European Commission

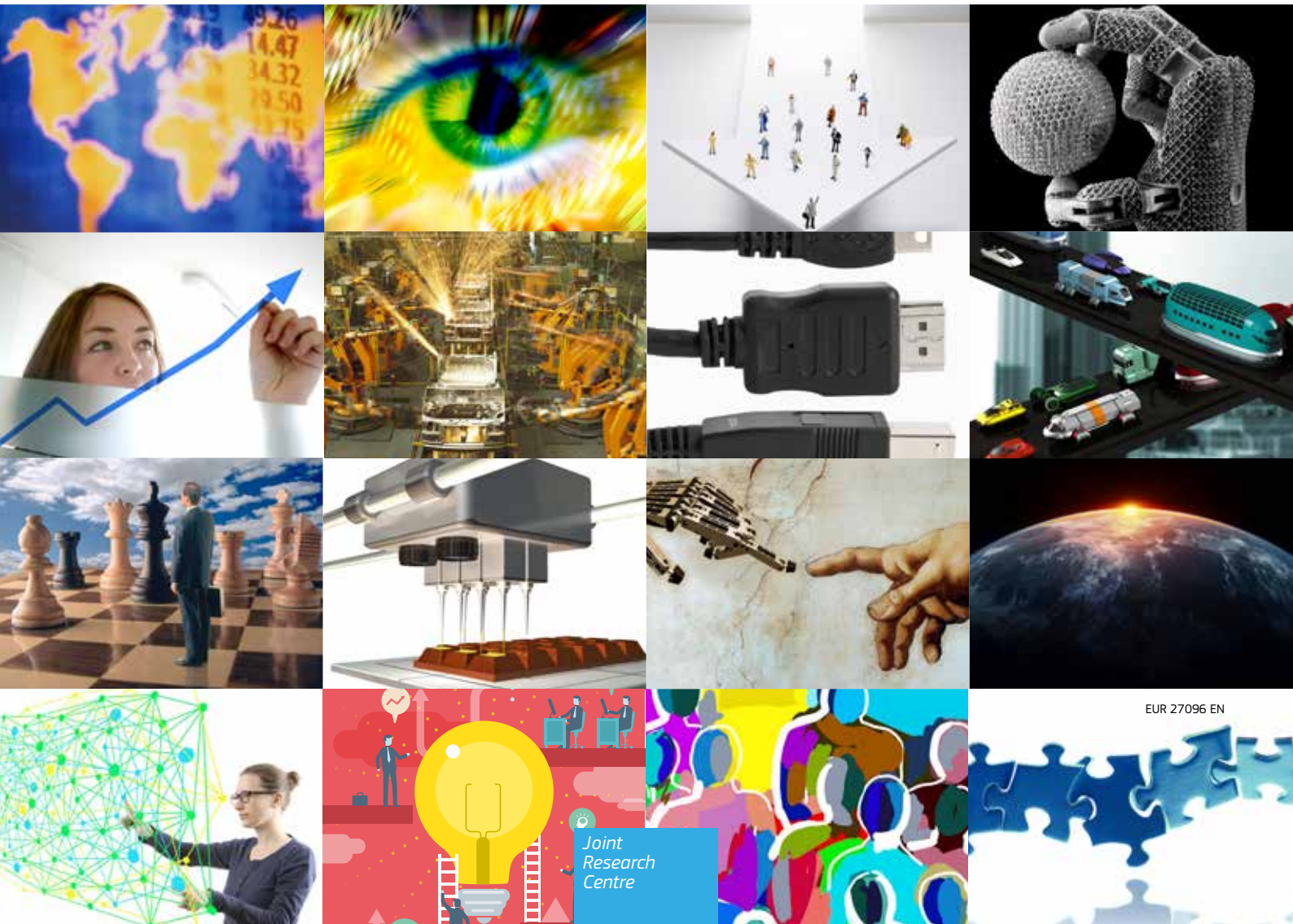
JRC FORESIGHT STUDY

How will standards facilitate new production systems in the context of EU innovation and competitiveness in 2025?

Final Report

Fabiana Scapolo, Peter Churchill, Vincent Viaud, Monika Antal, Hugo Córdova, Peter De Smedt

2014



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Abstract

Standards are very important as they provide requirements, specifications, guidelines or characteristics that can be used consistently to ensure that materials, products, processes and services are fit for their purpose. They contribute to remove technical barriers to trade, leading to new markets and economic growth for industry. They also facilitate technology transfer and they contribute to ensure safety of products thereby affecting the daily life of citizens. This report 'How will standards facilitate new production systems in the context of EU innovation and competitiveness in 2025?' is the outcome of a foresight process looking at how standards and standardisation can become even more relevant policy tool supporting different European policies. The study has especially looked at the areas where Europe drives innovation, where the development of new products and processes could lead to new trade of goods, services and technologies. The foresight process has dealt with standardisation by using a holistic approach. It explored at how effective standards can be developed within a European industrial landscape vision able to contribute to jobs and growth in a sustainable manner. The report provides a clear overview of the evolution of the European production system and illustrates what are the drivers of change influencing the future production system. The Industrial Landscape Vision was used to identify the its implications on the European Standardisation System and it highlights priorities for the development of standards in the future.

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Executive summary

This report is the final result of an 18-month foresight study that explored the role of standards and standardisation in the European Union in 2025.

Carried out by the European Commission's Joint Research Centre at the request of Directorate-General Enterprise and Industry, this study was undertaken based upon six highly interactive workshops that brought together more than 60 European experts from different backgrounds in standardisation, manufacturing, research, technology and innovation.

This report outlines the methodology that was applied, the key issues identified and the recommendations to strengthen the contribution of standardisation to European innovation and competitiveness by 2025.

The policy context

As underlined by **Europe 2020** and the associated Flagship Initiatives, standardisation has a key role to play in **stimulating innovation** in the European Union and fostering **European competitiveness** worldwide. However, it will only succeed in doing so if the European Standardisation System (ESS) – organised around the European Committee for Standardization (CEN), the European Committee for Electrotechnical Standardization (CENELEC) and the European Telecommunications Standards Institute (ETSI) – can effectively *keep pace* with research, technological development and innovation.

In its 2011 Communication on 'A Strategic Vision for European Standards', the European Commission identified the **acceleration of the standardisation process** as a necessary condition to achieve that objective, and underlined the potential of **anticipation and foresight studies** to identify in a more timely manner the needs for standards development.

The study approach

This foresight study was a first attempt to test the use of forward-looking techniques in standardisation. A **holistic approach** was used based upon the development of an **Industrial Landscape Vision (ILV).** Through the use of participatory techniques, an extensive literature review, and two case studies (on additive manufacturing (AM) and mobility) the **agents of change** in society, technology, the economy, environment and policy were identified which will either enable or constrain the development of new production systems. On the basis of this, the **production and consumption system** itself was analysed through a function-based rather than sector-based approach, and its internal dynamics was further explored from a qualitative perspective.

The ILV framework was then further expanded using a narrative that described a desirable vision for industry in 2025.

This was used as the framework against which the needs for standards and changes to the European standardisation system were defined.

The Industrial Landscape Vision for 2025

There will be a **globalised economy** serving an **informed and prosperous global middle class** that will require **personalised goods and services** based on **advanced, ICT-enabled manufacturing systems** supplied by **European resource-efficient and sustainable industries**.

First, consumers will increasingly demand a package of products and services tailored to meet their individual needs. The traditional model of ownership will evolve as societal and environmental pressures encourage people to demand more integrated products and services. As a result, manufacturing companies and service providers will work more closely together to build consumer-driven solutions combining products and services. Personalisation, enabled by new production technologies such as robotics and AM will become key drivers for industry.

Second, regional and local customisation will have a major effect on how industry operates. Globalised but diverse markets, distributed manufacturing and an increasingly informed and prosperous global middle class will set industry many challenges. Globalisation of the market will result in millions of new customers for products and services across the globe, emphasising the regional diversity of consumer choice, with different regions often requiring very particular products, offering different features and different pricing. Industry will have to respond by significantly improving its market analysis capabilities to capture consumer requirements adequately. The production of goods and services will therefore be driven by the requirements of increasingly demanding consumers, and will become localised and networked to be closer to customers, to respond to local demand, and to reduce costs.

Underpinning this will be 'big data'. Data will become the 'new oil'. Increasingly complex and large sets of data, supported by advanced analytical tools, will enable manufacturing firms to better understand and optimise all stages of their value chains, from design to distribution, including supply chain management, production processes and marketing.

The result will be agile manufacturing, enabled by new production processes and technologies, such as additive manufacturing, software-enhanced added-value services, and ICT. Companies will create more intelligent products based on cyber-physical systems. These products will be manufactured in 'digital factories', with each part of the production process able to communicate with different manufacturing 'players' (e.g. humans, intelligent machinery, robots, etc.). The value chain, with complex logistics systems able to supply materials and distribute products flexibly, will result in a manufacturing process that is more efficient and responsive to change.

Priority areas for developing standards

Five priority areas have been defined where new standards, and/or the update of current ones are needed to facilitate new production systems that will foster European Union (EU) innovation and competitiveness in 2025.

'Standards for integration' are essential in order to respond to the challenges of a fully globalised economy where value chains are more disaggregated and products and services more integrated. Standards that can cope with converging technologies, infrastructures, industries and business models, and can assure the required interoperability and interconnectivity, are particularly necessary if the European industrial system is to reach its optimal cruising speed. As a result, considering technologies or sectors in isolation for the development of standards is no longer an option. The main challenge lies mainly in the higher level of coordination needed within the European standardisation system (i.e. among European Standards Organisations – ESOs – but also among their technical committees) and beyond (e.g. with other international standardisation bodies and with industry fora and consortia).

Resource efficiency, clean production, zero waste and energy neutrality will be at the core of industry in 2025 in order to make business more competitive, to close the material loop, and to respond to certain consumer desires for a more sustainable world. **'Standards for environmental sustainability'** are essential to support public policies on sustainability issues, as well as to guide the whole European industry towards sustainable practices and environmental friendliness. The challenge for ESOs is to engage a wider range of stakeholders and actors (e.g. service providers, small and medium-sized enterprises - SMEs) in standardisation work in an efficient and coordinated way, and to ensure that standards continue to keep pace with rapidly developing technologies and business practices.

Stronger competition to sell increasingly integrated goods and services globally to more informed and demanding consumers leads to a growing need for performance-based standards ensuring the required quality of materials, products and services, and the performance of processes and technologies. Traditionally well-covered by standardisation activities, the development of **'standards for quality and performance'** is increasingly challenging for the ESOs due to shorter innovation and product cycles. It is also more challenging as products and services become more personalised to the individual, or customised to meet the needs of regional markets. The endorsement of European standards by the international community will continue to be key to putting Europe ahead of its international competitors in the global market.

With the ongoing shift from product ownership to service leasing (e.g. from car ownership to mobility services), and the increasingly vast number of products and processes that can be offered as a cloud-based

service, **'service standards'** are needed to ensure and demonstrate to consumers the quality of services through more standardised, mainstreamed and simple methodologies which will facilitate comparability and evaluation.

Giving consumers confidence, and protecting them and the environment will be increasingly important roles for standards, particularly as consumers purchase services in conjunction with products. It is therefore proposed to cluster the standards dealing with health and safety, security and privacy, accessibility, and environmental protection issues in a single category – **'de-risking' standards** – since, in terms of innovation and competitiveness, the main benefit of all these standards is to reduce the risks related to the acceptance, uptake and dissemination of the proposed innovative solutions.

Main implications for the European Standardisation System

The study has also identified some important implications for the ESS. Three main areas were identified:

Accelerating the standardisation process

The foresight study confirmed that acceleration of the European standardisation process is essential for standardisation to keep pace with both technological developments and the evolution of societal, environmental, economic and geopolitical challenges. It also highlighted that it should be implemented carefully, as the quality of the outputs, respect of the consensus principle of standardisation, and the need to involve a broader scope of stakeholders should not be jeopardised.

Anticipating the needs for standards in a more systematic manner applying horizon scanning and foresight techniques is probably the best way to accelerate the whole standardisation process. The present foresight study is a first step in applying such a forward-looking approach. However, it should be completed by other foresight methodologies used on a recurrent basis by the ESOs themselves so as to identify earlier the specific standards that are needed for specific themes, sectors or technologies.

The development of standards can also be accelerated, and innovation enabled by helping to bridge the gap between research and marketable products or services. To do so, fora need to be set up in Europe to facilitate discussions between **the scientific and standardisation communities**. Incentives should also be developed to foster greater scientific involvement in standardisation activities.

Integrating European efforts in standardisation

To boost its competitiveness in the increasingly globalised market, Europe should aim to promote its standards as early as possible so that they are endorsed by the international community as world-leading standards. Key thematic areas need to be identified and prioritised, and international activity and European participation assured. This requires Europe to put in place an integrated **international standardisation strategy** involving the three ESOs (and in coordination with national standardisation bodies, too) and driven by Europe's policy priorities.

In addition, Europe must address complex technical, social and political challenges. Cross-border, interconnected, interoperable, smart infrastructures, for example, require integrated, cross-cutting European initiatives if they are to be implemented successfully. This means that standards have to follow the same **integrated approach**, incorporating a coordinated, coherent response from the three ESOs.

Engaging more stakeholders in standardisation

With the increasing importance of consumer demand for innovative products and services, more user-oriented standards need to be developed. Online collaboration tools and gamification should be used to **engage more consumers and private citizens**.

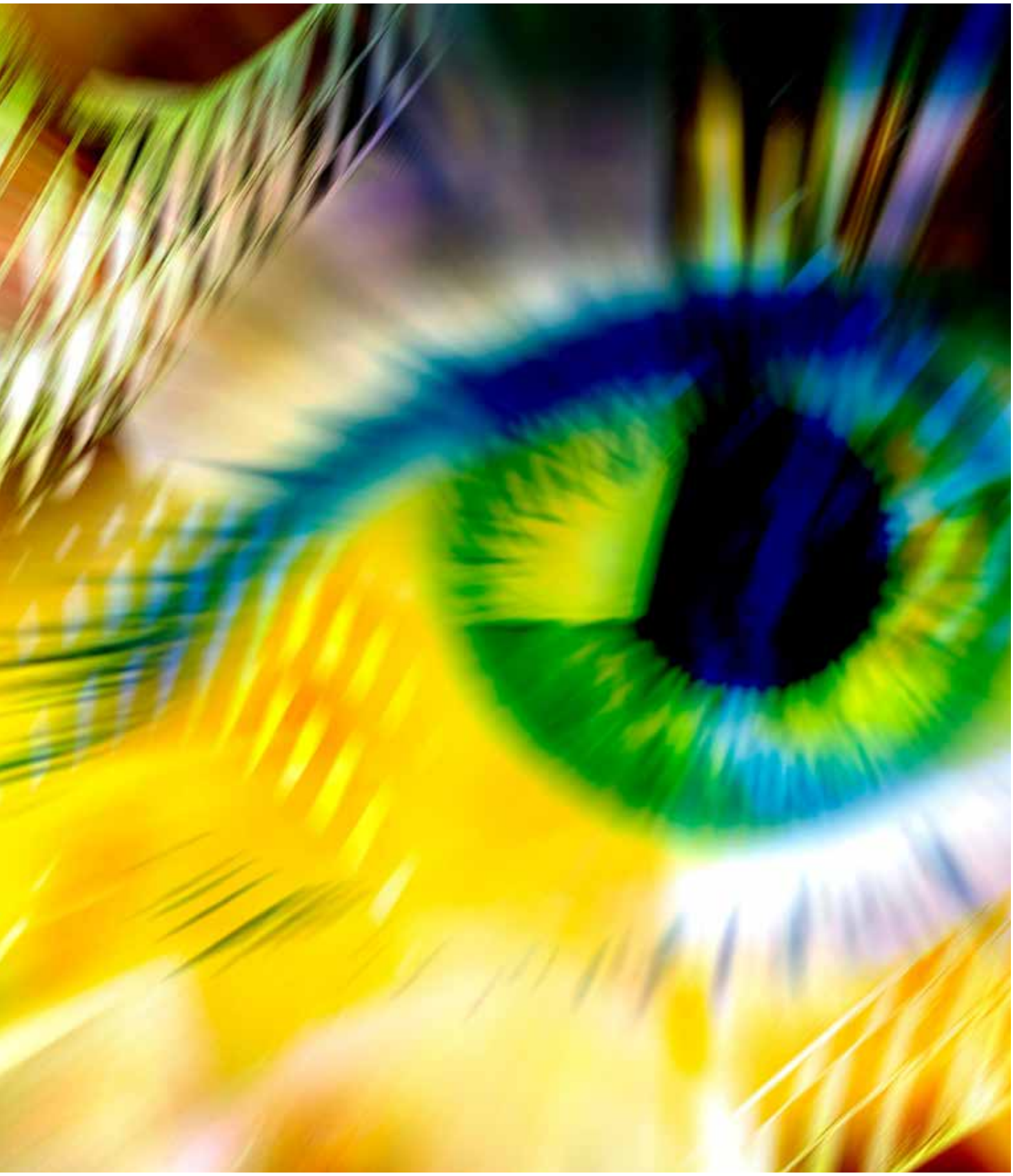
Engagement of consumers, as well as SMEs, could also benefit from communication and awareness campaigns on the impact of standardisation on society and the economy. Crowd-funding approaches should then be explored to fund more **experts representing SMEs' interests**.

Closer cooperation should be ensured between the ESOs and the **European Patent Office** (EPO) in an effort to come up with joint approaches to facilitate European competitiveness.

A template for horizon scanning and foresight

Based on the Industrial Landscape Vision 2025 and the two case studies on AM and the future of mobility, a **foresight template for identifying standardisation needs** has been developed to allow ESOs to identify new issues for standardisation earlier and in a more systematic way. It should be managed by the three ESOs working together through a joint strategic governance scheme.

The ILV and the analysis of standardisation needs have led to a number of **research recommendations**. For example, economic analysis is required to better understand and measure the impact of standardisation on both innovation and trade.



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The pictures at pages-52-53 are illustrations by Nick Payne, graphic designer, Brussels (Belgium). They were used to facilitate the future mobility case study.

1. Introduction to the foresight study

1.1 Study background

The foresight study on 'How Will Standards Facilitate New Production Systems in the Context of EU Innovation and Competitiveness in 2025?' was carried out by the European Commission's Joint Research Centre (JRC) at the request of Directorate-General Enterprise and Industry (hereafter referred to as DG ENTR). The study officially began in mid-December 2011 and concluded with a validation workshop in mid-September 2013.

The report does not necessarily reflect the view or the position of the ESOs, the national and international standardisation bodies, and other stakeholders identified by Regulation (EU) No 1025/2012.

1.1.1 Why standards?

The importance of standardisation in stimulating and enabling innovation and competitiveness in Europe is at the heart of European policy.

The March 2008 Commission Communication[1] started the current policy trend in standardisation as an essential component of the drive for innovation and jobs. This Communication identified the challenges faced by Europe as regards standardisation, and stressed that "a stronger role for standardisation in support of innovation is important for the European effort to address economic, environmental and social challenges".

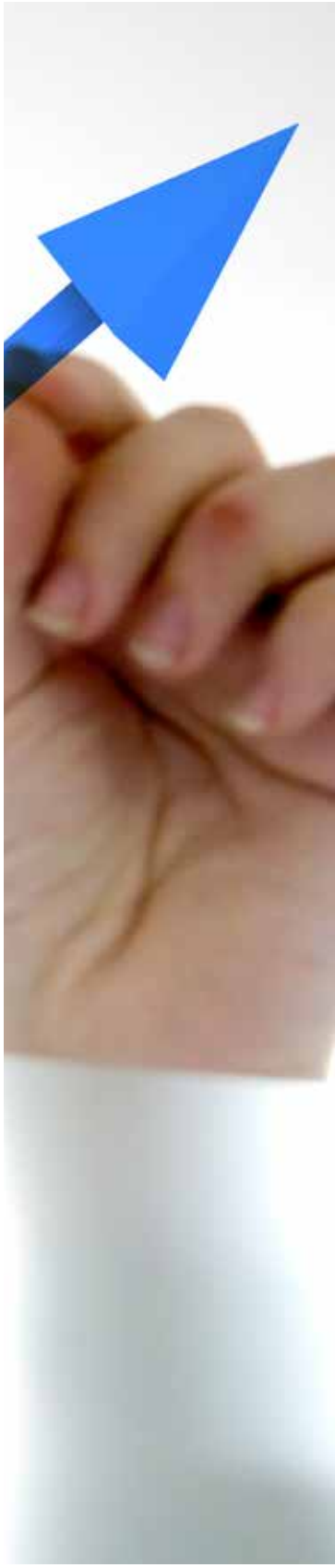
The importance of standardisation as a vital element to stimulate and enable innovation and competitiveness in Europe is reiterated in Europe 2020[2] – Europe's growth strategy. In particular, Europe 2020 makes reference to the need to "improve the way in which European standard setting works to leverage European and international standards for the long-term competitiveness of European industry".

The message is taken up by the associated Flagship Initiatives[3]. In particular, the Innovation Union Flagship Initiative stated that standardisation is one of the tools that can facilitate European competitiveness if the system can effectively "keep pace" with research, technological development and innovation.

In June 2011[4], in accordance with the Flagship Initiatives, the Commission produced a new Communication on a 'Strategic Vision for European Standards', and the associated Regulation[5] (hereafter referred to as the 'Standardisation Package'), which came into force on 1 January 2013. The Communication emphasises that the "standardisation processes should be accelerated, simplified and modernised" to ensure that standards are in place to address the needs of innovative processes and products. It also underlines the importance of standards as a policy tool supporting different European policies, especially in areas where Europe drives innovation and where the development of new products and processes could lead to new trade in goods, services and technologies. Standards are identified as being important for European industrial policy to support European competitiveness in the global market, and to meet the requirements of both industry and public authorities.

The Communication goes further, and includes a number of objectives for a highly responsive standardisation process, including an annual work programme; accelerating the standardisation process; the conditionality of financing ESOs on performance criteria; a better integration of standardisation and research; and the need to raise awareness of standardisation through education.

The Regulation on standardisation consolidates the legal basis for European standardisation[6] ; enhances the European Commission's cooperation with ESOs;



[1] European Commission (2008), Communication from the Commission 'Towards an increased contribution from standardisation to innovation in Europe', COM(2008) 133 final, 11 March 2008.

[2] European Commission (2010), Communication from the Commission, 'EUROPE 2020: A strategy for smart, sustainable and inclusive growth', COM(2010) 2020 Final, 3 March 2010.

[3] In particular, the following Flagship Initiatives address standardisation: 'Digital Agenda for Europe', COM(2010) 245, 'Innovation Union', COM(2010) 546 final, 'An Integrated Industrial Policy for the Globalisation Era', COM(2010) 614, 'A resource-efficient Europe', COM(2011) 21 final.

[4] European Commission (2011), Communication from the Commission, 'A strategic vision for European standards: Moving forward to enhance and accelerate the sustainable growth of the European economy by 2020', COM(2011) 311, 1 June 2011.

[5] Regulation (EU) No 1025/2012 of the European Parliament and of the Council of 25 October 2012 on European standardisation.

[6] It would replace Directive 98/34/EC (Standardisation part only), Decision 1673/2006/EC (Financing), Decision 87/95/EEC (ICT standardisation) and amends several Directives (objections to harmonised standards).

improves support to consumers; encourages small businesses (SMEs), environmental and social organisations to participate in the standardisation process; recognises that global ICT standards play a more prominent role in the EU; increases the number of European standards for services if there is a demand from business; and sets up a committee for the approval of mandates.

1.1.2 What are standards and standardisation?

A **standard** is a voluntary formal agreement on doing something in the same way, repeatedly. It can be developed for products, processes, management and services.

More specifically, standards are defined by the International Organization for Standardization (ISO) as "documents, established by consensus and approved by a recognised body, that provide for common and repeated use, rules, guidelines or characteristics for activities or their results, aimed at the achievement of the optimum degree of order in a given context".

The 2011 Commission Communication on 'A strategic vision for European standards' defined standards as "voluntary documents that define technical or quality requirements with which current or future products, production processes, services or methods may comply. Standards result from voluntary cooperation between industry, public authorities and other interested parties collaborating within a system founded on openness, transparency and consensus".

Standardisation is the process of creating a standard, and includes all the supporting activities that ensure the proper functioning of the system, such as the infrastructure to gather together the experts and stakeholders who create, approve and update standards, the distribution of standards, the financing of the activities, etc.

Not only are there a considerable number of types of standards but there is also a very wide variety of organisations developing standards. Standard organisations do not create standards themselves, but gather experts, mostly from industry, to develop, revise and amend them. They also support the dissemination of standards by publishing them, coordinating work items, conducting public consultation, undertaking lobbying, making agreements, etc.

In Europe, there are three recognised European Standards Organisations (ESOs):

- The European Committee for Standardization (CEN), which covers all areas of economic activity with the exception of fields covered by CENELEC and ETSI;
- The European Committee for Electrotechnical Standardization (CENELEC), which covers the field of electrotechnical engineering;
- The European Telecommunications Standards Institute (ETSI), which covers the fields of telecommunications, ICT and other electronic communications networks and services.

Together with the National Standards Bodies (NSBs) of the EU and EFTA[7] member states, they form the European Standardisation System (ESS).

The three ESOs are independent non-profit organisations. They adhere to the founding principles of standardisation recognised by the World Trade Organization (WTO), namely coherence, transparency, openness, consensus, voluntary application, independence from special interests and efficiency[8].

CEN and CENELEC share a common management centre and have similar structures and functions, while ETSI has a different organisation and business model. Whereas the participation model of CEN and CENELEC is based on national representation (i.e. the National Standards Organisations – NSOs), ETSI's model is based on the direct participation of a wider scope of stakeholders (e.g. NSBs, administrations, research institutes, industry, etc.).

Annex 3 provides more details.

1.1.3 Why a foresight study?

The Communication on a strategic vision for European standards stated for the first time that "anticipation and foresight studies can help to anticipate the need for standards development by linking emerging technologies and their research needs for future products and processes to the definition of policy". This foresight study is the first attempt to test this approach. By so doing, this study also addresses the wider requirement stated in the Communication: to accelerate the standardisation process by identifying issues requiring a standardisation effort much earlier in the industrial, technological or scientific process.

Future-oriented thinking is vital for any forward planning or policy activity to be able to meet future challenges proactively. Foresight enhances such thinking by gathering anticipatory intelligence from a wide range of knowledge sources in a systematic way and linking it to today's decision-making. Foresight does not aim to predict the future, but it invites consideration of the future as something that can be created or shaped.

Foresight supports actors and stakeholders in actively shaping the future. Foresight methods (i.e. vision building, scenario building, Delphi, etc.) are used to structure the debate on possible futures to ensure the emergence of collective intelligence from all relevant stakeholders and experts. In addition, foresight methods help thinking beyond established pathways.

[7] European Free Trade Association (Iceland, Liechtenstein, Norway, Switzerland).

[8] Regulation (EU) No 1025/2012

1.2 Study objectives

The objectives of the foresight study were:

- To develop an Industrial Landscape Vision 2025 (ILV 2025) by identifying the key elements and driving forces of the 2025 industrial system;
- To identify the need for the development or update of standards that will facilitate the ILV 2025;
- To identify how the standardisation system should evolve to facilitate the ILV 2025;
- To test the ILV 2025 on two case studies, to derive the need for new standards and for changes to the standardisation system;
- To develop of a template for undertaking future foresight studies to identify standardisation needs.

The study is not a technical report and therefore does not provide an assessment or comprehensive review of the ESS. An independent review of the ESS is being carried out by DG ENTR in a separate study.

It is not among this study's objectives review the ESOs' current business model. The study aims to explore how manufacturing and service industries will develop in the next 10 to 15 years, and how the ESS should develop to meet their needs.

1.3 Methodological approach

The foresight study has addressed and explored the following framing question:

How will standards facilitate new production systems in the context of EU innovation and competitiveness in 2025?

The study relied mainly on expert panels, desk-research analyses, and a restricted number of interviews with key players from industry, academia and the ESOs (see Annex 1 for details).

Foresight is, by definition, a participatory, multidisciplinary and discursive activity that should be based upon the best available evidence and judgment. These conditions make the use of expert panels a natural choice in foresight studies. A core group of experts representing as wide a range of stakeholders as possible (including industry representatives, academia, consumers and standardisation organisations) was selected to follow the study from beginning to end Additional experts were invited at key moments during the foresight process to deal with specific issues (e.g. additive manufacturing, future of mobility). The full list of the experts who participated in the study is given in Annex 1.

The expert panels were used as a forum for in-depth discussion and debate. The functions allocated to the expert panels were:

- Gathering relevant information and knowledge;
- Stimulating new insights and creative views and providing a vision of future possibilities, as well as creating new networks;
- Synthesising and testing the information gathered;
- Diffusing the foresight process and its results to much wider constituencies;
- Influencing follow-up actions.

Six interactive workshops were held with the experts. These formed the framework for the study, and were instrumental in the process of achieving its objectives and setting the study logic:

- The purpose of the first workshop (29 February – 1 March 2012) was to finalise the design and scoping phase of the study and detail the preliminary 'straw-man' structure of the ILV 2025;
- The second workshop (20-21 September 2012) set out to detail the ILV 2025 structure and components and established the basics to look at a possible roadmap for standardisation based upon the implications of the ILV. It identified the need for standardisation in order to facilitate the ILV 2025, as well as implications for the European standardisation process;
- The third workshop (17-18 December 2012) covered the first case study on additive manufacturing. The aim was to apply a technological subject to the ILV 2025 – AM – in order to identify the need for standards, and the actions required by the standardisation system to address these needs;
- The fourth workshop (20-21 March 2013) identified and prioritised the dynamics (i.e. forces and flows) both within and among the different layers and components characterising the ILV 2025. It also looked at possible standards that could facilitate the prioritised forces and flows. Implications were drawn on how the standardisation system should evolve to facilitate the ILV 2025;
- The fifth workshop (15-16 May 2013) covered the second case study which addressed a thematic or sectoral subject: the future of mobility. This case study identified where and how standards could foster the emergence, development and mainstreaming of new mobility behaviours, patterns, systems and technologies contributing to the creation of smart, sustainable and inclusive growth and jobs in Europe. The workshop was also used to test both the effectiveness of the proposed template based on foresight methodology, and the efficacy of the ILV 2025 for identify-

ing the needs for standards and standardisation for a particular topic;

- The sixth workshop (12 September 2013) aimed at validating the results of the entire foresight process, the vision and narrative supporting the ILV 2025, the main findings on the implications of the ILV 2025 on standards and the European standardisation system, and the proposed foresight template for the identification of standardisation needs.

Discussions during the workshops focused on standardisation as a policy-making instrument and the role of 'formal (European) standards'. However, during the workshops there was no focus on details as to how standards are currently being developed.

1.4 Structure of the report

The development of a vision of the industrial landscape in 2025 (ILV 2025) is at the core of the study, and has been used as a basis to analyse the needs for standards and the implications for the ESS to facilitate European innovation and competitiveness. Based upon this vision, it would be desirable in a further study to consider building scenarios that would provide additional elements for analysis. This development would also enable wider stakeholder involvement.

The ILV 2025 consists of a holistic, qualitative model that details the drivers of change that will influence the future production and consumption system in 2025 (see Chapter 2). It also describes the characteristics and components of the production and consumption system in 2025, including its dynamics and flows.

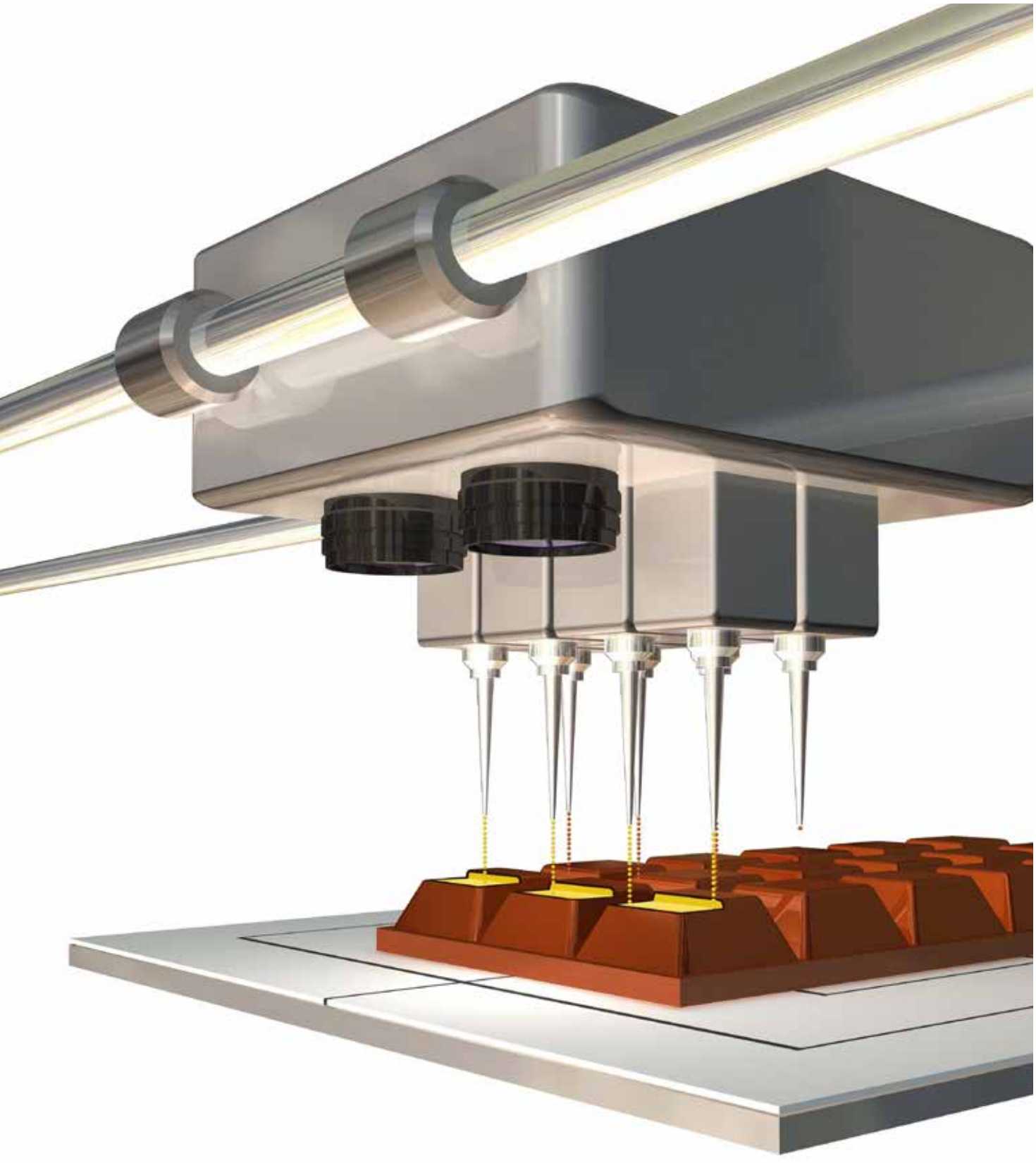
Finally, the ILV 2025 is fleshed out through a vision and a narrative that depicts the main directions for the economy and society and how products and services will be consumed and produced in the future.

By using a holistic view, the ILV 2025 introduces a paradigm shift from the traditional sector-based description of the industrial system to a more function-based representation of the production and consumption system.

