clothing companies, especially SME's, which want to innovate, produce and trade across Europe. On the other hand, they also serve as a barrier to potential outside competitors who are unfamiliar with them or whose products and processes fail to reach the strict standards for environmental protection and consumer safety applicable in the EU.



The European textile and clothing industry supports policies aimed at a high level of environmental, worker and consumer protection guaranteeing a good quality of life and social integrity in Europe. These policies must be based on sound scientific evidence, attainable targets, a reasonable balance of the environmental, social and economic dimensions of sustainability and implemented reliably, with the least possible red tape and evenly across the EU. There must be a strict level playing field for producers and importers and sufficient control and enforcement to ensure compliance by all market actors.

Many new legislations and standards in the environment, health and safety domain can only be met by the generation of new knowledge and development of new processes and technologies, such as the substitution of hazardous substances in chemical textile processing, the treatment of waste and effluents, the optimisation of ecological footprints of products or the protection of workers and consumers exposed to new materials and technologies. In these domains, public support for the generation of sound scientific knowledge, development of appropriate models and test methods or piloting of new processes and technologies should always be considered.

The funding of collaborative research between industry, science and research at European level mainly implemented through the **European Framework Programmes for Research and Innovation** is a crucial driver for the global competitiveness of the European textile and clothing industry. The European textile research community has been making extensive use of these funding opportunities

since their inception. Since its establishment in 2014, the European Technology Platform has played an instrumental role in organising the European textile research and innovation community and effectively connecting it with European funding opportunities. Results of this work during the 6th and 7th EU Framework Programmes, which provided a total EU funding of around € 250 million to textile-related research, have found their way into the market through new materials, processes, technologies and business models adopted by the European industry and innovative products and services offered to consumers or industrial customers around the globe.

The current **HORIZON 2020 Programme** with its focus on a number of key societal challenges and enabling industrial technologies covers all relevant research and innovation domains for Europe's textile and clothing sector. **The experience of the sectoral research community from participation in HORIZON 2020 however, has been mixed so far.** On the positive side, the focus on multidisciplinary and cross-sectoral collaboration to address concrete societal challenges suits a sector that offers a very broad range of material, process and product solutions for many end markets. Allocation of significant resources to key innovation themes such as sustainability and circular economy or digitisation and new business models that are also squarely in the sector's innovation focus, have already led to the funding of a number of flagship projects. On the negative side, the size and complexity of most funding instruments is often beyond the reach of this SME-driven industry. The efforts required for proposal preparation linked with the average low funding rates, have discouraged many sectoral key research and industry players who have eagerly and successfully participated in previous framework programmes. Significant pre-defined budget allocations to a growing list of Public-Private Partnerships limits the programme's flexibility and reduces the scope of high potential research topics that fall outside the scope of these PPP's. The SME instruments with their particularly low success rates and too high average project allocations, limit their use too much to the most research-intensive and public funding driven part of Europe's SME community, which may not be the most impactful in terms of industrial investment and job creation.

The European textile research community therefore calls for the following changes in HORIZON 2020:

- A reduction of average project sizes and funding levels with more funding allocated to smaller, shorter term projects.
- A re-evaluation of the scope and funding allocation to PPP's with assurance of ample funding opportunities for research priorities outside the PPP scopes.
- A strengthening of the weighting of economic impact criteria such as realistic industrial investment and job creation targets when evaluating project proposals and a stronger involvement of business experts in evaluation processes who have the appropriate competences to judge such criteria.
- The introduction of an SME-dedicated funding instrument based on cascading funding, enabling representative organisations of thematic or sectoral SME research and innovation communities to allocate very small-scale grants to SME-led small consortia based on a simplified application, evaluation and reporting system. Inspiration can be drawn from the WORTH concept for design-based innovation piloted under the COSME Programme.

4. Game changers and long shots for 2025 and beyond

The textiles and clothing sector is among the largest industries in the world with a total end market worth over € 2 trillion on a global level. It thereby also represents an enormous field of opportunity for disruptive innovators which can bring to market radically new material and production approaches or game-changing business models.

These disruptions can potentially come from any of the following science or technology domains which are expected to make massive progress in the coming years and decades: nanotechnology, synthetic biology and bio-engineering, robotics and additive manufacturing, high performance computing and big data processing, virtual reality and artificial intelligence or combinations of those. They are already in the process of creating paradigm shifts in sectors such as media and publishing, fossil fuel based transport and energy or the chemical industry. Digitisation is about to disrupt decades-old retail systems for consumer goods and increasingly also distribution of industrial supplies.

Below are just a few examples of what may be possible within a time frame of perhaps not much beyond the next 10 years. Still the technologies enabling such disruptions are far from industrial readiness today and in some cases require **fundamental research**. It is important that also such radically new approaches and long shots are **supported by public research funding**.

Europe's textile and clothing industry is a world innovation leader, but due to its small-to-medium-sized company structure it generally lacks the capacity to engage in very long term transformative research using exclusively internal resources. To stay a global leader, it cannot afford to lose its thought leadership and the technological edge.

