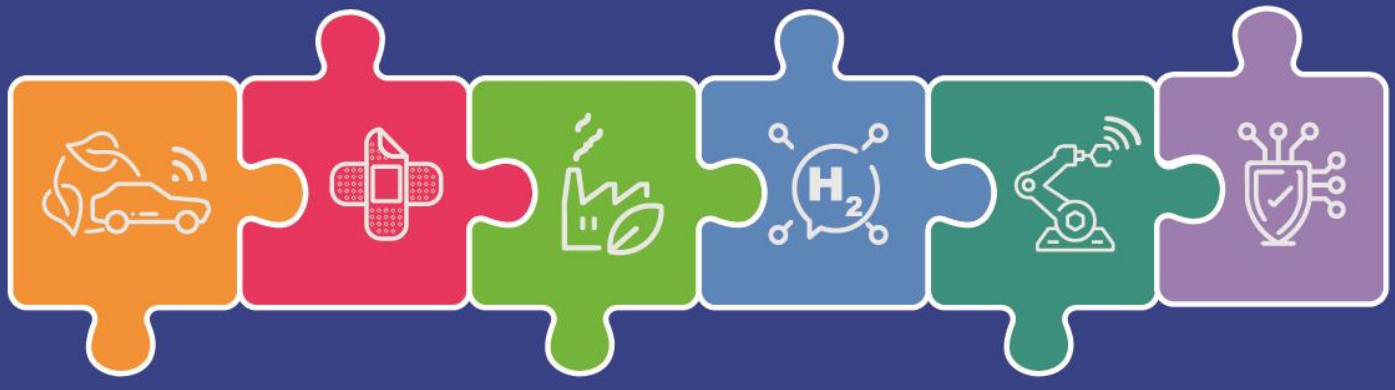
Strengthening Strategic Value Chains for a future-ready EU Industry

Report of the Strategic Forum for Important Projects of Common European Interest



Disclaimer

This report reflects collective views of the Strategic Forum; the recommendations do not necessarily represent the position of individual members nor the position of individual Member States or the European Commission.

About Strategic Forum for Important Projects of Common European Commission

This expert group was established by the Commission Decision C(2018)475 of 30/01/2018.
The Strategic Forum consists of 44 members representing Member States, industry and the research community.
More information about the expert group is available at https://europa.eu/!nT98kN

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Strategic Forum

Report

Foreword

European industry plays a vital role in shaping the life of our citizens and our society. Our industry has been crucial for creating prosperity and sustaining our social model. Today, it faces challenging structural transformations. Climate change, the degradation of our environment, the high pace of technological change as well as a more volatile geopolitical situation all form part of a new reality. Addressing these challenges and seizing the opportunities of the ongoing transformation requires new approaches and new solutions.

The European Commission aims at empowering our industry to adapt and to innovate. In 2017, the Commission issued a renewed Industrial Strategy for Europe with key actions for making our industry embrace innovation, digitalisation and decarbonisation.

The report of the Strategic Forum for Important Projects of Common European Interest is an important contribution to a common vision for the EU's industrial future. The Forum's role has been to provide the Commission with independent advice on how to strengthen Europe's industrial base by focusing on value chains of strategic importance. This approach allows us to reinforce Europe's competitive advantage and industrial leadership by focusing on our strengths and assets.

With participation from Member States, industries and research community, the Forum is an outstanding example of the new approach to industrial cooperation in Europe. My frequent discussions with ministers in the Competitiveness Council confirm the European added-value of this approach. Relying on national markets and instruments is not enough as they are too small and fragmented to pull weight on a global level; so Europe needs to join forces. We need to build cross-border industrial cooperation between EU, Member States and industrial stakeholders. We need to pull public and private resources across Member States to build critical mass. This pooling of resources will reinforce our industrial leadership and ensure the technological sovereignty and strategic autonomy of Europe.

The EU will play an important role in facilitating such strategic cooperation and overcoming coordination failures. Public support might be necessary to fill funding gaps for large innovation projects. EU state aid rules allow public funding, including for the first industrial deployment, for Important Projects of Common European Interest. At the same time, the EU will continue to support these efforts by removing the remaining barriers to our single market, promoting a broad approach to research and innovation; and ensuring the availability of a skilled workforce all around Europe.

Supporting industrial cooperation with strong European industrial players is not about picking winners or about the involvement of just a few companies. It is about an open and inclusive process that includes companies of all sizes from all EU Member States, covering a whole range of activities from research and development to manufacturing to other related services. Adhering to values of openness, transparency and fair competition is what makes Europe unique.

This is an important time for Europe's industries. I am convinced that the next European Commission will drive this work forward with leadership, vision and determination to make sure our industries turn these challenges into opportunities and create value to our citizens, our economy and our environment.

Elżbieta Bieńkowska, *European Commissioner for Internal Market, Industry, Entrepreneurship and SMEs*

Preface

The collection of recommendations in this report represents a collective contribution from the Strategic Forum; the recommendations do not necessarily represent the position of individual members nor the position of individual Member States or the European Commission.

This report has a twofold objective. First, it contributes to the analysis to be undertaken by the European Commission in view to develop a long-term vision for the EU's industrial future, with concrete measures for its implementation, , as requested by the European Council in March 2019. Second, the report represents an important building block for further actions in the context of the cooperation between Strategic Forum members, other stakeholders and the European Commission, with a view of ensuring that these strategic value chains will keep on contributing to the competitiveness of European industry and enhancing Europe's technological sovereignty.

Executive summary

The Strategic Forum on Important Projects of Common European Interest (IPCEI) is a high-level expert group set up by the European Commission in March 2018 and announced in the renewed EU industrial policy strategy a year earlier. This work complements the more horizontal reflections of the high-level Industrial Roundtable which called for a sustainable, inclusive and competitive transformation of Europe's industry by 2030. It also builds on successful examples of two existing initiatives on strategic value chains, where cross-border cooperation in Europe is already ongoing. These include the European Batteries Alliance and an IPCEI in microelectronics, an €8 billion investment project enabled by public support from 4 Member States.
The objective of the Strategic Forum, which consists of 45 members representing Member States, industry and the research community, was to identify key strategic value chains in Europe and propose a common vision for joint actions and investments between EU, Member States and industry. These strategic value chains are interlinked and integrated industrial activities with great potential to contribute to Europe's green and digital transformation and to improve Europe's industrial competitiveness. The Forum analysed several European industrial value chains and selected six strategic value chains where further joint and coordinated efforts are needed.

The identified areas have been prioritised on the basis of their potential impact on Europe's industrial competitiveness, climate ambitions, strategic autonomy and security as well as the willingness of Member States and industry to develop joint coordinated actions in each area.

The six identified key strategic value chains are:

- Connected, clean and autonomous vehicles,
- Smart health,
- Low-CO2 emission industry,
- Hydrogen technologies and systems,
- Industrial Internet of Things,
- Cybersecurity.

The report identifies enabling actions for six selected strategic value chains which range from joint investments, consolidation of Single Market through regulations and standards to development of new skills. It also calls for an agile governance process to monitor technological and industrial developments, to identify emerging strategic value chains and to monitor and evaluate the progress of work on these value chains. The Strategic Forum for the first time enabled regular exchange and cooperation among all stakeholders, including Member States and industry, in a type of setting that fosters cooperation and pools resources across several other value chains.

Turning the recommendations of the Strategic Forum into reality will require the continued support and investment by Member States and industry at all levels. The European Commission will play an important role in coordinating these efforts and ensuring coherence among actions and investments.

Vision for industry in Europe in 2030

Vision for industry 2030

"In 2030, European industry will be a global leader that will responsibly deliver value for society, the environment and the economy. By 2030, the EU will successfully become an innovative, sustainable, competitive and human-centred collaborative economy in an increasingly populated, resource-constrained and interconnected world. We will invest heavily in cutting-edge and breakthrough technologies, respect planetary boundaries and biodiversity, take leadership in smart European and global alliances, reinforce our global competitiveness and, last but not least, invest in current and future generations by addressing key societal challenges, providing innovative jobs in all regions and investing in new skills."[1]

This proactive vision set by the High-Level Industrial Roundtable "Industry 2030" shows the firm commitment of industry to take its share of the responsibility in dealing with current and future societal challenges and grasp opportunities that arise. The European industry – currently being a global leader – should continue to remain a global leader, responsibly delivering value for the society, the environment and the economy.

To successfully achieve this transformation, the EU needs a modern industrial policy around three strategic imperatives:

- Sustainable transformation
- Global competitiveness
- Social inclusiveness

This can be only be achieved by tackling challenges and seizing opportunities through an integrated approach addressing five interdependent drivers of success, defined by the High-Level Industrial Roundtable "Industry 2030", which should not be considered in isolation (figure 1). Strategic value chains (meaning, networks of interdependent and interlinked economic actors creating future added value around a product, process or service), as areas of strategic European interest for competitiveness and technological autonomy, will play an increasingly crucial role in fostering the transformation of the European industry through technology, innovation and sustainability.

[1] "A vision for the European industry until 2030", Final report of the Industry 2030 high level industrial roundtable, June 2019.

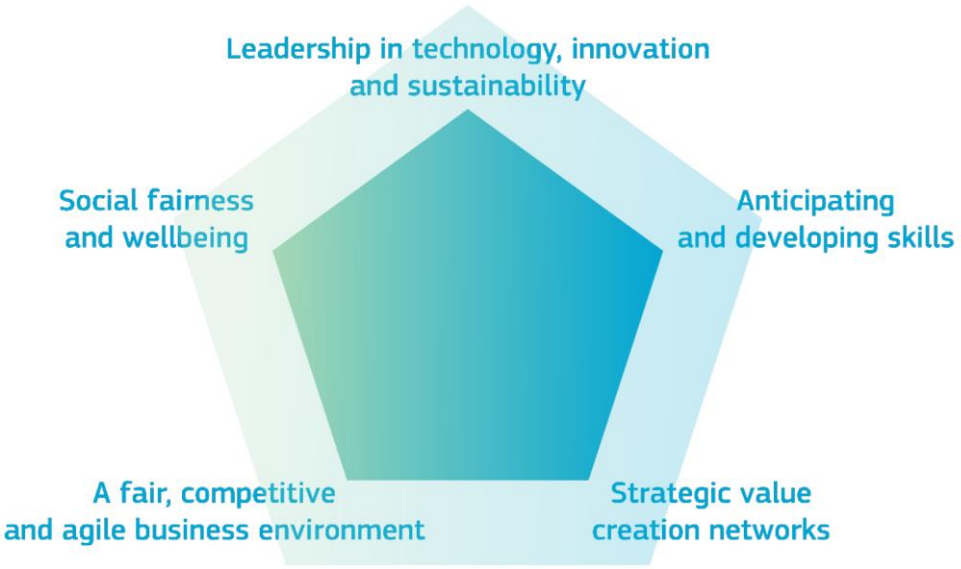


Figure 1. Five key drivers to achieve the Industry 2030 vision (Source: HLG Industry 2030)

Why is a more strategic approach needed?

The rise of climate, environmental and societal challenges and a fast-changing world in terms of technological development and geopolitical context are calling for an urgent change of mindset and behaviour. As the world's second largest economy, the EU can and must do better in tackling these challenges and seizing the related opportunities, and the time to do so is now.[2] Due to the complexities and the importance of scale, smart and strategic cooperation within and between Europe's key industrial value chains is of vital importance to reinforce our European industry's competitiveness for the longer-term future and to become the worldwide leader in sustainable development and finding solutions to societal challenges. Such strategic cooperation can in particular smooth the pooling of public and private resources at the critical phase of moving innovative technologies from labs to first industrial deployment and commercialization. The EU has a role to facilitate such strategic cooperation to overcome coordination failures. In addition, public support may be necessary to fill funding gaps to overcome market failures.

Climate, environmental and societal challenges and opportunities

Challenges such as climate change, the ageing population, food and water security, scarcity of natural resources or migration are putting growing pressure on our societies. The EU has the chance to lead the way in turning these challenges into opportunities. For example, the 2018 United Nations Intergovernmental Panel on Climate Change (IPCC) report[3] shows the urgency of the Paris ambition to limit global warming to 1.5°C. In this context, in November 2018, the European Commission

[2] See also "EU Industrial Policy after Siemens-Alstom", European Political Strategy Centre, 2019.
[3] http://www.ipcc.ch/report/sr15/

presented its strategic long-term vision on how Europe can lead the way to climate neutrality[4]. Reaching these ambitions requires massive industrial and societal transformations. Therefore, strong collaborative efforts within the EU are needed to empower industry to make its technologies and processes climate-neutral, while maintaining its long-term competitiveness. An agile and entrepreneurial mind-set in industry, public institutions and the entire society is crucial when transforming these challenges into opportunities, driven for instance by digitalisation, platform businesses or carbon-neutral and circular pathways.

Economic and geopolitical challenges and opportunities

The rise of emerging economies in the last decades, in particular China, has been impressive. While many emerging and quickly developing economies maintain an economy that is not yet sufficiently open, this entails new market opportunities for European companies, while at the same time result in ever-fiercer competition as other emerging countries move rapidly up the value creation ladder[5]. Ambitious industrial strategies, in some cases including unfair trade or other distortive practices or other market distortions, are placing firms of third countries in a strong position in the market. These third countries' strategies raise important questions with regard to the safeguarding of critical infrastructures, strategic access to key enabling technologies and raw materials in Europe, as well as civil rights and security in terms of data flows. At the same time, trade openness has benefitted the entire EU and therefore is and will always be one of the true European values. Trade tensions and unilateral actions threaten rules-based trade and the functioning of global value chains and put at risk standards and values defended by the EU in environmental and social issues, which are key to the EU.

Innovation and technological challenges and opportunities

Disruptive new economic actors challenge traditional industrial value chains. These new technology-intensive, data-driven firms are moving into industrial markets. Innovation creates entirely new markets of the future, challenging traditional sectoral approaches. Around the globe, traditionally strong industries find it challenging to compete with new tech-start-ups. The emerging champions in these areas tend not to be European, but rather American and, increasingly, Chinese. Innovation often starts on a small scale, e.g. when a new technology is first applied in the company where it has been developed. While many European firms are very innovative (for example 5 out of the top 10 companies in the New Energy Global Innovation index are from the EU), and operate in high-tech areas, many innovative firms have difficulties in scaling up their systemic presence. A well-functioning EU Single Market for all segments of industrial value chains will be crucial to create the framework conditions that allow innovation to spread across the EU economy and benefit regional and local communities and their companies throughout the value chain. The EU Framework Programme for Research and Innovation is the largest publicly funded research programme in the world. Public investment in R&D&I in the EU is on a par or higher than in the US and Japan. However, industrial deployment of innovation in Europe is still facing obstacles. For this to change, it is necessary to build

[4] COM(2018) 773 final

[5] In 2005, the size of the European economy, in current market prices, was more than six times larger than China's (EU 28: 11.6 trillion euro vs. China: 1.8 trillion euro). Today, China has all but caught up, with an economy worth 11.4 trillion euro, against 15.9 trillion for the EU28. Source: EPSC report "EU industrial Policy After Siemens-Alstom"/ European Commission and International Monetary Fund, World Economic Outlook

on existing capabilities with a more holistic approach that focuses on the critical stage from the lab to markets and makes finance available for scale-up activities. To make this happen, we need to work on attitudes and develop new models of collaboration.

Strategic value chains: a new approach to industrial policy

What are strategic value chains?

The term "value chain" is associated with both a set of interdependent economic activities creating added value around a product, process or service, and a group of interlinked economic actors, operating in a strategic network across firms **of different sizes, including SMEs**, sectors and borders.

Strategic values chains (SVCs) are of systemic importance and make a clear contribution to growth, jobs and competitiveness. They are characterised by the following three dimensions:

- **technological innovativeness**, i.e. the value chain is based on the exploitation of strategic key enabling technologies[6], technological breakthroughs, major outcome of R&D or disruptive innovation (e.g. autonomous driving, low carbon technologies).

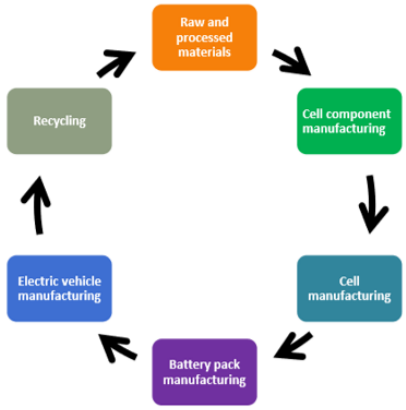
- **economic and market potential**, i.e. the value chain has considerable economic weight, actual or potential.

- **societal and political importance** for Europe, i.e. the value chain makes an important contribution to European societal challenges and/or policy goals (e.g. climate change, ageing population). The value chain is also instrumental to Europe's security and autonomy. In a world where more and more industrial processes are fully interconnected, certain key technologies need to be produced and intellectually owned in Europe to achieve a degree of technological independence for example in critical infrastructure, components or intellectual property sets in order to ensure economic security.

[6] Report from the High-Level Strategy Group on Industrial Technologies 'Re-finding industry' of 23.2.2018, http://ec.europa.eu/research/industrial_technologies/pdf/re_finding_industry_022018.pdf

An example: Battery Value Chain

The European battery value chain has been identified as strategic for the EU. Batteries are a **key enabling component** and will be **essential for the decarbonisation of the European mobility sector,** the transition towards a **climate-neutral economy** and, as well as for many other fields of applications. The future demand could reach a **European market potential worth up to EUR 250 billion annually** from 2050, according to EIT[7]. Therefore, European-produced batteries are expected to be a key driver for the EU's industrial competitiveness in a key industry for the future, supporting jobs and economic growth in enabling the transition towards a circular economy in Europe.



Thus, the European Commission is promoting a cross-border and integrated European approach covering the whole value chain of the batteries ecosystem, **starting with the extraction and processing of raw materials, the design and manufacturing phase of battery cells and battery packs, and their use, second use, recycling and disposal in a circular economy context**. Such an approach will promote the production and use of high-performing batteries and set sustainability benchmarks throughout the value chain and processed materials.

This Strategic Action Plan combines targeted measures at EU level including in raw materials (primary and secondary), research and innovation, financing/investment, standardisation/ regulatory, trade and skills development, in order to spur the competitiveness of European industry in the field of sustainable battery production and use, in line with the circular economy objectives.

In February 2019, the Strategic Forum selected a first set of six strategic value chains, for which this report includes recommendations for actions.

The six strategic value chains are:

- Clean, connected and autonomous vehicles

[7] European Institute of Innovation and Technology.

What are strategic value chains?

- Smart Health
- Low CO_2 emissions Industry
- Hydrogen technologies and systems
- Industrial Internet of Things
- Cybersecurity

The Strategic Forum has also recognised three additional strategic value chains – (i.e. batteries, high-performance computing and microelectronics) as of key importance for the EU. However, the Strategic Forum has not developed specific recommendations for these value chains due to already ongoing coordinated initiatives[8].

These strategic value chains were selected via a 3-step process:

1. Based on proposals from the Strategic Forum members, the Strategic Forum identified 31 strategic value chains (see annex), after an assessment of value chains along the above-mentioned three dimensions. (i.e., technological innovativeness, economic and market potential and societal and political importance).

2. These 31 strategic value chains then underwent a two-stage prioritisation process, which allowed to identify a limited number of the value chains with the highest potential for coordinated investments by Member States and industry.

3. In the first stage, value chains were prioritised based on their potential contribution to competitiveness and value creation, the existence of relevant European or trans-national initiatives, the contribution to Europe's autonomy and security, the contribution to the EU climate and energy targets, and the potential impact of coordinated action.

4. In the second stage, the final prioritisation was based on the commitment of the Strategic Forum members, taking into account evidence on the high-risk and capital-intensive nature of the value chain, the maturity level of the key technologies crucial for the value chain, the level and geographic distribution of industrial base supporting the value chain, the EU competitiveness.

These strategic value chains are all related to the two main drivers of industrial transformation – the transition to a climate-neutral economy and to a data-driven economy. They are directly linked to improving competitiveness, fighting climate change, and enhancing technological development.

[8] Namely the European Battery Alliance, the EuroHPC Joint Undertaking on High-Performance Computing, and the IPCEI in Microelectronics. As the technological, industrial and geopolitical reality in which the current IPCEI on microelectronics was conceived, compared to the context in which it is now being implemented, has drastically changed, the microelectronics industry is contemplating the set-up of an additional future IPCEI.

The objective of the Strategic Forum was to identify key strategic value chains that require joint or well-coordinated actions and investments. Therefore, the prioritisation has focused on the potential for coordinated action. The result of the prioritisation does not imply that the other strategic value chains originally identified are not of strategic importance.

What is this process (not) about?

The work on strategic value chains (SVCs) has been a new and transformative process at EU level. It is not about replacing but complementing on-going efforts of the EU to tackle societal challenges and to develop its industrial excellence. It is facilitating cooperation between EU, Member States and industrial stakeholders.

The concept of SVCs should not be confused with so-called Important Projects of Common European Interest (IPCEI), despite similar characteristics, objectives and selection criteria. The mandate of the Strategic Forum was to identify strategic value chains for joint or well-coordinated investment and action and to develop a joint vision for these strategic value chains. Therefore, the vision for SVC is following a much broader approach to strengthen industrial value chains, aiming at facilitating large-scale transnational innovation investments but also considering other actions needed. In this context, IPCEI is a special instrument under state aid rules[9] that can be used to strengthen the competitiveness of strategic value chains when it comes to new breakthrough technologies. The IPCEI instrument can also be used as a financing instruments for environment, transport, energy projects of strategic European importance. Public support may be necessary not only to overcome market failures, but also to unlock or leverage significantly higher amounts of private investments. Nevertheless, alternative or complementary financing which does not constitute State Aid can be made available, for example from the European Investment Bank (including the European Fund for Strategic Investments) or from centrally managed EU programs (e.g. Horizon Europe, Digital Europe Programme, Connecting Europe Facility, LIFE etc.)

The work of the Strategic Forum has been characterised by a proactive approach to identify SVCs, analyse them and understand the enabling conditions to make them grow (e.g. through an IPCEI or other means), as well as the barriers for expansion and further market integration. It is an inclusive process on EU level to coordinate efforts of Member States and stakeholders with a view to boost research, innovation and strategic autonomy in key value chains. It intends to improve industrial competitiveness and strategic autonomy and to meet major challenges ahead, such as the transition to a digital and safe, sustainable, climate-neutral and circular economy, strategic access to raw materials, and affordable energy prices.

By boosting, innovation, technological development and exploiting research results, as well as furthering excellence in education and training, this process aims to contribute to economic growth and to enhance competitiveness of the EU industry in strategic areas of the economy. Industrial leadership and strategic autonomy does not require autarky or closed European value chains.

[9] See Communication from Commission Criteria for the analysis of the compatibility with the internal market of State aid to promote the execution of important projects of common European interest (2014/C 188/02)

However, strategic autonomy requires avoiding critical industrial and technological[10] dependence from third countries. It is not about inward-looking national industrial policies, shielding sectors from marked developments nor about hampering free trade. Such inward-looking policies would only hurt Europe.

It is also not about picking winners nor about the involvement of just a few companies. Furthermore, the relationship between industry and services is changing fast and has become more and more intertwined. It is therefore important for the approach on SVCs to address the so-called servitisation of industry as well. This process should be inclusive in order to maximize positive spill-over effects. It must be open to all Member States and companies of all sizes. It will fully respect EU and Member States' international obligations, notably in the WTO framework. It is important that SMEs and start-ups are proactively included in the strategic value chains, as this will help them collaborate and scale up across the EU Single Market. The process is about the whole ecosystem of strategic value chains, covering the whole spectrum from research and development to manufacturing and related services. The idea is to pool all available resources –, both public (e.g., EU, national, regional, local) and private, and foster interdisciplinary, cross-sectoral and cross-regional collaboration. Hence, defining SVC and making recommendations to promote them deserves the broadest possible expertise and thus needs be driven in an inclusive manner between the European Commission, Member States and stakeholders.

The work on strategic value chains should not be a one-off action, but the starting point for a long-term process that will require an appropriate stable governance (see section 'next steps: permanent and high-level governance at EU level').

Cross-cutting recommendations - pooling available resources

A number of policies and instruments that already exist at EU, national and regional level could be mobilised in support of strategic value chains (SVCs). Depending on the features of each SVC, the needs might vary and therefore, hence the supporting policies and instruments as well, might vary.

Based on the lessons learned so far, this section outlines cross-cutting recommendations to support SVCs. It is structured around three main building blocks: a) pooling financial resources, including public (i.e., resources from EU funding programmes and national funding) and private investment, to facilitate large-scale transnational innovation investments; b) recommendation ensuring the best use of policies to strengthen strategic value chains; and c) taking a broad-based approach to research and innovation.

Building a critical mass by pooling resources and funding synergies

[10] "Rethinking Strategic Autonomy in the Digital Age", EPSC Strategic Notes, Issue 30, July 2019.

Public and private finance is often key for the strengthening of SVCs. The combination of public finance both at EU and national level, together with private investments, can be decisive to generate the direction, scale and speed of investment needed, notably in the case of market failures. Without concerted public and private investment in cases where markets alone cannot meet the demand for capital, Europe risks underinvesting in the large-scale deployment of innovative technologies in strategic value chains. Interregional, macro-regional and transnational dimensions are important for pooling the resources needed to fund the necessary investments in the SVC.

Depending on the capital needs, state of activities and R&D development in an SVC, a range of funding schemes at EU and national level can be mobilised in order to incentivise, leverage and/or 'de-risk' private investment. The support to SVC should build on an innovative approach, enabling multilevel funding synergies (regional, national, European), and the basic principle should be using public resources to leverage private investments in cases where private investment is insufficient. In the next Multiannual Financial Framework, the relevant funding opportunities include:

- The InvestEU Programme[11], bringing together all EU financial instruments, with relevant windows for research, innovation and digitalisation; sustainable infrastructure; small and medium-sized businesses; social, investment and skills.