On the basis of the ILV 2025, the study has identified five clusters detailing the future needs of standards, as well as the implications for the ESS (see Chapter 3).

Finally, the ILV 2025 formed the basis of the 'foresight template for identifying future standardisation needs' (as described in Chapter 4), which explains how ESOs can use horizon scanning and foresight to:

- Take a longer-term strategic approach;
- Make the current standardisation business model more resilient to future uncertainty and optimise its ability to stimulate innovation;
- Identify and analyse in a structured and systematic way the new subjects and areas requiring standardisation;
- Accelerate the standardisation process on new subjects requiring standards;
- Engage more stakeholders in a coordinated way.



2. The Industrial Landscape Vision 2025

2.1 Why an Industrial Landscape Vision for standardisation?

In order to answer the framing question of the study 'How will standards facilitate new production systems in the context of EU innovation and competitiveness in 2025?' a necessary preliminary step was to get a clear overview of the evolution of the European production and consumption system. To achieve this, the study adopted a (typical foresight) holistic lens to identify and understand the production and consumption system in the context of the drivers that will influence the future, not only of the production and consumption system, but of the whole European industrial landscape in 2025.

The vision of the industrial landscape in 2025 was based on the analysis of the importance and the potential impact of the society, technology, economy, environment and policy (STEEP) drivers on industry. The ILV 2025 was then used as a basis to analyse the needs for new standards and the evolution of the ESS to meet these needs.

The ILV 2025 was developed using desk analyses and review of existing research and literature on current and future trends of manufacturing at both the European and global levels. Literature on long-term trends and analysis on future developments of society was also consulted. In addition, consultations were held with experts and stakeholders at an individual level and, more importantly, at a group level during six workshops for experts.

The resulting holistic view of the industrial system, its interlinkages and dynamics introduced a paradigm shift from the traditional sector-based description of the industrial system to a more function-based representation, which is more appropriate to identifying the needs of new standards and the new roles for standards.

2.2 The structure of the Industrial Landscape Vision 2025

The Industrial Landscape Vision 2025 comprises three closely interrelated layers:

- **Layer 1 – Agents of change**

  The agents of change are the driving forces that will shape the industrial landscape. The components of these agents describe the nature and direction of the STEEP that will affect the evolution of the production and consumption system. Each such component is then detailed in a series of descriptors.

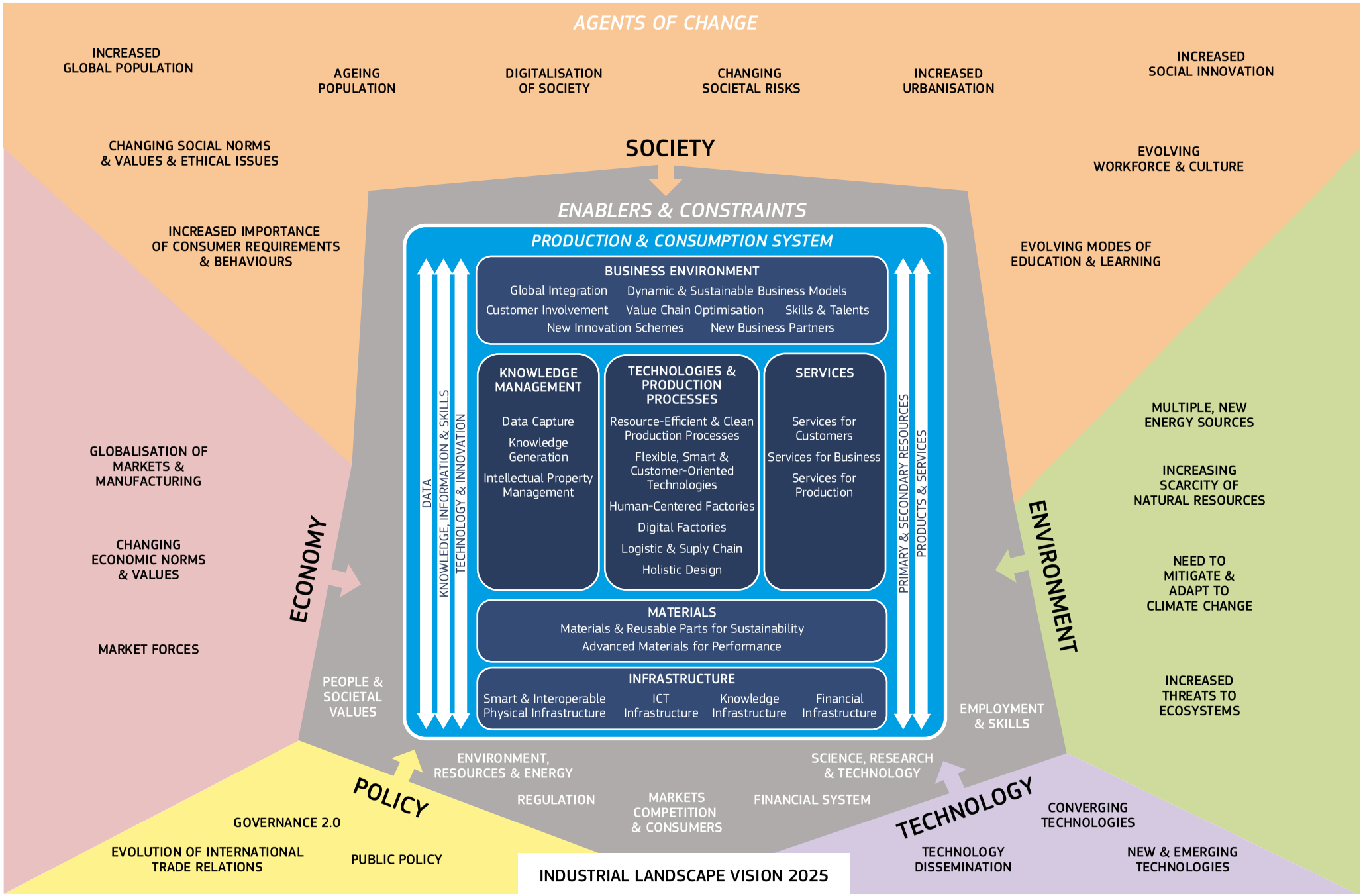
- **Layer 2 – Enablers and constraints**

  The enablers and constraints are the factors that can either enable or constrain the evolution of the industrial landscape. These factors are influenced by the agents of change and can act as 'switches' in determining the direction and development of the different components of the production and consumption system (i.e. the third layer). The content of each component of the enablers and constraints is briefly explained.

- **Layer 3 – Production and consumption system**

  The production and consumption system is the heart of the industrial landscape. It describes how people are going to produce and consume in the future. The components of this system are strongly affected by, and linked to the agents of change and the enablers and constraints. Each component identifies the mechanisms of change for a particular function or process in the production and consumption system. There are descriptors and sub-descriptors for each component that detail the production and consumption system.

A detailed description of the ILV 2025 is available in Annex 4.


AGENTS OF CHANGE
INCREASED GLOBAL POPULATION
AGEING POPULATION
DIGITALISATION OF SOCIETY
CHANGING SOCIETAL RISKS
INCREASED URBANISATION
INCREASED SOCIAL INNOVATION
SOCIETY
CHANGING SOCIAL NORMS & VALUES & ETHICAL ISSUES
EVOLVING WORKFORCE & CULTURE
ENABLERS & CONSTRAINTS
INCREASED IMPORTANCE OF CONSUMER REQUIREMENTS & BEHAVIOURS
EVOLVING MODES OF EDUCATION & LEARNING
PRODUCTION & CONSUMPTION SYSTEM
BUSINESS ENVIRONMENT
Global Integration
Dynamic & Sustainable Business Models
Customer Involvement
Value Chain Optimisation
Skills & Talents
New Innovation Schemes
New Business Partners
KNOWLEDGE MANAGEMENT
Data Capture
Knowledge Generation
Intellectual Property Management
TECHNOLOGIES & PRODUCTION PROCESSES
Resource-Efficient & Clean Production Processes
Flexible, Smart & Customer-Oriented Technologies
Human-Centered Factories
Digital Factories
Logistic & Suply Chain
Holistic Design
SERVICES
Services for Customers
Services for Business
Services for Production
DATA
KNOWLEDGE, INFORMATION & SKILLS
TECHNOLOGY & INNOVATION
PRIMARY & SECONDARY RESOURCES
PRODUCTS & SERVICES
MATERIALS
Materials & Reusable Parts for Sustainability
Advanced Materials for Performance
INFRASTRUCTURE
Smart & Interoperable Physical Infrastructure
ICT Infrastructure
Knowledge Infrastructure
Financial Infrastructure
ECONOMY
GLOBALISATION OF MARKETS & MANUFACTURING
CHANGING ECONOMIC NORMS & VALUES
MARKET FORCES
ENVIRONMENT
MULTIPLE, NEW ENERGY SOURCES
INCREASING SCARCITY OF NATURAL RESOURCES
NEED TO MITIGATE & ADAPT TO CLIMATE CHANGE
INCREASED THREATS TO ECOSYSTEMS
PEOPLE & SOCIETAL VALUES
EMPLOYMENT & SKILLS
ENVIRONMENT, RESOURCES & ENERGY
SCIENCE, RESEARCH & TECHNOLOGY
POLICY
REGULATION
MARKETS COMPETITION & CONSUMERS
FINANCIAL SYSTEM
TECHNOLOGY
GOVERNANCE 2.0
EVOLUTION OF INTERNATIONAL TRADE RELATIONS
PUBLIC POLICY
CONVERGING TECHNOLOGIES
TECHNOLOGY DISSEMINATION
NEW & EMERGING TECHNOLOGIES
INDUSTRIAL LANDSCAPE VISION 2025

2.3 The vision and narrative

To animate the ILV 2025 components, and to provide a target for European industry to aim for, against which the need for standards can be defined, requires a vision. This vision, supported by a narrative, is not predictive. Rather, it is a desirable and plausible future which can provide Europe with a strong industrial base, competitive in a global market. Both the vision and the narrative are the normative representation that indicates focus and direction for the ILV 2025. This representation defines the context against which the ILV 2025 can be interpreted and the need for standards defined, and provides the underpinning conditions for a dynamic standardisation system, where standards are contributing to facilitate European innovation and competitiveness.

The ILV 2025, its vision statement and the narrative should be used as a tool to stimulate strategic thinking about future policy options and opportunities for Europe.

The narrative highlights important trends, trend breaks, critical challenges and opportunities for the industrial landscape in 2025.

The vision statement is:

> *In 2025, there will be a **globalised economy** serving an **informed and prosperous global middle class** that will require **personalised goods and services** based on **advanced, ICT-enabled manufacturing systems** supplied by **European resource-efficient and sustainable industries**.*

The next sections describe the status and the industrial landscape responses for each of the five central ideas in the vision statement. The narrative should be read as if the reader is in the year 2025.

2.3.1 A globalised economy

In 2025, the world's economy will be fully globalised, with the global market expanded to include the mature economies of the BRICS[9] countries. The "next 11"[10] countries will be reaching economic maturity, while other African countries, such as Ethiopia, Kenya and Uganda, will be undergoing rapid industrialisation. As a result, the **competition for markets will become fiercer**. New industrial players from emerging and newly emerged industrial economies will fight for market share with multinationals and companies from traditionally industrialised countries, including the EU. Freedom to trade has been a key constraint on the industrial landscape. However, in the past 20 years, regional trading blocs have become more important, seeking to liberalise trade by bringing down trade barriers on the basis of international trade agreements. The effect has been to create **a real global production and distribution system**, although protectionism remains. Nascent economies in particular seek to protect their new industries by applying hidden trade barriers through standards.

Companies will drive constantly to seek innovation to develop a competitive edge for new products and services, and to adopt more efficient operations. **Smart and interoperable infrastructures**[11] will underpin industrial competitiveness and innovation, including smart energy grids and intelligent transport systems.

To take advantage of the new opportunities, industries will fundamentally change their business models. Over time, service-type functions will have a larger share in manufacturing companies' activity. The ratio between service-type activities and production could reach more than 50 % of manufacturing employment in advanced economies[12]. Companies will create global manufacturing structures that seamlessly operate collaboratively around the world. They will be **flexible and agile** in order to be able to produce products and services designed to meet the local requirements of a target region. This will result in a **disaggregation of the supply chain** with an **increased localisation of production** to address local requirements, as well as to reduce transport and distribution costs. This approach will be enabled by **new production technologies**, such as additive manufacturing, as well as by the automation of production and vastly **improved information and communication technologies**.

Environmental and social pressures will contribute to the changes in manufacturing business models. **Corporate social and environmental responsibility** will become a core element of corporate strategy, with reporting and accounting requiring companies to address environmental and social rules.

Overall, these developments will introduce a new era in manufacturing. Manufacturing companies will need to be highly agile, networked enterprises that **use information and analytics** as skilfully as they employ talent and machinery, to deliver products and services to diverse but globalised markets.

2.3.2 An informed and prosperous global middle class

The global population is approaching 8 billion people, partly due to an increase in life expectancy. This is creating a society with **large new potential markets** based upon a **growing middle class** in

[9] Brazil, Russia, India, China and South Africa.

[10] Bangladesh, Egypt, Indonesia, Iran, Mexico, Nigeria, Pakistan, Philippines, Turkey, South Korea and Vietnam.

[11] Energy, transport, water, data, knowledge and financial infrastructure.

[12] 'Manufacturing the future: The next era of global growth an innovation', November 2012, McKinsey Global Institute.

the BRICS countries' mature economies and the increasing economic maturity of the "next 11". Since 2013[13], there are 1.8 billion people with a disposable income, having joined the global consuming class in Asia and Africa. However, at the global level the distribution of income varies across countries and within different regions of the same country. As a result, the **distribution of income is more unequal** with patterns differing significantly among different population groups.

Global migration will also increase, and will continue to be driven by political and economic factors plus increasingly by population imbalances and environmental factors. This will also result in **increased urbanisation**, especially in emerging industrialised countries, as people look for work. Factories with zero environmental impact will have a key role in this urbanisation trend as they become integrated into the urban society to take advantage of lower distribution costs.

In the majority of global regions, an **ageing society** will have an effect on the demand for products and services, with new markets emerging to serve older populations. Furthermore, the improved quality of life and advanced health care will enable some senior segments of the population to work longer, often contributing to addressing a skills-shortage problem.

In parallel, **consumer behaviour will also evolve** thanks to the digitalisation of society. Consumers, especially in the more affluent, mature economies, will increasingly choose products on the basis of their social and environmental impact rather than on price alone. This will be driven by the fact that there is increased awareness of the ethical issues surrounding product production. **Consumer choice** will be better informed thanks to the widespread use of social networking. This will result in an enhanced social ranking of products and services.

Social acceptance and approval of products and services and their perceived utility, safety and environmental friendliness, occur online and are important for product and service market success.

In addition, with the increased wealth available globally, some people have the possibility to improve their quality of life without producing more wealth (i.e. to embrace a post-materialist mindset). This not only enhances the ethical consideration that consumers give to products and services prior to purchase, but it also changes the features that consumers look for when deciding to make a purchase. For example, consumers are increasingly looking for **'enhanced experiences'** (including emotional ones) when they buy a product or service.

2.3.3 Personalised goods and services

An informed and prosperous society will drive consumer requirements for goods and services. The traditional **ownership model** will evolve as societal, economic and environmental pressures encourage people to demand more integrated products and services. As a result, manufacturing companies and service providers will work more closely together to build consumer-driven solutions combining **products and services**.

In many cases, consumers' requirements will go one step further. Consumers will increasingly demand a package of products and services tailored to meet their individual needs. **Personalisation**, enabled by new production technologies, such as robotics and AM, will become a **key driver for industry**. This will change the relationship between consumers and manufacturers, with consumers being much more active in their relationship with companies, and more involved in the entire production chain. Personal choice will also define the manner of purchase and delivery: far fewer goods and services will be purchased or leased from the traditional shops on the high street. Online personalised services will be used more and more, with companies storing individual's personal preferences and measurements to aid selection, alongside new visualisation technologies. A greater variety of delivery mechanisms will also be used, ranging from automated drones to dedicated courier services.

Regional and local customisation will have a major effect on how industry operates. Globalised but diverse markets, distributed manufacturing and the increasingly informed and prosperous global middle class will set industry many challenges. Globalisation of the market will result in millions of new customers for products and services across the globe, emphasising the regional diversity of consumer choice, with different regions often requiring very particular products with variable features and pricing. Industry will have to respond by significantly improving its market analysis capabilities to be able to fully capture consumer requirements.

Some companies have gone a step further by enabling customers to be part of the production value chain via techniques such as **social manufacturing**. There is also an increasing presence of **'Do-it-yourself'** (DIY) movements that start from the concept that the user is involved in the product-design of products and services. This has been enabled by improved ICT and 3D printing which has permitted the creation of micro-factories where customers produce and assembly their own products.

[13] The middle class includes people earning or spending $10–$100 (8€-80€ euro equivalent) a day (in 2005 purchasing power parity terms).

2.3.4 *Advanced, ICT-enabled manufacturing systems*

To address the globalised economy and the regionalisation of markets, companies will implement production chains that will be geographically spread around the world, and connected by advanced ICT. These will require ever-more sophisticated **logistics systems** to produce and distribute products.

More complex value chains will be available to deliver highly personalised products and services, with companies relying increasingly on intelligent, automated and integrated logistic tools. Similarly, firms will also rely more and more on asset-tracking software enabling the real-time monitoring of materials and products to ensure their recovery and multi-level management. The use of such tools will allow for better coordination of production activities and will assure good process reliability, short delivery times, reduction of stocks, and low production costs.

The production of goods and services will be more localised and closer to customers, in particular to respond to the increased demand for customisation/personalisation and to reduce costs. Globally, companies will be required to engage in regional-based operations to fulfil local demand. This **distributed manufacturing** will be enabled by new production processes, such as additive manufacturing, software-enhanced added-value services, and new ICT technologies allowing for the digital interconnectivity of different parts of the production process.

Companies will also seek to ensure the **flexibility of their supply chain** and the fast reconfigurability of their production lines (e.g. through self-adaptive and modular machine tools and robots) to meet changing consumer requirements. However, the regional customisation of demand will mean that the production system will become more fragmented, with parts of it distributed geographically across different locations worldwide so that products and services can be more easily adapted to local needs. There is also a trend that sees factories moving into cities to secure optimal integration in their social and urban environment (e.g. through urban transport, parking, shopping and entertainment centres). This move to the cities is also facilitated by the fact that manufacturing firms have adopted greener production processes to improve resource and energy efficiency and to achieve minimal environmental impact. Companies will therefore practice **'hybrid manufacturing'**, incorporating a mix of production processes located in both high-cost and low-cost nations according to geographical advantages and based on a wide range of factors (labour costs and skills, infrastructure, regulation, policy, materials, market demand, etc.) enabled by technological developments, especially in the ICT field.

Different **business models** will be developed to cope with the complexities of a global market. Clusters of partners offering specialised services will form in certain geographical locations, based on similar technological skills, a common interest in a nearby source of raw materials or shared energy schemes. These partners will act as an **'ecosystem'**, applying industrial symbiosis, feeding off each other in the value chain, and enabling the 'cross-fertilisation' of technology.

The need for efficiency, and the realisation of an increasing scarcity of natural resources, will drive some companies to seek full control of their value chain through **vertical integration**. Enabled by new technologies, the entire value chain will be controlled by individual companies, from the supply of raw materials through to the sale of products and services.

In order to be competitive, many companies will apply **holistic design**, taking into account the entire life cycle of products and services. This holistic approach, enabled by new design technologies, will address all aspects of products and services, from consumer requirements to their environmental impact and cost. Other design techniques will also be applied. Consumers will be much more closely involved in the design and prototyping of products and services. New practices, including **social and open innovation**, will be implemented to maximise consumer input and innovation. The widespread use of online social tools (e.g. collaborative platforms) and solutions (e.g. crowd-funding and crowd-sourcing), together with digital fabrication software (i.e. CAD) and ready-to-use manufacturing hardware (e.g. 3D printing), will result in new forms of product design, development and testing, directly involving customers.

Materials will remain one of the critical factors for the competitiveness of any advanced manufacturing company. The scarcity of many important materials will continue to push the development of new, advanced materials. These will provide industry with increased functionality, lower weight, a lower environmental burden, and greater energy efficiency. New material science and technologies will improve productivity, ease material recycling and reuse, and open the path towards efficient manufacturing processes. **Smart, multifunctional materials**, able to change properties according to the environment (e.g. temperature, pH, light, magnetic field, etc.) will become increasingly available, and will permit the development of new, advanced and environmentally friendly products. These are frequently based on organic, non-toxic, non-harmful synthetic materials which can be used endlessly in different product cycles to enable a waste-free manufacturing system that can even protect and enrich ecosystems. New technologies arising from **nanotechnologies** and associated **nanomaterials** will underpin these developments.

The **development and characterisation of new, advanced materials** has facilitated advanced manufacturing processes, such as AM. New technologies, such as nanotechnologies and associated nanomaterials, have also opened up whole new industries based around bionics and bio-nanotechnology. However, this has only been achieved by developing specialised approaches to the testing and monitoring of their effects on human health and on the environment.

Underpinning the manufacturing industry today has been major developments in technology. This has been greatly helped by the **global diffusion of technologies**, thanks mainly to the widespread use of ICT. There has also been a widespread convergence of technologies that has allowed an increase in the production of multifunctional products.

Considerable development will take place to ensure the **interoperability of technologies**, as this will be key to providing integrated solutions to both industrial advancement and societal challenges. Different technologies are being combined to improve the quality, safety, sustainability and costs of products and services. This includes technologies to provide industry with its smart, advanced infrastructure whereby ICT is used in combination with energy, mobility, water, financial and knowledge infrastructures. It also covers advanced technologies, such as AM and online, real-time manufacturing monitoring tools used to provide industry with new products and production-chain efficiency.

Key Enabling Technologies (KETs) will continue to be developed and deployed. They provide indispensable technology bricks that enable a wide range of product applications, including those required for developing low-carbon energy technologies, improving energy and resource efficiency, tackling climate change, or facilitating healthy ageing.

Ubiquitous computing has already become pervasive, connecting all aspects of daily life, ranging from industrial processes to the 'Internet of Things' and cloud-based computing. Developments in artificial intelligence will increasingly drive automation in production processes and form the basis for new products, such as automated, driverless cars and intelligent, hand-held mobility management systems.

Data will become the 'new oil'. Increasingly complex and large sets of data **('big data')** with the Internet-of-Things will enable manufacturing firms to better understand and optimise all stages of their value chains, from design to distribution, including supply-chain management, production processes and marketing. To cope with the huge amounts of data, analytical techniques will have to be developed, with the data protected by resilient security systems and moderated by robust and transparent data-privacy regulation.

Artificial intelligence is ubiquitous, enhancing the Internet of Things, enabling increasingly automated production processes, and forming the basis for new products. Combined with advanced robotics, it has enabled the manufacturing process to become much more efficient, and on the way to achieving a fault-free production cycle. **Robotics** will advance to the point where humans and robots work in harmony on the plant floor, thanks to personalised machine-to-user interfaces and human-like robot behaviour and features (e.g. humanoid design, voice recognition, natural language, and gesture understanding).

Firms are investing in powerful data-capture platforms based on supercomputing technologies that will collect and collate real-time data from a wide range of internal and external sources (customer feedback, product radio-frequency identification – RFID – tags, machinery, sensors, robots, online libraries, cameras, etc.) and make it available, in a targeted way, to all areas of the production chain.

These developments will enable the **'digital factory'**, a network of digital models, methodologies and applications used to integrate the planning and design of manufacturing facilities within the manufacturing process itself. The digital factory concept focuses on an integrated planning and monitoring process that includes product design, process planning, and planning and implementation of the manufacturing operation, making the manufacturing process more efficient and responsive to change.

Knowledge management has become a crucial task for companies. It requires an integrated approach to identify, capture, create, evaluate, store, retrieve and share all a company's knowledge assets. Firms are focused intensively on knowledge production related to customers' requirements and behaviours, market trends and forecasts, competitors, product design, supply chain flows, machinery performance, and the life cycle of products in the field. New software based on artificial intelligence and machine learning will help humans to exploit big data, manage complexity, draw appropriate conclusions and define strategies. New smart devices can augment the cognitive skills and capacities of humans in performing their knowledge-based work.

Knowledge-intensive manufacturing requires firms to implement new knowledge-management schemes across the organisation so as to remove barriers between workers, technicians, engineers, designers, big data experts, managers and executives. Firms succeeding in this task have achieved full business/ICT alignment through expertise and experience sharing.

The development of **open and social innovation** and new collaboration patterns for the design and production of products and services has forced a reconsideration of trademarks and patents. The intellectual property (IP) portfolio is now less used to protect ideas and exclude other parties from using the technology without authorisation, and more to facilitate the diffusion of technologies and collaboration with other partners.

The increasing use of technology, especially automation technology, will make future manufacturing processes a **less labour-intensive industry**, although still requiring an increasing number of highly qualified staff.

To deal with the growing skills gap, companies are also developing internal training schemes or apprenticeship programmes to fill their specific workforce needs. They are collaborating more and more with universities, research centres and other partners to offer younger talented recruits work-study programmes with recognised degrees. This has proved a useful measure to promote a more inclusive and empowered society for the younger generation and to address youth unemployment.

To improve productivity and attract the best workers, factories will focus on the **well-being of workers** (e.g. through human-centred factory design) and their better integration with technologies, machines and systems (e.g. through personalised user interfaces, enhanced ergonomics, etc.). Many workers will also follow more flexible working practices, especially as ICT technologies develop, making it possible to have your 'office' constantly accessible to you globally.

2.3.5 European resource-efficient and sustainable industries

The effects of **climate change** will become more evident, **natural resources** will be increasingly scarce, and **energy demand** will increase globally. This will have a considerable impact on manufacturing as environmental and societal concerns develop, and the cost of materials and energy increases. **Life-cycle approaches** will be applied to minimise waste and maximise efficiencies. There will be a concerted effort to **reduce the environmental impact** of production and consumption. This will focus on **saving energy**, **minimising waste**, **recycling and reusing** products and their parts, and a large demand for energy-efficient products.

Companies' business models will be further refined by the demand for a **'circular economy'** (i.e. the 'triple-zero' objectives: zero waste, zero net-energy cost and zero environmental impact). This movement will be enhanced as companies seek savings in order to remain competitive in the global market. Firms will invest in services and technologies to achieve their 'triple zero' objectives. They will also invest in technologies to manage the disassembly and de-manufacturing of materials, parts, products and even factories, as well as the recovery of trace elements, so as to foster end-of-life reuse, remanufacturing and recycling. Indeed, companies will make their business models 'environmentally friendly' as a marketing strategy to seek commercial advantage (e.g. sustainable packaging and remanufacturing).

Environmental and societal pressure will also encourage **eco-innovation**, resulting in the development of innovative products and services that will reduce environmental impact, enhance resilience to environmental pressures, or achieve a more efficient and responsible use of natural resources. Eco-industries will become a growing sector in 2025.

Underpinning this effort will be a continuing move to **de-carbonise the energy supply,** requiring the use of multiple, different renewable energy sources supported by a new energy infrastructure able to receive and provide energy from multiple distributed energy sources – the so-called **smart grid**. The development of a smart electrical power grid infrastructure, combining ICT and energy-supply technologies, will enable factories to optimise their energy flows, acting as both energy providers and users. Contributing to this, the results of the manufacturing process (such as heat and waste) will increasingly be used as sources of energy, enhancing the energy balance of many factories, and making them **energy self-sufficient** and **carbon neutral**. **New energy storage facilities** will also enable factories to adjust energy flows according to their off-the-grid needs.

As natural resources have become scarcer, suppliers have become more technologically advanced and specialised as they seek to extract the remaining key natural resources. To cope with the increasing scarcity of key natural resources, companies are investing in the development of new, replacement materials. Firms will increasingly consider Nature and its ecosystems as a design model for maintaining sustainability. In particular, the use of organic materials and non-toxic, non-harmful synthetic materials which can be used endlessly in different cycles will help to achieve a waste-free manufacturing system that can protect and even enrich ecosystems.

2.4 Implications of the ILV 2025

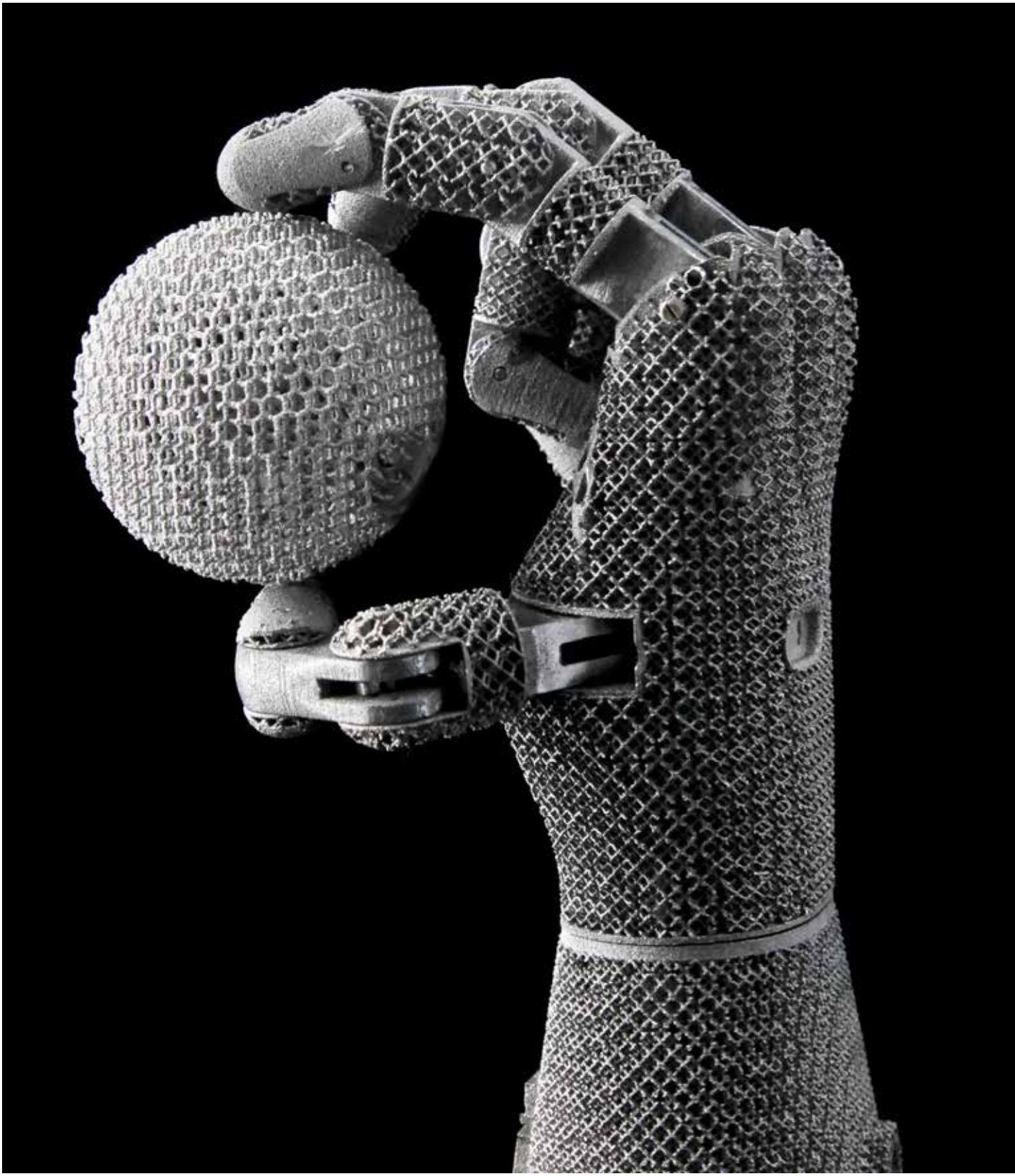
The vision and associated narrative presented in this report is based on discussions with a wide range of experts, as well as extensive desk-research analysis. The narrative is not aiming to predict the future – rather, it is a potential future industrial landscape that would benefit European competitiveness and jobs.

The study has used this vision and narrative to bring the future to life, providing a framework for the assessment of standards development and changes to the European standardisation system.

While certain elements of the vision, for example, the globalisation of the economy, are to some extent independent of the European policy arena, other factors can be shaped and influenced by policy measures at European level. However, they require an even more coordinated approach to support the achievement of the goals and objectives laid down in European industrial policy. However, the narrative affects other policy areas, e.g. energy, transport, regional research and innovation, which should be connected with industrial policy to assure key elements of the future industrial landscape.

The vision and narrative could be used in a wider sense, providing a target towards which manufacturing industry in Europe could develop. Already, the Task Force for Advanced Manufacturing Technologies for Clean Production in the EU's industrial policy has adopted this vision and narrative as the basis for their work.

However, this has implications. To achieve the vision requires policy and technological development. The current state of the manufacturing industry needs to be determined, different aspects of the vision should be further analysed and defined, and technological and policy roadmaps towards the vision must be developed and implemented.



3. Implications of the ILV 2025 on standards and the ESS

3.1 Identified needs for standards

3.1.1 Introduction

3.1.1.1 General approach

The purpose of the study is to identify where and how standardisation could contribute to the realisation of the ILV 2025. Standardisation is one of the instruments which can foster the innovation needed to stimulate the manufacturing industry, reinforce its competitiveness in a period of ever-increasing global competition, and create sustainable and inclusive growth and jobs in the EU.

More precisely, the aim of the study is to identify the main – high-level – priorities for standardisation. The objective is not to enter into technical details regarding each specific standard, for which only the standardisation bodies' technical committees can mobilise the relevant expertise for a longer period of analysis. This detailed analysis should take place following this foresight study.

As standards are generally technical documents, traditional approaches to understanding and categorising them at the high level are also technically based. Examples of clusters of standards that are used include: 'terminology standards', 'measurement standards', 'test methods standards', 'process standards', 'product standards', 'material standards', 'interface standards', and 'management standards', etc. Whereas these categories describe accurately what standards are, they do not explain why they were needed in the first place. 'Meta-categories' are required to better acknowledge, visualise and communicate the main objectives of standardisation, particularly when they are in support of European innovation and competitiveness. These broader categories should also go beyond the sectoral or technological approach, which remains too fragmented to get an overall understanding of the added value of standardisation.

As a result, the foresight study adopted an objective-oriented approach for clustering the required standards that were identified by the experts throughout the process. This clustering is useful to facilitate the dissemination of the results to policy-makers and the public at large. Furthermore, such an approach could facilitate the definition of an international standardisation strategy for Europe, as well as contributing to the engagement of more stakeholders (e.g. consumers, SMEs, researchers, etc.) in standardisation work, particularly if they better perceive the concrete benefits of standards for both the economy and society.

3.1.1.2 From the ILV 2025 to standardisation needs

Throughout this foresight study, the ILV 2025 was systematically confronted with the associated needs for standardisation, both through general discussions and dedicated case studies (i.e. additive manufacturing and mobility). This resulted in the identification of five priority areas for standardisation, as well as concrete examples of standards required, which fall into the following five categories.

The five priority areas for standardisation are:

1. Standards for integration

2. Standards for environmental sustainability

3. Standards for quality and performance

4. Service standards

5. 'De-risking' standards.

The next section explains the rationale for these five priority areas and presents the main outputs from the foresight workshops – supported by desk analysis – related to each of them.

