2016 Multi Annual Strategic Research and Innovation Agenda for ECSEL Joint Undertaking

ECSEL Joint Undertaking

MASRIA 2016 as prepared by the ECSEL PMB

Aeneas

ARTEMIS Industry Association

EPoSS European Technology Platform on Smart Systems Integration

Table of Contents

1 Introduction 5
1.1 Vision, mission and strategy 5
1.2 Objectives 7
1.3 Relationship with other programmes 9
2 Roadmap 12
2.1 High-level goals 12
2.2 Strategic Thrusts 13
3 Making it happen 15
3.1 Research and development projects 16
3.2 Pilot lines and test beds 16
3.3 Demonstrators, innovation pilot projects and zones of full-scale testing 16
3.4 Multi-funding actions 17
3.5 KETs/ multiKETs 17
3.6 Excellence and competence centres 18
3.7 Innovation support actions 18
4 Financial perspectives 19
5 Project selection and monitoring 20
6 Strategic thrusts Part A: Key applications 21
6.1 Smart Mobility 21
6.1.1 Objectives 21
6.1.2 Strategy 21
6.1.3 Impact 22
6.1.4 Cross references 22
6.1.5 Schedules/Roadmaps 23
6.2 Smart Society 30
6.2.1 Objectives 30
6.2.2 Strategy 31
6.2.3 Impact 33
6.2.4 Cross references 34
6.2.5 Schedules/Roadmaps 35
6.3 Smart Energy 37
6.3.1 Objectives 37
6.3.2 Strategy 37
6.3.3 Impact 38
6.3.4 Cross references 40
6.3.5 Schedules/Roadmaps 42

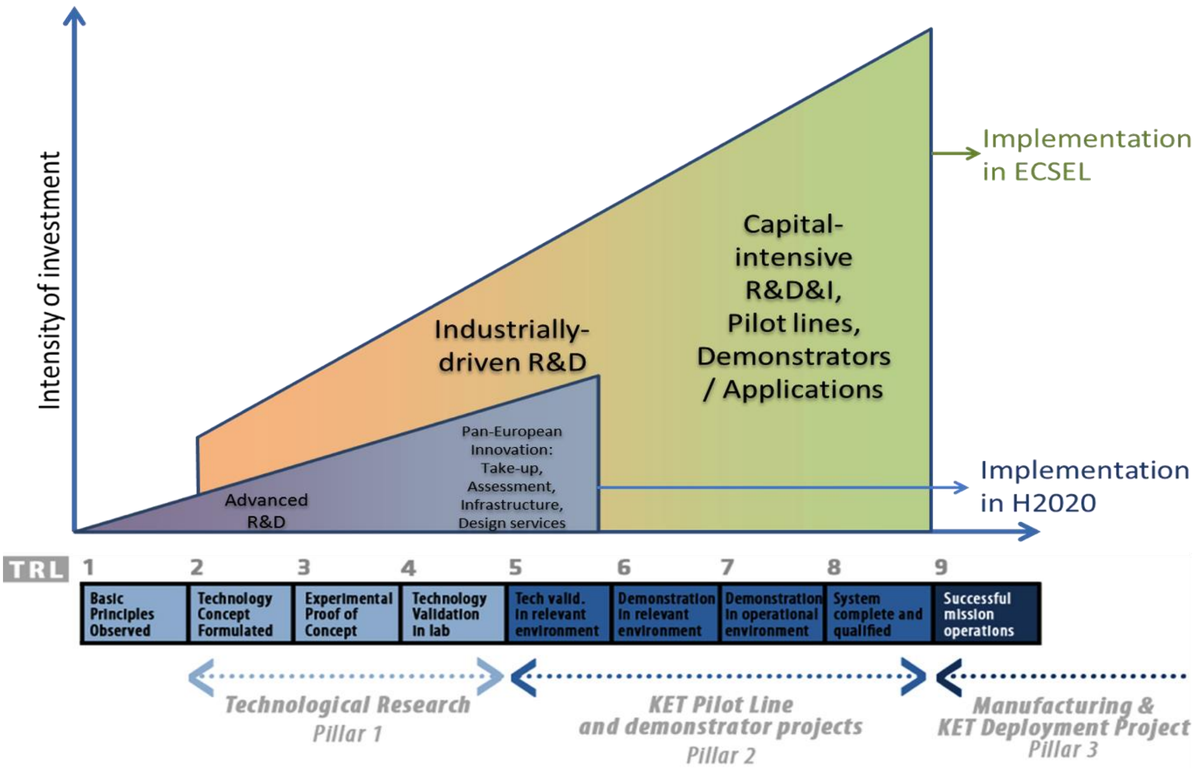
6.4 Smart Health ... 43
6.4.1 Objectives ... 43
6.4.2 Strategy ... 44
6.4.3 Impact ... 47
6.4.4 Technical challenges ... 48
6.4.5 Cross references ... 49
6.4.6 Schedules/Roadmaps ... 50
6.5 Smart Production ... 51
6.5.1 Objectives ... 51
6.5.2 Strategy ... 51
6.5.3 Impact and expected major achievements ... 55
6.5.4 Cross references ... 55
6.5.5 Schedules/Roadmaps ... 55
7 Strategic thrusts Part B: Essential technologies ... 59
7.1 Semiconductor Manufacturing, Technology, Equipment and Materials ... 59
7.1.1 Objectives: Semiconductor Manufacturing, Technology, Equipment and Materials ... 59
7.1.2 Strategy: Semiconductor Manufacturing, Technology, Equipment and Materials ... 59
7.1.3 Impact: Semiconductor Manufacturing, Technology, Equipment and Materials ... 60
7.1.4 Cross-references ... 60
7.1.5 Roadmaps: Semiconductor Manufacturing, Technology, Equipment and Materials ... 61
7.2 Design technology ... 64
7.2.1 Objectives ... 64
7.2.2 Strategy ... 65
7.2.3 Impact and main expected achievements ... 65
7.2.4 Cross references to other chapters ... 65
7.2.5 Schedules and Roadmaps ... 66
7.3 Cyber-Physical Systems ... 71
7.3.1 The Objectives ... 71
7.3.2 Strategy and Strategy implementation ... 72
7.3.3 Impact ... 76
7.3.4 Cross references ... 76
7.3.5 Schedules / Roadmaps ... 77
7.4 Smart Systems Integration ... 78
7.4.1 Objectives ... 78
7.4.2 Strategy ... 79
7.4.3 Impact ... 79
7.4.4 Cross references ... 79
7.4.5 Schedules/Roadmaps ... 80

Part C: Relevant Annexes 83
8 ANNEXES 84
8.1 Annex to A1: Smart Mobility 84
8.2 Annex to A2: Smart Society 84
8.3 Annex to A3: Smart Energy 86
8.4 Annex to A4: Smart Health 87
8.5 Annex to A5: Smart Production 90
8.6 Annex to B1: Semiconductor Manufacturing and Technology 91
8.6.1 Semiconductor Manufacturing 91
8.6.2 Semiconductor Processes, Equipment, and Materials 91
8.7 Annex to B2: Design Technology 94
8.8 Annex to B3: Cyber-Physical Systems 94
8.9 Annex to B4: Smart Systems Integration 94
9 Contributors 95

1 Introduction

This 2016 ECSEL Multi Annual Strategic Research and Innovation Agenda (MASRIA), on behalf of the ECSEL Private Members Board (PMB), serves as input/recommendation for the 20156 Multi-Annual Strategic Plan (MASP) of the ECSEL Joint Undertaking. This MASRIA describes the Vision, Mission and Strategy of the ECSEL JU as well as the strategic research and innovation activities (in its Parts A and B) to be undertaken through the ECSEL-Calls of coming years in order to enable the ECSEL JU to fulfil its objectives.

