Digitising European Industry

Working Group 2
Digital Industrial Platforms

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Executive Summary

Digitisation of the industrial sector, which constitutes one of the main pillars of the European economy, has an impact on innovation, growth, and prosperity in Europe that significantly exceeds the size of the sector itself. However, as opportunities of digitisation are recognised around the world, triggering a corresponding level of investments across the globe, digitisation can be either an opportunity or a threat, depending on the timeliness and the adequacy of one's response to it.

Against this background, a key element of the Digitising European Industry (DEI) initiative, set out in a Communication adopted in April 2016, is a concerted action to strengthen Europe's position in digital technologies and digital industrial platforms across value chains in industrial sectors. This is the focus of the working group on Digital Industrial Platforms (WG2).

WG2 was set up during the Roundtable of 20 September 2016 in Brussels and was tasked to support the creation of next-generation digital platforms by defining possible next-generation platforms, reflecting on how building platforms should be approached on European level, and considering how existing and planned EU-wide, national, and/or regional platform development activities could contribute. This has required collective effort involving public and private stakeholders across Europe at regional, national and EU level.

WG2 defined next-generation digital platforms for the vertical sectors of Connected Smart Factories, Smart Agriculture, and Digital Transformation of Health and Care. These sectors were chosen as examples of industrial domains. Two horizontal topics were also addressed: Industrial Data Platforms and the Internet of Things (IoT). Subgroups were set up for each of the five vertical sectors and horizontal topics.

As part of its work, WG2 performed fact finding exercises, collected best practices and formulated recommendations, e.g. on policy matters and mobilisation and leveraging of investments. This report builds on the discussions during the WG2 meetings and on additional inputs received. It describes the current landscape of platform development and related activities in Europe, reflects on the type of supporting initiatives needed, and outlines recommendations addressed to the High-Level Representatives attending the Roundtables, who oversee the implementation of the DEI initiative.

While the level of detail of the debate and the resulting findings and recommendations showed differences in each subgroup, they nevertheless reflected an overall high level of consistency. WG2 defined the following set of main recommendations:

1) Member States should enhance their R&I programmes on digitisation and digital industrial platforms: Digitisation is only expanding and deepening, with far-reaching effects on innovation opportunities, productivity and employment. Digital industrial platforms are widely seen as a strategic requirement for Europe to master new and changing value chains. However, most Member States still need to enhance their research and innovation programmes concerning digitisation, to prepare themselves for the upcoming changes. These programmes should facilitate the unique contribution of research institutes, universities, public authorities and industry, based on their specific expertise. Furthermore, they should specifically encourage SMEs to participate.

2) Coordination and orchestration of platform development are needed to reduce fragmentation: Various platform development activities exist at EU and national level. However, the level of fragmentation of initiatives is currently quite high. Hence, it is crucial that national programmes become more closely linked to each other and to widely accepted priorities at EU level. European policy aims to ensure that future global standards and platforms are driven by the interests of EU actors. For that, EU actors should join forces along common interests. Coordination and orchestration is necessary to ensure that platform development takes

place efficiently and effectively, and that the resulting platforms are truly leveraging the interests of European industry. The EU should stimulate cooperation between relevant activities at national, regional, and European level, most notably through the management of new Horizon 2020 projects. It should also monitor to what extent the collaboration actually takes place.

On the basis of preliminary inputs by Member States and industry, a selection of focused platform development and large-scale piloting activities in sectors important for Europe have been reflected in a dedicated Focus Area in the R&I Horizon 2020 work programme 2018-20. In addition to platform development and large-scale piloting, they address ecosystem building and standardisation. A total amount of 300 MEuro is available for these projects.

3) An environment should be created to support promising initiatives to achieve critical mass: Joint attempts should not aim for the creation of a single platform for everyone. Given the needs and expectations regarding industrial platforms, it is clear that a joint effort should be undertaken to create an environment to support promising initiatives to achieve critical mass. At technical level, a key focus should be on interoperability and integration of legacy systems and evolving platforms. Validation, demonstration and experimentation in realistic settings (labs, testbeds, pilot lines) is emphasised. Furthermore, to effectively combine activities and to ensure a wide take-up of specified functions, interfaces, and protocols, a sincere early commitment to standardisation is crucial.

4) Mechanisms need to developed that can help to federate dispersed activities and establish industry-relevant platforms: EU-wide partnerships have enabled the latest technologies to be brought to market and strengthened collaboration of academia and industry with important spill-over effects on the whole economy. Building on the success so far, it is essential to further continue the development of technologies and systems building blocks, and their integration into digital industrial platforms.

Horizon 2020 Public-Private Partnerships should reinforce their role in developing and scaling up of key technology components that are brought together in digital platforms for various sectors at the EU level. They should also further facilitate pooling resources and linking Member States programmes, projects and initiatives, such as testbeds, experimentation facilities and pilot lines. Nevertheless, Member States and other stakeholders might want to reflect on a new partnership instrument to implement joint industrial digital strategies across the EU to tackle grand challenges.

5) Socio-economic aspects should be considered when assessing industrial platforms: In this process, significant attention should be given to non-technical aspects. The legal, economic and social challenges of digital platforms are not trivial. The legal aspects of what exactly "sharing" of data means need to be addressed thoroughly, preferably in a way that creates legislative harmonisation and clarity across the EU. What is more, sufficient attention should be given to education and training, in tandem with technology development, to avoid a further deepening of the *Digital Divide* and a subsequent erosion of the social capital base. Therefore, the assessment of a platform should also consider socio-economic effects; the benefits of a platform need to be distributed in a fair way.

In conclusion, the most immediate recommendation calls for further and more intense joint action of the EU and the Member States to address the challenges of digitising industry in general and digital industrial platforms in particular. Therefore, all parties are encouraged to sit together and – even more actively than they have done so far – assess where opportunities for collaboration, joint programming, co-investment and federation exist.

1 Introduction

1.1 Background

Digitisation offers impressive new opportunities to strengthen the position of European industry. Close to a third of the growth of the overall industrial output in Europe is already thanks to the uptake of digital technologies[1]. Moreover, according to reports by PwC[2] and Boston Consulting Group[3], digitisation of industry would offer benefits that could generate additional annual revenues of € 110 billion for industry in Europe.

As opportunities of digitisation are recognised around the world, triggering a corresponding level of investments across the globe, digitisation can be either an opportunity or a threat, depending on the timeliness and the adequacy of one's response to it. Whilst it is for business to take the lead in adapting to market realities, an EU-level effort to help coordinate national and regional initiatives to digitise industry is important in bringing the necessary scale and coverage to ensure impact. Addressing the challenges of digital transformation at national level alone bears the risk of leading to further fragmentation of the single market and thus of failing to achieve the critical mass needed to attract private investments.

Against this background the Digitising European Industry (DEI) initiative, set out in detail in a Communication[4] adopted in April 2016, establishes a framework for coordination between national and EU-level initiatives in this area and relevant policy actions including investments in digital innovation capacities. It also looks at accelerating the development of ICT standards, exploring regulatory conditions and adapting the workforce by preparing the human capital with the necessary skills for the digital transformation. The purpose is to reinforce the EU's competitiveness in digital technologies and to ensure that any industry in Europe, large or small, wherever situated and in any sector can fully benefit from digital innovations to upgrade its products, improve its processes and adapt its business models to the digital age.

The DEI initiative requires ambitious collective effort involving public and private stakeholders across Europe at regional, national and EU level. Therefore, the implementation of the DEI initiative has been supported by high-level Roundtables of representatives of Member States' initiatives, industry leaders, and social partners, aiming for a continuous EU-wide dialogue. The first Roundtable was held on September 20, 2016 in Brussels when specific Working Groups were launched to ensure proper preparatory work for the next Roundtable in autumn 2017. The first Roundtable defined the focus areas of the two Working Groups as follows:

- WG1: Mainstreaming digital innovations across all sectors;
- WG2: Strengthening leadership in digital technologies and in digital industrial platforms across value chains in all sectors of the economy.

Each working group produced a report supporting the implementation of specific DEI actions. The working group performed fact finding exercises, collected best practices and formulated recommendations, e.g. on policy matters and mobilisation and leveraging of investments, addressed to the representatives attending the Roundtables. This report concerns the results of WG2[5].

[1] Estimates by LIFE + series of studies 2016, referred to in COM(2016) 180 final
[2] http://www.strategyand.pwc.com/media/file/Industry-4-0.pdf
[3] https://www.bcgperspectives.com/content/articles/engineered_products_project_business_industry_40_future_productivity_growth_manufacturing_industries/
[4] Digitising European Industry (DEI): Reaping the full benefits of a Digital Single Market. Communication (COM(2016) 180)
[5] For the final report of WG1, please refer to https://ec.europa.eu/futurium/en/content/report-wg1-digital-innovation-hubs-mainstreaming-digital-innovation-across-all-sectors-final

1.2 Methodology

WG2 aimed to support the creation of next-generation digital platforms by defining possible next-generation platforms, reflecting on how building platforms should be approached on European level, and considering how existing and planned EU-wide, national, and/or regional platform development activities can contribute.

In order to cover digital platforms in a variety of industrial domains and topics, several subgroups were initially set up that could draw on the experience and knowledge of representative organisations and structures. Two horizontal topics were chosen: the **IoT Subgroup** to look into platforms and scaling up of IoT deployment in different sectors; and the **Industrial Data Platforms Subgroup** to reflect on how data platforms could support the exploitation of the potential value of data across different sectors.

For the vertical sectors three subgroups were chosen as examples of industrial domains: the **Connected Smart Factory Subgroup** to think about how platforms enable companies (in particular SMEs) to undergo digital transformations and be fully connected with their upstream and downstream supply chains; the **Digital Transformation of Health and Care Subgroup** to provide insights in how platforms can help transform the health and care industry by integrating different technologies for better diagnoses and advice; and the **Smart Agriculture Subgroup** to define how platforms support the push towards a future of precision farming and support of rural communities.

Obviously, defining next-generation digital platforms is relevant for other domains as well, such as Smart Mobility, Smart Energy, Smart Finance (Fintech) and Smart Construction; however these sectors were often referred to but not tackled in detail by WG2.

The working group kicked off with a first workshop on 21 October 2016[6], where the roles of digital industrial platforms were discussed. Around 80 representatives from industry (including SMEs), the research community, Member States, regions, and social partners attended and addressed a series of questions related to the WG2 objectives. The meeting included a series of scene-setting presentations and more focused discussions and exchanges within a series of parallel sessions. These parallel sessions focused either on specific vertical areas (Smart Agriculture, Connected Smart Factory and Digital Transformation of Health and Care) or on horizontal issues (Industrial Data Platforms and Internet of Things). The four key issues discussed during this first meeting were:

- What is the current landscape of platform development and related activities in Europe?
- What is the vision for where we should go next?
- How do we bridge the gap between what we have and what we want to achieve?
- Who are the main stakeholders to be involved?

Building on the results of the first workshop and on the inputs received in the weeks following it, a second meeting was held in Brussels on 8 December 2016[7]. Again, approximately 80 representatives from a variety of organisations and Member States attended. Similar to the schedule used during the first meeting, the second meeting included a plenary session and more focused discussions in parallel sessions. The parallel sessions were devoted to the same five areas that featured in the first meeting. The second meeting focused on the following four issues:

[6] https://ec.europa.eu/futurium/en/content/wg2-digital-industrial-platforms-all-presentations-21-october-2016
[7] https://ec.europa.eu/futurium/en/content/dei-wg2-presentations-workshop-8-december-2016

- Stocktaking of results so far;
- Developing further ideas for next-generation platforms;
- The type of supporting initiatives needed;
- Suggestions for action plans, including possible contributions from PPPs and links with national initiatives.

The first draft WG2 report[8] was released on December 23, 2016, reflecting the findings and the conclusions after the two meetings and the feedback collected in the first months; subsequently more contributions were received. During the First Stakeholder Forum[9] in Essen (January 31 – February 1, 2017), WG2 had the opportunity to report and get additional input on its activities. It organised an open session where the report was presented for wider consultation and outreach with a range of stakeholders. A second, updated version of the report followed[10].

On May 4, 2017 the third WG2 meeting was held in Brussels[11]. It had parallel sessions devoted to the selected vertical and horizontal areas and concluded with a plenary session. This meeting concentrated on the specification of recommendations, per area and for WG2 overall. The results are incorporated in this third, final version of the report.

Furthermore, insights from the Working group were helpful inputs at strategic programming level. Recommendations relevant for the development of Horizon 2020 Work Programmes, where the European Commission works together with Member States and advisory groups, have been taken into consideration for the Work Programme 2018-2020.

After an introduction of the general approach in Chapter 2, the report presents the more specific findings and recommendations per area in the subsequent chapters. First the findings for the three vertical sectors are discussed in Chapters 3-5. The results for the two horizontal topics are presented in Chapters 6-7. A conclusion is provided in Chapter 8. Finally, an Annex gives examples of relevant activities in platform development, piloting, and testbeds.

[8] https://ec.europa.eu/futurium/en/content/dei-wg2-1st-report-activities-8-december-2016
[9] https://ec.europa.eu/futurium/en/content/report-first-stakeholder-forum-essen-de-311-and-122017
[10] https://ec.europa.eu/futurium/en/content/wg2-report-digital-industrial-platforms-version-february-2017
[11] https://ec.europa.eu/futurium/en/content/dei-wg2-presentations-workshop-4-may-2017

2 Towards Leadership in Next-Generation Digital Industrial Platforms

2.1 Mastering digital value chains

Michael Porter first described the concept of a Value Chain in 1985 as a set of activities that a firm performs to deliver a valuable product or service for the market[12]. Five steps in the value chain give a company the ability to create value that exceeds the cost of providing its good or service to customers, namely inbound logistics, operations, outbound logistics, marketing and sales, and service. Value Chain is a way of getting a competitive advantage, through which a company can beat its competitors along with fulfilling customer requirements. In contrast, Supply Chain is a 'tool' of business transformation, which minimises costs and maximises customer satisfaction by providing the right product at the right time at the right place and the right price[13].

These days the term "digital value chain" is prominent. Digital transformations make value chains more digital and business processes become digitised business processes. When used effectively, digital transformation is key to competitiveness in today's world. In all industry sectors, mastery of digital technologies in value chains offers very significant opportunities to create value for customers.

Digital innovation is driven by a convergence of key technological trends, including connecting "things" to the digital space (driven by IoT – embedded software, sensors, actuators, connectivity, low power ICT, etc.); creating value from knowledge (driven by (Big) Data, HPC, cloud computing etc.); and deploying autonomous systems (driven by robotics, automation, machine learning, etc.). Together these trends facilitate digital innovation in products, processes, services and business models in all industry sectors.

Europe has key strengths to contribute to these developments, for instance its industrial know-how, its networks of industrial sectors and value chains, as well as its integration of industrial development with societal challenges[14]. At the same time, important gaps exist in Europe's profile to lead the creation of digital value chains. Most notably, efforts – from R&D to experimentation to deployment – are often spread across Europe and are fragmented, making it difficult to reach the critical mass that is needed for a leading position.

2.2 From development of technology to full solutions

In technology development, going from low Technology Readiness Levels to higher ones, three rough stages can be distinguished, each with different means and intensity of possible public intervention[15]:

1) Research and development of technology and systems building blocks. This can be addressed through better alignment of national R&D&I programmes, both with each other and with EU programmes around strategic priorities established in PPPs.
2) Development, validation and piloting of digital industrial platforms. This can be addressed through co-investment in large-scale integration, testing and experimentation facilities.
3) Roll-out of digital industrial platforms. This can be addressed through co-investment in large-scale deployment actions (support to first production, infrastructure, etc.).

This step-wise increase in the scale of the initiatives and of their impact on society at large is illustrated in Figure 1.

[12] Porter, Michael E. (1985). *Competitive Advantage: Creating and Sustaining Superior Performance*. New York.: Simon and Schuster
[13] http://keydifferences.com/difference-between-supply-chain-and-value-chain.html
[14] http://www.europarl.europa.eu/sides/getDoc.do?pubRef=-//EP//TEXT+REPORT+A8-2017-0183+0+DOC+XML+V0//EN
[15] Adapted from the Background Note to the 20 September 2016 Roundtable on Digitising European Industry: https://ec.europa.eu/futurium/en/content/roundtable-september-20-2016-objectives-and-scope-mandate-working-groups

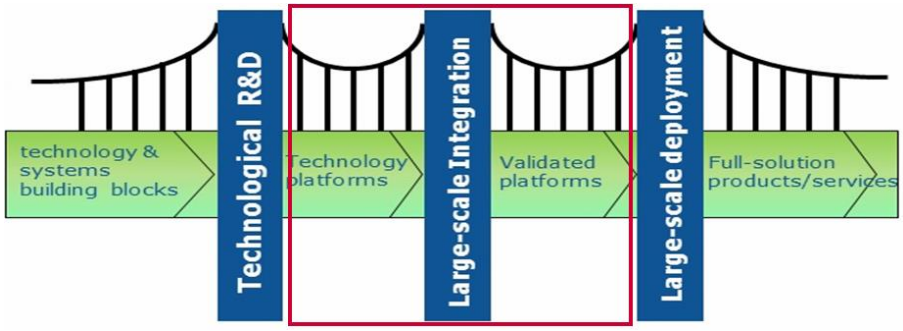

Figure 1 Three stages of technology development

The work of WG2 focused on the second stage, as indicated by the red rectangle in Figure 1. Thus, the emphasis is on establishing digital industrial-scale technology platforms and large-scale integration. Development of technology & systems building blocks and large-scale deployment were not addressed in this working group. Development of technologies and building blocks is a key area of work for ongoing Public Private Partnerships. Their envisaged roles as coordinators of EU-wide R&I effort in such development is outside the scope of this report. Large-scale deployment is dealt with, amongst others, by important projects of common European interest (IPCEIs), e.g. on micro- and nanoelectronics, and on High Performance Computing and Big Data enabled Applications.

2.3 Digital industrial platforms and their roles

Digital technologies need to be integrated. Different technologies are rarely used in isolation; instead, a mixture of technologies can be found in products and services. Take for instance connected and automated driving (see also Figure 2, 'autonomous driving'). Here, one sees combinations of vision systems, robotics, artificial intelligence, mobile communication, and more. A designer needs to specify how different functions are organised and integrated, what the interfaces are, and how technologies implement those functions. In other words, a designer needs to specify a **system architecture** for their product or service.

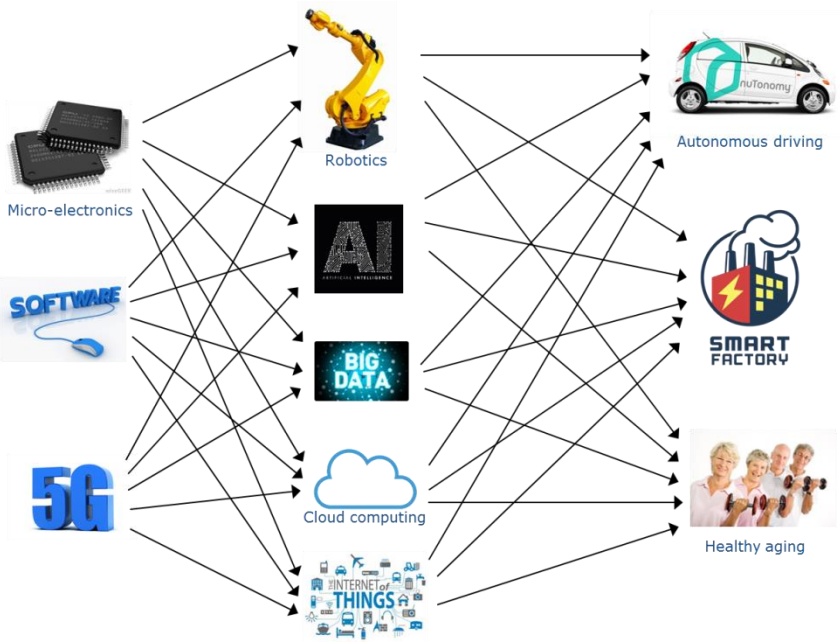

Figure 2 Links between technologies

Industries need to agree on functions, interfaces, and technologies to realise digital products and services. Nowadays, few individual companies are able to cover the whole supply chain themselves;

they need the products and services of other companies, and supply their own products and services as inputs for other companies. Therefore, enterprises in a certain industrial sector need to agree on how different components can be integrated, what the interfaces are, and how technology implements specified functions. In other words, they need to agree on **reference architectures** (often called 'reference models'). An example of such reference architecture from the Connected Smart Factory subgroup, the FAR-EDGE reference architecture, is given in Figure 3.

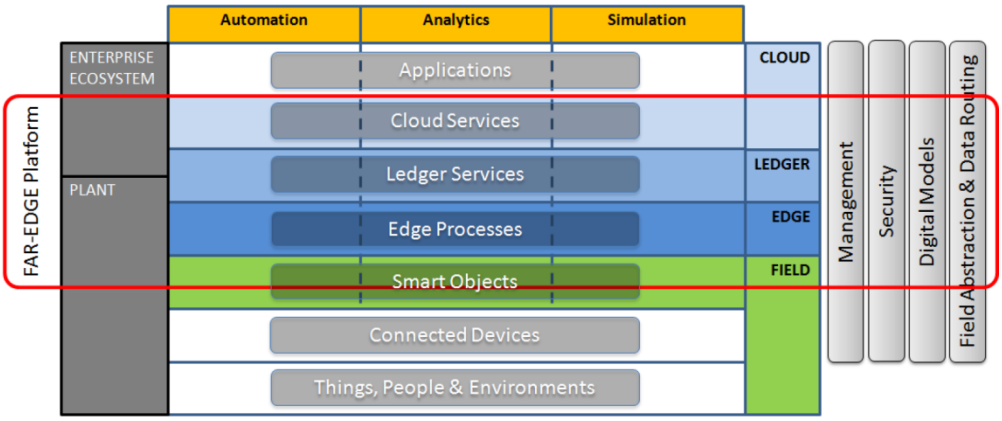

Figure 3 FAR-EDGE reference architecture[16]

Such **industry agreements** facilitate product and service design among industry players. Product (components) and services developed by company A will interoperate with those of company B, and can be interchanged by those from company C. Such industry agreements have an instrumental role in creating new markets and market opportunities.

A **digital industrial platform** can be an essential part of a reference or system architecture, especially in layered and 'hourglass' architectures. Such platform integrates (data from) various functions implemented by different technologies via clearly specified interfaces, and makes data available for use by applications. For instance, a platform could make available product quality data from a factory floor provided by visual inspection machines and human operators, for use by monitoring applications that process quality data. Platforms are like *operating systems* that bring together different technologies, applications and services. They open up data from e.g. the machines, products and operators on a shop floor, make it accessible to e.g. monitoring and control applications, may provide open interfaces that allow third-parties to develop applications on top, and connect different stakeholders, such as users and application developers. An example of such platform from the Connected Smart Factory subgroup, the FAR-EDGE platform, is positioned in the reference architecture in Figure 3. An overview of that platform is given in Figure 4.

Reference and system architectures do not have to consist of a digital industrial platform per se. Although a digital platform is often an essential part of reference and system architectures, such architectures can be defined without.

Moreover, even though we focus on digital industrial platforms, one should bear in mind that industry agreements leading to new markets and market opportunities are paramount and that digital industrial platforms are often a key element in such agreements, but not by definition.

[16] See http://cordis.europa.eu/project/rcn/205577_en.html, Horizon 2020 grant agreement 723094, deliverable D2.4 (to be published on Cordis in autumn 2017).

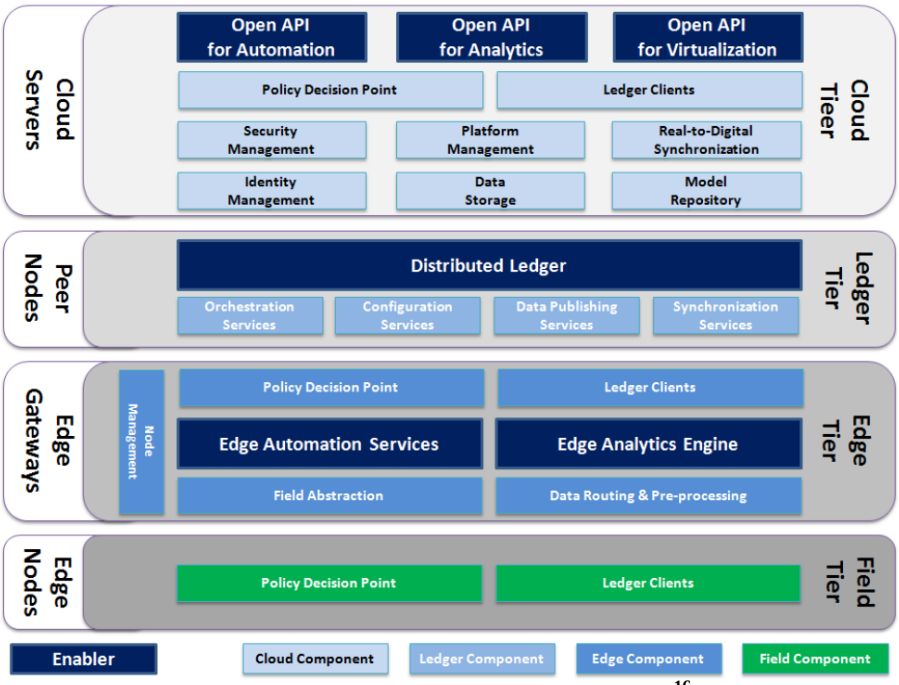

Figure 4 FAR-EDGE platform overview[16]

In general, three main aspects/roles can be distinguished in (digital industrial) platforms[17]:

1. In a **community role**, digital industrial platforms may have users explicitly connecting with each other, as in social networks. Some may have users exchanging items as in marketplaces. The community is where third-party producers create value and is a key source of value for the platform. To enable this value creation, the next role is needed.
2. In an **infrastructure role**, digital industrial platforms provide infrastructure and functionality, and more importantly, may allow users and partners to build applications and create value on top of this infrastructure. This openness to and reliance on third-party complementary applications determine the value of digital industrial platforms: more developers working on the platform create more applications; more applications make the platform's offering more valuable, and results into more customers using the platform; more customers using the platform attracts more developers. The infrastructure role also channels the data that the platforms unlock and integrates different technologies and systems.
3. In a **data role**, every digital industrial platform makes data accessible and uses and processes data in some way. In many cases, the value may exclusively lie in the data that is made available from connected applications, sensors and devices.

Different platforms fill in the above three roles in different ways and to varying degrees. Some focus more on connecting users and providers (e.g. Facebook), some on unlocking data (e.g. Nest), and others act as development platforms for third parties (e.g. Android). Many real-life examples show a combination of the three roles.

Successful platforms offer an **ecosystem** where four types of players can be distinguished: the owners of platforms who control their intellectual property and governance; providers who serve as the platforms' interface with users; producers who create their offerings; and consumers who use those offerings[18].

[17] Adapted from http://platformed.info/platform-stack/
[18] https://hbr.org/2016/04/pipelines-platforms-and-the-new-rules-of-strategy

It should be noted that this report does not consider online platforms in the consumer world, but **industrial platforms** in the business world. In contrast to the consumer-oriented online platforms, industrial platforms often need to address varying and specific requirements of particular industries and companies that call for customised products[19].

A few examples of ongoing platform development activities are given in Annex A.2.

2.4 Platforms, forums, and marketplaces

One should note that the meaning of the word "platform" changes based on the context it is used in. Within a policy context, the term 'platform' is often used for a place or opportunity for public discussion, i.e. as a **'forum'**. For instance, the "European Platform of National Initiatives" is a forum for coordination and governance, where national initiatives, such as *Plattform Industrie 4.0* in Germany, *Industrie du Futur* in France, *Piano Nazionale Industria 4.0* in Italy, etc. (see Figure 5 below), share national best practices and together build a critical size of initiatives and investments to support more actively digitising European industry. Essentially, a forum focuses on the community role of a platform, as described in the previous section. This report does not address the above meaning of the term 'platform'.