However, it should be stressed that this study did not attempt to provide an exhaustive list of standards or even to develop a detailed roadmap for standardisation that fosters the realisation of the ILV 2025. Due to the strong technical dimension of standards and the multiple areas of expertise required, a more exhaustive approach would demand the continuous deployment of specific foresight methodologies involving a wider range of stakeholders and experts (cf. section 4 for related proposals).

Annex 5 provides more details on existing standards and standardisation needs related to the different components of the production and consumption system within the ILV 2025.

3.1.2 Five priorities for standardisation

3.1.2.1 Standards for integration

Rationale

Standards are essential in order to respond to the challenges of a fully globalised economy: more disaggregated value chains, the merging of ICT and physical infrastructures (e.g. smart grids), the cross-border integration of these infrastructures, the challenge of business-ICT alignment (cf. cloud computing), greater integration of products and services, as well as the convergence of technologies, industries and business models. The keyword here is integration, where the physical interoperability of infrastructures, data interconnectivity with the physical world, communication and information exchange protocols, and product interfaces, etc. are key to facilitating the future, desired production and consumption system.

Without the relevant standards that ensure a high level of integration, the whole production and consumption system loses its efficiency, suffers from redundancies, and cannot reach its optimal cruising speed required to allow Europe to address adequately and efficiently its economic, environmental and societal challenges. Considering technologies or sectors in isolation is no longer an option, and consequently related standards must also be considered in a wider context. Reviewing such standards on a recurrent basis through a holistic approach such as the ILV 2025, or considering the broader theme of mobility, for example, rather than just (the sector of) car transportation or (the technologies related to) electric cars, allows for the adoption of broader approaches that enable a better understanding of the challenges raised by an integrated production and consumption system.

The main challenge to the development of 'standards for integration' lies mainly with the higher level of coordination needed within the ESS (i.e. among ESOs but also among their technical committees) and beyond (e.g. with other international standardisation bodies and with fora and consortia).

Main findings from the study

Globalisation of the economy has a significant impact on standardisation activities. In particular, it leads to the need for new standards that will foster the further integration of the production and consumption system at the European and global levels. Indeed, as the value chain of European businesses becomes increasingly global and relies on more disaggregated supply chains in which a wide range of heterogeneous stakeholders – in size, location and nature – interact constantly, a high level of coordination and integration among these actors, their activities and processes, the products and services they sell as well as the underlying infrastructure has become a necessary condition for the success of their business models. More standards are therefore needed to facilitate the integration of multiple specialised parts of the value chain and disaggregated supply chains. For example, experts involved in the study underlined that more data-exchange and interface standards are needed to optimise information flows across the global value chain and ensure compatibility among multiple proprietary processes.

In a global economy, such standards need to be international – i.e. ISO, ITU (International Telecommunication Union) and IEC (International Electrotechnical Commission) endorsed standards. More importantly, a wider range of stakeholders and countries need to collaborate on their development to facilitate their smooth implementation worldwide – which will eventually enhance the conditions for fair competition on the global market. In particular, the participation of BRICS and 'next 11' countries in formal international standards development processes has become compulsory. This aim is to ensure that new competitors better understand and respect the standards applied in Europe, especially in the social and environmental fields, as well as facilitating – through common standards – European businesses' access to the emerging markets.

In addition, as infrastructure underpins industrial competitiveness, standards are increasingly required to support comprehensive, integrated approaches to the full interoperability of all physical and ICT infrastructures. The ongoing standardisation activities led jointly by CEN, CENELEC and ETSI on smart grids enter fully into this scope. However, similar – and also broader – approaches are needed to ensure interoperability between all infrastructures, not only energy, across European countries. For example, in the field of transportation, standardisation has a key role to play in the building of a network of smart and interoperable infrastructures across national borders and across modes (i.e. road, rail, air, water). The challenge is all the more important since national systems are far from being harmonised in this field, even though such harmonisation is obviously a key condition of European industrial competitiveness.

For instance, during the workshop dedicated to the theme of mobility, experts highlighted the need for standards for interoperable freight and passenger handling, with particular emphasis on European intermodal standards for advanced freight handling and loading systems, as well as tracking and tracing systems, in order to simplify and speed up the movement of goods and people across Europe no matter what modes of transportation were chosen. They also mentioned the role of standardisation in facilitating the shift towards an alternative fuel infrastructure (e.g. hybrid energy sources and ve-

hicles, wireless charging, connection to smart grids, hydrogen, etc.).

The need for standards for integration also comes from the convergence of technologies (e.g. nano-biotechnologies) and the need to ensure their interoperability. The development of these standards implies the creation of joint working groups coordinating several standardisation technical committees within and across the ESOs.

Experts also stressed that cloud computing requires standards that ensure service interoperability, for both the software and hardware (i.e. the infrastructure). They underlined that ESOs should support the development of open international standards (i.e. public specifications, no restriction in access, implementation and reuse of standards, royalty-free IPR rights) so as to foster a high level of compatibility across all segments of the global society.

In addition, they mentioned the need for integrative standards fostering the modularity and reconfigurability of production processes (e.g. assembly lines) so that manufacturing companies can better adapt to increasingly short product cycles.

3.1.2.2 Standards for environmental sustainability

Rationale

Standards are needed to foster the environmental sustainability of the production and consumption system, with a strong focus on resource and energy-efficiency, clean production, and closing the material loop. An additional role of standardisation here is to support public policies on sustainability issues (e.g. ecodesign, recycling, reuse, etc.). In this field, standards can almost be considered as indirect policy instruments to guide the whole industry (not only the forerunners) towards more sustainable practices and environmental friendliness.

However, the market relevance of these standards has still to be fully explored. Indeed, by allowing manufacturing firms to respond to the desire of many for a more sustainable world, standards for sustainability are ultimately beneficial to the competitiveness of their businesses. The standardisation process itself can be seen as a collaborative space among all relevant stakeholders from the public and private sectors, as well as civil society and academics, on sustainability issues. The challenge for ESOs is to engage all those actors in an efficient way. If they succeed in so doing, standardisation can increasingly offer an interesting alternative to regulation in a wide range of fields.

Main findings from the study

Increasing energy demand and scarcer fossil energy resources worldwide require a considerable enhancement of the energy efficiency of Europe's production and consumption system in order to improve both its cost effectiveness and sustainability. Standards for environmental sustainability have a key role to play in improving the energy efficiency of production processes. European standards can indeed foster the dissemination of innovative solutions in this field across the whole European manufacturing industry. As stressed by the experts, standardisation can also help improve the optimal use and exploitation of alternative energy sources by European factories – i.e. mainly renewable energies and the reuse of energy losses from production processes (e.g. heat).

In addition, the scarcity of materials is a growing concern for the production and consumption system, especially as regards rare earths and noble metals which are essential to an electronics-based society. Hence, the circular economy and closing the material loop becomes a necessary condition for the ILV 2025 to become a reality. The role of standardisation in these fields has already been acknowledged by ESOs, and many recycling standards for materials already exist. However, greater international consensus is needed on these standards since the material loop has a global dimension.

Furthermore, more materials need to be covered (e.g. new, advanced materials), and standardisation activities should go beyond recycling to include reuse, recovery and remanufacturing of materials, parts and products in an holistic approach. The latter should also apply at the factory level with standards related to de-manufacturing and disassembly lines in European factories. Further, the workshop on AM showed that recycling protocols should be adapted to 3D-printing home applications.

Participants also identified that existing ecodesign standardisation activities could be extended to more products in order to reduce their overall environmental impact (material consumption, water use, waste, noise, emission, etc.).

More generally, new measurement standards are required to compare the overall sustainability performance of production processes and underlying infrastructure. In particular, they are required to measure and improve the resource and energy-efficiency of the overall ICT infrastructure, as experts stressed that the energy consumption of this particular infrastructure is generally underestimated or at least not clearly assessed.

For all these sustainability aspects, standards related to business-to-business services delivered by eco-industries would help mainstreaming eco-innovation throughout the whole production and consumption system.

3.1.2.3 Standards for quality and performance

Rationale

Stronger competition to sell increasingly integrated goods and services to more informed and demanding consumers leads to a growing need for performance-based standards ensuring the required quality of materials, products and services, and the performance of processes and technologies. Traditionally, this requirement has been covered by standardisation activities. However, it is becoming more and more challenging for ESOs as they need to keep pace with shorter innovation cycles for a widening range of technologies, including biotechnologies, AM, nanotechnologies, advanced robotics, etc.

As a result, the line between standardisation as an enabler of innovation – if in phase with product cycles – and standardisation as a constraint – if it does not keep pace with technological development – becomes narrower.

In that context, the use of performance-based standards actively encourages innovation by taking away the constraints of prescriptive standards. Innovators are free to design and build what they wish, as long as it meets the performance criteria. Performance-based standards are also increasingly necessary to ensure minimum quality and performance of personalised goods and services, for which prescriptive technical standards can no longer apply.

At the global level, 'standards for quality and performance' are especially important to put Europe ahead of its international competitors in the global market. The challenge for ESOs is to develop and promote those standards as early as possible so that they are endorsed by the international community as world-leading standards.

Main findings from the study

In a fully globalised economy where competition has become fiercer, in 2025 European industry will have to rely more strongly on new, advanced manufacturing systems and technologies, for which standards will be needed on a constant basis to ensure quality and performance throughout the production and distribution system.

Indeed, the digitalisation of society and easier access to information and education worldwide will result in consumers – in Europe, in today's other industrialised countries but also in developing countries in Asia and Africa – who are better informed and more demanding as regards the price and quality of products and services. To help companies respond to these growing requirements, in particular, an update of existing standards and the development of new ones focusing on the quality and performance of materials, products, services, processes, and technologies are needed.

Standards will be required to foster the uptake of advanced manufacturing systems and other key enabling technologies by the entire European industry. In particular, to help companies become more responsive to changes in demand, standards are especially important for innovative technologies fostering automated production (e.g. artificial intelligence), faster and more flexible logistics, reverse logistics and supply chains, as well as the modular approach of assembly and disassembly lines.

Beyond manufacturing systems and technologies, the scarcity of a growing number of materials has pushed the development of new, advanced materials that offer a widening scope of functionalities and properties to build on. The relevance and importance of standardisation in the field of materials was stressed many times during the foresight workshops. New performance-based methods, including testing, are needed to keep pace with the development of innovative new materials such as graphene, and smart materials (e.g. materials that interact with the environment, self-healing materials, etc.).

Furthermore, the workshop dedicated to AM strongly underlined the need to better characterise the properties and responses of all materials relevant to this process (e.g. metals, ceramics, polymers, paper, etc.). All existing standards should be reviewed to integrate applications for both subtractive and additive manufacturing.

The future industrial landscape is also underpinned by advanced ICT (e.g. the Internet of Things) and the management of big data. Companies must collect and analyse larger and more heterogeneous sets of data in order to better understand the dynamics affecting the business environment, in particular the volatility and diversity of markets worldwide. The efficient management of these data and their associated technologies (e.g. cloud computing, quantum computing, visualisation and simulation tools, etc.) is key to that success. First of all, standards are needed to help preserve data quality throughout more intensive data life cycles and to facilitate data comparability, in particular among the various stakeholders of the global and disaggregated value chains.

In addition, standards should be developed to help companies, in particular SMEs, implement efficient data-cleansing and archiving protocols to avoid information overload and to improve long-term data accessibility.

Furthermore, participants underlined that international data-format standards for the exchange of high-resolution 3D computer-aided design files are required to foster the take-off of 3D printing applications. Even if not yet mature, the development of quantum computing will also require new kinds of data-format standards (i.e. with a shift from bits to qubits).

Beyond data, the management of knowledge would benefit from standardisation activities, for example to foster knowledge sharing between industries and research and technological centres via standardised digital research repositories and information systems. Standards should also be developed to ensure that knowledge will not be lost when ICT infrastructures are upgraded.

3.1.2.4 Service standards

Rationale

As often mentioned by the participants during this foresight study, standardisation activities do not sufficiently embrace the strong service dimension of the European economy. Indeed, services account for around 70 % of the economic activity and employment in the EU Member States, whereas service standards represent less than 10 % of all European standards[14].

The importance of the service dimension can only grow with the ongoing shift from product ownership to service leasing (e.g. from car ownership to mobility services), and the increasingly vast number of products and processes that can be offered as a cloud-based service.

Service standards are needed to ensure and demonstrate to consumers the quality of services through more standardised, mainstreamed and simple methodologies which will facilitate comparability and evaluation in a more transparent way. Standards related to customer satisfaction, complaint management, contract management or dispute resolution should be developed to better protect the consumer. Accessibility to key services for all segments of the population (e.g. disabled and elderly people, but also across the social layer) should also be fostered through standards.

Likewise, the dissemination of eco-innovation throughout the entire European industry would also benefit from service standards that ensure quality and facilitate the comparability of eco-industry services (e.g. waste management, energy efficiency, etc.) to all businesses, in particular small players.

Main findings from the study

The business models of manufacturing companies and service providers can no longer be limited to the assumption that consumer choice is based on only two factors – i.e. the price and quality of goods and services. Evolving social norms and values, as well as new individual and collective behaviour, lead to an increased volatility and diversity of factors upon which consumers base their choices.

First of all, the traditional model of ownership is challenged by new consumption models based on leasing, renting or shared use, as these models respond better to the increasing user requirements for flexibility and mobility in a highly dynamic, interactive society. Consequently, existing standards need to be reviewed to take into account this new consumer behaviour and consumption models. For example, as mentioned during the workshop dedicated to mobility, standards related to cars (e.g. equipment, engines, maintenance protocols, insurance models, etc.) should differ significantly if their use is based mainly on an ownership model (i.e. a few users throughout their lifetime) or on a car-sharing or car-renting model (i.e. thousands of users in a lifetime).

Moreover, as these new models focus more on the service side, new service standards are needed in the field of customer services and customer satisfaction. An essential objective of standardisation is to facilitate the evaluation of these services by users in a systematic way, and present the related information through a few standardised user-friendly formats. International standards related to contract management, complaint management and dispute resolution during or after the purchase or leasing of goods and services are also needed to help establish harmonised solutions worldwide, despite the various national regulations.

At a more general level, and keeping in mind the recent European financial crisis, experts involved in the study mentioned a possible role for standardisation to enhance the quality of the financial infrastructure, as well as to ensure the traceability of the financial flows within it.

Acknowledging the evolving economic norms and values and the push towards corporate social and environmental responsibility, they also emphasised the need for new accounting standards enabling measurement of a company's full environmental, social and economic costs which could contribute to introducing a positive shift in the performance rating of businesses worldwide. In particular, with consumers' increased concern over sustainability issues, standards could foster corporate social reporting through the inclusion of information on sustainability in companies' reporting cycle worldwide. Consumers are also more and more sensitive to the social conditions of production and delivery (e.g. working conditions, child labour in some countries, etc.). Hence, a harmonised approach to allow for the social ranking of products and services could also be pushed by standards.

In 2025, the emergence of a highly informed society will have been fostered by a wide range of open online educational solutions. Even though, traditionally, standardisation has not been involved in education, participants mentioned that standards are needed in the short term to ensure the quality of e-learning, especially for those online education solutions that

[14] See for example: Technopolis Group (2010), 'Mapping services standardisation in Europe'.

certify skills and competencies through virtual assessment. Standardisation activities at the European level that would help define a reference framework for skills in the fields related to manufacturing – similar to the approach initiated by the CEN on e-skills – would also benefit the industrial sector.

3.1.2.5 'De-risking' Standards

Rationale

Giving consumers confidence and protecting them and the environment will become increasingly important roles for standards, particularly as consumers purchase services in conjunction with products. It is therefore proposed to cluster the standards dealing with health and safety, security and privacy, accessibility, and environmental protection issues in a single category – 'de-risking' standards – since the main benefit of all these standards in terms of innovation and competitiveness is to reduce the risks related to the acceptance, uptake and dissemination of the proposed innovative solutions.

First of all, the importance of services to the consumer, often based on big data and the Internet of Things, means that the consumer will increasingly need assurance that his/her security and privacy are being properly protected, and that their purchase actually fulfils their requirements.

In addition, as risks – and their perception – increase with technology and innovation (e.g. chemical toxicity, food safety, nanotechnologies, GMOs, climate change, electromagnetic radiation, financial crisis, price volatility, etc.), standards have a key role to play in fostering the social acceptance of innovations – and consequently facilitating business take-up – by ensuring a high level of safety and security for the related products, services and infrastructures.

Furthermore, by widening the scope of potential consumers (e.g. disabled and elderly people but across the social layer, too), standards related to accessibility also foster the uptake of innovative products and services.

Main findings from the study

A key underlying condition of the ILV 2025 is the deployment of smart and interoperable infrastructures. Participants emphasised the need for 'de-risking' standards that reduce the risks and vulnerabilities of increasingly complex infrastructure relying on ICT-based technologies. Securing data flows throughout the infrastructure network, ensuring full privacy to the users, as well a high level of accessibility to all segments of the population are key challenges where standardisation can make an important contribution.

As stressed by the experts during the case study addressing the future of mobility, the issue of intelligent transport systems and mobility management solutions requires the development of standards to ensure that any user can see and control the flows of personal data that (s) he exchanges with service providers or public authorities. Standards act as enablers to increase the trust of users of these technologies and services that ultimately improve the conditions of their choice through information. With more and more data being shared and circulated worldwide, the issues of data tracking, data protection, data storage and source authentication have also been highlighted as relevant fields for standardisation. In particular, the development and periodic update of international standards for data protection in response to global cyber threats and vulnerabilities is especially important.

This implies stronger coordination within the ESS (i.e. between CEN, CENELEC, ETSI and national standardisation bodies), and between formal and informal standardisation bodies worldwide. Indeed, a vast amount of ICT-related standards are produced by fora and consortia outside the formal standardisation system.

As the effects of climate change become more evident, the resilience of infrastructure is an increasingly important issue to ensure user safety. Existing standards must be reviewed to integrate climate change mitigation measures and facilitate their implementation across Europe. In addition, new standards should be developed for technologies for adapting to climate change, especially in the building, transportation and infrastructure sectors.

In addition to infrastructure, experts also highlighted the importance of technological developments in advanced manufacturing systems, in particular advanced robotics, and the need to constantly update standards that ensure security for people working with robots.

The workshop dedicated to AM also identified new safety issues. As additive manufacturing technologies often use material powders with potential harmful ultrafine particle emissions, standards are required that ensure the safety of the (amateur) operator, in particular in the field of 3D printing which offers a promising potential for home-made – and thus less controlled – manufacturing. 'De-risking' standards are also needed to ensure the integrity of the 3D design files exchanged through peer-to-peer file sharing.

The workshop addressed the issue of personalisation, too. At first sight, the standardisation and personalisation of goods and services are conflicting activities, since standards often lead to a reduction in variety. However, de-risking standards are required, probably more than before, to ensure that the personalisation of goods and services will not be undertaken at the expense of safety, security, privacy and environmental protection.

With an ageing society in many regions of the world, especially in Europe, the need to better address the expectations of elderly people regarding accessibility to products and services is becoming increasingly important. Standardisation activities have already started in this field, as they have for other categories of the population such as disabled people. However, this approach needs to be extended to all standards. In addition, since an ageing population is leading to a relatively shrinking workforce, the inclusion of elderly and disabled people in the workplace needs to be fostered, and standardisation has a key role to play here.

Finally, in the field of environmental protection, and in addition to the sustainability issues mentioned above, existing standards regarding the exploitation and extraction of raw materials should be transferred to and/or reviewed with countries with large resource supplies.

3.1.3 Cross-cutting issues

With increasingly short innovation cycles for products and services resulting from the continual development of new technologies and the volatility of consumer requirements and behaviour, standards must build in adaptation-to-change. Drafting standards in such a way that their update can be achieved easily and flexibly should be the norm applied by all ESOs and for all kinds of standards, rather than creating new ones.

In addition, the study's experts recognised that the existence of standards in a particular field is not necessarily followed by implementation in a consistent way by all stakeholders. In particular, standards are sometimes not suited to small players, especially in areas which are not purely technical, such as quality management, safety management or services. Hence, when creating or updating such a standard, ESOs should consider developing differentiated guidelines (e.g. the level of detail) according to the size and the nature of businesses (e.g. SMEs vs. large firms, service providers vs. factories, etc.).

Furthermore, globalisation of the economy and the need for international rather than national standards should not hide the fact that implementation of standards, especially service and management standards, could differ slightly according to regions, values and cultures. Therefore, the definition of standards with differentiated guidelines for implementation that take into account specific regional requirements should also be considered by ESOs, as this will facilitate the endorsement of European standards worldwide.

Finally, the rising trend towards the personalisation and mass customisation of products and services is often said to escape the field of standardisation, since the latter can lead to the antagonistic trend of reducing variety. Standardisation has an important challenge to address here. New approaches are needed to deal with products and services that can be personalised to meet individual requirements. A possible solution would be to adopt performance-based standards to assure the required quality, performance and safety.

3.2 Implications for the European Standardisation System

This section summarises the implications of the ILV 2025 for the ESS (i.e. the three ESOs) in order to prepare for and facilitate this vision. The foresight study has identified three main areas that could be translated into recommendations for actions.

3.2.1 Accelerating the standardisation process

As already acknowledged by several European policy documents[15] in recent years, this foresight study confirms that the acceleration of the European standardisation process is essential if standardisation is to keep pace with both technological developments and the evolution of societal, environmental, economic and geopolitical challenges. If it succeeds, then standardisation will act as an enabling instrument that fosters social and market acceptance of innovative products and services. In addition, the country or region that develops new standards first, and manages to have these standards recognised at the international level, will gain the competitive advantage.

There are, however, many potential side effects associated with an acceleration of the standardisation process if it is not implemented carefully, in particular regarding the quality of the outputs, respect of the consensus principle of standardisation, and the need to involve a broader scope of stakeholders. In short, a minimum time is required to develop a high-quality standard through a consensus-based process. However, this does not mean that the process cannot be organised differently or start earlier. Indeed, identifying the needs for standards earlier is probably the best way to speed up the whole standardisation process.

3.2.1.1 Anticipation and foresight

Anticipation is key to adopting the right standard at the earliest possible and timely moment. Applying horizon scanning and foresight techniques in a systematic way will allow ESOs to prepare, well in advance, for future industrial and societal issues. The present foresight study is the first attempt to apply a forward-looking approach dedicated to the identification of standardisation needs. This approach facilitates the identification of the main, high-level

[15] In particular, European Commission Communication 'A Strategic Vision for European Standards', COM(2011) 311 final.

objectives for standardisation. However, it should be completed by other foresight methodologies used on a recurrent basis by the ESOs themselves so as to identify the specific standards required for specific themes, sectors or technologies.

Previous studies have linked standardisation to foresight. In particular, the Delphi methodology has already been highlighted as a good example of foresight techniques that could be applied to identify future fields of standardisation, i.e. through the combination of quantitative indicator-based analyses and qualitative in-depth Delphi surveys[16].

Details of how horizon scanning and foresight should be applied are set out in a template described later in this report (cf. Section 4).

3.2.1.2 Fast-tracking important issues

Once new, priority subjects have been identified that require standardisation, it is important that mechanisms are put in place to 'fast track' those subjects within the European standardisation system. Decision-making mechanisms are needed to assure that strategically important standards are developed as quickly as possible. The Specialist Task Forces (STFs)[17] used by ETSI to accelerate the standardisation process in strategic areas are a good example of such mechanisms.

3.2.1.3 Keeping pace with rapidly developing and converging technologies

New mechanisms must be implemented in a more structured way to keep pace with rapidly developing and converging technologies. They should go beyond the ad-hoc joint working groups (e.g. smart grids) to enable constant dialogue and long-term synergies between the three ESOs' technical committees in order to better address the challenges of converging technologies.

Existing alternative standardisation outputs, such as workshop agreements and technical reports, should also be increasingly considered by ESOs so as to kick off standardisation work at an early research and development (R&D) stage where standardisers and researchers can interact more closely.

3.2.1.4 Putting science into standards

Fora to facilitate communication between scientific and standardisation communities

As previously mentioned, accelerating the standardisation process to meet the requirements of a fast-changing global landscape is one of the main policy drivers currently facing the European standardisation community. Science can play a key role in addressing this issue. Standards can also help to bridge the gap between research and marketable products or services.

However, this can only be achieved if standards keep pace with the development of science and technologies, and ever-faster product-development cycles.

Fora need to be created in Europe to facilitate discussions between the scientific and standardisation communities in order to fully assess the potential of scientific and technological developments, to analyse the need for standardisation effort, and to set the standardisation agenda (from pre-normative research to the preparation of standards).

Recognition of scientific involvement in standardisation activities

To encourage scientific involvement in the standardisation process, incentives need to be developed. This can be done in a similar manner to scientists gaining recognition for publishing peer-reviewed papers.

In reviewing proposals for funding, for example, the scientists' involvement in standardisation activities should be taken into account as a key part of the evaluation criteria, based, perhaps, on dedicated indicators.

In any case, the ESOs and the European Commission must be more proactive to attract researchers' interest in standardisation activities (e.g. when funding research programmes).

Dedicated research programmes for pre- and peri-normative research

Standards are often based on pre-normative research. Their preparation often depends on peri- or co-normative research. To facilitate this, dedicated research programmes should be put in place which address preparatory research and the development of test methods and measurements, and are coordinated strictly with European standardisation planning.

Coordinated approach to research-supporting standards

In the research domain, European activity to support standards has to be coordinated to ensure a complete and coherent approach. Various groupings already exist, such as CEN-CENELEC's

[16] Identification of future fields of standardisation: An explorative application of the Delphi methodology', Goluchowicz, K, Blind, K., Technological Forecasting & Social Change, vol. 78, issue 9, November 2011, pp. 1526-1541.

[17] Specialist Task Forces (STFs) are "teams of highly skilled experts, brought together to perform specific technical work under the direction of an ETSI Technical Committee". They "work intensively over a period of time, typically a few months, to accelerate the drafting work".

Standardisation, Innovation and Research (STAIR), to oversee the integration of standardisation in research projects. However, this effort should be strengthened to ensure European-wide coordination and action.

In addition, a more systematic approach needs to be applied to harvest the results of European research programmes to support standardisation.

3.2.2 Integrating European efforts in standardisation

3.2.2.1 Developing an international standardisation strategy for Europe

Europe participates actively in international standardisation actions. However, this participation depends mainly on the initiative of individual European stakeholders. A more strategic approach is required in order to maximise the strategic advantage of international standards for Europe. Key thematic areas must be identified and prioritised, and international activity and European participation assured.

This requires Europe to instigate an **international standardisation strategy** involving the three ESOs (also in coordination with the national standardisation bodies) and driven by Europe's policy priorities (e.g. completion of the Single Market). It also needs to ensure that resources are allocated adequately to enable the broad consultation of stakeholders around these strategic areas, and to fund the expenses of experts representing European interests in international standardisation organisations.

3.2.2.2 Integrating standardisation efforts to address complex cross-cutting issues

To stay competitive in an increasingly globalised market, Europe has to address complex technical, social and political challenges. Cross-border, interconnected, interoperable, smart infrastructures, for example, require integrated, cross-cutting European initiatives for their successful implementation. This means that standards have to follow the same, integrated approach, incorporating a coordinated, coherent response.

To achieve this requires the implementation of a governance structure at the European level, ensuring that the three ESOs respond in a coherent and complementary manner. This should be the case both in terms of the work of the various technical committees addressing the subject, and the international dimension assuring that European effort is properly recognised among international standards organisations.

3.2.3 Engaging more stakeholders in standardisation

3.2.3.1 Engaging consumers and private citizens directly

To better understand consumers' behaviour, to satisfy their requirements regarding social, environmental and ethical issues, and to respond to their increasing demand for personalised goods and services, companies are increasingly involving them in the design and development of products and services.

European standardisation activities already benefit from the involvement of consumer representatives, such as ANEC (the European consumer voice in standardisation)[18], which defends consumer interests in the creation of European standards, in particular when they are developed to support the implementation of European regulations (harmonised standards) and specific public policies related to the environment, health, safety and accessibility, the Information Society, etc.

However, as the need to understand consumer behaviour has become crucial to the development of standards, ESOs should also engage consumers and private citizens (e.g. hobbyists, craftsmen, etc.) directly in order to develop more user-oriented standards and receive direct feedback on existing ones. In particular, participants in the study emphasised that ESOs should explore the use of internet collaboration tools and social networks for that purpose. This would provide cost-efficient solutions in response to the financial constraints related to physical meetings. Furthermore, existing methods used in the field of open innovation should also be explored by ESOs.

The separation of the standard-setting process into two phases, with an initial stage focusing on the high-level objectives/ requirements for the standard being developed prior to the technical phase of drafting, was also suggested as a way of engaging individual and small stakeholders more easily (i.e. less expertise and less resources required, more 'attractive' fields of discussions).

Besides, as the global market expands to include consumers from developing countries, ESOs should try to get new insights into Chinese, Indian and Brazilian consumer behaviour, either through direct involvement with them or their representatives in the European standardisation process, or through dedicated market studies that would benefit all European companies involved in the standardisation process.

[18] http://www.anec.eu/anec.asp?p=about-anec&ref=01-01

3.2.3.2 Engaging SMEs through new incentives

More than 99 % of all European businesses[19] are SMEs. They provide two out of every three private sector jobs and contribute to more than half of the total value added created by businesses in the EU. Participation and/or membership of SMEs in the different ESOs (e.g. 27 % of ETSI members are SMEs and smaller) remain a long way from reflecting these figures.

Participation in the standard-setting procedures is time-consuming and expensive, which significantly favours larger stakeholders. SMEs are also less aware of the relevance and importance of standards for their own business. The issue is fully acknowledged by ESOs and the European Commission – the current system already publicly finances SMEs' representative organisations to facilitate their involvement on standards technical committees.

However, experts involved in the study mentioned that crowd-funding approaches should be explored as additional ways to pay (more) experts representing SMEs' interests.

3.2.3.3 Ensuring closer coordination with the European Patent Office

Although serving different specific objectives, the overall aims of standards and patents are not dissimilar. Innovation and communication are at the heart of both processes. ESOs should seek closer links with the European Patent Office (EPO) in order to come up with joint approaches to facilitating European competitiveness. The EPO already has long-standing cooperation with the ETSI, and more recently with the IEC at the international level. This collaboration should be extended to CEN-CENELEC to address a wider scope of strategic areas where both patents and standards are playing a key role in innovation.

3.2.3.4 Communicating on standards

Standardisation awareness

Standardisation activities are often perceived by the general public as a purely technical field. However, as highlighted by this foresight study, standardisation is closely linked with social, environmental, ethical and policy issues, and the development and mainstreaming of the right standards can be a strong enabler for innovation, competitiveness, growth and jobs.

Therefore, more awareness activities on the role and impact of standardisation on society and the economy are needed to engage more stakeholders and build trust around European standards.

In particular, there is a need to change the language around standards – and this particular study is a first step in doing so – so as to make the field of standardisation more attractive and accessible to the public at large. Participants mentioned the possible use of online gamification, open competitions to develop standards (e.g. annual prize) as well as popular online votes to identify new standards citizens would like to see developed.

Raising awareness should also include the creation of dedicated platforms addressing new issues, such as additive manufacturing or synthetic biology. These platforms will enable the new subjects to be fully explored, involving the widest possible set of stakeholders, and will set the overall context and need for standards development. They will also act as a communication mechanism allowing new subjects to be explored by potential innovators.

Standards dissemination

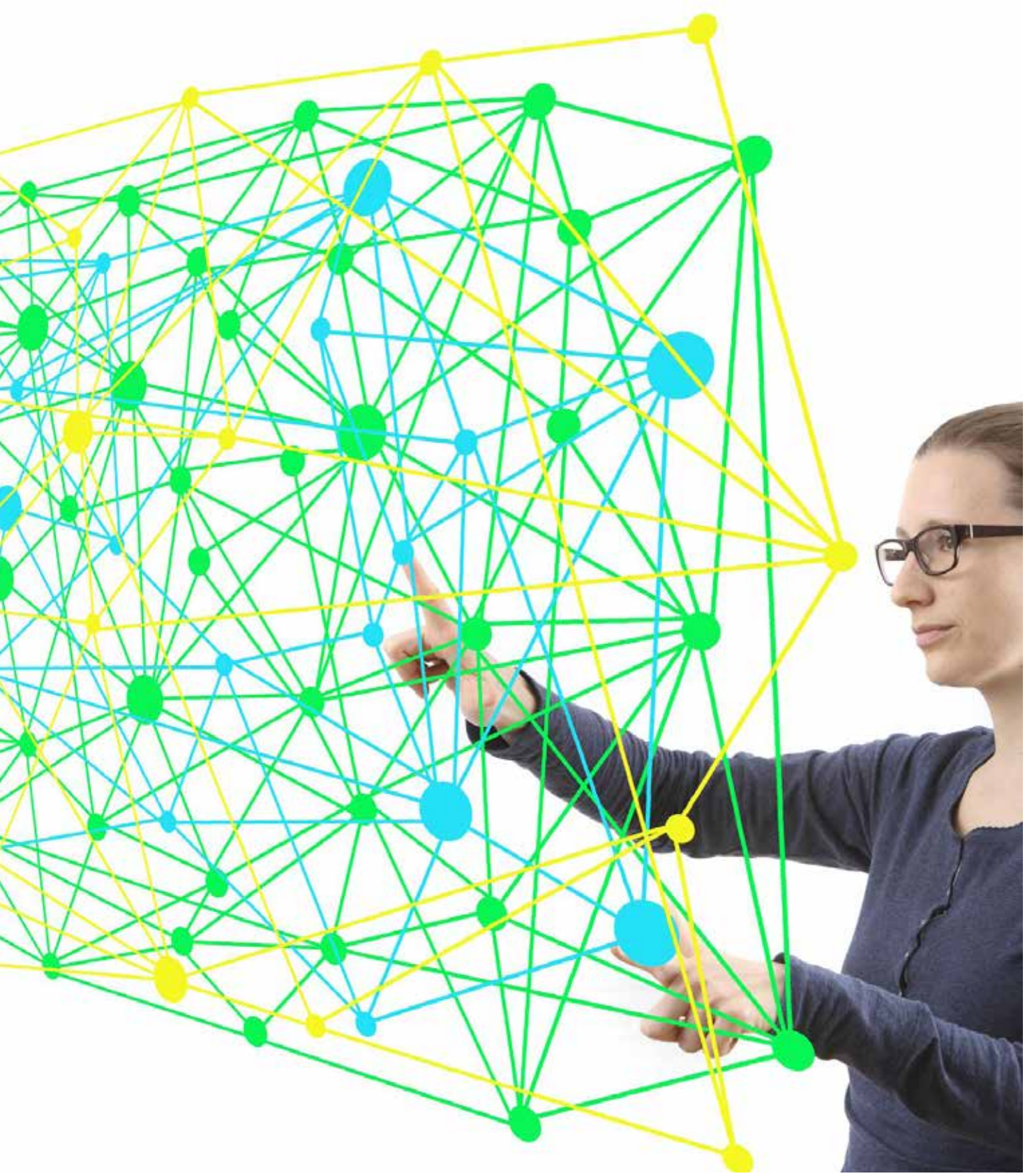
The global standardisation system is somewhat opaque. In some cases, it is extremely difficult to ascertain which standards are available for a given subject, globally or regionally, and whether or not they are compatible. For users of standards this is a major block to market access, trade and innovation. A single, user-friendly database providing an overview of all globally available standards should be freely available to European citizens and businesses.