The MASRIA identifies and explores specific Electronic Components and Systems (ECS) technology solutions for smart applications relevant for societal challenges and industrial leadership in Europe. In order to maximise the impact of the programme, ECSEL JU will generally have its centre of gravity around larger projects, e.g., over 10 million euro, addressing higher Technology Readiness Levels (TRLs). However, this does not preclude smaller projects and/or projects addressing lower TRL's that focus on topics with strong industrial support. In this way, the ECSEL JU agenda complements other PPPs as well as generic actions within the overall Horizon 2020 program (see the diagram below, courtesy of the European Commission).



The MASP, which is based on the MASRIA, provides the basis for the Work Plan of the ECSEL JU, where the selection of the activities and the type of actions to be initiated per year/Call is made in accordance with the funding budget available.

1.1 Vision, mission and strategy

The European Electronics Components and Systems (ECS) industries and knowledge institutes share a common vision, mission and strategy at the highest level based on the Vision, Mission and

Strategy as published in the High Level SRIA of the ICT Components and Systems Industries in 2012[1].

The **vision** driving the ECS industries and knowledge institutes is one of mankind benefiting from a major evolution in intelligent systems, a world in which all systems, machines and objects become smart, exploit relevant information and services around them, communicate which each other, with the environment and with people, and manage their resources autonomously. Furthermore, the vision is to provide Europe, in a concerted approach, with the controlled access for creating the indispensable technology basis for the above as an essential element in a smart, sustainable and inclusive European 2020 society.

The **mission** of the ECS industries and knowledge institutes is to progress and remain at the forefront of state-of-the-art innovation in the development of highly reliable complex systems and their further miniaturisation and integration, while dramatically increasing functionalities and thus enabling solutions for societal needs.

The **strategy** of the ECS industries and knowledge institutes is based upon exploitation of European strengths and opportunities. Exploiting strengths implies building on the leading positions in specific capabilities, technologies and/or applications by increasing industry effectiveness and reducing fragmentation. Creating opportunities implies for Europe to be positioned at the forefront of new emerging markets with high potential growth rates and to become a world leader in these domains. Innovation is a key point for the strategy. It is propelled by efficient transnational ecosystems of industry, institutes, universities and public authorities.

In exploiting strengths and opportunities both supply of and demand for technologies need to be boosted simultaneously and in a balanced way. A strong supply will make Europe competitive and it will ensure its controlled access to technologies essential for the implementation of the vision. On the other hand concerted contributions to a smart, sustainable and inclusive European society will create a strong demand for these technologies.

Innovations are essential in all market segments where Europe is a recognized global leader or has the opportunity to become one. Stepping up R&D&I in ECS applications and technologies is a key enabler for sustainable European economic growth and wealth creation. For all these reasons, it is vital that judicious investments are made to assure Europe of access to ECS know-how and to industrial capacities to guarantee strategic independence in the face of increased globalisation.

Opportunities for large projects, exploiting our strengths in embedded software and systems know-how exist. Such projects exploit the opportunities offered by ECSEL in value chain integration and will lead to increased global demand for ECS related technologies.

The ECS domain is enabled by the key technologies micro/nano-electronics, embedded/cyber-physical systems, and smart/microsystems. In Europe, these technologies drive a value chain that employs over 9 million people including services[2] of which over 1 million direct and induced jobs in

---

[1] High Level Strategic Research and Innovation Agenda of the ICT Components and Systems Industries as represented by AENEAS (ENIAC-ETP), ARTEMIS-IA (ARTEMIS-ETP) and EPoSS-ETP, April 2012

[2] ITEA/ARTEMIS-IA High-Level Vision 2030, version 2013

the semiconductor industry[3] .Together, they allow Europe to address a global market of more than 2,600 billion $[2] enabling the generation of at least 10% of GDP in the world[3]

The ECSEL JU strategy endorses and supports the vision, mission and strategy of the ECS industries and knowledge institutes. In executing its strategy, ECSEL builds on the experience of successful European initiatives of the ENIAC JU, the ARTEMIS JU and the European Technology Platform (ETP) EPoSS addressing micro/nano-electronics, embedded/cyber-physical systems and smart/microsystems respectively. By consolidating these disciplines along the innovation and value creation chain, ECSEL offers a unique way forward to the next level of ECS know-how, for the best benefit of the European industries and citizens alike.

The ECSEL strategy includes the following essential features:

1) ECSEL is the instrument of preference for implementing the R&D&I aspects of the ELG strategy[3]. It will extend this strategy where needed to ensure coverage of the complete ECS value chain.
2) The ECSEL actions will focus on European strengths and opportunities. Its innovation actions will continuously boost supply and demand in a balanced way. ECSEL enables here an accelerated innovation because the total ECS value chain is included.
3) Whilst emphasizing large projects at higher TRL level, ECSEL will address industrially relevant projects of any size at TRL 2-8 by engaging the whole ecosystem, including large, medium and small enterprises, and knowledge institutes, from countries and regions both more and less developed.
4) ECSEL will pursue a defined agenda and complement it by mechanisms capable to update the overall strategy when necessary to respond swiftly to future societal evolutions and to enhance the global competitiveness of this fast moving industry. It will combine the dynamism and agility to respond to unexpected market developments of an open, “bottom-up” approach to participating R&D&I actors, with the rigour of a “top-down” defined, strategic framework approach connected with high-level societal and economic ambitions.

1.2 Objectives

The objectives of the ECSEL JU are listed in the Article 2 of its basic act, paraphrased here:

1) Contribute to the implementation of Horizon 2020, and in particular to LEADERSHIP IN ENABLING AND INDUSTRIAL TECHNOLOGIES.

The objectives pursued by Horizon 2020 are summarized in the “REGULATION (EU) No 1291/2013 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 11 December 2013 establishing Horizon 2020 – the Framework Programme for Research and Innovation (2014-2020)”. Further details are in the “COUNCIL DECISION of 3 December 2013 establishing the specific programme

---

[3] A European Industrial Strategic Roadmap for Micro- and Nano-Electronic Components and Systems (Jan. 2014)

implementing Horizon 2020 - the Framework Programme for Research and Innovation (2014-2020)" 2013/743/EU.

2) Contribute to the development of a strong and competitive ECS industry in the Union.

This ECSEL MASRIA is based upon inputs of many opinion leaders and experts from the member-organizations of the Private Members, representing the R&D actors in ECS at large, in all disciplines encompassed by the ECSEL JU. This MASRIA[4] and its annexes contain an overview of the societal/technical demand and trends, justifying the selection of topics and highlighting the requirements for the future in schedules and roadmaps. For background reading the SRA's of the ENIAC-ETP, the ARTEMIS-ETP and EPoSS-ETP can be consulted[5]

3) Ensure the availability of ECS for key markets and for addressing societal challenges, aiming at keeping Europe at the forefront of the technology development, bridging the gap between research and exploitation, strengthening innovation capabilities and creating economic and employment growth in the Union.

The Regulation No 1291/2013 describes in detail the areas addressed by Horizon 2020, defining for each of them the specific objective, the rationale and the Union added value, as well as the specific actions to be taken. In addition, the Council Decision 2013/743/EU defined in detail the activities that shall implement the Regulation No 1291/2013, in particular with reference to the Leadership in Enabling and Industrial Technologies. The ECSEL JU MASRIA and MASP will rely upon these documents; it will make reference to concepts and actions put forward therein defining the specific topics to be addressed in its programme. For details regarding the rationale of the strategic choices, the reader is referred to the Regulation No 1291/2013 and the Council Decision 2013/743/EU.

4) Align strategies with Member States to attract private investment and contribute to the effectiveness of public support by avoiding unnecessary duplication and fragmentation of efforts, and easing participation for actors involved in research and innovation.