Truly game-changing innovations in the textile and clothing sector could include:

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1. Synthetic generation or regeneration equivalents of natural fibres such as cotton, wool or silk in efficient large-scale industrial processes and with material properties that match or even exceed the finest varieties of today's naturally grown counterparts. Europe would be the greatest beneficiary as it is currently almost entirely dependent on sourcing of these fibres from other parts of the world.
2. Development of the next generation of high performance fibres with higher production efficiency, better sustainability profile and based on renewable feedstock but at comparable or better functional properties and easier processability than carbon fibres
3. Development of efficient small-scale on-demand production units for yarns or fabrics (spinning, twisting, weaving, knitting, non-wovens etc.), fully digitised and equipped with a highly versatile modular material feeding system, similar to cartridges of a digital printer or capsules of a coffee machine. This would enable on-demand lot size 1 production of personalised fashion products or textile-based consumables in the industrial or medical sector (e.g. filters, labels, bandages) starting from basic material building blocks. It would massively eliminate stock-keeping, logistics and waste of semi-finished products.
4. Fully integrated, automated and digitised small-scale production units for clothing, footwear, bags, accessories and other assembled textile based consumer products at the point of sale or use. They will allow rapid design, textile production or at least colouration and finishing, product assembly, packaging and delivery of single piece personalised fashion products very near to where the end consumer lives, works, shops or travels. They would replace slow, complex and wasteful global supply chains for such products today.
5. Distributed small-scale textile recycling systems for rapid and cost-effective separation, disassembly, dissolution, biodegradation or other transformation processes of end-of-life textile products into valuable inputs for a next productive lifecycle, enabling a truly circular economy at local scale.
6. Complete virtualisation of the human-textile interaction allowing realistic digital communication of all aspects of a textile or clothing product including visualisation, fabric behaviour, fit and haptic sensation. This would remove the need for any physical interaction with a product before a purchase/use decision is made, both in B2B transactions within the supply as well as when dealing with the final consumer.

Glossary of abbreviations and terms

AI	Artificial Intelligence	PLA	Polylactic Acid
AR	Augmented Reality	PPE	Personal Protective Equipment
CAD	Computer-aided design	PPP	Public Private Partnership
CAM	Computer-aided manufacturing	REACH	A European Union regulation concerning chemicals, entered into force in 2007. REACH stands for Registration, Evaluation, Authorisation and Restriction of Chemicals.
D4R	Design for Recycling	RiD	Recycling in Design
ETP	European Technology Platform	SC-CO₂	Supercritical Carbon Dioxide
FEM	Finite Element Method	SCM	Supply Chain Management
HORIZON 2020	The EU Framework Programme for Research and Innovation for the period of 2014 to 2020	TCI	Textile and Clothing Industry
Investment scale	As used in the research priority descriptions of chapter 2. Describes the approximate investment required to build and install an operational pilot demonstration system at (semi)industrial scale. Small = up to € 1 million, medium = € 1-10 million, large = over € 10 million	Time horizon to industrial pilot readiness	As used in the research priority descriptions of chapter 2. Describes the approximate time frame it is expected to take from today's research/technology state-of-the-art until an operational pilot demonstration system at (semi)industrial scale can be developed. Short = up to 3 years, medium = 4-7 years, long = 8+ years
IOT	Internet of Things	TRL	Technology Readiness Level, defining the maturity of a technology along a continuum from 1 (basic scientific principles observed) up to 9 (full-scale functioning system proven in a relevant operational environment)
LCA	Life Cycle Assessment	VET	Vocational Education and Training
OEM	Original Equipment Manufacturer	VR	Virtual Reality
PBS	Polybutylene succinate		
PEF	Product Environmental Footprint		
PHA	Polyhydroxyalkanoates		

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Useful further information sources

- The European Technology Platform for the Future of Textiles and Clothing, www.textile-platform.eu
- AUTEX – Association of Universities for Textiles, www.autex.eu
- EURATEX – The European Apparel and Textile Confederation, www.euratex.eu
- Textranet – Textile Transfer Network, www.textranet.net
- European Commission, DG Internal Market, Industry, Entrepreneurship and SMEs – Sector Textiles and Clothing https://ec.europa.eu/growth/sectors/fashion/textiles-clothing_en
- European Commission, DG Research and Innovation, Directorate for Industrial Technologies, http://ec.europa.eu/research/industrial_technologies/index_en.cfm
- European Commission - HORIZON 2020 Programme: <https://ec.europa.eu/programmes/horizon2020/>

About the Textile ETP

The European Technology Platform for the Future of Textiles and Clothing (Textile ETP) is the largest European network dedicated to textile research and innovation. Its main objectives are to ensure long-term competitiveness of the EU textile and clothing industry through collaborative research across national borders in Europe and a rapid translation of research results into industrial innovation. Its services and activities include strategy and policy development for European textile research, information provision about EU textile research funding opportunities, brokerage of partnerships for EU research funding applications, dissemination of results of EU-funded textile research projects, organisation of conferences and seminars on textile innovation trends and new technology developments and networking among its members and other organisations interested in textile research and innovation in Europe. The Textile ETP currently has about 175 member organisations from industry, research and higher education with a total of over 500 registered individual experts. For more information, visit: www.textile-platform.eu

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