Coordination with national standardisation bodies in the Member States will remain key to better promote European standards locally. Factsheets on these standards should also be made available in all European languages to foster their adoption and implementation.

3.2.3.5 Educating on standards

The lack of standardisation experts in Europe was also stressed during the study as a constraint for the representation of European interests within the international standards-setting processes. Standardisation-related courses (both theoretical and practical) should be included in some European curricula (e.g. Masters/PhD in Engineering or Economics) so as to broaden the European long-term expertise in such fields. Short-term professional programmes and e-learning courses should also be developed to build the capacities of researchers, engineers and entrepreneurs in standardisation work.

[19] Source: Facts and figures about the EU's SMEs http://ec.europa.eu/enterprise/policies/sme/facts-figures-analysis/index_en.htm



4. A foresight template for standardisation

4.1 Why a foresight template for standardisation?

4.1.1 Introducing anticipation and foresight into the standardisation process

Foresight is a discipline that is used to help different stakeholders and experts to look into the future with the aim of understanding and analysing possible future developments and challenges and supporting actors to actively shape the future.

Horizon scanning is a methodology that researches and draws out weak signals of change and key trends which are at the margin of today's landscape but which might have an impact on our future lives. These weak signals and trends interact with each other and with the strategies, policies and regulatory frameworks that are put in place to create new future conditions.

Horizon scanning and foresight are also used to develop strategic intelligence that can be used by the decision-makers in an organisation to position it strategically on the market.

For standardisation organisations and processes, foresight and horizon scanning can help decision-makers to take a longer-term strategic approach, and makes the current standardisation business model more resilient to future uncertainty. Foresight and horizon scanning can help standardisation organisations to develop new insights and to think 'outside the box'. Horizon scanning is also useful as it helps to manage risk by planning ahead for unlikely, but potentially high-impact events. In the standardisation context, horizon scanning can be used to identify new subjects that might require an effort in standardisation.

4.1.2 Objective of the foresight template for standardisation

A key objective of this study is to facilitate the better planning of standards by applying horizon scanning and foresight techniques. Early identification and analysis of subjects requiring standards much earlier in the development process of either a given technology or a business area means that the standardisation process will be effectively accelerated. Consequently, European standards will be developed earlier, in a more timely fashion, enabling international competitive advantage.

The foresight template for standardisation has been developed to satisfy this need. It consists mainly in better organising the identification of new issues for standardisation through the use of existing horizon scanning and foresight approaches customised to meet the needs of the standardisation process. The template has been developed in conjunction with the study's experts, and its approach tested and refined in two case studies: additive manufacturing, used as a technology-based example, and mobility, used as a thematic-based example.

It should be stressed that the foresight template for standardisation does not imply any modification of the current standardisation drafting processes and business models used by CEN, CENELEC and ETSI. Its introduction is simply intended to help ESOs identify new issues for standardisation earlier and in a more systematic way.

It also offers ESOs the possibility to involve a broader scope of stakeholders (e.g. industry as well as civil society, customers, public authorities, researchers, etc.) into standardisation work through the introduction of more participative, holistic and high-level discussions than those in technical committees. Hence, it should be seen as an efficient way to address the challenge underlined in the 'Industrial Policy in the Globalisation Era' Flagship Initiative[20] which states that: "for manufacturing industries, the overall goal in the decade to come is to develop a standards system for Europe that will meet the expectations of both the market players and European public authorities". Indeed, this template respects the market-orientation of standardisation while providing a forum for non-industrial stakeholders to present their expectations.

[20] European Commission (2010), Communication on 'An Industrial Policy for the Globalisation Era' – COM(2010) 614

4.2 Description of the foresight template for standardisation

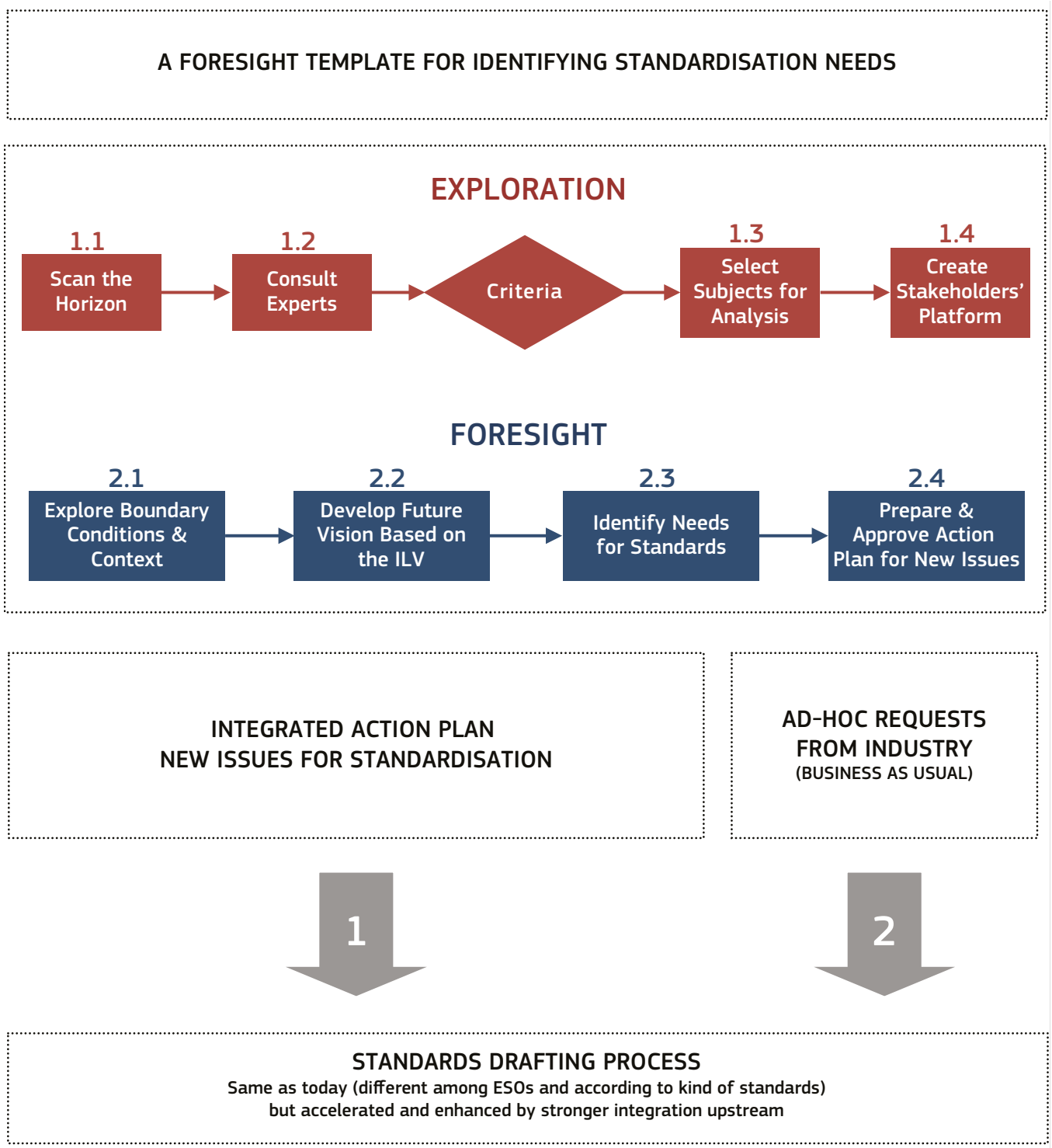
The foresight template for standardisation operates continuously, and is used only for the identification of new issues for standardisation. For example, it is not a prerequisite to start the development process for a standard requested by the industry.

It is based on two steps that better organise the identification phase of the current standardisation process:

- **Step 1. Exploration:** scans the science, technology, business, environment and societal horizons to identify new subjects requiring further analysis with respect to the needs for new standards;
  - **Step 1.1. Scan the horizon**: to scan the societal, technological, environmental, economic and industrial horizon and search for perturbations (novel and expected issues) from the norm that may require input from the ESS;
  - **Step 1.2. Consult experts**: to review the results of the horizon scan and prepare for the selection of identified issues requiring further in-depth analyses;
  - **Step 1.3. Select subjects for analysis**: to take the results of the expert consultation and, based upon pre-defined criteria, select subjects for further analysis;
  - **Step 1.4. Create stakeholders' platform:** to create a group of stakeholders representing as wide a range of related interests as possible concerning the selected subject;
- **Step 2. Foresight:** explores the current status and future development of selected subjects, analysing them and identifying where standardisation effort is required;
  - **Step 2.1. Explore boundary conditions and context**: to explore the boundary conditions and context of the selected subject;
  - **Step 2.2. Develop future vision based on the ILV**: to develop a future vision of the subject under analysis, using the ILV as the template;
  - **Step 2.3. Identify the need for standards**: to identify the need for standards and for changes to the standardisation system, based upon a common vision of the future development of the subject;
  - **Step 2.4. Prepare and approve an action plan for new issues**: to prepare an approved action plan for the development and implementation of standards, and for required changes to the ESS.

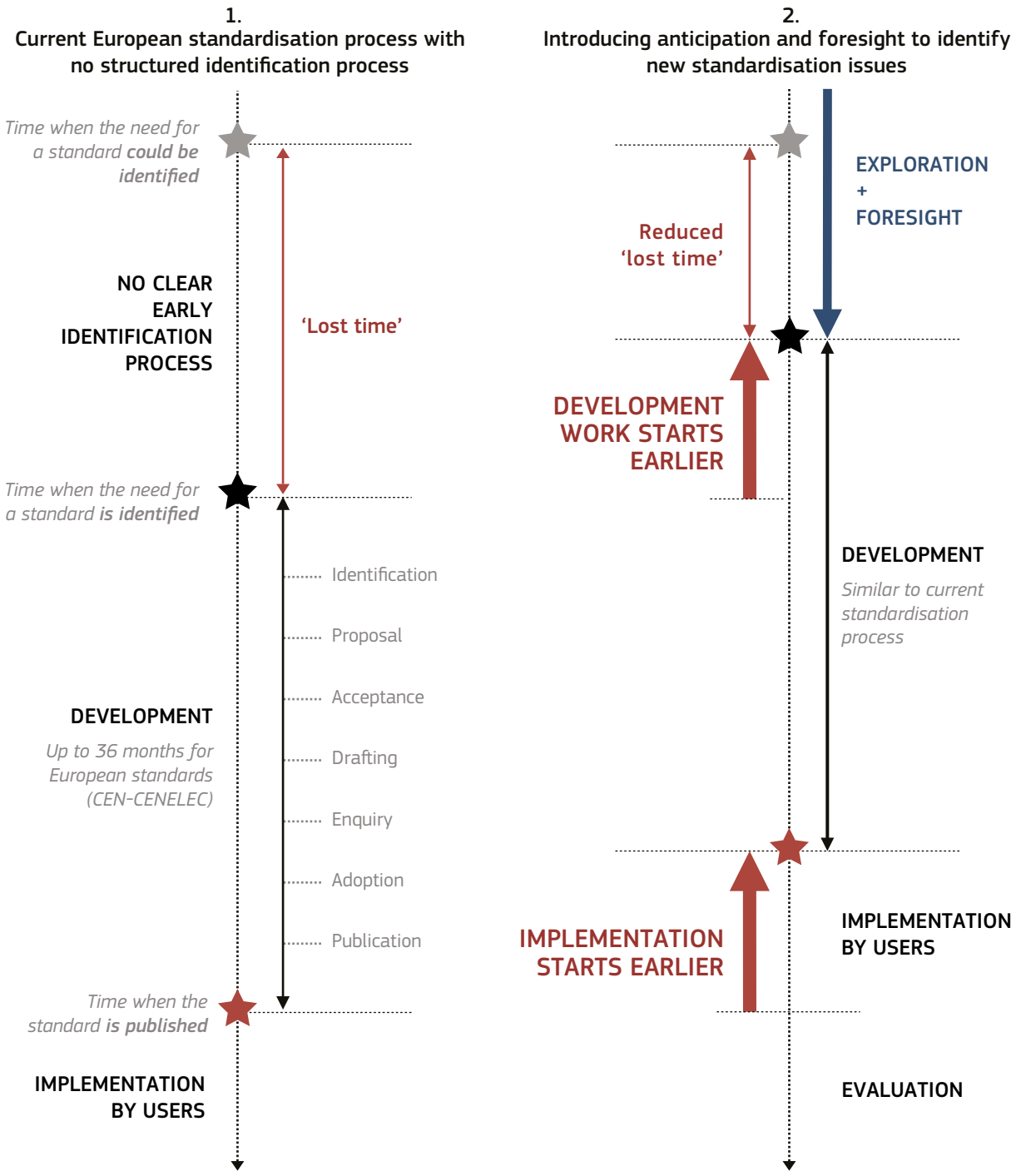
The template is meant to be managed by the three ESOs working together. This might require an extra level of governance, but it is necessary to ensure a coherent approach to subjects that may cut across the responsibilities of individual ESOs.

4.2.1 *Graphic representation of the template*



'SPEEDING-UP' THE STANDARDISATION PROCESS THROUGH ANTICIPATION AND FORESIGHT

The proposed template for the introduction of anticipation and foresight in the current European Standardisation System impacts mainly its identification phase, not the development process in itself.



4.2.2 Detailed description of the template

	Steps	Objectives	Techniques	Schedule	
1. Exploration	**Step 1.1. Scan the horizon**	To scan the societal, technological, environmental, economic and industrial horizon and search for perturbations (novel and unexpected issues) from the norm that may require input from the European standardisation system.	• Targeted online scanning • Review of targeted literature • Dedicated meetings with science and technology experts	Quarterly	
	Step 1.2. Consult experts	To review the results of the horizon scan and prepare for the selection of identified issues requiring further in-depth analyses.	• Experts workshops	Quarterly, following each horizon scan	
	Step 1.3. Select subjects for analysis	To take the results of the expert consultation and, based upon pre-defined criteria, select subjects for further analysis.	• Management meeting from all three ESOs, empowered to select and authorise subjects for further investigation	Quarterly, following each horizon scan and expert consultation	
	Step 1.4. Create stakeholders' platform	To create a group of stakeholders representing as wide a range of related interests as possible related to the selected subject.	• Regular meetings of the stakeholder platform	The stakeholder platform should be initiated following the selection of subjects for analysis and should follow the whole remaining process	
2. Foresight	**Step 2.1. Explore boundary conditions and context**	To explore the boundary conditions and context of the selected subject.	• Background paper • Stakeholder platform workshop (as established in Step 1.4.) • Online communication tools should be used to gather the widest possible input at this stage of the process • Study plan	The exploration of the boundary conditions and context should be completed within two months of the start of the study.	

	Management	Details
	Horizon scanning should be undertaken as a single ongoing activity, and at the level of all three ESOs working together.	**Horizon scanning process** The horizon scanning function can be set up internally with dedicated staff acting as scanners, or it can be contracted out to specialised companies. It comprises the systematic examination of potential threats, opportunities and likely future developments, including those at the margins of current thinking and planning. The process can be structured as follows: • Identifying emerging issues: extended review of existing future-oriented literature, technology-oriented studies (e.g. technological trends, emerging technologies), scan of future-oriented websites, including subscriptions to professional scan services; • First evaluation of threats and opportunities: initial review of material obtained through the scanning process to highlight possible threats and opportunities. Examples of selection criteria are size and type of threats affecting quality of life, environment, and economy for the identification of threats; economic benefits, improved quality of life, societal and environmental benefits for the identification of opportunities. The first identification of threats and opportunities can be compiled into of a first list to be submitted to Step 1.2. • Preliminary linking and clustering: the list identifying the threats and opportunities can be organised in clusters with some broad categories (e.g. technological development and innovation, etc.) that can be submitted for refinement to step 1.2.
	Expert workshops should be undertaken as a single activity, and at the level of all three ESOs working together.	**Experts** Experts should be selected for a fixed (renewable) period of three years in order to assure consistency of approach and experience. They should be selected to represent a wide range of different fields, including: science and technology; manufacturing and service industry; standardisation, metrology; patents; policy; consumers.
	Selection of subjects for analysis should be undertaken as a single activity, and at the level of all three ESOs working together.	**Criteria** Pre-defined criteria should be used to support the selection of subjects requiring further analysis. These criteria should include policy importance, market potential, innovation potential and societal/ environmental impact.
	The stakeholder platform should be managed as a single activity, and at the level of all three ESOs working together.	**Stakeholder platform** The stakeholder platform should be convened to facilitate a full exploration of the subject under consideration from all perspectives, and to act as a communication vehicle for it. The stakeholder platform will form the basis for the expert workshops that will provide input throughout the remainder of the process. As wide a range of stakeholders as possible should be invited to participate in the platform in order to broaden and enrich the discussion and the communication. This should include the following stakeholder communities: consumers, policy-makers, scientists and technologists, NGOs, manufacturing industry including forerunners and innovators, service industry, patents, standards, and metrology experts.
	The exploration of the boundary conditions and context should be undertaken as a single activity managed by all three ESOs together.	**Background paper** The ESOs' management team, working with the stakeholders' platform, should prepare a background paper on the selected subject. As far as possible, this paper should be factually based and should address the technological status, the main actors and their geographic location, the current market, the business process currently applied, and the potential future technological/industrial/market development of the subject. It should also address the status and plans for the subject within European and international standards bodies. **On-line communication tools** Key issues and supporting documentation should be placed online for open comment. Questions should also be placed online for public response. **Exploration workshop** Based upon the background paper, and the results of the online communication tools, the stakeholders' platform should be convened to participate in a workshop to explore three subjects: 1. Context of the subject (definition/focus; time horizon to be considered; geographic dimension of the analysis); 2. Boundary conditions for the analysis (scientific, technological and industrial status; standards, metrology, patents and copyright status; international status); 3. Objectives of the analysis (strategic objective; specific objectives). A range of techniques should be used at the workshop to facilitate and capture the expert discussion, including world cafés, break-out groups, and mind mapping. The background paper should be updated to take into consideration the conclusions of the stakeholders' platform. **Study plan** Based upon the outcome of the expert workshop, a study plan should be prepared by the ESOs' management team. This should be approved by the stakeholders' platform by written procedure.

	Steps	Objectives	Techniques	Schedule	
2. Foresight	**Step 2.2. Develop future vision based on the ILV**	To develop a future vision of the subject under analysis, using the ILV as the template.	• Background paper and study plan (as established in Step 2.1) • Background documents (selected expert(s) should be contracted to produce key inputs to support the process) • Visualisation tools • Expert workshops (based on the members of the stakeholders' platform) • ILV	The development of a future vision based on the ILV should be completed within six months of the start of the study.	
	Step 2.3. Identify needs for standards	To identify the need for standards and changes to the standardisation system, based on a common vision of the future development of the subject.	• Expert reports • Expert workshops (as described in Step 2.2.) • Delphi techniques	The identification of needed standards should be completed within 10 months of the start of the study.	
	Step 2.4. Prepare and approve action plan	To prepare an approved action plan for the development and implementation of standards, and for required changes to the ESS.		Preparation and approval of the action plan should be completed 12 months from the start of the study.	

	Management	Details
	The development of a future vision based on the ILV should be undertaken as a single activity managed by all three ESOs.	**Expert workshops** Expert workshops are at the core of this step. At least two workshops should be held to complete the step. Each one should be minutely choreographed and supported by targeted background documents, as well as material to support each session. There should be clearly identified roles for all the staff managing a workshop, from facilitators (minimum of two), through to break-out group chairs, collators of expert comment, managers of the microphone, and staff to manage administrative issues. A minimum of five staff are needed to manage a workshop. A range of techniques (expert presentations, world cafés, break-out groups, voting on key issues) should be used to conduct events. Visualisation tools to summarise key issues and provoke discussion are a key to success, as well as to gather expert comment during the workshop (e.g. mind mapping, post-it sessions, etc.). **Industrial Landscape Vision** The expert workshops should analyse the subject under consideration using the framework of the Industrial Landscape Vision: relevance of the 'agents of change' to the subject; impact of the 'agents of change' on the 'enablers and constraints' and the 'production and consumption system'; common vision of the 'production and consumption system' that will be the basis upon which the analysis of the need for standards and changes to the standardisation system will be based.
	The identification of needed standards should be undertaken as a single activity managed by all three ESOs.	**Expert reports** Selected expert(s) should be contracted to produce key inputs to support the process. This should include an analysis of the current extent of European and international standards for the selected area, and a first assessment of the need to develop new standards. **Expert workshops** Based upon the document prepared by a recognised expert in the field, there should be a common understanding amongst the stakeholders' platform of the status and plans for standards within the selected subject area. The expert workshops should identify, based upon the common, agreed vision of the future development of the subject (defined in Step 2.2) the need for new or updated standards and for the development of the European standardisation system. A report describing the conclusions from the expert workshops, and establishing the need for new/updated standards, and changes to the standardisation system should be produced by the ESOs' management team, and approved by the stakeholders' platform by written procedure. **Delphi surveys based on online questionnaires** In parallel, and in order to provide further evidence from a wider stakeholder community, a Delphi on-line questionnaire should be implemented. The goal (and the result) of the Delphi study is to organise a debate, collect and synthesise opinions and to achieve a degree of convergence. It is a valuable tool for communication and for exchanging opinions on a topic, making experts' tacit knowledge of the future more explicit. Delphi is particularly useful to assess, for example, when an emerging technology could become widespread in the future, which would provide insights on when standards should be developed. The Delphi survey, especially if conducted online, has the advantage of reaching out to a wider constituency of experts with different levels of knowledge, backgrounds and geographically dispersed, and can complement their knowledge with that of the experts involved in the workshops. More information on Delphi: http://forlearn.jrc.ec.europa.eu/guide/4_methodology/meth_delphi.htm
	The preparation and approval of the action plan should be undertaken as a single activity managed by all three ESOs.	**Preparation of the action plan** The action plan should be prepared by staff from the three ESOs to take into account the results of Step 2.3. It should identify which ESO will manage the drafting of each standard. The stakeholders' platform should be consulted on the contents of the action plan. **Authorisation of the action plan** The action plan should be authorised for implementation by the management of the three ESOs, in consultation with the European Commission's DG ENTR. The action plan should list the activities, deliverables, schedule, responsibilities and resources required to develop and implement the identified standards, and to make the required changes to the European Standardisation System.

4.3 Testing the foresight template for standardisation

4.3.1 Introduction

Two case studies were used to develop, test and improve the foresight template for standardisation. As each case study was addressed during one single workshop, the aim was not to implement and test the whole template (i.e. the five steps above mentioned) but rather to validate its inherent logic, i.e. the added value of using an anticipation and foresight approach to identify standardisation needs in a particular area.

The two topics were chosen in order to test the template on both a technology-oriented case study – additive manufacturing – as well as a broader theme – mobility.

4.3.2 Case study on additive manufacturing

Presentation of the expert workshop on additive manufacturing

The expert workshop on additive manufacturing was held on 4-5 December 2012. Forty experts participated: they were generalists in the field of manufacturing, foresight and innovation (25), and specialists in the field of AM (15). Experts were selected in order to achieve a good diversity of backgrounds (e.g. researchers, entrepreneurs, standardisers, designers, etc.) and organisations (e.g. firms, SMEs, service providers, universities, technological centres, FabLabs, etc.).

A background document on AM (see Annex 6) was prepared and sent to the participants prior to the workshop. It addressed the terminology related to AM, the technological status, the main actors, the current market and business models, the potential future technological/industrial/market development, as well as the challenges and barriers to its adoption. It also presented the ongoing standardisation activities and the standards already adopted in the AM field.

An additional presentation, given by one of the experts on AM, completed the introduction to the subject at the start of the workshop.

Additive manufacturing within ILV 2025

The first stage in the expert workshop comprised placing AM in the broader context of the LV 2025. The aim of the first interactive break-out sessions was to identify the main agents of change that will impact the development of AM, as well as the production and consumption system components which are most closely linked with AM technologies and processes.

Experts pointed out the relevance of the ILV 2025 approach for identifying and analysing all the challenges and opportunities at stake when considering a new technology like AM. They also agreed that this particular technology fits very well within this vision, especially since the issues of the personalisation and localisation of production are of particular importance to ILV 2025. The agents of change identified by the experts as being the most likely to impact the development of AM were: the increased importance of consumer requirements and behaviour (society); greater urbanisation (society); the digitalisation of society (society); globalisation of markets and manufacturing (economy); increasing scarcity of natural resources (environment); and public policy (policy). As for the components of the production and consumption system, skills and talents (business development); materials and reusable parts for sustainability (materials); advanced materials for performance (materials); services for customers (services); and holistic design (technologies and production processes) were identified as the key elements to be prioritised in order to foster the development of AM technologies.

During these discussions, experts commented in particular that the high level of uncertainty regarding the evolution of some drivers made the task of assessing the true potential for developing AM by 2025 particularly challenging. On the one hand, the development of AM could benefit from the need for industry to respond faster to the increasing demand for the personalisation of goods and services. On the other hand, the competitive advantage of a highly distributed production system – which could be fostered by AM – has still to be proven compared to the current globalised cargo shipping-based system which remains extremely cost-efficient for transporting manufacturing goods from Asia to the rest of the world. Therefore, the evolution of energy prices, the availability of resources throughout the world, as well as the behaviour of the new 'prosumers' were considered as key drivers for the development of AM.

Experts also highlighted the unclear relationship between AM processes and energy/resource efficiency. On the one hand, home-based 3D printing could lead to overconsumption through greater trash printing (and excessive home storage of material) and possibly to overall energy inefficiency (is a 3D printer in every home energy-efficient at European level?). On the other hand, AM processes minimise waste and could foster longer product life cycle thanks to closed-loop AM processes, more intensive use of bio-materials and more systematic use of spare parts.

The experts considered that the most promising development in AM technologies was to be expected in industrial applications (e.g. manufacturing of complex and light parts for high-tech products, especially in the automotive and aerospace sectors), whereas the mainstreaming of home-based 3D printing was more uncertain, even though strongly correlated with the trends of personalisation and mass customisation. The on-demand localised

printing of personalised goods and services (and also spare parts) was considered as a more likely option, especially in the context of increased urbanisation and the growth of smart cities (e.g. local 3D printing centres within the city).

They also stressed that R&D funding dedicated to AM technologies was critical since many improvements had still to be achieved regarding materials (limited number of usable materials, insufficient characterisation and poor performance at the moment); CAD software and file formats (user-friendliness is key for home-made applications while enhanced professional solutions are needed for industrial applications); closed-loop AM processes, speed of AM processes, 3D printing of active components (e.g. electronics); behavioural science (e.g. to better understand DIY-related behaviours as well as consumer desires for personalisation), etc.

In addition, skills and talents (especially in design and 3D computing) are not yet there for the mainstreaming of AM technologies, and their development will require new, dedicated education curricula and training programmes. In short, public policies have a key role to play in creating the positive conditions required for the development (and the acceptance) of AM technologies.

Additive manufacturing and standardisation

Since AM is still a technology at an early stage of development and many factors remain unclear, experts stressed that the standardisation process must be cautious: standards produced too early could 'kill' the development of the technology. In the case of AM, first there is a need to increase R&D, especially in the field of material science (development and characterisation), and to capture experience and feedback from users and manufacturers. Only afterwards, when the market calls for it, will standardisation be able to play its role in fostering innovation by mainstreaming innovative solutions and fostering social acceptance. However, the sooner the discussion starts on AM standardisation, the better it is for facilitating its implementation later.

An initial interesting result for standardisation in the field of AM was achieved thanks to the use of both the ILV 2025 holistic approach and the multidisciplinary expertise of the panel of participants. Indeed, according to their backgrounds and fields of work, experts considered heterogeneous applications and future business models for AM technologies and processes, which eventually led to the identification of different challenges and needs in terms of standardisation. The AM case study showed that, when trying to identify the needs related to standards, it is not enough to consider the technology itself but rather a distinction has to be made between its different applications/markets (i.e. for AM, home and industrial applications, and even sub-applications like prototyping, direct parts, etc.).

When considering home-use applications, the discussion focused mainly on safety, security and privacy issues, and the need for de-risking standards as well as the call for new functions for standards. Indeed, unlike traditional subtractive manufacturing, the 3D printing operator is no longer necessarily a professional. Therefore, to ensure the safety of this operator – when manipulating material powders, for example – will require new standards better adapted to amateur usage. For instance, experts pointed out that it was not reasonable to expect home users to follow standards in the same proactive way as a manufacturer would, and consequently standardisation organisations should attach a greater importance to awareness campaigns.

Safety issues were also raised when considering the reliability of personalised home-manufactured products, or the use of home-manufactured spare parts to replace a piece of a product. Standardised additive manufacturing protocols and design rules should be made available for home producers. Besides, new standards will also be needed to ensure the security and integrity of the 3D design files being exchanged to a significant extent on peer-to-peer networks (e.g. authentication, file format, etc.).

Experts also underlined the strong IPR issues related to the exchange of these 3D design files – in a similar way as for music and video files – which should be addressed jointly by standardisation and patent organisations.

When considering AM industrial applications, which should be mainly high-tech, standards for quality and performance were considered as the most important for fostering the adoption of AM technologies. There was a large consensus that material development and characterisation must be at the heart of the research effort, as well as standardisation activities. All material standards should be reviewed to integrate their specific properties in response to AM processes compared to subtractive manufacturing. Characterisation of material properties should be realised according to an international standardised framework. More advanced materials with improved response to AM processes need to be developed, and related standards made available for manufacturers. Standards for sustainability are also required to close the material loop for AM processes (e.g. use of biomaterials, reuse, etc.). Furthermore, the performance of AM processes needs to be enhanced, in terms of process cost-efficiency and energy-efficiency, process reliability, process capability (e.g. larger 3D printers), process speed (e.g. data acquisition, scanning, building, finishing, etc.) or process applicability (e.g. multi-material, printing of active components, etc.). Standards will be needed to ensure and to demonstrate the minimal performance of these processes, mainly through testing, measurement and quality control protocols.

Experts also mentioned that there was a need to educate and inform the public at large about AM to

foster the acceptance of many new AM products that are as robust as traditionally manufactured products although they may look more fragile (e.g. ultra-light robust lattice structures). Standardisation organisations have a key role to play here. Video tutorials, social networks and smart notes are options identified by the experts.

Main findings on the foresight template for standardisation

The expert workshop on additive manufacturing demonstrated the relevance of using a holistic and foresight approach to address the standardisation dimension of a particular technology. It supports the idea that the standardisation process should not rely only on the technical committees, but should also integrate an initial phase where all relevant stakeholders (e.g. standardisers, manufacturers, but also the new prosumers, service providers, FabLabs, etc.) are engaged in a much broader and forward-looking discussion around the related social, economic, environmental, safety and security challenges and opportunities.

The workshop helped to conceive the first two initial steps of the foresight template for standardisation. It also underlined the closer coordination needed between research and standardisation. In that sense, the recent STAIR-AM Platform launched by CEN-CENELEC together with the SASAM FP7 project, was identified as a very relevant pilot initiative.

4.3.3 Case study on the future of mobility

Presentation of the expert workshop on the future of mobility

The expert workshop on the future of mobility was held on 15-16 May 2013. Thirty experts participated: they were generalists in the field of manufacturing, foresight and innovation (20), and specialists in the field of mobility (10).

The theme of mobility was selected to further test the effectiveness of the foresight template within a broader thematic scope. As in the workshop on additive manufacturing, this event introduced the participants to the role of a standardisation stakeholder facing the problem of identifying the main standardisation needs for a particular issue. However, rather than proposing a background document which could not have covered such a broad theme, narratives and visualisation tools were used by the participants, alongside participatory techniques, to discuss images of the future of mobility.

Use of visualisation tools

Visualisation can be an effective way to develop and communicate ideas. In the workshop set-up, special attention was given to combining textual and visual information. This included the schematic representation of the ILV 2025 and a set of visual representations of the narratives on the future of mobility (see figure 1). The narratives and related illustrations were based on literature review and desk analysis. The project team, including an external designer, prepared them in order to achieve coherent and appealing future images of mobility.

In the first session of the workshop, three narratives were presented with a focus on: (a) the mobility user's perspective; (b) mobility and consumption; and (c) mobility and production. The illustrations helped the participants to visualise the related products and services and the underlying infrastructure and business models. Using a 'day in the life of a future mobility user' approach allowed the project team to highlight the different dimensions and elements of mobility in 2025 and to engage participants in constructive and forward-looking discussions on the future of mobility.

Fig.1: *Examples of illustrations and extracts from the related narrative*

Andrea's personal mobility package: [...] Andrea checks her integrated mobility system (IMS) to plan her travel for the day. Her IMS is based on a personalised mobility service contract that she purchased for the family from the international service provider. This provides her with a range of mobility options, valid on a global basis. Andrea has selected a package that prioritises speed of arrival, with cost being a secondary consideration. [...]

Ed-City infrastructure: [...] Arsene takes the Bus Rapid Transit system to school. This is an electric-powered, driverless bus on two levels. The lower level is open and straddles the road, acting like a tunnel that cars can drive through and making it independent of congestion. Passengers board the upper deck which has a maximum capacity of 300. The bus runs on rails either side of the car lane. The bus is powered by relay charging, and also charges when it stops to let passengers on and off. [...]

Andrea commuting: […] On arriving at her destination, Andrea collects a pre-booked hydrogen-powered car at the railway station. Whilst travelling using the automated car function, Andrea uses the on-board internet to manage her e-mails, and holds online meetings with customers and colleagues. […]

During the workshop, the external designer continued to enrich the graphic representations with the participants' ideas. This approach created ownership which supported the development of a common understanding of the future of manufacturing and mobility among the participants.

Use of participatory techniques

The second session was organised following a World Café approach. In this conversational and creative process, participants move between groups and build on the ideas of previous discussions. As a result, the process fostered collaborative dialogue, cross-pollination of ideas, and a deeper analysis of the issue under discussion.

By the end of these sessions, and using the ILV 2025 as a structured and systematic process, each group had identified the different elements of the proposed narrative on the future of mobility that require standardisation efforts, and had organised them according to the main components of the ILV 2025.

Main findings on standardisation needs

The third session focused on developing and discussing the priority areas where the development of standards is needed in particular to foster the emergence, development and mainstreaming of new mobility behaviour, patterns, systems and technologies which would contribute to smart, sustainable and inclusive growth and jobs in Europe.

In a nutshell, the following areas emerged from the discussions:

- Standards to foster smart interoperability of all transport infrastructure across Europe;
- Standards for alternative fuel and charging infrastructure to promote more sustainable infrastructure;
- Standards for cross-border and cross-mode payment (e.g. in support of European personal mobility solutions for citizens);
- Standards for data interconnectivity (infrastructure, mobile devices, vehicles, etc.);
- Data privacy and security standards to reduce the risks, vulnerabilities and threats of increasingly complex infrastructure relying on ICT-based technologies (e.g. user authentication, 'personal shields' standards for the user to control data exchange, etc.);
- Standards for mobility services, in particular to foster accessibility to all segments of the population (e.g. disabled and elderly people, and across all social layers);
- Audit standards to measure and express customer satisfaction on mobility services;
- Standards related to passenger rights;
- Cradle-to-cradle manufacturing standards to foster the mobility of material and goods in a sustainable way.