The governance structure of the ECSEL JU involves the Public Authorities Board including the ECSEL Participating States to decide upon participation and public funding, and the Private Members Board drawing up the MASRIA, preparing the Research and Innovation Activities Plan (RIAP) and bringing the in-kind contribution. The progress of the engagements in the actions selected for funding is a direct measure of the alignment of strategies and procedures that shall bring together all actors, avoiding duplication and overcoming fragmentation.

5) Maintain and grow semiconductor and smart system manufacturing capability in Europe, including leadership in manufacturing equipment and materials processing.

Semiconductor technology, including materials, equipment and processing, is at the basis of ICT at large. The ECSEL JU shall use the Horizon 2020 instruments both R&D&I, to leverage the

---

[4] The MASRIA is a document of the Private Members Board of the ECSEL JU, and published concurrently on their respective web-sites. See: www.aeneas-office.eu, www.artemis-ia.eu, www.smart-systems-integration.org.

[5] The pan-European Strategic Research Agenda's (SRA's) of the respective ENIAC-ETP, ARTEMIS-ETP and EPoSS-ETP can be found on www.aeneas-office.eu, www.artemis-ia.eu, www.smart-systems-integration.org, respectively.

required investments to secure the sustainable controlled access to this technology for the European industry.

6) Secure and strengthen a commanding position in design and systems engineering including embedded technologies.

The value of modern semiconductor microchips or other miniaturised electronic components and embedded software is increased substantially when combined with system and integration know-how in the creation of cyber-physical and smart systems.

This is one of the synergetic benefits of ECSEL: linking ENIAC with ARTEMIS and EPoSS provides the essential link between large system design and requirements on chip level and vice versa, thus assuring the adherence to the required quality and safety standards by appropriate processes and tools along the value chain. Hardware and software are coming together, and the ECSEL actions shall strongly support both the advancement of the state of the art in each discipline and their concurrent application towards impactful applications.

7) Provide access for all stakeholders to a world-class infrastructure for the design, integration and manufacture of electronic components and embedded/cyber-physical and smart systems.

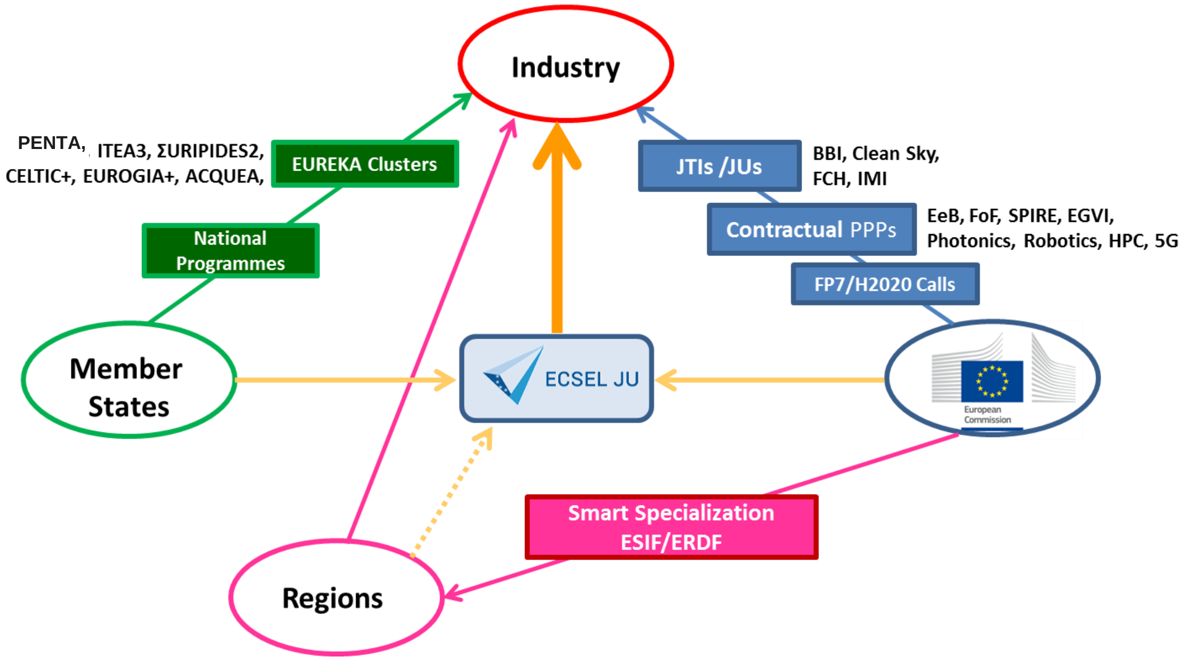
Microchips and embedded software can provide effective solutions to the societal challenges only if integrated in smart systems. Smart systems are here understood in the wider sense, extending the scope of ECS to include complex and large platforms. The ECSEL JU actions shall include projects that integrate the various ECS technologies described into systems that address the industry-defined applications included in this document.

8) Build a dynamic ecosystem involving Small and Medium-Sized Enterprises (SMEs), thereby strengthening existing clusters and nurturing the creation of new clusters in promising new areas.

The ECSEL JU shall continue the very successful activities of the Joint Undertakings established previously under the Framework Programme 7, engaging a large proportion SMEs within the winning ecosystem of the industry that also includes large industry and academic and institutional research institutions. Likewise, it shall continue creating opportunities to join powerful consortia for entities from all around Europe, with specific emphasis on SMEs from less developed regions, which shall thereby have opportunities to work together with the world leaders in the field, reducing differences and increasing cohesion.

1.3 Relationship with other programmes

The programme of the ECSEL JU is designed to provide valuable Key Enabling Technologies, components and competencies, as well as related know-how in design, manufacturing and implementation, allowing the community of R&D&I actors, alongside other existing programmes on ICT and related technologies in Europe, to benefit from new opportunities. Insofar, ECSEL is complementary to the other programmes.



ECSEL JU - the Tri-partite Joint Undertaking: one Mechanism among Many

Regarding EUREKA clusters, and in particular with respect to PENTA and ITEA3, the policy of complementarity at project level and cooperation at programme definition level remains: One strategy – Two instruments. For EPoSS a constructive relation with Euripides can be mentioned.

As part of the funding for ECSEL projects comes from the Horizon 2020 programme of the EC, the complementarity is particularly important and is assured as follows:

1) TRL and scale of activity: ECSEL envisages generally larger-scale, market-facing activities. While work at lower TRLs within larger projects is not excluded in ECSEL, the Horizon 2020 programme[6] offers advantages for smaller, focussed projects (see insert) on generally lower TRLs and it is the expectation that the output of such Horizon 2020 projects will provide valuable inputs for further development towards market-readiness within the context of later ECSEL projects.

2) The H2020 facility for platform building provides for smaller CSAs or Innovation Actions. While the facility for CSA is foreseen in ECSEL, it is certainly not the focus of the programme,

---

[6] *HORIZON 2020 – WORK PROGRAMME 2014-2015. LEIT – Information and Communication Technologies: (http://ec.europa.eu/research/participants/portal/doc/call/h2020/common/1587758-05i._ict_wp_2014-2015_en.pdf)"If indicated in the specific challenge description, the Commission considers that proposals requesting a contribution in the brackets indicated below for Small or Large would allow the specific challenge to be addressed appropriately. Nonetheless, this does not preclude submission and selection of proposals requesting other amounts:*

- Small contribution: Contribution from the EU of between EUR 2 million and EUR 4 million

- Large contribution: Contribution from the EU of between EUR 5 million and EUR 8 million "

and the ECSEL community can make use, when appropriate, of platform building activities to form the mandatory seeds from which larger innovation ecosystems can grow.

3) “Networks of Design Centres” is an activity designed to promote the use of ECS in newly emerging or developing applications. It offers a funding flexibility conducive to experimentation, designed to trigger new market opportunities. Once these have been triggered, ECSEL (or other) provides a scheme much better adapted to further support the market-readiness of such new approaches on a larger scale. Such larger scale initiatives (“Pilot Lines”, “Innovation Pilots”, “Zones of full-scale testing” etc…) could also provide a means of access for SMEs and academia to leading-edge tools and infrastructures thereby contributing to the expected outcomes of the H2020 programme ICT2 and ICT25[7] [H2020WP].