- Horizon Europe Programme for research, development and innovation[12]. European Public-Private Partnerships (institutionalised, co-funded, and co-programmed) have proven to increase R&I investments around a commonly agreed long-term agenda and create cross-sector cooperation. They should therefore be closely involved in the process and strengthen research and development and the deployment of innovative technologies in the SVCs.

- Digital Europe Programme[13] for capacity building in key digital sectors such as cybersecurity and artificial intelligence.

- Connecting Europe Facility will support infrastructure projects and can be relevant for strategic value chains with infrastructure needs (e.g. autonomous mobility)).

- The European Structural and Investment Funds (ESIF) implemented in partnership with Member States and their regions. The bulk of the investments will go towards innovation, support to small businesses, digital technologies and industrial modernization and the shift towards a low-carbon, circular economy and the fight against climate change[14]. Often, these investment objectives overlap, increasing the added value of investments (e.g. innovative solutions to fight climate change).

[11] InvestEU is building on the success of the Juncker's Plan European Fund for Strategic Investments EFSI
[12] the European Research and Innovation Framework Programme for 2021-2027
[13] the first European programme for capacity building key digital sectors in 2021-2027
[14] European Regional Development Fund ERDF, European Social Fund ESF, Cohesion Fund, European Agricultural Fund, European Maritime and Fisheries Fund

Lending facilities from the European Investment Bank can complement funding from EU, national programmes or other sources to reach the needed scale for innovation and deployment projects.
In addition to those funding programmes financed under the next EU long-term budget, the EU Innovation Fund and the Modernisation Fund, established under the EU Emission Trading System Directive, will support the demonstration of low-carbon technologies and processes in energy intensive industries, environmentally safe carbon capture and utilisation and storage of carbon dioxide, innovative renewable energy and energy storage technologies[15].

Making the best use of policies to strengthen strategic value chains

Single Market without barriers

The EU Single Market offers opportunities for both businesses and consumers and is the cornerstone of the economic development of the EU. However, there are still many barriers within the single market due to missing implementation and enforcement of existing EU law. These barriers are a constraint for the full development of EU industrial value chains. Therefore, more could be done to strengthen the further integration of the market in all segments of industrial value chains (i.e. goods, services, energy and data) and ensure a level playing field through a uniform and effective enforcement of the Single Market rules.

In particular, services are increasingly important to the EU economy as an integral part of industrial value chains. Moreover, the manufacturing and services sectors are increasingly intertwined as this brings value to the solution developed. Therefore, removing the remaining barriers in the Single Market for services will help EU manufacturing firms to improve their competitiveness.

Norms and standards can help to reduce uncertainties for industry and avoid fragmentation within the Single Market.

Coherent EU-wide public procurement rules are an important achievement of the Single Market. Especially innovation procurement can be an effective measure not only to satisfy the primary needs of public entities, but also to promote innovative solutions and new business opportunities for industries along an SVC, in particular in markets with substantial public procurement activities such as public transport, health or security.

Ensuring the availability of a skilled workforce

The availability of the right skills is crucial for the future competitiveness of European industry. This is true for companies of every size, in all parts of the value chain and concerns every level at the

[15] EU's Emissions Trading System to deliver EU's commitments under the Paris Agreement and the vision of a climate-neutral Europe by 2050

company. Based on a comprehensive mapping of the skills needed along the value chains and means to fill the possible gaps, involved stakeholders should cooperate to define short-, medium- and long-term actions.

In the implementation of smart specialisation strategies, especially in terms of SVCs, actions should be taken to ensure the availability of a skilled workforce in the regions. The European Social Fund can be used by the regions to address the skills need related to strategic value chains. The Blueprint for Sectoral Cooperation on Skills and the European Centres of Excellence are relevant initiatives to address the skills gap that may prevent promising strategic value chains from growing. Also, EIT[16] Knowledge and Innovation Communities can support the specific training needs that could emerge. The integrated use of those instruments should be explored at SVC level.

Actively promoting a global level playing field

SVCs are important for Europe but they operate in a global environment. For strengthening European SVCs, a global level field is vital. This includes the modernisation of international trade rules and a stricter enforcement of existing trade agreements and rules, in particular through the WTO dispute resolution system or through corresponding commitments in bilateral trade and investment agreements. Moreover, in order to protect technologies and infrastructure that are critical for the functioning of SVCs, we should make full use of instruments available to address potential distortive effects of foreign state ownership and state financing by third countries.

Alleviate the process for permits

In light of the fast-changing world, the window of opportunity to act in support of a strategic value chain is often narrow. Therefore, it is important that on-the-ground activities develop as fast as possible while respecting existing legislation. Where appropriate, ways to reduce the administrative burden, notably by accelerating procedures for permits or licences, should be explored in order to avoid unnecessary delay in the development of certain parts of an SVC.

Taking a broad-based approach to research and innovation

Strengthening of ecosystems

European industrial innovation policy should be developed in parallel with the development of a **European research and innovation ecosystem approach,** to ensure that companies of all sizes, in collaboration with all relevant actors, can be part of open innovation, embracing transformative change.

Special focus should be given to dynamic industrial innovation ecosystems, connecting with place-based competence centres for development, testing and scaling-up of new technologies. Connectivity

[16] European Institute for Innovation and Technology

and collaboration will be key in establishing the EU as a region for transformative research and innovation in the global scene.

Ensuring access to state-of-the-art technology infrastructures

Access to state-of-the-art technology infrastructures is increasingly important for companies to stay ahead in global competition.[17] However, companies often do not have enough information about possibilities for accessing technology infrastructures, especially across borders. It is clear that SMEs with limited resources and low absorption capacity are in the weakest position concerning access to technology. There is a critical momentum for the EU together with Member States to be more ambitious, exploring with relevant national and regional stakeholders a shared vision and jointly developing a European strategy for technology infrastructures to support industry scale-up and technology diffusion across Europe[18].

Technology infrastructures require high investment both in the set-up and in the keeping up with the state-of-the-art. Most technology infrastructures rely upon a mix of private and public (national and EU) funding, but it is a challenge to ensure their long-term financial sustainability. Business models with a long term vision are needed. A new PPP model for setting up technology infrastructures should be explored.

The role of technology infrastructures should also be more visible in national innovation policies across the EU. Creating networks of demonstration infrastructures linked to the competitive advantages of regions[19] could also help to maximise the use of existing technology infrastructures all over the EU and to avoid duplication.

Building on regional strengths

It is important to promote the cluster policy work, ongoing in many regions, and to strive for joint cluster initiatives and inter-regional coordination in the design and implementation of smart specialisation strategies in terms of SVCs. Parallel to efforts in regions, dedicated programmes are needed to explore the full potential of inter-regional collaboration. Novel approaches are needed for inter-regional innovation projects to strengthen SVCs. It is necessary to develop further the interregional and cross-border dimension by creating interregional investment opportunities. Member States should therefore incentivise national, regional and local efforts towards such purposes. Member States and regions can give a real boost to industrial innovation ecosystems by aligning their smart specialisation strategies with SVCs.

In order to maximise the interregional innovation potential of the regions, it is recommended to create synergies between the proposed European Territorial Cooperation Regulation[20] and other EU

[17] SWD on Technology Infrastructures
[18] Technology Infrastructures Commission Staff Working document SWD(2019)158 final
[19] See Smart Specialisation policy initiative: https://s3platform.jrc.ec.europa.eu/what-is-smart-specialisation-
[20] Component 5, proposed under the European Territorial Cooperation Regulation, can contribute to accelerate the cooperation dynamics and to unlock the innovation potential that is present in EU regions.

programmes (e.g. Horizon Europe) directly managed by the EC or managed by national and regional authorities (e.g. ERDF).

Building on experience gained in European Partnerships

European partnerships in the Horizon 2020 Programme (e.g. contractual Public-Private Partnerships, Joint Undertakings, and Knowledge and Innovation Communities) involve broad research and innovation communities: companies, Research and Technology Organisations, universities, and in many cases regional/national authorities. These partnerships have developed common views on challenges and opportunities through research and innovation to develop European competitiveness. This work needs to be taken into account and integrated in the work on strategic value chains to maximize impact and avoid any duplication, responding to the needs and opportunities. There are also several national/regional programmes aligned with European partnerships, thus increasing the possibility to leverage efforts and investments.

In the next MFF (2021-2027), Horizon Europe sets a new framework for partnerships[21] with industries, which should have systemic effects beyond research and innovation projects and thus have a strong potential to strengthen strategic value chains.

Regions have an important role to play mobilising public and private stakeholders willing to cooperate in the validation and deployment of innovative technologies. Co-investment in innovation deployment and acceleration of the development of SVCs should be stimulated.

Specific recommendations to the instrument of IPCEI

There are situations where the market alone cannot deliver efficient investment outcomes. This is particularly the case for innovative, cross-border, ambitious and complex projects, which involve a high degree of technological, financial or market risks, require coordination and cooperation among multiple operators within a value chain, and generate positive spill-over effects beyond the investors. These projects often entail significant risks, which private investors are not willing to assume by themselves. In such cases, public support from several Member States working together may be necessary to overcome the market failures and fill the funding gap so as to allow the projects to see the light of day. At the same time, public funding could significantly stimulate/leverage additional private investments, which would otherwise not have taken place.

In this respect, the state aid rules for IPCEI can provide an opportunity to overcome existing market failures while leveraging private investments while ensuring that the level-playing field in the internal market is not distorted.

What is an IPCEI?

[21] Horizon Europe distinguishes between three types of European Partnerships: Institutionalised, Co-funded, and Co-programmed.

The notion of IPCEI is enshrined in Article 107(3) (b) of the Treaty, which provides that "aid to promote the execution of an important project of common European interest" may be considered to be compatible with the internal market. The IPCEI Communication[22] provides guidance as to the criteria for the assessment of public financing of IPCEIs. For a project to be eligible as an IPCEI[23], it is required that: (i) it contributes in a concrete, clear and identifiable manner to one or more EU objectives and has a significant impact on the competitiveness of the Union, sustainable growth, addressing societal challenges or value creation across the Union; (ii) it involves several Member States working together to design an integrated large project; (iii) there is co-financing by the beneficiaries; (iv) the benefits are not confined to the financing Member States, undertakings or sector(s) concerned, but to the whole European economy or society through positive spill-over effects. In addition, for a project to qualify as an IPCEI, specific criteria should also be met. In particular:

- R&D&I projects must be of a major innovative nature or constitute an important added value in terms of R&D&I in the light of the state of the art in the sector concerned.
- Projects comprising of first industrial deployment must allow for the development of a new product or service with high research and innovation content and/or the deployment of a fundamentally innovative production process.
- Environmental, energy or transport projects must either be of great importance for the environmental, energy, or transport strategy of the Union or contribute significantly to the internal market.

If the European Commission finds that the aid is necessary, proportional and transparent, and that its negative effects in terms of potential to distortion of competition and effect on trade between Member States are limited, and outweighed by the positive effects, it may declare the aid compatible with the internal market. In such cases – and where justified by the funding gap analysis – the aid can cover up to 100% of the funding gap based on a large set of eligible costs. The aid can also cover the critical phase between R&D and mass production, namely the first industrial deployment, i.e. the upscaling of pilot facilities and the testing phase.

Where it allows for the development of a new product with high R&D&I content or of a fundamentally innovative production process, the aid may cover the costs for the first industrial deployment, i.e. the critical phase of upscaling or ramping up of the first demonstration or pilot line, which includes the upscaling or first-in-kind equipment and facilities during which significant research and development work is still necessary.

Although the IPCEI concept is not new, it has only recently been applied for a technology innovation integrated project in microelectronics.[24] A case-by-case assessment is needed, in particular as to what makes a project truly "integrated", constitutes an R&D&I project of "major innovative nature" and how positive spill-over effects can be satisfactorily demonstrated.

[23] Under the IPCEI framework, it is possible to have single projects or integrated projects

[23] Under the IPCEI framework, it is possible to have single projects or integrated projects

[24] Commission decision of 18.12.2018, *IPCEI on Microelectronics*, State aid SA.46705, (France), SA.46578 (Germany), SA.46595 (Italy) and SA.46590 (United Kingdom), not yet published.

Specific recommendations to the instrument of IPCEI

A few key learnings can be derived from the IPCEI on Microelectronics.

- First, openness to all Member States, to demonstrate their interest already at an early stage, and to companies (i.e., selection by the participating Member States via open tenders or open calls) is essential.
- Second, the European Commission, together with the Member States should be involved in the design phase of an IPCEI as early as possible. The Member States, on their part, should intensely cooperate and coordinate with each other in building up the overall project.
- Third, an "IPCEI-specific" approach, which depends on the specificities of the project and the technologies involved, needs to be followed.
- In addition, the use of templates and standardised project portfolios can prove helpful to facilitate both the notification process and the scrutiny by the Commission. Member States, on their part, need to thoroughly and accurately prepare and screen all individual company project documents.

High-Level meetings serve to ensure good coordination, set the timing, monitor progress and keep the pace of the project.

At the same time, many stakeholders are not yet sufficiently familiar with the novel concept of IPCEI. Therefore, more transparency, clarity, simplification and hands-on guidance is needed about the IPCEI framework and the notification process, both for industry and Member States.

Recommended actions

- Transparency & guidance: Ensure transparency, clarity and hands-on guidance about IPCEI rules and the notification process, both for Member States and industries.

- Inclusiveness: Make the formation/design phase of the IPCEI inclusive to all Member States and companies of all sizes, and ensure that the results of an IPCEI are available to the wider European industrial ecosystem. I

- Funding: provide the possibility for such integrated projects to be financially supported not only through national resources and Structural Funds, but also through central EU funding programmes.

- Efficiency: Ensure efficiency of proceedings and speed of decision-making process, especially in projects where the window of opportunity to gain or regain a competitive advantage in terms of innovation is limited in time.

Next steps: a permanent and high-level governance at EU level

Setting up a permanent and high-level governance at EU level should be explored to monitor strategic areas, promote effective cross-value chain collaboration and suggest improvements to the framework for Strategic Value Chains. It should ensure a strong coordination and cooperation process between governments and the private sector. The European Battery Alliance has shown the value in mobilising and bringing together actors along a whole value chain, enabling joint investments and a shared view of challenges and opportunities.

The window of opportunity for successful deployment of technologies is typically at the interface between applied research and commercialization. Therefore, an agile governance process is needed to monitor developments vigilantly and identify the need for action early on. The work that has been carried out so far in close cooperation with stakeholders should be also applied to other strategic value chains when appropriate, in order to embrace the pace of innovation. Thus, it needs to be sufficiently agile to react on changing framework conditions or strategic needs, with the mandate e.g. to propose coordinated action in new value chains when they become strategic and phase-out work streams on value chains that are not strategic anymore or that require adaptations of the action plan. An evaluation and monitoring governance involving Member States and stakeholders ought to be set up for each of the value chains.

It is important to have strong political leadership on each of the value chains. For example, an assignment of a value chain alliance or action plan to the Commissioner in charge of the strategic value chain, as it has been the case with the first IPCEI on microelectronics and now the European Battery Alliance, could enhance its visibility and strengthen the cross-sectoral implementation of action plans.

Next steps: a permanent and high-level governance at EU level

Specific recommendations for key Strategic Value Chains

Clean, connected and autonomous vehicles

The automotive industry and the related value chain is crucial for the prosperity of the EU[25]. The EU is among the world's biggest producers of motor vehicles and the sector provides jobs for 12 million people (3 million in manufacturing, 4.3 million in maintenance and 4.8 million in transport) and accounts for 4% of the EU's GDP. Additionally, the automotive industry has an important multiplier effect on the economy, being important for steel and other metals, chemicals and textile industries, as well as industries such as ICT, repair, and mobility services[26].

The global automotive industry is at the forefront of one of the largest changes in the domain of mobility. Combinations of new technologies and services will have a large impact on mobility in the coming years. They will likely have great implications for the European industry and economy.

The transition to clean, connected and autonomous vehicles (CCAV) is driven by the sustainability objectives adopted at EU and international level[27] , technological progress and anticipation of future consumer demand. It will require huge investments in R&D on all the vehicle components, on charging and connection infrastructures, on the road system, on vehicle and infrastructure maintenance, on the end of life of vehicles and components, and mobility services. Action will also be necessary to adapt the skills of current and future employees, the definition of new business models and shared standards.

This new type of mobility brings challenges for Europe, but also offers opportunities to keep European automotive industry at the forefront.

CCAV offers a huge potential to boost Europe's economic and innovative power and helps to maintain its technological and market competitiveness by defining technical standards, e.g. concerning data protection, implementing European technology roadmaps from R&D&I to production, sustain employment and increase key enabling technology skills in education.

To support the sector's transformation, the following recommendations for action are based on proposals submitted by over 100 organizations, over the period March/May 2019.

Vision 2030

[25] https://ec.europa.eu/growth/sectors/automotive_en

[26] GEAR 2030 Strategy 2015-2017 - https://publications.europa.eu/en/publication-detail/-/publication/24c9ad0e-da38-11e7-a506-01aa75ed71a1/

[27] E.g. Paris Agreement on Climate change

The recommendations for action are designed to reinforce the "Clean, Connected and Autonomous Vehicle" (CCAV) value chain in Europe, with the following key five strategic objectives in mind:

Competitiveness → Strengthen the global competitiveness of European CCAV value chain

- Increase competitiveness of the EU industry for CCAV products and services.

Footprint → Reduce the negative health and environmental externalities of mobility in Europe

- Reducing air pollution (CO_2, fine particles, other emissions), noise, visual pollution, utilisation of public space consumption of resources
- Further improve safety of road transport to reduce health and mobility externalities
- The footprint is measured on a life-cycle basis and/or from "well to wheels", using an assessment connected to product-category rules

Independence → Increase European strategic autonomy in CCAV

- Reduce critical dependence on foreign products, raw materials, technologies,
- Succeed in having competitive EU suppliers in all important parts of the CCAV value chain,
- Ensure access to key raw materials,
- CCAV data managed responsibly with EU interest in mind.

Leadership → Achieve European leadership in key areas of CCAV

- Achieve leadership in key technologies

User experience → Enhanced mobility experience for all EU citizens

- Mobility is to become cheaper, safer, less time consuming, more enjoyable & comfortable, more accessible to all EU citizens and residents.
- Mobility as a service (MaaS) allows seamless, comfortable, affordable, safe on demand point-to-point transport all over Europe
- High level of public embrace for CCAV technologies and services

Specific recommendations

Considering the scope and complexity of the CCAV value chain, the Strategic Forum has collected a large number of detailed recommendations (the full list of which can be found in the Annex). On this basis, the report focuses on recommendations in two areas:

- **Coordinated Investments:** 11 proposals for coordinated investments in the areas of on-board components, infrastructure and applications.[28]
- **Related supporting actions:** five areas of actions that would be required and useful to support the development of the CCAV value chain

Coordinated Investments	
On-board components	1. New generation high-efficiency electric motors
	2. High-power inverters based on wide-band gap semiconductors
	3. Hydrogen system for vehicles (storage + fuel cells)
	4. Next generation tyres for connected, clean and autonomous vehicles
Infrastructure	5. High power charging stations
	6. Vehicle-to-grid
	7. Hydrogen refuelling stations
Application specific initiatives	8. Sustainable road transport ecosystem for heavy freight logistics
	9. Boost the adoption of clean and autonomous buses by municipalities
	10. Digital infrastructure to enable big data analytics and advanced AI for connected and autonomous driving
	11. Connected autonomous driving in real conditions
Related supporting actions	
Transversal	12. Boost the development of the CCAV ecosystem with an "Accelerator Network" and a dedicated Investment Fund
	13. Accelerate the creation of a common European CCAV market through harmonization of frameworks, platforms and policies
	14. Encourage the transition to CCAV by end users and fleet operators with public policies, procurement, guidelines and incentives

[28] These proposals are supported by a total of 26 industry stakeholders, of which 19 industrial players and 7 industry associations and RTOs.

	15. Support industrial deployment of new CCAV technologies
	16. Develop a highly skilled workforce in all parts of the CCAV value chain

Coordinated Investments

1. Develop new generations of high-efficiency electric motors

For the long-term competitiveness of the European clean vehicles value chain, it is important to develop new generations of powertrains (including new generations of key components such as battery, fuel cell system, electric motor, and power electronics) which improve performance, reduce costs, and reduce need for critical raw materials. This applies especially for mass transport (buses, coaches, ships, trains…) and heavy-duty vehicles. For this objective, it would sustainable processes should be defined along the whole value chain (including reuse, repair and recycling) as well as Life Cycle Analysis and eco-design.

The objective is to allow mass market production of clean powertrains for electric vehicles with optimised performance for passenger cars and heavy-duty vehicles. For passenger cars the following criteria could be used:

- high-speed motor performance,
- reduction of use in critical raw materials (e.g. rare earth),
- transmission optimization including new materials and surface treatment
- life cycle analysis, waste reduction in production and reuse, repair and recycling potential,
- regenerative braking,
- integrated power electronics and battery management systems
- improve simulation tools and production method for overall powertrain and individual component design

Recommended actions[29]

- Support development of clean powertrain technologies and their deployment in the European vehicle fleet
- Support investment of car manufacturers and suppliers in the deployment of most recent powertrain technologies such as those demonstrated in Horizon 2020 projects in mass production of clean vehicles.

[29] See action R7 in the annex

2. Develop new generations of high-power inverters based on wide-bandgap semiconductor technology[30]

Technological improvements are enhancing the electrical efficiency of high-power inverters, which take power from the batteries or fuel cells, convert it and inject it into the electric motors. More efficient inverters allow higher mileage for a given energy source or a reduction or battery/hydrogen-storage size for the same mileage. High-efficiency inverters can mitigate the issues associated with batteries (availability, disposal and cost) and increase the mileage autonomy of electric vehicles, thereby addressing major obstacles to the proliferation of clean vehicles. The European industry should coordinate investments across the full value chain (substrates, components, inverters) with the support of Member States and EU institutions, to deploy inverters based on compounded silicon components, maximize their electrical efficiency and ensure a competitive cost structure. The mainstream technology is silicon carbide (SiC) inverters, and a possible emerging technology is gallium-nitride (GaN) inverters.

The use of wide-bandgap materials is expected to reduce the volume and weight of the power modules used in vehicles. At system level, such an improvement in efficiency will lead to less cooling effort resulting in the smaller physical size of the system.

This new technology has an impact on the whole value chain, including additional components (like capacitors) or packaging processes and materials. In the past ten years, all packaging materials have changed and with the arrival of these new semiconductor components, it is expected that this trend will continue.

The European industry should, therefore, coordinate investments across the full value chain (substrates, components, power modules, appropriate driver devices and sensors) with the support of Member States and EU institutions, to deploy power modules based on compound semiconductor components, maximize their electrical efficiency and ensure a competitive cost structure

3. Hydrogen system for vehicle (storage + fuel cells)[31]

The European Union has identified hydrogen and fuel cells as a key enabler to fight CO_2 emissions, to reduce dependence on hydrocarbons and to contribute to economic growth. The main challenge for large-scale deployment of hydrogen as a clean fuel for transport is the initial cost.

The hydrogen tank is an important component in a fuel cell vehicle and has a direct impact on costs and safety. Existing solutions for on-board high-pressure hydrogen storage are still not mass-produced and therefore expensive. The European industry with public support should increase investments aiming at mass production of cost competitive high-pressure hydrogen storage for mobility applications.[32] The increased funding should be directed towards both the R&D effort

[30] See action R46 in the annex.
[31] This section concerns on-board components in clean hydrogen vehicles. Other coordinated investment needs are covered by the Hydrogen technologies and systems strategic value chain.
[32] See proposal R38 and R50 in the annex.

required to further develop such solutions, first industrial deployment and the capital expenditure required to move to mass production.

The key component in a fuel cell vehicle is the fuel cell itself. European companies are frontrunners in fuel cell technologies, but there is increasing innovation and deployment activity in Asia coupled with considerable potential for volume and market adoption. In order to maintain leadership in innovation, a coordinated industrial scaling-up initiative must be set up with the support of key EU RTOs and industrial players, together with Member States and EU institutions.

4. Next generation tyres for connected, clean and autonomous vehicles[33]

Future tyres of CCAV will have to be capable of meeting the outstanding challenges set by the technological evolution towards electric vehicles and autonomous vehicles. Electric vehicles will require specifically designed tyres, with excellent performance in terms of rolling resistance, noise, load capacity and grip. Moreover, there is a lack of knowledge by vehicles' on-board systems (e.g. Advanced Driver Assistance Systems, ADAS) of the actual forces exchanged between tire and asphalt to be used as a primary control input. Therefore, autonomous vehicles will require sensors on the tyres able to read and monitor the road condition. This will greatly improve the preventive safety system of vehicles, compared to current reactive actuation based upon chassis kinematic features. Beyond the individual vehicle safety, the objective should be to exploit the vehicle-to-vehicle communication as well as vehicle-to-infrastructure communication. This would allow drivers to use the valuable information provided by the tyres of other vehicles for an improved total mobility safety and comfort. Moreover, the new tyres will have to be clean not only as far as reducing road transport emissions (including emissions of tyre dust) are concerned but along all the supply chain: from raw materials to manufacturing processes up to refurbishment, end-of-life disposal and recycling.

Recommended actions

- Develop more "green" and clean tyres, making more use of materials with a low impact on non-renewable resources and with reduced tyre dust.
- Manufacture tyres with digitalised low energy consumption processes
- Develop new tire structure for electric vehicle, i.e. lighter and suitable to bear higher loads - batteries are heavier than combustion engines - but have at the same time lower rolling resistance to reduce battery energy use and noise emissions);
- Develop new tyres that are able to provide information to the vehicle system (full integration with ADAS) on the working conditions of tyres (vertical load, wear, etc.) and on the boundary condition (road condition/temperature, etc.)