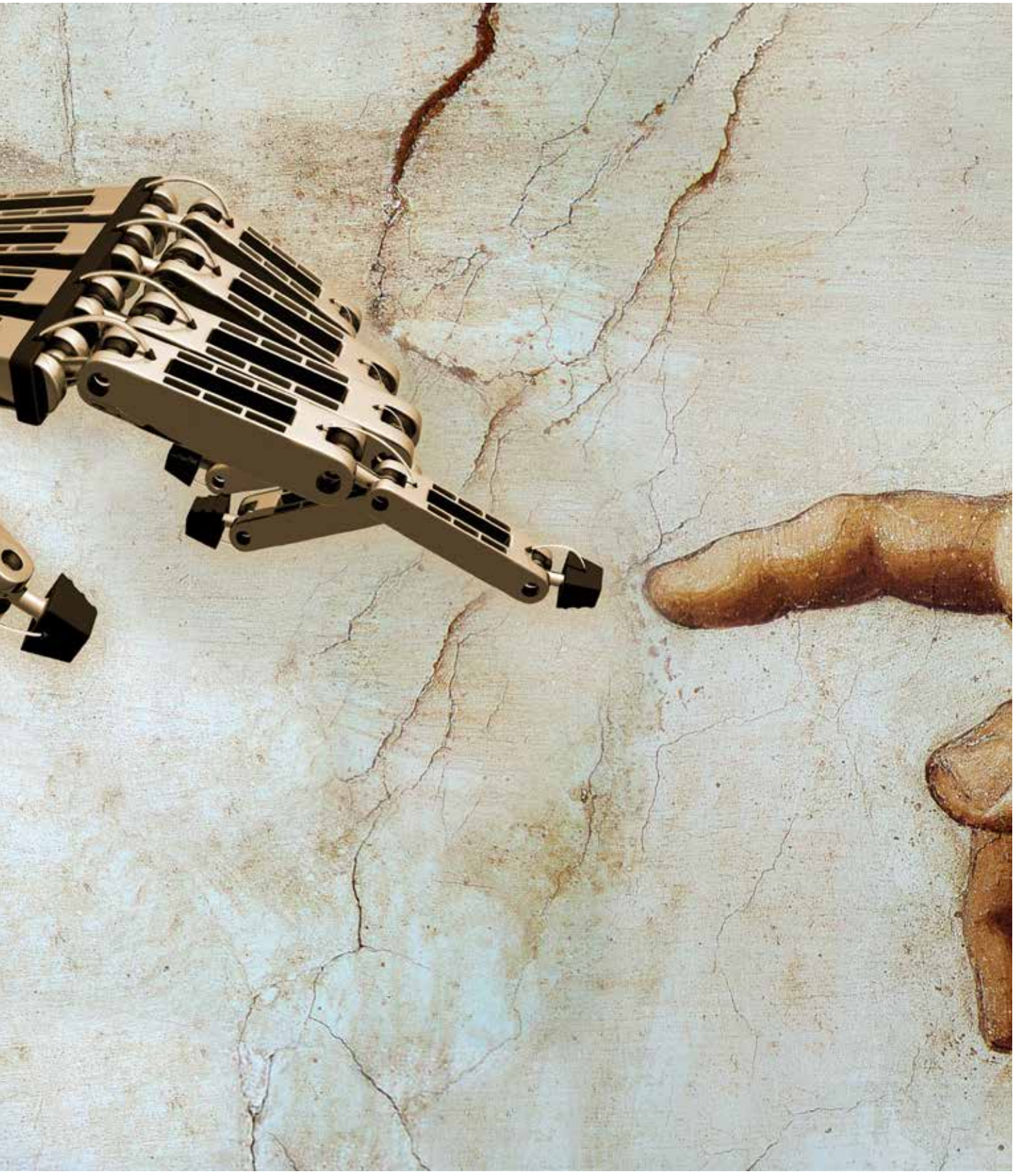
Fig.2: *Raw outputs of the World Café sessions*

Main findings on the foresight template for standardisation

The plenary discussions during this workshop helped to build the high-level categories for standards development defined in section 3.1.2., as participants identified the five following in the field of mobility: integration; communication; safety, security and privacy; services and business models; and materials.

Participants also confirmed the effectiveness of the applied template for identifying standardisation needs. On the one hand, the ILV 2025 provided the structure for the workshop sessions and fostered both a holistic and pragmatic approach (i.e. using the ILV 2025 as a checklist to consider all related issues). On the other hand, the foresight visualisation and participatory techniques allowed the participants to better envisage standardisation needs from a forward-looking and user-oriented perspective (i.e. narratives centred on individuals experiencing mobility in 2025).

As in the workshop on AM, this event mainly addressed the first two steps of the foresight template, and should be completed by other meetings which look at the technical details of standards development.



5. Recommendations

1. Standards need to be developed in **five priority areas** in order to facilitate the Industrial Landscape Vision 2025:

- ***Integration*:** standards that can cope with converging technologies, infrastructures and business models, and assure the required interoperability and interconnectivity;

- ***Environmental sustainability:*** standards that place resource efficiency, clean production, zero waste, energy neutrality at the core of industry in order to make business more competitive, and to respond to consumers' demand for a more sustainable world;

- ***Quality and performance:*** standards that can assure quality and performance in an era of rapidly changing and integrating technology, and where consumers increasingly want personalised products and services;

- ***Services:*** standards that address consumers' requirement for high-quality services as part of any product package to be purchased;

- ***'De-risking':*** standards that give consumers confidence in innovative solutions and protect them from potential risks to their health, safety, security and privacy;

2. The European Standardisation System should be enhanced in **seven key areas** to facilitate innovation and competitiveness:

- ***Patents and copyright:*** a common strategy should be developed between European standards, patents and copyright organisations to ensure a coherent approach with maximum support for innovation and competitiveness;

- ***Communication:*** dedicated platforms and online communication tools should be implemented to assure optimum communication with the widest possible range of stakeholders concerning new issues requiring standards, in order to facilitate innovation.

The ESS has different requirements, involving different players with different interests. All these interests should be involved in any future platforms, enabling all the relevant stakeholders to work together.

- ***Putting the science into standards:*** fora must be created to facilitate communication between the scientific and standardisation communities in order to better anticipate the needs of new science and technology in the planning of standards. To facilitate this, incentives need to be created to encourage scientific participation in the standardisation process. Techniques should also be developed to better harvest the results of research projects to support the standardisation process;

- ***New approaches to keep pace with technological development:*** new approaches need to be adopted by the ESOs to accommodate the increasing speed of technological development. This should include a reassessment of the use of existing techniques, such as workshop agreements, in order to improve their perception. It should also include the increased use of performance-based standards to provide a more flexible approach;

- ***Fast track:*** mechanisms have to be developed to fast track the preparation of standards in areas of strategic importance to Europe;

- ***Information accessibility:*** the availability of information on global standards (international, regional and national) for any given subject is extremely limited. The ESOs should create a database of all standards which are available globally to facilitate industry access into markets, and international trade negotiations;

- ***Education and training:*** new approaches need to be developed to educate and train people about the role and process of standards, particularly about their role in facilitating innovation and competitiveness;

- ***Evaluation***: the level and quality of standards implementation drafted by the ESOs should be evaluated periodically (e.g. through online surveys), and the economic benefits of these standards should be analysed (e.g. through socio-economic studies);

3. A **horizon scanning and foresight capability** should be established that is managed by all three ESOs working together to assure the better planning and acceleration of the ESS. This capability should follow the template provided in this report;

4. Europe should develop an **international standardisation strategy** to define where and how it participates in international standards organisations. This should be based on Europe's policy and industrial priorities;

5. The Industrial Landscape Vision suggests the **need for a stronger coordination approach to policy measures** from the field of, for example, energy, transport, the single market, regional dimension, research and innovation, which should be connected to industrial policy to ensure key elements of the future industrial landscape. The ILV and associated narrative should be further developed to better meet the requirements of the **EU's industrial policy**. In particular, the following aspects should be further analysed in a new foresight study:

- Personalisation of products and services to meet individuals' needs;

- The localisation of production chains and associated mass customisation to meet local/regional consumer needs;

- The use of ICT to manage disaggregated and globally distributed production chains;

6. Through the development of the ILV and the analysis of standardisation needs, a **series of research recommendations** has been identified:

- Economic analysis is required to better understand and measure the impact of standardisation on innovation;

- Economic analysis is required to better understand and measure the impact of standardisation on trade;

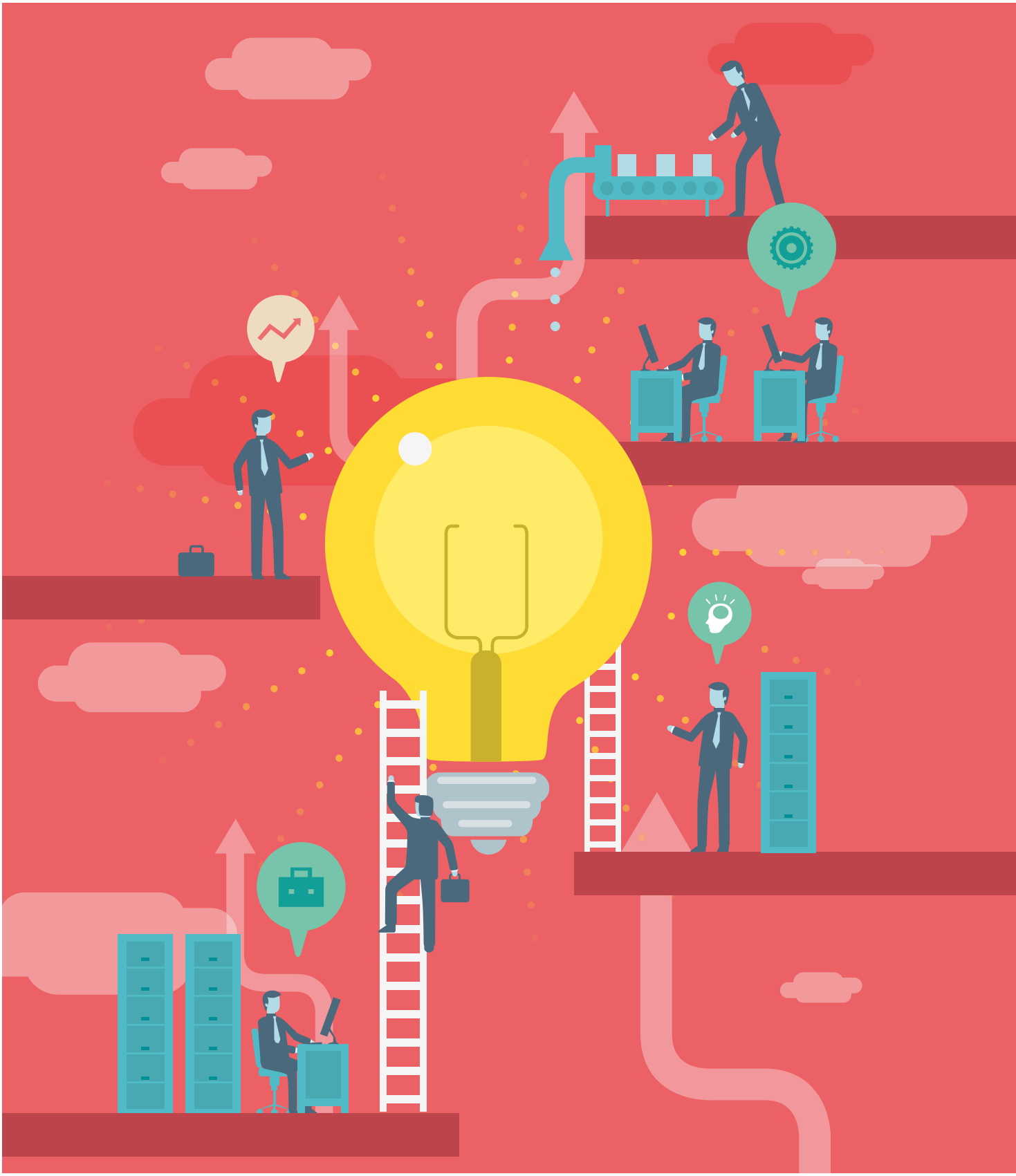
- New approaches for standardisation need to be identified in the field of personalisation and mass customisation, in particular for the service dimension;

- Comparative analysis of the different approaches to standardisation across the globe should be undertaken;

- Increased research on materials is key for European competitiveness.

7. The scope of this foresight study, its outcomes and recommendations are **a starting point in the exploration of standardisation as a policy-making instrument** contributing to innovation and competitiveness. There is still scope for a more detailed discussion and research on these issues, starting from this initial set of recommendations.

8. **Future foresight studies**, either carried out by the ESOs, and/or NSBs **should keep the strategic vision updated**.



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Abbreviations

AM	Additive manufacturing
ANEC	European Association for the Co-ordination of Consumer Representation in Standardisation
BRICS	Brazil, Russia, India, China and South Africa
CAD	Computer-aided design
CEN	European Committee for Standardization
CENELEC	European Committee for Electrotechnical Standardization
CSR	Corporate social responsibility
EFTA	European Free Trade Association
EN	European Standard
EPO	European Patent Office
ESOs	European Standards Organisations
ESS	European Standardisation System
ETSI	European Telecommunications Standards Institute
EU	European Union
FP7	EU's Seventh Framework Programme for Research 2007-2013
IEC	International Electrotechnical Commission
IoT	Internet of Things
ILV	Industrial Landscape Vision
IP	Intellectual property
IPR	Intellectual property rights
ISGs	Industrial Specification Groups (ETSI)
ISO	International Organization for Standardization
ITU	International Telecommunication Union
KETs	Key Enabling Technologies
NSBs	National Standards Bodies

NSOs	National Standards Organizations
R&D	Research and development
RFID	Radio-frequency identification
SASAM	Support Action for Standardisation in Additive Manufacturing (FP7 project)
SMEs	Small and medium-sized enterprises
STAIR	Standardisation, Innovation and Research (CEN-CENELEC Platform, ETSI as an observer)
STAIR-AM	STandardization, Innovation and Research – Additive Manufacturing
STEEP	Society, technology, economy, environment and policy (foresight methodology)
STF	Specialist task force
TC	Technical committee
TR	Technical report
TS	Technical specification
WTO	World Trade Organization

Annexes

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JRC FORESIGHT STUDY

How will standards facilitate new production systems in the context of EU innovation and competitiveness in 2025?

Annexes

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List of Experts and Interviews

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Willem COPPENS	Waterwegen & Zeekanaal NV (Belgium)
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Laura DELGADO-HERNANDEZ	Regional Transport Consortium of Madrid (Spain)
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Knut BLIND	Fraunhofer FOKUS (Germany)
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Interviews

Ashok GANESH	CEN/CENELEC – Several occasions
Eoin O'SULLIVAN	Institute for Manufacturing, University of Cambridge (UK) - *12 January 2012*
Engelbert WESTKÄMPER	Fraunhofer IPA (Germany) - *16 August 2012*
Paul McCAFFREY	UK Government Office for Science, Foresight (UK) - *24 August 2012*

Annex 2.
Glossary

Glossary related to Foresight

(Source: JRC For-Learn Website)

Delphi Survey

The Delphi Survey Method was invented by Herman Kahn and others to pool expert opinion on a specific topic. It is carried out in a series of rounds, each of which is modified by the results of the previous one. It produces a collective view about likely developments.

Driver of Change

Factor from the social, technological, economic, environmental or political fields that is directly or indirectly causing a change in the system under analysis.

Foresight

Systematic, participatory, future-intelligence-gathering and medium-to-long-term vision-building process aimed at present day decisions and mobilising joint actions.

Horizon Scanning

Systematic examination of potential threats, opportunities and likely future developments including those at the margins of current thinking and planning.

Participatory

Foresight activities are participatory by nature. They offer and encourage the participation of a wide and diverse range of actors concerned with the issues at stake.

Multidisciplinary

Foresight is based on the principle that the problems we face cannot be correctly understood if reduced to one dimension. Consequently, it provides an approach that captures realities in their totality with all the variables influencing them, regardless of the type (quantitative and qualitative).

Qualitative

In the context of foresight, the term qualitative is used to describe methods, information or research based on subjective estimates, such as the judgement of experts, rather than on quantifiable information.

STEEP Analysis

Methodological tool used to identify and evaluate external factors from the social, technological, economic, environmental and political fields that impact the system under analysis.

Time Horizon

The time horizon is a point in the future where the scenarios or visions of the foresight exercise are set. 2025 is the time horizon of the present study.

Vision

In the context of future-oriented activities, a vision is an imagined representation or a shared picture of the (usually desired) future.

Wild Cards

Low-probability, high-impact events that happen quickly (John Petersen, The Arlington Institute).

Glossary related to Standardisation

(Sources: CEN, CENELEC, ETSI, ISO)

CEN-CENELEC Guide

Reference document published by CEN-CENELEC to give orientation, advice or recommendations on standardisation principles and policies and guidance to standards writers. Guides may also address issues of interest to all users of European documents such as manufacturers, designers, service providers and educators. *(Source: CEN-CENELEC website)*

CEN-CENELEC Technical Report (TR)

Informative document that provides information on the technical content of standardisation work. Established by CEN or CENELEC, but not suitable to be published as a standard or as a Technical Specification, it involves no obligation at national level. *(Source: CEN website)*

CEN-CENELEC Technical Specification (TS)

Normative document published by CEN or CENELEC, about which there is the possibility of future approval as a standard, but for which at present there are reasons precluding immediate publication as a standard. *(Source: CEN)*

Consensus

General agreement, characterised by the absence of sustained opposition to substantial issues by any important part of the concerned interests and by a process that involves seeking to take into account the views of all parties concerned and to reconcile any conflicting arguments. *(Source: ISO/IEC Guide 2:2004)*

ETSI Standard (ES)

ETSI deliverable used when the document contains technical requirements. An ES is submitted to the whole ETSI membership for approval. *(Source: ETSI website)*

ETSI Technical Specifications (TS)

ETSI deliverable used when the document contains technical requirements and it is important that it is available for use quickly. A TS is approved by the Technical Committee that drafted it. *(Source: ETSI website)*

ETSI Guides

ETSI deliverable used for guidance to ETSI in general on the handling of specific technical standardization activities. It is submitted to the whole ETSI membership for approval. *(Source: ETSI website)*

ETSI Technical Report (TR)

ETSI deliverable used when the document contains explanatory material. A TR is approved by the Technical Committee that drafted it. *(Source: ETSI website)*

ETSI Special Report (SR)

ETSI deliverable used for various purposes, including to make information publicly available for reference. An SR is approved by the Technical Committee which produced it. *(Source: ETSI website)*

ETSI Group Specification (GS)

ETSI deliverable that provides technical requirements or explanatory material or both. Produced and approved within our Industry Specification Groups (ISGs) *(Source: ETSI website)*

European Standard (EN)

Standard that has been adopted by one of the three recognised European Standardisation Organisations: CEN, CENELEC or ETSI. It is carrying out an obligation of implementation as an identical national standard and withdrawal of conflicting standards. *(Source: CEN/CENELEC Internal Regulations, Part 2:2002)*

European Standardisation Organisations (ESOs)

CEN, CENELEC or ETSI are the three recognised European Standardisation Organisations.

Harmonised Standard

European standard elaborated by one of the three European Standardisation Organisations on the basis of a request from the European Commission (i.e. a mandate) to develop a European standard that provides solutions for compliance with a legal provision. Compliance with harmonised standards provides presumption of conformity with the corresponding requirements of harmonisation legislation.

Industry Specification Groups (ISGs)

Activity organised around a set of ETSI work items addressing a specific technology area, and supported by Working Groups where appropriate. With their own membership, voting rules, work programme and deliverables, ISGs can draft and approve on its own ETSI Group Specifications (GSs) which will be published by ETSI. *(Source: ETSI website)*

International Standards Organisations

The three formal international standards organisations are the International Organisation for Standardisation (ISO), the International Electrotechnical Commission (IEC) and the International Telecommunications Union (ITU).

Mandate

Request from the European Commission to the European Standardisation Organisations to draw up and adopt European standards in support of European policies and legislation. Around 30% are mandated by the European Commission in the framework of EU legislation.

Principles of Standardisation

The European standardisation process is based on a certain number of principles recognised by the World Trade Organisation (WTO), namely coherence, transparency, openness, consensus, voluntary application, independence from special interests and efficiency.

Specialist Task Forces (STF)

Teams of highly skilled experts, brought together to perform specific technical work under the direction of an ETSI Technical Committee. They work intensively over a period of time, typically a few months, to accelerate the drafting work. *(Source: ETSI website)*

Standardisation

Activity of establishing, with regard to actual or potential problems, provisions for common and repeated use, aimed at the achievement of the optimum degree of order in a given context. *(Source: ISO/IEC Guide 2:2004)*

Standard

Document, established by consensus and approved by a recognized body, that provides, for common and repeated use, rules, guidelines or characteristics for activities or their results, aimed at the achievement of the optimum degree of order in a given context. *(Source: ISO/IEC Guide 2:2004)*

Technical Committee (TC) or Technical Body (TB)

Technical decision-making body responsible for a particular area of standardisation work.. Organisation depends according to CEN-CENELEC and ETSI.

Workshop Agreement (CWA)

Agreement developed and approved in a CEN or CENELEC workshop in a fast and flexible way, but which does not have the status of a European Standard. It involves no obligation at national level and conflicting national normative documents may remain. However, a Workshop Agreement may not conflict with a European Standard. *(Source: CEN website)*

Annex 4.
Industrial Landscape Vision 2025
Descriptors

Layer 1.
Agents of Change

1. Society

1.1 Increased Importance of Consumer Requirements and Behaviours

1.1.1 Increasing Public Awareness of Environmental Issues

Consumers increasingly choose products on the basis of social and environmental issues, although price remains the key issue. Consumers are aware that natural resources and raw materials are scarce. Products that are produced through clean industrial processes (e.g. recycling, green energy) appear to be the first choice of consumers.

1.1.2 Changing Methods of Ownership and Collaborative Consumption

Traditional concepts of ownership are changing. People require more integrated products and services. For example, consumers buy mobility rather than owning a car as they look for the provision of an overall service package involving a full range of options from leasing to shared use.

1.1.3 Increased Personalisation of Products

Consumers ask for personalised products, as technologies and production processes allow for mass personalisation. This move has provided changes in the supply chain of companies and in the value chain of a wide range of market sectors.

1.1.4 Increasing Importance of Social Ranking of Products

The social ranking of products and services is common practice thanks to on-line social networking, enabled by enhanced ICT technologies. The social acceptance and approval of products and services and their perceived utility, safety and environmental friendliness are facilitated by online social media, and are important for products and services market success.

1.1.5 Faster Product Turnover

Product turnover is faster due to very rapid technological development of products. Products and services experience pressure for continuous innovation resulting in a shorter lifecycle.

1.1.6 Products Entailing Experience

Consumers are increasingly looking for products that provide experience (e.g. "*eatertainment*" model of Hard Rock Café, Nespresso clubs, etc.).

1.1.7 Do-It-Yourself (DIY) Movements

These movements start from the concept that the user is involved in the design of products and services. ICT and 3D printing have allowed the creation of micro-factories where customers produce and assemble their own products.

1.2 Changing Societal Risks

1.2.1 Building Resilience to Global Risks

Society and administrations (mainly at national level) are increasingly aware that the nature of global risks is constantly changing due to new information and perceptions. The increased awareness of global risks challenges global leaders to improve their system thinking and strategy development to improve their approaches to global risks.

1.2.2 Risk and Globalisation

Global markets and manufacturing, coupled with rising populations and a scarcity of natural resources result in an increased risk of social, economic and political tensions between global, national, regional, and individual interests.

1.2.3 Globalised Organised Crime and Cybercrime

The increased use of ICT in complex global infrastructures provides opportunities for exploitation by organised cybercrime groups, anarchic disruptors and terrorists who threaten business, individuals and governments that are increasingly relying on digital systems.

1.2.4 Data Protection

As computers become ubiquitous and more of our lives are managed on-line, people become more vulnerable to attack and manipulation by others. Issues of personal privacy protection are therefore increasingly important. There is an increased demand to governments and businesses to maintain a balance between transparency and privacy.

1.3 Increased Global Population

1.3.1 Growing Global Population

The population has approached 8 billion people, with the traditional industrialised countries only accounting for a small proportion of that increase (increasing by 3.6% from 1.2 billion to 1.3 billion) and the newly industrialised and other countries being responsible for the majority of the increase (increasing by 24% from 5.7 billion to 7.0 billion). This results in an increased potential market, but also increased environmental and societal impact.

1.3.2 Industrial Evolution to Meet the New Demography

Targeted industrial sectors and services have evolved to meet the new demography with improved workplace design to attract disabled, female and older skilled workers in a globally competitive employment market.

1.3.3 Markets for an Increased Middle Class

The middle class has grown rapidly with implications for the demand for consumer goods that has risen sharply. By 2030, the global middle class[1] will have increased to 1.2 billion from the 400 million in 2005. This is set to drive middle class demand from $21 trillion in 2009 to $56 trillion in 2030. Already today in 2025 25% of the global middle class live in India and China. Manufacturing and services industries are seeking to exploit the market potential of an increasing, global middle class. The emergence of a global middle class is contributing to narrow the material and cultural divides that slow the emergence of a global set of values (democracy and fundamental rights).

[1] Population in low- to middle-income countries earning $4,000-$17,000 per capita per annum (purchasing power parity)

1.3.4 Increased Global Migration

Global migration is not only characterised by employment opportunities and political and environmental factors, but also foreign investments and trade liberalisations amongst regions of the world and enhanced communications.

1.4 Ageing Population

1.4.1 Ageing Population

Life expectancy in Europe and in western societies is high. There are an increased number of people who need care as they cannot live independently and the number of age-related and degenerative diseases is high with an increased demand on public health. Improved quality of life and advanced health care has enabled some senior segments of the population to work longer.

1.4.2 Markets (Potential) to Serve the Ageing Population

New markets of products and services for the ageing population are available as their demand has increased in the past decade. There are individualised products, services (health tourism) and medical treatments like personalised medicine (e.g. medicine food) serving the ageing population.

1.4.3 Science Support for a Longer Life

Scientific studies on ageing and to understand the biological mechanisms of ageing are well established. The outcomes are used to enable people to live healthier for longer. The effects of these studies take burden off social security and insurance systems.

1.5 Increased Urbanisation

1.5.1 Increased Migration Streams

Inter- and intra-national migration has increased as people seek economic opportunities to improve their life styles, with skilled people moving to areas of high employment demand. This is somewhat mitigated by skilled staff who increasingly work remotely using advanced ICT tools.

1.5.2 Rise of Urbanisation

The increased urbanisation contributes to intensified environmental depletion and increased tensions over resources such as water, energy and logistics, which are very important to support large population centres. Developed countries will be more urbanised than developing countries (80% compared to 55% in 2030), but urban growth is faster in the developing and emerging countries.

1.5.3 Cities Governance

Governance at urban level goes beyond service provision. City management includes the management of the networked infrastructure. Cities are developing novel approaches to water and energy use, food supply, waste management, transportation, retail and new building technologies. These have the goal to enable the entire urban ecosystem (circular) economy from design to implementation.

1.5.4 Smart Infrastructure

Cities start to implement self-repairing, self-monitoring, and self-sensing systems to build, maintain and operate infrastructures.

1.5.5 Decreased Available Living Space

With increased urbanisation there will be a significant decrease in available living space; product demand will be focused on smart solutions able to cope with limited living space.

1.5.6 Change in Consumer Demands

Increased city populations and associated societal needs have implications for consumer demands. People demand more convenience, greater choice, faster solutions and more services.

1.6 Changing Social Norms and Values and Ethical Issues

1.6.1 Social and Cultural Disparities

The globalisation of the economy brings into play markets based on a wide range of disparate cultures. This presents industry with challenges concerning product requirements, which can often be regional or even local, through to production chain management due to different work practices and regulation.

1.6.2 Increased Individualisation

Higher number of smaller households and increasing individualisation result in new social structures where the traditional family is not as dominant as before. There are a plurality of norms and values that are less based on traditional social groups (e.g. church, ethnic groups, etc.).

1.6.3 Group Identities and Collective Intelligence

Despite growing individualisation, there are an increased number of social groups emerging that are characterised by collective interests. 'Group think' and 'wisdom of crowds' are popular. These groups are based on the principle that aggregation of information in groups results in decisions that are often better than could have been made by any single member of the group. These groups heavily rely on social media.

1.6.4 Gender

Economic and social differences between men and women are narrowing. There are increased government and market regulation of women's rights in the work place and less "generalised" roles for both men and women with respect to work-life balance obligations and choices. Women are equally active in business and (new) socio-political movements and participate in determining the political orientation of communities, countries and regions.

1.6.5 Global vs. Regional Values

Regional and local communities are emerging as a reaction to globalisation. These communities are online and offline with people that share the same interests that could be driven by specific local demands (e.g. localised services).

1.6.6 Life-Style Changes

The configuration of society has changed. The traditional family is not the norm anymore. People identify themselves with more than one social group and have different relationships depending on the context and activity with a variety of social groups.

1.6.7 Ethical Management Approaches

Societal/customer requirements will drive more ethical management approaches by companies. The ethical issues driving the approaches range from the treatment of people in the manufacture of a product or service, through to environmental issues concerning the value chain.

1.6.8 Corporate Social Responsibility

There are more positive examples of Corporate Social Responsibility with companies that are more cautious of the impact of their operations towards the environment and human health. Some companies offer employees a wide range of social services. International initiatives to persuade companies to adopt business practices in line with universally accepted principles in the areas of human rights, labour standards, the environment and anti-corruption are proliferating.

1.6.9 Social Acceptance of New and Emerging Technologies

New technologies can raise ethical questions and resistance to acceptance. Two contrasting societal stances 'techno-progressivism' and 'bio-conservatism' are becoming more evident. But the controversies over new emerging technologies are normalising due to more rational evaluations that underline in a transparent manner the positive potentials of new technologies in terms of innovation capabilities.

1.6.10 Ethical Concerns and Risks

Increasing socio-technological complexity and technological novelties (e.g. human enhancement technologies) are contributing to increased uncertainties and ethical concerns. More implementation of the precautionary principle is demanded by society.

1.7 Evolving Modes of Education and Learning

1.7.1 Education Levels

The level of global education will increase, resulting in 55% of people worldwide having completed at least secondary level education; illiteracy rates will fall globally to 0% - 25% depending on the region.

1.7.2 Demands for Skills

The demand for qualified people exceeds supply; high-tech manufacturing increasingly needs skilled staff (engineering, science and technology, ICT). The larger service sector is also demanding skilled staff'. The global improvement in education partially fills the skills gap, and there is a major migration of skilled staff to places offering the best employment opportunities. There is closer collaboration between industry and universities for the development of curricula to address the demanded skills.

1.7.3 Fight for Talent

Attracting and retaining talent is one of the most important assets of a country or company. Competition to attract talent is high, and the quality and availability of talent is becoming increasingly important in order to improve production and facilitate innovation.

1.7.4 Lifelong Learning

Education, training and personal development is a life-long experience as the needs of jobs change to meet new technology and industrial process demands.

1.8 Increased Social Innovation

1.8.1 Widespread Implementation of Social Innovation Practices

Social innovation practices are more widespread. They involve new techniques to involve consumers in the development and implementation of new products, services and business models to meet customer needs.

1.8.2 Social Design

Social design brings human and social capital to the design process in a way that makes the end product more socially useful, as well as profitable. This technique is being increasingly used as ethical issues become more important to consumers in their selection of products and services.

1.9 Evolving Workforce and Culture

1.9.1 Different Collaborative Working Patterns

Different and more open patterns of work and collaboration, making extensive use of crowd sourcing and open-sourcing, are being applied. This is being driven by the fact that skilled staff are becoming increasingly hard to recruit. It is also being driven by the recognition that wider consultation on technical issues sometimes brings new, innovative and profitable solutions. The approach has become more accepted as new ways of recognition for input provided have been devised and implemented.

1.9.2 Rise of Self-Organising Communities

Driven by unemployment and social exclusion new types of self-organising communities have developed that bring alternative solutions to various parts of the value chain.

1.9.3 Pressure on Individual's Time and Mobility

The immediacy of knowledge and information, and business demand for "instant" solutions place greater pressures on workers' time.

1.9.4 Global Hiring Strategy

Companies are implementing global hiring strategies to counterbalance increasing global lack of skilled staff.

1.9.5 Reduced Mass Employment in Manufacturing

The increasing use of technology, especially automation technology, is making future manufacturing processes a less labour intensive, and more skills intensive.

1.9.6 Highly Dynamic and Flexible Working Practices

Many workers are following more flexible working practices, e.g. teleworking. Advances in ICT technologies, plus pressures to minimise carbon footprints by reducing travel, make it possible and necessary to have your "office" accessible to you globally 24 hours per day.

1.9.7 Collaborative Methods of Working

Social and open innovation has been enabled by ICT technologies facilitating a completely new way to design and develop products. Many companies will become more specialised, focussing on one particular part of the value chain, working in collaboration with other companies to develop products (a product ecosystem).

1.9.8 Workplace Innovation

Companies are increasingly implementing practices to improve aspects of work organisation and introduce modern management techniques that involve workers. Workplaces with flatter hierarchies and the possibility for workers to contribute have been recognised as being more creative and ultimately more productive and open to addressing both social and technological challenges.

1.9.9 Flexible Working Patterns for Ageing Workforce

Companies use new types of contracts for older employees to improve the participation of the elderly in the labour market, and to maintain knowledge and experience.

1.10 Digitalisation of Society

1.10.1 Ubiquitous Computing

Computers pervade and connect all aspects of daily life, ranging from industrial processes to household products including the "Internet of Things" and cloud based computing.

1.10.2 Increased Sharing of Knowledge and Information

New technology and social values result in a greatly increased sharing of information and knowledge, contributing to individual empowerment and democratisation.

1.10.3 Personal Information Availability

Ubiquitous computing has resulted in the fact that much of citizens' personal and working lives is managed on line. As a consequence individuals have had to accept that more of their personal information is held by private and public organisations. Even the move towards personalised manufacturing is based on personal information held by private companies. This has resulted in greatly strengthened personal data protection legislation, as well as service packages whereby citizens agree to the use of their private data in return for contracted benefits.

1.10.4 Data Management and Exchange

Information management and exchange has greatly increased, with users downloading on average 3 gigabytes per day. New tools have been developed to manage these data permitting new forms of social communication, participation and organisation. New businesses in data and information management have been created by "digital natives" to serve the individuals and companies.

1.10.5 Decreased Digital Divide

Even as the digital world becomes increasingly flat, the digital divide has not disappeared entirely. Elements of society are excluded as technology rapidly develops, with individuals unable to follow, or afford the developments. However key benefits of the networked society (e.g. free communication and access to essential business and educational content) are cheap enough for most societal groups, increasing the market and social potential of the technology.

1.10.6 Benefits of Social Media

The widespread use of social media has created new ways of exchanging and sharing information that is influencing the behaviours of consumers, values and cultural expressions. Social networking is used for collaboration and learning. Data privacy underpins this development, with a range of new regulation and initiatives in place.

2. Technology

2.1 Converging Technologies

2.1.1 Combining Technologies

Key to the development of technologies, and their application to industry is the way that they are combined. Different technologies are used in combination to improve product and service quality, safety, sustainability and cost. This includes technologies to provide industry with its smart, advanced infrastructure where ICT is used in combination with energy, mobility, water, financial, and knowledge infrastructures. It also includes advanced technologies, such as additive manufacturing and on-line, real time manufacturing monitoring tools used to provide industry with new products and production chain efficiency.