In addition, Article 7.1a of the Statues of the ECSEL Joint Undertaking takes provision to assure such complementarity by stipulating that “*the Commission, within its role in the Governing Board, shall seek to ensure coordination between the activities of the ECSEL Joint Undertaking and the relevant activities of Horizon 2020 with a view to promoting synergies when identifying priorities covered by collaborative research.*”

[7] Horizon 2020 Work Programme 2014-2015: 5. Leadership in enabling and industrial technologies: Information and Communication Technologies”

2 Roadmap

2.1 High-level goals

Electronic components and systems (ECS) is a high-growth area, with a worldwide market growing faster than the industry average. European companies have dominant global positions in key application areas for Europe, such as transport, health and security, as well as in equipment and materials for worldwide semiconductor manufacturing. The technology domain is also very R&D intensive, with semiconductors industry investments reaching 20% of total revenues[8].

Competitiveness of key European industrial domains heavily depends on the availability of leading edge ECS technologies. 80% to 90% of the key differentiating competitive features of e.g. leading edge medical device, automotive or avionic suppliers are dependent on the built-in Electronic Components and Systems. Therefore mastering these is decisive for the future market position of European strongholds.

Key companies and institutes in Europe's ECS ecosystem have proposed to invest up to 150 billion euro in R&D&I from 2013 to 2020, when leveraged by public and private co-investment programmes of up to 15 billion euro with the Union, the Member States and the Regions[2,8]. Objective of this holistic approach is to reinforce the ecosystem and have Europe expand its leading position and exploit new opportunities for products and services in this highly competitive domain. By 2020, this will increase Europe's world-wide revenues by over 200 billion euro per year[8] and create up to 800,000 jobs in Europe's ECS enabled ecosystem[2]. Within this context and overall ambition, the semiconductor industry has accepted the challenging goal to double their economic value in Europe by 2020-2025[3].

Realisation of the above goals and objectives requires extensive collaboration across the innovation and value chain for ECS, with research institutes and academia, SME and large companies, and R&D&I actors from materials, equipment and microchips, together with design tools and architectures, to embedded and full-blown systems and applications in ECS. A two-pronged approach will be needed, combining demand-pull and supply-push throughout the value chain. Within ECSEL all these actors are together with Public Authorities united behind a single European Strategy, thus making ECSEL the instrument of preference to realize the above.

[8] Nano-Electronics and beyond 2020: Innovation for the Future of Europe (Nov. 2012).

2.2 Strategic Thrusts

The ECSEL JU will contribute to the above industrial ambition of value creation in Europe and the objectives in its basic act by establishing a programme through a two-dimensional matrix of key applications and essential technology capabilities, the ECSEL Strategic Thrusts

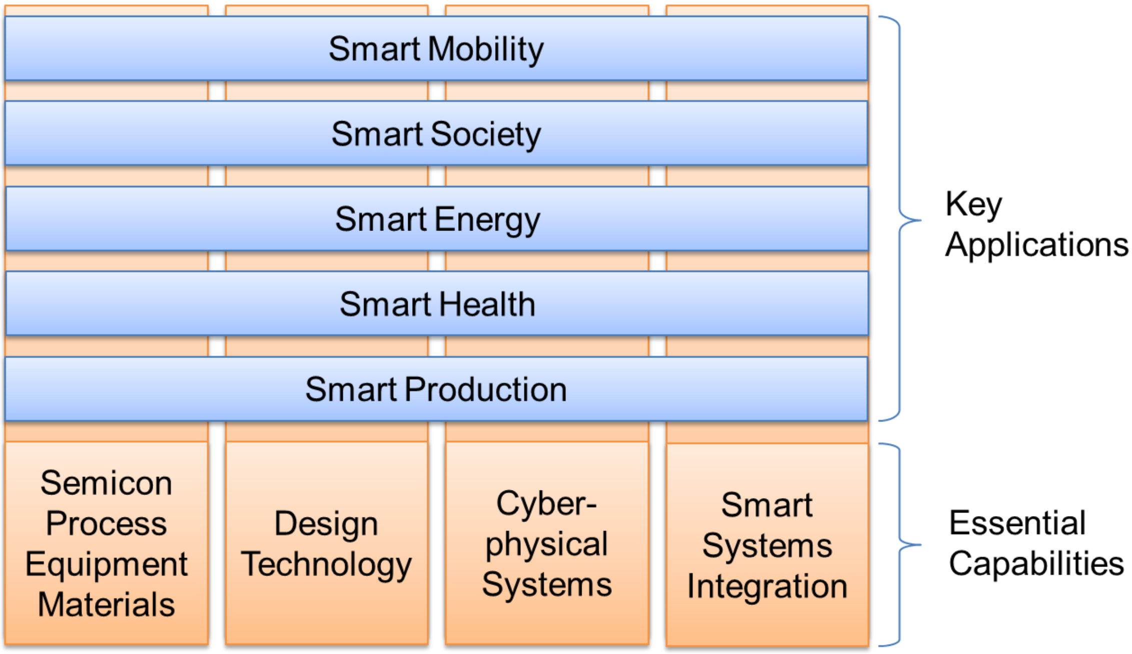
These Thrusts support the European industry in the indicated top priority domains with key enabling elements (such as enabling technologies, components, processes and interconnected tool chains), bringing them in a position to generate innovative products and services in very competitive markets. Part A and B of this document describe all these Thrusts respectively for key applications and essential technology capabilities.

Each Trust in part A and B is following the same structure:

- Objectives
- Strategy
- Impact
- Cross references
- Schedules and Roadmaps (**only indicative!**)

For each Thrust an optional annex is provided including additional information and a list of implementation examples. The intention of the examples is to provide a better explanation of the scope and content of the thrust at hand for potential project consortia and funding authorities.

In the MASRIA, the ECS community has identified opportunities for European leadership in existing and emerging markets that will create value and wealth for the European citizen at large. These Key Applications are strongly connected to the Societal Challenges identified under Horizon 2020, and can be summarized under the umbrella of ‘Smart Everything Everywhere’, riding the next Internet wave (i.e. Internet of Things [IoT]) by integrating networked electronic components and systems in any type of product, artefact or goods. The Key applications are enabled by Essential capabilities in technologies from each of the three ETP domains in the MASRIA.



Structure of the ECSEL Applications/Capabilities domain arena

The Figure above shows the resulting structure of intertwined and interdependent applications and technologies domains. This matrix approach maximizes effectiveness of the ECSEL programme by addressing the R&D&I activities along two axes, and maximizes impact by combining demand acceleration with strengthening of the supply chain. The Strategic Thrusts capture and summarize the high-level priorities of the Private Members; the full description of the technical challenges and the underpinning market analysis is available in the MASRIA. In addressing the major economic ambitions of the ECSEL program the dynamics of the ECS market do not allow the setting of additional a priori priorities within these high level priorities.

Projects of the ECSEL programme should not limit themselves to covering only one of these key applications or essential technology capabilities; on the contrary, multi/cross-capability projects will be encouraged wherever relevant. This cross-capability work leverages the presence of all actors along the value chain inside ECSEL. It is vital in creating initiatives of adequate critical mass and vital in fostering innovation that will contribute to the overall goals of ECSEL: for example they will be prevalent in Pilot Lines and Innovation Pilot Projects.

3 Making it happen

Because of comprehensive incentives outside Europe, the world is not a level playing field. Achieving the goals and objectives stated in the 'Roadmap' chapter of this MASRIA requires a holistic approach with multiple modalities for public-private co-investment. The chapter on 'Making it Happen' outlines the modalities in which the ECSEL JU will contribute, either directly through funded projects, or indirectly, as by informing and encouraging the partners in the JU.