Figure 5 European Platform (or 'Forum') of National Initiatives

A **marketplace** is a specific type of platform that facilitates exchanges between buyers and sellers. Some authors consider two fundamental types of platform businesses, namely exchange platforms and maker platforms. A marketplace is a type of exchange platform. Both types of platforms create value by facilitating interactions between consumers and producers. An exchange platform creates value primarily by enabling direct exchanges between its consumers and producers. In contrast, a maker platform creates value by enabling its producers to make content (including the development of applications and services) and distribute it to an audience. Figure 6 gives some examples of exchange and maker platforms, both online and industrial platforms[20].

[19] http://www.economist.com/news/business/21711079-american-industrial-giant-sprinting-towards-its-goal-german-firm-taking-more

[20] https://www.quora.com/What-is-the-difference-between-a-marketplace-and-a-platform-Examples-are-great. Based on Moazed, Alex, and Johnson, Nicholas L. (2016). *Modern Monopolies: What It Takes to Dominate the 21st Century Economy*. St. Martin's Press

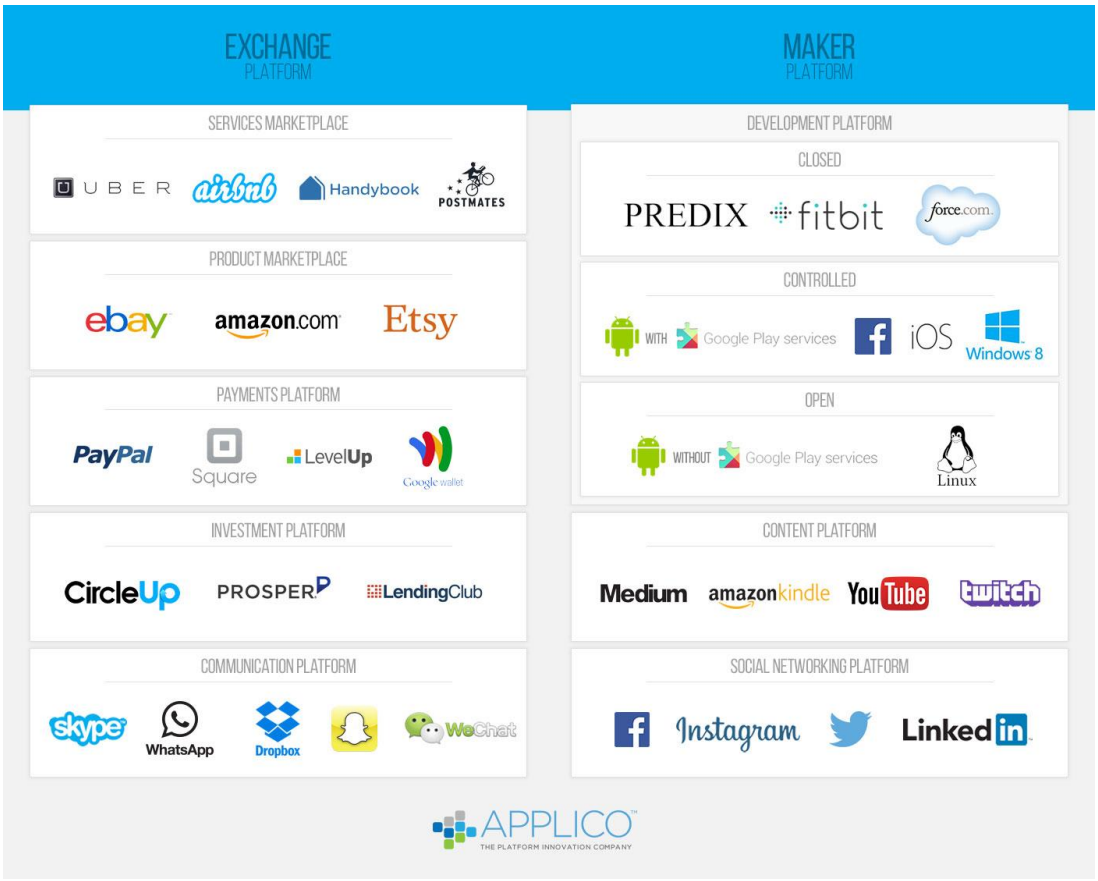

Figure 6 Examples of maker and exchange platforms

2.5 From platforms to markets

WG2 aimed to support the creation of next-generation digital platforms by defining possible next-generation platforms, reflecting on how building platforms should be approached on European level and considering how existing and planned EU-wide, national, and/or regional platform development activities can contribute.

WG2 defined next-generation digital platforms for the vertical sectors Connected Smart Factories, Smart Agriculture, and Digital Transformation of Health and Care, and for the horizontal topics Industrial Data Platforms, and Internet of Things.

In addition to platform building, WG2 considers large-scale piloting, ecosystem building, and standardisation essential (see Figure 7).

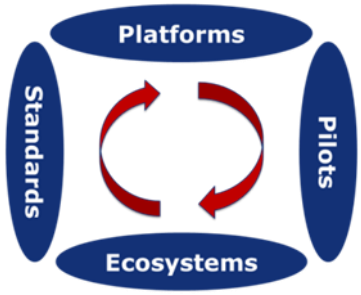

Figure 7 Essential activities

In **platform building**, the next-generation digital platforms are developed, interfaces are described via open specifications, and reference implementations are developed. Platform building involves the development of next-generation digital platforms, which build on the state-of-the-art, reuse what is available, and integrate different technologies, such as IoT, Artificial Intelligence, robotics, cloud and Big Data. Platforms should aim for openness, avoiding lock-ins, preventing dominant positions of individual players, and compliance with standards and regulation. Widely agreed and used reference architectures should be adhered to. Furthermore, the interfaces of the platform need to be described via open specifications and reference implementations need to be developed, so that outsiders can see how specifications are interpreted.

In **large-scale piloting**, pilots are set up that make use of the digital platforms, develop prototype applications on top of the platforms, and validate the platforms in both reduced, controlled environments, such as testbeds, and in real-life use cases. Pilots can adapt platforms to specific application needs and validate their relevance for such needs, in order to foster take-up and large-scale deployment. The key need is to deliver interoperable solutions that provide an experience that customers or businesses require, to test them in complex environments, to validate the platform specifications, and to give guidance for future implementation of applications and services on top of the platform.

A few examples of ongoing large-scale pilots and testbeds are given in Annexes A.3 and A.4.

In **ecosystem building**, the take-up of a specific digital platform is fostered by increasing the ecosystem of players involved in using that platform. Entrepreneurs may see market opportunities to develop services/applications with clear economic and societal value, on top of the digital platforms. Moreover, additional small-scale pilots can be conducted by SMEs, validating the digital platforms and prototype applications. Experiments running in the pilots, under specific scenarios, will allow for validation and acceptance by any actor in the ecosystem and by users in particular.

In **standardisation**, contributions are made to suitable standardisation bodies or pre-normative activities, leading to new or improved standards. Such standards are based on broad, international consensus of companies, users, governments and other stakeholders. Standardisation contributes to compatibility, interoperability, quality and safety of products and processes. Platform development activities, large-scale piloting, and ecosystem building need to be complemented by contributions to suitable standardisation bodies.

2.6 Towards large-scale federating initiatives

WG2 promotes a bottom-up approach for future platform building and standardisation, which builds on large-scale piloting and ecosystem building efforts. Nevertheless, for Europe to be successful vis-à-vis the competition of large, online incumbents, focused and aligned efforts in platforms and pilots are needed. Accordingly, Member States and the European Commission can help by ensuring that R&I investments across the EU are aligned and federated.

In the context of WG2, a survey of existing platforms, pilots and testbeds in the Member States, was performed in the first months of 2017 to assess the current state of affairs. The main results are presented in Annex A). The survey confirmed that several/many platform development activities, large-scale pilots, and testbeds exist at EU and national level. The survey shows a picture of fragmented development, with relatively little interaction between the various activities.

The European Union has launched under H2020 a set of projects in 2016-17 on digital industrial platforms and piloting, which has led to a first structuring of the effort around European-led platforms and reference architectures. For example, in the Internet of Things Focus Area of the Horizon 2020

Work Programme 2016-17, the EU is supporting large-scale pilots to foster the deployment of IoT solutions in Europe through integration of advanced IoT technologies across the value chain. With an EU investment of 100 M€, five IoT pilots were launched in the following vertical domains: Smart Living for Ageing Well, Smart Farming and Food Security, Smart Cities, Wearables, and Autonomous Driving[21]. Moreover, under the Factories of the Future PPP, in 2016, ten projects (with 70 M€ EU funding) were started for developing reference implementations and pilots of platforms for the shop floor and for collaborative manufacturing[22].

Ongoing and future platform development activities, large-scale piloting, and testbeds need to be used where possible, mostly in platform building activities and large-scale piloting. The survey shows some of the existing platforms, pilots, and testbeds at EU and national level. To develop next-generation digital platforms, new EU-level initiatives need to bring various activities together and act as **linking pins** between these activities. New platforms and large-scale pilots should build on existing platforms, pilot sites, testbeds, and experimental environments that have been developed in these various activities, where applicable.

The European Commission expects to launch a number of projects in the 2018-2020 timeframe that continue and extend the federation of EU-wide efforts and pooling of resources. These projects aim to make a significant step forward in the development and maturing of platforms, interoperability between existing platforms, integration of relevant digital technologies such as Internet of Things, Artificial Intelligence, photonics, robotics, cloud and Big Data, and validation via pilots and experimentation facilities. Starting from suitable reference architectures, platforms will be defined, tested via piloting, supported via ecosystem building for their roll-out, and evolved into standards.

A main goal of these new projects is to bring together various EU and/or national programmes and act as linking pins between them. These projects need to build on existing platforms, pilot sites, testbeds, and experimental environments that have been developed in various (national) programmes. As such, these projects provide the "glue" to connect currently disparate projects, programmes, and initiatives. As a result, the projects act as a central point in large-scale federating initiatives where **pooling of resources** results in a bigger critical mass and ultimately a higher chance of impact on the market.

Figure 8 shows a hypothetical example from the Connected Smart Factory domain, where platform development and integration activities link to several ongoing initiatives (e.g. a model factory, an experimentation lab, digital innovation hubs, and real production sites), and pooling investments from various sources (by e.g. Member States, regions, industry, and EU).

Annex A presents information about some of the more relevant programmes, projects and initiatives on European and national level, so that future activities may establish links, where appropriate. To facilitate such cooperation, the survey presented in Annex A should be seen as a first attempt to list relevant ongoing and future platform building activities, pilots, and testbeds.

Opportunities for large-scale federating initiatives for each of the five vertical sectors and horizontal topics are discussed in more detail in the next chapters.

[21] https://european-iot-pilots.eu/
[22] http://www.effra.eu/project-cluster

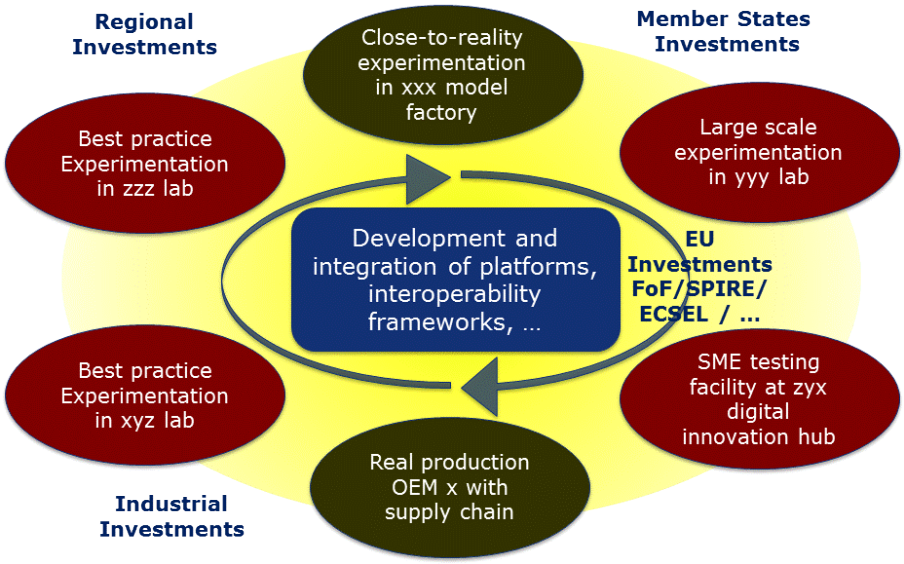

Figure 8 Approach to achieving leadership in digital technologies value chains

2.7 Role of Public-Private Partnerships

The previous section illustrates the approach of large-scale federating initiatives. It also illustrates the role of ongoing activities on national and regional level, whether they are focused on platform development, large-scale piloting, or testbeds. Public-Private Partnerships could play an essential role here as well.

In general, Public-Private Partnerships (PPPs) play a number of roles in European research, technology development, and innovation. They are an important means to develop the technology building blocks which underpin the digital revolution. They are also of significance to obtain the level of scale that is required for large-scale experimentation and standardisation. Furthermore, testbeds developed within PPPs can play an important role to create consensus about approaches and solutions, initially inside sectors but partly also across them.

The Digitising European Industry initiative advocates the continuation of technology development by PPPs, with reinforced roles as coordinators of EU-wide R&I effort. Enhanced coordination is required between the different PPPs. It also means that their Strategic Research and Innovation Agendas (SRIAs) should be better aligned to reach critical mass. Besides alignment and better articulation of efforts, the DEI Communication foresees focused investment by the EU, Member States and industry. The proposed approach is to maintain and reinforce the European support in Horizon 2020 to the PPPs in core technologies. Simultaneously, national programmes could align with the priorities defined within these PPPs, and vice versa.

The exact role of Public-Private Partnerships in the large-scale federating initiatives approach towards platform development, large-scale piloting, and ecosystem building, as outlined in this chapter, needs to be made more concrete.

3 Connected Smart Factories

3.1 Introduction

Value chains in manufacturing are changing across the board, becoming more integrated and more complex. Industry-driven platforms are widely seen as a strategic requirement for Europe to master these new value chains. The European Roundtable of Industrialists has called for greater efforts to drive global standards for the industrial Internet and to foster industry-driven platforms[23]. EFFRA, too, sees interoperable digital manufacturing platforms as central to its vision for factories of the future[24]. IndustriAll European trade union considers the Internet of Things in "locomotive" application markets as a major industrial opportunity to boost European industry's non-cost competitiveness. It recommends that significant public and private investment be dedicated to the development of industrial digital platforms, both from design to production to sales to customer care and maintenance, within each company, and from the component manufacturer to the equipment manufacturer to the systems integrator, between companies[25].

Digital platforms provide a means of addressing the many challenges facing manufacturing in the 21st century, including:

- Enabling **more agile and flexible approaches**, in line with new delivery and service opportunities ('Logistics 4.0').
- Facilitating **mass customisation** (so-called 'lot size one'), allowing every product to be unique and custom-made.
- Allowing **autonomous and Artificial Intelligence (AI) systems to be integrated** into the manufacturing environment – so-called 'cobotics'.
- Promoting **excellence**, eliminating defects in processes and products and allowing human competences to be developed in synergy with technological assets.
- Providing **a means to bridge two key trends**: fully linked physical and digital worlds, on the one hand, and fully-linked products and production, on the other.
- Enabling **servitisation** of manufacturing, creating substantial opportunities through intelligent after-sales service on top of the revenues created by the sales of the core product.
- Improving **energy and resource efficiency** and creating **more sustainable value networks**, key steps towards making the Circular Economy a reality.

It is clear that the Circular Economy requires an enormous traceability of industrial products in order to define where individual products are sourced, produced, disposed of, etc. This will create major data requirements across the whole value chain and could make the Circular Economy a key market driver for the digitisation of industry. Similarly, the concern for better resource use and less stress on the environment is also a main driver for smarter approaches in Agriculture (see Chapter 4).

European policy aims to ensure that future global standards and platforms for the Connected Smart Factory are driven by the interests of EU actors; and that to achieve this, EU actors join forces along common interests in the 'platform economy'.

[23] ERT Position Paper: Towards European Leadership in the Industrial Internet (August 2016)
[24] EFFRA Recommendations: Factories 4.0 and Beyond (Sept 2016), http://www.effra.eu/attachments/article/129/Factories40_Beyond__v30_public.pdf
[25] Strategic study on anticipation of change in the European ICT sector, Sept. 2016, http://www.industriall-europe.eu/proj/ictstrat/industriAllEurope_2016-09_ICT_StrategicStudy_EN.pdf

3.2 Current landscape of activities

3.2.1 European activities

Key initiatives at the European level are the Public-Private Partnerships (PPPs). Two PPPs explicitly address manufacturing/production: Factories of the Future (FoF) (discrete manufacturing) and Sustainable Process Industry through Resource and Energy Efficiency (SPIRE) PPP (industrial processing). The role they could play towards the DEI objectives is detailed in Section 3.5.

Under the FoF PPP, a set of ten projects (plus one coordination and support action, called "ConnectedFactories") were started in autumn 2016 that develop reference implementations of platforms in a multi-sided market ecosystem and include user-driven proof-of-concept demonstrations and validation in several different scenarios[26]. The projects focus on factory automation or collaborative manufacturing and logistics. Their positioning and that of three other relevant projects (Industrial Data Space, Arrowhead, and Productive 4.0) on a two-dimensional cross-section of the RAMI 4.0 framework is depicted in Figure 9.

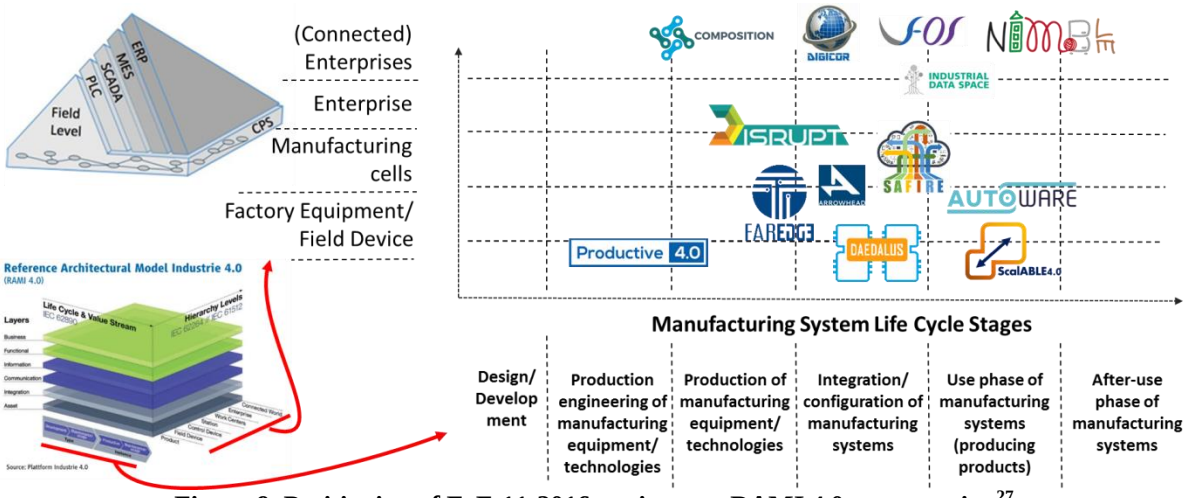

Figure 9 Positioning of FoF-11-2016 projects on RAMI 4.0 cross-section[27]

RAMI 4.0 (Reference Architecture Model for Industrie 4.0) is a framework to position different applications, specifications, standards with respect to each other, and promotes common understanding. In order to achieve a common understanding of what standards, use cases, etc. are necessary for Industry 4.0, a uniform architecture model is needed as a reference, serving as a basis for discussion of applications, specifications, standards, their interrelationships, and their details. The result is the RAMI 4.0 framework (see Figure 10). It contains some fundamental aspects of Industry 4.0, and expands the hierarchy levels of the IEC 62264 standard by adding the "Product" or workpiece level at the bottom, and the "Connected World" going beyond the boundaries of the individual factory at the top. The left horizontal axis is used to represent the life cycle of systems or products, also establishing the distinction between "Type" and "Instance". Finally, the six vertical layers/levels define different aspects of applications and IT components.

See also Annex A for more information on activities at EU level.

[26] Known as FoF-11-2016 ("Digital Automation"), see http://www.effra.eu/project-cluster
[27] Source: presentation by the ConnectedFactories project, http://www.effra.eu/connectedfactories

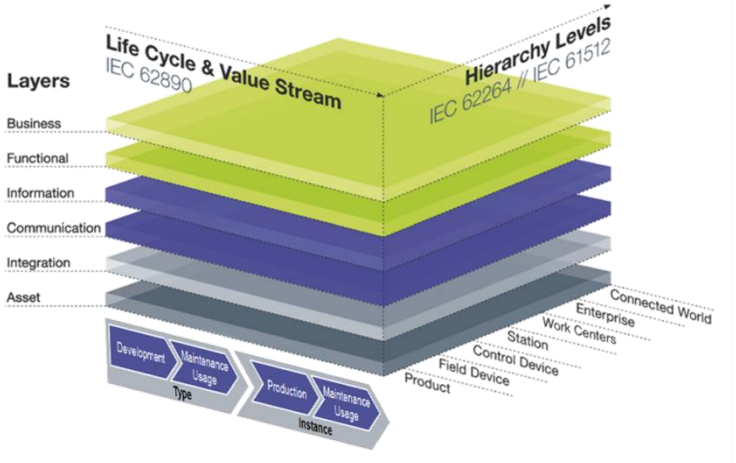

Figure 10 RAMI 4.0

3.2.2 National and regional activities

Developments are also underway at national level in many Member States, often – but not per se – as part of national initiatives. The Netherlands, for example, has 25 field labs established as high TRL (Technology Readiness Level) environments, as part of its *Smart Industry* national initiative. Some of these actions are clustered around the EU's Vanguard initiative. Germany started the *Industry 4.0* national initiative, connecting embedded systems technology and smart production processes to enable smart factories. During the past year key players in the initiatives in the Netherlands and Germany have signed agreements, committing themselves to standardisation. For example, the ProSTEP iViP Association in Germany has developed a "Code for PLM Openness" (CPO) which provides a criteria catalogue for interoperability, infrastructure, extensibility, interfaces, standards, architecture, etc. to business users and hence opens the way for transparency in digital industrial operations (see Figure 11)[28].

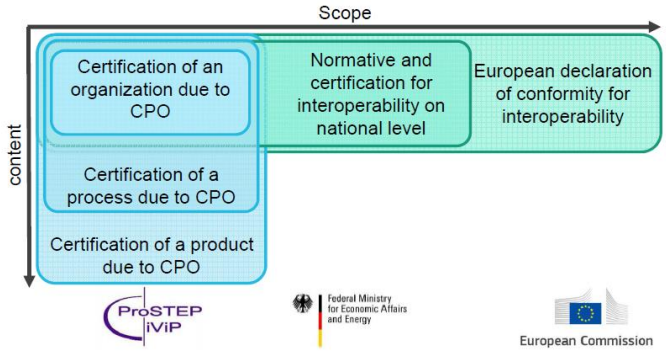

Figure 11 Towards a European CPO certification roadmap

Sweden introduced the *Produktion 2030* national initiative to boost digitisation of its manufacturing industry. Spain has also launched an Industry 4.0 initiative and is experimenting with various approaches. Italy's National Industrial Plan, announced in September 2016, foresees government investments that will be matched by industry. It includes investments in competence centres and digital innovation hubs, some of which will be linked internationally. In France, the Industry of the Future Alliance (*Industrie du Futur*) was launched, aiming to strengthen the country's global position as a leader in new industrial systems. Several cooperation agreements have been signed between French organisations and those in other countries, most notably in Germany. In December 2016,

[28] http://www.prostep.org/fileadmin/CPO/ProSTEP-iViP_CPO_V14_151019.pdf

Plattform Industrie 4.0 and *Industrie du Futur* jointly released a Joint Working Program and a Common List of Scenarios.

For some of the concrete activities and projects under the above-mentioned national initiatives, please refer to the Annex A.

3.2.3 International activities

Obviously, in North America and Asia relevant developments regarding Connected Smart Factories occur as well. PwC predicts a global investment level in technologies for industry digitisation in 2020 of more than $ 900 billion annually. It also reported that 72% of the companies included in its survey expect to have achieved "advanced levels of digitisation" by then, compared to 33% today[29]. A growing awareness exists in the business communities of what these levels of investment imply in terms of market opportunity for platform suppliers. In December 2016, The Economist compared the GE approach based on its Predix platform with that of Siemens and its MindSphere platform, to assess their chances on eventually dominating the industrial Internet[30]. It concluded that a single platform is unlikely to achieve a position of total dominance and stressed the importance of an "open" approach. This only emphasises the need to carefully follow international initiatives and develop relations with them.

In addition to the efforts by large industrial conglomerates such as Siemens and GE, machine tool builders transform their businesses digitally. For instance, by making use of data deriving from the machine tools they build, they develop predictive and prescriptive solutions for customers, improving machining performance, health and safety, energy-efficiency, business domain integration and so on. Some machine tool builders invest more and more in digital platforms, e.g. Trumpf with Axoom and DMG Mori Seiki with CELOS.

In the US the digitisation of industry is strongly driven by large companies, such as AT&T, Cisco, IBM, GE and Intel. In the past two years more than 250 other companies, including several from Europe, have joined the US-led Industrial Internet Consortium (IIC), which aims to coordinate the priorities for the industrial Internet and to enable related technical applications. IIC focuses on progress through testbeds in specific application domains, as opposed to more generic standard setting. Close contacts exist between the IIC and European companies. For instance, Bosch played a prominent role in the first IIC test bed, about the connection of tools and work steps in aeroplane maintenance.

Likewise, Chinese companies have shown a keen interest in the European developments regarding Connected Smart Factories, especially in Germany's Industry 4.0 initiative and its stakeholders. However, they take a different approach, relying more heavily on direct investment in European companies that are relevant for them. For instance, in the past few years Chinese companies have invested quite substantially in German companies that are affiliated with Industry 4.0, such as machine tool builders Krauss-Maffei, Stoll, and Manz Group, and robot maker Kuka.

Bearing in mind the demographic changes in China, the government supports a transition away from an industrial context that emphasises low labour cost and that exploits the availability of a vast labour force. To overcome reduced availability of workers and rising labour costs, China stresses investments in automation, especially robots, more than investment in connection and truly smart factories. It also puts less emphasis on the development of skills for the digital age. Nonetheless, the

[29] Industry 4.0: Building the digital enterprise. April 2016. http://www.pwc.com/gx/en/industries/industries-4.0/landing-page/industry-4.0-building-your-digital-enterprise-april-2016.pdf

[30] http://www.economist.com/news/business/21711079-american-industrial-giant-sprinting-towards-its-goal-german-firm-taking-more

Chinese investment level in relevant technology is very significant and exceeds the level of investment in the EU. The two most relevant programmes in China are "Made in China 2025", often considered the Chinese equivalent of Industry 4.0, and "Internet Plus (IP)"[31]. Towards 2025, IP aims to increase security of and access to Internet, to improve the convenience of (Internet-based) social services and to link manufacturing and retail in an effort to move away from labour-intensive manufacturing towards activities with more value. The "Made in China 2025" plan is focused on manufacturing and moving industrial companies up the value chain and increasing domestic innovation capacity. Its ambition is to turn China into a 'strong' manufacturing nation within a decade, with the priority on digitisation and modernisation of 10 sectors.