2.1.2 Interoperable Technologies

In order to address the needs of society in general, and manufacturing in particular, technologies have to be used in combination. This has meant that considerable effort has been undertaken to assure the interoperability of technologies. With ubiquitous computing the interoperability of data, for example, is crucial. To achieve smart, advanced infrastructure has required significant effort to assure the interoperability of different technologies permitting, for example, the use of ICT to enable smart grids.

2.2 New and Emerging Technologies

2.2.1 Key Enabling Technologies

KETs have been developed that are a key source of innovation. They provide indispensable technology bricks that enable a wide range of product applications, including those required for developing low carbon energy technologies, improving energy and resource efficiency, boosting the fight against climate change or allowing for healthy ageing. KETs are a key source of innovation. They provide indispensable technology bricks that enable a wide range of product applications, including those required for developing low carbon energy technologies, improving energy and resource efficiency, boosting the fight against climate change or allowing for healthy ageing.

2.2.2 ICT

The internet of things has become a reality, enabled by mobile internet, cloud technology and quantum computing. ICT has also enabled improved, geographically distributed manufacturing processes underpinned by knowledge management systems able to cope with the entire production cycle from design to sales and service supply.

2.2.3 Advanced Manufacturing Systems

Advanced manufacturing has revolutionised the production and consumption system increasing the flexibility of production plants, and enabling personalised manufacturing. Additive manufacturing (3-D printing), assembly technologies, photonics based manufacturing technologies, advanced moulding technologies and advanced robotics have significantly contributed to the development of new products and services, as well as to making the production chain more efficient.

2.2.4 Artificial Intelligence

Artificial intelligence is ubiquitous, enhancing the internet of things, enabling increasingly automated production processes, and forming the basis for new products such as automated, driverless cars and intelligent, hand held mobility management systems.

2.2.5 New Energy Approaches

Renewable energy has reached 20% of the European energy supply needs supported by a partially implemented smart grid infrastructure, whilst vehicles are now powered in the main by hybrid engines driven by a range of energy sources from bio-fuels to electricity and hydrogen.

2.2.6 Next Generation Genomics

The potential of synthetic biology is now starting to be realised with large benefits for human health, a safer food supply and cleaner, more abundant supplies of energy.

2.2.7 Advanced Materials

The development of advanced materials has mitigated the scarcity of natural resources, and has enabled the development of new markets and products.

2.2.8 Big Data

Ubiquitous computing has resulted in the collection of data sets that are large and complex. To process these data new algorithms have been developed that permit capture, storage, search, sharing, transfer, analysis, and visualisation. This has allowed information to be derived by business and public organisations that provide the intelligence to greatly improve products and services.

2.2.9 Next Generation of Internet Technologies

Social networks, semantic technologies and open innovation tools play an important role in the sharing and the generation of knowledge, with the next generation of Internet (Web 2.0 will advance to Web 3.0) allowing increased functionality and intelligent searching.

2.2.10 Widespread Use of Sensors and Radio Tags

Sensors and radio tags have continued to decrease both in size as well as price. Billions of these small electronic components, known as the "Internet of Things", are everywhere collecting data. For example, RFID will allow washing machines to automatically adapt their washing programmes to the clothes introduced, robots will separate waste depending on the composition of the objects, and sensors will monitor sensitive infrastructures to assure their structural integrity. As a result life is more secure, and tasks are automated. However questions of data use and data protection continue to be addressed by regulatory organisations.

2.1.11 Potential Vulnerability of Technical Infrastructures

There are increased risks related to new technical infrastructure, e.g. smart grids, as the infrastructure is more complex, interconnected, multi-modal and based on complex ICT introducing potential vulnerability.

2.3 Technology Dissemination

2.3.1 Technology Diffusion

Technology diffusion has been greatly enhanced by the major global increase in broadband users, which has reached 2 billion users today, and is expected to increase to 4.9 billion by 2030.

2.3.2 Intellectual Property

Intellectual property rights and patents have been re-balanced to address the needs of technology dissemination as well as intellectual property protection as part of an overall, coherent regulatory package with standardisation. Markets buying and selling IPR and patents have been established.

3. Economy

3.1 Market Forces

3.1.1 Volatile Economy

The global economy continues to be volatile driven by the scarcity of natural resources, the requirements to mitigate and adapt to climate change and the increasing competitiveness of the market as companies seek to benefit from a globalised market and a rapidly increasing global middle class.

3.1.2 Globalised Flow of Capital

Capital is increasingly global, following industrial innovation and markets. Financial globalisation has proceeded at an even more rapid pace than trade globalisation. While the developed economies continue to be the most financially integrated, more and more countries have meanwhile liberalised and at least partially opened up their financial systems.

3.1.3 Pressure To Increase Economies of Scale

Confronted by very competitive and often less affluent global markets, companies seek to maximise efficiency and reduce unit costs.

3.1.4 Increase of New Multi-Sector Industrial Partnership

In order to be successful in a globalised market with many different societal and cultural demands companies are evolving to include partnerships which involve a “ecosystem” of globally distributed specialists, each flexibly contributing different elements of products and services, and better enabling mass customisation / personalisation.

3.2 Globalisation of Markets and Manufacturing

3.2.1 Increased Globalisation

The global market has now expanded to include the mature economies of the BRIC countries. The “next 11” countries are also reaching economic maturity, with rapidly increasing middle classes and an eradication of official poverty. This has resulted in increased competition for market share, forcing companies to become more innovative in order to maintain a competitive edge.

3.2.2 Regionalisation of Demand

Societal, economic and cultural differences remain across the world. Therefore, whilst the market globalises, the demand often remains regional or even national and local.

3.2.3 Globalised Production Processes

With the globalisation of markets production moves closer to customers in order to minimise logistics costs, and maximise the potential of mass customisation.

3.2.4 Growth Regions

Economic investment focuses on areas of the world where there is an increasing middle class, with an increasing income per capita.

3.2.5 Stimulation of New Technology

The challenges of the global economy stimulate new technology as companies seek competitive advantages by improving their supply chains, and customising production to meet the local needs of a globalised market.

3.3 Changing Economic Norms and Values

3.3.1 Beyond GDP

The key criterion for a company's success remains profit. However societal pressure has broadened the success criteria to include environmental and societal indicators such as waste and energy management, and societal contribution.

3.3.2 Ethical Markets

In more affluent parts of the world consumers increasingly use ethical and environmental criteria to select the products and services that they purchase.

3.3.3 From Products to Services

Product ownership is no longer the dominant market driver; consumers increasingly require "bundled" products and services, often with a significant leasing component.

4. Environment

4.1 Multiple, New Energy Sources

4.1.1 Global Primary Energy Consumption

The requirement for energy has increased by 26% in Western Europe and North America since 2013, and by 45% in the BRIC and the "next 11 countries".

4.1.2 Decarbonisation of Energy Supply

In order to mitigate the effects of climate change, and to address the shortage of oil worldwide there is a shift away from fossil fuels to new, often renewable energy sources. Previously unobtainable energy sources also become available as technology improves; shale gas and oil is one example of this. This is compensated by carbon capture technologies, which have now become economic to use.

4.1.3 Revolution in Resource Efficiency

Environmental, societal and economic pressures result in large efforts to preserve energy, and a large increase in the use of energy efficient products.

4.1.4 Distribution of Energy

In order to cope with multiple sources and a resultant de-centralisation of energy supply the energy grid is being significantly upgraded; smart grids are in the process of being implemented across the European Union.

4.1.5 Risk of Environmental Problems

The pressure to industrialise across the globe results in countries seeking to use all forms of energy supplies to serve their industrial and economic energy needs, including those from environmentally hazardous energy sources (e.g. brown coal).

4.1.6 New Geo-Political Map of Energy Supply

As sources of energy change, the geo-political map of energy supply has also changed with many countries that were net importers of energy in 2013 becoming energy self-sufficient, or energy exporters.

4.2 Increasing Scarcity of Natural Resources

4.2.1 Strategic Resource Scarcities

Key materials and natural resources are increasingly scarce, and in some cases unavailable.

4.2.2 Substitute Raw Materials

To cope with the increasing scarcity of key natural resources companies invest in the development of new, replacement materials.

4.2.3 High Price Volatility for Resources

As natural resources become scarce, and occasional new sources are found, prices change greatly and quickly.

4.2.4 More Highly Specialised Suppliers and Natural Resources

As natural resources become scarcer the suppliers have become more technologically advanced and specialised as they seek to extract the last remaining sources of key natural resources.

4.2.5 Rising Demand for Food

The pressure to feed an increasing global population of 8 billion is rising.

4.2.6 Increasing Demand for Water

Half the world's population live in areas of high water stress as increasing industrialisation and an increased population place pressure on water supply.

4.3 Need To Mitigate and Adapt To Climate Change

4.3.1 Increased CO_2 Emissions

As more countries industrialise, and the global population increases the world CO_2 emissions increase by 16% from 2013 levels.

4.3.2 Global Temperature Rise

The average global temperature rises by between 0,5°C and 1,5°C compared to 2013 values.

4.3.3 Mitigation and Adaptation Strategies

The need to mitigate and adapt to climate change increasingly influences industrial practice as companies move to become carbon neutral.

4.3.4 Climate Change Fatigue

Society has become divided, with some elements becoming increasingly weary of the need to mitigate and adapt to climate change, whilst others push increasingly hard for climate adaptation approaches.

4.4 Increased Threats To Ecosystems

4.4.1 Population and Industrialisation Impacts on Biodiversity

With increased global population and industrialisation many ecosystems are changed or destroyed, threatening biodiversity.

4.4.2 Climate Effects on Ecosystems

As the climate changes many ecosystems evolve affecting biodiversity and food production potential.

5. Policy

5.1 Evolution of International Trade Relations

5.1.1 Evolution of International Trade Relations

As markets and production chains become global, international trade relations are continuing to follow suit. Regional economic communities continue to expand, often with bi- or multi-lateral trade agreements with other blocks.

5.2 Public Policy

5.2.1 Alignment of Policies

Sectoral policies are becoming more aligned to tackle complex issues and challenges that require holistic measures, targets and instruments. For the competiveness, strategic and economic development of industry and manufacturing policy makers are aware that for effective policies it is important to have the right combination of trade, tax, labour, energy, education, science, technology, innovation and industrial policy levers.

5.2.2 Industrial Policy

Industrial policy is more sophisticated than in the past and it is used to influence positive outcomes and accelerate development. Companies have more interaction with policy makers to help strike a balanced approach to enable success for all stakeholders including citizens.

5.2.3 Evolving Framework Conditions on a Social, Political and Macro-Economic Level

Governments continue to seek to develop and implement framework conditions to encourage innovation, competitiveness and economic growth. This includes taxation and trade conditions, as well as regulatory conditions such as intellectual property and standards.

5.2.4 Macroeconomic Policy Coordination

As the commercial advantages of new technology in a global market become more apparent, private investment in research and innovation is increasing. Public funding continues to be squeezed with the public sector forced to continually re-think how and where it should be applied, and how it should be combined with private investment.

5.3 Governance 2.0

5.3.1 Regionalism

The capacity to build regional economic and social groups to promote economic growth, trade, peace and social development is a crucial element of global governance.

5.3.2 Public Procurement

Public procurement continues to be a major driver of innovation and competitiveness. Mechanisms have been implemented to maximise these effects.

5.3.3 New Governance Setting (E-Governments)

Web 2.0 is becoming widespread and allows greater citizen participation. Through ICT and social networking, people from all over the country interact with politicians or public servants and make their voices heard. The Web 2.0 is contributing to increase collaboration and transparency and potentially transform the way government agencies relate to citizens and operate.

6. Wild Cards

Natural Disasters

Man-Made Disasters

Pandemics

World War

Layer 2.
Enablers and Constraints

The future of manufacturing will be characterised by a number of transformative elements that amplify the dynamic behaviour of the global industrial landscape. The effects of these transformative elements will either enable the development of manufacturing, or constrain it depending on the interactions with the drivers of the landscape (the "Agents of Change"). In this study these transformative elements are referred to as the "Enablers and Constraints".

People and Societal Values

People, their demography, their attitudes and their expectations will set the societal norms within which the industrial landscape will develop, and for which industry will develop its future markets and products.

Employment and Skills

The availability of workers with the adequate skills will define the ability of industry to develop new technologies, production processes, services and markets. The regions of the world able to attract the workers with the right skills at the right cost will have competitive advantage.

Regulation

The regulatory framework in which industry will develop is crucial. A regulatory framework can either provide industry with clear guidelines and encouragement, enabling industry to develop well considered markets and products. Conversely a regulatory framework can block the development of industry, closing potential markets and reducing industrial competitiveness.

Financial System

Financial regulation, crowd funding, future banking systems and the evolution of the monetary systems are elements that will affect the financial capacity of the production industry. The availability and price of money will continue to be a determinant for the manufacturing business for investing in new plant facilities, new processes, research and development. Volatility in the financial system will also impact the ability of the production industry to develop value and compete.

Science, Research and Technology

The direction and rate at which scientific knowledge is generated, innovation occurs, and new technology is developed is a key determinant in defining the extent of opportunities for developing new markets, processes and products. Countries and regions able to optimise investment in sciences, research and technology, and assure the transfer of the knowledge to industry will have competitive advantage.

Environment, Resources and Energy

The availability of materials and energy at a reasonable cost is a fundamental requirement of industry. The production and use of these resources in an environmentally sustainable manner is a fundamental requirement of today's society. Failure to achieve both these needs will result in industrial decline and environmental damage.

Markets, Competition and Consumers

Markets for products constantly shift and change, in order to adjust to consumer behaviour. These shifts and changes happen within one geographical area, as well as between global regions. The ability of industry to agilely adapt their business models to these changes defines their potential to maintain or develop competitive advantage.

Layer 3.
Production and Consumption System

1. Business Environment

'Business Environment' is the manner in which the Production and Consumption System operates and sets the basis for product consumption.

Business Environment is the process that allows a company to understand the mechanisms for addressing local and global markets and for generating profits with operating supply chains. The dynamic of the business environment pushes manufacturing companies to explore new approaches in the design of new products involving user experience, customer intelligence, social networks, by introducing social science methods, qualitative and quantitative analysis to generate insights, in order to identify new path to create value and market success. This is particularly key as markets and manufacturing globalise, forcing companies to take a global approach to customer requirements and production, whilst recognising that the granularity of product demand can remain regional, or even local.

1.1 Global Integration

The economy of the world is global. Markets, and the industries that supply them, operate in a global environment. Transport, information and communication infrastructures have enabled this. Production and consumption chains are spread across the globe requiring ever more complex logistics systems to supply, produce and distribute products. Elements of the production and consumption chains move globally, driven by the cost and availability of skilled labour, the availability of materials and resources, the state of infrastructure, and the needs of the consumers. However, even though the world is more connected, great social, geographical and economic differences persist at regional and national levels. This results in a diversity of production conditions, such as access to materials, energy and skilled workforce, as well as diversity of markets, regulation, economic power and societal values. These factors determine where a company locates the different elements of its *value* chain. It also governs the type and form of products to be offered in different parts of the world. Companies take advantage of the new opportunities by moving to reach new markets and new sources of skills and talents and by concluding new strategic international alliances.

1.1.1 New Global Markets

Business will increasingly focus on new global markets, initially the "BRIC" countries (Brazil, Russia, India, China), followed by the "next 11" countries (Bangladesh, Egypt, Indonesia, Iran, Mexico, Nigeria, Pakistan, Philippines, Turkey, South Korea, and Vietnam) and other developing countries (e.g. Kenya, Ghana, Ethiopia, Morocco, South Africa etc.). Emerging markets will not only be considered as a supplier for low-cost, and often skilled workforce but also, and mainly, as an ever-increasing source of new customers with specific and diverse requirements that firms will need to analyse.

Main Agents of Change
Economy – Globalisation of Markets and Manufacturing
Policy – Evolution of International Trade Relation
Society – Evolving Mode of Education and Learning
Main Enablers and Constraints
Markets, Competition and Consumers
Employment and Skills

1.1.2 Global Production System

The production system will be even more fragmented at the global level, both geographically and sectorally. Companies will practice "hybrid manufacturing", incorporating a mix of production processes located in both high

cost and low cost nations according to geographic advantages from a wide range of factors (labour costs and skills, infrastructure, governance, policy, materials, market demand, etc.) enabled by technological developments, especially in the ICT field. However, the level of hybridity, in scope and in scale, will vary greatly according to sectors and business strategies. Firms will in particular weigh the balance between cost-efficient globally optimised value chains and traditional operation schemes more resilient to the increasing risks and uncertainties of the global environment (e.g. natural disasters, conflicts, price volatility as well as government intervention on sector, energy, carbon emissions, and tax and customs policies).

Main Agents of Change
Economy – Globalisation of Markets and Manufacturing
Policy – Evolution of International Trade Relation
Technology – New and Emerging Technologies

Main Enablers and Constraints
Markets, Competition and Consumers
Science, Research and Technology

1.1.3 Distributed Production Near To Consumption

Production of final goods and services (i.e. assembly sites) will be more localised and close to customers, in particular to respond to the increased demand for customisation/personalisation and for a European sustainable industrial ecosystem. Firms operating at the global level will rely on regionally-based factories to adapt their offer to local demand, which will be greatly enhanced due to the expansion of the affluent middle class in emerging countries. This distributed manufacturing will be enabled by new production processes, such as additive manufacturing, and new ICT technologies allowing the digital interconnectivity of different parts of the production process. However, the cost-efficiency of international cargo shipping will moderate this trend.

Main Agents of Change
Society – Increased Importance of Consumer Requirements and Behaviours
Technology – New and Emerging Technologies
Environment – Need to Mitigate and Adapt to Climate Change

Main Enablers and Constraints
People and Societal Values
Science, Research and Technology
Environment, Resources and Energy

1.1.4 Production Near To Skills and Talents

Firms will consider human resources globally and factories will move where skills and talents are located. According to the stage of the production processes, they will operate trade-offs between the productivity, creativity and cost–effectiveness of the working force. Continuing geographic differences in skills will result in a divergence of value chains across the world, and will result in the "hybridisation" of the global value chain with specialist parts of the value chain geographically located in the part of the world where the correct skills exist at the best cost.

Main Agents of Change
Economy – Globalisation of Markets and Manufacturing
Society – Evolving Mode of Education and Learning
Technology – New and Emerging Technologies

Main Enablers and Constraints
Employment and Skills
Science, Research and Technology

1.1.5 Production Near To Raw Materials

Manufacturing companies in many sectors, in particular energy and resource-intensive sectors, will seek physical proximity to raw materials in order to secure a cost-effective and flexible supply. In selecting the geographical location they will especially consider the state of infrastructure, mainly interoperability and digital connectivity. When physical proximity to raw materials is not possible, firms will increase business proximity with suppliers (e.g. by purchasing them or by negotiating exclusive rights).

Main Agents of Change
Economy – Globalisation of Markets and Manufacturing
Environment – Increasing Scarcity of Natural Resources

Main Enablers and Constraints
Environment, Resources and Energy

1.2 Value Chain Optimisation

With the increasing complexity of the production environment and associated production technologies, companies continue to think strategically on how to optimise their value chains. The issues at the forefront of companies' thinking in this area cover a wide range, from environmental and resources issues (e.g. securing material supply), through to the advantages of specialisation, the maturity of new production technologies (e.g. additive manufacturing) and the management of risk. There is a trade-off between the advantages and inconvenience of having a closed or an open value chain. Virtual environments help firms to deal with the complexity of inter-organisational flows, and clusters with other stakeholders offer opportunities for cross-fertilisation within the value chain.

1.2.1 Complex Value Chain

Enhanced competition for local and global markets will result in increasingly complex and diverse value chains. Driven by an increasingly globalised market, and based upon new technologies firms will seek to minimise the supply chain risks, minimise environmental impact and maximise savings through various strategies according to the geo-political situation, sectors and market segments.

Main Agents of Change
Economy – Globalisation of Markets and Manufacturing
Environment – Need to Mitigate and Adapt to Climate Change
Technology – New and Emerging Technologies

Main Enablers and Constraints
Environment, Resources and Energy
Science, Research and Technology

1.2.2 Vertical Integration

As natural resources become increasingly scarce, and markets become more globalised, firms will seek full control of their value chain through vertical integration. Enabled by new technologies the entire value chain will be controlled by individual companies from the supply of raw materials, including the purchase of suppliers of key materials and the 'near-shoring' of material supply in order to reduce logistic costs through to the selling of products and services.

Main Agents of Change
Economy – Globalisation of Markets and Manufacturing
Environment – Need to Mitigate and Adapt to Climate Change
Technology – New and Emerging Technologies

Main Enablers and Constraints
Environment, Resources and Energy
Science, Research and Technology

1.2.3 Niche Industries

An increased number of niche industries will develop, often in very technical and specialised areas. These could include specialised software, highly technical electronics or advanced new materials. These niche industries will work in loose alliances with other companies to produce the personalised products and services that consumers will increasingly require.

Main Agents of Change
Economy – Market Forces
Society – Increased Importance of Consumer Requirements and Behaviours
Technology – New and Emerging Technologies

Main Enablers and Constraints
Markets, Competition and Consumers
Science, Research and Technology

1.2.4 Value Chain Ecosystems

Clusters of suppliers, researchers and other partners will form in certain geographical locations, based on similar technological skills, a common interest in a nearby source of raw materials and shared energy scheme, or acting as an "ecosystem" with companies feeding off each other in the value chain through 'cross-fertilisation' of technology and business models. The 'smart specialisation' pushed by policy will foster clusters between businesses, public entities and knowledge organisations at the regional level on the basis of competitive assets and technology.

Main Agents of Change
Policy – Public Policy
Technology – New and Emerging Technologies

Main Enablers and Constraints
Regulation
Science, Research and Technology

1.2.5 Virtual Enterprise Environments

ICT-based virtual environments, allowing the real-time monitoring and visualisation of inter-organisational flows and the sharing of skills and knowledge, will add value to the product-service value chain by enhancing supply chain management of globally dispersed production processes and complex firm operations.

Main Agents of Change
Economy – Globalisation of Markets and Manufacturing
Policy – Evolution of International Trade Relations
Technology – New and Emerging Technologies

Main Enablers and Constraints
Science, Research and Technology
Markets, Competition and Consumers

1.3 Dynamic and Sustainable Business Models

The business model is the core of the competitive response of the firm to the market. The business model determines how to operate and integrate all aspects of the value chain from the design of products, services and processes, through to the supply chain, the relationship with the stakeholders and the "spirit" of the company. In future business environments, new business models respond to multiple competitive dynamics driven by economic constraints, environmental awareness, societal changes and new manufacturing technologies. Globalisation sets the international context for the business models, as does the need to involve a wider range of business partners and to recruit a more skilful workforce. The increasing demands and involvement of customers in the value chain is perhaps the biggest driver of changes to the business model. The environmental perspective of business models emphasises the whole product life cycle, to minimise the environmental impact of products, processes and service delivery.

1.3.1 Dynamic and Agile Business Models

Firms will need to go beyond 'business as usual' approaches and develop new, dynamic, and flexible business models based on a forward-looking and thorough analysis of the long-term trends of the global environment, the short-term uncertainties and the diversity of the markets, the diversity (e.g. age, geography, subcultures) and volatility (e.g. fashion) of consumers' behaviours, the potential of new technologies, etc. They will seek the right balance between long-term strategic commitment and risk management in implementing faster, shorter product cycles.

Main Agents of Change
Economy – Globalisation of Markets and Manufacturing
Society – Increased Importance of Consumer Requirements and Behaviours
Technology – New and Emerging Technologies

Main Enablers and Constraints
Science, Research and Technology
Markets, Competition and Consumers

1.3.2 'Circular Economy' Business Models

Energy- and resource-efficient business models will be needed for factories to achieve the 'triple-zero' objectives: zero waste, zero net energy cost and zero environmental impact. This type of business model will not only be driven by market costs, but also by the demands of the society, and hence the consumer for more environmentally friendly business solutions. The cost structure of business models will be increasingly oriented towards efficiency and "leanness", in particular to reach the 'zero-waste' objective and to foster the flexibility of the value chain. Companies will make their business models "environmental-friendly" as a marketing strategy to seek commercial advantage (e.g. sustainable packaging and re-manufacturing).

Main Agents of Change
Economy – Changing Economic Norms and Values
Society – Changing Social Norms and Values
Environment – Increased Scarcity of Natural Resources

Main Enablers and Constraints
Science, Research and Technology
Markets, Competition and Consumers
Regulation

1.3.3 New Business Models for Integrated Products and Services

As demand shifts from product ownership to service experience, 'Pay As You Use' models for selling integrated products and services will become increasingly important to the market and will include strong 'after-sales services'.

Main Agents of Change
Society – Increased Importance of Consumers Requirements and Behaviours

Main Enablers and Constraints
People and Societal Values

1.3.4 Business Models for Small Players

New business models for small companies are developing as manufacturing technologies (e.g. 3D printing) become cheaper and more accessible (easier entry in manufacturing), and as ICT worldwide deployment and lower customs barriers enable SMEs to have access to niche markets across the globe.

Main Agents of Change
Economy – Globalisation of Markets and Manufacturing
Technology – New and Emerging Technologies

Main Enablers and Constraints
Science, Research and Technology
Markets, Competition and Consumers

1.3.5 Ethical Business Practices

As consumer attitudes evolve there will be increasing pressure for companies to become more ethical in their business practices. This will range from how and where they source their materials through to environmental, social and deontological issues, e.g. fair trade, financial contracting, product testing protocols, sex in advertising, etc. Business decisions and models will therefore be partly based on factors than other than financial aspects.

Main Agents of Change
Economy – Changing Economic Norms and Values
Society – Changing Social Norms and Values and Ethical Issues
Environment – Increased Scarcity of Natural Resources

Main Enablers and Constraints
Science, Research and Technology
Markets, Competition and Consumers
Regulation

1.3.6 'Craftsmanship' Approach

As technology develops, particularly in software development and ICT services, there will be an increasing number of highly skilled "software craftsmen" whose unique skills and creativity will be available on a free-lance basis. The work of these developers will accelerate the innovation and will be in demand by all major businesses. The rise of the maker and fixer movement (e.g. Fab Labs, makerspaces, etc.) will also be integrated by firms in their business models.

Main Agents of Change
Economy – Market Forces
Society – Evolving Work Force and Culture
Technology – New and Emerging Technologies

Main Enablers and Constraints
Science, Research and Technology
Employment and Skills

1.4 New Innovation Schemes

Innovation is at the core of the competitiveness of successful companies. This is especially the case due to the increasing customer demand for greener, more customised and higher quality products. To address this, the concept of innovation is being consistently extended to include a wider range of stakeholder and fields of innovation. Innovation is increasingly being applied in non-technological areas, especially in the value services area where mass customisation and personalisation now dominate the market, and customers demand packages of products with related services. Consequently the innovation process is seeking to innovate across the whole value chain, from product design, to services offered and product perception ("greener", "faster", "higher quality"), through to product disposal. By so doing business hopes to increase speed to market, to enable the creation of new business models and to foster the development of new dimensions such as "frugal innovation" across a global innovation network.

1.4.1 Open Innovation

Pressured to capture diverse and geographically distributed human talent, and enabled by ICT technologies, firms will use and combine internal and external innovative ideas to take advantage of a wider distribution of knowledge across the globe. They will rely on a more diverse range of sources (customers, social networks, competitors, academics, etc.) and apply new techniques to extract innovative ideas (e.g. collaborative games, idea competitions, etc.).

Main Agents of Change
Economy – Changing Economic Norms and Values
Society – Increased Social Innovation
Technology – New and Emerging Technologies

Main Enablers and Constraints
Science, Research and Technology
Employment and Skills
People and Societal Values

1.4.2 Consumer Innovation

Consumers will increasingly be engaged in the development of innovative solutions that build on their experience of current products and services. Web-based forums (i.e. "virtual customer environment") and other ICT solutions will help firms to consult their customers at all stages of development.

Main Agents of Change
Economy – Changing Economic Norms and Values
Society – Increased Importance of Consumer Requirements and Behaviours
Technology – New and Emerging Technologies

Main Enablers and Constraints
Science, Research and Technology
Market, Competition and Consumers
Regulation

1.4.3 Service Innovation

There will be an increasing focus on the provision of services as the consumer requirements move towards purchasing packages of products with services. Companies will therefore increasingly offer services, such as mobility, rather than products, such as a car. Service innovation will therefore become more important, and will focus on non-technological issues (e.g. new marketing methods based on behavioural analysis) often addressing ethical and environmental objectives.

Main Agents of Change
Economy – Changing Economic Norms and Values
Society – Increased Importance of Consumer Requirements and Behaviours
Environment – Need to Mitigate and Adapt to Climate Change

Main Enablers and Constraints
People and Societal Values
Market, Competition and Consumers
Environment, Resources and Energy

1.4.4 Frugal Innovation

Developing more frugal but cheap products and services will be a focus of attention for firms in their attempt to conquer vast market segments of developing countries. Frugal innovation focuses on a step-by-step approach, through commercialisation itself and reverse-engineering, that enables firms to understand which nonessential features of a product or service they can remove.

Main Agents of Change
Society – increased importance of consumer requirements and behaviours
Economy – Changing Economic Norms and Values

Main Enablers and Constraints
People and societal values

1.4.5 Integrated Innovation

Firms will increasingly look at synergies between scientific/technological, social and business innovation to develop solutions to complex challenges, where the consideration of local and cultural contexts as well as affordability and accessibility barriers enhance the penetration of an innovative product or service.

Main Agents of Change
Economy – Globalisation of Markets and Technologies
Society – Increased Importance of Consumer Requirements and Behaviours
Technology – Converging Technologies

Main Enablers and Constraints
Science, Research and Technology
Market, Competition and Consumers
Regulation

1.4.6 Eco-innovation

Eco-innovation aiming at developing innovative products and processes that reduce environmental impacts, enhance resilience to environmental pressures, or achieve a more efficient and responsible use of natural resources, will be a key focus for firms as a response to increased societal demand for sustainable development.

Main Agents of Change
Economy – Changing Economic Norms and Values
Society – Increased Importance of Societal Conscience
Environment – Need to Mitigate and Adapt to Climate Change

Main Enablers and Constraints
People and Societal Values
Environment, Resources and Energy

1.5 New Business Partners

The increasing pressure for companies to address the ever more complex requirements of the consumer, allied to the fact that markets are now global, technology is becoming increasingly specialised and natural resources are becoming increasingly hard to find has forced companies to change the way they seek and engage business partners. Many companies are now focussing on one particular element of the production process, and then working in partnership with a wider range of different partners to complete the value chain in strategic but loose alliances. Traditional engineering companies are working in partnership with non-governmental organisations (NGO) in order to bring societal issues to product manufacturing, and Corporate Social Responsibility (CSR) is becoming a compulsory requirement. Governments are also working together with companies in order to facilitate the creation of jobs and wealth ensuring at the same time the reduction of health and environmental risk, especially on innovative products.

1.5.1 Strategic and Loose Alliances

As technology develops, and consumer requirements become more personalised many firms will increasingly move towards specialisation, focusing on specific tasks rather than covering the whole production process of goods and services, and will rely on "interconnected manufacturing" where a network of suppliers, producers and buyers from different countries work together within strategic but loose alliances able to adapt to the changing requirements of globalised markets.

Main Agents of Change
Economy – Globalisation of Markets and Manufacturing
Society – Increased Importance of Consumer Requirements and Behaviours
Technology – New and Emerging Technologies

Main Enablers and Constraints
Science, Research and Technology
Market, Competition and Consumers

1.5.2 Corporate Social Responsibility

As society increasingly demands ethical and environmentally friendly business, products and services, firms will integrate Corporate Social Responsibility (CSR) in their business models and look for stronger collaboration with a wide range of stakeholders to enhance these schemes. Fair Trade and 'Creating Shared Value' (CSV) approaches will replace traditional corporate philanthropy.

Main Agents of Change
Economy – Changing Economic Norms and Values
Society – Increased Importance of Societal Conscience
Environment – Need to Mitigate and Adapt to Climate Change

Main Enablers and Constraints
People and Societal Values
Environment, Resources and Energy

1.5.3 Global Partnership with NGOs

Companies will seek partnerships with key non-governmental organisations (NGOs) and other civil society organisations (CSOs) in order to gain global competitive advantage and to improve intelligence and knowledge gathering.

Main Agents of Change
Economy – Market Forces

Main Enablers and Constraints
Market, Competition and Consumers

1.5.4 Collaborative Regulatory Science

Firms will collaborate with governmental bodies in the field of "regulatory science" so as to develop new tools, standards and approaches to meet regulatory requirements for products and services.

Main Agents of Change
Economy – Market Forces

Main Enablers and Constraints
Market, Competition and Consumers

1.6 Skills and Talents

Human resources are a vital factor for the success of a company. Customer demand for personalised, high quality products and services requires that companies increasingly seek to employ highly qualified staff with creativity and social skills. Consequently companies are moving to areas where the required skills and talents exist, and staff is being recruited globally. In addition new human resource management techniques are increasingly being applied to maximise output, including the latest discoveries of behavioural sciences. The situation is exacerbated by the fact that the size of the active workforce is shrinking in many parts of the world, and the shortage of technical workers is increasing. As a result emphasis is being placed on effectively increasing the size of the potential work force by improving working conditions for women, disabled and older employees.

1.6.1 Competition for Skills and Talent

Firms will aggressively compete for high-skilled workers worldwide as global supply will not match the demand. Advanced manufacturing systems and technologies required to remain competitive in a global market demanding personalised products and services will need a wide range of highly skilled staff ranging from engineers to creative staff able to understand the ever-changing consumer requirements and the specificities of markets, especially in emerging countries. General engineers and tech-oriented managers will also be essential to achieve business/ICT alignment and convert data into strategic insights.

Main Agents of Change
Economy – Market Forces
Society – Evolving Workforce and Culture
Technology – New and Emerging Technologies

Main Enablers and Constraints
Employment and Skills
Science, Research and Technology

1.6.2 Effective Use of Talent

As the size of the active workforce shrinks in many parts of the world, increasing emphasis will be placed on extending the size of the potential workforce thanks to better inclusiveness and enhancement of working conditions for disabled and older employees. Retirees will be hired back to train new young employees.

Main Agents of Change
Economy – Market Forces
Society – Evolving Workforce and Culture
Policy – Public Policy

Main Enablers and Constraints
Employment and Skills
Market, Competition and Consumers

1.6.3 Developing Talents

Companies will develop internal training schemes or apprenticeship programmes to fill their specific workforce needs. They will increasingly collaborate with universities, research centres and other partners to offer work-study programmes with recognised degrees to younger talented recruits.

Main Agents of Change
Economy – Market Forces
Society – Evolving Workforce and Culture
Policy – Public Policy

Main Enablers and Constraints
Employment and Skills
Market, Competition and Consumers

1.6.4 New Human Management Models

As creative and conceptual tasks become more prominent, firms will use new insights from behavioural science on human motivation to redesign their human management models. Employees will be more autonomous in achieving objectives intrinsically shared with the organisation. Self-motivation will be fostered by new business cultures based on decision voting and peer reviews as well as '20% time'-like scheme for personal experiment.

Main Agents of Change
Society – Evolving workforce and Culture
Society – Increased Social Innovation

Main Enablers and Constraints
Employment and Skills
People and Societal Values

1.6.5 Technological Human Enhancement

New human enhancement technologies will help to increase the inclusiveness in work of disabled people as well as the comfort and performance of all employees. Technologies will be both cognitive (pharmacological, cognitive training, brain stimulation, etc.) and physical (hearing aids, mobility devices, visual enhancement, etc.).