The strategic Thrusts of the MASRIA define the key areas of activity for the ECSEL programme. The width and depth of the Thrusts will ensure a broad participation of Member States. Together, the identified activities encompass the complete lifecycle, from technology concept to system qualification, i.e., from TRL 2 to TRL 8 in terms of Technology Readiness Levels. On top of this the Thrusts encompass the complete value chain from design tools and materials to system-architectures and end-user products. For higher TRL's, the model foreseen for execution in the ECSEL programme builds on the positive experience of developing Pilot Lines (in the ENIAC JU) and Innovation Pilot Projects (AIPP's in ARTEMIS JU) respectively.

Standardization will drive the development of interoperable products/methods and tools addressing several fragmented markets. Large ecosystems will be created from the ECSEL projects sustaining European competitiveness. In the context of Innovation Pilot Projects reference platforms are foreseen that will lead to standardisation and interoperability while taking into account strategic standardization activities undertaken by the Private Members.[9]

For consistency with the policy of open and transparent access to public funding, projects will be launched by the ECSEL JU through a process of open Calls for Proposals. For consistency with the annual budget cycles of the Union and of the participating states, at least one Call for Proposal per year shall be launched. To accommodate the broad range of TRL's that must be addressed, multiple Calls per year are foreseen, handling lower and higher TRL's in separate Calls. Each Call will identify its own budget and scope: the possibility of transferring unused National Contributions from the budget between Calls will be determined on a case-by-case basis.

SME's are an important consideration when shaping new consortia and proposing projects. Fostering innovative SME's is a cornerstone of our strategy given the importance of SME's for the size and increase of employment in Europe in the ECS domain. Embedding them in eco-systems of large companies, RTO's and academia, and giving them access to funds is a prerequisite for continuous growth. Within each integrated project, a realistic representation should be found for the underlying R&D&I ecosystem in Europe, including large corporations, SME's, institutes, and universities. The mechanisms to accommodate smaller partners, SME's, institutes or universities in larger integrated projects shall be kept flexible, e.g., by allowing direct participation in the project, special links with one of the direct project partners, or a set of linked smaller projects. Being part of H2020, ECSEL aims to contribute towards the goal that SMEs will achieve 20% of the total combined budget for the specific object "LEIT" and the priority "Societal Challenges" (Regulation EU 1291/2013 establishing Horizon 2020, recital 35).

The ECSEL JU Work Plan (WP) will guide the content of the Calls in each year. Each Call can identify specific topics for projects (as described in the MASP that is derived from this MASRIA), and identify specific selection and evaluation (sub) criteria and weightings within the limits imposed

[9] As in the ARTEMIS-IA Standardisation SRA

by the H2020 programme. In this way, the desired steering of the programme can be achieved within the principle of open and transparent selection of projects.

The following chapters describe a number of formats for projects that proposers may consider, for optimising the contribution of their projects to the strategic goals of ECSEL, and by extension to Horizon 2020. The types of project format available for each Call will be listed in the relevant Work Programme.

3.1 Research and development projects

Research and development projects in JU ECSEL are R&D&I actions primarily consisting of activities aiming to establish new knowledge and/or to explore the feasibility of a new or improved technology, product, process, service or solution. For this purpose they may include basic and applied research, technology development and integration, testing and validation on a small-scale.

3.2 Pilot lines and test beds

Pilot lines and test bed facilities focus on R&D&I actions requiring high levels of investment in bringing innovations to market. These activities are specifically relevant for micro and nano-electronics and comprise the work necessary to prepare innovation in the market with focus on validation and demonstration in relevant and operational environments to be established within the project. Also system completion and qualification must be part of the project focus. On the other hand, minor parts of the planned projects may need to address also lower TRLs in order to prepare the scientific and engineering ground for the pilot activities.[10]

3.3 Demonstrators, innovation pilot projects and zones of full-scale testing

Demonstrators, innovation pilot projects and zones of full-scale testing are essential building blocks in stepping up Europe's innovation capacity by the development of technologies and methodologies to support the integration of ECS applications and technologies into any type of end product, artefact or goods. This will provide Europe with reinforced means to significantly raise its competitive edge across the economy and to address its key societal challenges.

Innovation Pilot Projects are intended to transfer promising capabilities and results from lower TRL research activities into key application domains, allowing the well-known “valley of death” to be crossed. They are frequently the application-oriented counterpart of the more processing technology-oriented Pilot Line approach. These activities will foster and sustain the European innovation environment by creating new innovating eco-systems, by setting up and sharing of R&D&I infrastructures, by combining and leveraging R&D efforts to overcome the resource deficit for R&D&I in Europe, and by insuring successful valorisation and take-up of the results.[11] [12]

---

[10] As in the ENIAC Pilot Lines

[11] As in the ARTEMIS-JU Innovation Pilot Projects

[12] This concept also embraces real-life experiments by systematic user co-creation approach integrating research and innovation processes in Living labs

Zones of full scale testing of new and emerging discoveries in the ECS domain address the comprehensive investment in equipping and/or upgrading infrastructures for both the private and the public space, including homes, offices, transport systems, schools, hospitals, and factories. They require public-private partnerships involving the ICT supply chain and industries like engineering, energy, construction, health, tourism, and financial. ECSEL Innovation Pilot Projects can supplement the existing smart cities European Innovation Partnership and the Energy Efficient Building initiatives under Horizon 2020. They can also prepare for future large-scale innovative pre-commercial public procurement actions in the area of 'Smart Everything Everywhere'.

3.4 Multi-funding actions

Where the infrastructures required by Pilot Line and Innovation Pilot Project actions require significant additional investment, the incorporation of additional funding will be needed. Mechanisms for accessing such financing are already in place, such as the European Structural and Investment Funds, of which there are many with potential relevance to ECSEL R&D&I actions.

When preparing such large-scale actions through Multi-Funding, the following points must be addressed. Depending on the source of funding, the complexity of mixing funding streams from the Union remains problematic. To avoid this, the different elements of such multi-sourced action must be clearly identified, with exact description of the demarcation between them. A top-level Master Plan is essential for successful execution, including Intellectual Property Rights (IPR).

To be recognised as such, a Multi-Funding action must:

1) Build on a recognized ECSEL Pilot Line or Innovation Pilot Project action;
2) Provide a Master Plan that clearly identifies the demarcation of funding sources and IPR;
3) Provide clear tasks and demarcations for each funding source;
4) Provide for adequate risk management, should one of the components within the Master Plan fail.

3.5 KETs/ multiKETs

The European Commission has identified 6 Key Enabling Technologies (KETs) that are crucial to the development of the European economy. These Key Enabling Technologies should play a crucial role for ensuring the competitiveness of European industries as a main driving force (enablers) for European R&D and innovation[13].

Beside the KET initiative, the EC has also opened the possibility to set Multi-KET pilot lines, for topics that could be driven by a combination of technologies. These Multi-KET pilot lines will be considered in the ECSEL Strategy implementation as an opportunity to develop, jointly or separately with the Pilot Lines and with the Innovation Pilot projects instruments described above.

[13]Brussels, 26.6.2012 - COM(2012) 341 final COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS. 'A European strategy for Key Enabling Technologies – A bridge to growth and jobs'

3.6 Excellence and competence centres

Excellence and competence centres are important elements of the ECS ecosystem. In the context of ‘Smart Everything Everywhere’ solutions for the European Societal Challenges as identified in the MASRIA, they can be the coordination heart for business, industry and academic activities. Ideally, each will establish its own top class R&D&I capabilities, and will be charged with inclusion of other research centres within its region, and with coordination with the other excellence and competence centres, to form a virtual excellence centre to span Europe. To have impact, they will need to cover skills extending from chip design to embedded software, cyber-physical systems and systems integration, and offer a one stop shop for low-tech or non-ICT industries wishing to embrace the opportunities that the momentum of the ‘Smart Everything Everywhere’ agenda provides. Financial support should come from Horizon 2020 as well as from national and regional R&D&I budgets including from the European Structural Funds.