[33] See also R55 in the annex.

5. Large-scale deployment of high power charging solution in collective buildings and public areas[34]

High power charging is difficult in terms of financial sustainability as well as crucial in terms of mass-market consumer acceptance. Therefore, large-scale deployment of cost-effective charging stations in urban areas and national/international roads is a key requirement for the mass-market uptake of electric vehicles in Europe.

High Power Charging (HPC) stations today are capital-intensive projects with more than EUR 500,000 investment per site.

For fuel cell vehicles, deployment of large-scale hydrogen refuelling stations is a key requirement to develop the sector, especially for heavy-duty vehicles. More on this topic is covered in the section on Hydrogen technologies and systems.

Large-scale deployment will require improvements in terms of technology:

- a significant reduction in the cost of HPC sites, e.g. below EUR 200,000;
- a large European industrial base to drive this cost reduction;
- modular architecture of the HPC site including the possibility to integrate storage;
- high level of quality with adequate certification

EU-based manufacturing at scale is needed to drive European industries' leadership in the most important charging segment within the e-mobility mass market. Furthermore, in order to minimize operating expenditures in the first years of operation with low or non-existing utilization rate, dedicated tariffs at Medium Voltage with no fixed grid charges would be appropriate, including the possibility to benefit from stationary storage coupling and the provisioning of grid services depending on the utilization rate.

Such a project requires the collaboration between utility companies, regulators, vehicle OEM/suppliers, charging station manufacturers, electrical equipment manufacturers, EU and national institutions, infrastructure funds, and construction/installation companies.

Recommended actions

- Animate a medium-term (2 to 5 years) European cooperation project in order to identify the best technical solutions to be developed, financially supported and deployed.
- Design of new electric vehicle chargers fully integrated in ecosystems with active loads to be optimized, renewable and storage

[34] More details on this recommendation can be found in the Annex – R53 and R23

- Certification: creating of a dedicated quality standard with certification & training programs for Innovative Charging Stations Technologies (bidirectional, wireless, etc.) to ensure also full compatibility with new electric vehicles coming into the market

- Review the Directive for Alternative Fuels Infrastructure (2014/94/EU) and ensure an ambitious implementation of the Energy Performance in Buildings Directive to facilitate the deployment of intelligent charging infrastructure

- Introduce a transitional support scheme to encourage early adoption of intelligent charging solutions for electric vehicles and allow the market to grow until it becomes economically attractive without support

- Finance the market uptake of High Power Charging systems in extra-urban environment coupled with innovative Stationary Storage Systems, in order to smooth the impact on the power grid.

- Test and develop pricing schemes to align interests and share the value creation between utility companies, infrastructure operators and fleet operators, vehicle owner/user, and vehicle manufacturers evaluating also if there could be an impact on the life of the battery. Coordinated investments in large-scale manufacturing of intelligent charging stations: ensure interoperability across EU, improve functionalities, and reduce costs.

6. Deploy vehicle-to-grid on a large-scale in Europe[35]

The massive deployment of electric vehicles in the coming years will increase interactions between transport and energy infrastructures. The deployment of equipment enabling smart management of a bi-directional exchange of energy between the vehicle and energy systems (vehicle-to-grid, V2G) can contribute to meet energy policy goals. The capacity storage of electric vehicles connected to the grid could provide the power system with additional flexibility to enable higher penetration of local renewable energy sources at a lower cost, to increase the security of supply and to reduce the use of carbon-intensive imported fossil energy. It is also an opportunity for vehicle users to reduce the cost and the footprint of their energy consumption. To sum up, V2G is an important asset for Europe i) to provide secure, competitive, and sustainable energy and ii) to foster the decarbonisation of transport while protecting the purchasing power of EU citizens and businesses.

Developing and building first pilot lines in support of future large deployment of V2G across Europe (KPI: 1 million V2G systems by 2030) would foster this promising emerging industry by overcoming remaining technical, economic, commercial and social challenges and by promoting stronger cooperation required between EU industrials from the energy and the transport sectors.

Recommended actions

[35] More details on this recommendation can be found in Annex – R20

- Deploy a large-scale pilot program to deploy DC vehicle-to-grid charging systems equipped with off-board bidirectional AC/DC chargers and ICT components to manage bi-directional exchange of energy between the vehicle's battery and energy networks infrastructures.

- Consolidate technical standards and create dedicated V2G certification program to control it.

- Test and develop pricing schemes to align interests and share the value creation between utility companies, infrastructure operators and fleet operators, vehicle owner/user, and vehicle manufacturers considering the impact on the reduced life of the battery.

- Coordinate investments in large-scale manufacturing of bi-directional charging stations to ensure interoperability across EU, improve functionalities and reduce costs.

- Finance schemes to help municipalities, transport authorities, fleet operators to equip in V2G charging stations.

7. Deploy hydrogen refuelling stations on a large-scale in Europe

Description

Hydrogen refuelling infrastructure should enable circulation of fuel cell vehicles across EU. This requires significant expansion of current network of refuelling stations

Recommended actions

Detailed recommendations are in the section for the strategic value chain for hydrogen technologies and system.

8. Sustainable road transport ecosystem for heavy freight logistics

Global freight demand will triple between 2015 and 2050 from 112 000 to 329 000 billion tonne-kilometres[36], based on current demand pathways. Road freight traffic is forecast to grow substantially in most countries.

Using high capacity vehicles could accommodate some of this growth. Improving the efficiency of road logistics will also benefit other transport modes. High capacity transport has potential to save human lives, money and lower CO_2 emissions: according to a recent ITF/OECD study, switching to high capacity transport solutions could result in 27% CO_2 savings and lower accident rates. Clean, connected and automated trucks are part of the global transport systems. The integration of the vehicles with new logistics services, harmonised traffic management on the European roads has the potential to drive transport efficiency.

[36] ITF/OECD forecast

While road freight transport is a fundamental component in the integrated freight transport system, it is also a relevant contributor to greenhouse gas emissions. Significant technology investments in innovation are needed to reduce its impact on the environment. While manufacturers are starting to offer clean trucks for urban and regional distribution, it is necessary to further support research and deployment of alternative drivelines and clean technology for long-haul transport as these applications represent the bulk of greenhouse gas emissions from road transport activity. Fuel cell electric vehicles represent an excellent clean alternative (zero tailpipe emission) due to the high energy density of hydrogen compared to battery electric vehicles, the heavy payload. The range is being improved (400-500 km today). The main challenges are storage space, but the industry is currently working to develop well fitted on-board storage tanks. Another challenge is the lack of refuelling infrastructure.

A sustainable integrated road freight transport system can be achieved by combining in the most efficient manner, the following elements:

- cleaner vehicles with the most efficient utilisation of capacity
- innovative technology for high-level of automation
- sensors to monitor and control the area surrounding the vehicle and the vehicle-road interface
- systems for vehicle-to-vehicle and vehicle-to-infrastructure communication
- interaction with logistic and generic service providers
- cooperation with inter-urban and urban traffic management systems

Recommended actions

- Support the EU-wide circulation of high-productivity trucks (longer and heavier transportation, aka EMS combinations), s by developing performance-based standards for both vehicles and road infrastructure (to be also included in EU regulations on high-productivity vehicle) and possibly a scheme for intelligent access to infrastructure[37]
- Support the digitalization of all haulage operations (including docking, cargo loading and unloading, refuelling…) to enable automation in all phases of transport mission
- Investigate new logistic business models related to platooning/autonomous vehicles
- Develop clean powertrains for heavy freight vehicles
- Coordinate platooning with similar projects concerning passenger cars

[37] See more details in annex R47

9. Boost the adoption of clean and autonomous buses by municipalities

Europe must decarbonise its transport sector if it intends to fulfil its commitments under the Paris Agreement. Public transport is a perfect use case for large-scale decarbonisation due to the captive nature of the fleets (geographical concentration, regular services) and the role of Public Transport Authorities in the management and renewal of both vehicles and infrastructure.

In addition, Europe benefits from a strong and innovative industry supplying public transport. Bus suppliers, tramway suppliers, and electrical infrastructure suppliers all have been historically very competitive, if not global leaders in their respective fields. Technological solutions are thus now reaching a high level of maturity. Accordingly, in 2018 Europe has set itself ambitious targets in the Clean Vehicles Directive, mandating Member States to ensure that a sizeable portion of their public transport fleets is made of clean vehicles by 2025.

However, various third countries have since some years identified clean vehicles and electric buses in particular as a cornerstone of their industrial policy. Through a combination of market access restrictions, mandatory investments and subsidies, they have built an industrial footprint which due to its scale has a significant competitive advantage.

Therefore, coordinated European support to the transition to clean and autonomous public transport, from innovation to mass deployment would ensure that Europe decarbonizes its transport sector while preserving its industrial leadership.

Recommended actions

- Provide medium-scale procurement programs for deployment on the market (>100 buses per projects, 10 000 in total by 2025) for mature technologies[38]
- Provide small-scale pilot programs for research (>10 buses per projects, 1 000 in total by 2025) for innovative technologies (autonomous, wireless charging, other solutions…)
- Provide funding for R&D for clean and autonomous buses.
- Certification: create a dedicated quality standard with certification & training programs.
- Coordinate investments for first industrialisation of innovative clean and autonomous buses, with a roadmap to reach EU manufacturing capabilities of 50 000 per year by 2030
- Introduce a transitional subsidy scheme to encourage early adoption and allow the market to grow until it becomes economically sustainable.[39]
- Create financing schemes to help Public Transport Authorities to finance the switch to clean/autonomous buses.

[38] See more details in annex - R54.
[39] See more details in annex – R6

- Support best practices and twinning exercises between municipalities[40]

- Support the review of the Directive on Alternative Fuels Infrastructure – hydrogen to become a mandatory target

- Support the review of the Industrial Emissions Directive – the concept of "chemical conversion on an industrial scale" should be defined in a manner which excludes the production of hydrogen via electrolysis in small quantities

- Develop an appropriate regulatory framework to allow the deployment of fully autonomous buses

10. Digital infrastructure to enable big data analytics and advanced AI for connected and autonomous driving

Coordinated investments to support European solutions in big data (navigational database) and in advanced AI could accelerate development in connected and autonomous driving in Europe. Joining efforts in developing a database for high definition maps and advanced AI for autonomous driving, taking advantage of new sources of data coming from Galileo and LIDAR sensors, would avoid dependencies on foreign mapping data and AI technologies. It would be more effective than dispersed small-scale initiatives that may eventually be overtaken by global giants.

European technology leadership will require better coordination and collaboration between small and dispersed EU players. As a result, European citizens could benefit from a highly performing infrastructure and databases (mapping, autonomous driving…) respecting the EU regulatory framework. The deployment of 5G as well as a high-capacity HPC developer in EuroHPC Joint Undertaking will play an important role.

The main challenge to the development of AI in autonomous driving is not the technology itself or the computing capacity, but access to large sets of real data. Foreign competitors such as Alphabet benefit from large data pools. In Europe, it is necessary to consolidate data sets and build up capacity and create appropriate digital infrastructure. An ecosystem of companies needs to support the Original Equipment Manufacturers (OEMs) in the development of AI with access to a large set of real data.

Recommended actions[41]

[40] See e.g: European Clean Bus Deployment Initiative

[41] More detailed information on concrete actions in annex:
Define common standards to increase interoperability and competition along each layer of the MaaS value chain in Europe – R14
Define in-vehicle data access rights and security level requirement including for maintenance purpose (e.g. battery, localisation) – R22,
Develop secure platforms for CCAV data sharing (storage and communication) – R49,
Develop and upgrade Intelligent Transport Systems (ITS) for CCAV – R3.

- Develop and apply a secure and cost-effective European digital infrastructure and back-end. This digital infrastructure could, for example, tackle challenges such as the massive amounts of data generated by CCAV as well as common European interfaces for infrastructures like traffic lights, traffic and transport management.42

- Develop and deploy connected and autonomous driving communication and data infrastructure

11. Deploy connected and automated driving on a large scale in real road conditions

Human error continues to be the main reason for road accidents. Perfectly aligned with the European initiative to reduce road deaths to almost zero by 2050, "Vision Zero", Connected and Automated Vehicles is a field of innovation of common European interest since it has significant potential to contribute to reduce the risk for human errors and improve the protection of vulnerable road users. Furthermore, connected and automated vehicles also can contribute to the European strategy of clean and energy efficient vehicles. Avoiding traffic congestion through optimal traffic guidance and vehicle routing as well as less energy-consuming search for parking spaces has the potential to reduce emissions. Additionally, CCAV will provide new and better mobility services to citizens, increasing inclusiveness and improving rural mobility. CCAV will also enable increased freight transportation and help the logistics sector meet the increasing demand for goods transportation in Europe.

The industry, the Member States as well as the European Commission have already made strong efforts to enable excellent research concerning Connected and Automated Driving through dedicated funding schemes. This support of the European industry is crucial in order to maintain its standing as innovation leader despite the strong international competition from especially China, Japan and the US, where large-scale funding of CCAV is already a reality. Recent examples of European projects funded by the European Commission aim at bringing together the considerable expertise of the European automotive sector include testing and demonstration projects.[43]

However, in order for the full benefits to be achieved, the results of such projects need to be deployed. The deployment phase can establish and validate the economic and societal impact of higher-level automated driving functions in real road conditions, i.e. with mixed traffic scenarios and real (prototype) passenger or freight vehicles. This is critical to ensure the functionality of systems and technologies as well as to guarantee the required safety and reliability.

Coordinated investments are necessary in order to leverage the huge costs for a) R&D for crucial automated driving components and systems, b) homologation and c) the required digital infrastructure (e.g. roadside units, cloud and computing backbone). The development, testing, deployment and sharing of common core systems, components and standards will allow the European industry to remain competitive.

[42] See more details in Annex – R31
[43] L3Pilot and ENSEMBLE

Through the European Commission's 5G Public Private Partnership, the EU supports three 5G cross-border corridor projects for large-scale testing of connected and automated mobility. These 5G corridors make Europe currently the biggest experiment area in 5G technology for connected and automated mobility. Building on this existing initiative, it is recommended to go one step further, beyond deployment of 5G infrastructure, to deployment of the various connectivity and autonomous driving capabilities, both on-board and in the infrastructure, as well as generating and collecting massive data about actual automated driving in real conditions.

Recommended actions

- Ensure large-scale verification, validation and deployment of advanced automated driving systems and services for vehicles and fleets, embedded in mixed traffic scenarios in a selected number of countries, corridors or regions (potentially geo-fenced).[44]
- Scale-up from demonstrator vehicles to large-scale pilots to speed-up deployment with thousands of automated vehicles to secure expected impact on the road system, drivers, users and society.[45]
- Develop a common policy and instruments for connected & autonomous transport[46].

Related supporting actions

12. Boost the development of the CCAV ecosystem with an "Accelerator Network" and a dedicated Investment Fund

It is important to encourage vertical and horizontal collaboration and sharing of best practices in order to boost the European CCAV ecosystem. To this end, a network of accelerators open to all European stakeholders and players in CCAV should be created, incl. national and regional technology clusters, industrial players, SMEs, start-ups, universities and RTOs, industry associations, private equity funds, incubators, industry experts. This "Accelerator Network" would support centres focusing on entrepreneurial CCAV initiatives in clusters of emerging CCAV industry, academic excellence and a conducive entrepreneurial culture.

CCAV companies need financing to scale and to improve competitiveness. A dedicated investment fund could support the Accelerator Network, finance start-ups, and develop a platform for match-making between CCAV players and investors. The European Innovation Council pilot under Horizon 2020 provides new financing opportunities in that context.

In addition to financing CCAV companies, the fund should have a proactive role on the demand side, financing the massive investments required for replacing or upgrading current mobility equipment (infrastructure and vehicles) with CCAV. The fund can develop financing products designed to

[44] See more details in Annex – R52
[45] See more details in Annex – R25
[46] See more details in Annex – R3

encourage transitions to CCAV by making it economically attractive for municipalities, fleet or infrastructure operators and end users.

Recommended actions

- Create a dedicated fund for CCAV within the European Fund for Strategic Investments[47]
- Design and implement a specific platform aiming to facilitate match-making between CCAV companies and private investors
- Create a "CCAV Accelerator" network of regional technology clusters ("CCAV Valleys"), based on a mapping of existing networks and initiatives[48]
- Create dedicated strategic funding programs to help SMEs in CCAV in support of SME growth, cross-national collaboration and market consolidation in Europe.[49]
- Develop and deploy "soft-financing" tools and programs that can bridge the funding gap between research and large scale industrial deployment[50]

13. Accelerate the creation of a common European CCAV market through harmonization of frameworks, platforms and policies

The development of CCAV in Europe will require a continued effort to harmonise regulatory frameworks, standards, certification and the various technological bricks so that a system designed and licensed to operate in one country can be deployed all the other EU countries. This harmonisation and compatibility is essential to develop a single EU market with the critical size to be at the forefront of technological development.

A seamless level of interoperability with Mobility as a Service (MaaS) requires common European standards for each aspect of the underlying solutions, incl. communications, charging, booking, payment. The EU CCAV ecosystem should allow interoperability and competition along each MaaS layer, incl. booking apps, fleet operators, infrastructure operators, energy providers, OEMs, tier 1 suppliers.

To gain widespread acceptance of autonomous driving, safety issues must be resolved satisfactorily. Full transparency of safety regulations for autonomous vehicles is needed to assuage public concerns. To this end, the regulatory framework needs to provide common standards for safe autonomous

[47] More details in Annex – R6
[48] See more information in Annex R51

[49] More details in Annex - R39.
[50] "Soft financing" refers to all the interventions that favour the development of companies through the granting of public facilities. These are financial instruments that are made available on more advantageous conditions than the traditional ones, to support the investment and development of enterprises and associations, through different types of subsidies. More information in Annex R8

vehicle operations. Industrial players need clear liability rules to clarify their legal liabilities in case of accidents.

Recommended actions

- Establish a common regulatory framework for CCAV[51]
- Enhance the certification process of CCAV[52]
- Define common standards to increase interoperability and competition along each layer of the MaaS value chain in Europe[53].
- Openly share data and information, while enforcing existing privacy regulation and standardization measures, in a platform open to all stakeholders and all transport modes.
- Coordinate ongoing testing of connected and automated mobility in accordance with the Single European Platform for Connected and Automated Mobility.
- Develop common standards for communication interface, data connection and storage between vehicles and users (infrastructure, customers) as a basis for governance of communication data flows
- Develop an open and interoperable booking and payment solution, based on standards
- Create a European agency for CCAV and MaaS (Mobility as a Service)[54],
- Introduce economic incentives for clean mobility and logistics for consumers/professionals + public procurement for heavy-duty vehicles[55].

14. Strategy to encourage the transition to CCAV by end users and fleet operators with public policies, procurement, guidelines and incentives

Europe must use all levers to encourage end users and fleet operators to switch to CCAV in order to gain all the expected environmental, societal and consumer benefits.

Based on a growing number of municipalities launching tenders for new CCAV solutions, best practice recommendations for municipalities could be developed. Funding support could be provided to municipalities (or other procurers) when following these guidelines.

Recommended actions

[51] See annex recommendation R19
[52] See annex recommendation R26
[53] See annex recommendation R14
[54] See annex recommendation R27

[55] See annex recommendation R42

- Create an EU “bonus/support” scheme for clean vehicles (for the end user, and for transport authorities[56])

- Boost European research funding for CCAV through DARPA-style research focusing goals and excellence.

- Introduce some level of risk sharing between the municipality, operators, technology providers, and end users[57],

- Separate infrastructure operators, vehicle fleet operators and booking platforms to ensure competition and specialization at each level, and facilitate transition from one operator to another[58].

15. Strategy to support the industrial deployment of new CCAV technologies

Description

A large-scale transition to clean and autonomous mobility will require not only major technological improvements but also substantial cost reductions to make these new solutions commercially attractive. Financial incentives such as public subsidies can help in the short term to overcome market failures, but market forces must drive the transition in the long term. Some technologies are reaching maturity and required public funding to move towards industrial deployment, but may not be sufficiently

Recommended actions

- Develop and deploy "soft-financing" tools and programs that can bridge the "funding gap" between research and large scale industrial deployment[59]

- Create common standards, interfaces & architectures for vehicle electronics.

- Support competitive industrial production of battery packs

16. Develop a highly skilled workforce in all parts of the value chain

Description

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[56] See „Introduce economic incentives for clean mobility and logistics for consumers/professionals + public procurement for heavy-duty vehicles” in Annex

[57] See „Establish guidelines and incentives for innovative procurement by municipalities and transport authorities for deployment of CCAV solutions” in Annex

[58] See „Establish guidelines and incentives for innovative procurement by municipalities and transport authorities for deployment of CCAV solutions” in Annex

[59] See „Strengthen research and innovation funding for CCAV with greater coordination and "soft-financing"” in Annex

The automotive value chain is at the edge of transformation with the quick development of new technologies for clean, connected and automated mobility. This will have a substantial impact on the skills needed to stay competitive However, workers in the automotive value chain are not necessarily skilled for these new technologies today. . This represents also an opportunity for workers to cope with the transformation with re- or upskilling. In order to allow for a just and efficient transition, it is therefore important that the needs of the EU automotive value chain in terms of skills and competencies are well identified and that appropriate curricula and reskilling programs are developed accordingly.

Recommended actions

- Launch a sector skills alliance that will implement the Blueprint in CCAV.
- Develop a platform that provides insights into the current and needed skills capacity, per Member State
- Help universities and other education training institutions to build new CCAV courses/degrees
- Establish CCAV apprenticeships and training centres
- Set up a special e-training program and professional certification in the CCAV

Smart Health

Description and scope

Whilst there is no single definition of what constitutes Smart Health, it essentially refers to the development of smart (usually digitally aided) solutions to improve the way healthcare solutions are delivered. Smart Health products and services are expected to lead to faster, better and more personalised healthcare with better health outcomes and improved wellbeing. Digital and biotechnological developments in areas such as health data analytics, artificial intelligence, cloud computing, mobile and portable devices, sensor technology, robotics, augmented and virtual reality, synthetic biology, 3D printing and nanotechnology drive the Smart Health value chain.

For the purposes of this action plan, we define Smart Health as blending healthcare and digital technologies, digital media, mobile devices and biomedical engineering. Health data and data analytics have become the key 'currency' in the stream of healthcare that radically improves the way healthcare is provided. The development of Smart Health industries depends heavily on the availability and quality of the underlying data infrastructure, 'big data' analytics and ICT solutions to generate the required knowledge and support innovative healthcare solutions. Therefore, the Strategic Forum has put health data in the centre of this action plan.

Nevertheless, it is important to understand that the Smart Health Strategic Value Chain is about more than health data alone. Health data is essential for enabling research and development as well as the deployment of Smart Health products and services. These Smart Health products and services rely on additional technologies and their application. The annex does contain numerous examples showing the complete value chain. However, the availability of health data is an essential starting point for building a sustainable Smart Health value chain in Europe.

Health data and data analytics includes the collection of data through electronic health records, patient registries, bio-based and connected health devices, as well as (open) data-driven infrastructure, data sharing platforms, big data and AI-based analytics. Health data means validated medical data that can include health records, clinical trials, patient outcomes, real-world data and data generated by CE-marked medical devices.

However, it is important to be aware of the specific nature of the healthcare sector and its various stakeholders. A large variety of healthcare providers provide healthcare services within national health systems. These healthcare services are paid for either through insurance schemes or public single payor systems, depending on the national health system. Healthcare payors and healthcare providers are usually subject to regulation or supervision by national health authorities and national regulatory bodies. Industry usually will provide Smart Health products and solutions to healthcare providers, who again depend in their purchasing decision on healthcare payors and/or health authorities and health regulators. The successful development of the Smart Health value chain, therefore, depends on the interaction of all these stakeholders at national and European level.

Contribution to EU strategic goals

Good health and well-being is one of the Sustainable Development Goals[60] and timely access to affordable, preventive and curative healthcare is a key principle of the European Pillar of Social Rights. Nevertheless, Europe's healthcare systems face serious challenges such as ageing, workforce shortages, the rising burden of preventable non-communicable diseases or growing threats from infectious diseases[61]. At the same time, all this has a huge cost as spending on healthcare grows fast and accounts for 9.6% of GDP in the EU as a whole (2017)[62]. In this context, a paradigm shift is needed towards proactive and responsive health care systems, where maintenance of good health is the prime focus instead of disease management.[63] Fundamental to the paradigm shift is the availability of continuous health monitoring data from both clinical and citizen/patient generated sources as well as strategic and multidisciplinary collaboration between citizens/patients, researchers, healthcare and medical professionals and firms of different sizes.

The impact of Smart Health technologies concerns diverse fields such as preventive medicine, precision medicine, digital surgery and self-management of chronic disease, understanding disease trends, understanding citizen perception, enhancing practitioners' skills and finally exchanging standard messages based on multilingual ontology/taxonomy. Innovative digital solutions can provide better health outcomes and contribute to the sustainability of health systems if designed purposefully and implemented in a cost-effective way[64].

Intervention needs and challenges at EU level

There are increasing public and private investments directed towards using health data and data analytics in the EU, with EU initiatives making more funding available for e-Health solutions. The need for large-scale and good quality healthcare data including the collection, use, distribution and utilization of this data by public and private entities requires long-term investments in data infrastructure and platforms. High costs associated with the installation of systems using advanced technologies, as well as concerns over data security, and a lack of integration and information sharing are hampering the speed of the digital health market growth.