3.3 Visions for the future

3.3.1 Needs and expectations

High on the wish list of manufacturing company CIOs are applications that provide effective, fluid digital information and communication across the value chain with the ease of use, updatability and convenience of those they use in private life[32]. Today's consumer-oriented apps and cloud-based software are intuitive to use, updatable, and affordable for the masses. Manufacturing companies would like to have design and manufacturing software solutions and an app-store ecosystem that can reach the same bar. In other words, they would like to have a more flexible and modular intra-factory digital information and communication structure than the traditional automation pyramid (see Figure 12).

Figure 12 Traditional industrial automation pyramid

In Europe, a certain level of fragmentation exists in the area of Connected Smart Factories. Several activities can be found already, with different motivations, objectives and funding streams. Less fragmentation is clearly desirable. Joint attempts should not aim for the creation of a "holy grail" solution: a single platform for everyone. Future initiatives must reduce limitations to access that currently exist as a result of fragmentation and lack of interoperability. Simultaneously, the supported approaches should be socially sustainable.

3.3.2 Bridging the gaps and addressing the issues

Given the needs and expectations regarding Connected Smart Factories it is clear that at the technical level, interoperability and integration of legacy systems should be a key focus for testing and validation efforts. Platforms do not only integrate new and upcoming technologies, but must also be able to handle legacy systems. Standardisation is an important instrument to enhance interoperability. Interoperability is especially important in the context of federating initiatives where activities seek to build on what has gone before (i.e. a so-called 'brownfield approach'). Such an approach is for instance being followed in the five large-scale IoT pilots that started in January 2017. These will be multi-stakeholder efforts from the outset so as to create trust and confidence across the community.

[31] http://www.europarl.europa.eu/RegData/etudes/STUD/2016/570007/IPOL_STU(2016)570007_EN.pdf
[32] http://www.mckinsey.com/business-functions/operations/our-insights/digitizing-the-value-chain

Economic considerations also play an important role in the context of Connected Smart Factories. On the one hand demonstrating added value is key to successfully establish digital platforms. The platforms have to meet – and be shown to meet – the needs of their stakeholders, especially the users. This means a strong emphasis on validation, demonstration and experimentation in realistic settings (labs, testbeds, pilot lines). Moving from the laboratory into realistic facilities creates trust and confidence for all concerned, including large enterprises, SMEs and users. Initiatives must reach out to engage with SMEs, startups and entrepreneurs. Like other stakeholders, SMEs will engage if they see and understand the benefits, such as new customers, cost reductions, etc. Specific measures will be needed for this and should be part of concrete actions. However, the levels of investment have to be feasible, especially for SMEs. Here digital innovation hubs can play a key role, because they have a relatively low access threshold.

A promising approach with regards to validation and standardisation that is specifically aimed at the needs of SMEs is taken within the context of Industry 4.0, through the Labs Network Industrie 4.0 together with the Standardization Council Industrie 4.0. The latter initiates and coordinates standard development and the former validates standards via practical testing[33].

Furthermore, platform success is very much driven by the exploitation of network externalities: the networking potential that a platform offers to an aspiring user depends heavily on how many other users are already connected to the platform. As a result there is a strong tendency for a trajectory where a few winning platforms eventually take all users. Oligopolies or even monopolies result rather easily. Such an outcome would make it tempting for the winning platform providers to force users to pay more than they normally should for their offerings and it would reduce the drive for new and better services.

In the debate about "the user" one should bear in mind that traditional distinctions between platforms for business-to-business (B2B) versus business-to-consumer (B2C) operations look increasingly outdated. As value chains become more integrated, it becomes ever more difficult to separate the business and consumer dimensions. Google, Amazon and Facebook, for example, largely position themselves as consumer platforms, yet the majority of their revenues come from B2B activities that rely on the data about consumer behaviour. The media industry reacted late to this situation and has suffered significantly at the hands of new entrants who have become monopolistic gatekeepers. Europe cannot afford other sectors – e.g. automotive, smart homes, smart cities – to go the same way and become controlled by players in other parts of the world. To safeguard their position these sectors have to become more focused on the consumer and invest in servitisation.

The legal regime is also important, for issues such as IPR. Clearly the fact that data will be more accessible does not mean that it always has to be provided for free. Yet, all players need to be able to compete without giving up their data or paying fees that would be incompatible with their business model. This issue is treated in more detail in the Industrial Data Platforms chapter (see Chapter 6).

3.3.3 Priorities

Stakeholders in WG2 considered the priorities for this area to be as follows:

Stocktaking of relevant activities should be completed as soon as possible
It is clear that many relevant activities already exist and while they are all somewhat different they also have much in common. Opportunities for collaboration and joint effort clearly exist. Together with the EU, Member States should perform a more detailed assessment of their national activities, to consider how they could be strengthened by further synchronisation.

[33] https://ec.europa.eu/futurium/en/system/files/ged/a2-pichler-standardisation_council_industrie_4.0.pdf

Experimentation should be encouraged
WG2 advises against "Big Bang" attempts to launch one or few new platforms and make them the preferred solutions for everyone. Instead, experimentation with different solutions should be encouraged. This applies especially to for instance Manufacturing as a Service (MaaS), platforms for the Circular Economy, collaborative engineering, additive manufacturing and real-time advanced factory analytics.

The scale of successful initiatives should be leveraged through federation
Rather than focusing on introducing a single big new initiative, existing platforms should be made interoperable and leveraged through federation. Enhanced platform connectivity based on the definition and use of open APIs can facilitate this. This should be accompanied by enhanced security measures, e.g. against cyber-attacks. This will help to remove doubts about the reliability of the platforms and increase the acceptance among potential users.

Besides technical aspects economic, legal and social issues should be addressed as well
Sufficient attention should be given to the social effects of establishing connected smart factories. Educational programmes at various levels should equip (future) workers in European industry with the knowledge and skills to address the challenges of the digitised world. Furthermore, regulatory and economic safeguards against the risks of monopolistic positions of platforms need to be in place. Obviously, this should not strangle promising initiatives or put undue pressure on the direction of their development. Nonetheless, the regulation should effectively protect the interest of workers, consumers, competitors and other stakeholders. Digitisation creates new opportunities for all these members of society, but also new threats and both need to be properly addressed.

3.4 Implementing the vision

3.4.1 Objectives for next-generation platforms

Development from scratch of new large platforms may not be required per se. Industry needs targeted demonstrators where manufacturing companies can merge expertise in manufacturing with advanced digital approaches. This will lead to services that were impossible to provide before. Especially demonstrators that connect actors in different Member States are to be encouraged. In line with this priority, it is necessary to collect good practices and identify successfully established platforms wherever they are to be found – including those outside Europe – and build on them, rather than seek to re-invent platforms and opening up new initiatives. This may be the quickest way to reach critical mass.

3.4.2 Definition of supporting initiatives

The overall approach (see Chapter 2) defines an important role for large-scale federating initiatives. With so many competing activities, federation of the more promising activities could help to convince industry of the value of digital platforms and would encourage them to develop the accompanying ecosystem. Such activities must have clear added value for the constituency concerned and be driven bottom-up (i.e. be voluntary and pre-competitive). Platform development and use may be supported by administrations but need to be embraced by industrial users, while research institutions and universities can play important roles in the process of establishing such industry-driven ecosystems. Hence, there is a clear need for an international, inter-sectoral dialogue between public sector and private sector representatives.

3.4.3 An action plan

In many Member States, overarching national initiatives exist (see overview in Section 3.2.2). Especially these initiatives should be involved in joint road mapping, together with the PPPs. This collective action should be focused on the development of platforms from small demo-scale to commercially supported ecosystems. This also means bringing together users and suppliers of existing platforms.

3.5 Contributions from PPPs

Both FoF and SPIRE could in principle be involved in developing digital platforms, large-scale piloting, ecosystem building, and standardisation in a variety of sectors. For example, existing project clusters within FoF could be the basis for a series of digital platforms which together could help realise a true 'plug and produce' approach. Specifically, these are:

- Targeted Innovation Actions, focusing on bringing validation of digital platforms as close as possible to the manufacturing environment;
- Research & Innovation Actions that focus on specific challenges such as security, data liability and data analytics.

Potential contributions from SPIRE include:

- Towards Cognitive Production: enhanced digitalisation to implement cognitive production plants for improved performance in the process industries;
- Process Decision Making: integration of life-cycle assessment and costing tools for process decision making;
- Towards Industrial Symbiosis: optimisation of industrial processes based on standardisation.

3.6 Contributions from Member States

The results from the survey performed by WG2 (see Section 2.6) and the outline of national initiatives in Section 3.2.2 already showed the significant effort many Member States currently take to work towards Connected Smart Factories. More details about these initiatives are still needed to explore how they can cooperate with the PPPs and how they can support each other. See also the priorities in Section 3.3.3.

3.7 Recommendations

Based on the previous considerations the main recommendations for "Connected Smart Factories" are:

Platforms

- Enhance the visibility of initiatives' platform development in the Member States and at EU level, and stimulate their synchronisation;
- Encourage experimentation, rather than an unrealistic "Big Bang" approach;
- Stimulate that new activities build on existing platforms, to prevent further fragmentation;
- Facilitate alliances across sectors and domains, to gain from re-use of expertise and solutions and to create critical mass.

Pilots

- Emphasise piloting and validation in realistic settings; too many results do not leave the laboratories and their scale remains small;
- Increase the availability of demonstration facilities and independent testbeds, to stimulate validation;

- Ensure that validation of new results includes sufficient attention for integration with legacy systems; without such integration the adoption of new results will be seriously hampered.

Ecosystems

- Put a strong focus on the development and growth of ecosystems and on establishing critical mass;
- Actively engage SMEs, startups and entrepreneurs to involve them in ecosystems.

Standardisation

- In research and innovation programmes of Member States and the EU, put more emphasis on the need to standardise. From the very start, standardisation should be a key consideration in any platform development;
- Efforts towards European leadership in standardisation should also extend to de-facto standards and open APIs.

4 Smart Agriculture

4.1 Introduction

Smart agriculture offers very significant opportunities for Europe. Applying digital technologies to agriculture holds important promises for most of the challenges the sector is facing. Beyond farming itself, digitisation of the food supply chain has important consequences, including for instance for health care (see chapter 5) and quality of life of Europeans in general. However – as in other areas – currently platform development is fragmented across Europe in this vertical. To maximise potential a clear need exists for a co-ordinated strategy rather than many individual initiatives. To support this, a liaison is needed across DGs and Member States, to come up with integrated solutions and an appropriate supporting infrastructure. Currently, there is a lack of awareness of initiatives at Member State level and a list of all projects in the area should be created. This information needs to be disseminated, and to encourage collaboration there is a need for an annual general meeting for the sector to bring key stakeholders together.

Individual farmers are central to the uptake of the technology. It is therefore crucial that they are intimately involved and are at the centre of development of new platforms. However, reaching them is difficult. Larger farms have a vested interest in adopting technologies, but smaller farms do not have the time or inclination to attend meetings. A different strategy is required to reach these farmers on site. Co-operatives and advisory services could play a vital role to address them.

As in the case of Connected Smart Factories, concepts from the Circular Economy also act as an important driver for digitisation in this area. The notion of the Circular Economy matches well with the resource efficiency that farmers desire in order to be competitive and profitable. The farmers are intrinsically driven to produce more with less, addressing concerns about for example minimising water leakage and use of fertiliser. Consequently, opportunities to create greater transparency about how things are produced will be embraced across the sector.

Further sustainability and efficiency improvements can be gained through exploitation of digital platforms. First of all, there is a need for sensors and seamless connectivity. Consequently, at a basic level there is a need for widespread rollout of Rural Broadband for connectivity, also in remote areas. Secondly, a need exists for the development of expert systems for optimisation and prediction that farmers can use, e.g. in so-called Precision Farming. Here care needs to be taken not to re-invent the wheel and to provide solutions that meet the needs of both large and small farms.

In order to engage with farmers and developers and promote the use of new technologies there is a need for hands-on experience. The use of Open Living Labs is seen as a very appropriate way to achieve this. Large scale demonstrations are needed to show the benefits of interoperable platforms and the usage of data within smart agriculture. This needs support from Structural Funds from the European Agricultural and Rural Development Fund (EARDF) and the Smart Specialisation Strategy RIS3 to engage with Member States and connect rural development programmes with EU projects. Co-operatives, advisory services and the most relevant parts of the broader agricultural knowledge and innovation systems have a key role to play in connecting at the local level along with Innovation Hubs. Other technology stakeholders e.g. Big Data PPP, FoF PPP, 5G PPP, SPARC PPP and Cyber Security PPP, should also be engaged to address the key issues highlighted by the sector, e.g. interoperability, connectivity, data management and analysis, and security.

4.2 Current landscape of activities

Already some farmers are using a variety of platforms to support and manage their farming activities. Recent exhibitions addressing the agricultural community reveal a considerable presence of cloud computing and robotics technologies, indicating that these are now driving the sector. However, most suppliers in the domain are small start-ups and there is involvement from many regional agencies.

This has led to the creation of many platforms by start-ups, agencies and farmer co-operatives across Europe. Sometimes platforms are targeted at single farmers, sometimes they are targeted at groups of farmers, and sometimes at agencies to help with the management of subsidies. Overall, however, development is very fragmented. Typical platforms support farm management for family farms, irrigation, data services, food processing and the management of subsidies.

In the area of robotics, farmers are embracing digital technologies for increased automation, e.g. automated feeding and milking systems and automated farm machinery. These are seen as very beneficial as they release time for performing other activities and also allow farmers to spend more time with their families. A number of areas were specifically highlighted:

- **Autonomous Tractors and Combines Harvesters** – Autonomous farm machinery is already commercially available, e.g. from John Deere, and due to the more relaxed safety considerations with respect to traffic it is possible to have much higher levels of automation than is currently possible in the automotive sector. It was noted that uptake of autonomous vehicles within the farming community was still at the early adopter level.
- **Robotic Systems** – Robotic systems are increasingly being used for feeding cattle and for automated milking of cows.
- **Monitoring Systems** – Monitoring systems are being used to monitor the health of livestock to identify illness and also for crop management, e.g. water use.
- **Optimisation for Sustainability and Efficiency** – Sustainability and efficiency are key drivers in the farming industry and this has led to development of software tools to optimise and provide decision support for use of fertilisers, seed sowing and management of fields. Increasingly this is being combined with monitoring systems to provide feedback.

Overall it was noted that the platforms being developed and used are being produced with little/no coordination, leading to a fragmented offering in the marketplace. Farmers currently have to contend with multiple platforms with little or no interoperability between platforms. This is increasingly becoming an issue and the need for coordinated platform development is growing.

4.2.1 European activities

DG AGRI supports a number of activities on smart agriculture, specifically under the EIP-AGRI and H2020. Innovation projects (operational groups) under EIP-AGRI are funded by Member States through Rural Development Programmes. DG AGRI has set up a strategic framework for agricultural research and innovation activities where ICT has an important role to play. An EIP-AGRI Focus Group was set up on Precision Farming that addressed the lack of take-up of ICT technologies by farmers. This provided research recommendations and ideas for operational groups to overcome existing barriers for adoption of precision farming technologies.

To promote further digitisation, a seminar on data driven business models was organised by DG AGRI where different models were analysed. In addition a workshop on "Digitising the agri-food sector" had been held to bring together actors from the IT sector (large companies and SMEs) and the Agri-Food sector (farmers and other stakeholders) to analyse current challenges and end-user needs[34]. The aim of this was to identify where emphasis should be placed for the next H2020 Work Programme in the area.

In addition, DG AGRI has prepared a series of events for 2017 related to digitisation in agriculture[35]. The first event on "**Data Sharing: ensuring a fair sharing of digitization benefits in agriculture**" took place on the 4th and 5th of April 2017 in Bratislava (Slovakia). During the workshop the existing

[34] http://ec.europa.eu/programmes/horizon2020/en/news/digitising-agri-food-sector-workshop
[35] See the EIP-AGRI website, http://ec.europa.eu/eip/agriculture/

or potential arrangements, frameworks and pathways to enable effective, fair and valuable data sharing were discussed[36].

Some European activities started in January 2017. DataBio is a new project funded via the Big Data Value Association which addresses data for agricultural applications[37]. The EU is also funding an IoT Large Scale Pilot called IoF2020[38]. This 4 year pilot with 73 partners started on 1 January 2017 and addresses 19 use cases and 5 trials. The core of the project lies within the 5 trials, which cover 5 sectors (arable, dairy, fruits, vegetables, and meat), while involving end-users and IoT develeopers. Amongst the many real demonstrations in the agri-sector, IoF2020 also aims to promote interoperability and standardisation. The project will exploit many existing platforms and standards such as FIWARE, FIspace, ISOBUS, etc. There are also opportunities for further projects via an Open Call which will distribute 6MEuros. In the robotics sector, the European Union is already funding 7 projects in the domain and euRobotics (the private side of the SPARC PPP) is planning to set up an Agri Food Lighthouse Project in the context of the SPARC PPP.

4.2.2 Regional and national activities

Sustainable agriculture and food safety are driving regional and national initiatives. At that level an increasing interest in data platforms exists, with initiatives being set up in different regions and Member States. For instance, the "Smart precision farming" initiative has been put forward by the Tuscany region of Italy within the framework of the Agri-Food Smart Specialisation Platform. This initiative is looking for partner regions around Europe. Likewise in Spain the "Traceability and Big Data" Initiative for the exploitation of data throughout the whole agri-food chain, has also been proposed by the Andalusia region, again within the framework of the Agri-Food Smart Specialisation Platform. This is also in the process of launching and looking for partner regions. The Galician government has set up the PRIMARE Public Procurement of Innovation initiative. The aim here is to build a regional data platform for capturing and managing of CAP subsidy data. The Spanish Ministry of Agriculture has set up the SIAR Network which is an Agroclimatic information system for the estimation of crop irrigation needs. Already the system has more than 300 sensing stations nation-wide and an open web system for accessing data. This network started building in the early 2000s. There are also other national initiatives such as one in the Netherlands on precision farming. Notably there is a lack of visibility of initiatives at this level across Europe and it would be beneficial to compile a list across Europe.

Name	**Scope**	**Link**
High-tech farming	Tuscany (Italy)	http://s3platform.jrc.ec.europa.eu/documents/20182/183310/Tuscany.pdf/70146a39-1909-47f9-aa4b-0de1b904fe41
Traceability and big data	Andalusia (Spain)	http://s3platform.jrc.ec.europa.eu/documents/20182/183310/Andalusia.pdf/8950733d-66a0-4771-835d-06092d90c34c
PRIMARE	Galicia (Spain)	http://amtega.xunta.gal/cpti
SIAR Network	Spain	http://eportal.magrama.gob.es/websiar/Inicio.aspx

4.2.3 International activities

Large initiatives at the international level are being funded by a mixture of private and public sector funds. Notably the use of data for efficiency, sustainability and business creation is a common factor in these initiatives. The Agricultural Industry Electronics Foundation (AEF) is an alliance of more

[36] https://ec.europa.eu/eip/agriculture/en/event/eip-agri-workshop-data-sharing
[37] https://www.databio.eu/en/
[38] https://www.iof2020.eu/

than 100 companies. It was initially focused on developing the ISOBUS protocol standard for communication between implements, tractors and computers, however, now it also addresses other topics such as Farm Management Information Systems. For sharing data, the Global Open Data for Agriculture and Nutrition (GODAN) initiative is supporting the proactive sharing of open agriculture and nutrition data. Currently there are 400 partners from national governments, non-governmental, international and private sector organisations in this initiative. For business-to-business (B2B) connectivity, FIspace provides SaaS cloud platform based on FIWARE technologies. Already several pilot projects in the agri-food platform have been built using FIspace.

Name	Scope	Link
Agricultural Industry Electronics Foundation (AEF)	Global	http://www.aef-online.org/en/
Global Open Data for Agriculture and Nutrition (GODAN)	Global	http://www.godan.info/
FIspace	EU	https://www.fispace.eu/

4.2.4 Co-operatives

Co-operatives are already actively developing platforms for their members. Many of the data platforms and services for B2B and B2C being produced are closely addressing farmer's immediate needs. An issue is that co-operatives tend not to be connected with European innovation networks while there are lessons that could be learned. An example is the LILA Virtual Community which was launched in 2008. LILA is a company owned by dairy farmers and the dairy industry in the region of Asturias. A platform has been created that shares data about milk analysis results from 2000 farmers in the region. Netfarming, a subsidiary of AGRAVIS (an agricultural trade and services company owned by German co-operatives), has developed the Netfarming Suite of farm management applications for its members. Likewise in France, SMAG has developed a suite of farm management applications for French farmers. SMAG is a company which is part of INVIVO, one of the largest French agricultural co-operatives. Notably in these tools special attention is paid to rights to access and process data.

Name	Scope	Link
LILA Virtual Community	Asturias (Spain)	https://www.lilacv.com
Netfarming	Primarily in Germany	http://www.netfarming.de/
SMAG	Primarily in France	http://www.smag-group.com/en

4.2.5 Commercial providers

There is a move in the commercial sector to make proprietary systems and architectures more open, to make them compatible and accessible to third parties. Examples of this are 365FarmNet which is an open platform for linking together applications and services of different manufacturers and service providers. John Deere has now provided an open API for their MyJohnDeere Farm Management Information System to allow access to agricultural machinery data to other systems such as those provided by SMAG and Agro-Office. Similarly New Holland has provided the PLM Connect Farm Management Information and Decision System with an open API.

Although not strictly a "platform", Microsoft's Azure is increasingly used in commercial products for the agri-food domain and a number of EU companies are offering commercial services for farmers built on Azure cloud services.

Name	Link
365FarmNet	https://www.365farmnet.com/en/
MyJohnDeere	https://myjohndeere.deere.com/
PLM Connect	https://www.plmconnect.com/
Microsoft's Azure	https://azure.microsoft.com/

4.3 Visions for the future

4.3.1 Needs and expectations

The vision for the future is one of increased connectivity and interoperability between platforms. With this it would be possible to provide more services through gathering and combining information from a wide range of smaller platforms gathering data from sensors, machinery, animals, etc. Provision of such platforms would increase resilience within farming, e.g. managing resource efficiency and managing the health and welfare of animals (i.e. removing sick animals from herds and in transportation of animals), and it could also be used to decrease red tape and bureaucracy which farmers currently contend with. At the same time this would allow farmers to maintain high quality and produce safer products.

This vision places the farmer at the centre of collecting and processing of data. The data can be used internally by the farmer for efficiency and optimisation, but also externally to provide better public services and tools, for instance to mitigate climate change. To enable this, farmers need to control access to data from the farm and must also be compensated when others use this data, to provide them with an incentive to share. To support this change, farmers will need training and education on how to exploit data. They will also need to understand their rights and responsibilities in a digital world. As "data generators" farmers will have a different role in the value chain. They are more likely to give access to data if they understand how it will be used by external parties. This requires development of trust and partnerships.

The key requirements are for interoperability and standardisation. Farmers need to be able to pick and choose the most appropriate combination of tools from different suppliers. As highlighted in the vision, the farmer needs to be at the centre of the system and thus there is a need for development that is driven by the demand side rather than by the technology providers. Farmers also expect high reliability from equipment as in many cases farm operations are time sensitive. Already it is common for farmers to share expensive equipment via joint ownership of machinery, or call in external companies to harvest or spray a field. Looking to the future, the "Uberisation of tractors" is likely to become easier, leading to lower costs and less ownership.

Furthermore, there is a big opportunity to gain benefits through open data sharing amongst farmers. A lot of data collection is still paper based but in the future sensors may be used to automatically collect data. By sharing sensor data the number of installed sensors can be reduced cutting costs for individual farmers. It may also be possible to provide complementary data. Examples of this are the provision of historical yield maps for fertiliser application which can be combined with algorithms and information on the local soil type to control smart spraying machinery. Likewise map information can be used intelligently to irrigate areas based on statistical information or to deposit more seeds in regions of sparse vegetation. An integration and extension of existing benchmarking practices with digital technologies could provide profound insights in farm management in general, as well as the value of further digitalisation of the sector.

Ideally data should be stored in such a way that it can be accessed by different stakeholders. This is already being utilised by business farmer networks in the US. This would allow other companies to create innovative solutions that farmers may buy as add-on services. The business models for this need to be developed, as creating revenue from data is different from selling hardware to farmers. In the case of data driven revenue generation the model should be subscriber based and needs to be

scalable. Barriers to this at present relate to rights to access and process data and to discovering how to create value from data. Security of data is also a concern.

For sharing of data in a farmers coalition there is a need to agree on principles for sharing. Potentially this could lead to disruptive business models for coalitions that process and store data and also provide services and training.

4.3.2 Bridging the gaps and addressing the issues

There is a key need for interoperability and standards for connecting platforms. Consensus on platforms and cross sectorial compatibility is needed to achieve this. Although some platforms are advertised as sector agnostic this is often not true in practice. The requirements for platforms should come from the farmers and the farmer should be at the centre of development. It was noted that in the US farms are large and it is easier to see the benefits from adopting platforms there, as farms are operated more like factories in the US. Within Europe the size of farms differs considerably. There are many smaller farms and here there are different requirements, with a significant market for low cost web services.

Already platform building initiatives and Large Scale Pilots started in January 2017 that will begin to address some of the highlighted issues. A key need is to provide open APIs and provide a platform that is open to all farmers. Demonstration of the efficacy of the technologies is also important to provide confidence. Test regions for smart farming are also needed where new ideas can be tested.

To support this there is a need to combine large scale demonstrators across the EU and link these with activities going on at the national level. These should be used to demonstrate ideas that can be replicated. There is also a need to link with co-operatives at the regional level. However, disparity across regions presents a challenge.

The Common Agricultural Policy generates a significant amount of data, creating an opportunity for the integration with other services and practices requiring similar data. This is typically a case where the already existing data flows are unexploited by the potential other uses and where platforms linking and integrating this kind of data are needed.

4.3.3 Priorities

Four key priorities were highlighted. These are the need for interoperability for connecting machinery and sensors, the need for approaches for data management and handling, the need to address the digital divide and the need to provide connectivity for farmers.

Connecting machinery and sensors

There have been significant advances in smart tractors and combine harvesters. The farm machinery suppliers often work with the automotive suppliers and the levels of automation used in agriculture is currently ahead of that in use within the automotive sector. This is possible because of the more controlled environment with an absence of traffic in the field. Already coordinated control of combine harvesters and pick-up tractors exists and is marketed. The original smart tractors provided a plethora of information screens and the farmer had to integrate information in the cab. This has much improved. Likewise interoperable connection of tractors to different implements has been addressed through development of an ISO bus connector between the tractor and a range of add-on implements allowing control of equipment. This definition of common interfaces was led by the Agricultural Electronics Standardisation body.

Looking to the future, the tractor is now becoming part of the cloud and the farm management system. There is thus a need for a new level of interoperability to ensure that all connected systems can all talk to each other. Interoperability standards are thus the focus at the moment.

Addressing the Data Challenge
There is an opportunity for the Big Data Value Association to support the areas of AgriFood, Forestry and Fisheries and produce a Strategic Research Agenda around this. Interoperability is a key requirement and there is a need to provide access to a Big Data stack across different sectors. Here it is possible to gather data from IoT in the field, combine this with earth observation information and also data from farmers associations for instance, satellite imagery, CAP data, GIS information, Eurostat information and weather data. The approach being promoted by the BDVA is to use Innovation Spaces (I-Spaces) that provide a safe environment for experimentation. Solutions providers can access and use this data. This can be linked to national activities to explore how value can be created from data in terms of money, jobs, etc. This can be done in partnership with trade associations and projects exploring horizontal platforms. Large-scale demonstration of the successful exploitation of data can be used to persuade farmers (usually family businesses) to adopt and trust platforms.

An issue already highlighted is the increasing amounts of data being collected from machinery which is not just used by the farmer. This presents a trust issue. Rights to access and process data need to be clarified. Farmers will only accept this increased data gathering if they are given a fair deal on the data with sufficient control over what data is collected. Security is also an issue with respect to data.