Main Agents of Change
Economy – Market Forces
Society – Evolving Workforce and Culture
Technology – New and Emerging Technologies

Main Enablers and Constraints
Employment and Skills
Market, Competition and Consumers
Science, Research and Technology

1.7 Customer Involvement

Customers are more active in their relationship with companies. This is linked to the fact that consumers are increasingly demanding products and services that meet their own personal needs. Thanks to the maturity

of new communication technologies, including the Internet, the reputation of companies is more vulnerable to criticism through social media, which leads them to pay more attention to their public image. Companies are therefore working more closely with customers in the design, development and testing of their products in order to closely capture new requirements that can be personal, national or regional. A step further in customer involvement consists in enabling customers to be part of the production value chain via techniques such as social manufacturing.

1.7.1 Social Manufacturing

The widespread use of online social tools (e.g. collaborative platforms) and solutions (e.g. crowdfunding) together with digital fabrication software (i.e. CAD) and ready-to-use manufacturing hardware (e.g. 3D printing) will result in new forms of product design, development and testing, directly involving customers and a new innovative type of entrepreneur.

Main Agents of Change
Economy – Market Forces
Society – Evolving Workforce and Culture
Technology – New and Emerging Technologies

Main Enablers and Constraints
People and Societal Values
Market, Competition and Consumers
Science, Research and Technology

1.7.2 Mass Customisation

To answer increasing customers' requirements, firms will still seek to maintain the cost-efficiency of mass production by integrating the highest degree of flexibility in individual customisation and differentiating the product/service at the latest possible point in the supply chain.

Main Agents of Change
Economy – Market Forces
Society – Increasing Importance of Consumer Requirements and Behaviours
Technology – New and Emerging Technologies

Main Enablers and Constraints
People and Societal Values
Market, Competition and Consumers
Science, Research and Technology

1.7.3 Personalisation

Firms will increasingly focus on the personalisation of their integrated products and services, allowing their dynamic modification according to the user's implicit (e.g. ads on social network websites) or explicit (e.g. through online product configurators) preferences or behaviours.

Main Agents of Change
Economy – Market Forces
Society – Increasing Importance of Consumer Requirements and Behaviours
Technology – New and Emerging Technologies

Main Enablers and Constraints
People and Societal Values
Market, Competition and Consumers
Science, Research and Technology

1.7.4 Customer-Oriented Design

To enrich personalisation and customisation, companies will work more closely with customers in the design, development and testing of their products in order to closely capture new requirements, including regional and national differences, and to fine-tune new features and services. They will use virtual design environments to facilitate this collaboration.

Main Agents of Change
Economy – Market Forces
Society – Evolving Workforce and Culture
Technology – New and Emerging Technologies

Main Enablers and Constraints
People and Societal Values
Market, Competition and Consumers
Science, Research and Technology

1.7.5 Self-Production

New manufacturing technologies (e.g. 3D printing) will change the ways products are made, allowing small players to enter more easily into manufacturing and prototyping when needed. In addition firms will sell data files to customers who will 'print' their products at home or in 3D printing local factories. Customers will however increasingly use web-based collaborative production forums where they will exchange data files on an open peer-to-peer basis.

Main Agents of Change
Economy – Market Forces
Society – Evolving Workforce and Culture
Technology – New and Emerging Technologies

Main Enablers and Constraints
Employment and Skills
Market, Competition and Consumers
Science, Research and Technology

1.7.6 Collaborative Consumption

Firms from a wide range of sectors will seek to obtain shared access to integrated products and services rather than pursue a business model based on individual ownership. Companies - especially SMEs - will also apply this approach in their own manufacturing process by sharing ideas, knowledge and components with other SMEs through collaborative work schemes (e.g. peer-to-peer task assignments) and funding (e.g. peer-to-peer lending).

Main Agents of Change
Economy – Market Forces
Society – Evolving Workforce and Culture
Technology – New and Emerging Technologies

Main Enablers and Constraints
Employment and Skills
Market, Competition and Consumers
Science, Research and Technology

2. Infrastructure

'Infrastructure' is the layer upon which the Production and Consumption System is based.

Infrastructure enables firms to achieve overall efficiency in terms of dependency on energy, use of materials, emissions and waste, to ensure full real-time connectivity worldwide, to better manage innovation and financial risks, and to fasten delivery of products and services.

2.1 Smart and Interoperable Physical Infrastructure

Infrastructure underpins industry and industrial development; improving infrastructure is therefore a key component of industrial competitiveness and growth. The development of new technologies will upgrade and integrate ICT, water, transport and energy infrastructures. These new, smart infrastructures will enable industry to be more competitive and efficient, as well as allow industry to better address societal challenges such as climate change and scarcity of natural resources.

Secure material and energy supply and the high-speed production and delivery of goods and services are key success factors for manufacturing success, both in terms of customer satisfaction and cost reduction. Efficient, timely logistics relies on a good transport infrastructure. The development of intelligent transport systems has seen the movement of goods become more reliable, faster, and more secure and energy-efficient.

Many companies have become net suppliers to the energy grid. This is in comparison to 2010 when industry accounted for 25,3 % of the total energy consumption. New energy capture technologies have permitted many companies to use renewable energies (solar, wind) and sell it back into the energy grids. This has been driven by societal pressure for industry to consume less and greener energy, as well as by the ever increasing cost of energy. The ability of companies to supply energy into the grid has been enabled by the development and implementation of smart grid energy infrastructure.

Water management infrastructure, ranging from access to water supplies through to drainage and sewage management, underpins much of the manufacturing process. To this end the sustainable use of water in industry has become the main objective. This has been achieved by developing and implementing reliable, cost-effective technologies, tools and methods for sustainable water supply in order to significantly reduce water use, mitigate environmental impact and produce standard water qualities from all possible sources in an economical, sustainable and safe way. This has been achieved by applying an integrated water resource management approach using cross-sectorial technologies.

2.1.1 Upgraded, Integrated Infrastructure Networks

To optimise their global, fragmented supply chains and ensure safe and fast delivery, manufacturing industries will increasingly require upgraded physical infrastructure networks that are more intelligent, resilient and secure (e.g. with sensors ensuring continuous monitoring of the flows). These networks will be more and more integrated, with various key functions shared between the different infrastructures.

Main Agents of Change
Economy – Market Forces
Society – Digitalisation of Society
Technology – Converging Technologies

Main Enablers and Constraints
Employment and Skills
Market, Competition and Consumers
Science, Research and Technology

2.1.2 Smart Grids

The de-carbonisation of the energy supply will require the use of multiple different renewable energy sources. This will require a new energy infrastructure able to receive and provide energy from multiple energy sources – the so-called "smart grid". The development of smart electrical power grid infrastructure, combining ICT and energy supply technologies, will enable factories to optimise their energy flows, acting as both energy providers and users. New energy storage facilities will also enable factories to adjust energy flows according to their needs off-the-grid.

Main Agents of Change
Economy – Market Forces
Environment – Multiple, New Energy Sources
Environment – Need to Mitigate and Adapt to Climate Change
Technology – Converging Technologies

Main Enablers and Constraints
Environment, Resources and Energy
Market, Competition and Consumers
Science, Research and Technology

2.1.3 On-Site Energy Generation

The consequences of the manufacturing process (such as heat, waste) will increasingly be used as sources of energy. In addition there will be the increased use of renewable energies (photovoltaics, wind turbines, pumped hydroelectric power, etc.) by individual factories to off-set their energy needs. This will enhance the energy balance of many factories, and make some factories energy self-sufficient.

Main Agents of Change
Economy – Market Forces
Environment – Multiple, New Energy Sources
Environment – Need to Mitigate and Adapt to Climate Change
Technology – New and Emerging Technologies

Main Enablers and Constraints
Environment, Resources and Energy
Market, Competition and Consumers
Science, Research and Technology

2.14 Intelligent and Intermodal Transport Infrastructure

The development of intelligent transport systems - allowing real-time traffic and mobility management - will enable manufacturing firms to have quicker logistics chains thanks to a more reliable, more secure and faster movement of goods across different but fully intermodal infrastructures (road, rail, air, water).

Main Agents of Change
Economy – Market Forces
Environment – Multiple, New Energy Sources
Environment – Need to Mitigate and Adapt to Climate Change
Technology – New and Emerging Technologies

Main Enablers and Constraints
Environment, Resources and Energy
Market, Competition and Consumers
Science, Research and Technology

2.1.5 Efficient Water Infrastructure

Access to water to support the production processes will remain of strategic importance for many industrial sectors. However there will be increasingly societal and political pressure to use less water in the industrial process, with much effort being giving to minimising the waste, or loss of water. New technologies will be developed to facilitate this. Water infrastructure will also be increasingly integrated into the transport network, and will continue to be used for local freight shipping to reduce road congestion.

Main Agents of Change
Society – Increased Impact of Societal Conscience
Environment – Multiple, New Energy Sources
Environment – Need to Mitigate and Adapt to Climate Change
Technology – New and Emerging Technologies

Main Enablers and Constraints
Environment, Resources and Energy
Market, Competition and Consumers
Science, Research and Technology

2.2 ICT Infrastructure

With the advent of the knowledge economy based on dedicated technologies (such as knowledge engineering and knowledge management) economic benefits have been accrued, including job creation. To enable this ICT infrastructure has become critical. The increasing traffic of data continuously challenges the ICT infrastructure capacity as our daily lives rely more on ICT. In parallel the requirements on ICT infrastructure resilience and safety increase. Not only this, but the advanced manufacturing techniques being applied, ranging from the use of collaborative manufacturing networks through to advanced asset and logistical tools can only become ubiquitous when the speed, reliance and availability of ICT infrastructure is in place.

2.2.1 Upgraded ICT Networks

Firms will seek connection to the highest-capacity ICT networks (e.g. Next Generation Networks for convergence of voice, data and video) to answer the increased demand from customers for fast delivery of large broadband services and applications, and to take all the benefits from cloud computing and supercomputing technologies (e.g. grid computing, cluster computing, etc.).

Main Agents of Change
Society – Digitalisation of Society
Economy – Market Forces
Technology – New and Emerging Technologies

Main Enablers and Constraints
Market, Competition and Consumers
Science, Research and Technology

2.2.2 Secure and Resilient ICT Infrastructure

As ICT infrastructure becomes more and more critical for the manufacturing daily operations and the manufacturing network at large, firms will require more secure and resilient ICT infrastructure with a high level of data protection, a stable broadband and no service disruption.

Main Agents of Change
Society – Digitalisation of Society
Economy – Market Forces
Technology – New and Emerging Technologies

Main Enablers and Constraints
Market, Competition and Consumers
Science, Research and Technology

2.3 Knowledge Infrastructure

The knowledge infrastructure underpins innovation, and consequently the whole European economy. It supports research and education, fosters enhanced communication and knowledge-sharing throughout the population, develops the know-how and creativity of the work force, and ensures access to knowledge across generations. To achieve this a knowledge infrastructure has been put in place that has successfully addressed a number of technical issues such as digital visualisation and analysis of very large scale data sets, authentication, storage and re-use of digital assets on the long-term, etc. as well as related social and economic issues regarding digital accessibility and preservation.

2.3.1 Knowledge-Based Environment

To fulfil their requirements for a talented, highly skilled work force, and to stimulate their innovation processes, firms will locate in knowledge-oriented environments where governments invest heavily in STEAM education (Science, Technology, Engineering, the Arts, and Mathematics), support strong R&D policies and invest massively in technology and cyberinfrastructure projects.

Main Agents of Change
Policy – Public Policy
Economy – Market Forces
Society – Evolving Modes of Education and Learning

Main Enablers and Constraints
Employment and Skills
Market, Competition and Consumers
Regulation

2.3.2 Collaborative Knowledge Networks

Firms will locate where access to international networks of research and technology expertise is easy, and where cross-sector collaboration among public and private data and knowledge stakeholders is fostered.

Main Agents of Change
Policy – Public Policy
Economy – Market Forces
Society – Digitalisation of Society

Main Enablers and Constraints
Science, Research and Technology
Market, Competition and Consumers
Regulation

2.3.3 Sustainable Knowledge Infrastructure

With the Big Data explosion, the sustainability of the knowledge infrastructure - and mainly the issue of collecting, collating and archiving valuable information in secure digital storage media - will be increasingly important to companies. This includes for SMEs that will rely increasingly on cloud computing and third-party archival services. To assure the sustainability of information collection, analysis and storage, the issue of data protection and privacy becomes a major issue to be resolved.

Main Agents of Change
Economy – Market Forces
Society – Digitalisation of Society
Society – Increased Social innovation
Technology – New and Emerging Technologies

Main Enablers and Constraints
Employment and Skills
Market, Competition and Consumers
Regulation

2.4 Financial Infrastructure

Financial infrastructure constitutes the foundation of the European financial system, being then a critical component for the smooth functioning of the economy. Indeed, the quality of financial infrastructure is correlated with the financial system robustness. It includes all institutions, information, technologies, rules and standards that enable safe and efficient financial intermediation taking into account exchange of information. Key financial infrastructure elements are credit bureaus, credit ratings, enforcement of collateral and functioning payment, securities settlement and remittance systems.

Well established cross-border infrastructure is a sine qua non to foster global financial services which are necessary for global corporates as well as exporting SMEs. However, differences exist between countries, especially between developed and developing countries, which limit the efficiency of intermediation and then access to finance. Improvements of financial infrastructure decrease the risks and then the transaction costs for economic agents of financial services and promote a modern integrated market. The development of the scope and the depth of financial infrastructure have also to cope with a legal and regulatory framework.

2.4.1 Efficient Financial Infrastructure

Firms will seek environments with a safe and efficient financial infrastructure where transparent and stable market institutions (central banks, market regulators, etc.), resilient networks and inclusive physical infrastructure facilitate the trading of goods and services and the exchange of financial data and information (e.g. credit ratings) for enhanced risk management and optimisation of flows.

Main Agents of Change
Policy – Governance 2.0
Economy – Market Forces

Main Enablers and Constraints
Market, Competition and Consumers
Regulation

2.4.2 Innovative Systems of Payment

Payment systems allow businesses to receive and facilitate payments related to their activity. At the same time, international payment is recognised as being not easy and improvement can generate cost saving. Based on consistent and compatible systems and with the development of technological and web-related applications, payment services are increasingly integrated into companies' everyday routines.

Main Agents of Change
Economy – Market Forces
Economy – Globalisation of Markets and Industrialisation
Technology – Emerging Technologies

Main Enablers and Constraints
Market, Competition and Consumers
Financial System
Science, Research and Technology

2.4.3 Digital Security in Financial Infrastructure

Societal requirement for a controlled and secure financial environment will become more and more important. Moreover, security improvement of the system will further protect investors' and creditor's rights. Due to digital inclusiveness, firms will need to strengthen their trust for on-line financial services.

Main Agents of Change
Society – Increased Societal Risks
Society – Digitalisation of Society
Economy – Changing Economic Norms and Values
Technology – Emerging Technologies

Main Enablers and Constraints
People and Societal Values
Market, Competition and Consumers
Financial System
Science, Research and Technology

2.4.4 New Providers of Financial Services

Services and products will need to be provided by multi-technology and multi-channel means. The growth of online and wireless technologies will encourage the non-banking firms such as big card firms or telecommunication companies to provide banking services. Strategic alliances might be developed to provide the companies a digital ecosystem including a full range of global financial services being simple, reliable and customer-focused.

Main Agents of Change
Economy – Market Forces
Economy – Globalisation of Markets and Industrialisation
Technology – Emerging Technologies

Main Enablers and Constraints
Market, Competition and Consumers
Financial System
Science, Research and Technology

3. Materials

'Materials' are the raw materials that feed the Production and Consumption System.
Materials constitute a critical factor for competitiveness and for environmental protection. Traditional and new industries in Europe are working with new materials to take advantage of increased functionality, lower weight, lower environmental burden, and energy efficiency. New material science and technologies improve the productivity, ease materials recycling and reuse, and open the path to efficient manufacturing processes.

3.1 Materials and Reusable Parts for Sustainability

Demand for raw materials continues to grow unabated as a result of global population growth, the rapid rise of the middle class in emerging countries and the continuous emergence of new technologies and applications. This is placing ever greater demand on natural resources. Some raw materials are concentrated in certain parts of the globe creating excessive dependence and a risk to its access. The environmental cost of raw material extraction is sometimes considered excessive. In parallel society is increasingly demanding that material waste is minimised. To address the situation there has been a strong emphasis on the re-cycling and re-use of strategic materials, as well as on materials research resulting in new materials that are able to replace rare, expensive and environmentally sensitive materials.

3.1.1 Secure Material Supply

In a context of increased raw material scarcity, firms will apply a variety of strategies to secure an easy, flexible, cost-efficient and sustainable material supply according to their sector, size and location. They will either locate plants near to raw materials or even purchase suppliers (especially for strategic and rare raw materials) or, when there are no other options, collaborate with a large number of suppliers worldwide to minimise shortage risks, enabled by increasing numbers of free trade agreements.

Main Agents of Change
Policy – Trade Strategy and Policy
Environment – Increasing Scarcity of Natural Resources
Economy – Market Forces

Main Enablers and Constraints
Environment, Resources and Energy
Market, Competition and Consumers
Regulation

3.1.2 Full Recovery of Rare Materials

Due to their scarcity and high value, critical raw materials (e.g. rare earth elements) that are dispersed or are to be found in small quantities in the products will be increasingly recovered thanks to the development of new technologies.

Main Agents of Change
Environment – Increasing Scarcity of Natural Resources
Economy – Market Forces
Technology – New and Emerging Technologies

Main Enablers and Constraints
Environment, Resources and Energy
Market, Competition and Consumers
Science, Research and Technology

3.1.3 Circulation of Materials and Parts

As 'life cycle' and the 'sustainability by design' approaches become increasingly part of the mainstream of the value chain, materials will circulate between different industries, value chains and production processes. This circulation will be enabled by a range of advanced technologies including the reuse, remanufacturing and recycling of secondary materials, parts and products.

Main Agents of Change
Environment – Increasing Scarcity of Natural Resources
Economy – Market Forces
Technology – New and Emerging Technologies

Main Enablers and Constraints
Environment, Resources and Energy
Market, Competition and Consumers
Science, Research and Technology

3.1.4 Replacement Materials

As competition for increasingly scarce natural resources heightens firms will increasingly develop and/or use new materials. This will in many cases reduce costs. It will also, as new complex and smart materials become available, enable new or improved products.

Main Agents of Change
Environment – Increasing Scarcity of Natural Resources
Economy – Market Forces
Technology – New and Emerging Technologies

Main Enablers and Constraints
Environment, Resources and Energy
Market, Competition and Consumers
Science, Research and Technology

3.1.5 Bio-Based Materials

Renewable and biodegradable materials (e.g. bio-degradable polymers) and other biomaterials will be increasingly used to reduce the environmental impact of products, services and processes.

Main Agents of Change
Environment – Increasing Scarcity of Natural Resources
Society – Increased Societal Risks
Technology – New and Emerging Technologies

Main Enablers and Constraints
People and Societal Values
Environment, Resources and Energy
Science, Research and Technology

3.2. Advanced Materials for Performance

Advanced materials have enabled new technologies and products with enhanced functionalities, such as lightness and self-repairing properties. Advanced manufacturing processes, such as additive manufacturing, have been enabled by the development and characterisation of new materials. New technologies, such as nanotechnologies and associated nanomaterials, have also opened up whole new industries based around bionics and bio-nanotechnology. However this has only been achieved following the development of specialised approaches to the testing and monitoring of their effects on human health and on the environment.

3.2.1 Material Science

Firms will be actively engaged in and/or will depend on material science to develop and use advanced materials with smart, high-strength, low-weight and bio-compatible properties. Use of these materials will provide companies with product advantages due to improved performance, as well as saving costs as natural resources become increasingly scarce and expensive. Advanced materials will range from advanced metals to synthetic polymers, ceramics, bio-based polymers and novel composites.

Main Agents of Change
Environment – Increasing Scarcity of Natural Resources
Economy – Market Forces
Technology – New and Emerging Technologies

Main Enablers and Constraints
Environment, Resources and Energy
Market, Competition and Consumers
Science, Research and Technology

3.2.2 Material Characterisation

New production processes, such as additive manufacturing, will require the upgraded characterisation and mapping of existing and new materials in order to be able to market new and innovative products. The access to a materials database (open and proprietary), perhaps established following policy demands, will become increasingly important for manufacturing companies.

Main Agents of Change
Policy – Public Policy
Economy – Market Forces
Technology – New and Emerging Technologies

Main Enablers and Constraints
Regulation
Market, Competition and Consumers
Science, Research and Technology

3.2.3 Smart Materials

Smart, multifunctional materials able to change properties according to environment (e.g. temperature, pH, light, magnetic field, etc.) will become increasingly available. These materials open up a whole new range of products and markets, and will significantly change industrial processes as their capabilities expand. This could range from acting as sensors by design, to materials that self-repair themselves or change shape by programme or stimuli.

Main Agents of Change
Economy – Market Forces
Technology – New and Emerging Technologies

Main Enablers and Constraints
Market, Competition and Consumers
Science, Research and Technology

3.2.4 Nanomaterials

The non-classical physical properties of new materials from 1 to 100 nanometres will be increasingly used by industries to improve product intelligence, performance, robustness or elasticity. Nanomaterials of biological origin (e.g. self-assembling nanofibers, nanolaminates spray and nanosensors) will be a key focus due to their 'greener' dimension. Safety issues related to these materials will become of greater public concern, requiring clear controls and tests to assure environmental and human security.

Main Agents of Change
Policy – Public Policy
Society – Changing Social Norms and Values and Ethical issues
Economy – Market Forces
Technology – New and Emerging Technologies

Main Enablers and Constraints
Regulation
Market, Competition and Consumers
Science, Research and Technology

3.2.5 Lightweight Materials

Carbon fibre composites, including carbon nanotubes, will challenge aluminium with increased cost-efficiency (material) and time-efficiency (process) for a wide range of manufacturing applications (electronics, sensors, energy, aeronautics, aerospace, etc.).

Main Agents of Change
Economy – Market Forces
Technology – New and Emerging Technologies

Main Enablers and Constraints
Market, Competition and Consumers
Science, Research and Technology

3.2.6 Flexible Plastic Electronics

Carbon-based plastic electronics will be increasingly used for roll-to-roll manufacturing of electronic devices.

Main Agents of Change
Economy – Market Forces
Technology – New and Emerging Technologies

Main Enablers and Constraints
Market, Competition and Consumers
Science, Research and Technology

4. Knowledge Management

'Knowledge Management' is the manner by which data, information and knowledge are managed in the Production System.

Knowledge Management enables firms to capture ever-increasing sets of data from the production system and its environment, and to generate knowledge available in a targeted manner in all areas of the value chain.

4.1 Data Capture

Data is the raw material of knowledge. Indeed by 2025 it has become apparent that "data is the new oil". In modern business practices the more information that an organisation has and leverage in business situations, the better "armed" it will be for competitive advantage. An exponential amount of data and increasingly-complex and larger sets of data from machinery, products and consumers will potentially enable manufacturing

firms to better understand and optimise all stages of their value chains, from design to distribution including supply chain management, production processes and marketing. To achieve this, improvements in complex event processing techniques and trend analysis through new data management platforms are required.

4.1.1 Big Data and the Internet of Things

As ICT technology and global markets develop, the value chain of many companies will become globally distributed. Firms will invest massively in powerful capture platforms (i.e. based on supercomputing technologies) that will collect and collate real-time data from a wide range of internal and external sources (customer feedback, product RFID tags, machinery, sensors, robots, online libraries, cameras etc.) and make it available, in a targeted manner, to all areas of the production chain.

Main Agents of Change
Society – Digitalisation of Society
Economy – Globalisation of Markets and Manufacturing
Technology – New and Emerging Technologies

Main Enablers and Constraints
Market, Competition and Consumers
Science, Research and Technology

4.1.2 Data Visualisation

To better use and understand the large quantities of data that will be collected firms will use a variety of visualisation tools. These tools will be developed to address all levels of expertise found in the value chain from the Big Data experts to the factory floor workers, including managers and executives. The data visualisation tools will be implemented to facilitate the constant improvement of companies' value chains as businesses continually strive to become more efficient, and to produce products required by an ever increasingly competitive global market.

Main Agents of Change
Society – Digitalisation of Society
Economy – Market Forces
Technology – New and Emerging Technologies

Main Enablers and Constraints
Market, Competition and Consumers
Science, Research and Technology

4.1.3 Data Storage

The arrival of "big data" on the industrial landscape will force companies to consider innovative, cheap and efficient mechanisms to store the data collected in a safe and secure manner. Internal high-capacity servers or outsourced storage services will be needed to store exabytes of valued data useful for ex-post analysis and evaluation.

Main Agents of Change
Society – Digitalisation of Society
Technology – New and Emerging Technologies

Main Enablers and Constraints
Market, Competition and Consumers
Science, Research and Technology

4.1.4 Data Process for Knowledge Acquisition

Considerable investment will be made in developing analytical techniques to manage the "big data" collected, permitting manufacturing firms to better understand and optimise all stages of their value chains, and to better understand their markets.

Main Agents of Change
Society – Digitalisation of Society
Economy – Globalisation of Markets and Manufacturing
Technology – New and Emerging Technologies

Main Enablers and Constraints
Market, Competition and Consumers
Science, Research and Technology

4.1.5 Cybersecurity

Firms will need to invest and implement strong, adaptive and resilient security systems and techniques to protect their data from cyber-attacks from competitors, foreign intelligence services or hacktivists. They will also need to define and communicate on a transparent privacy charter to manage customers' data with the right balance between privacy rights and expectations of protection by customers, and in compliance with the law.

Main Agents of Change
Society – Digitalisation of Society
Society – Changing Social Norms and Values and Ethical issues
Policy – Public Policy
Technology – New and Emerging Technologies

Main Enablers and Constraints
Regulation
Market, Competition and Consumers
Science, Research and Technology

4.2 Knowledge Generation

Products and services are becoming more sophisticated and "know-how" is as important as the materials and energy used to produce them. Manufacturing industry is increasingly investing on "intangible" capital such as R&D, design, software, human and organisational capital, and brand equity, and relatively less in investment in physical assets such as machines, buildings and vehicles as a means to be more competitive.

To manage the knowledge capital is therefore becoming a crucial task of a company. It requires an integrated approach to identify, capture, create, evaluate, store, retrieve and share all the knowledge assets of a company. Regarding tacit knowledge, these assets may include databases, documents, procedures, intellectual property, and capitalisation of experience. However, other knowledge assets are "stored" in workers and its actualisation and growth depends on the interaction of people within and outside the company.

Research and development is an important part of knowledge generation inside the company but it is not the only one. Knowledge is generated as a result of efforts to integrate improvements in each stage of the production process, from the R&D lab to the interface with customers including the factory floor.

4.2.1 Knowledge Management

Firms will focus intensively on knowledge production related to customers' requirements and behaviours, market trends and forecasts, competitors, product design, supply chain flows, machinery performance and the life cycle of products in the field. New software based on artificial intelligence and machine learning will help humans to manage complexity, draw appropriate conclusions and define strategies. New smart devices will also augment the cognitive skills and capacities of humans in performing their knowledge-based work.

Knowledge-intensive manufacturing will require firms to implement new knowledge management schemes across the organisation so as to remove barriers between workers, technicians, engineers, designers, Big Data experts, managers and executives. Firms that succeed will have achieved full business/ICT alignment through expertise and experience sharing.

Main Agents of Change
Society – Digitalisation of Society
Economy – Globalisation of Markets and Manufacturing
Technology – New and Emerging Technologies

Main Enablers and Constraints
Market, Competition and Consumers
Science, Research and Technology

4.2.2 Knowledge Sharing / Harvesting

Firms will actively participate into knowledge networks and technology platforms with universities, research centres and other knowledge-intensive companies, and will seek the contribution of individuals through open collaborative workplaces to share knowledge and get new ideas.

In order to maximise their knowledge, and to provide themselves with a competitive advantage firms will actively participate in knowledge networks and technology platforms with universities, research centres and other knowledge-intensive companies. They will also seek to gain from open and social innovation techniques as they seek the contribution of geographically distributed individuals.

Main Agents of Change
Society – Increased Social Innovation
Society – Evolving Modes of Education and Learning
Economy – Globalisation of Markets and Manufacturing
Technology – New and Emerging Technologies

Main Enablers and Constraints
Market, Competition and Consumers
Science, Research and Technology
Employment and Skills

4.2.3 Knowledge and Data Interoperability

As the effects of "big data" become more apparent, and companies struggle to collect, collate and analyse huge amounts of data in order to provide them with the knowledge that can give firms competitive advantage, increasing effort will be given to assure data interoperability in order to ease and improve data analysis.

Main Agents of Change
Society – Digitalisation of Society
Economy – Market Forces
Technology – New and Emerging Technologies

Main Enablers and Constraints
Market, Competition and Consumers
Science, Research and Technology

4.2.4 Standards

Companies, in particular SMEs, will be more engaged in standardisation work within formal standardisation bodies as well as fora and consortia to influence standards' settings and to reach the innovation level playing field.

Main Agents of Change
Economy – Market Forces
Policy – Evolution of international trade relations

Main Enablers and Constraints
Regulation
Markets Competition and Consumers

4.3 Intellectual Property Management

The management of trademarks and patents is being challenged with the development of open innovation, Internet and collaboration patterns. The IP portfolio will be less used to exclude other parties and more to collaborate with other partners.

4.3.1 Collaborative IP Management

With trademarks and patents being challenged by the development of open innovation, open source design and other web-based collaborative schemes, the use of intellectual property portfolios will be less used to exclude other parties and more to facilitate collaboration with partners on a jointly beneficial basis.

Main Agents of Change
Economy – Market Forces
Technology – New and Emerging Technologies

Main Enablers and Constraints
Market, Competition and Consumers

4.3.2 IP Trade Market

In the first part of the 21st century intellectual property (IP) was seen as something to be protected, helping to assure the exclusiveness and quality of products. However it became clear that this type of protectionism was blocking innovation and industrial development by restricting the use of good ideas. As a result firms will move towards creating a market for IP by exploiting it, rather than owning it.

Main Agents of Change
Economy – Market Forces

Main Enablers and Constraints
Market, Competition and Consumers

4.3.3 Digital Rights Management

Firms will need to invest in advanced protection techniques (e.g. code obfuscation, watermarking) to dissuade, detect, track and counter piracy and counterfeiting of their ICT-based products.

Main Agents of Change
Economy – Market Forces
Technology – New and Emerging Technologies

Main Enablers and Constraints
Market, Competition and Consumers
Science, Research and Technology

5. Services

'Services' are the service portion of the Production System.

Services directly contribute to high value-added manufacturing and represent the key economic sustainability factor for European industry. Firms are using a combination of advanced production processes and services to produce an increasing number of high-tech, smart, integrated products and services.

5.1 Services for Customers

Companies increasingly combine products and services in innovative ways to attract customers by offering "packages" tailored to customers' needs. A good example is the mobility package now being offered that provides you with transport wherever you are globally; this package can be tailored to your personal requirements for types of transport use. Customers are increasingly demanding this type of tailored package, and are no longer so interested in purchasing individual products, such as a car. Integrated products and services solutions increase demand by providing superior value through customisation possibilities, add-on features, "best-of-breed" product/service package. Indeed the service element is the main area where companies are being innovative in order to compete in an ever increasingly competitive global market.

5.1.1 Integrated Products and Services

Consumers will increasingly demand services as a fundamental part of their purchase of a product. Manufacturing companies and service providers will work more closely together in building appropriate solutions combining products and services.

Main Agents of Change
Society – Increased Importance of Consumer Requirements and Behaviours
Economy – Market Forces

Main Enablers and Constraints
Market, Competition and Consumers
People and Societal Values

5.1.2 Service as a Key Source of Profit

Companies, under pressure of global competition, will see services as the means to gain a competitive edge, and as a means to extract profit whilst keeping the basic product cost as low as possible. Service industries will increasingly join manufacturing as a source of export growth and innovation.

Main Agents of Change
Society – Increased Importance of Consumer Requirements and Behaviours
Economy – Globalisation of Markets and Industrialisation

Main Enablers and Constraints
Market, Competition and Consumers
People and Societal Values

5.1.3 Service-Oriented Design

As services become an increasingly important part of marketed products, the service component of a product will become a key element of the design and development process. The holistic design of the complete product / service value chain will be enabled by the emergence of new design tools.

Main Agents of Change
Society – Increased Importance of Consumer Requirements and Behaviours
Economy – Market Forces
Technology – New and Emerging Technologies

Main Enablers and Constraints
Market, Competition and Consumers
People and Societal Values
Science, Research and Technology

5.1.4 Experience Economy

Firms will go beyond products and services to offer memorable experiences to their customers. The experience element of the products and services will define their competitive advantage, and will provide the greatest part of the economic value.

Main Agents of Change
Society – Increased Importance of Consumer Requirements and Behaviours

Main Enablers and Constraints
Market, Competition and Consumers
People and Societal Values

5.2 Services for Production

With the increasing complexity of production systems, specialised services to support the production life cycle are increasingly needed. In some cases, given the high level of specialisation, the geographical reach or just economic reasons, those services will be outsourced, e.g. for the maintenance and repair of their products, but also production sites, adjusted to the regional preferences.

5.2.1 Enhancement of Traditional Services

As technology develops, and the technical complexity of many parts of the production system increases, niche companies will develop offering services to manufacturing firms to enhance their production processes. This service support will occur throughout the production cycle from design to maintenance. The services will offer increased production performance, through to helping companies close the material loop by offering energy saving, waste management and obsolescence services.

Main Agents of Change
Environment – Need to Mitigate and Adapt to Climate Change
Economy – Market Forces
Technology – New and Emerging Technologies

Main Enablers and Constraints
Market, Competition and Consumers
Science, Research and Technology

5.2.2 Virtual Service Management

New and converging technologies will permit remote service management to help to reduce costs for servicing (e.g. travel costs), increase service efficiency (e.g. first-visit-fix-rates) and accelerate innovation processes (e.g. remote update of device software).

Main Agents of Change
Economy – Market Forces
Technology – New and Emerging Technologies

Main Enablers and Constraints
Market, Competition and Consumers
Science, Research and Technology

5.3 Services for Business

With the increasing complexity and globalisation of the markets, services for business continue to contribute as important parts of the production system. In addition to classical services such as finance, insurance, legal services, accountancy, advertising, telecommunications, strategic consultancy, market analysis, other innovative services are emerging. Examples include eco-innovation companies that offer industry the possibility to present a “greener” image to the outside world, whilst at the same time saving on the use of valuable resources; savings in the use of water and energy are key elements here with many companies now becoming self-sufficient in energy consumption.

5.3.1 Enhancement of Traditional Services

Companies will continue to call upon a number of services to support their businesses. This ranges from financial services through to insurance, legal, accountancy, marketing and advertising, telecommunications, strategic consultancy, market analysis, travel services, purchasing, sales, and risk management.

Main Agents of Change
Economy – Market Forces

Main Enablers and Constraints
Market, Competition and Consumers

5.3.2 Eco-Industry Services

As the need to mitigate and adapt to climate change becomes more acute, and as pressure from society to address global environmental and natural resources issues becomes greater, companies will increasingly move to become "greener", seeking to become energy and waste neutral. In many cases companies will be enabled to do this by new and emerging technologies, often offered by service companies.