Therefore, there is a need for public intervention in order to generate a market for Smart Health products and solutions and to support and enable research and development in Smart Health in Europe. Public support can also leverage private investment. Joint public-private initiatives can foster the market uptake and large-scale roll-out of technologies and raise awareness among healthcare providers that need to adapt and change their processes. Within this framework, specialised funds can be created as well as targeted initiatives either on EU level or integrated in national investment

[60] https://sustainabledevelopment.un.org/?menu=1300
[61] Communication from the Commission on enabling the digital transformation of health and care in the Digital Single Market; empowering citizens and building a healthier society; COM(2018) 233 final
[62] OECD (2018). Health at a Glance: Europe 2018, State of Health in the EU cycle
[63] https://ec.europa.eu/digital-single-market/en/news/transformation-health-and-care-digital-single-market-gaining-more-support
[64] EXPH (EXpert Panel on effective ways of investing in Health) (2018). Opinion on Assessing the impact of the digital transformation of health services

programmes. Public funding is also needed to support investment by small and medium-sized enterprises in the Smart Health value chain towards multiple biomedical and bioengineering devices, procedures and services.

Funding gaps also exist in further research and technology development especially in next sequencing technologies or artificial intelligence. Big data in health would benefit from sufficiently large pools of data for search, analysis and visualisation. Building this suitable infrastructure for data management will need more European investments in the future. However, there is a need for regulating and harmonising the access to and use of health data at European level to address concerns about sharing private health data with a broad range of private firms.

The common European interest lies in generation of and fair access to health data and related digital solutions as raw material input for the development and deployment of Smart Health products and services accessible to everyone in Europe. The possibility of non-discriminatory access to reliable, curated health data of high quality and of sufficient quantity is essential for the development of a globally competitive European Smart Health industry. This „capacity building" approach differentiates the Smart Health value chain from value chains in other innovative industry sectors (e.g. microelectronics or batteries).

To scale up and create connectivity between high quality health data networks additional public-private cooperation is necessary at European level. Health data are not commodities. Therefore, the collection and the use of these data has to be governed following existing regulations. Private economic operators might not have economic incentives to invest in building large-scale European databases that are needed for the development of the Smart Health industry in Europe. Ideally, there would be a European common health data space accessible for every interested party under strict and agreed regulation.

At the same time, there is a need to address the use of health data and information (including genomic data) and the citizen needs in data governance and consent management models. This is an essential factor to create trust by citizens to share their data for research purposes. A quadruple helix of ethics, regulation, scientific and economic issues should provide input in development of a European health data platform.

The investment needed to set up such a European common health data space does not in itself generate immediate commercial opportunities, explaining the lack of private investment. The health data available through such a European common health data space is however crucial input for research and development processes by businesses that require considerable investment on their own. In parallel, legal and regulatory requirements need to enable and support the uptake of Smart Health products and applications to make such R&D efforts worthwhile. The commercialisation of Smart Health products and services requires a high degree of certainty on security, provided by transparent and reliable market access conditions.

Aspirations (vision) for 2030

Building a federated European common health data space that can compete with comparable sources in the USA, China or other parts of the world is only appropriate if there is the possibility to commercialise Smart Health products and services developed with the help of this data space. On the other hand, the development of Smart Health in Europe depends on the availability of such a data space.

The recommendations contribute to reaching Europe's aspired position as a global player in the area of Smart Health, by changing the current unfavourable market conditions towards a more balanced sharing of opportunities and risks between the health sectors in Member States and private companies. This goal is based on the following aspirations:

1: By 2030 there is a federated European common health data space across all Member States for use in research, medical science and healthcare services, driving the development towards patient-centred and outcome-focused healthcare systems

2: By 2030 there is a viable European ecosystem between users, payors, authorities and industry in compliance with the relevant data protection legislation and ethical standards for the development and uptake of Smart Healthcare products and applications, including digital therapeutics.

3: By 2030 European authorities, regulators, payors, healthcare professionals, users and citizens have access to the required resources and skills in order to understand and evaluate Smart Healthcare products and applications in order to support the quick uptake of Smart Health products and solutions.

4: By 2030 a European Smart Health Innovation Hub has been established as a pan-European platform to realize Smart Health projects and such projects are in practical use.

Specific recommendations

The following draft Action Plan is based on the recommendations submitted by Strategic Forum members and invited stakeholders to two stakeholder workshops organised over March/May 2019. Actions have been grouped in six key recommendation areas.

Create a federated European health data space without identification of individual data subjects

It is necessary to create an infrastructure where European health databases can genuinely interact, with a public-private data governance model and a platform where multiple data sources can converge, in full compliance with the General Data Protection Regulation (GDPR). The European health data infrastructure should provide a secure and reliable communication network and enable the access to and exchange of health data that are existing at national or European level. The infrastructure should facilitate federated data access strategies that have been developed for example in Horizon 2020 Innovative Medicines Initiative and similar initiatives.

The interoperability should be based on a federated model whereby the different sources of health data act as nodes in a network. The virtual database created by data federation should not contain the data itself but allow for standardised analysis of the data for different purposes. It will be based on normalized data/terminologies (also in multiple languages) in order to maximise the interoperability between the federated databases. This can substantially improve the retrieving of targeted contents by avant-garde semantic search engine that let end-users interact also by natural language questions. The data should be certified and its quality trusted, hence traceability and validation is an important step.

Recommended actions

- Provide incentives (e.g. financial rewards, reciprocity in access to data, giving credit to data providers and curators in publications that are based on the data) for data holders including citizens to share data.

- Rely on national, patient-centric and community-driven health data infrastructures in order to create a new EU-wide virtual layer of interoperability among the decentralised infrastructures including pilot initiatives (e.g. European Health Data Evidence Network - EHDEN, Meaningful Integration of Data Analytics and Services - MIDAS) as well as existing research networks (e.g. European Institute for Biomedical Imaging Research, BBRMI-ERIC a European research infrastructure for bio banking).

- Encourage efforts by Member States to develop strategies for electronic health record systems for their citizens and patients, with specifications that are in line with EC recommendation on a European Electronic Health Record exchange format and to share health records across borders through federated models.

- Promote technologies needed to anonymise data or to create synthetic data for AI algorithm training

- Accelerate the use of genomic data in healthcare taking into account ongoing initiatives such as the "1+ million Genomes initiative"[65] . Genomic data can be exploited in healthcare, e.g. in guiding drug therapy selecting optimal cancer treatment, developing a better understanding of rare diseases, discovering and evaluating new biomarkers for diagnosis, or in motivating patients for healthy lifestyles.

- Establish an adequately resourced Health Data Institute with a strong role in managing these actions and ensuring that health data is made available for secondary purposes.

Support the development of Smart Health products and services

Making the health systems across the EU more effective, accessible and resilient is a huge challenge. The existing healthcare value chain will have to transform its model from an acute-based paradigm to a more preventive, personalised and responsive health service. Leveraging Smart Health products and services and using advanced technologies will help to meet this transformation challenge successfully. The challenge is not restricted to healthcare providers but includes industry, authorities as well as citizens and patients. A key challenge is to provide clinical evidence for the validation of products and solutions. The promoters of digital solutions should demonstrate that their products will contribute to this transformative agenda.

Recommended actions

- Use financial instruments and regulatory procedures to support health-tech SMEs and other technology developers in their efforts to bring new products and services to the market. This should include support to address regulatory questions (i.e. hiring experts for the CE

[65] https://ec.europa.eu/digital-single-market/en/european-1-million-genomes-initiative

marking process). Funding schemes should use blended finance in order to leverage the investment afterwards, with the focus on commercialization and scale-up stages.

- Follow up on the European Commission Communication on enabling the digital transformation of health and care in the Digital Single Market[66] and its implementing activities and develop a roadmap in the area of Smart Health to integrate the use of digital and biomedical technologies (e.g. artificial intelligence, big data, advanced biomaterials, bioengineering solutions etc.) towards 2030.

- Create a specific European Investment Platform on Smart Health, e.g. under the European Fund for Strategic Investments or future InvestEU.

- Improve the quality and reproducibility of biomarker studies and establish a coherent biomarker development pipeline from discovery to market introduction.

- Support the development of Smart Health products and services to ensure quality healthcare in response to the social and demographic changes, e.g. by including a funding possibility in EU regional funds (i.e. „Smart Healthcare in rural environments“).

Adapt regulations and standards

Smart Health products and services will be subject to a number of European legislative acts, e.g. GDPR, Clinical Trial or Medical Devices Regulation. These regulations should create trust. However, applying such legislative requirements to Smart Health solutions may not be straightforward. Therefore, guidance will be needed, as well as an appropriate use of existing standards and a discussion on the need to develop additional standards. It is important to maintain the ability to research and to identify potential changes to existing legal and ethical requirements for data protection that are unduly burdensome.

Recommended actions

- Create further guidance to improve the consistency in Member States' implementation of GDPR when it comes to sharing health data (including genomic data). This includes clear guidance on cases when health data are without „personal identifiers“(i.e. fully anonymised or pseudonymised) and a template for „broad patient consent to scientific use of health data“. This should also include best practices and EU templates agreed among the European Data Protection Authorities.

- Develop further guidelines and policies for advancing standardisation and interoperability of healthcare data across Europe. Introduce strategies and instruments to incentivise such the uptake of interoperable solutions at the national and regional level.

[66] COM(2018) 233 final

- Regulations should be put in place that promote the secondary use of data for research and ensure fair, transparent and non-discriminatory access to data. Rules how to make the data available should be formulated. Access to data for commercial or non-commercial research with a societal goal should be the same, but can only be realised when citizens have trust and clear information related to its use.

- Establish protocols to standardise measurement conditions before data is acquired/measured (sample preparation, patient/citizen environment and activity). For smart medical devices, consider open international standards[67].

- Create a platform for Competent Authorities, Notified Bodies and the pharmaceutical and medtech industry regarding the application of the Medical Devices Regulation to digital therapeutics and combination products (device, medicine, diagnostics) with specific attention to the needs of start-ups and SMEs.

- Introduce more specific, common guidelines for applying AI-based products in healthcare and certifying AI-based products in terms of the technical regulatory framework of the Medical Devices Regulation building upon the ethics guidelines for trustworthy artificial intelligence.

Promote skills for the development, uptake and effective use of Smart Health products and services

There is a need to develop Smart Health literacy to build the appropriate knowledge and skills across all the stakeholders in the value chain. A new culture of data sharing requires an understanding these new data sources and how they can be used in healthcare decision-making. Incentives are needed for patients, healthcare providers, payors, regulators, and other data collectors and users to collect data consistently and share these data. In addition, clear information for citizens about the benefits and value of data sharing is required.

There is also very often a lack of knowledge and understanding of the ecosystem of Smart Health technologies, the convergence of health and technology and of the critical early product development path that eventually leads to commercialisation. Most academics and SMEs lack the awareness, in-house expertise, or funding to address key factors such as regulatory approval or generation of clinical evidence properly.

Recommended actions

- Promote digital literacy for Smart Health. This should include an EU-wide educational campaign on the benefits of and mechanisms and safeguard for health data sharing to break down misconceptions, including among patients and healthcare professionals.

- Provide a detailed description of the skills required in the value chain, including a digital health curricula for healthcare professionals and the creation of life-long training centres of

[67] such as IEEE 11073, ITU-T H.810, HL7 FHIR

excellence for specific digital skillsets. This includes cross-sectoral training, skills enrichment and cultural change in order to make optimal use of digitised biomedical devices, procedures and services.

- Invest, encourage and develop skills at all levels based on the skills descriptions:
    - Submit proposals on Smart Health in the Erasmus+ Programme and in the future Centres of Vocational Excellence;
    - Invest in deeper analysis of the digital skills needed for working in healthcare with modern technology tools such as artificial intelligence, cloud or Internet of Things;
    - Encourage the integration and uptake of skills supporting digital transformation in educational and training curricula. These curricula should be replicated throughout Member States. In doing so it is essential to develop skills/digital literacy at all levels of the value chain: citizen/patient, health professionals, regulatory bodies, private/public payors, industry, authorities.
    - Build the capacity of regulatory bodies to assess Smart Health products and services. Regulatory bodies need to be able to adjust to the state of technology quickly and to discuss with other stakeholders at the same level of knowledge.
    - Discuss the launch of a specific sector skills alliance

Stimulate the demand-side and the uptake of Smart Health products and services

Smart Health products and services need to be integrated in the regular healthcare system and reimbursement schemes in EU Member States and regions. The healthcare ecosystem has a number of players such as hospitals, healthcare institutions, regulators, public and private insurers or citizens that determine the actual demand. In this process, Smart Health initiatives should put patients and citizens at the core given their role in validating the credibility of the new healthcare solutions. This needs creating awareness, literacy and trust among citizens, including on the use of health data as well as when and how consent for use of health data can be given.

There is a need to foster an understanding of new data sources and how they can be used in healthcare decision-making and build the appropriate knowledge and skills. Incentives for patients, healthcare providers, payors, regulators, and other data collectors and users would support the shift towards value-based healthcare. A clear added-value of these digital health products and services must be proven to provide high quality-services in a cost-efficient way.

Recommended actions

- Provide support and incentives at EU level to contracting authorities to organise more innovative public procurement and take up Smart Health in their tendering procedures.
- Facilitate the networking between contracting authorities to exchange on good practices on Smart Health procurement. In this context, Member States are also encouraged to set up a national professionalisation strategy based on the European Commission recommendation on the professionalisation of public procurement aiming at equipping their public buyers with the required skills and knowledge.

- Provide more incentives for Smart Health deployment, in the context of value-based healthcare and more prevention-oriented paradigm shift, incl. the utilisation of non-clinical sources - like wearables and other self-monitoring solutions - for health prevention.

- Share the evidence of early adopters of innovative solutions in healthcare and transfer best practices from a region/nation to another one, e.g. building on twinning schemes and INTERREG projects.

- Create clear and transparent guidelines on the use of real-world evidence and big data analytics with regulatory and health technology assessment bodies.

- Support the transformation of hospitals to become smart digital, saving costs on inefficient processes and burden in clinical trials. Identify funding gaps and provide strategic guidance to promote health care transformation, including for research, develop and design the "Hospital of the Future", taking into account different models and with specific attention to cybersecurity issues.

Create a pan-European operational network as a mechanism (a European Smart Health Innovation Hub) that can assess and promote Smart Health initiatives

A European Smart Health Innovation Hub should provide a platform for Member States, regions, healthcare providers, research establishments, healthcare payors, health insurers and industry to establish consortia to realise ambitious large-scale projects. It would facilitate synergies between public and private actions at EU, Member State and regional levels. Regions play a particular role since in some EU countries healthcare is not under the control of federal or national government but organised at the level of region or city.

Such a public-private network is also important due to the Smart Health industry's dependency on public and regulated demand. The different levels of political decisions and the variety of involved actors are an additional complexity for any pan-European initiative to scale-up Smart Health pilots, especially when pilots include access to registries and therapeutic decisions.

Recommended actions

- Facilitate access to European Smart Health technologies through the Digital Innovation Hubs, for instance by providing cybersecurity solutions in health and care.

- Exploit the expertise and services of existing European health research infrastructures such as the European Infrastructure for Translational Medicine (EATRIS), the European research infrastructure for biobanking (BBMRI-ERIC) and the European Clinical Research Infrastructure Network (ECRIN) etc. as well as pilot initiatives, such as the European Health Data Evidence Network (EHDEN) and other European initiatives in this field.

- Scale-up Smart Health pilot and demonstration projects to accelerate learning curves, for instance to realise preventive strategies and utilise life health footprints, taking into account health insurers' and payors' objectives.

- Establish a continuous monitoring, benchmarking and exchange of good practices between Member States and regions, to incentivise effective reforms and track progress towards

value-based healthcare and sustainable healthcare systems. This could build on the on-going OECD initiatives in this field.

Low CO_2 Emissions Industry

Description and Scope

The strategic value chain on Low CO_2 Emissions Industry (SVC on LCI) aims at building a common vision at European Union level for joint, well-coordinated efforts and investments in low CO_2 technologies and at facilitating agreements between public authorities from Member States and industrial stakeholders. It is based on a list of concrete recommendations aiming at identifying areas for potential coordinated investment where Important Projects of Common European Interest (IPCEIs) could be established. This chapter is based on desktop research, workshop results and inputs from the members of Strategic Forum.

It particularly focusses on a number of technological pathways and projects within the steel, cement and chemicals sectors; aiming that by roughly 2030 those processes can be utilized commercially or ready for upscaling activities (long-term technologies). Due to infrastructure constraints and downstream needs, the most efficient and sustainable way towards a Low CO_2 Emissions Industry value chain could be achieved by using more than one technology or even by the combination of several technologies.

While this strategic value chain focuses on the aforementioned three industrial sectors, the respective recommendations could be applied to other energy-intensive industry sectors as well since they are facing similar challenges.

An assessment of potential IPCEI projects which can accelerate the transition towards a low CO_2 emissions in industry is included in the annex. For these pivotal projects, many interdependent actions will be needed to substantially bring down greenhouse gas emissions to live up to the Paris Climate Agreement and achieve a climate-neutral economy. The CO_2 abatement potential of technologies will depend on factors that are beyond the control of individual industries and Member States. However, coordinated investment projects are not bound to the list of projects and the scope of the value chain as defined in this report, but may go beyond, involving other industrial sectors that can contribute to a climate-neutral industry by 2050.

Finally, the focus of this report is essentially on measures enabling the development and deployment of key strategic technology options. The details concerning general enabling conditions for industry's transformation to low CO_2 emission industry in Europe will be elaborated by the High Level Group on Energy Intensive Industries[68].

Why the Low CO_2 Emission Industry value chain is strategic and how it contributes to specific EU strategic goals and autonomy/ security

Among the energy-intensive sectors, steel, chemicals and cement account together for more than two-thirds of all industrial CO_2 emissions in the EU. At the same time, these sectors directly employ

[68] Reference to HLG EII.

nearly 2 million workers, generating an annual turnover of about EUR 750 billion, forming the backbone of the European real economy, with a far greater impact on indirect employment. In a context of ever-growing competition from other major global economies and new emerging markets, Europe has to define an effective and efficient pathway for achieving its climate targets, in line with the Paris Agreement on Climate Change. Only if the EU demonstrates that it is possible to reconcile climate ambition with industrial innovation, other global economies will follow.

EU steel, chemicals and cement industries are today strong in innovative and efficient processes in low CO_2 technologies. However, all three sectors are facing challenging business environments.

In the United States, an investment boom is happening in the chemical sector, while companies from around the world are also heavily investing in new projects. Global capital investments in new projects since 2011 are estimated at USD 202.4 billon. China, the Middle East and India have all made successful efforts to build up large and increasingly sophisticated production facilities and attract high investments to compete with European exports.

Steel is an intensively traded product in a market suffering from significant global overcapacity, which has increased to 440.0 mmt in the first half of 2019, up from 413.0 mmt in 2018, with global capacity at 2 290.1 mmt and production at 1 850 mmt (annualized)[69]. This overcapacity, together with recently introduced tariffs on steel and aluminium by the US, are affecting the financial and economic sustainability of the European steel sector.

The European cement production, as well as the value, decreased since the peak production in 2007. At the same time, the production volumes increased significantly in China and India, resulting in a decrease in global market share of the EU. The cement market in Europe still suffers from a low return on investment. Recovery is happening in Europe, but it is gradual and cautious and uneven between the EU Member States.

It is now time to further build on the strengths of Europe, as compared to those of other competitors. The chemical, steel and cement sectors have strong connections to each other. In some European regions, production sites are even located inside the same industrial zone sharing similar infrastructures, logistics and resources. This interdependence can become a key factor in making the transition to low-CO_2 processes and products a success. By promoting industrial symbiosis and interconnecting sectors under a new circular economy, we can make the best use of European assets. At the same time, other solutions need to be developed targeting more dispersed situations. Switching to alternative energy and feedstock entails a high greenhouse gas abatement potential. The EU can build on its energy sector with long experience in providing low CO_2 solutions and growing expertise in renewable energy and on a growing hydrogen industry. The same logic applies to the role of biomass. Besides being an alternative for fossil raw materials, biomass will have a role in balancing the energy use in processes and for negative emissions in combination with carbon capture, utilisation and storage (CCUS). Creating strategic sub-value chains around low CO_2 steel, chemicals and cement will help create new, high volume markets for low CO_2 and CO_2 neutral technologies, production and products, including hydrogen and carbon feedstock, and spur the creation of new jobs

[69] OECD, DSTI/SC(2019)12. *Latest developments in steelmaking capacity - Interim Report*.

– all while responding to the climate change challenge and enhancing the EU circular economy. This can build on R&D activities e.g. under SPIRE partnership[70] and will be complemented by R&D&I activities in future Horizon Europe partnerships.

The strategic value chain on Low CO_2 Emissions Industry contributes to several EU strategic goals, such as circular economy, plastics strategy, and renewable energy and climate objectives. Innovative CO_2 conversion technologies can reduce the use of fossil carbon sources and the dependency on imports, as well as pressure on biomass, land use and other environmental stressors. Industrial symbiosis plays an important role whereby "waste" from one industry is used as a fuel or material resource for another.

Significant investments – both private and public – are needed to invest in extensive innovation and achieve the required greenhouse gas emissions reduction. Action needs to come from all stakeholders involved in the transition towards a low CO_2 industry; together we can demonstrate to the rest of the world that climate ambition and industrial innovation go hand in hand.

This requires combined action from various stakeholders, the European Commission, Member States and industries. The European Commission, will provide support already in the design phase of IPCEIs for the deployment of low CO_2 processes and hydrogen technologies. The industry, for its part, will be called to clearly define low CO_2 projects, by quantifying the CO_2 reduction potential, energy needs and investment levels of these projects, and identifying the possible cross-border cooperation of industry players and Member States. This also requires Member States to provide guidance to the "coalition of willing industries" for a low CO_2 emissions industry IPCEI project, e.g. by facilitating contacts with interested Member States as well as providing clarity on the selection criteria and on the extent of available funds for potential IPCEI(s).

Why intervention is necessary among all stakeholders at EU level

The challenges induced by climate change, and the actions needed to achieve the CO_2 reductions in line with the 2015 Paris Agreement are too large to be answered by one industry or by one Member State on its own. Let alone that the objective of climate neutrality by 2050 is discussed at highest EU political level following the 2050 vision presented by the European Commission in November 2018[71]. The European Council in its meeting on 22 March 2019 emphasised the importance of the EU submitting an ambitious long-term strategy by 2020 striving for climate neutrality in line with the Paris Agreement, while taking into account Member States' specificities and the competitiveness of European industry.

For the European industry, the shift to climate-neutral energy and to alternative feedstock represents a key option to abate greenhouse gas emissions significantly. Even though the capacity of renewable energy will gradually increase, it is estimated that the respective energy needs in different sectors will be exponentially growing, creating threats for energy availability and cost, with coal and nuclear power plants being phased out in some Member States. Therefore, solutions for deploying first-of-a-

[70] https://www.spire2030.eu/
[71] COM…

kind industrial projects need to be urgently identified and implemented, including a clear definition of the energy needs related to these technologies. IPCEI project(s) could allow bridging the last step between demonstration and first industrial deployment of technologies in the timeframe considered, thereby increasing the competitiveness of the European industry in the field of low CO_2 solutions for energy-intensive industries.

To create a future European low CO_2 emissions and circular economy, intervention is necessary at EU level to address changed needs in terms of investments, (cross-border) infrastructure and EU legislation.

Below there are specific recommendations so that the proposed first-of-a-kind pivotal projects within the steel, cement, and chemicals industries can be successfully realized, together with an outline of major challenges and accompanying measures necessary for the roll-out of technologies and implementation of the Low CO_2 Emissions Industry strategic value chain.

The vision for a low CO_2 emissions industry

The aim of the Low CO_2 Emissions Industry strategic value chain is to make a substantial contribution for climate neutrality in Europe through industrial projects and technological pathways achieving up to 95% greenhouse gas emissions reduction by 2050. It particularly focusses on a number of technological pathways and projects within the steel, cement and chemicals sectors, which should be utilized commercially or ready for upscaling activities (long-term technologies) roughly by 2030. This vision should steer and create a clear investment agenda as soon as possible for investments necessary today for the transition towards carbon neutrality in Europe. Although the focus is on three industrial sectors, the solutions also relate to other European industrial sectors.

The most efficient and sustainable way towards a low CO_2 emissions industry could be achieved by using more than one technology or even by the combination of several technologies. It is not the intention to steer the EU, Member States and industries towards one specific pathway. On the contrary, it is meant to identify opportunities, challenges and recommendations for this transition. Designing an IPCEI within this strategic value chain could be of interest for certain technological pathways and projects in their first industrial deployment phase, and would contribute to the acceleration of the transition and to achieving the Paris Agreement objectives.

Specific Recommendations

Support coordinated investments towards key technological pathways for greenhouse gas emissions abatement

The proposed areas for coordinated investment entail technological pathways with a potential to achieve - for each pathway or in combination of several pathways - at least 80 to 95% of CO_2 emission reductions, including through all mitigating measures. Technological neutrality and flexibility in future developments of other low CO_2 solutions are key factors for the overall success of the transition towards a lower CO_2 emissions. Therefore, other technological solutions with the potential to achieve significant greenhouse gas emission savings should not be excluded.

Main technological pathways for greenhouse gas abatement in steel, chemicals and cement that should be taken in consideration under relevant European programmes and/or programmes funded by Member States:

- CO_2 valorisation
- Process integration in steelmaking
- Carbon Direct Avoidance in steel: Hydrogen-based metallurgy
- Carbon Direct Avoidance in steel: Electricity-based metallurgy
- Chemical valorisation of waste (including chemical recycling of plastics)
- Electrification of chemical processes (e.g. electrification of crackers, Power-to-Heat)
- Electrification of cement manufacturing
- Alternative raw materials and fuels including hydrogen
- Development of new chemical production plants based on non-fossil feedstocks
- Development of alternative cement products (low CO_2 binders)
- Eco-design, and resource efficiency and recycling (including cleaner waste streams and higher quality recyclates)
- Energy efficiency: Innovative grinding technologies for cement manufacturing
- Artificial photosynthesis
- Carbon Capture Storage and permanent capture technologies (ex: cement recarbonation)

Identified areas for potential coordinated investment, e.g. via IPCEIs:

- CO_2 valorisation in chemical, steel and cement sectors (in combination with process integration in steelmaking and Carbon Capture and Storage)
- Carbon Direct Avoidance in the steel sector
- Chemical recycling of waste in the chemical sector

Scaling up projects to demonstrate low CO_2 technologies and prepare for future roll-out

The transformation of existing value chains to new, low CO_2 value-chains will require substantial investment by public and private actors. High investments are particularly necessary for the large-scale demonstration of low CO_2 technologies by 2030 approximately. This is a necessary prerequisite before the roll-out of new low CO_2 technologies. The contribution to the achievement of 2050 climate targets will highly depend on the demonstration phase.