Overall the use of Large Scale Pilots, such as IoF2020 and DataBio, is considered to be important for demonstrating the benefits of platform interoperability, in particular cost efficiency and sustainability gains. The only concern is how representative these are of smaller farms where the benefits are much smaller and are less clear. At this level it is important to provide things that are easy to use. Notably history shows that more complex systems are not being adopted by smaller farms.

Challenges to overcome in the area of data are provenance and security of data. Ideally platforms and data should be open, because if platforms are closed the benefits of aggregation and analysis of data will be missed. However, there is a need to find the right balance for industry between openness and generating revenue from data.

Addressing the Digital Divide
Most farms are family businesses and there is a lack of digital skills at this level. This means that solutions need to be plug-and-play and must take into account the needs of farmers. Users thus need to be involved at the design stage. In general farmers are not concerned about technology but are concerned about sustainability and efficiency. There is a need to promote practical experience and this may be possible by supporting linkages with regional co-operatives and providing advisory services to promote digital skills. There is also a need to open APIs and develop trust in digital systems.

Providing Connectivity
Some farmers who live in more remote regions do not have access to the Internet and in many places a reliable connection is not present. It is thus important to tackle connectivity to allow digitisation across all of Europe. The uptake of technology depends on this and there is a need to provide a level playing field for all farmers regardless of size, sector and location.

4.4 Implementing the Vision

4.4.1 Objectives for next generation platforms

A key objective is to provide platforms that help farmers optimise fertiliser/pesticide/water usage and quality of their product. There is also a need to support automation of tasks. A challenge is that there are different types and sizes of farms across Europe. Platforms thus need to support diverse needs. For a small farm a smartphone or computer available on a tractor may be used, whereas on a large farm there may be a server. There are now many sensors on a farm and there is a need for interoperability

(in terms of common protocols and data formats). There is also a need for platforms for aggregating data and suitable expert systems to extract insights from the data which the farmer can act upon. It was noted that there are many concerns over data collection and usage. In the first instance data transparency is needed. At the moment farmers are not always aware of which data is being collected and for what purpose. After transparency the next key issue is clarification of rights to access and process data. Interoperability and fear of vendor lock-in is another concern. Farmers do not want to be bound to one platform and are looking for plug-and-play freedom to use other platforms.

4.4.2 Definition of supporting initiatives

It was highlighted that farmers are interested in the natural environment, resource management and strategic farm management. Thus platforms need to support these interests. Farmers are increasingly using sensors, robotics and expert systems for managing farms with the aim of optimisation of farm operations. A Large Scale Pilot deploying digital technologies is needed to demonstrate interoperability across systems at scale. A challenge, however, is that any platform development also needs to meet the needs of both large and small farms across Europe. As highlighted, platforms also need to be flexible so that farmers can easily change platforms to avoid vendor lock-in concerns.

4.4.3 An action plan

Farmers are key stakeholders and are central to the uptake of the technology. It is therefore crucial that they are involved in the roll-out of new technology. Reaching them is, however, difficult. Engagement with farmers who are managing larger farms is seen as being easier as they have a more vested interest in adopting new technologies. Smaller farms do not have the time or inclination to attend meetings. Here a different strategy is required to reach farmers on site such as via the EPI-AGRI network and via co-operatives.

Although a number of initiatives are highlighted in this report there is a lack of awareness across Europe and also at Member State level of the initiatives that are currently underway. Thus, the most pressing need in the first instance is to create a list of all projects in the area. For dissemination of information and to encourage collaboration it was advocated that there should be an annual general meeting for the sector to bring stakeholders together. DG AGRI is organising a series of events for 2017 in which they address some of the issues mentioned in this report.

To support the development of the community the Structural Funds for the European Agricultural and Rural Development Fund (EARDF) and Smart Specialisation Strategy RIS3 plans should be mobilised. Notably there is a need to engage with Member States and connect rural development programmes with EU projects.

In terms of technology there is a need for sensors and seamless connectivity in the first instance. There is also a need to provide more widespread rollout of Rural Broadband for connectivity. Following this there is a need for development of expert systems and also predication tools that farmers can use. Here care needs to be taken not to re-invent the wheel. In order to engage with farmers and developers and promote the use of new technologies there is a need for hands-on experience. The use of Open Living Labs is seen as a very appropriate way forward.

A number of bodies can aid in the digital transformation of the farming sector. Co-operatives have a key role to play in connecting at the local level. Other technology stakeholders should also be engaged to address the issues highlighted by the sector, e.g. interoperability, connectivity, data management and analysis, and security. This could involve input from the Big Data PPP, FoF PPP, 5G PPP, SPARC PPP and Cyber Security PPP.

Activities must include the relevant end users. In research and innovation projects this can be achieved via participatory innovation, which is a key principle behind operational groups and multi-actor projects. A successful deployment of digital technologies and platforms needs to be embedded in the agricultural knowledge and innovation systems of the different Member States and regions. This may involve: clear demonstration of the benefits of digital innovations, training in digital skills to be confident on the use of the new technologies, development of technologies, applications and platforms accessible to all, including small farmers.

4.5 Contributions from PPPs

As highlighted a number of PPPs such as the Big Data PPP, FoF PPP, 5G PPP, SPARC PPP and Cyber Security PPP address issues of key relevance to the farming sector. Each can contribute to building platforms via creating a consensus on cross sectorial platforms. A key need is for them to work together at a European level to support this. Here there is already a BDVA task force addressing the Agri-Food sector. Following the recently funded DataBio project, BDVA is keen to support activities via European Innovation Spaces which have the aim of providing a place to store data that can be used across borders and sectors. In the area of robotics, SPARC already has 7 projects addressing smart farming, investigating topics such as drones for gathering data. euRobotics is discussing with the EC to start a larger scale Agri-Food Lighthouse Project to promote the uptake of robotics in the sector. AIOTI could play a relevant role collaborating with the PPPs primarily through its WG06 on "smart farming and food security", but also through WG03 (standardisation) and WG04 (policies) on the horizontal issues of interoperability and standardisation, trust and security. Existing PPPs can contribute to the agri-food platform building efforts in a number of ways. Below some possibilities are highlighted.

PPP	Action Line
Big Data PPP	Apply the Innovation Spaces (I-Spaces) approach to the farming sector, for providing experimentation environments that can help to understand more clearly the benefits of big data in agriculture, thus accelerating its adoption.
Factories of the Future PPP	Agri-food industries could play a relevant role as a vertical sector in the FoF PPP. The food and drink industry, according to Eurostat, is the largest manufacturing sector in EU. Prioritising this sector in the SRIA of the FoF PPP would guarantee a positive impact in EU economy.
5G PPP	Inclusion of agriculture as a priority vertical sector for the 5G PPP would help to ensure that future connectivity requirements for farming applications are properly met (the number of IoT devices/sensors in rural areas will need to increase).
Cyber Security PPP	Inclusion of agriculture as a priority vertical sector would pose use cases that in turn would act as drivers of security technologies for improving platform trust and data security, including sharing and provenance.
SPARC PPP	In SPARC, one of the identified priority areas is agri-food, addressing various aspects from mechatronics to AI.

4.6 Contributions from the Member States

It was noted that there are different priorities in different European regions, e.g. pesticides are less of an issue in Eastern Europe. The Member States, however, can facilitate technology take-up through public investments of Structural Funds or via strategic use of other funding sources. The EARDF (European Agricultural Fund for Rural Development) implements the Common Agricultural Policy 2014-2020 (CAP) and part of this must be invested in innovation for enhancing the competitiveness of the primary sector. Such funds are managed by regional or national authorities, who design and

implement investment programmes. In regions which have identified agri-food priorities in their Smart Specialization Strategies (RIS3 plans), measures can also be supported by ERDF funds (European Regional Development Fund) implementing Public Procurement of Innovation (PPI) initiatives. At a regional level Innovation Hubs are needed. Living labs are also seen as useful for testing sensors and ideas. Accelerators/incubators at a local level also provide a mechanism where SMEs can try out sensors, hardware and ideas. Overall there is a need for linkages between national initiatives, particularly considering sustainability and rural development. A key requirement to achieve this is to engage with national ministries and regional centres.

4.7 Recommendations

Based on the previous considerations the main recommendations for "Smart Agriculture" are:

Platforms

- Clarify and improve the role of PPPs, e.g. Big Data, FoF, 5G, euROBOTICS, Cyber Security and AIOTI, in building platforms in the agri-food sector;
- Use Structural Funds, e.g. EARDF, to stimulate the involvement of Member States;
- Link innovation projects under the Rural Development Programmes with other EU initiatives.

Pilots

- Call for large-scale demonstrators and pilots to show the benefits of interoperable platforms to farmers and to showcase how data can be used (as will be done in the topics in Work Programme 2018-2019);
- Encourage that new initiatives complement existing pilots.

Ecosystems

- Involve cooperatives in the organisation of demonstration days;
- Connect with ERDF (INTERREG Europe) to engage farmers;
- Initiate advisory services dedicated to Smart Agriculture;
- Use Social Funds to train farmers.

Standardisation

- Explore and emphasize avenues towards standardisation to leverage that platforms will reach critical mass.

5 Digital Transformation of Health and Care

5.1 Introduction

In the past decades, remarkable progress has been made in terms of increased health, partly as a result of improved treatment options and access to high quality health care. These successes have not only increased longevity and health of populations, but also contributed to productivity and prosperity. Nevertheless, as a consequence of demographic changes and progress in medicine, Member States (and the world) face an increasing challenge with regard to sustainable provision of high quality health and care to citizens. Public expenditure on health care and long-term care accounted for 8.7% of GDP and about 15% of total government expenditure in the EU in 2015. The ageing population and prevalence of chronic diseases is estimated to increase public health and care budgets significantly in the next decades. The challenge we are facing in the domain of Health and Care consists of the following three main elements.

First, as a result of substantial advances in molecular biology, computer science, micro-electronics, radio physics and many other fields, health care's influence on the average individual's walk of life has significantly increased in the past half-century. Consequently, indicators of health such as (healthy) life expectancy have soared. In Europe, life expectancy currently increases with "one weekend per week". Partly due to the advances in medical technology opportunities for a growing influence of (preventive) health care on our lives continues and even accelerates. We are becoming older and are ageing more healthily than ever before. (Minimally invasive) interventions that were unimaginable even 10 years ago are now commoditized in peripheral hospitals and accessible to many. Further improvements are foreseen. However, at the same time, it is clear that we could do even better.

Avoidable mortality and morbidity remain large. An epidemiological transition from communicable diseases to non-communicable diseases is an important driver of morbidity and mortality. Hence, more fully exploiting the health potential of individuals, especially those in vulnerable socio-economic groups, remains of great importance. A shift currently takes place in healthcare from symptomatic treatment of (acute) diseases by blockbusters towards Predictive, Preventive, Personalized, Participatory and Precision medicine that will offer new opportunities for patients and the healthcare systems in Europe.

Secondly, the increased sophistication of curative care, relying on more accurate but often also more expensive new technology, has caused a strong rise in the costs of health care besides delivering the increased benefits already mentioned above. Furthermore, the rapidly ageing population that results from better public health increases the need for (labour intensive) long-term care, which also causes costs to rise significantly. The shortage of labour supply in health and caring services in Europe is estimated to reach 20 million people by 2025. Moreover, insurance systems tend to reward health care providers for performing more activities, instead of rewarding them for working more efficiently. At the same time health care consumers, with increasing demands and expectations, typically receive limited encouragement to require less care, e.g. by engaging in preventive action where possible. Several other important reasons for rising health care costs exist. Without mitigating efforts those causes will persist. As a result, without effective action health care costs may become unsustainable, when they are allowed to account for a large and increasing share of GDP.

Finally, despite the increased inclusiveness of health care, health is far from evenly distributed across the population. For years the World Health Organization (WHO) has stressed that health inequity, i.e. unfair, unjust and avoidable causes of ill health, continues to kill people on a grand scale[39]. It is obvious that health inequity exists when considered at a global scale, in a comparison between

[39] http://apps.who.int/iris/bitstream/10665/69832/1/WHO_IER_CSDH_08.1_eng.pdf

countries. However, it also applies to differences inside countries (including EU Member States), to the point where even within one city life expectancy can differ by a decade or more, depending on the neighbourhood. Socio-economic status is important in this context. According to the WHO the "social gradient", i.e. the link between income and health, is a universal phenomenon. The differences in health tend to become larger rather than smaller, because the "(health) haves" tend to benefit most from new knowledge and technological opportunities. Addressing this social gradient is key in an EU that strives to be inclusive.

Digital technologies such as Big Data, IoT, robotics, Artificial Intelligence (AI) or High Performance Computing offer new opportunities to address these challenges. They can radically transform health and care systems and delivery, enabling new approaches to prevention, personalised medicine, access to integrated health care and independent living.

Personalised medicine, enabled by vast amounts of data from various sources, marks a real paradigm shift. Throughout their own life cycle individuals become more central, not only as recipients of care, but also as more informed and empowered players in their own health and living. They can access and manage their personal health records, decide to participate in "data donation" for the greater good, and rebalance their relationship with doctors[40]. Digitisation can also help to provide technologies that improve prevention and can assist in nudging[41] towards healthy behaviour.

Digitisation opens up new frontiers for research as well, as large data sets can be analysed to push the borders of knowledge further, such as in the Human Brain Project[42]. There are new opportunities for medical equipment manufacturers, to meet demand for sophisticated technology for healthcare providers (e.g. scanners, such as those for fMRI). Mass-market demand is emerging for user-friendly mobile devices and fitness or healthy ageing solutions in the home environments.

Digitisation can thus contribute to more efficient health care delivery and to fairer and stronger health systems around the globe. One obvious example is the streamlining of the exchange of medical data between health care providers. Consequently, digitisation can support more health achieved by given budgets, i.e. health care that is increasingly value-based. Finally, digitisation can also help to increase the equity of health, e.g. by improving access to health care.

5.2 Current landscape of activities

As in the other areas described elsewhere in this report, the digital disruption as outlined above has already arrived to some extent in the domain of Health and Care. This transition is to a large extent driven by an explosion of available data. Advanced data analytics open new possibilities for personalised, predictive, preventive and participatory medicine, for efficient continued and integrated care, and for attractive wellbeing products and services, as illustrated in Figure 13 below.

On this basis new prospects are envisaged by the pharmaceutical industry. They expect to shorten the cycle of drug development (including through "in silico" trials), while designing medicines, and monitoring their impact in a much more targeted way (pharma increasingly positions itself as a "data industry"). In Europe, health is already a major industrial sector in its own right (around 10% of EU GDP) and the prospects of massive digitisation open big opportunities for further expansion.

Consequently, there is much more at stake than just transforming health data into digital formats to facilitate data storage, exchange and analysis. The changes under way towards "Health 4.0" are a

[40] Prahalad, C.K. and Krishnan, "The new age of innovation". McGrawHill, 2008.
[41] Thaler, Richard and Sunstein, Cass. "Nudge: Improving Decisions about Health, Wealth and Happiness". Yale University Press. 2008.
[42] https://www.humanbrainproject.eu/en/

significant part of the wider transformation of digitisation including developments like Industry 4.0 and the agendas for Smart Cities. Health and Care will constitute a major part of the data economy. This domain offers significant market opportunities for large and smaller European companies if one considers that the European home health and care market is estimated to be worth 57 B€ by 2017. It can be a source of new jobs in healthcare, industry and academia.

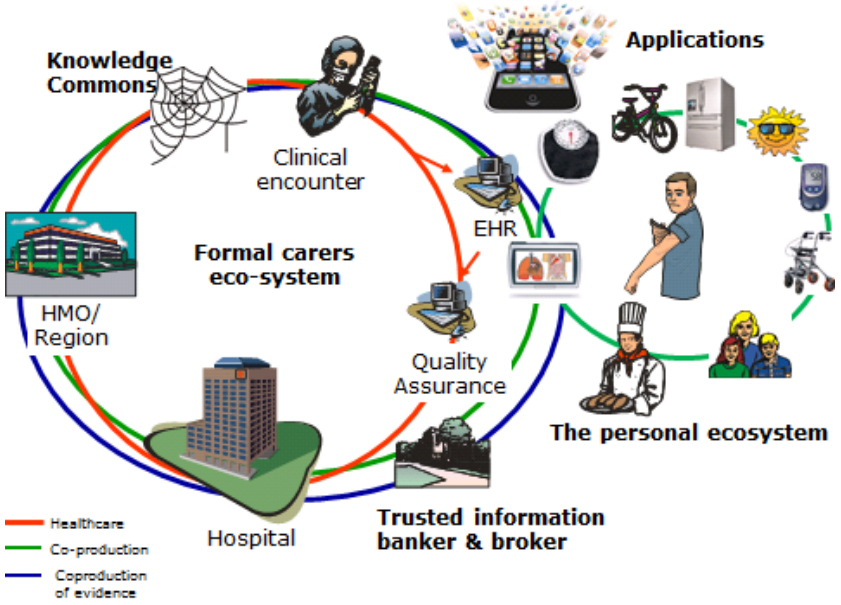

Figure 13 Integrated Personalized medicine

However, a big gap still remains between the potential of digital transformation and the realities of health and care systems today. For example, many restrictions to the movements of health data exist (even concerning the exchange of data between nearby hospitals). While these restrictions can sometimes be understood, e.g. from the point of view of privacy protection, they are not always justified and sensible. As a result of these constraints, legacy health and care systems often remain fragmented and innovate relatively slowly, despite the existing opportunities. Major impact will only become possible if the right incentives and regulatory conditions are in place, notably for data management and sharing (e.g. data integrity, confidentiality, security, interoperability, portability, liability…). See also Chapter 6 for a more general discussion of these issues.

5.2.1 European activities

Current activities of DG CNECT targeting digital innovation for health and social care include:

- Research and innovation under Horizon2020-Societal Challenge 1 (Health, Demographic Change and Wellbeing) with a budget of more than 1B€;
- Research and innovation under Horizon2020-LEIT and FP7 relating to Micro-Nano-Bio Systems (MNBS) regrouping more than 100 projects with about 500M€ EU funding;
- The Active and Assisted Living Programme with Member States;
- The EIT-KIC on healthy living and active ageing;
- The European Innovation Partnership on Active and Healthy Ageing (EIP on AHA) co-managed with DG SANTE and DG RTD[43];
- The eHealth Action Plan[44];
- The Joint Programming Initiative with Member States on More Years, Better Lives

[43] https://ec.europa.eu/eip/ageing/home_en
[44] See https://ec.europa.eu/digital-single-market/en/news/ehealth-action-plan-2012-2020-innovative-healthcare-21st-century

- The EU Silver Economy strategy[45].

The work on Micro-Nano-Bio Systems has been driven by both technology offer and user/market demand for about 15 years. The portfolio analysis showed a clear trend towards (i) higher levels of integration of building blocks/functionalities and (ii) increased portability and wearability of systems for measuring/monitoring at the point of need, thus avoiding expensive and time-consuming laboratory-based tests. Proven concepts and functional prototypes exist with the potential to create new opportunities to improve our healthcare systems, in particular personalized or precision medicine, food safety, environmental monitoring and security. Nevertheless, most of them need reliability testing and validation in real life environments.

Other EU policy and funding activities and priorities within the LEIT part of H2020 that are relevant and can benefit from further synergy include IoT, Smart Homes and mobility, Big Data, Inclusion, Industry 4.0 and Robotics, the technology platform of construction industries (DG GROW), medical devices (DG GROW), health technology assessment, cross border care and performance of health systems (DG SANTE), long term care and labour inclusion (DG EMPL), smart specialisation strategies (DG REGIO), innovation for health and ageing (DG RTD, JRC).

See Figure 14 for a schematic representation of the Horizon2020-Societal Challenge 1 initiatives.

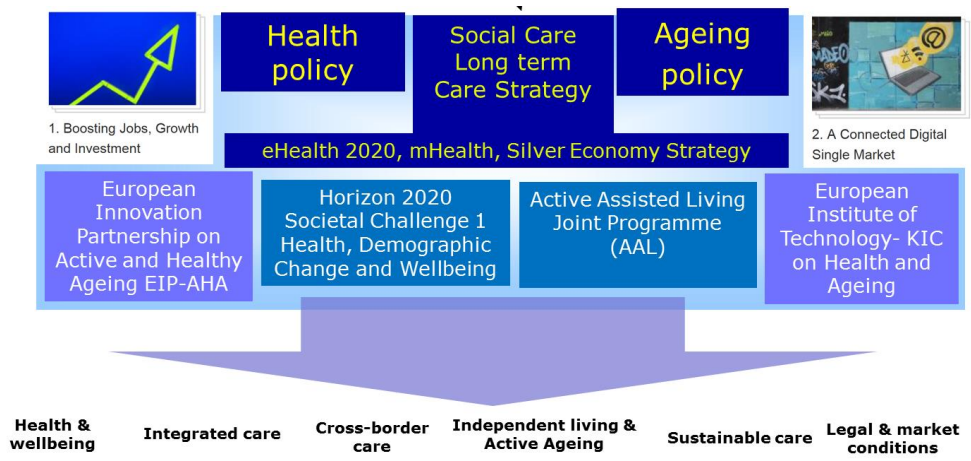

Figure 14 Examples of EU initiatives in the domain of Health and Care

Only a few examples of projects and initiatives can be given here in relation to Figure 14.

ACTIVAGE (2017-2020) is a Multi Centric Large Scale Pilot on Smart Living Environments[46]. The main objective is to build the first European IoT ecosystem across 9 deployment sites in seven European countries, reusing and scaling up underlying open and proprietary IoT platforms, technologies and standards, and integrating new interfaces needed to provide interoperability across these heterogeneous platforms, that will enable the deployment and operation at large scale of Active & Healthy Ageing IoT based solutions and services, supporting and extending the independent living of older adults in their living environments, and responding to real needs of caregivers, service providers and public authorities.

The main goal of the universAAL project is to make it easier for the ICT industry in Europe to develop and successfully deploy solutions for Ambient Assisted Living (AAL)[47]. To achieve this, the project is developing an open standardized platform/specification on which the AAL service providers

[45] https://ec.europa.eu/digital-single-market/en/news/growing-silver-economy-background-paper
[46] http://www.activageproject.eu/
[47] http://universaal.sintef9013.com/index.php/en/

can quickly and cheaply build AAL services. The project also assists the developers by providing development tools to further decrease the development costs. Moreover, UniversAAL helps to further expand the AAL market by providing an application store, called uStore, through which developers, service providers and end users can offer and obtain AAL applications.

AEGLE (2015-2018) will build an innovative ICT solution addressing the whole data value chain for health based on: cloud computing enabling dynamic resource allocation, HPC infrastructures for computational acceleration and advanced visualization techniques[48]. It thus addresses the big health landscape characterized by large volume, versatility and velocity (3Vs) which has led to the evolution of the informatics in the big biodata domain. It also takes into account that data generated in the health domain is coming from heterogeneous, multi-modal, multi-lingual, dynamic and rapidly evolving medical technologies.

The EIT launched a Knowledge and Innovation Community on Health and Aging, devoted to entrepreneurship and innovation regarding healthy living and active ageing in December 2014. Headquartered in Munich, EIT Health has co-locations in London, Paris, Heidelberg, Barcelona, Stockholm and Rotterdam and brings together nearly 100 partner organizations.

5.2.2 National and regional activities

In line with the developments outlined in this chapter's introduction the health care industry is growing in many Member States. In Germany it is already one of the largest, most successful and most diverse industrial sectors. Many Member States have taken initiatives to federate their R&D and business development in this domain. One example is the Top Sector initiative Health in the Netherlands. 93% of WHO European Member States (42 countries) have made public funding available for e-Health programmes, showing the strong commitment of governments for further development in the sector.

Health analytics and Big Data hold significant potential for health, but this potential is not being explored rapidly enough. Few policies are available to support progress in this area. Currently, only 6 countries have a national policy or strategy regulating the use of Big Data in the health sector.

80% of Member States have legislation to protect the privacy of individual health-related data in electronic health records – an increase of nearly 30% since 2009. This indicates significant progress in adopting electronic health records responsibly.

73% of WHO European Member States (33 countries) do not have an entity that is responsible for the regulatory oversight of mobile health apps for quality, safety and reliability, despite widespread use of such technology.

38% of WHO European Member States (17 countries) have yet to establish a dedicated telehealth policy or strategy.

Several regional initiatives exist as well. Some examples are the following:

Some 45,000 senior citizens currently benefit from ICT-enabled telecare services integrated with Community Care across Scotland. This has led to record improvements in the perception of safety and wellbeing by the targeted population, and saved the national health and care systems over €90 million in 5 years.

[48] http://www.aegle-uhealth.eu/en/

Northern Ireland's NHSCT (Northern Health and Social Care Trust) launched an innovative ICT-enabled integrated medicines' optimisation programme (MOIC) covering over 400.000 people. The innovative solution was designed to reduce adverse incidents with medicines especially amongst the ageing population. The programme resulted in 10% fall of hospital admissions due to adverse drug events and savings of £60 million in terms of bed days. It resulted in efficiencies of £48 per month per patient. Thanks to the EIP on AHA this programme is now being replicated across Northern Ireland and 3 regions: Lund (Sweden), Tallaght (Southern Ireland) and Central Norway.

The Andalusian strategy on Active Ageing emerged from the EIP on AHA targets and focuses on all 65+ citizens in the region aiming to improve their social welfare by integrating policies on living safely, healthy living, participation, contribution and innovation, and lifelong learning. The initiative has contributed to the creation of 322 non-profit organisations and over 2600 jobs.

The region of Southern Denmark develops new solutions in health by closer integration of hospitals, universities and businesses. The regional smart specialisation strategy inspired by the EIP on AHA has identified health and innovation as one of the priorities, and is linked to a comprehensive growth model. This has resulted in 776 additional jobs in the period 2012-2013, as well as a positive impact on the turnover of companies estimated to be in the region of Dkr 3.7 billion.

Within the EIP-AHA, 74 regions and initiatives have been awarded status of Innovation Reference Sites based on their local initiatives in health and care innovation.[49]

Finally, several large industrial companies have embraced the domain of health and care as (one of) their core market(s). For instance, Philips has developed a platform dedicated to health care (HealthSuite) and Siemens has also invested substantially in the strengthening of its position as a provider of medical technology.

5.2.3 International activities

In the US many complain that while costs for health care have increased sharply, the health care system is actually delivering less (results) for more (costs). Digitisation is embraced as an opportunity to change this and initiatives for eHealth can be found across the country, such as the Massachusetts Digital Health Cluster (which includes world class universities in the Boston area and 13 of the top-100 Health Technology firms in the country).

5.3 Visions for the future

5.3.1 Needs and expectations

Whilst the many current EU and national/regional initiatives are important and complementary, there is a lack of an overarching strategy as to how some of these initiatives can interact and create stronger synergies amongst themselves. A coherent vision will also require a new model for linking up different EU initiatives, with clear industry commitments as well as support from Member States and Regional strategies.

Accordingly, stakeholders in this area support the overall WG2 recommendation for experimentation and bottom-up integration and for interoperability and connectivity that was already outlined in general terms in Chapter 2. In addition, to specifically use digitisation to address the challenges in Health and Care outlined in Section 5.1, the following needs were identified.

[49] See https://ec.europa.eu/eip/ageing/reference-sites_en

To achieve patient-centric healthcare and improve efficiency in prevention, diagnosis and care at the point of need, advanced digital technologies such as robotics, cyber-physical systems, micro-electronics, photonics and artificial intelligence, combined with new discoveries in life sciences, need to be fully integrated, tested and demonstrated in real life. Furthermore, the emergence of open platforms/open environments and big data will enable the provision of innovative health and care solutions in homes, health centres and hospitals. Indeed, the improvements offered by the massive deployment of digital data technologies in the management, aggregation, analysis and contextualisation of medical data (including human genotype and phenotype data) and the possibility to build bio-medical models with virtual reality tools for diagnosis, therapy planning or education, is unprecedented. This in turn will trigger innovation, new business models and opportunities for many SMEs in the healthcare/e-health sector.