3.7 Innovation support actions

To address the ECSEL objectives of aligning strategies with Member States and building a dynamic ecosystem involving SMEs certain activities which are not directly related to R&D&I will be needed. Typical activities of such an action can include, but are not limited to:

1) Eco-system building support;
2) SME integration;
3) Roadmapping;
4) Standardisation;
5) Education / training actions;
6) Coordination of actions across European R&D&I programmes;
7) Planning and organisation of important dissemination events.

In part, such activities are on an in-kind basis by the Private Members. Funding through Horizon 2020 actions will be pursued.[14]

[14] An example is the much needed development of a roadmap for specification and standardisation of More-than-Moore equipment and materials

4 Financial perspectives

The funding made available by the European Union is projected to be 1.17 billion euro, which is to leverage **at least** an equal amount of funding to be provided by the ECSEL Participating States. This, when added to an in-kind contribution from the R&D actors of 2.34 billion euro, is expected to leverage a total investment approaching 5 billion euro for the whole programme.

5 Project selection and monitoring

This topic is not applicable for the MASRIA, however applicable in the MASP. It is mentioned here as a numbered section title to obtain consistent numbering for section titles as in the MASP that is derived from this document.

6 Strategic thrusts Part A: Key applications

6.1 Smart Mobility

6.1.1 Objectives

The mobility sector faces **crucial societal challenges**: **reducing CO_2 emissions, improving air quality**, and **eliminating congestion** for improved logistics and traffic efficiency using existing infrastructure wherever possible while advancing towards an accident-free and causality-free mobility scenario, which also addresses the needs of **vulnerable road users** such as children or an **ageing population**. In this context, Europe shall strive to **maintain global leadership** while serving the needs of society. The development and deployment of new capabilities provided by ECS (Electronics, Components and Systems) as well as the introduction of the necessary new methods and tools for the design, verification & validation and production are key to achieving this: ECS aims to provide vehicles, transportation systems and infrastructure with the required intelligence and flexibility by extending and reinforcing the well-established strengths of the European industry. In section “Smart Mobility” vehicle shall mean cars, airplanes, vessels, trains, off-road vehicles, satellites, drohnes.

6.1.2 Strategy

In the framework of ECSEL, research, development and innovation in “Smart Mobility” will focus on capabilities in the domains of sensing, communication, navigation/positioning, computing and decision-making, control and actuation based on ECS and the necessary development and validation tools and methods.

These functions will lead to **resource-efficient transportation** as they enable partly or fully electrified as well as advanced conventional vehicles that are clean, CO_2-optimized and smartly connected to renewable energy sources.

ECS will also enable different levels of **partial**, **conditional, highly and fully automated transportation** posing new challenges to traffic safety and security in mixed scenarios where vehicles with different automation levels coexist with non-automated vehicles. Additionally the target shall be to ensure flexibly coordinated logistics, mobility for the elderly, reduce congestion in cities, airspace, harbors, and further increase energy efficiency as it makes vehicles and traffic management systems smarter.

Finally, ECS will be fundamental for **integrated and multimodal mobility networks** based on smart vehicles and smart infrastructure (on roads, rails, in airspace and on waterways, stations, airports, hubs, etc.) and an increased level of information awareness (vehicle, route, weather conditions, etc.). Connecting cars to the Internet of Things (IoT) will lead to massive information exchange capabilities between mobile components and enable (entirely) new service possibilities, resulting in more comfortable and efficient travel and logistics. Thus, it also contributes to less congestion, increased safety and security, higher resource efficiency, faster point-to-point transfer, smooth intermodal shifts, and less pollution by the transportation system as a whole. ECS is also essential for promoting and extending the use of sustainable modes among users, including public transport (bus, metro, light rail, “last mile” transport, etc.), and “soft” transportation for “last-mile” transportation (eBikes, bicycle, pedestrians, etc.).

6.1.3 Impact

The innovation provided by ECSEL in Smart Mobility will help to shape the convergence of the worlds of digital data and transportation meeting the needs and capabilities specific to Europe and providing functionally safe and reliable products and related efficient processes. This will not only strengthen European leadership in electronics and smart embedded computer systems, but also supports Europe's role as a frontrunner for innovation and engineering quality in the automotive and other transportation sectors, such as for instance aerospace and railways. Hence, it will help to strengthen those industrial sectors that are most important for employment and economic growth in Europe.

ECSEL is supporting and will take into account the activities of the European Green Vehicles Initiative PPP, JTIs as Clean Sky 2, Fuel Cells and Hydrogen 2, and specific parts of the three pillars of H2020, e.g. Mobility for Growth, Smart Cities and Communities by advances in electronic components and systems for smart mobility. In doing so, ECSEL is helping to achieve the long-term objectives of the EC's Transportation White Paper[15].

6.1.4 Cross references

Covering the step from basic functionalities to use cases in the value chain, ECSEL takes advantage of general technology research results from ICT and NANO Work Programmes of Horizon 2020 as CPS-based control, big data, cloud infrastructures and services, MEMS-based (single or multi-) sensor technologies, high-performance real-time processors, power-electronics, highly reliable components, and qualification procedures etc.

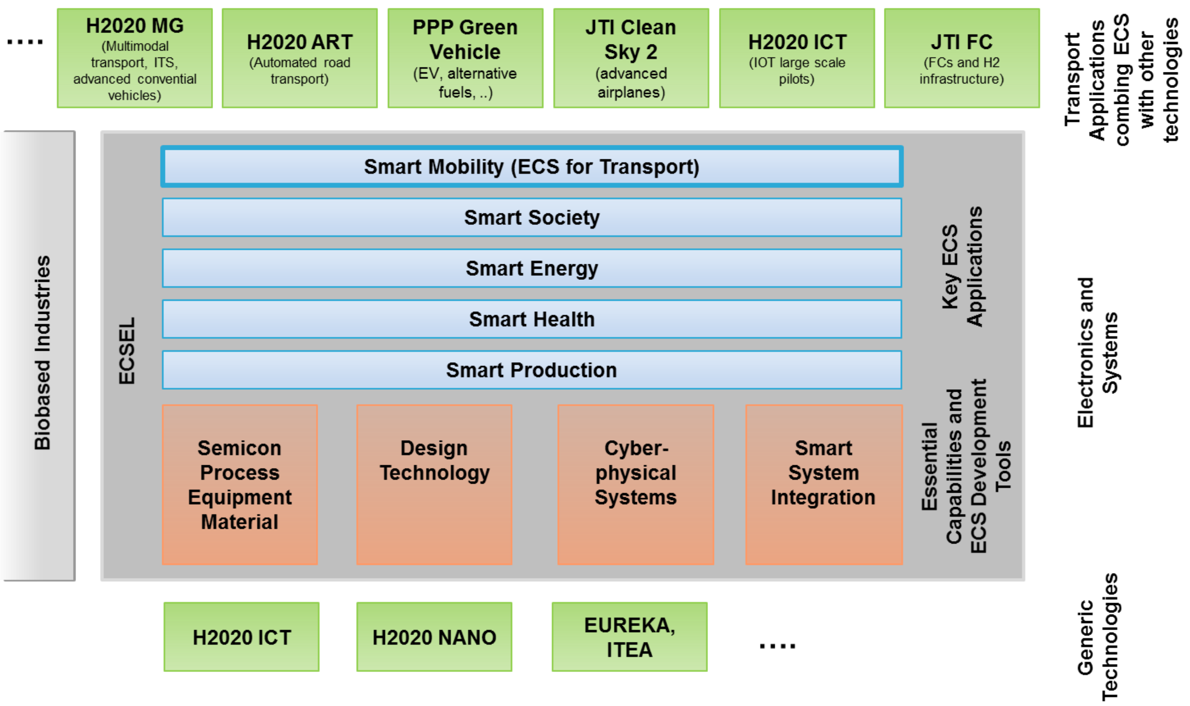


Figure 1 - Relation of ECSEL Smart Mobility with other EU Research Programs

---

[15] White Paper Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system (COM/2011/0144 final)

ECSEL delivers new revolutionary ECS functionality to application-oriented transport research programmes as H2020-"Mobility for Growth", H2020-"Automated Road Transport", H2020-"Green Vehicle", H2020-ICT-IOT Large scale Pilots (focusing on cloud infrastructure for intermodal and automated transport), JTI Fuel Cells and Hydrogen 2 and Clean Sky 2, where ECS results are combined with mechanical, chemical material and other application-oriented research to solve European transport problems. Synergies are also present between ECSEL and the H2020-"Space" Work Programme (e.g. in the navigation, communication and remote sensing domains), which contributes to the modern, efficient and user-friendly transport systems.