Recommended actions

- Bring multiple technologies to full-scale size – first-of-a-kind -full-scale size to allow for experimentations with design improvements on an industrial scale, which is necessary to achieve cost optimization of new low CO_2 technologies and facilitate market uptake.

- Support deployment of first-of-a-kind projects, including a review of the relevant state aid guidelines and regulations to address first-mover disadvantages

- Combine ETS Innovation Fund with support provided by other EU programmes and by the Member States (e.g. in the context of a possible IPCEI).

- Support financing of infrastructure elements of the projects (e.g. via coordinated investments in Connecting Europe Facility and European Structural and Investment Funds, or under state aid rules for IPCEI)

- Provide additional investment support in the form of loans and guarantees (e.g. InvestEU Fund)

- Ensure that sustainable finance regulation will attract low CO_2 emission investments in energy-intensive industries.

- Allow integration of projects at different Technology Readiness Level (TRL) under one or more IPCEIs where synergies are an indispensable element for the success of the overall project

- Consider support via IPCEI of technologies that are currently still at a low TRL level, yet entail significant potential for a very high impact in the long term, and of complementary technologies necessary for intermediate steps of technology demonstration

Continue R&D support for lowering CO_2 emissions in industry

Sustained support to the development of low CO_2 emissions technologies in the energy-intensive industries through research and innovation at EU and national levels will remain fundamental. Many technologies must be supported in the next decade in order to bring them to TRL 6-8 by 2030 and be ready for industrial deployment to deliver impact by mid-century, building on R&D activities in the SPIRE PPP.

Develop guidelines and assessment methodologies for low CO_2 emissions technologies

The complex structure of energy-intensive industries, which are interlinked in the value chain, entails that the exact product CO_2 footprint needs to be thoroughly assessed over the production, use and end-of-life phases by using concrete guidelines and methodologies.

Create an appropriate EU regulatory framework

New low CO_2 technologies will require an enabling regulatory framework both at EU and national level. Review of the State Aid framework need to sustain the transition of industry towards lower CO_2 emissions by consideration to high CAPEX and increased OPEX for at least a certain period of time before and during roll-out. New low CO_2 technologies should be properly accounted for and recognized under the regulatory framework.

Recommended actions

- Establish a supporting EU policy framework for the deployment of low CO_2 emissions technologies, including securing the supply of materials for the energy transition and the

low CO_2 emissions industry, e.g. European Council Conclusions on an "industrial transformation masterplan".

- Review the state aid rules to reflect higher energy use in low CO_2 emissions technologies and production modes; e.g. expand the existing Energy and Environmental State aid Guidelines (EEAG) in a way that allows for exemptions for energy-intensive users from environmental levies to other areas (such as use of, hydrogen production or its use) and provides for the support of investments in climate-neutral energy sources (such as the use of hydrogen production). The EU framework for state aid on low CO_2 technologies should foster and strengthen the competitiveness of the European industry.

- Facilitate cross-border transport of CO_2 and the redesign and conversion of existing installations, including permitting procedures.

- Recognition in ETS Monitoring and Reporting Regulation of greenhouse gas emissions reduction, such as use of CCU, CCS, electric boilers and of CO_2 emissions avoidance resulting from the utilisation of CO_2 as a carbon source for products (e.g. chemicals or fuels)

- Create lead markets, which will allow innovative low CO_2 and circular products gain access to the market (via e.g. creating awareness and willingness to pay more for low carbon products, product standards and public procurement, once a critical mass of the new low CO_2 products is available)

- Promote recycled carbon fuels in the implementation of renewable energy directive (2018/2001/EU – RED II) at national level

- Promote free and fair international trade for industry, e.g. continue improving the application of the EU Trade Defence Instruments against dumping and subsidies and other market-distorting support schemes for industry in third countries.

Ensure support for the transition to Circular Economy

Almost all energy-intensive industries already depend highly on recycled materials as raw materials input, while the security of raw materials supply (especially critical raw materials) is indispensable for others. Enhanced circularity will become more important over the next decades as a strategy to reduce emissions, reduce raw material use, maintain security of supply, and enhance production and growth while reducing costs. Collection and sorting of waste represent an important challenge; for some value chains this will prove crucial for maintaining the quality of basic materials in recycled product streams.

Recommended actions

- Improve the circularity of materials by requiring the design of products that are reusable, repairable and recyclable in the first place and support the waste hierarchy.

- Improve the traceability of materials and chemicals in the supply chain to enhance recyclability.

- Facilitate transfer and valorisation of waste, CO_2 and CO. Support and facilitate industrial symbiosis

- Optimize pre-treatments for reducing production costs
- Improve existing sorting technologies and facilitate the deployment of new and more efficient technologies for the treatment of end-of-life material streams (e.g. copper removal from ferrous scrap)
- Facilitate access to waste streams. Facilitate chemical, cement and steel recycling.
- Establish a level playing field for environmental requirements between European installations and installations located in third countries that use ferrous scrap (i.e. full application of the waste shipment regulation)
- Ensure regulation on waste that supports material circularity and prioritises reuse, repair, recycling and re-manufacturing over waste incineration
- Reduce contamination of end of life materials streams.
- Harmonisation across Member States of end of life and end of waste criteria, definition of by-products and hazardous waste.
- Simplification of the permitting process.

Ensure access to competitively priced low CO_2 energy supply

Securing adequate and competitively priced low CO_2 energy supply for industries using low CO_2 technologies will be a key factor of success for the transition to a climate-neutral industry. Development of the low CO_2 energy system to secure growing energy demand for transition to low CO_2 technologies needs to be urgently planned and undertaken. The EU needs to recognize that transition of energy-intensive industries (EII) towards climate neutrality will entail a significant increase in energy demand in the EU. High and rising electricity prices as a consequence of EU and national regulations could close off the road to several technological solutions.

Recommended actions

- Ensure access to competitively priced, low CO_2 and climate-neutral energy and adapt industrial processes to the switch towards alternatives
- Develop an EU energy masterplan for EIIs, including a mapping, aligning energy supply to EIIs transition towards climate neutrality and addressing challenges such as infrastructure, variability and storage
- Adapt existing EU regulatory framework to the transition of EIIs towards climate neutrality and provide consistency within the EU energy and climate policy framework (e.g. Energy-Efficiency Directive, indirect costs under EU ETS, recognition of CCU-fuels as source stream in ETS etc.)
- Lower regulatory costs related to electricity consumption by EIIs on a level playing field basis across the EU and also vis-à-vis international competitors (e.g. power purchase agreements)

Plan and develop infrastructure for a low-CO_2 industry

Low CO_2 technologies will require either a completely new infrastructure or retrofitting and adapting the existing infrastructure. There is an urgent need to start planning and investing in the infrastructure needed for new low CO_2 technologies in order to guarantee a sufficient and continuous supply e.g. with hydrogen and climate-neutral energy. No single company will be able to provide the capital for these infrastructure investments on their own, hence public financial support is a necessary prerequisite.

Recommended actions

- Align with measures of the Energy Union, plan necessary infrastructure for low CO_2 technologies (waste, H_2, gas, electricity grids, pipelines for CO_2 and for other gases and by-products to be valorised in a circular system, (seasonal) H_2 and CCS storage) by developing an EU infrastructure mapping

- Facilitate system integration, adaptation and market regulation of (new) cross-border infrastructure involved with the climate neutral economy, such as the cross-border transport of CO_2.

- Promote investments and implementation of infrastructure for low CO_2 technologies (e.g. Connecting Europe Facility, IPCEIs, etc.)

- Minimise time needed for permitting procedure

Ensuring international competitiveness throughout the transition and beyond

The industrial transition will have to happen in a highly competitive and dynamic international environment. Given that the transition to low CO_2 technologies will be a high-risk operation, it is essential that this process is accompanied with a continuous monitoring of the adequacy of measures against carbon leakage in EIIs. In addition to carbon pricing policies, product and market related policies need to be part of the proper mix of pull and push measures to promote the transition to a low carbon economy.

Recommended actions

- Ensure carbon leakage protection measures from both direct and indirect costs of the EU ETS during transition, for example by avoiding that unilateral direct or indirect carbon costs are borne at the level of the best installation

- In the absence of a global level playing field, examine the economic feasibility of different carbon inclusion mechanisms which are aiming at establishing a level playing field at global scale[72]

[72] Joint Statement, Friends of Industry Group, December 2018 https://www.gouvernement.fr/en/6th-ministerial-conference-friends-of-industry

- Analyse the adequacy of EU ETS measures to provide sufficient incentives for EIIs to invest in low CO_2 technologies and explore complementary measures for medium/long-term framework not only for CO_2 compliance, but also for CO_2 cost

- Modernize the WTO rulebook to tackle more effectively trade distorting practises.

Develop a highly skilled workforce

The deployment of these technologies at large scale and at European level will require a large number of highly skilled scientists, engineers and workers.

Recommended actions

- Develop and strengthen a highly skilled workforce for the whole low CO_2 emissions industry value chain

- Promote education and skills and anticipate future skills to prevent shortages and mismatches at Member States level for e.g. chemical and material science engineers, engineers for the development of e.g. electricity and renewable energy infrastructure, specialists in industrial innovation, environmental engineers and designers for eco-design of products and the development of sustainable industry in Europe etc.

- Support reskilling and upskilling: e.g. via life-long learning programmes

Raise awareness of EU citizens for low CO_2 technologies and products

Public acceptance for low CO_2 technologies, including for transport of CO_2, which is also a precondition for a successful deployment of CCS, will require cooperation between industrial sectors and Member States.

Recommended actions

- Raise the awareness on Low CO_2 technologies and the implications of their deployment. Design and promote information campaigns especially when end-user markets are needed for a broader diffusion of technologies

- Develop initiatives that promote market deployment of low CO_2 emissions (considering their whole life cycle) products and technologies

Next steps

This report includes a call for concrete action. The report encompassed its vision, the common European interest thereof, the necessity for coordinated European action, based on a SWOT-analysis and recommendations. This is a major stepping stone to make a substantial contribution to climate neutrality in Europe through industrial projects and technological pathways achieving at least 80% and up to 95% greenhouse gas emissions reduction by 2050. The focus is essentially on measures enabling the development and deployment of key strategic technology options. Complementing this report, the detailed general enabling conditions, which are needed for industry's transformation in Europe, will be elaborated by the High Level Group on Energy Intensive Industries. To create carbon neutrality, we need to act together, the European Commission, Member States, industries and society

as a whole. We need to take concrete steps within the European Union within the coming ten years and next decennia to achieve these goals.

Follow-up conference on Low CO_2 Emission Industry

A follow-up conference will be organised accordingly. In addition, industry players and Member States can strengthen this strategic value chain by coming together, acting upon the recommendations and by identifying potential IPCEIs.

Hydrogen technologies and systems

Hydrogen is an environment- and climate-friendly (zero-emission) energy carrier. Produced from renewable energy sources, e.g. photovoltaic and wind energy, or by low CO_2 technology, it has the potential to essentially replace fossil-based energy.

Today, it still suffers from a supply/demand deadlock that keeps the cost too high for a wide market uptake. A determined shift towards low-emission technologies can significantly increase the availability of green hydrogen at lower cost, enabling low-emission applications in the mobility, industry and energy sectors. Hydrogen-based low-emission technologies would then rapidly become economically viable decarbonisation pathways. During the transition period, low-carbon hydrogen will also have an important role as facilitator of introduction of renewable and low-carbon technologies into the mainstream applications.

At the same time, a level playing field has to be established between fossil and hydrogen-based solutions. Additionally, the regulatory context and standards have to be updated in a timely fashion to facilitate an accelerated technology transition.

European manufacturing capacity or potential exists for many of the key technologies, but scaling-up of manufacturing is held back by a supply/demand deadlock that effectively hinders cost reductions by economies of scale.

On the other hand, many Member States are struggling to achieve the agreed emission reduction targets in sectors which could be decarbonised with hydrogen.

Hydrogen presents a win-win-win opportunity for Member States to provide the required (significant) kick-start capital that is a launch pad for a disruptive hydrogen economy, and would also provide additional jobs and improved industrial competitiveness.

Description and Scope

Hydrogen systems provide a link between renewable and/or low CO_2 electricity generation or other low-carbon hydrogen sources and the end-uses of this energy carrier. The deployment of this seemingly simple concept requires a coordinated action among the stakeholders and implementation at significant scale to tap on economies of scale. In return, hydrogen enables a transition to sustainable economies and a boost in innovation and European technological leadership.

Hydrogen is an essential lever in decarbonisation, making large-scale integration of renewable electricity possible and integrating sectors and regions. The central aspects are explained in the Hydrogen Roadmap Europe (2019)[73]. First, hydrogen is an optimal choice for deep decarbonisation of energy-intensive industry, industrial and domestic heating and cooling, and segments of the

[73] Hydrogen Roadmap Europe (2019): Fuel Cell and Hydrogen Joint Undertaking, Hydrogen Roadmap Europe: A sustainable pathway for the European Energy Transition, January 2019. https://www.fch.europa.eu/studies.

transports sector. Second, hydrogen will play a systemic role in the transition to renewable energy sources providing an essential option for seasonal renewable energy storage. By stabilising the power grid and potentially reducing power infrastructure investments, it is a key to the third phase of the energy transition with over 60% of renewable energy in the power mix. Third, the transition to hydrogen is aligned with customer preferences and convenience.

The hydrogen strategic value chain (SVC) covers multiple sectors of significant size and provides solutions for tangible progress towards several EU policy objectives. Hydrogen will support improved competitiveness and innovation in industries, contribute to reaching climate and energy objectives and provide high skilled jobs for Europeans, while also strengthening autonomy in energy and materials[74].

Implementing the vision of this report will bring changes to several sectors along the value chain: in the Hydrogen production from renewable electricity with electrolysers; in conversion technologies to convert hydrogen to gas, liquids or chemicals to enable use of hydrogen-based fuels or other derivatives, like methanol, DME, and ammonia, on industrial scale; in the gas grid with adaptation of the natural gas grid or construction of hydrogen grid and in end-use applications. The end-use applications are, for example, industrial processes, transport solutions (i.e.: trains, heavy-duty vehicles, maritime, aviation), domestic appliances, and electricity and heat generation at proximity of point of consumption. For some of these elements the technical maturity is now sufficient to consider scaling up pilot or demonstration lines for their first industrial deployment and pre-commercial application.

Deploying projects supporting this vision requires strategic decision making. The initial investments are significant and the payback periods are long, and often combined with high perceived technical, financial and policy risk. The benefits of implementation will outweigh the investments, but the investment decisions need to be anchored in a strategic framework.

An agreed implementation roadmap among the stakeholders and, potentially, a platform for making progress on concrete actions related to the hydrogen vision will facilitate the investment decisions by industrial companies and other stakeholders. This will ensure the availability of next generation hydrogen technologies through sustained, efficient and targeted R&I activities, as well as of industrial capacities when needed, both in the manufacturing of equipment and in the use of hydrogen technologies.

The benefits of hydrogen-related projects will, in many cases, go beyond the initial investors. These positive external effects could result in under-investment if investment decisions are made based on individual profit optimisation. Financial engineering (e.g. revenue stacking: ancillary services and hydrogen supply) and policy support are necessary to correct this market failure.

Below is a brief description of the different elements in the hydrogen value chain, shedding light on basic characteristics and how they contribute to the implementation of the vision.

[74] E.g. European low-carbon steel manufacturing and reduced use of rare or expensive imported materials, etc.

Different fields of Hydrogen deployment

Hydrogen production

The electrolyser sector is still small, but the European electrolyser manufacturers are innovative and ready to scale up their efforts. Electrolysers are needed for the production of hydrogen from electricity and are a key technology in a low-carbon system. Further development of the electrolyser technologies and mass production will significantly reduce the total system cost.

Hydrogen production mainly from renewable sources is a long-term objective, but low-carbon hydrogen from fossil sources and hydrogen produced by low CO_2 energy could provide an opportunity for faster large-scale deployment of hydrogen infrastructure and end-use applications, then enabling gradual shift to renewable hydrogen over time.

Transmission and distribution infrastructure

Hydrogen requires infrastructure for delivery. Due to its similarities to natural gas in physical properties, hydrogen can be transported in existing natural gas pipelines, which will need to be converted to deliver pure hydrogen. In some cases, building a dedicated hydrogen pipeline is the most suitable option. It is also possible to blend hydrogen into the natural gas in existing pipelines, to the extent the gas quality is acceptable to the end-user.

It should be noted that transport via tube trailers (e.g. train, truck) for various liquid hydrogen carriers (e.g. ammonia and liquid organic hydrogen carriers) or on a distance-basis might be the most relevant, cost-effective solution. The electricity grid is today at its capacity limits in many places in Europe and it is not feasible to expand the grid capacity to cover the transmission of all renewable electricity that will be generated. At the same time, it is expected that there will be markets for renewable hydrogen, making the use of hydrogen as an energy carrier and energy buffer in a low-CO_2 energy system a logical solution.

Infrastructure for hydrogen can be made available for most parts, but the long payback periods and especially the perceived high financial risk need to be addressed to make the infrastructure available where needed. Transmission of energy in a hydrogen pipeline is cheaper and has less losses than transmission via an electrical cable, making it an interesting option especially over long distances. Infrastructure is a part of the chicken-and-egg problem for hydrogen: infrastructure is not built if there is no market for renewable and low-carbon hydrogen, and the market will not take off if there is no reliable and cost-efficient delivery of hydrogen.

Hydrogen for the electricity sector

The fluctuations in renewable electricity generation and hydrogen demand could require flexibility in the form of hydrogen storage. Large-scale hydrogen storage can provide flexibility already at low shares of renewables in the energy system. The first commercial uses could be at locations with large renewable energy installations and a weak electrical grid. Long-term storage of hydrogen becomes an unavoidable functional element for the energy system when the share of renewables increases, providing both the function of storing renewable energy during periods of excess generation and providing low-CO_2 energy from these storages when renewable power generation is not sufficient.

Large-scale seasonal energy storage can be achieved by putting hydrogen in underground salt caverns, which are located in many places in Europe. Some of the salt caverns which are used to store natural gas today could be repurposed to store hydrogen. Additionally, the potential of hydrogen storage in porous rock formations is currently investigated. Hydrogen can be re-converted into electricity via turbines or fuel cells.

End-use – industries

A large share of the CO_2 emissions in the EU comes from the industry. Especially, the energy-intensive industry is facing significant challenges during the energy transition. Many of the processes where natural gas or other fossil sources are used as feedstock could be converted to use hydrogen. Additionally, fossil sources are used to manufacture 325 TWh of hydrogen every year[75]. Emission could be significantly reduced if the fossil-based hydrogen would be replaced with renewable and low-carbon hydrogen, thereby decarbonising the industrial processes.

Concrete examples for the use of hydrogen replacing fossil feedstock are the production of low carbon steel by replacing coke coal with hydrogen and the use of renewable hydrogen in refineries.

The industrial dimension is also covered by the section on "Low-CO_2 industries" and in the High-Level Group on energy-intensive industries.

End-use – mobility

Hydrogen can fuel any transport applications from ships to bicycles. The first large commercial solutions can be in car fleets, heavy-duty transport (buses and trucks), trains, maritime and aviation. Some hydrogen-powered fuel cell vehicles are available today, but the quantities are at the level suitable for demonstration. There are some emerging markets, with hydrogen trains in passenger traffic in Germany. First industrial deployment of vehicle manufacturing is needed.

As a fundamental prerequisite a hydrogen refuelling infrastructure with significant capacity and density is required, in particular with regards to heavy-duty road transport. In the maritime sector, a respective port infrastructure for hydrogen supply to ships and multimodal transport solutions is essential. The use of hydrogen in aviation requires different approaches for different size aircrafts.

The fuel cell in a hydrogen powered fuel cell vehicle contains only a limited amount of materials and it could be recycled. The materials can be sourced from multiple suppliers globally. The total amount of material needed for a fuel cell is only a fraction of the material needed in other types of electric energy sources. This difference grows with the maximum range of the vehicle. Hydrogen could provide a long range even for heavy-duty vehicles and it is safer than some alternative fuels.

[75] Hydrogen Roadmap Europe (2019): Fuel Cell and Hydrogen Joint Undertaking, Hydrogen Roadmap Europe: A sustainable pathway for the European Energy Transition, January 2019. https://www.fch.europa.eu/studies

Another promising option is to convert the hydrogen to other types of gaseous or liquid fuels. Liquid electro fuels such as methanol or DME[76] can be a promising bridging solution between today's technology and future drivelines, especially in the maritime sector. Many electro fuels are so-called drop-in fuels, meaning that the existing refuelling infrastructure can be utilized and the fuels can be utilized both in traditional combustion engines and fuels cells and thus provide a cost-efficient transition.

Certain aspects of the use of hydrogen in mobility are also covered by the section on 'Clean, connected and autonomous vehicles'.

End-use – heat and electricity

Hydrogen can be used for electricity and heat production for residential or industrial use. Both solutions are free from CO_2 emissions. Electricity generation can be done with fuel cells or hydrogen turbines. In case of electricity generation, the heat produced from the process should also be used to maintain high efficiency along the energy delivery chain. Reducing emission from local heat and electricity generation is a low-hanging fruit when renewable and low-carbon hydrogen is made available.

Vision

The Hydrogen Roadmap Europe estimates a European market worth EUR 85 billion in 2030 in an ambitious scenario. The EU industry is expected to be able to capture about 3/4 of that market. In addition, EU industries could participate in the global market, adding another EUR 65 billion in revenues from exports. The employment for Europe could sum up to 1 million jobs until 2030. In order to realize this ambitious scenario, the Roadmap estimates the amount of required (cumulative) investments to set up a hydrogen-based economy throughout Europe at about EUR 65 billion by 2030 along the full value chain.

At a global level, by 2050 and deployed at scale, estimates show that hydrogen could account for almost one-fifth of total final energy, create a USD 2.5 trillion market for hydrogen and fuel cell equipment, and provide sustainable employment for more than 30 million people[77].

Hydrogen's strategic contribution to EU objectives

Climate objectives are one of the main strategic drivers for the deployment of hydrogen. The EU aims to reduce greenhouse gas emissions by 40% by 2030 and up to 80-95% by 2050. This commitment has been further confirmed by the 28 Member States signing the Conference of the Parties (COP21) Paris agreement[78]. There is growing awareness that the energy transition will not succeed unless it finds ways to decarbonise the "hard-to-abate" sectors like industry and heavy transport while

[76] Dimethyl ether, a hydrogen carrier.
[77] http://hydrogencouncil.com/hydrogen-scaling-up-new-roadmap-launches-at-cop-23/
[78] Hydrogen Roadmap Europe (2019): Fuel Cell and Hydrogen Joint Undertaking, Hydrogen Roadmap Europe: A sustainable pathway for the European Energy Transition, January 2019. https://www.fch.europa.eu/studies.

providing sufficient flexibility to balance electricity grids all year round[79]. Low carbon hydrogen is regarded as an ideal complement to green electrification, with significant synergies in the synchronised deployment of these two elements.

The energy transition will radically transform how the EU generates, distributes, stores and consumes energy. The transition will be based on virtually carbon-free power generation, increased energy efficiency and deep decarbonisation of transport, buildings, and industry. The transition needs to address also emissions from non-energy sources linked to fossil fuels, like the natural gas used as feedstock in industrial processes. Hydrogen is a key enabler for this transition, as it can be used to integrate large quantities of renewable electricity into the energy system. It is the most economical option for large-scale long-term renewable energy storage. This contributes to EU energy & climate goals, including security of energy supply.

Deployment of hydrogen technologies will boost innovation in several sectors. This will create jobs for a high skilled workforce and build on the potential to compete in sectors where the EU has a strong position through innovation. The long-term vision and the strategic decisions and initiatives that are needed to reach the objectives of the vision require coordinated action across EU industries and other stakeholders. The renewed industrial policy has already adopted initiatives that support this kind of strategic approach to industrial development. Building further on those initiatives could provide a suitable framework for making the hydrogen vision a reality.

Making the vision a reality will significantly contribute to the achievement of several policy objectives, related to climate, energy, industrial and other EU policies.

Why is an intervention necessary at EU level? - Overcome market failure and unlock EU cross-border barriers

EU level action is necessary to coordinate the initiatives that allow for development and deployment of hydrogen technologies in several different applications (including in sectors that are hard to decarbonize by electrification alone) and the development and deployment of the hydrogen supply chain, infrastructure and other framework conditions.

Some hydrogen technologies and systems are technologically mature for large scale deployment but are not cost competitive due to a lack of economies of scale. Therefore, decisive action is necessary to scale up initiatives within the hydrogen sector. An EU level support in coordinating and structuring large scale initiatives could accelerate the deployment of massive hydrogen production and utilization beyond RDI.

Furthermore, the hydrogen value chain includes actors and industries across multiple sectors, Member States and regions. Unlocking cross-border barriers has a clear EU dimension.

Specific recommendations

[79] https://www.iea.org/newsroom/news/2018/december/how-northwest-europe-can-shape-a-clean-hydrogen-market.html

EU Strategy

Develop a joint EU-wide vision and integrated masterplan/roadmap for a future European Hydrogen Economy and ensure a coordinated approach of the EU, national and regional support to the H_2 technologies.