One example to illustrate the new possibilities but also the complexity of the new medical options are smart wearable or implantable devices, for providing therapeutic treatments and monitoring their effect. For example, in cardiac rhythm management or neuromodulation, beyond existing products, integrated solutions are needed, which can sense various electrophysiological stimuli, biomarkers or other health indicators (dehydration, stress, BMI, muscle fatigue, balance, etc.) as well as the therapeutic products themselves. Integrated signal processing algorithms will be needed to monitor and alert for significant physiological changes as a means of monitoring disease, as well as providing feedback on the efficacy of a treatment programme. These systems will communicate with relevant electronic medical record (EMR) systems and prompt action by healthcare professionals as applicable based on sophisticated algorithms designed to identify patterns or ranges of concern (i.e. using data analysis and IT communication tools to inform unambiguously clinical decision protocols). These smart wearable and implantable systems will therefore require multi-Key Enabling Technologies (KET) capabilities, involving integration of micro- and nanoelectronics, microsystems, photonics, likely including integrated circuits for miniaturisation and power efficiency, energy harvesting and storage technology, advanced sensors, embedded software for signal processing, safe and secure RFID and wireless connectivity, data encryption, and communication to EMR system. They will also require biocompatible packaging (advanced materials) and encapsulation, and need to combine precision engineering and electronic/photonic assembly.

Trends such as these translate to an urgent need to support cross-disciplinary research and the development and clinical validation of lab-proven medtech technologies and prototypes in several healthcare applications. Technologists and clinicians/healthcare practitioners will need to closely cooperate to deliver solutions at the point of need whether at the hospital (e.g. to support logistics, surgery and image guided intervention) or at the primary care and in remote settings (e.g. companion diagnostics, health monitoring, e-health).

Furthermore, in the domain of Health and Care it is expected to be more difficult to go beyond national platforms than in other areas, as each country has its own specific regulations and usually stringent constraints concerning the use of medical data. In this area in particular issues concerning ethics and privacy need to be carefully taken into account, preferably at an international level. Furthermore it is expected that within the health domain several platforms and ecosystems will develop and grow around specific aspects of the health care value chain, e.g. for imaging, telemonitoring, teleconsultation and genomics.

5.3.2 Bridging the gaps and addressing the issues

In December 2015 at the 4th Conference of Partners of the European Innovation Partnership on Active and Healthy Ageing (EIP on AHA), European Commissioner Günther Oettinger (Digital Economy and Society) outlined how digital innovation, enabled by a functioning Digital Single

Market, can transform demographic change and the growing number of chronic health conditions into an opportunity for Europe's economy and society[50]. Commissioner Oettinger invited all stakeholders to work together with the European Commission in the development of a blueprint. A "shared vision" on how innovation enabled by a Digital Single Market can transform Europe's ageing society in the 21st Century and contribute to the European Silver Economy.

Recognising that a shared vision is essential to mobilise investment and guarantee the commitment of all actors to this digital transformation of health and care for the ageing society, a number of industrial players, regional authorities, professional organisations and multistakeholder platforms such as the EIP on AHA have accepted the invitation from Commissioner Oettinger and have developed a first version of this blueprint[51]. The Blueprint was handed over to Commissioner Oettinger during the 2016 European Innovation Summit on Active and Healthy Ageing in Brussels on 7th December 2016. This includes a commitment to spend more than 4B€ in procurement of innovation solutions for health and ageing from the 72 Reference Sites of the EIP-AHA and to demonstrate the returns of investment from innovation by providing new services to more than 4 million citizens by 2018.

The Blueprint is a means to "*connect the dots*" in a very complex landscape on digital health and social care and active and healthy ageing. The Blueprint can create an overarching "political vision" that is aligned with the major priorities of the Juncker Commission (notably on promoting Economic Growth and Jobs, and realising the Digital Single Market). This vision is a necessary pre-requisite to set a clear political agenda across the European Union and harness resources to act, particularly as results are not likely to come overnight and fall within short-term political cycles at regional, national and European levels. The Blueprint will serve as a mechanism to raise awareness about the potential of better care coordination amongst the large community of relevant stakeholders, including users. The Blueprint will also rely on some of the important methodology tools currently available (especially those originated by the EIP-AHA partners) to assess their readiness to integrate services supported by digital services.

The DEI initiative can build on this and contribute to taking this vision forward in order to overcome innovation barriers and to reach scale and critical mass in Digital Transformation of Health and Care in Europe for the benefit of citizens, for improved sustainability of health and care systems and in order to create new markets and growth for industry in digitally enabled health and care. Against this background, potential areas for digitisation in health care that have been discussed by the WG are:

- Trusted Big Data solutions and cybersecurity for health and care (see chapter 6 for more details);
- Deployment of robotics, AI and autonomous systems for health care;
- Enabling cross-cutting technologies, e.g. micro-nano-bio systems, bio-photonics, wearables, IoT, to address healthcare at the point of need (see Chapter 7 for more details), especially in remote and low resources settings.

Regarding robotics, AI and autonomous systems, the primary objectives are to further develop, integrate and demonstrate solutions for:

- Providing better delivery of care, diagnosis and treatment, lower risk and improved information and monitoring that delivers the right treatment to the right person at the right time in a minimally invasive and focused way (e.g. endoscopic wireless capsules with sensing, vision and biopsy capabilities, AI-assisted diagnosis).
- Improving the operation of the health systems (e.g. by lowering costs, delivering higher quality of service with less variation across Europe, better utilisation of resources, more efficient movement of goods and services, and better knowledge to support decision making) through robots and autonomous intelligent systems that support hospital personnel (in addition to conventional logistics).

[50] http://ec.europa.eu/research/innovation-union/pdf/active-healthy-ageing/oettinger_cop_2015.pdf
[51] http://ec.europa.eu/newsroom/document.cfm?doc_id=40787

- Improving the quality of working life/environment for hospital staff: better safety, lower risk, fewer accidents at work, better support, allowing them to deliver a better quality of care e.g. for doctors (e.g. the robot as a dedicated tool in psychiatry), nurses (e.g. helping lifting patients) and medical assistants (robotic, friendly presence in corridor for ill kids).
- Addressing health care's current and future challenges (access, costs, demands, quality) by developing innovative solutions, technologies and processes. Mobilising interdisciplinary efforts and all relevant stakeholders through the whole value chain. Providing Europe with the world leading health system and supply industry. Improve the quality of life for European citizens (ex: social robots supporting elderly at home or at the point of need).

Initiatives should aim at demonstrating how health systems and robotics empowered with artificial intelligence capabilities can be integrated to provide more robust, highly autonomous, personalised and collaborative quality and cost-efficient healthcare. The provision of pilots, demonstrators, platforms and standards is essential for integration. Projects will target health systems improvements, physical logistics, personalised treatment, data privacy and analysis, infrastructure, certification and validation. Critical to success will be the engagement of centres of excellence, innovation hubs and pilot sites. Projects must attract private and national investment to reach the long term goals; this cannot be achieved by funding from the EU alone.

Regarding enabling cross-cutting technologies, opportunities exist with regard to better understanding of the origin and the expression of diseases. When supported by technologies that are capable of detecting pre-disposition to disease conditions or earliest possible signatures of emerging disease, the possibility of providing immediate, specific and highly targeted intervention will revolutionize the healthcare landscape. Today, several well performing prototype systems and solutions have been developed, with great potential to meet these challenges in the short to mid-term. They are at the level of full integration and/or at lab testing level (e.g. new diagnostic devices, smart implants, lab-on-chip for cancer detection, drug delivery and wearable monitoring systems). These smart integrated systems, which are often highly connected and often operate outside traditional healthcare settings, result from research efforts at the interface of key enabling technologies (e.g. micro-nano electronics, photonics, nanotechnologies and biotechnologies) and are able to intervene and monitor phenomena from macro to micro or nano scale (e.g. from organ/tissue to cells, molecules, genes). They have the potential to be used by professionals and consumers and disrupt existing solutions. However, the penetration to the market is slow and many advanced prototypes remain at the laboratory level or fail in real subjects/samples. Current solutions at the level of proof-of-concept have to be validated in traditional settings before both the consumers and regulators feel confident enough to enable the widespread adoption.

Hence, the main objective of initiatives related to the adoption of cross-cutting technologies is to accelerate the translation of lab-proven bio electronics, photonic and nano-medicine systems to the healthcare market by providing technology and product developers with a one-stop-shop access to a full range of required expertise, capabilities and infrastructure for:

- Validation and testing in a real application environments;
- Pre-clinical and clinical testing, prototyping;
- Pilot manufacturing (in appropriate volume for clinical testing);
- Health technology assessment, business development, market intelligence, access to finance;
- Regulation, certification, ethics and data protection and reimbursement issues.

Projects in this area must play a strong role in joining up the full ecosystem, in particular the medtech device supply chain (including the ESTHER initiative), public authorities including HTA, social security and end-users, including the eHealth network, the eHealth stakeholders group and the EIP on AHA.

5.3.3 Priorities

WG2 recommended the following priorities:

Develop a world-leading health and care research and innovation infrastructure
This could build on the European Cloud Initiative and European Open Science Cloud, by providing access to large scale datasets, longitudinal data and a High Performance Computing infrastructure with simulation and advanced computer models required for development of predictive and personalised medicine. Existing efforts from industry and academia should be federated to realize this, with a strong research focus while also seeking business exploitation. Ongoing and planned research activities supported by H2020 in the area of technologies and health should be linked to this cloud initiative.

The further development of advanced testing infrastructures should be stimulated, where new ideas for digitally enabled products and services for improved health and care can be tried in realistic environments with end-users, in order to validate the benefits and societal impacts. This should include hospitals, health and care settings and smart living environments and homes. This can build on a number of ICT PPPs, smart and age-friendly cities, European and national/regional living labs, 5G testbeds, in order to stimulate innovative new products and services for improved health and care.

Support for large scale market creation of digitally-enabled products and services for health and care
A European priority roadmap for scaling up deployment should be developed, with a timeline for commitments for large scale deployment of innovative products and services, with relevant demand and supply side stakeholders in health and care, including some of those active in the EIP-AHA, following on the process initiated with the Blueprint for digital transformation of health and care.

This could be supported by large-scale pilots for market testing of digital solutions in priority areas of health and care, supported by Horizon 2020. This can in the short time frame build on the newly launched H2020 LEIT-SC1 large scale IoT pilot on age-friendly and smart living environments, as well as big data pilots for health applications currently funded under H2020. mHealth pilots could be launched as well, further to the recently adopted privacy code of conduct on mHealth apps, and ongoing work on medical validity of data from mHealth apps. All these pilots should be linked to policy priorities, e.g. the data generated would be dealt with according to the recommended principles and would feed the health cloud initiative. These initiatives should also provide a strong socio-economic evidence base to monitor and feed the future policy in the domain.

Moreover, significant support from the European Structural and Investment Funds is already devoted to health and care, including its digital aspects. Further mapping and support should be developed in order to have a better view on what has been done so far and what more can be done in the future, e.g. through regional innovation "twinning schemes".

Improving enabling conditions
Mobile devices, modern care institutions, smart homes and living environments – enabled by sensors and connected devices, in a context of IoT and cloud computing – generate an enormous amount of exogenous health and lifestyle data. These technologies, and the data they generate, are at the core of connected hospitals, monitoring of patients while they are at a distance and on the move, independent living solutions and age-friendly housing. However, rolling out innovative, technology-enabled, approaches is challenging as a result of fragmented market forces, national legislations and uncertainty linked to issues such as rights to access and process data, liability, re-use and sharing. Indeed, today there are many restrictions to health data access and sharing, as well as uncertainty about liability for adverse outcomes further to decisions taken, or not taken, based on that data.

Big Data in healthcare is overwhelming because of its volume and the diversity of data types and the speed at which it must be managed. Therefore, in addition to the issue of access to data it is important to adequately address issues of data storage and processing. The criteria include availability, continuity, ease of use, scalability, ability to manipulate at different levels of granularity, privacy and security enablement, and quality assurance. Real-time big data analytics is a key requirement in healthcare as it can significantly improve understanding of disease management and give new insights in clinical effects of medical procedures and medicines. The lag between data collection and processing has to be addressed. The European Open Science Cloud, Free Flow of Data Initiative and High Performance Computing support these aspects of data management.

Individuals should be able to access, use and share their data. The aim is to allow them to have greater control over data about their health and lives, including the possibility to donate or trade with the data, also across borders. Portability of health and lifestyle data collected in smart homes or other environments would enable innovative services for individuals and new business models. It would also facilitate public health services and health-related research. Not all such data are per se personal data, notably data generated by home appliances, by the lighting system, etc. Identifiers linking the data to the person living in a smart home or other environment can be taken away and re-identification, e.g. through recognition of specific usage patterns of home appliances that identify an individual person, can be made impossible.

Following up on the Data Communication (January 2017) and consultation[52], there should be a further analysis of the restrictions and uncertainties concerning health-relevant data, in view of providing legal guidance and addressing unjustified barriers. This analysis could also address issues of liability for harm caused by data captured by devices and sensors, and possibly go beyond machine-generated data. Guidance on health data may range from a fresh legal orientation on health data (e.g. in light of possible legislation on free flow of data) to interpretation of existing legislation (General Data Protection Regulation, medical devices, clinical trials...). Such legal guidance would aim at tackling unjustified restrictions and fragmentation, while promoting certain principles: minimal localisation restrictions, Free Flow of Data, portability, individuals must be the owners of their health data, etc.

Specific guidance on data donorship should be provided to identify major sources of health and care related data and help mobilise systemic donorship and conditions for their use, accompanied by reference implementations.

Moreover, work should continue on interoperability and standards for eHealth and smart living solutions, as foreseen in the DEI initiative.

Relevant European legislation and policy includes the cross-border care Directive (notably activities on interoperability of electronic health records and electronic prescriptions, supported by the CEF), European Reference Networks for rare diseases, pharmacovigilance system, etc.

5.4 Implementing the vision

In order to fulfil the proposed vision, there is a need for an ambitious large scale European initiative on “Health 4.0” which would address the priorities listed above and could inform the development of future national and European research and innovation priorities beyond H2020, from basic and applied research, to innovation and large scale deployment. Research efforts should aim at faster translation into interoperable digital solutions and services with a high impact. See Figure 15 for a schematic representation.

[52] https://ec.europa.eu/digital-single-market/en/policies/building-european-data-economy

Figure 15 Health 4.0 components

This could build on existing relevant EU initiatives such as the "Active and Assisted Living joint Programme", the Joint programming initiative "More Years Better Lives" and the EIT on Health and Ageing as well as a number of industry PPPs and Joint Technology Initiatives.

5.4.1 Objectives for the next generation platforms

Personalised tools and services for tailored management of health, care and wellbeing will aim at early prediction and prevention of diseases, as well as avoidance of unnecessary institutionalisation. They will also promote prolonged independent living for an ageing population. Advancements in understanding disease and behaviours will allow discovery of efficient biomedical products, a safer medicine and a better quality of life in all environments (home, work, healthcare institutions). The goal is also to make Europe a global market leader in transformative digital solutions for health and care by supporting demand and supply side stakeholders in piloting, procuring and testing promising ideas in realistic environments across Europe. The aim is to provide scalable solutions ready for large scale market uptake, including socio-economic evidence of impacts.

Thus, as in the other areas, much attention should be given to connectivity and interoperability of platforms in this domain. Opportunities to deploy platforms that were not specifically designed for the health sector should also be considered. Co-creation of an ecosystem of digital propositions and integral solutions on a cloud based platform that is open, secure, collaborative should be emphasized.

5.4.2 Definition of supporting initiatives

A set of supporting activities are already under way within the DSM, Blueprint, the EIP-AHA and through the eHealth Action plan, but should be further enhanced with support from relevant PPPs, JTIs, EIT KIC Health, AAL Joint Programme, and others.

ECSEL's 2017 Multi Annual Strategic Research and Innovation Agenda (MASRIA) provides an entry point for creating an open digital health platform ecosystem, enabling cost effective development and validation of healthcare appliances and applications. The platform should provide an open environment, enabling a wide range of collaboration opportunities and easy market access for new applications. The platform is supposed to be open for new appliances and applications by providing APIs (Application Programming Interfaces), while taking safety, security and privacy into account.

5.4.3 An action plan

The acceleration of the introduction of Robotics, IoT, Big Data, AI and cross-KETs as cost-effective technologies into the healthcare system large pilot projects should be established, in order to demonstrate added value to for instance medical diagnostics, surgical procedures, clinical services, prosthetics, rehabilitative care, smart hospitals, healthy living and active ageing or age-friendly housing. Regulatory and legislative aspects of the use of the platforms should receive specific attention, especially considering privacy regulations. The action plan should reflect the following:

- Build on the Blueprint for digital transformation of health and care in Europe, which has already established an outline action plan for reaching first targets by 2018;
- Launch a set of large scale pilots to address key areas of interest as outlined in this chapter, building on the Horizon 2020 Work Programme 2018-2020;
- Build a platform for all relevant stakeholders to define a strategic research and innovation agenda, facilitate networking, define new business models, specify standards and provide training;
- Provide specific support to SMEs, through information and guidance, clustering and benchmarking.

5.5 Contributions from PPPs

The stakeholders in WG2 consider PPPs such as the ones on Big Data, Robotics, 5G, High-Performance Computing, cyber security an important asset in Europe to advance collaboration and ensure quick market uptake. Large projects such as those mentioned in Section 5.2.1 can help towards adoption of new technology in the Health and Care domain, in particular by scaling up what is working already and by testing what is new.

5.6 Contributions from Member States

Member States can contribute by engaging more actively in the assessments of opportunities for federation, based on successful (national) bottom-up platforms. The 74 Reference Sites from the EIP-AHA already represent leading regions within Member States that are willing to spearhead upscaling of innovative solutions for digital transformation of health and care.

Member States are also invited to engage further through mobilisation of relevant national initiatives which can make a strong contribution to taking this vision forward. This could include testbeds and innovation centres, providing access to health and care data resources and by being an active partner in the implementation of the joint vision.

In this domain Member States also have an important role to play by addressing and harmonizing regulatory, legal and ethical aspects of digitisation in the domain of Health and Care.

5.7 Recommendations

Based on the previous considerations the main recommendations for “Digital Transformation of Health and Care” are as follows.

Platforms

- Build a world-leading research and innovation infrastructure for health and care;
- Build on the Blueprint for digital transformation of Health and Care;
- Bring together relevant stakeholders at the level of Member States and EU to define a strategic research and innovation agenda for areas where convergence does not exist yet;

- Where key areas for new initiatives have already been identified, such as in the H2020 Work programme 2018-2019, stimulate implementation that builds on previous work and existing platforms;
- Emphasize the development of platforms that are open and explore opportunities to integrate with platforms that were developed for other domains.

Pilots

- Launch a set of large scale pilots;
- Enhance the role of PPPs, JTIs, EIT KIC Health, AAL Joint Programme and other large initiatives to federate platforms and create critical mass.

Ecosystems

- Define new business models that exploit the advantages of digitisation, especially bearing in mind opportunities for personalisation and prevention;
- Invest in the involvement of SMEs, through information, guidance and benchmarking;
- Address regulatory hurdles that prevent proliferation of solutions.

Standardisation

- Enhance current work on standardisation for eHealth and smart living.

6 Industrial Data Platforms

6.1 Introduction

Industrial Data Platforms (IDPs) are virtual environments facilitating the exchange and connection of data between different companies and organisations within a secure business ecosystem, through a shared reference architecture and common governance rules. Such platforms are of three main types:

- Community-led sector-specific (vertical);
- Community-led cross-sector (horizontal);
- Proprietary with open interfaces.

IDPs may take the form of open, multi-company-led environments that meet the requirements of a wide ecosystem of users from different industrial sectors. They can, however, also take the form of single company-led initiatives where an individual company or organisation establishes its own platform and opens it to others for commercial purposes. Common governance rules, in particular, could technically implement an open, generally recognized process and a standardised data ecosystem for the transfer of property and possession on data assets.

IDPs will be crucial for the digitisation of industrial production[53] because they could provide the technical infrastructure that allows data to be shared with the players that make best use of them. This should happen while respecting the rights and interests of the party that has invested into the collection of the data.

In the context of the DEI, the aim is to support the development of competitive data platforms and the availability of a world class data infrastructure in Europe. The data platforms should be open to new data actors interested in sharing data. Piloting actions would aim to support the development of virtual environments facilitating IDPs. Key aspects include legal and technical conditions to help businesses to make safe and secure exchange, transfer, access and reuse of data. Stakeholders consider public intervention critical to support first production and deployment of IDP technology.

6.2 Current landscape of activities

6.2.1 European activities

Several interesting examples of Industrial Data Platforms were noted during the meetings of WG2. Two concrete functional models, where innovation can take place on top of data, are the Industrial Data Space and MindSphere.

The Industrial Data Space (IDS) initiative[54] was launched in Germany in 2014 by representatives from business, politics and research. The IDS recognizes data as:

- The result of a process;
- An enabler of processes;
- An enabler of products and services;
- As a product.

The IDS aims to develop and pilot test a reference architecture model for a secure virtual data space using standards and common governance models. It thereby provides a basis for creating and using

[53] See Final Report on European Data Market, SMART 2013/0063, http://ec.europa.eu/newsroom/dae/document.cfm?doc_id=44400

[54] Outlined in the White Paper: Industrial *Data Space; digital sovereignty over data* https://www.fraunhofer.de/content/dam/zv/en/fields-of-research/industrial-data-space/whitepaper-industrial-data-space-eng.pdf

smart services and innovative business processes while at the same time ensuring digital sovereignty of the digital data owners. More specifically the IDS is based on the following principles:

- An open approach that is neutral and user driven;
- A decentralised approach, based on a distributed architecture;
- Trust between the users, based on the use of certified software;
- Data sovereignty, because the data owner always determines the terms and conditions of the data provided;
- Secure data exchange, across the entire data supply chain;
- Data governance, based on rules that are derived from the requirements of the users;
- A network of platforms and services;
- Economies of scale and networking effects.

Access to data owned by another party is based on bilateral agreements, which are based on templates developed by the IDS. Crucially, the party that owns the data does not surrender control over it when it engages with the IDS. The initiative has since evolved into two strands, a research project and non-profit user association with membership in Germany and several other European countries.

An example from the private sector is MindSphere, an open industrial cloud platform developed by Siemens and SAP. OEMs and application developers can access the platform via open interfaces and use it for their own services and analyses – for instance, for the online monitoring of globally distributed machine tools, industrial robots, or industrial equipment such as compressors and pumps. Using MindSphere, customers are also able to create digital models of their plants with real data from the production process. This allows them to synchronize the model and the plant, to carry out simulations and optimize business processes. In the future, users will also be able to develop their own web services with MindSphere as a basis for digital services such as predictive maintenance, energy data management, or resource optimization.

Concerning possibilities for funding, Innovation Spaces (i-Spaces) is one of the four main implementation mechanisms of the Big Data Value PPP under H2020. i-Spaces are cross-organisational and cross-sector environments that allow challenges to be addressed in an interdisciplinary way. i-Spaces will serve as a hub for other research and innovation activities. They bring innovation providers, such as data innovators, together with users and allow the two to experiment in a secure environment. i-Spaces will be incubators for new business models and skills bringing together data owners and data users.

The BDV PPP is also working with Lighthouse projects, large-scale projects serving as incubators for whole data-driven ecosystems. These will help raise awareness about the opportunities offered by Big Data and the value of data-driven applications for different sectors.

The FoF PPP is also active in this area, e.g. through its work on data management for increased production performance and linking products and processes to innovative services.

6.2.2 National and regional activities

Many Member States also have Big Data initiatives, including Germany (Smart Data Forum), Denmark, the Netherlands, Spain and UK. A European Network of National Big Data Centres of Excellence has also been launched to facilitate cooperation in research and education of data workers. In many countries (consortia of) universities recently launched new research and education programmes devoted to Big Data, e.g. the newly formed Jheronimus Academy of Data Science in the Netherlands (a collaboration of Tilburg University and Eindhoven University of Technology) which also has industrial sponsors, such as Philips.

6.3 Visions for the future

6.3.1 Needs and expectations

Sharing data can create significant technical challenges, e.g. related to standardisation and interoperability, but may also trigger issues in other areas, in particular the legal domain. Disputes can easily arise about right to access and process data. With a factory machine, for example, data may be collected and shared for various purposes (e.g. for preventive maintenance) between several parties: the owner of the machine, the manufacturer, the lessor, etc. Various types of law are relevant here, e.g. IP law including database law and design law, privacy law and competition law. Clarifying the relevant legal regimes can be complicated and time consuming, especially in an international context. The European Commission has launched a public discussion on these issues within its initiative 'Building a European data economy', released in January, 2017[55]. The communication addresses:

- The free flow of data
- Data access and data transfer
- Liability
- Portability, interoperability and standards
- Experimentation and testing

It should be noted that IDPs can provide technical solutions that tackle some of the legal issues, by way of defining rights of participating actors over the data exchanged over the platform.

Experience with automated milk machines in the Netherlands provides a useful example. In order to maintain the machines the manufacturer collected detailed data, including the milk yields of each cow. They realised that this data constituted a valuable resource: one potential market was with local veterinarians. The farmers, as owners of the cows, believed that they were the real data originators and also had a key interest in how the data was used. The two parties agreed to create a platform to share the data which has proved beneficial for both. The farmers have better information on yields. The manufacturer has created a foundation to collect and store the data, and has been able to capitalise on export opportunities to large-scale farms in China. The message: platforms prompt transparent discussions on trust.

6.3.2 Bridging the gap and addressing the issues

A fair legal regime has to accommodate the interests of those who originate the data and those who wish to use it. It may be necessary to develop a series of legal templates, to ensure that the interests of the various parties are protected and no party will claim exclusive rights (which in turn could lead to rents). Such model contracts would be made readily available by an IDP and be applied to data exchange scenarios performed on the given platform. IDS has also created templates as a foundation for bilateral agreements.

It was noted that under the IDS framework data originators keep control of access to and processing of data. There are framework contracts between companies that exchange data but at the moment these are not enforced by technology.

From the technology perspective, it was noted that Europe should be more aggressive in demonstrating use cases for Blockchain. This new technology, which is used in several Internet currencies (notably Bitcoin), will be very disruptive. One advantage is that, by avoiding the need for a central point of coordination, Blockchain offers a more transparent market in all forms of contracts. For example, in telecoms, there would no longer be a need for a centralised database in order to

[55] https://ec.europa.eu/digital-single-market/en/news/communication-building-european-data-economy

handle number portability between service providers. In the US more than US$1bn has already been invested in Blockchain-related startups, whereas Europe has invested very little.

6.3.3 Priorities

Lack of skills is the main barrier to the proliferation of Big Data approaches. Without dedicated action the shortage of good data scientists will only increase. Joint action is needed to educate many more people with the appropriate skills. A Coordination Support Action 'BDVe', which started in January 2017, supports the establishment of national centres of excellence, in order to exchange knowledge on universities' data science programmes and to align curricula and training programmes to industry needs.

The possibility of certification of parties who are involved in IDPs should be investigated further. When parties are certified to have a certain level of maturity with regard to the exchange of data, organising data exchange will be easier. In that case it will also be less complicated to organise multilateral data exchange.

The IDP landscape is complex. Many use cases and experiments are needed to fully understand it. The EU and Member States should collaborate to create an environment that encourages those experiments and contains instruments for federation.

Rules would need to be clarified at EU level regarding minimum standards on security, confidentiality, access to data by the worker, legitimate processing of data and international transfer of worker-related data (specifically: outside the EU).