On the other hand, ECSEL continues to develop more advanced electronic components and systems including the underlying embedded software, and uses results of application oriented projects (e.g. automated vehicles, electric vehicles) as validation platforms. Therefore interactions between ECSEL and application-oriented programmes will continue in future loops.

As ECSEL application domains take advantage of cross domain ECS technologies, the smart mobility research programme expects research results from horizontal ECSEL capabilities as semiconductor processes, equipment and material, design technologies, CPS technologies (as embedded systems design, development methods and tools, integration of real-time simulation with control, safety and security in CPS based smart systems) and smart system integration.

6.1.5 Schedules/Roadmaps

6.1.5.1 Roadmap: ECS for resource efficient vehicles

The deployment of alternative resource efficient vehicles in Europe is expected to follow a series of milestones which link the market penetration to the availability and affordability of key technologies under the assumption of major breakthroughs (see also [16]). The milestones for cars are exemplary listed below:

1) By 2017 the 2nd generation of electrical vehicles (EV) with updated powertrains including plugin capabilities, range extenders and the first small scale deployment and demonstration of fuel cell based electrical vehicles (FCEV) will be launched to the market.
2) By 2020 a wider (mass) production of EV as well as medium scale production of FCEV shall be established in Europe. In addition, very efficient ICE (internal combustion engine based) vehicles will partially coexist or be largely transformed to hybrid concepts to achieve the European CO_2 reduction goals.
3) By 2025 the production of 3rd generation commodity priced EVs as well as (small) mass market FCEVs are foreseeable, and 15 Mio units accumulated will be on the road.

Europe will also see progress in bio fuel based vehicles.

Similar roadmaps exist for other domains of mobility as rail, aerospace, off-road vehicles, trucks etc.

[16] European Roadmap for Electrification of Road Transport, ERTRAC, EpoSS, SmartGrids, 2012

The advances needed to achieve these milestones are expressed through specific targets in the domains of sensors and actuators, energy storage, drive trains, vehicle system integration, smart grid integration, safety, integration into infrastructure (e.g. parking, charging, billing systems …) and transport system integration. **All of these features are critically enabled by ECS** as such vehicles will demand for **novel and increasingly powerful but more complex hardware, mixed-criticality embedded software and dependable vehicular networks**. Apart, electrical and thermal architectures and interfaces supporting intelligent charging and refueling technologies are required. Overall, safety, security and transparent mobility services are a prerequisite for successful market penetration.

In parallel to the advancement of electric and plug-in hybrid passenger cars as well as light duty vehicle technologies, electrified trucks and buses or fuel cell vehicles will be developed. However, the ramp-up of their deployment is expected to start later. Furthermore, resource efficiency is the driving force of research and innovation in other transport modes, e.g. air transport[17].

Additionally, the use of wireless sensors, actuators and interconnections for non-safety critical functions will help to save precious raw materials during the production of vehicles. On the road, vehicle to vehicle (V2V) and vehicle to infrastructure (V2I) communication in combination with new vehicle control algorithms will also contribute significantly to energy savings and safety in road transportation. Therefore, however, wireless vehicular networks will have to improve significantly and guarantee highly dependable communication for distributed and safety-critical applications in flexible transportation and tightly collaborating smart vehicles.

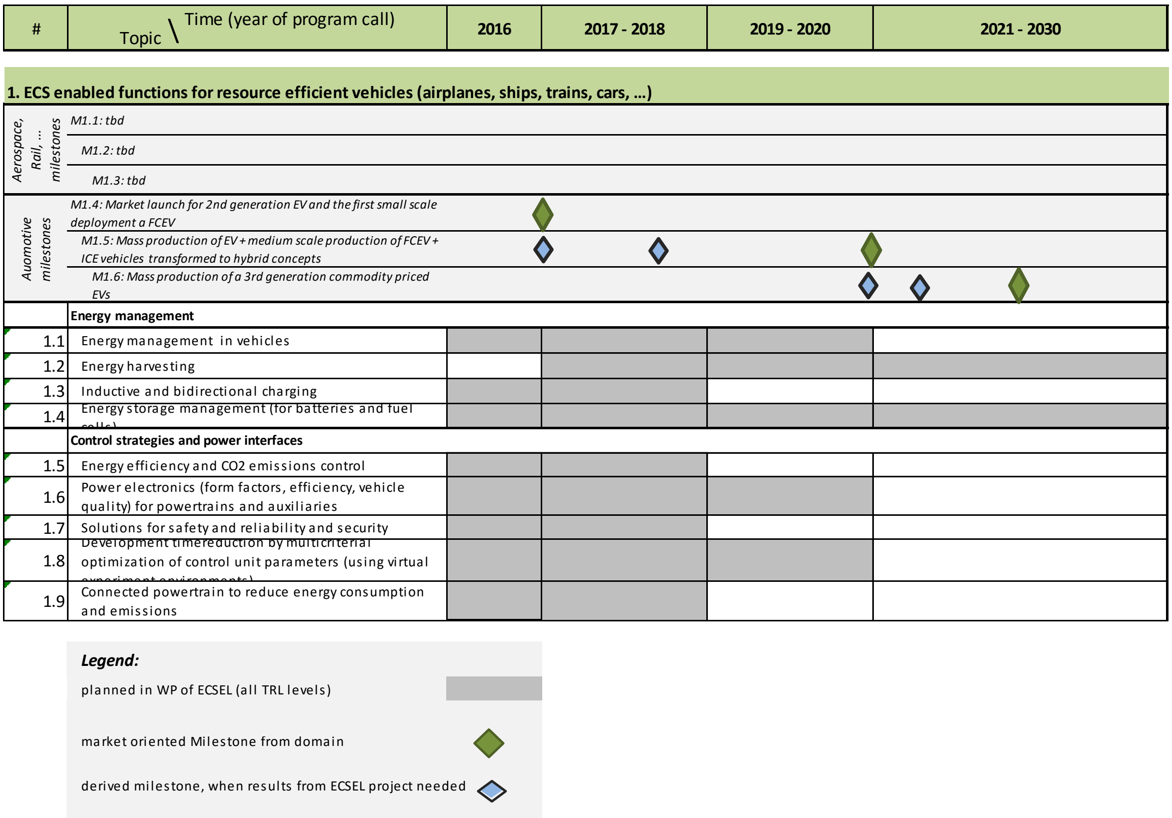


Figure 2 - Roadmap: ECS for resource efficient vehicles

---

[17] Clean Sky 2 JTI Work Plan 2014-15

6.1.5.2 Roadmap: partial, conditional, highly and fully automated transportation

Significant breakthroughs have recently been made in advanced driver assistance systems by European vehicle manufacturers and suppliers. In order to swiftly proceed towards highly automated driving and flying, where the system relieves the driver from steering, accelerating and monitoring of the vehicle environment, the following three steps can be foreseen in the automotive domain (see also [18] and [19], similar steps exists for the other domains in the mobility sector):

1) By 2020, conditional automated driving (SAE Level 3, see [20]) is expected to be available in low speed and less complex driving environments, e.g. in parking lots and in traffic jam situations on one-way motorways.
2) By 2025, conditional and highly automated driving (SAE Levels 3 and 4) is expected to be available at higher speeds in environments with limited complexity, e.g. on highways.
3) By 2030, (conditional and highly) automated driving is expected to be available in most complex traffic situations, i.e. in cities.