Several countries have committed to and announced to build up a hydrogen economy (e.g. Japan, Korea). Several Member States have also started preparing strategies and/or have initiated first actions. However, a clear EU-wide vision is needed on the different technologies, needs, actors to be involved along the timeframe from 2020 to 2050. Furthermore, a coordinated transnational energy policy focused on hydrogen is needed. Based on a joint vision, a coordinated or jointly agreed roadmap needs to be prepared taking into account compatibility, additionality, inter-dependency across regions and stakeholders. This would benefit from further analysis (simulations, studies) together with an agreed process to decide on selected technologies, systems, utilization cases and the timeframe for their scale-up. A fact-based, transparent decision base[80] is needed for any concerted roadmap and action.

A dedicated strategy for implementing the hydrogen vision, under the umbrella of the European Commission with participation, support and commitment of Member States and regions, should be urgently elaborated. Electrolysers enable a greater share of renewable electricity in the energy systems. Thus, the role of hydrogen technologies as enablers in the integration of increasing quantities of renewable energy in the energy system should be part of a future strategy.

Continuous R&D&I

To prepare the first industrial deployment and industrialization of next-generation hydrogen technologies and systems: ensure EU innovation leadership through continuous strong support to EU R&D&I

Concerted R&D&I projects along the hydrogen value chain and for next-generation key components are needed to build synergies across EU, national and regional programmes and complementary competencies. Cross-border cooperation and partnerships on close-to-market technologies need to be led by strong industrial partners and focused to support technologies around "hydrogen hubs/regional hotspots" with a clear target for later industrialization, taking into account the cross-sectoral integration aspect. Joint projects on next generation technologies for a future industrialized hydrogen value chain such as liquid organic hydrogen carrier, electro fuels, high-pressure tanks and stacks are important to generate knowledge and to deepen EU wide partnerships at an early stage. A systemic view and understanding along the full SVC are necessary, in particular with the target to improve the efficiency of the energy system and the smart integration of various solutions.

Existing networks and funding mechanisms on EU level should be continued and further extended to the timeframe 2020-2030: With a total budget of approximately EUR 1.3 billion through 2020, the

[80] E.g. clear, transparent and updated life cycle approach and comparison of CO_2 emissions depending on the primary energy, in terms of hydrogen technologies/ systems, business models, etc.

Fuel Cells and Hydrogen Joint Undertaking (FCH JU) mainly supports research and innovation activities in the FCH sector and issues annual calls for proposals on selected topics. As an industry-led public-private partnership (PPP), the FCH JU is only able to support FCH projects envisaged by coalition participants to a limited extent. The FCH JU and established structures around should be equipped with an appropriate budget (minimum at the same level as through 2020, e.g. EUR 1-2 billion for 2020-2030) and focus on RDI implementation of the roadmaps as set in the EU strategy. The FCH JU or its successor PPP could focus on the sustainable creation of the industrial ecosystem.

Build up a sustainable industrial ecosystem

Strengthen a skilled workforce as backbone, industrialize key components, create a more mature supply chain, scale-up technologies for multiple businesses, and create a circular economy

The European hydrogen supply chain is still developing. Currently, the hydrogen supply chain is fragmented and consists mainly of relatively small organisations. However, in terms of technologies, European companies and research organisations are world-class today in many of the technologies needed for fuel cell and hydrogen supply chains. About 300 companies with known positions in hydrogen technologies have been documented, and more exist in other supply chain areas. These suppliers are supported further by more than 250 identified knowledge-based actors across different domains of expertise[81].

Based on the existing R&D and industry network a highly skilled workforce in all parts of the value chain needs to be developed and strengthened as enabler for a future hydrogen ecosystem. This could mean e.g. supporting integration of hydrogen technologies and systems (such as electrolysers and fuel cells) as main subjects in university and vocational training engineering courses.

The first industrial deployment and industrialisation of key components (e.g. high-pressure tanks, stacks) through pilot manufacturing needs to be started. The value chain could be strengthened by supporting joint ventures and partnerships, SME integration and a more mature industrial structure or supply chain. The scale-up of low carbon hydrogen technologies through an ecosystem approach (multi-usage approach) is also needed. This includes the creation of new business opportunities and markets for hydrogen applications, starting with experimentation capacities and promising use cases. A future circular economy will need a highly integrated and seamless technology and system development, production and recycling. With Hydrogen Europe, the FCH JU, etc. there are existing actors and networks which can go in the lead to set up and strengthen an EU wide stakeholder platform to overcome current fragmentation and subsequently establish and successfully implement an EU industrial hydrogen ecosystem in the timeframe from 2020-2030.

Ensure public awareness and acceptance

[81] E4tech, ECORYS and SA-Strategic Analysis (Fuel Cell and Hydrogen Joint Undertaking; publishing waiting for final approval by the Governing Board of the Fuel Cells and Hydrogen 2 Joint Undertaking), Value Added of the Hydrogen and Fuel Cell Sector in Europe: supporting European growth and competitiveness. Draft final versions, including the Evidence Report, the Findings Report and the Publishable Summary accessed 15 Mar 2019.

Inform market players and consumers on positive potentials, demonstrate feasibility & ensure maximum safety for European citizens and create competitive advantage through standardisation

While the hydrogen economy is developing, there is a need to increase public awareness and acceptance for hydrogen in Europe as a critical component for energy security, sustainable economic growth and decarbonisation. Potential future market players, in particular SMEs, and consumers should be informed about the positive contribution of renewable and/or low carbon hydrogen to the environment, the potential and effectiveness of hydrogen in terms of supply chain, economy, ecosystem including effects on jobs and EU added-value (via information campaigns). In this context, it needs to be demonstrated that a hydrogen economy will be technically, economically, environmentally and societally feasible (e.g. conduct and make visible demo-projects and business cases along the whole hydrogen value chain and demonstrate the safety along the hydrogen value chain). Public awareness on hydrogen safety should be linked to similar information initiatives related to other fuels and solutions (including natural gas, gasoline, batteries, etc.), also underlining the high relative safety of hydrogen.

Set up supporting regulative measures and establish a clear regulatory framework (environmental, permitting, etc.) for a hydrogen economy to evolve

EU and/or national policies are needed to support the increasing rollout of green and low carbon hydrogen from production to the use in different applications. In accordance with an EU wide masterplan and long-term vision, a screening for deficiencies in the current regulatory and policy environment is needed as well as the development of innovative market designs and policy instruments. The adoption of low carbon hydrogen as the reference[82] is a basis for the development of a harmonized EU framework for a clear certification and for the introduction of guarantees of origin. Furthermore, continued action on more stringent pricing of CO_2 emissions in both EU ETS and non-ETS sectors are needed. Reaching the long-term climate goal for the EU may require fine-tuning or complementing the existing ETS system so as to reach an incentivizing CO_2 price, together with a series of additional measures. Systematic reforms of taxation and surcharges for electricity and fossil fuels to level the playing field are also needed.

EU legislation (e.g. Fuel Quality Directive, Clean Vehicle, Alternative Fuel Infrastructure, Gas Regulation, Electricity Market Design) are relevant and supporting legislative tools. The initiative of the European Commission to recast the Renewable Energy Directive (RED II) for the 2020-2030 period is regarded as positive to promote renewable energy in the electricity, heating & cooling and the transport sector83. However, although the RED II recognises the contribution of renewable fuels of non-biological origin, it does not properly address their effective and efficient use. It is therefore essential for the sector to ensure that hydrogen technologies are properly covered by the RED II,

[82] based on the definition developed under the EU project CertifHy

[83] In particular the introduction of renewable liquid and gaseous transport fuels of non-biological origin (REFUNOBIOs) as a transport fuel category as well as the recognition of renewable gases in the guarantees of origin market. In combination with the new Electricity Market Design it is expected that the European energy system will integrate renewables better by utilising all available technologies to avoid curtailment, thus helping the further decarbonisation of EU's energy and transport systems.

reflecting their broad potential and ensuring a level playing field between different existing technologies.

Further relevant measures are common standards, which can create an optimal environment for infrastructures to build up and for hydrogen deployment, facilitate access to existing and newly developed financing instruments to de-risk investments, etc.

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Recommendations along the Hydrogen Value Chain are more focused in concrete and quantitative measures with the need of investments in R&D&I, first industrial deployment, and scale-up at a multi-billion euro scale from 2020-2030 (~EUR 10 billion in a first phase to 2025, ~EUR 50 billion in a second phase towards 2030). The aforementioned cross-cutting measures need to facilitate and support the following measures (which might be implemented under the umbrella of an IPCEI if all the requirements are fulfilled)

Recommendations on Hydrogen Production (scaling up at demand centres)

The production of conventional hydrogen is on the carbon leakage list up to 2030. Thus, there is a need to eliminate the competitive disadvantage for renewable and low carbon hydrogen, i.e. via certificates or other support mentioned. A temporary support mechanism needs to be set up to compensate the lack of economic competitiveness of renewable hydrogen compared to grey hydrogen.

In the short to mid-term, low carbon hydrogen production bases need to be established close to existing hydrogen demand centres. In this context, clear, credible, robust and ambitious EU-wide targets should be developed for electrolyser manufacturing, possibly linked with green hydrogen production and/or consumption, in order to achieve cost-reductions for more mature technologies. A European Electrolyser Platform needs to be created and a scale up needs to be supported in two phases: in a first phase (2020-2025), the focus will be on scaling technologies to annual production capacities of several 100s of MW, including developing demonstration projects of innovative technologies at scale. In; in a second phase (2025-2030), scaling technologies to a GW-scale EU wide market and beyond will be needed. In addition, alternative hydrogen production technologies need targeted R&D&I and first industrial deployment support to develop energy-efficient technologies and scale-up to 100s of MW scale (e.g. pilot line for high temperature electrolysers, etc.) (2025-2030+)

Recommendations on Hydrogen Storage & Distribution (the important link between production and consumption)

Hydrogen does not only face a chicken and egg problem in the supply and demand sectors, but also at storage level as transport and distribution require development, new technologies, references and first deployment. Without a working transport and distribution technology and infrastructure, hydrogen production and consumption become useless. Thus, all supply chains need to be linked by suitable transport infrastructures to enable a hydrogen economy.

Recommended actions

- **Build on existing grids and pipelines for hydrogen distribution**: Create the backbone of hydrogen infrastructure to decarbonise today's oil and gas usages (e.g. create a hydrogen

distribution infrastructure around/to hydrogen refuelling stations, enable the blending of larger percentages of hydrogen into the natural gas grid, potentiate upgrading/retrofitting of natural gas grid, evaluate and test the hydrogen transport via oil pipelines with hydrogen carriers like liquid organic hydrogen carrier) (2020-2030)

- All transport technologies have to be applied in industrial scale to evaluate their feasibility and economics. **Distribution hubs** with a well-organised transportation network to the consumers could play a role. Thus, airports/railroad stations/ports should be developed as hubs for hydrogen logistics (2020-2030). In a first phase starting 2020 define at least 1 hub with several consumers and start installing and operating plants. In a second phase (2025+) at least 10 hydrogen distribution hubs are required to follow throughout Europe, preferably ports, airports or industrial complexes where large scale transports (e.g. ships for liquid organic hydrogen carrier, pipelines) arrive and transfer to smaller scale transports into the field takes place.
- Push forward **large-scale hydrogen storage**[84] for sustainable energy resilience and security, i.e. multi-purpose storage facilities to allow the integration of huge amounts of renewable energy (2020-2030). In a first phase (2020-2025), first large-scale storage facilities need to be created. From 2025 onwards, an expansion of facilities can be realized and beyond 2030-2040 commercial infrastructures can be build up. The electricity market regulation currently hinders this development as the market does not value storage. Grid fees also need to change as they are currently designed for a completely different framework and hamper the business case.
- In parallel and for beyond 2025-2030+: Develop, deploy and test further technologies for **alternative hydrogen storage and transportation** (e.g. liquid organic hydrogen carrier, metal hydrides, ammonia) at large scale.

Recommendations on Hydrogen for Industrial Use (industrial feedstock and process chemical for energy-intensive industries)

Hydrogen is an important feedstock, input and/or chemical reactant for many industrial uses; e.g. the use of hydrogen in the steel production would avoid CO_2-emissions and the use of coal completely. In order to be cost effective and provide the highest value, renewable and/or low carbon hydrogen should be directed primarily towards usages which are difficult to decarbonize and where they are most efficient, namely as raw material for industrial use, both as industrial feedstock and process chemical.

The energy-intensive industries (e.g. steel. chemical, cement) have in common that short-term targets (e.g. until 2025/2030) focus on the technological improvement of low-carbon "breakthrough technologies" for carbon direct avoidance. This includes R&D projects, pilot plants, first industrial deployment and integration of new technologies in existing industrial processes. The scaling up to industrial scale operation is typically seen in the timeframe 2025-2035 and beyond. This stepwise implementation will depend on the technical feasibility, the availability of renewable energy and

[84] In particular, develop technologies for large-scale use of liquid hydrogen and create liquid hydrogen supply chain (2020-2030)

competitiveness and it is thus aligned until ~2050 with the goal to reach 80-95% greenhouse gas emission reduction in the long-term.

Recommendations on Hydrogen for Mobility (push forward H_2 adoption in hard to decarbonize mobility applications - heavy duty and/or long range)

Level playing field for transport application*:* Support mechanisms to alternative fuels for transport should ensure a level playing field to let the most competitive and efficient solutions emerge. This is particularly key for the different infrastructure support to different zero emission technologies.

- Push forward the development and deployment of **hydrogen into road mobility** (2020-2025): Focus support on heavy duty vehicles with long range and intensive usage profiles, including captive fleets and their related infrastructure. To do so, develop and deploy zero emission vehicles (10,000 trucks and 5,000 buses per year in 2025). In order to reach procurement targets as indicated in the Clean Mobility Package, fuel cell buses[85] will be a good complement to battery electric buses to accelerate deployment of zero emission public transport, given that 50% of the bus targets under the Clean Vehicle Directive have to be fulfilled by zero-emission buses.
- Develop a hydrogen-based propulsion system for **regional and local trains** operating on non-electrified routes (to 2025): Set-up support mechanisms for the development of hydrogen trains, the infrastructure (hydrogen refuelling stations) and define a European certification framework for trains at European level (European Rail Agency).
- Push forward the hydrogen-based **inland or coastal ships and maritime vessels** as an alternative to highly pollutant diesel engines (to 2025: e.g. 1 big ship order + 10 inland ships and/or other sea-going ships). Support the development of new hydrogen inland ships or costal vessels, the related infrastructure (hydrogen refuelling stations) and develop a positive, stable legislative and regulatory framework.
- Push forward the hydrogen utilization in **air transport:** Start to build up hydrogen-logistics at airports by 2025, demonstrator for the propulsion system for small and large airplanes[86]
- **Regarding the infrastructure**, in the upcoming **revision of the** Directive on Alternative Fuels Infrastructure, a level playing field between the different zero emission technologies should be ensured: in this line **hydrogen should become a mandatory fuel**. In addition, an open approach should be fostered with hydrogen refuelling stations located on the TEN-T core, comprehensive network or on urban nodes, and distances between refuelling station should be reduced (from 300 to 150 km)
- Europe is a leader in electrolyser production and this leadership should be maintained. However, hydrogen refuelling station providers face high upfront investments, long lead-time due to regulatory barriers (e.g. long permitting processes), the uncertainty of vehicle deployments and the uncertainty of market acceptance. High operating costs and the

[85] As hydrogen buses are not at the same manufacturing readiness level as battery buses, it is important to spur the different players of the value chain (from infrastructure to components) in order to be as competitive as the other alternative powertrain initiatives.

[86] E.g. support the development of a <100-seater commercial passenger airplane (2025-2030).

relatively small number of vehicles in certain areas further discourage hydrogen refuelling station operators to take on development risks. Comprehensive strategies for parallel **infrastructure and vehicle deployment developed jointly by public and private actors** together are an effective instrument to ensure a sustainable network development.[87]

- Permitting requirements applicable to hydrogen production at the national level and the extent to which they stem from obligations under EU legislation should be identified and studied in detail at EU level. "Gold-plating" in national transposition of EU legislation should be highlighted and avoided.
- When a possibility of revision comes up, small-scale storage of H_2 for retail refuelling and the small-scale production of hydrogen via electrolysis should be excluded from the scope of the relevant EU acts. At the very least, legislation should be adapted to consider the specific nature of these activities.
- In the Member States, hydrogen refuelling stations should explicitly be treated as conventional refuelling stations from the perspective of land use plans and zone prohibitions. For that purpose, direct emission-free production of hydrogen should be excluded from the scope of legislative acts which currently cover the production of hydrogen. At the very least, the concept of "chemical conversion on an industrial scale" should be defined in a manner which excludes the production of hydrogen via electrolysis in small enough quantities from the obligations stemming from the Industrial Emissions directive, Environmental Impact Assessment and Strategic Environmental Assessment directives.
- Finally, to support practical implementation at local and regional level, the NACE[88] codes should be adapted to reflect the emission-free production of hydrogen separately from the manufacture of industrial gases under which hydrogen production currently falls. Furthermore, to further reduce the risk of unequal treatment from a land-use plan perspective, hydrogen refuelling stations should unequivocally fall under the same NACE code as conventional refuelling stations, i.e. 47.30 – Retail sale of automotive fuel.

Recommendations on Hydrogen for Stationary and Grid-scale applications

An electrolysis plant providing response services, reserve services or congestion management services to the electricity grid is helping to manage the variability caused by renewables. Thus, it helps to integrate more renewable energy by reducing curtailment and CO_2 emissions of conventional grid

[87] See for ex. the plan of Hydrogène Mobilité France. In France the strategy developed consists of starting early deployments following a "cluster" strategy model with the simultaneous deployment of vehicles and stations which enables a good usage rate of the station. In such a strategy HRS do not need to be oversized and might be upscaled in a second step when the number of vehicles deployed requires it. In addition, joint ventures are being formed such as H_2 Mobility in Germany in order to share the risks and high upfront costs. Best success stories in HRS deployment are when fleet operators have confirmed vehicles orders therefore ensuring the stations profitability such as in Switzerland – Hyundai will deliver 1,600 trucks to customers including retailers coop and Migros. An association has been formed between 7 Swiss companies to create a hydrogen refuelling network.

[88] The Statistical Classification of Economic Activities in the European Community

balancing techniques. Use-of-system grid fees for such power-to-gas systems should be waived and the hydrogen they produce classified as renewable hydrogen.

Even if the production costs of renewable energies have significantly decreased, the level of investments in infrastructure (electrolyser, storage, etc.) and the cost of electricity are such that renewable hydrogen is not yet competitive. Some measures have to be implemented to avoid market failure and accelerate the deployment of electrolyser capacity, for example, by stacking revenue streams.

Ensuring a level-playing field in the electricity market is required, meaning that electrolysers should be exempted from double grid fees. Furthermore, electrolysers require significant amounts of electricity and the electricity price represents one of the most important cost factors for the conversion of electricity into hydrogen. Therefore, it is important to reduce the price of the electricity used in the electrolyser process, provided that it comes from renewable energy sources. Considering the potential of renewable hydrogen for decarbonising the gas, mobility and industry sector, its production by electrolysis, regardless of the capacity of the *p*ower-to-gas/*p*ower-to-hydrogen plant, similar to the production of industrial gases, has to be included in the list of electricity- and trade-intensive sectors in order to reduce the charges in the electricity price associated with the use of renewable energies.

Finally, in its current guidelines[89], the European Union defined (art. 1.3.11) energy from renewable energy sources as "energy produced by plants using only renewable energy sources, as well as the share in terms of calorific value of energy produced from renewable energy sources in hybrid plants which also use conventional energy sources and it includes renewable electricity used for filling storage systems, but excludes electricity produced as a result of storage systems". In order for electrolysers to play their key role in renewable integration across sectors as well as contribute to the decarbonisation of the power sector through ancillary services, it is recommended that the guidelines are reviewed so that electricity produced *from a hydrogen energy storage facility* would be considered renewable.

Power generation and balancing, buffering together with pure hydrogen heating are seen as long-term opportunities beyond 2030 and are related to the further expansion of renewable energies. Thus, recommendations such as on grid services are set and need to be effective starting around 2030.

[89] Guidelines on …?

Industrial Internet of Things

Description and scope

The Industrial Internet of Things (Industrial IoT) – as a subset of the larger Internet of Things (IoT) - focuses on the specialized requirements of industrial applications in various industry segments such as manufacturing, oil and gas, transportation/mobility, energy, and utilities. Hence, Industrial IoT refers to the usage of IoT in industrial settings where intelligent edge devices, processing units and networks interact with their environments to generate information and knowledge to improve/optimise industrial processes.

Access to, and use of, relevant and high-quality data is widely recognised as the crucial element in the Industrial IoT and in particular for exploiting artificial intelligence in industry.

Industrial IoT systems are mainly set up to harvest, store and structure different types of data in a way that they can be easily managed and analysed. These systems are mainly installed to improve operational efficiency, energy efficiency, resource efficiency and productivity, to develop new and/or higher value-added services, or to decrease failures and business discontinuities and to support decision making.

The Industrial IoT is at the core of the digital transformation of Europe's industry.

Strategic importance

According to the World Economic Forum, industries that will be transformed by the adoption of Industrial IoT will account for almost two-thirds of the world economy. Analysis of Accenture points to a global GDP benefit of the Industrial Internet of Things of around USD 6 trillion dollar by 2025. By 2030, the estimated global value created by the Industrial Internet of Things is expected to be between USD 10-15 trillion. The value chain of Industrial IoT is structured along the way data gets captured, transferred, processed and analysed in order to manage and optimize processes, to support decision-making and to generate new products, new services and markets thanks to unexpected correlations among industrial data (see figure below).

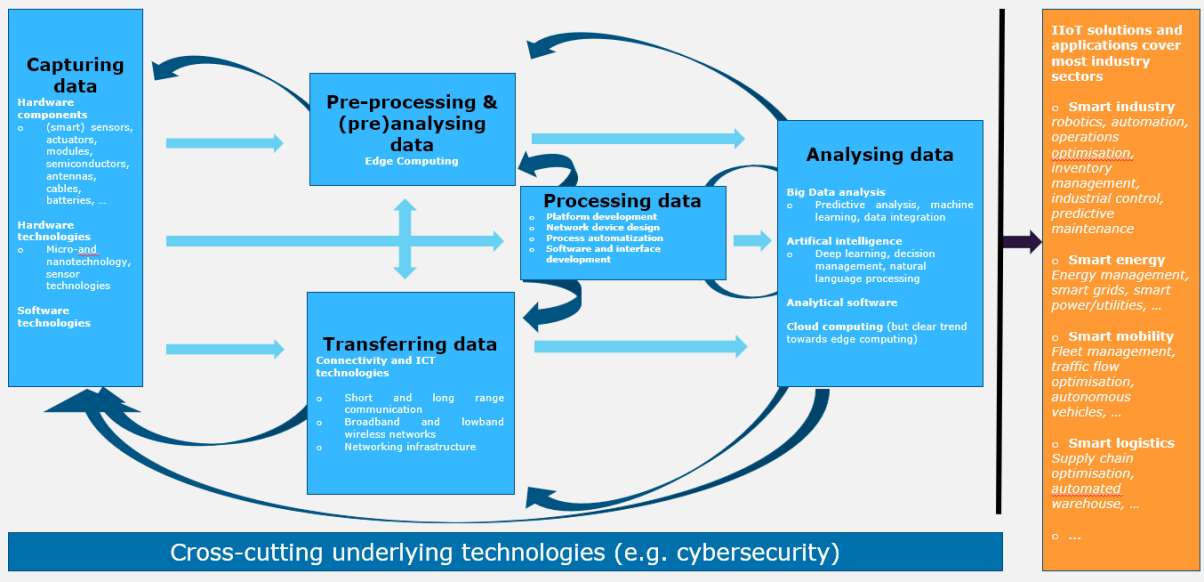
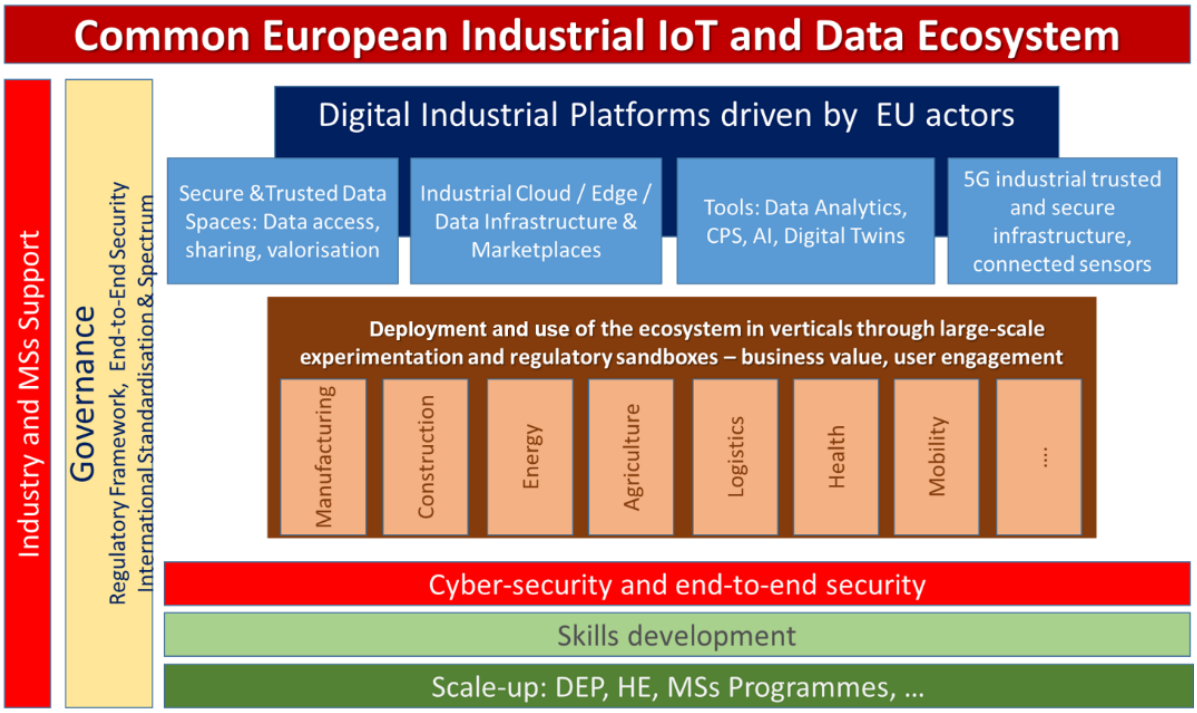


Figure 1. Several feedback loops exist between the various value chain segments (data for instance is not transferred only from left to right but can also be send back in the process). The future IIoT solutions will evolve around a decentralised and distributed value networks model across the different IIoT architectural layers

Industrial IoT technologies are at the centre of the digital transformation of our industry and open plenty of opportunities in all industrial sectors such as manufacturing, logistics, oil and gas, transportation, energy/utilities, mining and metals, healthcare, aviation and other industrial sectors. The Industrial IoT value chain is linked to microelectronics, High-Performance Computing and cybersecurity and to a broad range of other strategic value chains.