6.4 Implementing the vision

A key requirement is to ensure that the benefits of the data economy reach SMEs in all sectors, including traditional sectors such as agriculture. Initiatives such as the i-Spaces and Lighthouses will be important here. The Lighthouses aim towards replicable solutions across various communities and settings, through deployment based on verticals and utilisation of national initiatives.

There is no value in data without context. The notion of 'digital twin' (i.e. ultra-realistic computer modelling) is increasingly used in various sectors and requires very rich data, standardised models and semantic models.

Reaching a sufficient scale will be crucial to ensure appeal of IDPs, as for any multi-sided market.

There are two potential approaches in exploiting Big Data which may be summarised as: a 'fishing' approach, where users look for correlations in/from unstructured data in the hope of extracting value; and a 'targeted data collection on everything' approach, where huge amounts of data are collected and systematically analysed and the results presented through dashboards. The former is seldom a sensible approach for a business as they need to know what they wish to achieve, and therefore which datasets to analyse and to integrate. Preventive maintenance and many other examples rely on the second, very structured and controlled approach. As storage becomes cheaper, it is more practical to store all possible data, not just the most relevant bits. Thus, we need to think in terms of a hybrid 'discovery' approach: store everything and then look for the correlations later. One potential use will be in machine learning, where the massive stores of data will be a very valuable resource.

6.5 Contributions from PPPs

The PPPs will be key stakeholders in this area. BDV PPP, HPC PPP, FoF and SPIRE all have flagship projects that could form the basis of cross-sectoral IDP initiatives.

Most platforms will be vertical to some extent, addressing the needs of specific sectors. The options to organise this are essentially two-fold: the foundation/association approach (as with IDS); and the provider ecosystem approach (as with Siemens MindSphere and automotive platforms).

6.6 Contributions from Member States

Cooperation with Member States is essential to reinforce the role of PPPs as coordinators of EU-wide R&I effort, national activities, and industrial strategies by focusing on key technologies and their integration through large-scale federating projects. It is also important to address a significant part of the PPPs and national investments in this domain on cross-sectoral and integrated digital platforms and ecosystems including reference implementation and experimentation environments in real setting.

However, few examples of IDPs from the Member States are visible at present. This is clearly an area where more communication and a more thorough mapping is needed to identify opportunities for leverage and federation. That type of communication will also spread the IDP-concept within those Member States, where it is still not widely known. It could be useful to examine the possible role of Digital Innovation Hubs in the development and take up of IDPs.

6.7 Recommendations

Based on the previous considerations the main recommendations for "Industrial Data Platforms" are:

Platforms

- Between Member States and EU, create an environment for efficient experimentation;
- Stimulate development of open platforms that operate on the basis of FRAND rules;
- Explore opportunities to federate national/regional initiatives;
- Encourage H2020 applicants to link to existing national and regional initiatives.

Pilots

- Strengthen the role of PPPs to not only build, but also validate IDPs;
- Stimulate the growth of existing IDPs, e.g. by contributing public sector data, making available model contracts and publishing good practices.

Ecosystems

- Stimulate platforms that address several sectors, to leverage that they will achieve critical mass;
- Use flagship projects from the PPPs as a source of cross-sectoral IDPs with critical mass.
- Introduce further regulation concerning access and processing of data, where it is needed to remove hurdles to proliferation of promising IDPs.

Standardisation

- Harmonise data architectures and data models, benefitting as much as possible from ongoing standardization initiatives.

7 Internet of Things

7.1 Introduction

In the IoT sector a complete zoo of platforms exists and the domain is dominated by the US. Although there are 3BEuros of investment in national IoT strategies, national initiatives addressing platform building will not be able to compete at a global level as there is insufficient "home" user base. Many startups are created, but they are prone to takeover when they mature. In order to compete there is a pressing need for Europe to co-ordinate activities to create critical mass and avoid fragmentation and silos. However, in addition to addressing interoperability between platforms there is also a need for clear approaches that respect privacy and security.

Thus, in this area maybe even more than in the others, the EU needs to supply long term support with a clear mechanism and objectives to support European Platform building. It also has a key role to play in promoting fair rules, standardisation and guidance on data governance and security. The aim should be to promote openness to avoid lock-in, prevent the dominant position of one player while monitoring global competition, and provide supporting standards, regulation and policy.

In order to tackle fragmentation the implementation of platforms across Member States should be coherent, addressing key sectors and societal challenges. To encourage uptake there is a need for pilots at both lab-scale and in real environments, particularly at the regional scale. Key aims should be to support test beds and trials that demonstrate standards, data sharing, federation and interoperability. It is important that pilots are replicated in other regions to promote Best Practice and accommodate for the "Penguin Effect"[56]. Clearly, mitigation of this effect requires active coordination, to mobilise uptake and effectuate digital transformation in a direction that is visible to all.

A number of key initiatives are funding projects in the area of IoT such as FoF, ECSEL, Big Data, 5G and AIOTI. Coordinating these activities on cross-sectoral and integrated digital platforms would be very powerful. Bodies representing the sector, e.g. AIOTI and ETSI, could provide horizontal coordination for this with the aim of bringing together PPPs and national investments. The aim would be to create cross-sectoral and integrated digital platforms and ecosystems including reference implementations and experimentation environments in real settings. IoT incubator communities of startups and developers can then be used to promote the technologies to the SME community.

7.2 Current landscape of activities

7.2.1 European activities

At the European level, the IoT-EPI cluster brings together 7 RIAs and 2 CSA projects to work on emerging IoT platforms. Task forces have been created to address horizontal issues such as Innovation, Accelerators (to accelerate scale-up), International Collaboration, Interoperability and Business Models. Already two documents related to IoT business models have been created highlighting a change towards value networks. Additionally, other large European initiatives, e.g. FoF and ECSEL (ARTEMIS-IA, EPoSS, Aeneas) are supporting IoT projects. Overarching the IoT activities across Europe, the Commission had created AIOTI (Alliance for the Internet of Things Innovation) in FP7 with further support in Horizon 2020. This is now an independent non-profit organisation with 500 members acting as a technology platform.

[56] The Penguin effect can occur in 'adoption games', when users are reluctant to move first (in adoption of e.g. a new technology, standard or platform) as long as there is a significant risk that the choice may be wrong and the technology selected will eventually be orphaned. To prevent this, participants in the game will tend to "wait and see". The term refers to the challenge penguins face, when they stand together before they dive into a sea full of fish, where however predators may also wait for them. The first penguin to dive in follows a high risk/low gain strategy.

Siemens is strongly pushing the vision of a web of systems approach for interconnection between many devices. To support this, standards for semantic and format interoperability are needed to connect different platforms (be they proprietary, community-based or open-source) and federate cloud services. This could include elements from the consumer, business and industrial domains to create a web for things or systems. Siemens avoids the term "Internet" as this is strongly focused on connectivity. It also avoids the term "Things" as it does not adequately describe systems. Nonetheless, the company's strategy is strongly focused on the combination of services and World Wide Web.

7.2.2 Regional and national activities

Many countries now have national initiatives for IoT. For instance, within the UK the Digital Catapult coordinates IoT activities and it was highlighted that there is a significant programme of IoT research activities (£120M projects - 10% coming from the EU) funded by the Research Councils and also Industry led programmes. £40M had been dedicated to large scale pilots in smart cities and two health care pilots. A research hub on IoT had also been created on security and trust and a further £14M had been allocated to two hardware accelerators. Overall 170 different IoT companies from a variety of different sectors are engaged (pre-dominantly in healthcare and transport). Venture Capital was also strong for IoT with 45 companies receiving £40M. It was noted however, that although money was available to support startups, later stage funding for growing businesses was more challenging which often led to companies being bought out by international companies. A large proportion of UK IoT activities (75%) were in the London/Cambridge region. Many activities in the UK are not yet linked with Europe and there is therefore a clear interest in collaboration. Likewise there are national strategies in France such as "La French Tech" for digitisation with a number of supporting regional initiatives addressing key technologies and Industrie 4.0 in Germany which is supporting IoT-related research for manufacturing.

7.2.3 International activities

A study around the world by the Unify-IoT project has identified that around 360 known platforms exist, with the vast majority of these being developed from 2013 onwards. The initial explosion of new platforms and SMEs in the area is, however, slowing down. There will thus be a natural selection within the market over the next few years. The risk of US dominance was highlighted and large companies such as Google have the resources to dominate the future market. Google for instance has acquired a number of robotics companies recently. A notable difference identified between Europe and the US is that less barriers to deployment exist in the US. Another notable difference is that within Europe there is a generous culture towards international collaboration. In the US there is less interest in collaboration and the IoT area is driven by private investment, targeting a sizeable home market of 350 Million people before markets beyond the US are considered.

The threat to Europe, however, is a world-wide one and it was highlighted that any company can be bought as evidenced by recent acquisitions of ARM, Kuka, etc. There is thus a risk of losing EU investment in innovation in the area. In particular it was noted that Europe has lost leadership in the B2C area. However, the position with respect to the B2B market is better and there is scope for standards development and obtaining market share. It was noted that Europe is strong in mechatronics, systems integration and the automotive sector. Within Europe, work on platforms is concentrated on connectivity which reflects Europe's strong history in communications, connectivity and sensors. The US is stronger in the area of Big Data and data platforms where there is more added value from exploiting data aggregation and analysis.

A distinction was made between IoT for consumers and Industrial IoT, with the first covering smart phones, fitness tracking tools etc. and the second being exploited in areas such as smart factories, smart health care, etc. Advances are being made in the consumer world and a question is how this can be moved to the industrial space. In general there is a convergence of consumer and industrial Internet

with IoT becoming a "virtualisation infrastructure". Analysis of industry by IDC shows that 58% of organisations see IoT as strategic to business, while 24% of organisations see IoT as transformational to their business.

It was noted that the rise of the Circular Economy may offer opportunities for linking the consumer market to industrial processes, so as to capture use information on the product life cycle for maintenance, repair, upgrade/retrofit/refurbishing, dismantling and recycling. Within the industrial IoT domain, GE is a strong player and is in discussion with Bosch and Microsoft, all having joined the Industrial Internet Consortium (IIC). It was highlighted that if the large companies drive the market, the dominant solutions of the future may not match EU goals or be in the best interest of the EU. Open standards or APIs, accessible and usable under Fair, Reasonable and Non-Discriminatory (FRAND) economic and legal conditions are essential to give SMEs access to new technology and leverage the dynamics of new ways of making business as proposed by start-ups.

7.3 Visions for the Future

7.3.1 Needs and Expectations

Already there are a number of pilots being pursued and there is an opportunity, for instance, to put together the autonomous driving pilots being performed by IoT, ECSEL and 5G PPP (addressing communications for autonomous driving). There was a call for IoT platforms to be sector driven and to identify urgent problems. Interoperability of platforms and data is important and in the future the expectation is for more automated interaction between machines with reduced involvement of humans. Here there is a need to support standards as a key element of platforms. Looking to the future next generation platforms should take into account areas not currently addressed, e.g. the Circular Economy. The key need is to provide interoperable solutions that provide an experience that customers or business require, as well as guidance for secure and safe implementation (e.g. based on reference architecture models). Already a convergence is becoming apparent with the consumer space focussing on IT, and business focussing on operational aspects having more stringent requirements on timeliness, reliability and security. However, security and privacy need to be addressed at different levels and in the future platforms in the IoT space will be used to co-create value. Privacy needs to be protected within each sector and the EU has a role to play in providing data governance that supports European values. See Figure 16 for a schematic representation of consumers' feelings about using/selling of data about their behaviour, based on a 2015 survey by the Altimeter Group.

There is a need to identify the type of market value Europe wants to create. In the US targets are set reaching out for huge volume, and these are then pursued to create new technologies or increase market share. The current landscape of IoT platforms highlights that the European offer is very fragmented. Across the 360 platforms identified world-wide there was a mix of cloud companies, some open source platforms, some industrial sector driven platforms, e.g. by Bosch, Siemens or GE, and some standards based solutions. Looking to the future, international standardisation organisations, such as OneM2M, will be important and there is a need to create commercial platforms based on agreed international standards. There is an opportunity for gaining business in the edge computing domain as more processing will move close to the point of interest in the future and European companies have a strength in this area. Across Europe there is a need for a common, uniform market place to allow industry to up-scale their platforms and services to fully exploit the potential of a European digital single market. To be successful there is a need for market pull so that platform developments respond to requirements. Experimental pilots would bring together the supply and demand side. There is also a need for a strong IoT incubator space, building on the dynamics of a vibrant IoT developer and startup community (as it is the case in the U.K.) and access to finance within Europe to create platforms.

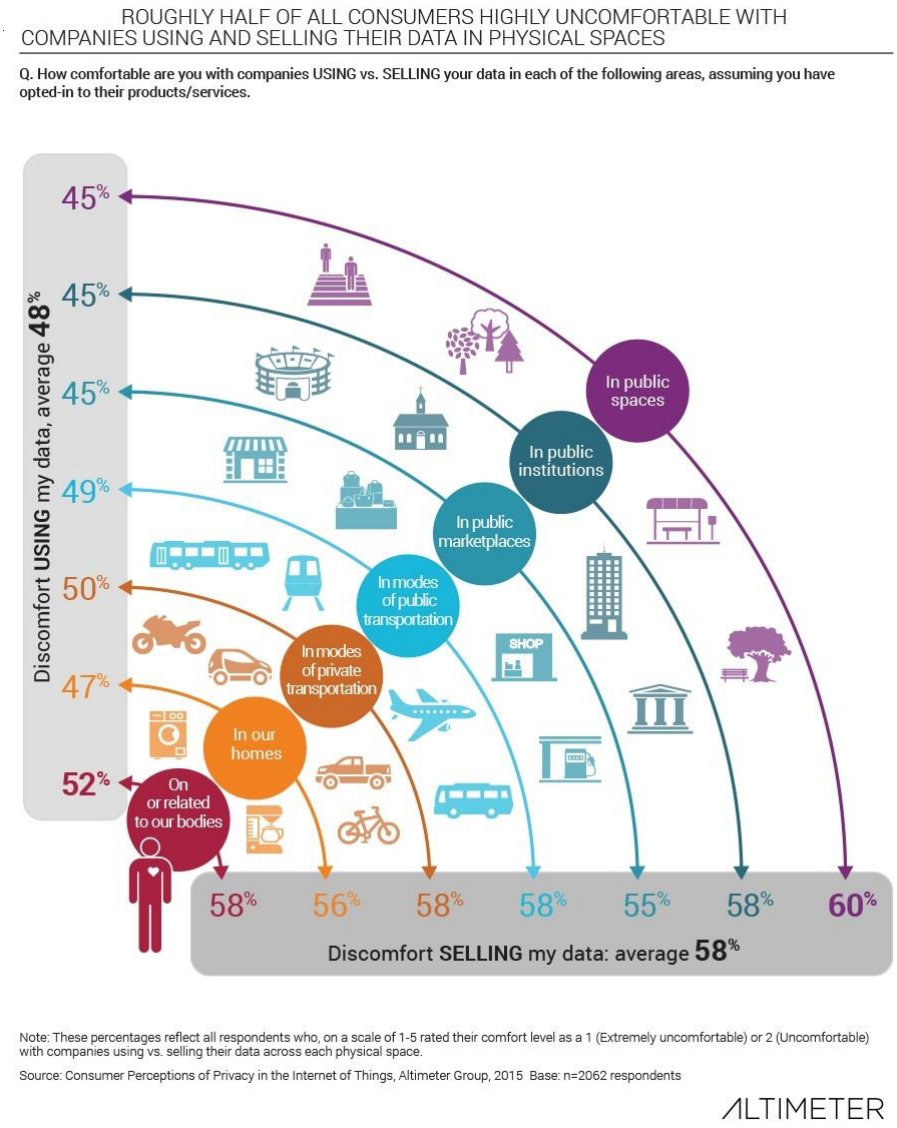

Figure 16 Data use and consumer perception of IoT

7.3.2 Bridging the gaps and addressing the issues

Platform development and large-scale initiatives at a European level should address consumer IoT applications as well as industrial IoT, one inspiring the other. There is a need for PPPs to coordinate with one another and link their large demonstrations that address IoT and related technologies like Cyber Physical Systems (CPS). Interoperability issues, standardisation and the architecture used by the diversity of platforms all need to be addressed and mechanisms are needed across Europe to up-scale platform building and stimulate innovation.

7.3.3 Priorities

WG2 identified the following priorities for IoT:

Platform Building - Connecting Regional and National Initiatives across Europe
Already there is a plethora of platforms and convergence is clearly needed. This should be driven by market pull and the opportunity for Europe is in areas such as mechatronics, systems engineering and

automotive. There are a number of national activities on platforms and it would be beneficial to share information between these. However, there are some challenges. Useful information on the impact of platforms is not yet available and platform development is driven by different sectors. For instance, in France platform development is being driven by the micro-electronics industry and in the UK it is driven by applications. This leads to differences in national IoT strategies.

Initiatives that foster more explicit actions between Member States are needed that spread best practice and also increase the awareness of IoT. A horizontal approach is needed to support convergence of IoT platforms and the benefits can be maximised through coordination at a European level via connection of regional and national innovation hubs. Here one approach may be to fund a CSA to share experience and catalyse national initiatives. There is also a strong need to coordinate across PPPs and link their IoT demonstrations. This could be further supported at a European level by an ECSEL-type activity, using national IoT funding.

Creation of Open Platforms

There is a need for open platforms to avoid vendor lock-in. With the proliferation of platform offerings there is considerable fragmentation and at present there is no clear convergence towards one platform. Key aspects include the development of a reference architecture that allows for cooperation across value chains and openness to SMEs. It is very important for Europe to transform its IoT research results into innovations that succeed on the market. As large companies have frequently difficulties in integrating research results into their business model, SMEs could have a crucial role in leveraging the potential of IoT innovation, because they are faster in developing applications and exploring less conventional solutions. Future platforms should bridge the current interoperability gap between the vertically-oriented IoT platforms and mobilise third party contributions by creating marketplaces for IoT services and applications. A harmonised European market for IoT interoperability standards and open APIs are a prerequisite for a free marketplace which reduces dependencies and barriers for new business and SMEs.

Privacy and end-to-end security solutions should be addressed based on local reasoning and trust, validating novel business models when data is aggregated and shared across the value chains. Emphasis is put on open platforms cutting across sectors and acceleration of innovation by companies and communities of developers, building on existing open platforms that support digital transformation and cross domain adoption.

By bringing the ecosystem together, for instance by linking European projects focussed on autonomous driving such as 5G, ECSEL, and the IoT Large Scale Pilot it may be possible to create open platforms addressing several sectors. The main stakeholders in this should be ECSEL and the FoF, SPARC and 5G PPPs.

Promotion of Standards

As highlighted the current fragmentation of IoT platforms creates challenges. There is a need to address interoperability between commercial or non-commercial platforms, e.g. focusing on semantics and ontologies. This requires collaboration on common interfaces for interoperability and a starting point here could be addressing interoperability at different levels for the use cases supported by the EU funded Large Scale Pilots. This would support convergence of platforms through deployment and via creating critical mass. Large-scale pilots are instrumental to validate emerging standards and thus support standardisation activities. The focus should be on a European approach to standards that would eventually influence standards at an international level such as oneM2M or W3C in the case of defining semantic interoperability. The emphasis should be on developing a convergence on existing standards rather than in generating new platforms and new IoT standards. The policy and regulatory framework needs to support this.

Promoting Industrial Partnership
The overall objective should be to create an Industrial Partnership. This will facilitate successful exploitation. Many IoT platforms already exist and there are growing partnerships such as the IIC and the AIOTI. However, there is a need to promote a dialogue across a critical mass of stakeholders, including large companies as well as SMEs, and to promote consensus on platform up-scaling. This can be supported by the AIOTI with the aim of bringing different communities together. Legal issues, technical bottlenecks and market barriers need to be discussed. The aim would be to drive the convergence of standards across different sectors and accelerate adoption of IoT platforms in relevant sectors (sector-specific) whilst promoting spill-over effects to other sectors.

Supporting Large Experimental Facilities
To promote acceptance and prove the reliability of platforms there is also a need for large experimental facilities for testing and demonstration of novel standards, architectures and platforms, driven by selected verticals. Here there is a key need to avoid silos and a need to avoid vendor lock-in. Open standards and open APIs are important elements to allow SMEs to access and exploit an IoT platform. To ensure this it is important that small SMEs and start-up players get involved in these activities to address new business opportunities and business models. Here the emphasis should be on supporting convergence to fewer but open platforms, accessible and usable under FRAND economic and legal conditions. As highlighted Europe is strong in connectivity, which creates value that is distributed along the whole supply chain but weaker in the area of Internet platforms and Big Data analysis where the value is more concentrated and thus more visible. To address this gap there is also a need for connection between IoT platform development and other areas such as artificial intelligence, data analytics and security, etc. to capture market share. Fragmentation needs to be avoided through a coherent implementation of large-experimental facilities across Member States, vertical sectors, and across societal challenges. Large-scale pilots should build on converging technology trends integrating Artificial Intelligence, cloud, data analytics, robotics and edge computing, and addressing more application areas (smart living environment, smart agriculture, smart grids, smart cities, intelligent transport systems, automated transport, environmental monitoring, etc).

7.4 Implementing the Vision

7.4.1 Objectives for next generation platforms

An immediate issue is to define a strategy to address and coordinate developments in the "zoo of platforms" that are emerging. A key need is interoperability to allow platforms to be connected together. As more critical applications are connected via networks, e.g. autonomous driving, there will be a need for higher quality network connections. If high quality networks cannot be guaranteed there will be a need to keep processing local. Indeed there is a growing trend towards data processing close to the point of action, i.e. edge computing, to address real-time availability in platforms and also to limit liability and risk that would otherwise be incurred from performing processing in central clouds.

A vision and strategy is needed to achieve this. Here reference implementations could be used as test cases in order to develop a good strategy. There is a need to define a list of objectives to organise actions so that the degree of success of initiatives can be monitored. These objectives should consider both the future vision and also societal challenges, and not only the industry objectives. It was noted that there are a number of cross cutting topics that could be addressed that would have impact across domains such as autonomous vehicles, industrial robotics, robotics for health care, ageing well and farming. The importance of supporting infrastructure for industry was noted. For instance, the best effort approach provided by the Internet presently is not sufficient for some real-time services, particularly if a provider is asked to provide Service Level Agreements. This is becoming more of a problem as applications move towards using cloud platforms. This needs to be addressed at both the research and policy levels. At the research level, research is needed into new communications technologies such as 5G virtualisation and slicing to support different communication criticalities.

The future promises increased reliance on networks being interconnected to each other with the need for a connection to a reliable backhaul infrastructure. Notably there is a need to define what a "service" is, considering the growing move towards mobility as a service, health as a service, XaaS, etc. The infrastructure needs to be put in place to support different application domains with differing real time requirements. End-to-end security and security by design needs to be provided considering devices, platforms and the connecting network.

7.4.2 Definition of Supporting Initiatives

There is a need for de-siloing of development. Already there are a number of developments underway such as Industrie 4.0, Farming 4.0, Energy 4.0, Health 4.0. This bears a high risk that security, standards, applications and infrastructures are developed/deployed in silos. The highest benefit for IoT is created if data is shared and exploited across vertical sectors. This creates a need for coordination to develop solutions that apply across sector value chains. It was highlighted that the EU should play a role in this and maintain a long-term position. There is a need to ensure that monopolies are avoided and that the rules applied for platform development are fair and move in the right direction for Europe. Openness is needed, to support SMEs and also to encourage dynamic ecosystems. Privacy and security guidelines need to be developed that are win-win. Care needs to be taken to avoid creating "ivory towers" or platforms that will not be used in practice. Hence there is a need to identify supporting business models and define platform economics. A key need is for open platforms and these must be attractive across different verticals. To prevent vendor lock-in, interoperability and connection of different platforms should be provided, i.e. via platform gateways, to de-silo platform development.

It is up to ecosystems in Europe to bring platforms together, but the EU can provide support for experimentation of new business models considering multi-sided market players. It was noted that applications across domains would be a good way of demonstrating federated platforms. Potential key areas have been suggested that could be fruitful to support platform building. These include energy management in grids, homes, cities, autonomous systems and data management for farming, IoT for water management, fish production, autonomous systems and smart home for health and well-being as well as smart mobility in cities (which combines autonomous systems and energy efficiency). Another application across domains, currently not addressed, could be the Circular Economy which could demonstrate federated platforms. The need for federated platforms is most evident for the domain of Smart Cities as it encompasses a number of topics such as mobility, energy, environment, waste and water management and autonomy to aggregate data from various legacy platforms. This would also address cross-cutting issues such as connectivity, sharing of data between platforms and legal issues as well as demonstrating mixed criticality services. Another potential area would be in manufacturing. Here a central search engine for manufacturing data could be developed with different platforms being used to organise process and supply chain logistics.

Connectivity is another key area that needs to be addressed. Already the lack of connectivity in rural areas for autonomous cars is causing concerns. For instance, if autonomous cars use 4G LTE for connectivity there are many areas where they are not covered and thus the need for a fall-back option exists. In reality it is necessary to test a patchwork of wireless and satellite connectivity in rural areas. However, it must be stressed that IoT is not only about connectivity. It cuts across many applications, e.g. autonomous cars, service robots, drones, cobots and health care as well as energy and public transportation. Google is for instance providing a platform for autonomous vehicles where the primary interest is in data analytics and Apple has also announced a "self-driving platform" for autonomous cars.

When choosing the right way of platform support a clear distinction should be made between marketplaces building on a dominant position and platforms driven by industrial cooperation and alliances. Whereas Google and Apple promote a top down approach to platforms adoption, GE is

promoting an alliance forming approach in the Alliance for the Industrial Internet of Things (IIoT) to promote wider up-take of its preferred platform. This has led to Predix and ThingWorx being promoted via the alliance across a number of sectors. There are also a number of competing consortia to IIoT such as IIC, Open Interconnect Consortium and Allseen Alliance. Here the EU should support a middle way that promotes the interests of European commercial and non-commercial platform developers, reduces dependencies for SMEs and start-ups, and allows seizing the benefits of new business models and innovative services across societal challenges, by making sure that the platforms can be accessed and used under FRAND economic and legal conditions.

The key need is to support the European SME ecosystem to empower them to meet international competition. Platforms need to be attractive to SMEs, providing interoperability to avoid fragmentation while supporting security by design. Trust in platforms needs to be developed and supporting regulation should be linked to the evolution of the platforms, providing standardisation and enabling data valorisation.

Demonstration of platforms should be done at a suitably large scale and in real environments to provide confidence to industry. Ideally the pilot demonstration should address societal issues that are of interest across Member States and involve PPP pilots that operate across sector stakeholders, such as FoF, ECSEL, 5G and SPARC. For uptake there is a need for replication of demonstrations of platforms across Member States in applications to address the "Penguin Effect", and make sure it does not take too long before good examples are followed.

Regulation should be linked to the evolution of the platforms. The industrial internet poses new challenges for security, liability, and rights to access and process data. This requires policy makers to adapt the regulatory framework. Evolving new business models, increasingly integrated supply chains and a hyper-connected society are to be considered before legislative decisions are taken. Pilots and testing with real use cases would support the shaping of the future digital policy. Evaluation of pilots should be closely coordinated with Member State initiatives, allowing the collection of broad feedback on possible policy options before regulation is put in place.

7.4.3 An action plan

As highlighted the EU needs to supply long term support with a clear mechanism and objectives to support European Platform building. It also has a key role to play in promoting fair rules, standardisation and guidance on data governance and security. The aim should be to promote openness to avoid lock-in, to support fairness in the distribution of the value added along the supply chain, to prevent the dominant position of one player while monitoring global competition, and provide supporting standards, regulation and policy.