Main Agents of Change
Environment – Need to Mitigate and Adapt to Climate Change
Society – Increasing importance of consumer requirements and Behaviours
Technology – New and Emerging Technologies

Main Enablers and Constraints
People and Societal Values
Science, Research and Technology

6. Technologies and Production Processes

'Technologies and Production Processes' are the mechanics of the Production System, from design to distribution.

As the core function of manufacturing industry, state-of-the-art production processes are a key factor for performance, resource-efficiency and competitiveness. Firms need to continuously update their production processes with new technologies and innovations, particularly based upon Advanced Manufacturing Systems, Key Enabling Technologies and ICT, in order to deliver smart, high quality, highly personalised, integrated products and services.

6.1 Resource-Efficient and Clean Production Processes

The requirement to use less energy and less material in the production cycle has become increasingly important. This has been driven by the societal challenge of reducing the environmental impact of production and consumption, as well as the increasing scarcity of raw materials due in part to the increasing demand from Asia, and the increase of energy and raw material prices that undermines competitiveness. Increasingly life cycle approaches are now applied in order to minimise the extraction and waste of materials, as well as the emissions of pollutants and greenhouse gases.

6.1.1 Sustainable Manufacturing

Environmental, regulatory and societal pressures will force manufacturing firms to adopt greener production processes so as to improve resource and energy-efficiency (e.g. maximum productivity of materials, optimisation of energy flows) and reach minimal environmental impact (e.g. near-to-zero CO_2 emissions, use of biodegradable and renewable materials, eco-friendly extraction of materials, safe management of hazardous materials, green products manufacturing). They will use an energy mix with more local renewable energy. In many cases this will be enabled by emerging and converging technologies.

Main Agents of Change
Environment – Need to Mitigate and Adapt to Climate Change
Society – Changing Social Norms and Values and Ethical Issues
Technology – New and Emerging Technologies

Main Enablers and Constraints
People and Societal Values
Science, Research and Technology

6.1.2 Disassembly, De-Manufacturing and Recovery

In the framework of an emerging 'circular economy', firms will invest in technologies for managing the disassembly and de-manufacturing of materials, parts, products and even factories, as well as the recovery of trace elements, so as to foster end-of-life reuse, remanufacturing and recycling.

Main Agents of Change
Environment – Need to Mitigate and Adapt to Climate Change
Society – Changing Social Norms and Values and Ethical Issues
Technology – New and Emerging Technologies

Main Enablers and Constraints
People and Societal Values
Science, Research and Technology

6.1.3 Waste Minimisation

Enhanced automation and production processes (e.g. near net shape), as well as new advanced manufacturing techniques such as additive manufacturing, will enable factories to use a smaller quantity of materials to make a product with almost no waste.

Main Agents of Change
Environment – Need to Mitigate and Adapt to Climate Change
Economy – Market Forces
Technology – New and Emerging Technologies

Main Enablers and Constraints
Markets, Competition and Consumers
Science, Research and Technology

6.1.4 Smart and Agile Maintenance Approaches

Firms will use improved preventive and predictive maintenance techniques to increase the product life and improve the energy efficiency of the processes involved.

Main Agents of Change
Environment – Need to Mitigate and Adapt to Climate Change
Economy – Market Forces
Technology – New and Emerging Technologies

Main Enablers and Constraints
Markets, Competition and Consumers
Science, Research and Technology

6.1.5 Traceability

Firms will ensure that all stages of the global and fragmented supply chain are fully documented for control and evaluation. This will increasingly involve new and emerging ICT technologies, and will permit greater efficiencies.

Main Agents of Change
Economy – Globalisation of Markets and Industrialisation
Technology – New and Emerging Technologies

Main Enablers and Constraints
Markets, Competition and Consumers
Science, Research and Technology

6.2 Flexible, Smart and Customer-Oriented Technologies

Consumers increasingly require a package of products and services tailored to meet their own specific needs. “Mass personalisation”, enabling flexibility of the production system to be able to meet individual customer needs, increasingly dominates the production system, replacing “mass production” as the mainstream production process. This has driven technological development towards production systems able to cope with these requirements. Technologies such as additive manufacturing have become mainstream manufacturing approaches, moving beyond the

design and prototyping stages of the production process to become the dominant product producer in some areas. To improve the production process to meet consumer needs for quality, cheaper products automated production techniques are increasingly applied, including advanced robotics. Mass customisation has also resulted in a change in other aspects of the production process. Consumers are now much more closely involved in design and prototyping of products and services. New techniques, including open innovation, have been tried successfully by a range of industries in order to maximise consumer input and innovation.

6.2.1 Advanced Robotics

Robots with increased dexterity and intelligence, as well as a capability to work safely with human work forces, will enable factories to reduce variability, to increase flexibility and speed of their production processes, allowing the delivery of more complex, personalised and higher quality products.

Main Agents of Change
Society – Increased Importance of Consumer Requirements and Behaviours
Economy – Market Forces
Technology – New and Emerging Technologies

Main Enablers and Constraints
Markets, Competition and Consumers
Science, Research and Technology

6.2.2 Additive Manufacturing

With the development of larger and faster printers and the enhanced characterisation of materials, additive manufacturing technologies (e.g. 3D printing, selective laser sintering, fused deposition modelling, stereolithography, inkjet bioprinting, laminated object manufacturing, etc.) will be increasingly used by both SMEs and larger manufacturing firms to realise prototypes, to produce light and complex parts for low-volume high-tech applications, and to make customised products for jewellery, fashion, prosthetics and other medical applications.

Main Agents of Change
Society – Increased Importance of Consumer Requirements and Behaviours
Economy – Market Forces
Technology – New and Emerging Technologies

Main Enablers and Constraints
Markets, Competition and Consumers
Science, Research and Technology

6.2.3 Technological Adaptation

Advanced manufacturing technologies (e.g. new shaping technologies, micro- and nano-manufacturing, etc.) and other disruptive technologies (e.g. synthetic biology) will require from companies a constant effort to keep track of new developments and to combine their use so as to reach the latest quality and efficiency standards in manufacturing.

Main Agents of Change
Economy – Market Forces
Technology – New and Emerging Technologies
Technology – Converging Technologies

Main Enablers and Constraints
Markets, Competition and Consumers
Science, Research and Technology

6.2.4 Agile Manufacturing

To maintain their competitive advantage, companies will become more sensitive to changes in the demand and will consequently ensure the flexibility of their supply chain and the fast re-configurability of their production lines (e.g. through self-adaptive and modular machine tools and robots).

Main Agents of Change
Economy – Market Forces
Technology – New and Emerging Technologies
Technology – Converging Technologies

Main Enablers and Constraints
Markets, Competition and Consumers
Science, Research and Technology

6.2.5 Personalised Production Lines

New production approaches will be implemented to enable mass customisation and personalisation, such as a two-step production approach for (1) producing blank elements, and (2) assembling products from the blank elements according to customer preferences.

Main Agents of Change
Society – Increased Importance of Consumer Requirements and Behaviours
Economy – Market Forces
Technology – New and Emerging Technologies

Main Enablers and Constraints
Markets, Competition and Consumers
Science, Research and Technology

6.2.6 Zero Defect Manufacturing

The 'Six Sigma' process improvement approach will be a minimum standard for manufacturing, but firms will even target 'zero defect manufacturing', both in quality and in performance, in order to maintain the highest standards in the event of changing operating conditions. Factories will aim at preventing product defects thanks to the increased use of cost-efficient virtual prototyping for multiple testing (modelling and simulation tools), advanced failure analysis (e.g. data mining) and self-adaptive monitoring and control techniques (thanks to smart measuring devices).

Main Agents of Change
Economy – Market Forces
Technology – New and Emerging Technologies
Technology – Converging Technologies

Main Enablers and Constraints
Markets, Competition and Consumers
Science, Research and Technology

6.3 Human-Centered Factories

Factories have evolved to address simultaneously economic, environmental and societal challenges. Factories continue to be the core of the production system as the geographical place where material transformation is undertaken. However social expectation on how factories are related to workers and neighbours as a working place and as a dynamic element of the environment has significantly developed. Factories of the future have to properly address those expectations while remaining a competitive element of the production system that delivers cost-efficient and flexible manufacturing.

6.3.1 Socially Responsible Manufacturing

Moving towards high-value manufacturing will require firms to value, to respect and to reward the unique and irreplaceable role of human employees as innovators, problem solvers and decision makers. Factories will focus on the well-being of workers (e.g. through human-centred factory design) and their better integration with technologies, machines and systems (e.g. through personalised user interfaces, enhanced ergonomics, etc.).

Main Agents of Change
Economy – Market Forces

Technology – New and Emerging Technologies
Society – Evolving Workforce and Culture

Main Enablers and Constraints
Markets, Competition and Consumers
Science, Research and Technology

6.3.2 Human-Robot Symbiosis

Humans and robots will work in harmony on the plant floor thanks to personalised machine-to-user interfaces and human-like robot behaviour and features (e.g. humanoid design, voice recognition, natural language, gesture understanding, etc.). Human-machine interactions will be designed to capitalise on the outstanding capabilities of humans in terms of flexible process operation.

Main Agents of Change
Economy – Market Forces
Technology – New and Emerging Technologies
Society – Evolving Workforce and Culture

Main Enablers and Constraints
Markets, Competition and Consumers
Science, Research and Technology

6.3.3 Enhanced Human Performance

Advanced technologies will enhance the physical and cognitive performance of workers, e.g. by facilitating human access to data via 'bionic ears' or by helping workers carrying heavy loads, or employees with limited mobility, with exoskeleton.

Main Agents of Change
Economy – Market Forces
Technology – New and Emerging Technologies
Society – Evolving Workforce and Culture

Main Enablers and Constraints
Markets, Competition and Consumers
Science, Research and Technology

6.3.4 Safe, Attractive and Inclusive Workplace

In order to retain all available skilled workers, factories will become safe environments where ergonomics, interaction with the machines and exposure to chemical hazards, pollutants and noise are well taken into consideration. They will also become more inclusive workplaces, thereby adapting work demands to the physical and cognitive capabilities of workers, especially for older workers and disabled people. With robots ensuring all repetitive tasks, the jobs reserved to humans will also be more demanding, with a focus given to personal achievements.

Main Agents of Change
Economy – Market Forces
Technology – New and Emerging Technologies
Society – Evolving Workforce and Culture

Main Enablers and Constraints
Markets, Competition and Consumers
Science, Research and Technology

6.3.5 Factory as a Good Neighbour

As production will become closer to the customer and to skills, factories will move to the cities and will seek optimal integration in their social and urban environment (e.g. through urban transport, parking, shopping and entertainment centres, etc.).

Main Agents of Change
Economy – Market Forces
Technology – New and Emerging Technologies
Society – Increased Urbanisation

Main Enablers and Constraints
Markets, Competition and Consumers
Science, Research and Technology

6.3.6 Community Production Sites

Social innovation applied to production will create new ways to organise production in cooperative ways at very local levels. Publically available production facilities will enable people to create objects at a reasonable price. In particular, communal 'labs' will offer individuals the access to 3D-printers and other flexible manufacturing machines as well as an open, collaborative space for grassroots innovation.

Main Agents of Change
Economy – Market Forces
Technology – New and Emerging Technologies
Society – Evolving Workforce and Culture

Main Enablers and Constraints
Markets, Competition and Consumers
Science, Research and Technology

6.4 Digital Factories

There has been a realisation that success in manufacturing often hinges on the ability to frontload information. An integrated approach that makes data available as early as the conceptual stage offers a significant potential for savings. In response to this the "digital factory", a network of digital models, methodologies, and applications used to integrate the planning and design of manufacturing facilities with the manufacturing process itself, has now become common place. This approach brings together all the available information, determines the basic constraints of the complete factory before detailed planning is undertaken, consolidates information in the final planning phases, and provides information for manufacturing operations. This is the only way to arrive at an optimal factory layout that supports the manufacturing process, optimises space, production, and logistic requirements, links with enterprise resource planning systems (ERP), and guarantees a high maintainability and profitability. The digital factory concept today focuses on an integrated planning process that includes product design, process planning, and planning of the manufacturing operation. Integration shortens the time and delay between these steps and unites the different planning groups. It offers dedicated tools and makes accurate and up-to-date information available to all of the project team members right at the beginning of the planning phase and throughout operations. Networking and distribution of data, models, tools and computer resources with support of cloud technologies make the production more flexible and responsive.

6.4.1 Digital Modelisation, Simulation and Visualisation

Based on the data sent by ubiquitous sensors in machinery and products across the supply chain (i.e. the 'Internet of Things') and thanks to advanced computational methods, digital modelisation and visualisation tools will enable the representation of all operations of the production process on a real-time basis. The 'digital factory' image of the factory will be used for simulation in virtual reality labs and optimisation of the production processes and the resource flows.

Main Agents of Change
Economy – Market Forces
Technology – New and Emerging Technologies
Society – Digitalisation of society

Main Enablers and Constraints
Markets, Competition and Consumers
Science, Research and Technology

6.4.2 Digital Engineering Tools

Digital tools will increasingly support the management and the optimisation of integrated product-process-production systems allowing the collaborative interaction of multiple stakeholders on a real-time basis.

Main Agents of Change
Economy – Market Forces
Technology – New and Emerging Technologies
Society – Digitalisation of society

Main Enablers and Constraints
Markets, Competition and Consumers
Science, Research and Technology

6.4.3 Factory Life Cycle Management

Firms will run "factories as products", applying and transferring concepts, methods and tools from product development to factory design. They will implement a more integrated, holistic and long-term approach to optimise the life cycle of their factories and enable their continuous, flexible, real-time adaptation to changes caused by new market demands, regulation or innovation. The complexity of factory planning and optimisation – due to multiple functions, stakeholders and interdependencies –will be addressed by simulating the 'virtual factory' and synchronising it with the real factory.

Main Agents of Change
Economy – Market Forces
Technology – New and Emerging Technologies
Society – Digitalisation of society

Main Enablers and Constraints
Markets, Competition and Consumers
Science, Research and Technology

6.4.4 Factory Data Management

Firms will aim at managing factory data along the whole factory life cycle so that it is continuously actual, consistent, non-redundant, shareable and suitable for system integration. Factory data management will include the identification, collection and structuring of all relevant data to the definition and representation of corresponding dependencies and semantic-based data description, thanks to digital libraries, technical documentation, standards, etc.

Main Agents of Change
Economy – Market Forces
Technology – New and Emerging Technologies
Society – Digitalisation of society

Main Enablers and Constraints
Markets, Competition and Consumers
Science, Research and Technology

6.5 Logistics and Supply Chain

Advances in, and integration of robotics, cloud computing, RFID (Radio Frequency Identification), GPS and telecommunication technologies within the supply chain have led to a further automation of the logistics and supply chain process. These developments have increasingly optimised time, cost and the environmental impact in the flow of materials, semi-products, products and waste. In addition, the integration of cooperation tools between companies within the same value chain allow for a better coordination of production activities and assure good process reliability, short delivery times, reduction of stocks and low production costs. Changes on the value chains have changed the nature of logistics and the supply chain in many cases; mass customisation and personalisation requires that product finalisation is being done close to the final consumer, so the majority of logistics and supply issues now address intermediate parts of the value chain.

6.5.1 Smart Logistic Tools

In their attempt to integrate more and more complex value chains and to deliver highly personalised products and services with high frequency renewal, companies encounter bottlenecks in establishing, optimising and managing the internal and external logistics within the supply chain. Consequently, they will increasingly rely on intelligent, automated and integrated logistic tools and solutions to manage a random mix production of different products and services, to improve overall performance and to meet increased customer expectation of quality and faster delivery.

Main Agents of Change
Economy – Market Forces
Technology – New and Emerging Technologies
Society – Digitalisation of society

Main Enablers and Constraints
Markets, Competition and Consumers
Science, Research and Technology

6.5.2 Asset Management

Companies will increasingly rely on asset tracking software enabling the real-time monitoring of materials and products to ensure their recovery and multi-level management.

Main Agents of Change
Economy – Market Forces
Technology – New and Emerging Technologies
Society – Digitalisation of society

Main Enablers and Constraints
Markets, Competition and Consumers
Science, Research and Technology

6.6 Holistic Design

The design of products and services and their related processes is a critical part of the production cycle as it sets the requirements and the limitations of the product development. It is also during the design phase that creativity is initiated and that competitive advantage is created. To be most effective, design has become holistic, taking into account the entire life cycle of products and services. This holistic approach, enabled by new design technologies also addresses all aspects of the product and services from the requirements of consumers, to their environmental impact and their cost. To enable this, the design process involves a wide range of stake-holders, from representatives of society, including NGOs, through to potential customers.

6.6.1 Design for User Well-Being

Firms will not only shift from a technology-based to a user-oriented approach that ensures that the product design answers the obvious needs of the customers. They will also try to optimise the user well-being in terms of comfort and safety through a multidisciplinary approach, combining modelling, behavioural science, health science, ergonomics, etc., and allowing a better understanding of the final product-service in use.

Main Agents of Change
Society – Increased Importance of Consumer Requirements and Behaviours
Economy – Changing Economic Norms and Values
Technology – New and Emerging Technologies

Main Enablers and Constraints
Markets, Competition and Consumers
Science, Research and Technology
People and Societal Values

6.6.2 Design for Sustainability

Firms will design products with their entire life cycle in mind in order to optimise their durability and to reduce the costs of recycling, recovery of trace elements, reuse and remanufacturing of spare parts, and waste disposal. 'Circular design' will focus on material selection and modularity among standardised components to facilitate disassembly. Design for sustainability will support a holistic approach aiming at reducing also the negative social and economic impacts of products and services.

Main Agents of Change
Economy – Changing Economic Norms and Values
Environment – Increasing Scarcity of Natural Resources
Society – Increased Impact of Societal Conscience

Main Enablers and Constraints
Markets, Competition and Consumers
People and Societal Values
Environment, Resources and Energy

6.6.3 Full Eco-Design Integration

Firms will extend the eco-design approach to every product (not only energy-using and energy-related products) to reduce their overall environmental impact (material consumption, water use, waste, noise, emission, etc.) throughout their life cycle. They will benefit from a better measurement of ecological footprints by integrating embedded sensors in the design of product-services.

Main Agents of Change
Economy – Changing Economic Norms and Values
Environment – Increasing Scarcity of Natural Resources
Society – Increased Impact of Social Conscience

Main Enablers and Constraints
Markets, Competition and Consumers
People and Societal Values
Environment, Resources and Energy

6.6.4 Cradle-to-Cradle Design

Firms will increasingly consider Nature and its ecosystems as a design model for maintaining sustainability without renouncing abundance. In particular, the use of organic materials and non-toxic, non-harmful synthetic materials which can be used endlessly in different cycles will help to reach a waste-free manufacturing system that can even protect and enrich ecosystems.

Main Agents of Change
Economy – Changing Economic Norms and Values
Environment – Increasing Scarcity of Natural Resources
Society – Increased Impact of Social Conscience

Main Enablers and Constraints
Markets, Competition and Consumers
People and Societal Values
Environment, Resources and Energy

6.6.5 Design for Performance

Firms will use virtual prototyping as a cost-efficient and increasingly fast way to model and test the performance of products that exist only as a CAD drawing. They will rely on multiple sets of design data and intelligent design models with strong predictive capabilities to enable concurrent engineering and experimentation.

Main Agents of Change
Economy – Market forces
Technology – New and Emerging Technologies

Main Enablers and Constraints
Markets, Competition and Consumers
Science, Research and Technology

6.6.6 Safety and Security by Design

Firms will seek to eliminate health and safety risks during the product design development, and will integrate safeguards to conform to privacy and security norms.

Main Agents of Change
Economy – Changing Economic Norms and Values
Technology – New and Emerging Technologies
Society – Changing Social Norms and Values and Ethical Issues

Main Enablers and Constraints
Markets, Competition and Consumers
Science, Research and Technology
People and Societal Values

6.6.7 UX Design (User Experience Design)

Firms will use user experience design that takes into consideration everything that affects a user's interaction with a product. And the business needs. It looks at the overlaps of the user and business needs. This practice allows considering user's needs at every stage process of the product life-cycle.

Main Agents of Change
Economy – Market Forces
Technology – New and Emerging Technologies
Society – Increased importance of Consumer Requirements and Behaviours

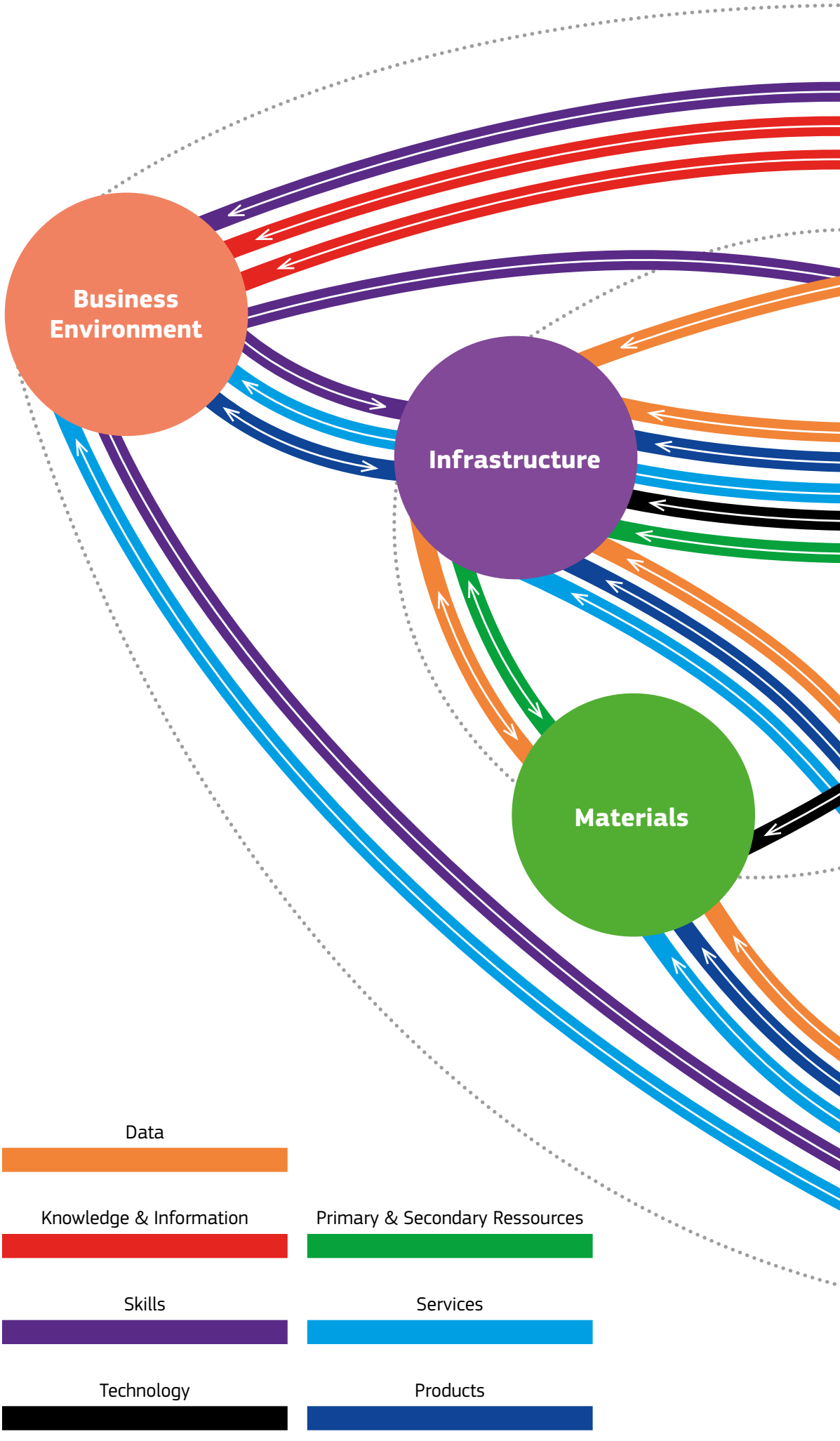
Main Enablers and Constraints
Markets, Competition and Consumers
Science, Research and Technology
People and Societal Values

Dynamics of the Industrial Landscape Vision 2025

One of the foresight workshops was dedicated to the dynamics of the Industrial Landscape Vision 2025 and identified the forces from the Agents of Change impacting the Production and Consumption System through the Enablers and Constraints (Cf. Figure 2), as well as the internal flows between the components within the Production and Consumption System (Cf. Figure 1).

This qualitative process helped understanding the high level of integration within the Industrial Landscape Vision 2025, which is particularly important when considering the needs for new standards.

Fig.1: *Sum-Up of the Flows between the Components of the Production and Consumption System*



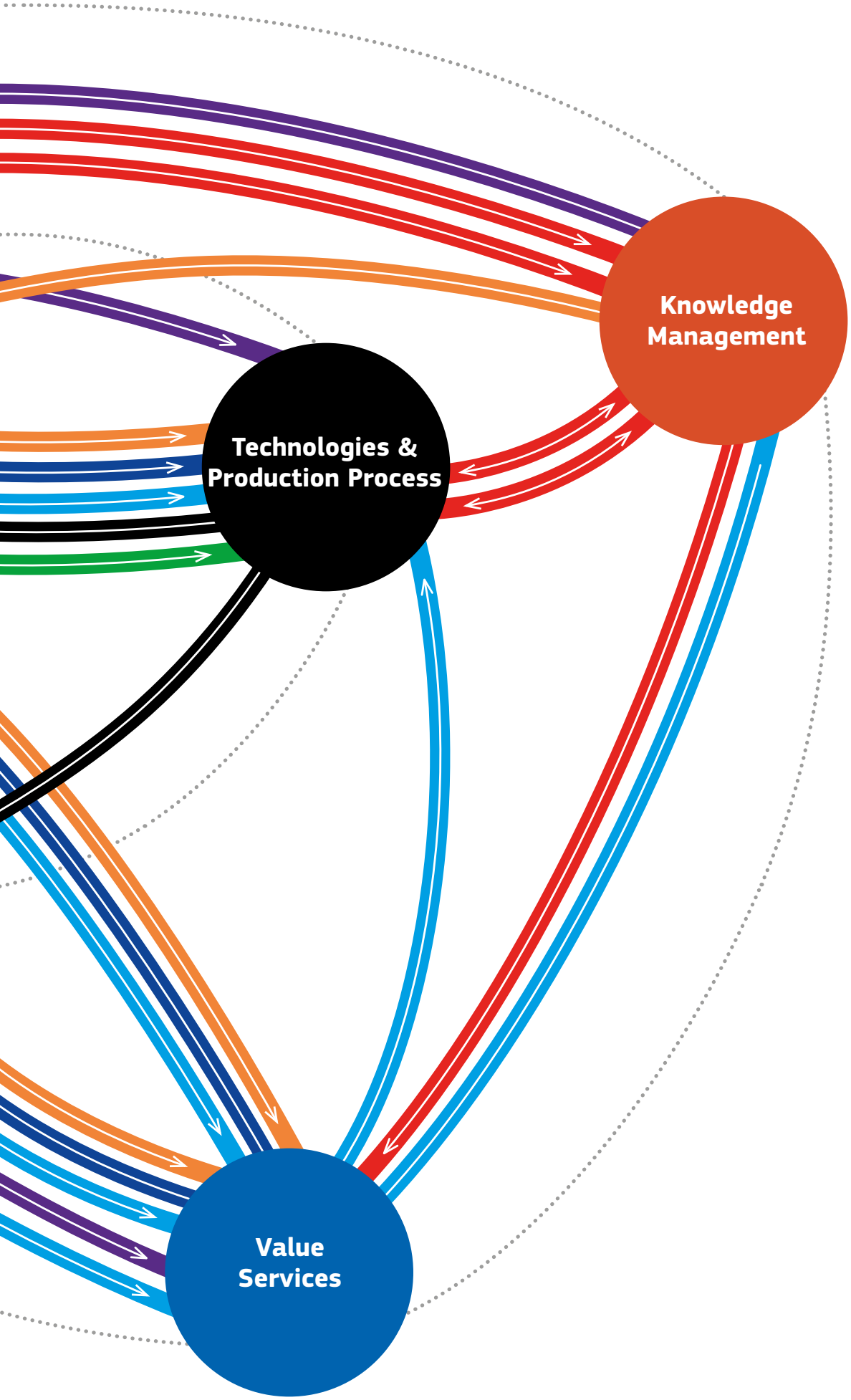
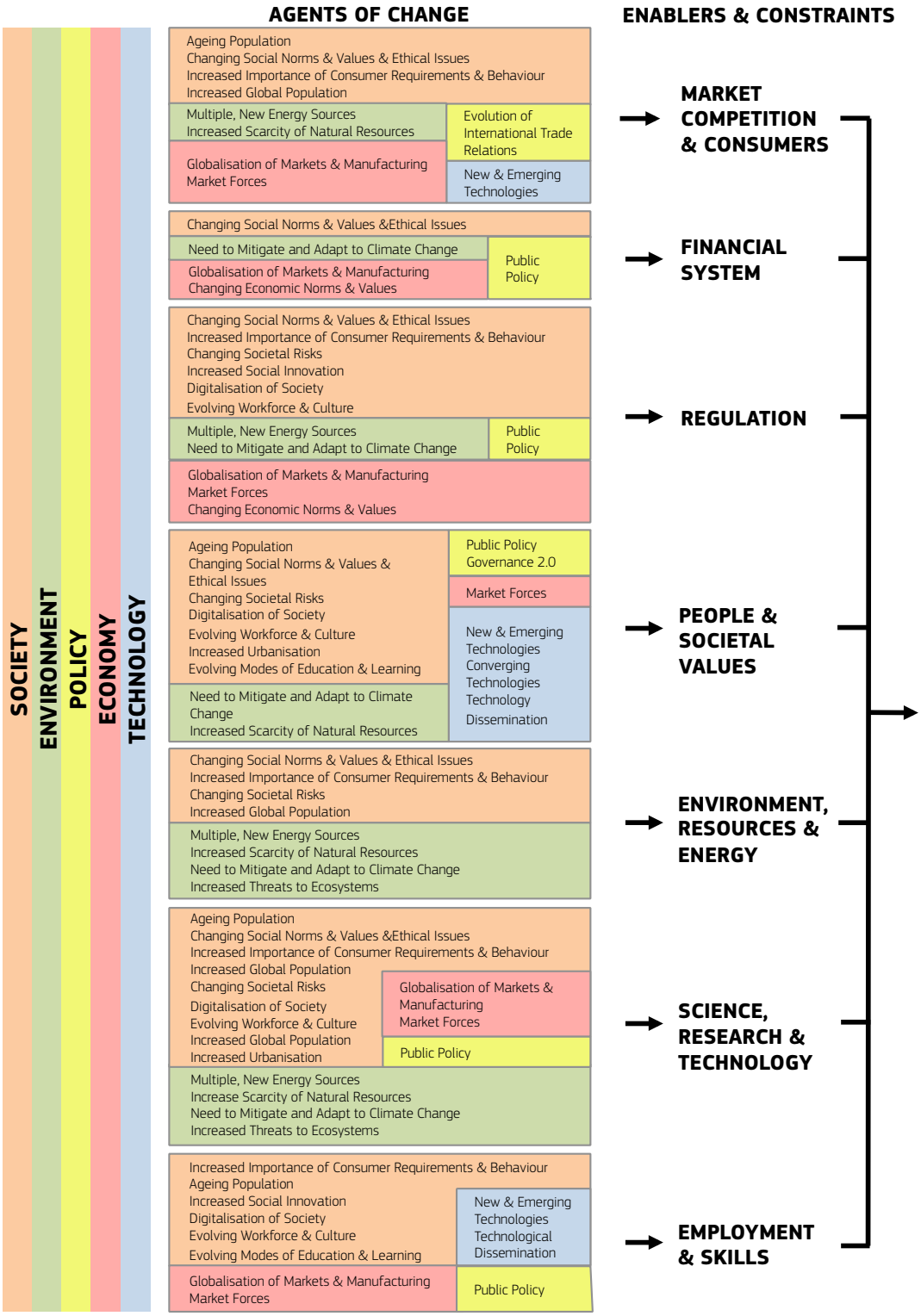

Knowledge Management
Technologies & Production Process
Value Services

Fig.2: *Sum-Up of the Forces from the Agents of Change to the Production and Consumption System*



PRODUCTION & CONSUMPTION SYSTEM

BUSINESS ENVIRONMENT

ICT for new business models
Global competition pressure
New sustainable business models
Push for new business models also to serve the ageing and global population
Globalised production systems and markets
Regulatory framework for ethical business environment and societal risks
New customer driven business environment with customers involved in the production processes
New business models emerge enabled by new, converging technologies and resulting in collaborative and social innovation
Shift in workforce structure (e.g. telework)
Broader and specific skillset for (fitting) business environment
Companies make strategic alliances with universities, research organisations addressing niche industries and specialised products
New business opportunities for recycling
Clustering of ecosystems/companies
New technologies enable easy access to manufacturing
Ethical issues influence business models
Corporate Social Responsibility
Effective use of talents

MATERIALS

Innovative new materials
Sustainable materials
Push for responsible sustainable use of materials
Skills for the development and use of advanced materials
Re-use and recycle of materials
Science for rare earth materials
Resource and energy saving materials
New advanced materials
Circular Economy

INFRASTRUCTURE

Market push for new infrastructure
Regulation pushes for new and upgraded smart energy infrastructure that is based on renewables
Size of public debt influences the investments on infrastructure
New community based social infrastructure
Increased infrastructure risks
Upgrade of the physical (i.e. energy, transport, water) infrastructure is a must
ICT Technologies enable interconnectivity of digital and physical infrastructure → this is the base for a possible industrial revolution
Improved global financial infrastructure, decreasing risks and lowering infrastructure costs
Six infrastructures to consider: knowledge, financial, water, energy, transport, and ICT

KNOWLEDGE MANAGEMENT

Security of (digital) knowledge
Demand on market intelligence to keep competitive advantages
Data protection assured by regulatory system
Increase of open access and open source knowledge
Comprehensive knowledge management across companies and workforce
Big data management tools / analytical techniques
Importance of creativity
New data capture tools (e.g. smart dust) to improve technologies and production processes and to improve marketing and sales
Data and knowledge interoperability
IPR and development of IP market

SERVICES

Shift from ownership to service (renting, leasing, using on demand)
Increased regulation for services
Demand for services to serve the ageing population
Increasing demand for interconnected products and services
Customised value services
Technology acts as an enabler for new services
Green services as a new industry

TECHNOLOGY & PRODUCTION PROCESSES

Advanced Manufacturing
Digital factories including advanced robotics (enabling agile and personalised manufacturing)
Factories lifecycle management
Boost of product personalisation
Production close to consumption and distributed across the production chains
Resource efficient production processes
Energy self-sufficient factories (supported by regulation)
Health & safety at work (e.g. robotics and ageing population)
Environmentally friendly production processes driven by consumers demand to mitigate climate change
Access to skilled workforce (e.g. also with the right skills to work next to robots)
Flexible engineer for holistic production approaches
Faster product cycle
Personalised production also away from traditional production lines
Modular production processes and re-use, recycle of parts
Production processes that save materials (e.g. additive manufacturing)
Globally connected production processes
Localisation of source materials
Real-time monitoring of globalised production chain
Regionalisation of production (e.g. different products for different regions)
Holistic design including for services
Smart logistics & smart asset management
Factories as good neighbours

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