Vision

A huge market potential for the EU lies on leveraging Industrial IoT, in particular exploiting artificial intelligence in industry and making the most out of high-quality data. Unlocking such potential benefits requires specific solutions to reduce fragmentation of data production, to overcome data silos and to minimize data lock-in. This **would ultimately lead to a "common European Industrial IoT and data ecosystem" as described in the graph below.**



A common European Industrial IoT and data ecosystem must include the following elements:

1. Secure and trusted data spaces

Data access, sharing and valorisation in sector-specific industrial data spaces.

Access to, and use of, relevant and high-quality data is a crucial element in the digital transformation of industries and in particular for exploiting artificial intelligence in industry. Currently, only a fraction of the value of industrial data is captured. The production of all kinds of data in Europe is very fragmented, if not in closed silos, and ownership is scattered. The current uncertainty over industrial data sovereignty may hamper the further development and deployment of Industrial IoT technologies, especially when data comes from various connected devices or nodes belonging to a variety of different owners and is afterwards combined into newly generated data and information.

Industrial data is an integral part of private companies' business models. Therefore, it has to be maintained confidential among a limited number of actors or offered to other companies under conditions which the data-owning enterprise may determine. Together with a governance framework based on European values, data spaces would enable business models for trading and monetizing data, based on interoperability frameworks, ontologies and standards for sharing data and collaboration across B2B platforms. Monetization of data would enlarge the economic value of a common European Industrial IoT and data ecosystem.

A thriving Industrial IoT and data ecosystem requires the engagement of different entities and actors in the value chain. It would result in closer cooperation among industrial data owners and users, while respecting the legitimate interests of industrial, public and private data holders. In order to reach shared value creation, Member States and industry must cooperate. Secure data spaces generate trust for the application of Industrial IoT with the industrial data owners and users.

Recommended actions

- Develop common European data spaces and/or boost the scale-up of common data spaces based on industry needs. Sector-specific industrial data spaces provide secure and trusted access to industrial and potentially private and public data. Seamless interoperability among the data spaces should be ensured and all data spaces should share the same level of detail and offer the same value added.

- Support the establishment of a PPP for the data ecosystem.

- Define accompanying measures to include SMEs in the Common European Industrial IoT and data ecosystem.

- Investigate what industrial data and/or private data can be collected, shared and utilised for new intelligent services in high-performing, reliable and secure ways. Investigate how such data could be harvested and harnessed to improve supply chain cooperation to retain and retrieve value through circular economy approaches. A metadata description of data available and contacts of the data owner could be also useful.

- Define an accompanying regulatory initiative addressed to industrial data protection

- Scale up the common data space by existing or emerging standards and technologies as well as accepted governance models.

- Establish international partnership networks to drive common international standards for data sharing and define the main standards for Industrial IoT systems.

- Define accompanying measures, such as awareness-raising, sharing of best practices and training for industrial data safeguard, protection, and valorisation, industrial data re-use and sharing, industrial data management, licensing, etc.

2. Industrial cloud, edge and data infrastructures

Store and process data and information where needed.

The next generation of European cloud infrastructures needs to be developed for highly sensitive industrial applications. Sharing non-confidential industrial data within the value chain can improve the value-for-money of investments, favour open innovation, and stimulate new entrepreneurship.

The whole computing continuum from cloud to edge and device needs to be covered. For example, in terms of data capturing, sensors detect, measure or indicate specific physical features such as humidity, motion, speed, pressure, light and temperature, and collect relevant data on the state and the environment. As such, they act as an information interface between physical devices and data processing and analysis. For practical applications, real-time processing (i.e. avoiding latency), security, safety, and autonomy are important concerns. A growing demand by companies for a hybrid cloud deployment mode combined with the need for optimisation of data workloads for faster data processing with no latency at the edge ('cloud-to-edge services') is emerging. Hyper-scalability is needed exploiting the whole continuum of computing capabilities (device, fog, edge and cloud) to scale out software systems based on demand and user needs. Ultimately, this will achieve new levels of resource efficiency and cost-optimal deployment of systems.

Recommended actions

- Develop next-generation cloud infrastructures, including possible cloud federation involving a multitude of European cloud providers.

- Provide non-discriminatory public support to the development of sensors and other devices for in-situ process monitoring, as part of establishing a full computing continuum.

3. Tools for data exploitation and AI

Software algorithms, Big Data and Artificial Intelligence methods for industrial competitiveness and sustainability and for new products

The effective usage of Industrial IoT data, generated within or outside a company, requires extracting potential value by determining unexpected correlations. Big Data techniques and Artificial Intelligence techniques including deep learning can improve value extraction.

Developing those methods and tools and making them available on-demand would greatly decrease costs, mitigate risks, enlarge industrial resilience, and increase productivity. It would affect suppliers and end users in the ICT sector, SMEs, mid-caps and large companies, with positive spillover effects on the competitiveness of industries in Europe in many different application fields.

It is important that ethical principles are complied with in such methods and tools. Trustworthy AI tools, for example, must be lawful (i.e. not operating in a lawless world), ethical (i.e. ensuring alignment with ethical norms), and robust (i.e. with the user in control and not causing any unintentional harm).

Digital twins can serve as an optimization tool to a number of industries by giving the ability to simulate changes in products and production processes quickly and with no risk to actual operations. These developments can be even more valuable in high-risk industries such as mining. For example, data-driven decisions in deep mining operations give better control through increased understanding in a shorter timeframe, thereby increasing safety and production. Digital twins help in understanding potential failure points, which may result in timely corrective actions or new insights. For example, in products produced with metal additive manufacturing, understanding potential failure points gives insights into the microstructural properties of parts and may lead to the discovery of new alloy types with previously unachievable functional properties.

Recommended actions

- Establish specific research and technology fora bringing together industry and R&D actors for the development of tools for data analysis and AI.

- Extend open EU platforms (e.g. FIWARE[90]) with big data analytics and AI capabilities to find automatically new correlations among Industrial IoT data in order to generate new information, and to perform real-time interpretation and visualization of Industrial IoT data.
- Define coordinated actions to develop kits for digital twins for different sectors.
- Extend open EU platforms with "Digital Twin" capabilities.
- Provide public support to European Big Data and Artificial Intelligence software provision specifically addressed to relevant industry sectors.

4. A future industrial 5G infrastructure that responds to industrial needs

Critical for the digital transformation of European industry towards smart factories (the same applies to smart farming, smart energy and smart mobility) is a resilient, low latency and secure local network infrastructure building on 5G and its evolution to 6G.

For the factory of the future, local industry-grade mobile networks with high quality of service need to be designed, developed and deployed. This is a pre-requisite for agile connection of machinery on the shop floor, for maximising operational efficiency, for managing increasingly complex supply chains and lean production. Such networks may require the allocation of specific spectrum "slices" to industrial entities other than telecom operators. It may also require governance and business models, which may deviate from those of classical public cellular networks.

Similar networks are needed in other sectors. This requires new cooperation between Industrial IoT integrators and the telecom sector; collaboration across industrial ecosystems and across European national borders; strong investments in industrial research and innovation; dedicating piloting, testing and certification along specific application fields; ecosystem building and adoption across all industrial sectors.

Recommended actions

- Earmark necessary funding for the deployment of industrial 5G infrastructure in Europe.
- Develop an innovation-oriented 5G regulatory framework in Europe, including an effective system for licensing standard-essential patents, with sufficient attention for the needs of 5G deployment in industry.
- Harmonize across Europe spectrum for industrial use; if needed, regulate the allocation of specific spectrum "slices" to industrial entities other than telecom operators.
- Support co-investments and shared infrastructure as well as a shared governance model.

[90] The FIWARE Community is an independent Open Community whose members are committed to building an open sustainable ecosystem around public, royalty-free and implementation-driven software platform standards that will ease the development of new Smart Applications in multiple sectors.

- Support coexistence of 5G with legacy systems.

- Ensure safety and security in industrial 5G networks and support the development of security standards.

5. Digital industrial platforms driven by EU actors

Investment in specific elements of a common European industrial IoT and data ecosystem is necessary, but not sufficient. In addition, it is crucial to take a holistic and co-ordinated approach, building on strategically managed platforms and ecosystems in key sectors.

Europe is well positioned in the industrial (B2B) platform area in sectors such as manufacturing, energy, and mobility. However, the European and global B2B platform landscape is characterised by a high proliferation and fragmentation of diverse solutions with few signs of consolidation. Continued European leadership in the B2B platform area requires commercial platforms to become more attractive to users by becoming interoperable, collaborative, simple, scalable, secure, and trusted. Data needs to seamlessly flow from one organisation to another.

In the last three years, Europe has invested EUR 1 billion in building digital industrial platforms and their large scale piloting via the Horizon 2020 programme (e.g. cPPPs, ECSEL JU). This is already now leading to increased collaboration across value chains and a pooling of resources across Member States, as well as the emergence and consolidation of digital industrial platforms in sectors such as manufacturing, agriculture, health, construction, and energy. For Europe to stay competitive, these efforts need to increase significantly.

Recommended actions

- Enhance the definition of common data models to enable interoperability and scalability of different Industrial IoT platforms.

- Provide smart manufacturing open platforms, based on industry standards and AI techniques, allowing the fast creation of data visualization and dashboards for real-time monitoring of industrial processes and finding correlation among data.

6. Cybersecurity

The Industrial IoT value chain is vulnerable to cyber-attacks. There are more and more digital devices connected to the Internet, and anything ‘smart’ means typically something vulnerable. Digitalisation has made cybersecurity everyone’s concern. It is of utmost importance that the Industrial IoT value chain has key cybersecurity capabilities at its disposal, supported by European essential service providers and a domestic cybersecurity industry.

Therefore, the Industrial IoT value chain would greatly benefit from cybersecurity capabilities developed under the Cybersecurity value chain (see next chapter)

7. Skills development - especially in advanced analytics and artificial intelligence.

Currently, there is an increasing shortage of the profiles needed in the Industrial IoT value chain on the job market. Defining a vision for skills for Industrial IoT and creating the right framework

conditions for turning Europe into a world-leading centre of excellence for skills in Industrial IoT will be instrumental.

The transition to new Industrial IoT technologies needs to rely on a large talent pool spanning across different knowledge domains. The skills shortage may even widen in the near future as more and more businesses embark on Industrial IoT projects. For many European companies, the transition to Industrial IoT means setting up a cyber-physical environment connecting machines and systems by merging production technologies with ICT. Therefore, long-standing expertise in advanced manufacturing needs to be coupled with a boost in in-house digital capacity embracing software developers, big data analysts, system designers as well as cybersecurity and cloud computing specialists. Talents will be needed to leverage the potential of digital solutions in offering services on top of the physical product to the customer, as well as to unlock the power of digital in optimizing in-house production processes.

To achieve all that, a paradigm shift is required in the way the workforce is trained. Europe has the right skills in mechanical and engineering domains but not in advanced analytics and AI. Policies to better embed Industrial IoT/Industry 4.0 concepts into education are required across Europe as well as quicker revisions of curricula to align them with the evolving industry landscape.

Recommended actions

- Define needed skill sets at industry level.
- Incorporate more flexibility in the education systems as the pace at which technology changes is substantial, in particular develop approaches and methodologies for a faster revision of curricula in higher education and VET contexts.
- Foster exchanges of best practices on Industrial IoT-based training and educational programmes across Europe and scale up the best practices.
- Involve industry in a European pilot programme where curricula and the respective skills needed can be co-developed for the different Industrial IoT value chain segments.
- Include more robustly Industrial IoT in engineering and manufacturing learning programmes all over Europe.
- Encourage the creation of new teaching concepts better tailored to the new reality of Industry 4.0.
- Attract AI and other needed talent for the Industrial IoT value chain.

8. Scale-up - existing initiatives

Several member states initiatives and best practices already exist at European, national or transnational level. These should be combined with other initiatives from the future Digital Europe Programme and Horizon Europe to maximise their impact. One should better promote these ecosystems as these are crucial in delivering substantial added value.

In particular the investments in networks of digital innovation hubs (DIHs) are crucial here. DIHs help SMEs and mid-caps in their digital transformation. They are instrumental in rolling out digital

advances into the broad economy. The current investment on European level of EUR 100 million per year is foreseen to be more than doubled in the next programming period. In particular, the Digital Europe Programme foresees significant resources for building DIH capacity across the European Union. The European network of DIHs must become an integral part of the common European industrial IoT and data ecosystem.

In addition, industry actors in a specific sector need to jointly define agreed Industrial IoT specifications. As different technologies are needed for Industrial IoT, technology providers need to agree on how different components can be integrated, what the interfaces are, and how technology can implement the specified functions. In other words, they agree on 'reference architectures'. Such industry-wide agreements facilitate product and service design among industry players. For example, they facilitate that product (components) and services developed by company A will interoperate with those from company B and can be interchanged by those from company C; company A's products are complementary to those from company B and can be substituted by those from company C. Such industry-wide agreements have an instrumental role in creating new markets and market opportunities.

Recommended actions

- Support the establishment of Digital Innovation Hubs in all EU regions.
- Provide public support to technology providers and lead users in Europe to define industry-wide specifications favouring the scale-up of digital solutions and the vendor-independent approach.

9. A sector-based approach

It is expected that the establishment of common European Industrial IoT and data ecosystems will take place for different industrial sectors. It should be noted that the business value of ecosystems can be significantly different across specific application fields (e.g. regarding time-to-market, flexibility, and business prospects). In addition, data definitions, industry-wide agreements, governance models, etc. may also differ from one sector to the other.

Therefore, the approach to investing in building European industrial IoT and data ecosystems needs to target different industrial sectors. The overall objective is to establish ecosystems where companies can securely exchange data and have access to data pools for AI training purposes. Sector-specific characteristics need to be taken into account while reusing common concepts, definitions, and technologies where possible.

Recommended actions

- Invest in building common European industrial IoT and data ecosystems in key industry sectors, including manufacturing, agriculture, transportation/mobility, energy, and utilities.
- Focus on relevant specific domains first.
- Provide support to large-scale pilot projects to test the integration of digital systems into discrete and continuous industrial processes, using open standards. Validate value extraction from process data aiming at process control and optimization and decision support. Test and verify developed solutions in specific industrial settings.

- Involve SMEs and mid-caps in pilot projects or set up specific projects for SMEs and mid-caps.

- Combine R&D and training for Big Data and Artificial Intelligence applications in large-scale pilot projects

Set a number of concrete KPIs to monitor the progress towards common European industrial IoT and data ecosystem, e.g. number or quality of use cases; the amount of private investment; development of infrastructure, etc.

Why intervention is necessary at EU level

Building such a common European industrial data ecosystem has been identified as crucial for Europe's digital sovereignty and for the competitiveness of its core industrial sectors, by means of actions addressed to microelectronics, super-computing infrastructures and AI reference sites for real-scale training of AI algorithms in several application domains. However, a clear Industrial IoT infrastructure strategy is still missing. Despite current European leadership in many important industrial sectors, such ecosystem could emerge too slowly in Europe for its industry to face competition by large multinational actors from East Asia and the US, due to the market fragmentation. This market failure calls for public intervention for building a "reference architecture" for relevant application fields, based on interoperability, integration in an end-to-end perspective, portability in order to avoid lock-in effect and ensure security and safety. The realization of a common European Industrial IoT and data ecosystem requires resources that no organisation or Member State alone could mobilise and would create benefits to all the European industrial sectors. The creation of the industrial data ecosystem and the positive spill-over effects of a public intervention call for an EU-level action, comparable to an extent to the investments in competing regions such as the US and China. Furthermore, the coordination needed to start building the ecosystems requires a neutral actor and would benefit greatly from public support.

Cybersecurity

Vision

Cybersecurity is a vast and often poorly understood topic. With the growing digitization of our world, it will continue to have ever greater importance in all aspects of our life: from the economy to defence and the health of our democracies.

Cybersecurity covers a wide range of topics: encryption, monitoring, identity management, authentication, endpoints (devices) and digital services. It encompasses hardware, software and services. Because of its breadth and complexity, it is challenging but necessary to have a holistic and integrated approach to cybersecurity. This should be done at a European level in order to reach critical mass and levels of excellence needed to strengthen the cybersecurity value chain, both for the benefit of its suppliers and its users.

The Strategic Forum developed a common vision for the "Cybersecurity in Europe by 2030", serving as a guide for formulating, prioritizing and coordinating recommendations for actions. This vision can be summarized as follows:

- Competitiveness: EU is to ensure competitiveness of the EU cybersecurity industry on the global cybersecurity market
- Protection: EU is to increase levels of protection with appropriate cybersecurity solutions
- Independence: EU to increase its autonomy and technological sovereignty in cybersecurity
- Leadership: EU to achieve global industrial leadership in key areas of cybersecurity

Stronger and more competitive European cybersecurity industry by 2030

The digital transformation, Internet of Things, Artificial Intelligence and 5G mean that also the interface for cyber-attacks is growing. There are more and more digital devices connected to the Internet, and anything smart means they are also vulnerable. Digitalization has made cybersecurity everyone's concern.

EU institutions, national and regional governments and businesses should join forces to protect societies, critical infrastructure, data and privacy of our citizens. It is of utmost importance for strategic autonomy that Europe has key cybersecurity capabilities at its disposal. In that context, Europe should strengthen European essential service providers and the EU cybersecurity industry.

The main challenge for the European cybersecurity industry is that, in some sectors, the biggest players and service providers are non-European. If the European cybersecurity market is 26% of the global market but European companies provide only 5% of the global market, there is a problem. A second challenge is that European cybersecurity companies are small compared to the global giants. Therefore, Europe needs a different approach and understanding on how to build effective cybersecurity ecosystems.

A third challenge is the skills gap. Europe will be competing on a global scale for the best cybersecurity talent. The skills gap for cybersecurity professionals working in the industry in Europe is predicted to be 350,000 by 2022 and globally 1.8 million.

EU to ensure competitiveness of EU industry on the global cybersecurity market

The EU should take into account the global level-playing field and ensure the competitiveness of the European cyber security industry globally. In the next few years, the global cybersecurity market is expected to grow at a double-digit compound annual growth rate. Depending on the methodology used, the cybersecurity market is estimated at EUR 100 billion to EUR 600 billion globally and is expected to grow in the next five years on average by approximately 17%.

EU as a global leader in key areas of cybersecurity

In the cybersecurity field, there seem to be two separate streams and even silos:

- "Non-Civil" areas (police, homeland security, defence and intelligence) on the one hand, and
- "Civil" areas (businesses, consumers, administrations and public services) on the other hand.

Whereas the first is considered as a high priority topic due its public security aspects, with historically strong public financing and other proactive measures for supporting national players and technologies, the latter is left to the market with a more *laisser-faire* philosophy. Cybersecurity should be looked at more holistically as a matter of security, both for civil and non-civil areas.

Greater awareness about cybersecurity

Many EU consumers, politicians or organizations are not even aware of cybersecurity risks, and hence users are not adequately protected. EU enterprises have high risk of losing their valuable intellectual property due to insufficient cybersecurity preparedness and resilience.

Cybersecurity is a strategic question and must become an integral part of any business strategy. Cybersecurity should be discussed at the highest level of companies, international organizations, and governments. It is important that cybersecurity is discussed not only in technical terms, but also in relation to (international) law, ethics, privacy and governance in order to provide sufficient context. The EU could contribute in raising awareness and ensuring that adequate solutions are deployed across the Union. The focus should not be put on one-shot protective technologies but a continuous response through technologies, processes and skills. Europe is strong and has world-class expertise in detection and response capabilities.

Europe needs to develop competitive and state-of-the-art European solutions for products and services across the cybersecurity value chain. Increasing competitiveness of the European industry means also including the local and regional levels through a variety of measures. It is also important that smaller companies can benefit from the use and development of standards, certification, procurement and investments. Public procurement and understanding the need and role of actual European solutions play a critical role in the development of the market and key capabilities.

Policymakers and legislators need to understand that no technology on its own is good or bad. Hence, when regulating it is important to look at the use and applications, not the technology itself (technology-neutrality). Therefore, it is necessary to bring technical, social sciences and ethics

expertise to those tables where policies are developed in order to fully understand the technical aspects and consequences.

Stronger cybersecurity players

European cybersecurity industry's aspiration is to become a global player that brings valuable solutions to the market. However, the European market is too fragmented, putting European players in a weak position for challenging existing global giants. There is a need to coordinate efforts, especially those of various SMEs, research institutions and governments, and encourage collaboration and, if appropriate, consolidation. European SMEs are often too small to compete alone with global players and promising European SMEs are often easy targets for non-European based buyouts.

The European Commission plans to launch in 2019 a pilot scheme within the COSME Loan Guarantee Facility (2014-2020) to support the financing of digitalisation projects including in the area of cybersecurity. Coordinated action by the European cybersecurity industry could lead to the emergence of world-leading European players in each market segment. This requires focusing investment on the competitive advantages of the European cybersecurity industry. There is a lack of knowledge on cybersecurity among investors, which results in under-investment in European cybersecurity companies/start-ups.

Action levers

There are certain key levers to achieve the vision for the EU cybersecurity value chain in 2030, to become stronger and more competitive in the cybersecurity market.

- Investments: coordinated strategic investments for technology deployment, new funding sources or modes.
- Collaboration: enhanced collaboration between public and private players at European, national and local level.
- Procurement: public and private procurement rules, guidelines and programmes.
- Technology: research, development, innovation, proof of concept and technology deployment.
- Skills: attract, develop, retain, deploy skills and build a career path.
- SME: stimulate and facilitate the move from research and innovation to market, grow start-ups into SMEs, and SMEs into large corporations and global players.
- Standards and Norms: regulation, standardization, certification and interoperability.

Specific recommendations

Considering the complexity of the cybersecurity value chain, Strategic Forum members and invited stakeholders have proposed a large number of detailed recommendations (the full list of which can be found in the Annex). On this basis, the report recommends action in two groups:

- **Coordinated Investments** in five areas. This is supported by a total of 40 industry stakeholders, of which 31 industrial players and 9 other players (industry associations, governments and RTOs).

- **Related supporting recommendations:** another eight areas of actions that would be required and useful to support the development of the Cybersecurity value chain.

Coordinated investments
1. Secure 5G for cybersecurity innovation and services
2. Sharing and exploiting information on threats, vulnerability and incidents
3. Secure highly critical applications and essential services: electricity, gas, water, vehicles…
4. Develop and deploy end-to-end data protection solutions using advanced cryptography
5. European Data Space: create a framework and infrastructure for secure data communication, storage and handling
Related supporting actions
6. Create a European Cybersecurity Investment Fund to support the European cybersecurity ecosystem
7. Create the next generation EU framework for PKI infrastructure and European DNS management for critical infrastructure
8. Leverage public procurement to enhance the cybersecurity environment in Europe
9. Accelerate implementation of the harmonisation process across the EU
10. Develop a comprehensive EU strategy to support EU players in critical cybersecurity areas
11. Boost research, innovation and technology deployment in cybersecurity
12. Develop and strengthen a highly skilled workforce in all parts of the cybersecurity value chain
13. Support development, consolidations and growth of start-ups and SMEs into scale-ups that can compete globally

1. Secure 5G for cybersecurity innovation and services[91]

5G provides a secure and capable platform, moving beyond today's consumer-oriented mobile broadband towards a more enterprise-oriented network where automation, critical systems and cyber-physical systems represent new constituents. According to GSMA Intelligence, 5G is forecast to create USD 2.2 trillion of economic value by 2034. A telecommunications generation lasts approximately 10 years and as such this investment has a future-proofed market.

[91] Sections with more detail in the annex: Secure 5G for cybersecurity innovation and services – R12

5G is the first generation of mobile telecommunications that allows network exposure functions (allowing more services to make use of the mobile network), cloud services and secured by design practices to be managed between networks. The 5G standards, defined by 3GPP[92], outline what will be secured but not how; this is being defined at present and will result in numerous opportunities that could be exploited within Europe.

Recommended actions

- Create favourable conditions for 5G networks and for its usage in the endpoints through various embedded systems like for vehicles, utilities, healthcare, and manufacturing.
- Support start-ups, scale-ups and research with a focus on securing strategic 5G services.
- Identify key technologies and service requirements for secure 5G and provide funding to accelerate these deliverables.
- Support software development that relates to new technology identified for 5G networks, such as secured APIs for service interaction between the 5G network and strategic verticals.
- Support hardware development for securing 5G technology, such as embedded systems and new appliances introduced in the standards.
- The EU should consider the cybersecurity impact regarding foreign suppliers' involvement in the implementation of 5G.