Already there is 3BEuros of investment in national IoT strategies and in order to avoid fragmentation and silos there is a need to try and coordinate work at a European level. It is natural that SMEs will engage with regional and national initiatives, however, national initiatives addressing platform building will not be able to compete at an international level as there is insufficient user base. Thus there is a need to encourage collaboration and to build spearheading platforms that build a link between initiatives that address different use cases. At present there is one large scale pilot for one sector but it is important to replicate pilots in other regions and promote Best Practice. Here it is necessary to support multiple demonstrations and mobilise transformation.

There is a need to support SMEs. Standards are needed for security and to provide interoperability between the many platforms that currently exist. In order to tackle fragmentation there is a need for coherent implementation of platforms across Member States addressing key sectors and societal challenges. In order to encourage uptake there is a need for clustering to create scale. This can be done using pilots at both lab-scale and in real environments particularly at the regional scale. Key

aims of this should be to promote standards and data sharing with test beds and trials that demonstrate federation and interoperability.

7.5 Contributions from PPPs

Several large scale pilots already exist that plan to introduce IoT in specific verticals, such as agriculture or health and care. Examples are IoF2020 (in Agriculture), ACTIVAGE (Health and Care) and AUTOPILOT (autonomous driving cars). Projects such as these can provide a foundation for further adoption of IoT in verticals.

As there are many common themes being researched by the PPPs, coordinating activities between the ECSEL, Big Data, 5G, etc., PPPs on cross-sectoral and integrated digital platforms would be very powerful. Here alliances like AOITI and ETSI may also have a role to play, providing horizontal coordination. The aim should be to focus a significant part of the PPPs and national investments on cross-sectoral and integrated digital platforms and ecosystems including reference implementations and experimentation environments in real settings.

7.6 Contributions from the Member States

Input was received from a number of Member States including France, the Netherlands, Germany, United Kingdom, Sweden and Austria. It was noted that France is keen to have a common standard platform for IoT that is agnostic of hardware. There are big initiatives in the UK on IoT, Smart Cities and 5G. Additionally, the UK is also looking to develop technologies to address markets in other parts of the world, such as China and India. Within Europe with respect to platforms a national market is not sufficient for survival and scale can only be provided by addressing platforms at a European level. Here the US has an advantage of a large internal market.

One approach to trying to bring developers together to create scale would be to develop smart specialisation platforms so that regions do not develop their own platforms in isolation. To achieve this it is necessary to convince regions to get together at the European level and develop interoperability between existing platforms. This bottom up approach requires horizontal coordination of development of federated platforms. Here AIOTI and ETSI have a role to play to create EU alliances and promote standards.

7.7 Recommendations

Based on the previous considerations the main recommendations for “Internet of Things” are:

Platforms

- Stimulate national IoT strategies in all Member States;
- Share best practices from Member States and increase awareness of existing platforms;
- Link existing alliances like AIOTI to lighthouse projects in Member States;
- Engage with Member States to address fragmentation and work towards an open integration platform that addresses cross-sector challenges;
- Enhance the role of JTI in building platforms.

Pilots

- Call for large scale demonstrators and pilots to show the benefits of cross-cutting IoT platforms (see also WP 2018-2019);
- Support access to and validation of emerging IoT platforms in national calls;
- Identify promising testbeds and stimulate that they are connected and validated in a complex policy context.

Ecosystems

- Engage SMEs and developer communities, partly to address the "penguin effect".

Standardisation

- Address interoperability issues, by better coordination of industrial, national and EU initiatives;
- Stimulate the definition of common interfaces and common data formats;
- Engage with regional and national policy actors, e.g. IoT standardisation and the Standardisation Council Industry 4.0.

8 Conclusions

The very significant opportunities associated with Digital Industrial Platforms are recognised everywhere, not only in Europe. Organisations around the world invest very substantial amounts to obtain an attractive position in a context of digitised industrial ecosystems. By 2020, the world-wide investment level associated with digitisation is expected to be close to 10% of industry's total added value. In Europe, as elsewhere, many activities exist already, but they are not very structured. The three "vertical" domains (Connected Smart Factories, Smart Agriculture and Digital Health & Care) and the two "horizontal" areas (Industrial Data Platforms and Internet of Things) that were assessed in more detail by WG2, currently show a high level of fragmentation. It is clear that European stakeholders will only succeed in making a world-wide impact through coordinated action. If current developments would be exclusively left to the market, many consider it unlikely that the result would be sufficiently aligned with European interests and values. If any industry in Europe, large or small, wherever situated and in any sector will adopt digital innovations to upgrade its products, improve its processes and adapt its business models to the digital age, then any customer in any transaction and any worker in any position will be affected as well. Digitisation will thus fundamentally change not just industry, but what we do in society at large. Commissioner Oettinger argued during the closing speech at the First DEI Stakeholder Forum on February 1, 2017, that the investment in the infrastructure for digitisation is probably the most important one that will be made by this generation. Definitely, no other infrastructure will have a more pervasive and more ubiquitous influence on how we live and work. Every fisherman and every farmer, every cardiologist and every car mechanic, every teacher and every truck driver anywhere in Europe will be affected; everyone of the more than 250 million members of Europe's working population. Moreover, everyone of the more than 500 million inhabitants of the EU will feel the influence of industrial digitisation, as customer and citizen. Hence, the standards that will be defined by the stakeholders in the industrial platforms of the future will together influence the ultimate standard: the standard of living in Europe. Thus, the need to collaborate and to develop a shared vision is not just a matter of quantity, of creating clout to be competitive in a global market, it is also a matter of quality: of being representative and comprehensive enough to make the right decisions about investments in initiatives that are sustainable and will have a strong influence on our future. Co-ordination, orchestration and regulation is necessary to ensure that the resulting platforms are truly leveraging the interests of European industry and will simultaneously improve the quality of life of European citizens.

Against this background the following general recommendations can be made, in addition to the more specific recommendations that were made for individual horizontal or vertical areas at the end of the previous chapters.

Building further on the successful EU wide partnerships, which have enabled the latest technologies to be brought to market and strengthened collaboration of academia and industry with important spill-over effects on the whole economy, it is essential to further continue the development of digital innovations, and their integration into digital industrial platforms, critical to the EU industry.

This requires to reinforce the role of the Horizon 2020 Public-Private Partnerships not only in developing at scale key technology components for digital platforms for their specific sectors at the EU level, but also across sectors and in pooling resources and linking Member States programmes, projects and initiatives, such as testbeds, experimentation facilities, and pilot lines.

Moreover, significant resources will be needed to ensure further leadership in key technologies such as the next generation building blocks in micro/nano-electronics, photonics, robotics and AI, 5G, HPC, and big data and to ensure their integration in future digital industrial platforms. This should be done by scaling up promising platform initiatives and pilot projects to full deployment and enlarging their ecosystems, which can only be achieved through a proper blending of several sources of EU, national, regional and private financing.

Member States should enhance their national programmes related to digitisation of industry (or initiate them if they do not exist yet) and link them to other initiatives, including those existing in other Member States and at the EU-level. Similarly, industrial sectors should start or enhance programmes towards industrial digitisation. In addition to the domains specifically addressed by WG2, several others have already taken significant effort towards broader awareness about digitisation, including the Finance sector and the Construction Sector. All merit support to widen their scope, take an international perspective and exchange expertise with other sectors. At the same time, applicants for H2020 who respond to calls in 2018-2019 should be strongly encouraged to link the work they propose to relevant activities that exist in the Member States or in specific industrial sectors. The EU should stimulate cooperation between the activities at the national, regional, sectorial and European level, most notably through the management of new H2020 projects, and it should monitor to what extent the collaboration actually takes place.

Hence, an open and inclusive environment between the EU and the Member States should be established that encourages learning and consensus building regarding digital technologies and digital industrial platforms, based on experimentation and validation on testbeds and on a commitment to standardisation. WG2 stresses that to this end more attention should be given to the testing of existing platforms under increasingly challenging "real world" circumstances, as opposed to stimulating the development of new (and local) platforms that are only tested in a lab. In fact, a variety of needs from different communities of users should be addressed and included in the process of validation and the opportunity (or lack thereof) to integrate with legacy systems should always be carefully considered. To this end sufficient attention for interoperability and connectivity in platforms is key. Projects that are considered promising because they meet the requirements of a broad range of stakeholders, can subsequently be supported to further develop into large-scale initiatives. Funds for federation should be enhanced, allowing efficient upscaling of initiatives that are successful and show potential. The PPPs can provide an important role in this process, but other means to do this exist as well, at the European level or elsewhere. It is therefore important that relevant agencies, including consumer organisations and unions, sit together to compare and tune investment agendas.

Advances towards large-scale initiatives can trigger the development of new scalable business models. Such models may be disruptive, e.g. when coalitions of users (e.g. farmers, machine owners, hospitals or telcos) pool their data to increase their power over suppliers or when service providers work together with users to share and process data in ways that create new value and new business opportunities. Therefore, the creation of large-scale initiatives should pay close attention to the alignment of the envisaged business models with fundamental European socio-economic values. To this end, involvement of a wide range of stakeholders is very important, to anticipate obstacles and produce a truly balanced result.

In this process significant attention should be given to non-technical aspects. Most notably economic, social and last but not least legal aspects were discussed quite extensively in WG2. Digitisation will create opportunities for new jobs and those with the right skills can benefit significantly from it. For instance, the lack of availability of properly trained data scientists is currently the main hurdle to the proliferation of Big Data approaches in industry and an urgent need exists for people with the right skills. However, digitisation will also eliminate jobs. Hence, the number of European workers with the appropriate knowledge and skills to face the challenges of digitisation should increase rapidly. It is therefore strongly recommended that the educational opportunities to develop the skills necessary for the digitised world are increased. Finally, digitisation creates many legal challenges. Some of them require a fundamental (international and comparative) re-assessment of legal assumptions, e.g. about the access to and use of results in digital form. Clearly, these non-technical considerations only further emphasise the need for a dialogue between EU and Member States.

For instance, data should be stored in such a way that it can be accessed by different stakeholders. This would allow companies to create innovative solutions, creating revenue from data. Barriers to such data-driven revenue generation at present relate to rights to access and process data and to

discovering how to create value from data. Ownership, rights to access and process data, and the role of contractual agreements need to be clarified. Many end users will only accept increased data gathering if they are given a fair deal on the data with sufficient control over what data is collected. In addition to a trust issue, the security of data is also a concern.

So far, not all Member States have actively contributed to the process of stock taking and suggesting opportunities for joint programming of roadmaps, co-investment in initiatives or regulatory and/or legislative harmonisation. The WG2 community therefore strongly encourages all parties to sit together and, even more actively than they have done so far, assess where opportunities for collaboration, joint programming and federation exist.

A. Relevant activities in platform development, piloting, and testbeds

This annex lists some relevant activities in platform development, piloting, and testbeds. These activities are the result of a survey on existing (and future) platforms, pilots and testbeds in the Member States[57]. Most of the activities mentioned in this annex are in addition to the ones mentioned in the main text of this report; some activities are also referred to in the main text. Extracts are taken from the survey rather than full texts; more information is available in the survey results documents.

In some cases, information given by survey respondents are re-classified, although it should be noted that the boundaries between the three categories are rather fluid. For instance, if an activity is stated as a 'platform', but would fit better under 'testbeds', it is stated under 'testbeds' here. In some cases, the information given in the survey does not fit well under any of the three categories of platforms, pilots and testbeds; often such cases refer to national or regional initiatives, Digital Innovation Hubs, or clusters of organisations. In such cases, no reference is made in this annex to the survey entry, but one should note that such initiatives and Digital Innovation Hubs might play important roles in future Platforms and Pilots projects. For an overview of national initiatives and Digital Innovation Hubs, please refer to other sources[58].

The original information given by survey respondents is stated in the survey results documents[59].

This annex does not aim to give a full, complete overview of all relevant activities in platform development, piloting, and testbeds.

A.1 Summary of survey results

This section is based on the responses given by the survey respondents, without taking into account any 'corrections or interpretations'. Data is taken as-is.

Based on the responses to the survey, 78 unique activities were identified. Contributions came from roughly half of the EU Member States. A few of the reported ones were identified as truly European but most of them had a national scope. Most notably, 34 activities were reported from Spain, 15 from France and 8 from Germany. The large number of activities from Spain (44% of total respondents) is explained by the contributions from / related to a single organisation (30 out of 34 respondents from Spain). Figure 17 (left) gives an overview of the contributions received.

Figure 17 (right) also shows the sectors or the horizontal topics in which activities are based.

[57] https://ec.europa.eu/eusurvey/runner/DEI-WG2-survey-on-platforms-piloting-testbeds

[58] National initiatives: https://ec.europa.eu/futurium/en/content/digitising-european-industry-catalogue-initiatives. Digital Innovation Hubs: for the moment, please refer to the link at https://ec.europa.eu/futurium/en/content/digital-innovation-hubs-catalogue-project-0; in a later stage, a Catalogue of Digital Innovation Hubs will be hosted under http://s3platform.jrc.ec.europa.eu/digital-innovation-hubs-catalogue

[59] See https://ec.europa.eu/futurium/en/implementing-digitising-european-industry-actions/results-dei-wg2-questionnaire-national-0

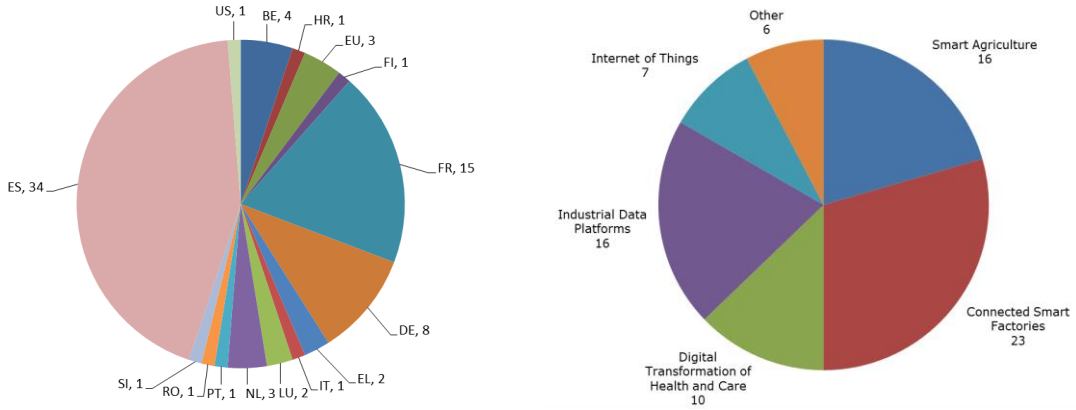

Figure 17 Countries and sector or horizontal topic in which activities are based

Finally, there are 56 platform development activities, 17 pilots activities, and 17 testbeds. Note that each response could have more than one activity. Table 1 gives an overview of the number of activities (platforms, pilots or testbeds) in the three vertical sectors and two horizontal topics.

Table 1 Number of activities per sector / topic

	Platforms	Pilots	Testbeds	Total
Connected Smart Factories	15	8	7	30
Smart Agriculture	13	4	2	19
Digital Transformation of Health and Care	7	1	2	10
Industrial Data Platforms	12	2	3	17
Internet of Things	4	1	3	8
Other	5	1		6
Total	56	17	17	90

A.2 Platform development

Connected Smart Factories

Smart, Safe & Secure Platform – S3P

An example of a digital platform is the Smart, Safe & Secure Platform – S3P, by the French S3P Alliance[60]. This software development and execution platform for the Internet of Things aims at enabling the rapid development and exploitation of IoT-capable devices and applications, combining safety, security, agility and portability. It is developed by a 45 M€ project, which is financially supported by the French Government "Nouvelle France Industrielle" initiative with an 18.3 M€ government funding.

Optician 2020[61]

The Optician 2020 ICT Platform is a web-based platform and a set of computational services that automates the design, manufacturing and logistics of the manufacturing of personalised spectacles in mini-factories. The platform is composed of a back-end and a front-end networked architecture and associated modules, automates the design and ordering of personalised spectacles and the communication between actors (designers, opticians, RX labs and lenses and frames manufacturers). The platform is flexible and extensible to cope with scalability requirements.

[60] http://www.esterel-technologies.com/S3P-en.html
[61] http://www.optician2020.eu/

Unmanned Systems Industrial Robotic Platform (USIRP)[62]
The industrial robotics platform based on unmanned systems is made up of machinery and cutting-edge infrastructures that have been put to the service of industry and civil organisations. The USIRP was born out of the need for unmanned ground, air and marine vehicles that were specially designed to carry out civil and military tasks. UGVs (Unmanned Ground Vehicles), are used in repetitive tasks of transport or work in polluted or dangerous environments where human beings would be unable to carry out the work safely.

Sense&React[63]
Sense&React has developed a context-aware and user-centric information distribution system required for distributing the data produced by sensors and other data sources (such as Manufacturing Execution Systems or Enterprise Resource Planning systems) so that it can speed up productivity and decision making ability of shop floor and back office personnel. Driven by the industrial pilots, Sense&React has developed an innovative framework for sensing data from the manufacturing environment, such as the state and location of tools, assets and parts that provide insight to the manufacturing activities performed in the shop-floor. The Sense&React API allows developers to build new apps on top of the Sense&React platform.

IMAGINE - Innovative End-to-end Management of Dynamic Manufacturing Networks[64]
The IMAGINE Platform is a fully functional prototype that is able to support the lifecycle phases of Dynamic Manufacturing Networks (DMNs). The IMAGINE Platform allows DMN partners to connect and expose their services and products to a network using a specific data format. The DMN Partners may also connect (and integrate) with the generic IMAGINE Platform using appropriately developed adapters that allow them to send/receive data in real time. The IMAGINE Platform allows the organization of partners in DMNs, which can be generated even ad-hoc in order to manufacture a product and/or respond to emerging needs. Overall, the IMAGINE Platform allows and fully supports the creation, design and management of DMNs.

SeRoNet[65]
The goal of the SeRoNet project is to develop a platform that supports dynamic networks in the efficient development of customer-specific solutions over the essential lifecycle phases of a service robot. The platform is intended to bring together suppliers and operators / users of an service robot solution and to ensure the service robot development process "first time right" from a system with regard to economy and implementation quality. The classic linear value chain is replaced by a value-added network in which manufacturers, system integrators and end users cooperate dynamically in solution-specific subnets of varying composition as actors in the development and operation of service and assistance robot systems. The SeRoNet platform supports these networks by providing access to ontology-based domain knowledge and a directory service for standardized (OPC UA) services.

Industrial Communication for Factories (IC4F)[66]
The IC4F project deals with holistic solutions for industrial communication in factory automation. For this purpose, a modular system for a trustworthy industrial communication and computing infrastructure is created as the basis for digitisation in industry. The communication solution includes new approaches to the computing infrastructure (edge cloud, data management) to enable industrial real-time applications. A central part of the IC4F project is the modelling of a communication kit as the basis for digitising industry. Particularly important is the integration in an architecture that fulfils different requirements in a heterogeneous environment. The IC4F project serves as a starting point for the provision of open, transparent and trustworthy communication and computing technologies.

[62] https://eurecat.org/en/centres-of-excellence/unmanned-systems-industrial-robotic-platform-usirp/
[63] http://www.sense-react.eu/
[64] http://www.imagine-future-factory.eu/index.dlg
[65] http://www.digitale-technologien.de/DT/Redaktion/DE/Standardartikel/PAICEProjekte/paice-projekt_seronet.html
[66] http://www.digitale-technologien.de/DT/Redaktion/DE/Standardartikel/PAICEProjekte/paice-projekt_ic4f.html

ROS-Industrial[67]
ROS-Industrial is a software framework and a worldwide open-source community. ROS-Industrial provides tools and libraries for the creation of intelligent industrial robots. Specifically, there are software components for 2D and 3D image recognition, motion planning, drivers for sensors and industrial manipulators, and several development and debugging tools. ROS-Industrial is based on the worldwide standard ROS (Robot Operating System).

Smart Agriculture

FIspace
FIspace is a SaaS cloud platform that can be extended by means of (1) adding functionality through Apps, (2) defining collaborative processes, (3) integrating data sources of users. FIspace is based on FIWARE Generic Enablers and has two particular extensions for business collaboration: the App Store and the Real-Time B2B collaboration core.

Robot-assisted movement[68]
This platform captures operators' positions and movements to design and build collaborative robots (cobots) to assist operators with job tasks, make manual task easier, improve operator precision and enhance their productivity. Activities have been developed in the field of agro-food factories. An example is embedded robots on machinery with integrated visual data control for high precision crop.

PRIMARE[69]
Public procurement of innovation initiative driven by the regional government of Galicia (Spain) for developing two platforms: 1) a data platform able to integrate and manage relevant data to monitor and control agrifood activity in Galicia, coming from different sensors (UAVs, IoT devices, other sensors); 2) a platform to process the data captured by the first platform to assist public agents in the management and decision making of the CAP (Common Agricultural Policy) subsidies. Development is expected to begin during 2017.

Tracciabilità e Big Data (Traceability and big data)[70]
The agri-food Sector of Friuli Venezia Giulia region needs a tool in the development of big data to share information related to agricultural and food production. The availability of a verifiable and shared set of information will satisfy regulations but will also offer many opportunities for agri-food companies. Regional food products will describe and narrate immediately and 'live' their story to consumers able to value them. Operators will be able to have stable and dedicated feedback to align productions to the needs of the market.

HortiCube[71]
The HortiCube platform is an infrastructure that enables secure access to market data and a variety of open data sources. It is being developed by Big T&U, a Public Private Partnership project in the Dutch horticulture. The platform incorporates structured transaction-oriented data sources, such as import/export data from stakeholders, and unstructured event-driven data sources, such as social media sources from consumers. These data sources are made accessible via linked data web-based mechanisms. As such, the Horticube platform enables big data analysis and app development over multiple combined data sources.

[67] http://rosindustrial.org, and also http://rosin-project.eu/
[68] http://www.cea-tech.fr/cea-tech
[69] https://amtega.xunta.gal/cpti
[70] http://www.regione.fvg.it/rafvg/cms/RAFVG/fondi-europei-fvg-internazionale/Strategia-specializzazione-intelligente/
[71] http://bigtu.nl/

Digital Transformation of Health and Care

CONNECARE: Self-management system for complex chronic patients[72]
The system supports patients in their daily-life activities to better follow-up and improvement of treatment and adherence as well as to their empowerment. The project works with the final users (professionals, formal and informal carers, as well as patients) to gather requirements and define functionalities. Main functionalities are: patient's monitoring (e.g., health status, activities, next tasks), interaction and communication between patient and professionals; and smart support to training, recommendations and alerts. The platform is a smart solution that gives the patient a self-management tool based on data provided by the patient her/himself as well as automatically gathered by a monitoring system. The solution will be completely personalised according to the patient profile.

eKauri[73]
eKauri is an ambient assistive living platform that integrates environmental and domotic sensors into a low-cost micro-architecture able to transmit the data remotely through wireless connection. The eKauri architecture is composed of a set of home automation (cheap, small, nonintrusive and wireless z-wave) sensors and actuators installed at the user's home. They continuously send retrieved data to a collector (based on Raspberry Pi) that collects all the retrieved data and securely redirects them to the cloud where they are be stored, processed, mined, and analysed. Intelligent monitoring in eKauri is aimed at continuously analysing and mining the data through 5-dimensions: detection of emergencies, activity recognition, event notifications, summary extraction, and rule triggering.

eKenku[74]
eKenku is an intelligent home monitoring and self-management system for chronic conditions, aimed at monitoring the user through selected medical devices and provide smart support to her/him. eKenku is currently in packaging and industrial validation phase while undergoing continuous testing in Hospital del Mar (21 patients with heart failure), in Hospital de Vic (5 patients with COPD and/or heart failure), and in Hospital de Mataró (13 patients with obesity). A user friendly mobile app lets the patients communicate, get notifications and alerts, and take own physiological measurements with simple devices connected through Bluetooth.

MyVitalink[75]
MyVitalink is a safe and user friendly mobile website that allows patients to access their health data stored on Vitalink, the health vault of the Flemish region. The data will only be accessible after a safe authentication. This can be seen as the first step towards a full Personal Health Record for each citizen in Flanders.

HealthSuite Digital Platform[76]
The HealthSuite Digital Platform (HSDP) forms the underpinnings of all informatics solutions for Philips HealthTech and beyond. This platform will be a vendor-agnostic, open ecosystem supporting applications spanning the consumer space, lifestyle coaching, behaviour modification, ambulatory care and healthcare domains. Rather than considering this a healthcare platform, one should view the HSDP as a dynamic patient/consumer modelling and management environment.

Luxembourg national eHealth digital platform[77]
The digital healthcare services platform is implemented in order to facilitate medical data sharing and exchange, including the implementation of the platform's main tool: the DSP (Dossier de Soins

[72] http://www.connecare.eu/
[73] https://www.ekauri.com/
[74] https://www.ekenku.com/?lang=en
[75] http://www.vitalink.be/
[76] https://www.usa.philips.com/healthcare/innovation/about-health-suite
[77] https://www.esante.lu/portal/fr/agence-esante/la-plateforme-esante-et-ses-services,394,425.html?

Partagé), the electronic health record. The ultimate goal of the implementation of the national eHealth services platform is to facilitate a seamless communication between healthcare professionals so as to enhance a better coordinated healthcare and a more comprehensive and efficient healthcare system. The overall aim is to put in place a user-friendly and technically optimised platform that complies with the relevant international standards, applies the highest possible data security measures and respects the data privacy laws.

Industrial Data Platforms

Industrial Data Space (IDS)[78]
The IDS is envisioned as a virtual data space using standards and common governance models to facilitate the secure exchange and easy linkage of data in business ecosystems. It is therefore less of a platform in the conventional sense, but more of set of standards, models and best practices (e.g. reference architecture, open-source implementation, white paper) to connect existing platforms that function and are managed independently. A central authority for data management is therefore not required. In this manner, the IDS provides a basis for creating and using smart services and innovative business processes, while at the same time ensuring digital sovereignty of data owners. The IDS is driven by the users, rather than the industry (although they might be data owners in the space).

CIMEC: New generation of Cyber Physical Systems for productivity increase in high added value industrial sectors[79]
CIMEC project aims to develop a set of solutions integrating Cyber Physical System form monitoring and improving mechanization processes for high added value products, such as windmills blades. Moreover a Data analytics platform will be designed to extract all the knowledge from the production data with the aim to improve the production process.

openEASE[80]
openEASE is a web-based knowledge service providing robot and human activity data. It contains semantically annotated data of manipulation actions, including the environment the agent is acting in, the objects it manipulates, the task it performs, and the behaviour it generates. It allows reasoning about the data and retrieving requested information based on semantic queries. Based on the data and using the inference tools robots can answer queries regarding to what they did, why, how, what happened, and what they saw. openEASE can be used by humans using a browser-based query and visualization interface, but also remotely by robots via a WebSocket API. Compared to attempts and initiatives from Google, Amazon etc. which collect all knowledge of robots in closed knowledge bases, openEASE is a 'democratised' initiative which becomes richer the more partners participate. It could be the model for a European platform; to this end, it may require some additional work to be more versatile.

Other

Another example in the automotive sector is AUTOSAR[81]. In that sector, leading OEMs and Tier 1 suppliers work together to create a development base for industry collaboration on basic electrical/electronic functions while providing a platform which continues to encourage competition on innovative functions. To this end a development partnership called Automotive Open System Architecture (AUTOSAR) has been formed. It aims to create and establish an open and standardised software architecture for automotive electronic control units excluding infotainment[82]. The AUTOSAR standard will serve as a platform upon which future vehicle applications will be implemented.

[78] http://www.industrialdataspace.org/en/
[79] https://eurecat.org/en/portfolio-items/cimec/?portfolioCats=138
[80] http://www.open-ease.org/
[81] http://www.autosar.org/
[82] https://en.wikipedia.org/wiki/AUTOSAR

Openair5GLAB[83]
Openair5GLAB provides truly open-source solutions for prototyping 5th Generation Mobile Networks and devices. To develop ecosystem for open source software/hardware development for the core network (EPC) and both access network and user equipment (EUTRAN) of 3GPP cellular networks.