2. Sharing and exploiting information on threats, vulnerability and incidents[93]

Cybersecurity incidents are a reality and attacks are becoming more and more sophisticated. It is difficult for industry to maintain a permanent up-to-date protection level. An expert and legitimate authority at EU level able to keep track of security incidents will help to understand better the threats, impacts and vulnerabilities. A centralised data collection point, where information is stored in a standard/normalized way, will lead to better and faster reaction for the community to provide appropriate countermeasures. The centralised data collection point would require coordinated investments. This body could help in certain circumstances to offer complete advisory information and/or services for investigations.

European policymakers have acknowledged the value of voluntary information sharing to understand threats, protection, information and networks, and how to prevent cyber-attacks. Under the Directive on security of network and information systems (NIS) and GDPR, it is now mandatory for Operators of

[92] 3rd Generation Partnership Project (3GPP) unites 7 telecommunications standard development organizations (ARIB, ATIS, CCSA, ETSI, TSDSI, TTA, TTC)

[93] Sections with more detail in the annex: Promote greater sharing of cyber threats, vulnerability and incident information – R6, Develop and maintain European excellence in cyber threat understanding and hunting – R7, Support to the development of European breakthrough technologies applied to cybersecurity – R10, Risk Information Sharing Platform: Collaboration in risk management towards informed governance – R71 and Shared Database for AI development in cybersecurity – R21.

Essential Services and Digital Service Providers (controllers, processors) to inform relevant authorities of a data breach and/ or incident.

Recommended actions

- Implement and optimize existing rules, guidelines and framework for disclosure and information sharing on incidents/breach reporting and for vulnerabilities detection.
- Make the most out of initiatives around "Cybersecurity Information Sharing Sector-Based Networks" where parties can join on a voluntary basis, and adhere to specific information sharing rules.
- Examine possibility of mandatory disclosure in certain areas/cases that are not covered by the NIS Directive.
- Create a cybersecurity ontology and taxonomy and the relevant semantic rules
- Build a horizontal network stimulating sharing information and collaboration without imposing fines on incidents. This creates trust and more transparency. Creating a feedback loop between those who report and the regulator/entity receiving notifications is crucial.
- Strengthen the role of trusted intermediary parties (as in the case of the Malware Information Sharing Platform MISP).
- Promote a culture of (in-house) ethical hacking.
- Define an Information Sharing and Analysis Centre ISAC standard (guidelines, requirements) in cooperation with CEN CENELEC JTC13 covering the ISAC information management, processes etc. (see ENISA's study), thereby establishing a harmonized environment which will facilitate collaboration among all European standards, as well as information sharing among regional/national/sectorial ISACs themselves throughout the EU.
- Support the cybersecurity analysis of emerging technologies (Artificial intelligence, quantum, cognitive technologies…) and their use in innovative protection products, services and processes (see the recent call for tender the ISACs Facilities manager).

3. Secure highly critical applications and essential services: electricity, gas, water, vehicles…[94]

[94] Sections with more detail in the annex: Secure highly critical applications and infrastructure: electricity, gas, water, vehicles – R18, Coordinated EU cybersecurity strategy and governance for the smart grid / Smart charging – R25, Develop cybersecurity solutions for connected and autonomous vehicles (V2X) and related infrastructure – R73, Enhance cybersecurity for the industrial domain and for the automation and communication systems that ensure safety, availability and process integrity – R72, Development of Industrial cybersecurity building on Europe's strong industrial base – R32, Certifiable secure firmware on open hardware for Europe – R65 and Provide funding for and set up an EU driven community for open source security software and hardware – R65.

Essential services, such as energy infrastructures (including electricity, oil and gas, water and nuclear) are very complex, as other sectors depend on them. We need to improve the cyber resilience in essential services to avoid as much as possible the unavailability of their supply system. This will provide Europe with a network of critical infrastructures with a high degree of resilience, supported by a network of European suppliers that meet the highest security requirements as established by international standards and norms.

The project will enhance the activities under the NIS Directive in three directions:

- Increasing the protection level of the infrastructure assets against cyberattacks.
- Developing advanced mechanism of early cyberattacks detecting and prevention systems.
- Restoring the system in the fastest way when a cyberattack has succeeded.

Recommended actions

- Set up an alliance integrating stakeholders of highly critical infrastructures (network operators, technology suppliers, cybersecurity solution providers, standard and certification bodies, etc.) for defining cybersecurity standards and test procedures[95] .
- Foster the development of specific cybersecurity solutions that satisfy functional and performance requirements coming from critical sectors.
- Support investment in R&D.
- Encourage cooperation of Computer Emergency Response Teams (CERTs) for high critical infrastructure through the NIS Directive Framework.
- Support hardware development for securing embedded systems and automation architectures.
- Support development of Scada systems secured by design.
- Support development of a detection system adapted to industrial protocols and fieldbus.
- Identify key technologies and service requirements for automation and provide funding to accelerate these deliverables
- Support the establishment of relevant partnerships between automation actors and cybersecurity firms to enhance the protection of installations
- Develop new equipment to prepare Industry 4.0 to be resilient using inter alia certification and approval systems.

[95] see the call for tender for enhancing EU cooperation under the NIS Directive

- Launch a European coordinated action to develop security, governance and security certification for sector-specific applications.

4. Develop and deploy end-to-end data protection solutions using advanced cryptography[96]

In parallel to efforts toward creating secure environments, it is necessary to develop the capabilities to operate safely in a (foreign) unsecured environment. Cryptography is the key technology to secure digital applications. Europe has a strong background in theoretical and mathematical basis of cryptography, and the development of innovative schemes should be encouraged, supported and pushed to proof of concept and standardization.

Homomorphic encryption[97] is the cloud privacy game-changer to come, enabling the use of untrusted cloud services. Identity- and attribute-based encryption enable global secure solutions with massively interconnected objects.

Recommended actions

- Develop ad-hoc advanced encryption algorithm to support European regulation (GDPR, NIS, Regulation on electronic identification and trust services for electronic transactions in the internal market eIDAS, …), and deploy these solutions to allow safe transmission, storage and exploitation of this data in insecure environments
- Develop algorithms in attribute-based encryption, identification-based encryption, homomorphic encryption, anonymization, zero knowledge, blockchain, quantum safe cryptography
- Develop adequate architecture to support this.
- Support technology from fundamental research to operational proof of concept in advanced cryptographic.
- Define EU policy and guidelines on cryptography (there is no such thing for the moment)
- Provide funding to encourage EU start-up companies with specified niche solutions to team up to develop more comprehensive solutions for cryptography

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[96] Sections with more detail in the annex: Develop and deploy end-to-end data protection solutions using advanced cryptography – R8 and Develop homomorphic encryption – R64.

[97] Homomorphic encryption is a form of encryption that allows correct computation using ciphertexts only without revealing the plaintext. Therefore, homomorphic algorithms can protect the privacy of data in hostile environments (e.g. in a foreign cloud) out of reach of laws like the American Cloud Act of March 2018.

5. European Data Space: create a framework and infrastructure for secure data communication, storage and handling[98]

We already have dedicated, European-wide, communication frameworks and infrastructures for secure data sharing in some sectors: banking, personal identification, health, social security and pension data. We also have such infrastructures at national levels and are currently trying to develop new ones for dedicated sectors (energy, transport). As more and more sectors become digital and connected, secure communication will become more and more important in new fields such as connected cars, intelligent houses, and health data.

Europe needs to develop a harmonised communication framework for such infrastructures and a coordinated approach to develop, finance and operate them. The inherent capabilities (e.g. latency, slicing) and security functionalities of 5G provides a foundation for such secure infrastructures. The aim is notably to facilitate communication within industries and knowledge sharing and trust between key EU players.

The objective is to create a European environment where users can securely communicate, store and handle their data, with high levels of security and confidentiality. This framework and supporting infrastructure may include securing communication networks with appropriate levels of cybersecurity, developing European cloud services solutions as well as governance-related issues.

Recommended actions

- Develop a cloud framework with a high level of authentication and secure data lake.
- Enable secure and privacy-enhancing end-to-end communication between devices, individuals and legal entities for pan-national and pan-sector specific use
- Create a dedicated European-wide harmonised communication framework and infrastructure for secure data sharing
- Support the cybersecurity analysis of emerging technologies (artificial intelligence, quantum, cognitive technologies…) and their use in innovative protection products, services and processes

6. Create a European Cybersecurity Investment Fund to support the European cybersecurity ecosystem[99]

[98] Sections with more detail in the annex: Create dedicated European-wide harmonised communication framework and infrastructure for secure data sharing – R34, Support emergence of a European cloud service that can provide the highest levels of security and functionalities, and can compete internationally – R22, Digital Trusted Attestation model – R9, Implementing a secure European Operating System – R23, Shared Database for AI development in cybersecurity – R21 and Market data availability and awareness – R59

[99] Sections with more detail in the annex: European Cybersecurity Fund & Private Investment Portal – R61, Create a "Cybersecurity Accelerator" network of industry players and regional ecosystems specialised in

Investments are needed to scale cybersecurity companies to grow and gain competitiveness. However, Europe is lacking a venture capital market with similar scale as that of the US market. An industry-specific investment fund for cybersecurity in the EU would encourage and leverage private investors.

A dedicated platform would provide better visibility for European cybersecurity players and more and better opportunities for venture capitalists and industrial investors to find potential deals in Europe. In order to develop the European market, it is essential to increase and open new funding opportunities for cybersecurity start-ups and SMEs to grow in Europe, instead of selling too early to third-country investors.

The objective is to create an EU Investment Fund, with public and private funds, dedicated to supporting the development of the cybersecurity value chain. In parallel, develop the cybersecurity ecosystem with dedicated platforms and networks to encourage development, collaboration and consolidation between EU players. The first fund would be an encouragement for the coming years to create cybersecurity-related investment funds across the EU.

Recommended actions

- Create a dedicated cybersecurity investment platform within the European Fund for Strategic Investments
- Design and implement a specific platform aiming to facilitate the match-making between cybersecurity companies and private investors
- Create a "Cybersecurity Accelerator" network of regional technology clusters ("Cybersecurity Valleys")

7. Create the next generation EU framework for PKI infrastructure and European DNS management for critical infrastructure[100]

Public Key Infrastructures (PKI) and the Domain Name System (DNS) are two extremely relevant enabling elements to create and maintain a trustworthy and reliable European Digital Society. PKIs play a key role in establishing trust over the Internet as they allow on the one hand to mutually authenticate parties (human or machines) and on the other, if used correctly, to secure communication channels and data. Today however, many PKI (Public Key Infrastructure) applications are not accepted on the long end, due to the lack of access to open, trustworthy, affordable and well-recognized PKI infrastructure, (i.e. cross-border applications for eHealth, eID, intelligent transport systems, e-government services etc.). This is a clear obstacle to the development of a more interoperable and secure digital space. The DNS is instead part of the backbone on which every digital

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cybersecurity – R50, Cybersecurity SME Hub: a unique platform supporting the "Cybersecurity Made in Europe" – R31 and Create a mapping of the European cyber-industry value chain or industry, which includes SMEs and end-users, to complement the one already developed by the JRC, based on a common taxonomy – R59.

[100] Sections with more detail in the annex: EU mutualised framework for PKI infrastructure and European DNS management – R66.

service is built on today. Even if the Internet has no central coordination point, its addressing structure is centrally coordinated through its DNS, roughly speaking a set of hierarchical phonebooks, where names of "online services" are associated with IP numbers. Today's PKI and DNS are managed by foreign private organisations and date back to the early days of the internet age. Europe needs to develop an innovative and EU-managed PKI and DNS for critical infrastructure, to improve both its functionalities and its governance.

Recommended actions

- EU common harmonisation and standardisation action to create a harmonised PKI standard. It would aim at the definition of a common trustworthy authentication framework.
- Enable secure, interoperable and privacy-enhancing end-to-end communication between devices, individuals and legal entities for pan-national and pan-sector specific use through the implementation of the identified PKI standard across all the digital sectors.
- Define an EU Public Key Infrastructure within a common harmonised framework.
- Establish an international debate and negotiation on the governance of the DNS with the involvement of Internet Corporation for Assigned Names and Numbers (ICANN), International Telecommunication Union (ITU), the Member States and the technical support of JRC and ENISA, aiming at guaranteeing the protection of European interests, security and autonomy in the governance of the DNS
- Ensure the establishment of a DNS fit for the next Internet generation, including harmonisation of security requirements for the existing DNS infrastructure and R&D and standardisation efforts towards the design of a European DNS fit for the next Internet generation.
- Establish an additional infrastructural layer of DNS targeting more specifically ICT critical access (i.e. smart grids, intelligent transport systems, eID solutions, eHealth, e-government…)

8. Leverage public procurement to enhance the cybersecurity environment in Europe[101]

Europe needs to look at public procurement of cybersecurity solutions from a new more holistic perspective as a matter of security, both for civil and non-civil areas. This means treating cybersecurity not just as any other commercial product, but as an essential vector in defending European sovereignty, both in the sensitive non-civil domains and in all the civil domains where sensitive information (personal privacy, intellectual property, financial data...) needs to be protected.

[101] Sections with more detail in the annex: Leverage public procurement to increase the overall levels of cybersecurity in Europe – R29, Increase innovative public procurement – R54, Develop a scheme for ICT vendors' screening evaluating their trustworthiness – R54, Create a network of experts to provide assistance and training to public procurement agencies for their cybersecurity procurement needs – R69, Incorporate the cybersecurity certification framework criteria into public sector procurement by default – R29 and Build cybersecurity functionalities within existing Public Procurement Competence Centres – R51.

In a context of growing geopolitical uncertainty, a certain level of European technological independence is crucial, with competitive and state-of-the-art European solutions in key areas. The guiding principle in European public procurement should be taking into account European security considerations. Europe should not rely solely on solutions and providers from third countries. This is key for end-to-end trusted services.

Public procurement should be used as a lever to:

- increase the level of resilience and autonomy against cybersecurity threats in Europe,
- boost the market for advanced, innovative and high quality cybersecurity solutions,
- promote European standards and schemes on cybersecurity in public procurement
- support the European cybersecurity ecosystem

Recommended actions

- Incorporate the cybersecurity certification framework criteria into public procurement.
- Develop guidance for the contracting authorities on how to impose various security of information requirements within their procurement procedures for cybersecurity solutions.
- Develop new procurement institutions or programmes to boost forerunner innovation in cybersecurity (DARPA style).
- Facilitate and encourage cross-border procurement from other Member States to create a common large EU cybersecurity market.
- Make a detailed mapping exercise to better understand the perimeter, structure and size of the cybersecurity market in public procurement.

9. Accelerate implementation of the harmonisation process across the EU to achieve a common cybersecurity ecosystem by leveraging the existing EU initiatives (agencies, standards, regulation, certification)[102]

[102] Sections with more detail in the annex: Clarify and raise awareness of the role of the various European bodies involved Cybersecurity: ENISA, ECSO, regional authorities and potentially the European Cybersecurity Competence Centre if established– R39, R59, Create a European optimized NIST-like framework – R39, Speed up the use of the EU Cybersecurity Certification Framework and support the SMEs to receive certification – R42, Align cybersecurity strategies of public institutions within the EU – R52, Assess the necessity for mandatory cybersecurity certification or general cybersecurity legislation for all IoT products – R36, R4, Standardization of cybersecurity protocols and languages for better interoperability, ergonomics and secure cybersecurity solutions – R3, Labelling of cybersecurity solutions in sensitive digital domains – R4, R11, Develop cyber-insurance in Europe – R68, Accelerate the adoption of the "International Procurement Instrument", also for Cybersecurity, to ensure an appropriate response to non-reciprocity in public procurement by foreign countries

Fragmentation is a key weakness in Europe, with different regulations and standards in different Member States and multiple agencies and regulators at different levels (national and European). This fragmentation creates problems of interoperability and limits the available market size. Market entry barriers between Member States should be removed, while product criteria for entering the market should be kept.

The wide range of quality/security levels of cybersecurity solutions in the market could hamper security. Regulation and certification is a way of raising the levels of cybersecurity protection, and supporting those companies that do meet the certification requirements. Guidance for companies on how to implement certification frameworks would be beneficial, linked to a clear image of threats.

10. Develop a comprehensive EU strategy to support EU players in critical cybersecurity areas[103]

European initiatives such as the creation of Airbus were driven both by innovation and by strategic considerations to reach independence in areas that were considered critical from an economic and/or a military standpoint. They were successful before there was a strong political and public support for them.

With regard to cybersecurity, Europe should develop a strategy to actively support cybersecurity players that have an innovative value-added technology and have the potential to become global players. Having some EU world-class and competitive players, in each critical area of cybersecurity would help both to achieve strategic independence and to improve competitiveness.

For each identified critical areas of cybersecurity, a comprehensive strategy should be developed using all available forms of public support:

- Research funding (grants): Horizon Europe, Digital Europe,
- Public investments (debt, equity): InvestEU, European Investment Bank, national and regional promotional banks, Sovereign Investment Funds,
- Public Procurement (revenues).

11. Boost research, innovation and technology deployment in cybersecurity[104]

– R2, Setup a pan-European campaign to educate and raise awareness about cybercrime – R17, R33, Maintain high security and privacy standards for better user protection and support for EU players – R5 and Launch a European coordinated action to develop cybersecurity and cybersecurity certification for sector-specific applications → see Cybersecurity Directive for a) connected/autonomous mobility, vehicle-grid communication – R18, R25, R40, b) health, energy and manufacturing infrastructure – R19 and c) telecommunications (5G) – R12.

[103] Sections with more detail in the annex: Coordinated EU investment strategy to support EU cybersecurity players – R35, Create European world-class player for Firewall and Antivirus – R38, Support European cybersecurity hardware suppliers – R24 and Enhance the use of AI (Artificial Intelligence) for cybersecurity – R20.

Cybersecurity is a race between attackers and defenders. Change is constant and extremely fast-paced. Cybersecurity solutions and products are becoming obsolete fast. Hence, by definition, the cybersecurity industry needs to be dynamic and agile to be able to react to this constant change.

Current public cybersecurity investments in the EU are estimated to be between EUR 1 billion and EUR 2 billion per year. This is far behind the government investments in the US (EUR 13.3 billion per year) and China (EUR 8.8 billion).

As majority of European cybersecurity companies are relatively small, they might not have resources to identify relevant projects and participate in long research projects in EU research programmes. The European Commission has proposed a European cybersecurity competence network and centre. Together with industry players, Europe as a whole should continue developing more agile innovation funding models to keep them attractive and relevant for the industry players. The European Innovation Council can play an important role in that context.

The EU would also need to develop a new type of market test-bed-model. That would allow researchers to test the innovation on the market already in the early stage and get critical feedback. This would show early on if there is a real market interest. The innovation could also be introduced to the investors at an earlier stage.

One indicator of cybersecurity innovation is patents. In cryptography, the EU accounts for 21% of patents. However, in total the EU owns less than 5% of global cybersecurity-related patents, while patent filing is dominated by China, followed by the US.

Research and education are scattered across EU Member States. There are a lot of research institutes and universities with a wide coverage of different academic fields. Cybersecurity is competing with other research areas over the limited resources. Research institutions should make choices and specialize on selected key success areas. With better focus and more coordinated resources, there will be significantly better outcomes and more innovations.

Europe needs to make strategic choices when allocating European budget. It is necessary to pay special attention on the deployment of Digital Europe Programme, Horizon Europe and other new funding instruments to create industrial impact for dynamic industries like cybersecurity.

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[104] Sections with more detail in the annex: Boost European research funding for cybersecurity through DARPA-style research focusing goals and excellence – R43, R44, Focus funding on areas of specific EU excellence and critical needs by integrating existing expertise into the EU decision making processes – R60, R62, R63, R59, Create dedicated strategic funding programs to fund proofs of concepts (POC) and large-scale industrial deployment – R43, R26, Set test labs using critical infrastructure as a platform for testing innovative solutions – R67, Security of emerging technologies (AI) – R43, Methodology to certify complex systems, complex solutions and services – R11 and Develop European key enabling technologies (KET) and key enabling platforms (KEP), which will help the development of other technologies: a) Develop and make available to the community analysis tools to reduce vulnerabilities in software and hardware – R13, R11 and b) Advanced cryptography/homomorphic encryption to allow data privacy in hostile environments – R64, R8, and R43.

Some key technologies need to be supported over an extended period, by multiple players, and in different forms, all along the process from fundamental research to large scale commercial deployment. Such support could include:

- funding proof-of-concept and demonstrators
- funding start-up companies, in their creation and ramp up phases
- funding scale-up processes for SMEs

12. Develop and strengthen a highly skilled workforce in all parts of the cybersecurity value chain[105]

There is a growing skill gap on cybersecurity experts globally. Industry, research and public sector (including defence) communities struggle to find skilled cybersecurity professionals for business and research purposes. The skills gap for cybersecurity professionals working in the industry in Europe is predicted to be 350,000 (globally 1.8 million) by 2022.

As a global leader, Europe should attract, develop and retain top talent, both in the private and public sector. This requires joint efforts across the Union. The objectives should be to raising awareness about the need to reinforce the skills base, to upgrade competences in cybersecurity all along the life (from students to professionals) with life-long-learning programs.

Recommended actions

- Help universities and other education and training institutions to build new courses for cybersecurity specialists in cooperation with industry. Cybersecurity is an area where experience and relevant certification may be more valuable than formal degrees. In order to develop new courses, teachers must be trained themselves, via knowledge transfer from technology experts to teachers.
- Encourage cybersecurity companies to be more involved in creating new courses together with universities, to ensure that courses are in line with the industry needs.
- Establish cybersecurity apprenticeships: It is important to ensure that the focus of these schemes should not only be on technical cybersecurity skills, but on risk management and other organizational aspects of cybersecurity.
- Launch an Erasmus+ sector skills alliance that will implement the blueprint in cybersecurity (including the mapping of skills demand and supply).

[105] Sections with more detail in the annex: Develop and strengthen a highly skilled workforce in all parts of the cybersecurity value chain – R16, Develop a platform that provide insights into the current and needed skills capacity, per Member State – R28, Establish cybersecurity apprenticeships and training centres – R16, R30, Blueprint for cybersecurity skills – R16, Set up a special e-training program and professional certification in the cybersecurity – R41, Generalizing the cybersecurity risk management in safety analysis frameworks – R14, R15.

- Map skills demand and create a blueprint for cybersecurity skills. In the future the new initiative under Erasmus 2021-2027 on Centres of Vocational excellence could be relevant for the sector as it aims at developing comprehensive skills ecosystems

- Create an interoperable network of cyber ranges

13. Support development, consolidations and growth of start-ups and SMEs into scale-ups that can compete globally[106]

The EU has mainly small and local cybersecurity service and product suppliers. They may be well-established in one Member State, but expansion across the EU is not taking place sufficiently. Encouraging cross-border collaboration and dismantling practical trade barriers are essential for creating a true European Single Market.

Programs where SME have opportunities to find new partners, distributors and solution integrators from the other Member States could help. SMEs should be encouraged to build joint offerings together. Best practices and examples would lay the ground for further cooperation and joint projects.

The EU should also develop tools to support the European cybersecurity industry's access in the global markets, using the extensive network of EU delegations all around the world.

As there are a lot of start-ups and SMEs in cybersecurity, the public sector should support the involvement of SMEs in forums and working groups for cybersecurity policy experts. Such a dynamic and critical business sector as cybersecurity requires continuous connections between the real economy and policy-making.

The EU in general needs stronger dialogue and connection between all the cybersecurity stakeholders, including the European Commission, the Member States and the industrial players. We could set up an industrial advisory board to the Commission with relevant cybersecurity stakeholders, including companies of different sizes, to bring the best European expertise on the table. The cybersecurity advisory board would also analyse and define the must-win battles and policies keeping track of the European cybersecurity market, its strengths and potential gaps.

[106] Sections with more detail in the annex: Create dedicated strategic support and funding programs to help SMEs in Cybersecurity, in support of SME growth, SME collaboration and market consolidation in Europe –R55, R56, and R58, Introduce advisory services for European Business within the EU delegations network – R57, Create a dedicated information, training and funding program to help European SMEs obtain certification – R31, Introduce specific rules/tools to support to simplify the participation of SMEs in EU-funded projects – R53 and Reinforce and promote the use of the European "Small Business Act"– R31.

Annexes

Annex I - List of 31 strategic value chains

Annex II - Key Strategic Value chains- detailed recommendations (separate document)

Annex I

List of 31 strategic value chains

Strategic values chains have been identified according to the following three criteria:

- technological innovativeness, i.e. whether the value chain is based on the exploitation of leading-edge key enabling technologies, breakthrough, major outcome of R&D or disruptive innovation.
- economic and market potential, whether the value chain has considerable economic weight, actual or potential.
- societal and political importance for Europe, i.e. the value chain makes an important contribution to societal challenges and/or policy goals (e.g. climate change, ageing population). The value chain is also instrumental to Europe's security and autonomy.

The Strategic Forum has identified the following 31 strategic value chains, based on proposals by the Strategic Forum members:

Strategic value chains for which coordinated initiatives are already ongoing

Batteries
High performance computing
Micro-electronics

Strategic value chains for which the report includes recommendations for actions

Clean, Connected and Autonomous Vehicles
Cybersecurity
Hydrogen technologies and systems
Industrial IoT
Low CO_2 Emissions Industry
Smart Health

Additional strategic value chains prioritised after the first stage of the prioritisation process[107]

Additive manufacturing
Bio-based materials
Critical raw materials for innovative applications
Net zero energy building construction and renovation
Smart vessels
Space - launchers

[107] See page 11 of the Report for information about the prioritisation methodology used.

Wired and wireless networks

Additional strategic value chains identified

Advanced materials
Augmented reality and virtual reality devices
Energy efficient and smart trains
Energy efficient and smart aeronautics
E-waste recycling
Industrial robotics
Nuclear decommissioning
Photonics, integrated circuits
Photovoltaics
Plastics recycling
Precision farming
Proteins from crops and residues (including aquaculture) and fermentation
Structural electronics products
Wave and tidal energy
Wind energy