A.3 Large-scale piloting

Vanguard Pilot Projects[84]
The Vanguard Initiative is supported by political commitments made by some EU regions to define their smart specialization strategies to promote new growth through bottom-up entrepreneurial innovation and industrial renewal in European priority areas. The Initiative is pioneering a new approach to support EU industry internationalisation and competitiveness by bringing regions (and clusters) together, with the objective to create "inter-regional smart specialisation platforms". The "VI methodology" consists of four subsequent phases: learn, connect, demonstrate and commercialise. The methodology is being tested through five pilot projects: three "1st generation pilots" (initiated in the Summer 2014) in the areas of 'high-performance production through 3D printing' (3DP), 'efficient and sustainable manufacturing' (ESM), and 'advanced manufacturing for energy-related applications in harsh environments' (Energy); and two "2nd generation pilots" (initiated in June 2015) in the areas of 'bio-economy' (Bio) and 'nanotechnology' (Nano).

Connected Smart Factories

Vendor-independent Industry 4.0 production line[85]
The vendor-independent Industry 4.0 production line is a pilot for demonstration and research on Industry 4.0 topics. It was first time presented at Hannover Fair 2013 (Germany) and shows how to realize Industry 4.0 paradigms as modularity and digitisation in a vendor-independent way by using existing and future technology.

Large 4.0 investments initiative[86]
The "Large 4.0 investments initiative" is a public initiative driven by the government of Galicia (Spain) to fund large-scale R&D projects in the domain of connected smart factories, with a budget of at least 20 M€. Eligible proposals must fulfil four conditions: 1) be aimed at building a new industrial model fully aligned with the concepts of smart, connected factories 4.0, in line with challenge #2 of the Galician RIS3 strategy; 2) be aligned with the strategic economic Galician sectors, with high impact potential in the full value chain; 3) be challenging from the R&D&I point of view.

PressNozz: AI-based modelling for production optimization based on an enriched data acquisition method[87]
Sensor-based technologies have become very popular in the past years as they add great value for process monitoring to Plastic Injection Moulding (PIM) industry and allow plastic converters to fulfil the high demanding market requirements in sectors of application such as medical, automotive, packaging and electronics. PressNozz provides a novel Cyber Physical System-based predictive system aiming at optimizing the production process and outperform current process control solutions allowing a reduction of scrap and energy consumption and an increase of productivity and flexibility. The PressNozz solution combines process monitoring sensors and advanced AI techniques to obtain accurate information about the process evolution and performances.

[83] http://openairinterface.eurecom.fr/
[84] http://www.s3vanguardinitiative.eu/pilotinitiatives
[85] http://dfki-3036.dfki.de/EN/industrie40_e.php
[86] http://gain.xunta.gal/artigos/62/captacion+inversiones+industria+4
[87] https://polimi.wixsite.com/beincpps/copia-di-experiments

Anella Industrial 4.0 (AI4.0)[88]
The "Anella Industrial 4.0" (AI4.0) project aims at providing advanced digital services to a wide range of industrial sectors and users. The AI4.0 is a project sponsored by the Catalan Government and is executed by Eurecat and i2CAT. First users are within the automotive Industry, but the aim is to include other strategic industrial sectors. AI4.0 consists of two main elements: the first is the AI4.0 portal (a service marketplace), where services/tools are presented and offered to the users community. These services may come from 3rd parties, considered as providers, or ad-hoc services coming mainly as results of research projects. The second element is the Service Orchestrator. This will allow the creation and execution of complex services.

Pilot Digital and Virtual Factory integrating planning and simulation into operative environment[89]
The Pilot Digital and Virtual Factory is designed over a geographical configuration of regions which define a network that covers as widely as possible the entire digital and virtual factory concept and framework. The Catalan participation is through the AI4.0 project. Results of the demonstration pilots to be developed within the AI4.0 project can also be part of the expected outcomes of Vanguard Initiative's Digital and Virtual Factory Pilot.

The Advanced Sustainable Surface & Coating Manufacturing Technologies on Polymer materials[89]
The pilot on Advanced Sustainable Surface & Coating Technologies on Polymers is oriented to pilot industrial plants and demonstrators on Functional Plastics by Surface Texturing, Advanced Coatings and Printed Electronic integration. Different regions such as Lombardy (IT), Nord-Pas de Calais & Rhone-Alps (FR) support this initiative. Eurecat links several Catalan entities (ICN2, Flubetech, Microrelleus…) towards this initiative.

ERICA: Establishing Regional Cluster Agreement for sharing good practices in Advanced Manufacturing[90]
The main objective of ERICA is to establish interregional strategic cooperation procedures among clusters and related technology centres for sharing good practices in Advanced Manufacturing in order to foster regional growth, both economic and employment, between Catalonia, Lombardy, Nord-Pas de Calais and South Netherlands. This pilot project will define a collaboration framework through a Strategic Partnership Agreement between the participating regions focused on one of their smart specialisation strategies, Advanced Manufacturing, and specifically in Efficient and Sustainable Manufacturing (ESM). ERICA will target the whole industry but will focus its attention on production systems and machinery as enablers of ESM deployment.

PREVIEW: PREdictiVe system to recommend Injection mold sEtup in Wireless sensor networks[91]
The PREVIEW project aims to develop a Cyber Physical System (CPS) for plastic injection manufacturing processes monitoring, control and optimization by incorporating several innovative and cutting edge technological solutions: advanced Artificial Intelligence and Machine Learning techniques, robust Industrial wireless communication, Internet of Things (IoT) and wireless indoor localization. PREVIEW is a middleware solution that facilitates easy, ubiquitous, holistic and fast sharing of product and process information across the entire injection production process. Demonstrations of the technologies involved are performed during the project in different pilot sites.

[88] http://anellaindustrial.cat/
[89] http://www.s3vanguardinitiative.eu/cooperations/efficient-and-sustainable-manufacturing-esm
[90] http://erica-project.eu/
[91] http://www.preview-project.eu/

Smart Agriculture

Internet of Food and Farm 2020 (IoF2020)[92]
The Internet of Food & Farm (IoF2020) consortium investigates and fosters a large-scale implementation of Internet of Things in the European farming and food domain. The project builds around 5 trials, in the areas of fruit, vegetables, meat, arable and dairy, with 19 use cases. In these use cases technology readiness levels of IoT technologies will be upgraded, whilst at the same time building a societal ecosystem to improve take-up of these technologies.

AgriTech Big Data Platform[93]
The main objectives include: evaluation of data that can be obtained from the food industry at all levels to develop tools that enable analysis and decision making to practical problems; improve efficiency and productivity of processes through an appropriate analysis of the data, with emphasis on the analysis of real time, and making use of state of the art technologies like IoT and BigData. The role of Big Data techniques in the agrifood sector was determined. Proof of concept projects and big projects, in collaboration with agrifood companies, local administrations, etc., were identified.

Fruit 4.0[94]
Fruit 4.0 is a public private partnership project on high tech sensing and data management for orchard management in the Dutch fruit industry. It aims to improve fruit quality, sustainability and efficiency in fruit supply chains by better cultivation and management information. The project includes use cases on blossom monitoring for location-specific pruning, on crop growth monitoring for better harvest planning and quality management and on the usage of information from sorting machined for orchard management optimization.

DATA-FAIR[95]
DATA-FAIR aims to enhance data sharing in the Dutch agriculture by creating a viable and open software and data ecosystem. The project conducts large-scale trials in different application areas, including credit assessment, risk management, slaughtering information, compliance to sustainability certificates, agricultural contractor information and soil management.

Pilot Project of Fraunhofer Society Germany in cooperation with State Country of Saxony developing digital technologies in Smart Farming
No information provided.

Digital Transformation of Health and Care

VINCLES[96]
Vincles is a social innovation project that aims to tackle a social problem in an innovative way. From an innovation perspective it is important to test the service, so it can be adjusted and corrected if necessary. The purpose of the pilot test is to tailor the service, technology and care to the elderly people who use it, to social reality in Barcelona, and to see how it might be sustained and eventually cover the whole city. Between November 2016 and June 2017 the first stage of the test was carried out with 400 residents in 5 Barcelona neighbourhoods. Between July and December 2017, the service is expanded to 10 neighbourhoods.

[92] https://www.iof2020.eu/
[93] https://eurecat.org/es/conveni-udl-eurecat/
[94] http://tuinbouwdigitaal.net/nl-nl/Projecten/Tuinbouw-Digitaal-projecten/ArtMID/6272/ArticleID/49/Fruit-40
[95] http://www.wur.nl/nl/nieuws/DATA-FAIR-agri-food-data-delen-voor-nieuwe-business-op-voorwaarden-van-ondernemer.htm
[96] http://ajuntament.barcelona.cat/vinclesbcn/en

Industrial Data Platforms

Exploiting mobile phone data for statistical and commercial purposes
This joint project of Statistics Belgium, Proximus, Eurostat, and JRC explores the information content of mobile phone data for statistical and commercial exploitation in the domains of population, migration, mobility, tourism, transport, retail trade, time use[97].

TeraLab[98]
Teralab is a platform for big data analytics research and experimentation, open to collaborative projects, education, and industrial pilots. The infrastructure at TeraLab involves software, hardware and cutting-edge solutions dedicated to data analysis. It enables batch or real-time processing of hundreds of terabytes of usable data (excluding replication and compression).

Mo3Dlling: Intelligent monitoring and visualization of injection process and smart moulds[99]
Mo3Dlling project optimizes and implements expert models based on machine learning techniques for analysing the real-time mould performance based on in-cavity sensor data, encoding and projecting it into a clustered 3D space for fast and easy process control, monitoring and part quality classification. Moreover, Mo3Dlling covers the entire sensorization value chain by offering recommendations on the best locations within the cavity, driven by a 3D analysis of the uploaded melt flow simulations results. This information is visualized by operators through an intuitive front-end based on 3D cloud of points and clustering visualization.

Piloting Industrial Data Space in Smart Industry Fieldlabs[100]
V1.0 is on data exchange with security and sovereignty requirements (e.g. sensor data is not copyright protected), V2.0 is planned to include blockchain (in the IDS connector architecture blockchain channels are expected to be included). SME are frustrated by the demands from OEMs to have a dedicated interface to each OEM for the interchange of product data, orders, etc. Today still a lot is done by email, fax and dedicated software products the SME has to install to be able to serve the OEM. In this fieldlab 20 SMEs are combined to enforce OEMs to shift to standards on industrial data exchange, in particular following European developments as in the Industrial Data Space.

Internet of Things

IoT Large-scale Pilots under the 2016 Internet of Things Focus Area (IoT-01-2016)[101]
Relevant ongoing initiatives at EU level include the set of Large-scale Pilots called for under the Internet of Things Focus Area in 2016 (IoT-01-2016). These pilots address the challenge to foster the deployment of IoT solutions in Europe through integration of advanced IoT technologies across the value chain, demonstration of multiple IoT applications at scale and in a usage context, and as close as possible to operational conditions. The pilots are targeted, goal driven initiatives that propose IoT approaches to specific real-life industrial/societal challenges. There are currently five pilots active:

1. Smart living environments for ageing well, project ACTIVAGE (EU contribution up to 20 MEuro)
2. Smart Farming and Food Security, project IoF2020 (30 MEuro)
3. Wearables for smart ecosystems, project MONICA (15 MEuro)
4. Reference zones in EU cities, project SynchroniCity (15 MEuro)
5. Autonomous vehicles in a connected environment, project AUTOPILOT (20 MEuro)

[97] See https://ec.europa.eu/eurostat/cros/content/assessing-quality-mobile-phone-data-source-statistics_en, and https://webgate.ec.europa.eu/fpfis/mwikis/essnetbigdata/index.php/WP5_Documentation
[98] https://www.teralab-datascience.fr/en/#
[99] https://polimi.wixsite.com/beincpps/copia-di-experiments
[100] http://www.industrialdataspace.org/ and www.smartindustry.nl
[101] https://european-iot-pilots.eu/

SmartGrids_CTM: Integration of renewable energy sources to smart grids[102]
The pilot of integration of renewables has a micro-net with maximum power of three-phase 18kVA. The lab has a series of market tools combined with experimental ones, which allows the use, monitoring and management of the entire system as well as the execution of control actions, based on different operating strategies.

Other

Pilot lines in nanotechnology and advanced materials[103]
Recent calls for proposals for pilot action projects in the nanotechnology and advanced materials areas in Horizon 2020 and FP7 have resulted in 30 projects with a combined funding of EURO 150 Million. Most of the pilot projects have the objective to help transferring new technology into industry by providing open access for upscaling and pilot testing to SME users. Additional investments by Member states, public or private organisations have contributed to establishing a variety of pilot upscaling facilities across Europe, mainly in the EU-15 countries.

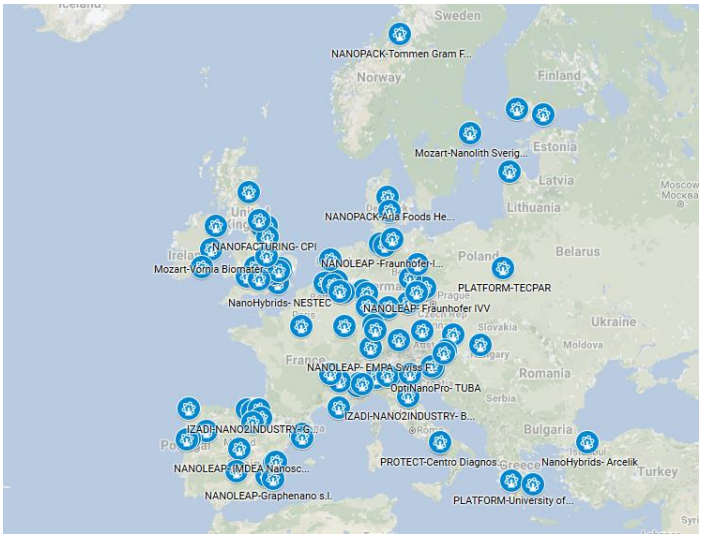

Figure 18 Pilot lines in nanotechnology and advanced materials

Figure 18 shows the location of 107 pilots, which use different raw materials, processes and products etc. The products address diverse sectors and markets, from automotive, aerospace, defence, energy storage, construction industry to cosmetics, health and packaging.

The European Pilot Production Network (EPPN) supports the exploitation of existing European pilot line production facilities across Europe in the area of nanotechnology and advanced material technologies by creating a network of fully connected and collaborating pilot lines. It boosts the effectiveness and the efficiency of existing (and future) pilot line facilities.

As part of the NMBP Work Programme 2018-20, the European Commission is planning to launch several calls for proposals on pilot lines.

A.4 Testbeds

Labs Network Industrie 4.0 is an example of a network of manufacturing testbeds in Germany[104]. Networking the numerous testbeds enables distributed production and application processes to be

[102] http://www.ctm.com.es/en/ctm-technological-services-development.php
[103] http://eppn.eu/eppn

simulated across several test environments. Labs Network Industrie 4.0 was founded in Germany as a one-stop shop for the coordination of the different approaches. It supports companies in the initiation of Industrie 4.0 projects, pools results from the testbeds, and forwards them to relevant standardisation and international cooperation bodies.

An example of a testbed is ARENA2036 – Active Research Environment for the Next Generation of Automobiles. The ARENA2036 research campus is a bridge between research and development in the field of lightweight construction and innovative production technologies. All activities of the ARENA2036 research campus are systematically combined in a "research factory". In the "research factory", the results of the development and construction research as well as the simulation can be tested immediately.[105] Digital manufacturing platforms could be implemented and validated in the research factory.

Connected Smart Factories

Testbed for cognitive autonomous work systems for human centered manufacturing in Industry4.0[106]
The testbed researches innovative approaches for the smart integration of human operators in ever more automated manufacturing systems. The focus of the research lies on topics such as safe human-robot-collaboration, sensors and perception capabilities for robots, cognitive and ergonomic assistance systems for human operators, consequent and consistent use of digital data as well as context sensitive provision of data through assistant systems in all lifecycle steps of production systems.

SmartFactoryKL[107]
SmartFactoryKL is a vendor-independent network of about 45 companies from large industry (e.g. Bosch, IBM, SAP) to SMEs. Objective is the transformation of Industry 4.0 from research into application. The SmartFactoryKL testbed has 7 demonstrators showing Industry 4.0-related topics. Examples are Cyber-Physical Systems, modularity, horizontal and vertical integration, digitisation from field-device to IT-system, Augmented Reality, and Virtual Reality. The demonstrators are the results of numerous research projects and activities within the SmartFactoryKL partner network. In several events, insights and hands-on-demonstrations is given especially to SMEs to show how companies can benefit from modern ICT and automation technology.

FactoryLab[108]
The FactoryLab platform aims to federate an affiliate program to accelerate the uptake of innovative digital and robotics technologies by industry, focusing on 4 areas and setting up technology demonstrators (TRL 6-7) to cover industrial needs in the following areas: flexible digital factory; physical assistance to workers; cognitive assistance to operators; and process and control automation.

FFLOR : Future Factory@LORraine[109]
Open, collaborative platform and pilot line located at the heart of the PSA Tremery motor factory. The platform consists of a testbed and pilot line for flexible, modular factories. Apart from a reconfigurable pilot line to bring new concepts together, the FFLOR platform serves as a testbed for flexible human-robot collaboration and flexible hardware and software equipment for industrial partners. It relies on an open architecture compatible with RAMI4.0 standards to achieve compatibility and easy reconfiguration for new use cases, e.g. furniture industry, automotive, heavy industries, etc.

[104] http://www.plattform-i40.de/I40/Navigation/EN/InPractice/Testbeds/testbeds.html
[105] http://www.arena2036.de/de/arena2036/inhalte-und-ziele
[106] http://www.iff.fraunhofer.de/
[107] http://www.smartfactory.de/
[108] http://www.cea.fr/presse/Documents/DP/2016/dossier-presse-inauguration-factory-lab.pdf
[109] http://www.cea-tech.fr/cea-tech/Pages/en-regions/pfa-usine-du-futur.aspx

VIRTUREAL[110]
In the disciplines of Additive Manufacturing and Rapid Product Development, the VirtuReal® hub/lab includes the equipment of three organisations (GIP-InSIC, CIRTES SRC, and PFI INORI SAS) for a total of 8,000 m². These entities provide businesses with complementary training, research, R&D, technology transfer, valorisation, dissemination, and assistance for the transition from R&D to industrialization. The lab owns digital tools, such as CAD, simulation tools, Virtual Reality (VR), digitisation, Additive Manufacturing, and subtractive manufacturing.

Plataforma Industrial 4.0[111]
Plataforma Industrial 4.0 (PI4.0) is a cloud platform for industry to innovate and experiment. It is provided as an experimental environment to SMEs to test and validate solutions in the cloud. Three types of activities are offered to customers: a) an Industry 4.0 experimental services laboratory that works in distributed clouds, b) "from experiment to services" where customers may deploy the solution in their facilities to manage the Marketplace for their clients or to manage an OpenStack implementation for cloud management, and c) several accelerating services for Industry4.0 adoption by SMEs.

Smart Agriculture

Dutch National Testbed Precision Agriculture (Nationale Proeftuin Precisielandbouw)[112]
The objective of the national testbed for precision agriculture is (1) to support existing, regional initiatives on precision agriculture, (2) stimulate knowledge sharing and (3) create additional facilities that would be useful for the entire precision agriculture sector. The testbed is expected to be ready mid 2017 after an exploratory study.

Simulareg[113]
Simulareg is an open training tool for farmers, irrigation technicians, experts and everyone who wants to expand their knowledge. The aim of the simulator is educational and it provides a test environment to check the behaviour of a crop or a virtual plot in relation to a specific irrigation schedule. Simulareg is based in an expert system that simulates, in a virtual crop, the irrigation schedules proposed by users.

Digital Transformation of Health and Care

The Experiment'HAAL Living Lab[114]
IMT has funded the creation of the Experiment'HAAL evaluation laboratory (a living lab of 50m²) that hosts and serves as a demonstrator of several projects. The Experiment'Haal laboratory (Human Ambient Assisted Living) promotes a multidisciplinary approach to develop and to host experimental assistive devices with the aim of tests of use. It allows testing in-situ services developed in its projects prior to their deployment in real situations.

Industrial Data Platforms

IPCEI on HPC and Big Data enabled applications[115]
Luxembourg launched together with France, Italy and Spain an Important Project of Common European Interest (IPCEI) on HPC and Big Data enabled applications. In the framework of this IPCEI a number of large scale Big Data testbeds are foreseen to be realized in the coming years. Examples

[110] http://inori.fr/images/VIRTUREAL.pdf
[111] http://plataformai40.com/
[112] https://www.rijksoverheid.nl/actueel/nieuws/2017/02/13/staatssecretaris-van-dam-kondigt-nationale-proeftuin-precisielandbouw-aan
[113] http://www.ies-sim.com/
[114] https://departements.telecom-bretagne.eu/info/recherche/ihsev/experiment-haal/
[115] https://ec.europa.eu/commission/commissioners/2014-2019/oettinger/blog/luxembourg-launches-supercomputing-project_en

are: Smart Space, Smart City, Smart Mobility, Industry 4.0, Personalized Medicine and others. The objective is to demonstrate the benefit that HPC and Big Data Applications can bring to industry to accelerate their innovation cycles, to develop a European digital industry; e.g. developing European IoT devices, hard- and software applications.

Big Data Centre of Excellence Barcelona (Big Data CoE BCN)[116]
The Big Data Centre of Excellence Barcelona is an initiative led by Eurecat Technology Centre with the support of Oracle, the Government of Catalonia and Barcelona City Council. It builds, develops and connects exclusive Big Data knowledge, tools, datasets and infrastructure, and makes them available to companies, enabling them to experience Big Data models and evaluate the impact on their business. It provides innovative solutions in a collaborative environment with key industry players.

Internet of Things

FIT[117]
FIT is an open large-scale testing infrastructure for systems and applications on wireless and sensor communications. FIT offers a federation of several independent experimental testbeds to provide a larger-scale, more diverse and higher-performance platform for accomplishing advanced experiments. Through its IoT-LAB testbeds, the FIT project will provide a very large-scale infrastructure suitable for testing heterogeneous embedded communicating objects of all sorts.

Smart Objects & IoT Platform Lab[118]
Platform for conducting testing of technologies and interoperability testing in IoT related areas among different sectors. The Smart Objects & IoT Platform Lab includes scientific equipment for tests and trials (Lab test as a service), including industrial and electronics setups and instruments. Areas of specialization are: Smart Objects; IoT – IoS – CPS; Data Acquisition Systems; Open Electronics; Industry 4.0, resource management (Water- Energy-Work Force); Agriculture, Food, Manufacturing Industries, Smart Cities, Environment; and control prototyping, machine monitoring and control systems.

Other

Open Innovation Test Beds[119]
As part of the NMBP Work Programme 2018-20, the European Commission is planning to launch several calls for proposals on Open Innovation Test Beds. These test beds aim to bring nanotechnology and advanced materials within the reach of companies and users in order to advance from validation in a laboratory (TRL 4) to prototypes in industrial environments (TRL 7). The test beds are physical facilities that offer technology access and services, and will allow European industry and SMEs to develop leadership in nanotechnologies and advanced materials across the whole value chain. This should be achieved by developing new or upgrading existing facilities, both private and public, and making them accessible to users for the development, testing and upscaling of nanotechnologies and advanced materials in industrial environments. An Open Innovation Test Bed will also set up complementary networked services that will allow to share experiments, and knowledge and offer a single entry point. It is likely that in 2018-19, over 100 MEuro will be dedicated to Open Innovation Test Beds.

[116] https://www.bigdatabcn.com/en/
[117] https://fit-equipex.fr/
[118] https://eurecat.org/ambits-de-coneixement/smart-management-systems/, https://eurecat.org/eurecat-maqcentre-lleida/, and https://eurecat.org/conveni-udl-eurecat/
[119] Please refer to the upcoming Horizon 2020 LEIT-NMBP Work Programme 2018-20, to be published in October 2017.

A.5 Major European projects/programmes

Programme	Projects	Objective	Stakeholder type	Public funding
Connected Smart Factories				
Factories of the Future	FoF-11[i] - automation	Reference implementations of platforms	Technology Providers Users	55 M€
ECSEL JU	ARROWHEAD[ii] - automation	Low-cost, service-oriented middleware for industry automation	80 partners users: Production, infrastructures, Electro mobility, Energy production	30 M€
ECSEL JU	Productive40[iii] - supply chain	Create systems for planning, virtualising and controlling of - Supply Chain - Product Life Cycle	120 partner Techn. Providers Users from electronics, automotive, construction	57 M€
Digital health & care				
IoT Large-scale Pilots	ACTIVAGE[iv] - cloud services - SC co-financing	Activate smart living environments for ageing well	Telco and IT services, electronics, system integrators	20 M€
CONNECT Societal Challenges	UNIVERSAAL[v] - development tool for medical services	open platform for Ambient Assisted Living	IT services, system integrators	10 M€
Big Data Value PPP	AEGLE[vi] - personalised services	Multi-parametric platform for data analytics on biological data	System integrators, health industry, IT systems	5 M€
Future Internet PPP	FI-STAR[vii] - cloud services	Predecessor of ACTIVAGE		13 M€
Smart agriculture				
IoT Large-scale Pilots	IOF2020[viii] - cloud services - AGRI co-financing	Build a platform of cloud based App-like services for agriculture industry	Telco providers, electronics, user industry	30 M€
Big Data Value PPP	DATABIO[ix] - satellite data in agriculture	Optimise production with data analytics in agriculture, forestry and fishery/aquaculture	Communication and IT services, user from bio-economy (farming, fishing, forestry)	Tbd
Future Internet PPP	FIspace[x] - cloud services	Predecessor of IOF2020		13 M€
Connected automated driving				
IoT Large-scale Pilots	AUTOPILOT[xi] - services for connected cars	Facilitate automated driving with connectivity	Automotive OEMs, IT and navigation services	20 M€
CONNECT Societal Challenges	SCOUT[xii] - 4G connectivity			
Big Data Value PPP	AUTOMAT[xiii] - Vehicle Data Services	open ecosystem for vehicle Big Data	Automotive OEMs, IT and navigation services	5 M€
ECSEL JU	ENABLE-S3[xiv] - ADAS systems	Interoperability platfoms for engineering of automotive electronic control units	Automotive suppliers, software tool vendors Automotive OEMs, IT services	32 M€
ECSEL JU	CRYSTAL[xv] - AUTOSAR	Interoperability platfoms for engineering of automotive electronic control units	Automotive suppliers, software tool vendors Automotive OEMs, IT services	35 M€
RTD/MOVE Societal Challenges	CARTRE[xvi] - WIFI connectivity	Coordination of Automated Road Transport Deployment for Europe	Automotive OEMs, tier 1 suppliers, IT services	3 M€

[i] http://www.effra.eu/project-cluster
[ii] https://artemis-ia.eu/project/49-arrowhead.html

[iii] http://productive40.eu/
[iv] http://www.activageproject.eu/
[v] http://universaal.sintef9013.com/index.php/en/
[vi] http://www.aegle-uhealth.eu/en/
[vii] https://www.fi-star.eu/fi-star.html
[viii] https://www.iof2020.eu/
[ix] https://www.databio.eu/en/
[x] https://www.fispace.eu/
[xi] http://autopilot-project.eu/
[xii] http://connectedautomateddriving.eu/about-us/scout/
[xiii] http://www.automat-project.eu/
[xiv] http://www.enable-s3.eu/
[xv] https://artemis-ia.eu/project/46-crystal.html
[xvi] http://connectedautomateddriving.eu/about-us/cartre/