In closed and secured environments (e.g. factory floor, new city areas with dedicated infrastructure, precision farming, business and leisure parks, university campuses etc.), a revolutionary scenario to introduce highly or fully automated vehicles without too many intermediate steps is likely to be proposed first. While ECS therein will probably also be closed and carefully tailored, support for open environments will follow and impose much more critical demands: embedded hardware and software will have to be updated on a regular base to follow e.g. legal requirements, respect the latest standards, introduce new security aspects, services and features, ensure electromagnetic compatibility and to finally stay compatible with the latest vehicle technology.

Eventually, vehicles with different levels of automation will be built on advanced driver assistance systems and cooperating components as well as on detailed driver status monitoring and environmental perception. Such systems will have to be validated under virtual, semi-virtual and real world conditions. This requires ESC providing dependable solutions for advanced sensors and actuators, data and ontology fusion, efficient computation and connectivity, security, precise location, time and velocity detection, detailed scalable low cost and dynamically updated maps, precise lateral vehicle control, novel man-machine interfaces and human interaction technologies, cyber security, black box recorder for near incident data, energy efficiency and (real-time) simulation concepts.

To separate the development of sensors and actuators from control strategies and trajectory planning, a (de-facto)-standardization of object handling, object descriptions, scene interpretation, situation classification and management is essential. Therefore the creation of industrial frameworks is recommended and an exchange of test procedures between OEMs and suppliers is encouraged.

As it seems impossible to define all the safety relevant scenarios upfront, new “learning” concepts and adaptive lifecycle models are required, which continuously analyze real-world data for near incident scenarios, evaluate the potential impact, modify the control software or strategies, validate the improved systems and update all related vehicle components (maps,

[18] European Roadmap for Automated Driving, EPoSS, 2014
[19] ERTRAC Roadmap for automated driving, 2015

[20] Gereon Meyer, Sven Beiker (Editors); Road Vehicle Automation; page 11 ff; Springer 2014

control software, information on road conditions etc.) in a highly dependable way, i.e., safe, secure, and in real-time..

Traffic and fleet management systems are crucial for highly and fully automated systems. Dependable communication networks (enabled by terrestrial and space systems) with a wide coverage and high availability and data links among vehicles as well as between humans, vehicles and the infrastructure will be fundamental for traffic management systems. This will allow cooperative decision making in vehicle guidance and benefit from high performance computing systems (HPC) (see also paragraph 1.5.3.).

Technology transfer to and from robotics and aeronautics and space is an essential part of the development process, and the creation of regulatory frameworks as well as in-vehicle and inter-vehicle standardization has to go hand in hand with technology development. Similarly, development of advanced and utilization of existing traffic infrastructure is mandatory to provide a frameset for automated transportation systems.

The development of smart & connected highly automated vehicles compared to conventional vehicles is by far more complex. Thus, new core elements for automation - as described below – and development and validation technologies are needed for these new vehicles. For example, it is not possible any more to thoroughly test a vehicle with automated features with conventional approaches only. It would simply not be possible to cover all possible street, track or air scenarios with these stages alone. Frontloading of testing activities, i.e. earlier testing is more needed than for the conventional vehicles. Model centric development and virtualization of testing by simulation is one technique to cope with the complexity.

- Architecture of automated vehicles as system as well as traffic systems
- Sensors and actors incl. their SW for real-time data acquisition management
- Big data: Handling of big data in order to enable real-time decision making
- Development and standardization of common model of environment
- Communication and transfer of relevant information between vehicles and between vehicles and infrastructure.
- Safety and security aspects, esp. for communication (inside and outside vehicle)
- Human interface aspects, human centric design
- Legal aspects

A large programme on Smart Mobility could deliver ECS for connected and highly automated that can be operated and trained in the unique test field that European roads and cities provide. It shall provide Europe a new leading-edge technology platform providing hardware and software components including their smart integration for the cost efficient intelligence of smart & connected highly-automated vehicles together with the effective and efficient development & validation methods and tools. This shall ensure the leadership of European industry in automated vehicles (cars, airplanes, ships, farming machines, trains). Such a large programme would play a crucial role in the context of all the diverse arising initiatives in the EU and the member states on that topic, and thus could help to prepare an “Integrated Project of Common European Interest” on automated driving. [21]

[21] KET Final Report, 2015

#	Topic \ Time (year of program call)	2016	2017 - 2018	2019 - 2020	2021 - 2030
2. ECS enabled functions for partial, conditional, highly and fully automated transportation					
Aerospace, Rail, … milestones	*M1.1: tbd*				
	M1.2: tbd				
	M1.3: tbd				
Auomotive milestones	*M2.4: Conditional automated driving in low speed and less complex driving environments, e.g. in parking lots and in traffic jam situations on one-way motorways*				
	M2.5: Conditional automated driving at higher speeds in environments with limited complexity, e.g. highways.				
	M2.6: Highly automated driving in most complex traffic situations				
	Environment recognition and data distribution within vehicles (airplanes, ships, trains, cars)				
2.1	Sensing, actuation and data fusion – in- vehicle and with sensors and actuators in the environment				
2.2	Positioning (absolut position and velocity measurement using sensor fusion) and navigation (e.g. as input for V2V communication)				
2.3	Scene and object recognition				
2.4	Traffic scene interpretation; scenario cataorization; catalogue of safety relevant scenarios; scenarion description language				
2.5	Lifetime, reliability, robustness; quality attributes of sensors; aging of sensors;influence of environment to sensor quality; handling of quality attributes of sensors in software; on-board diagnostics for automated transport systems, electromagnetic compatibility				
2.6	Automative EtherNet based on OABR (open alliance broad reach communication): Higher Data Rate Ethernet for AutomotiveObjective; Pave the way to 1Gbit/s Ethernet suitable for automotive				
	Control strategies				
2.7	Framework for scene interpretation, environment object handling to separate sensing from control stategies; object standardization; standardization of test procedures				
2.8	Service oriented distributed dynamically reconfigurable HW/SW architecture (e.g. using automotive Ethernet)				
2.9	Mission oriented automated system sw: Mapping and routing, Control strategies & real time data processing; online mission verification				
2.10	Goal oriented collaborative automated system sw: Mapping and routing, Control strategies & real time data processing				
2.11	Value oriented automated system sw: Mapping and routing, Control strategies & real time data processing (cognitive modelling)				
2.12	Human-vehicle interaction				
	Communication				
2.13	Safe and secure communication; build-in data security and privacy; cybersecurity for C2X				
2.14	Seamless integration and cooperation of multiple communication platforms : C2X, Radar, DAB, 5G, eLicense Plates, NFC, Bluetooth, 802.11p, etc.				
	Cloud backbone				
2.15	Infrastructure supporting autonomous transport				
2.16	Intelligent in-vehicle networking				
2.17	Interacting safety ; testing in complex traffic scenarious				
	Testing and dependability				
2.18	Verification, validation & simulation and decomposition of environment, sensors, tracks, objects etc. to increase resusability and decrease validation effort; teststands for real-time scenario testing with varying combinations of real and simulated components				
2.19	Fail operational concept for unknown envirionments; fail safe and secure operation				
2.20	functional safety and dependability				
2.21	Certification and testing				
2.22	Quality of services in extreme situations				
	Lifecycle				
2.23	Reliable and temper-free blackbox recorder for near incendent data (including dependable communication and near incident scenario evaluation, definition of minimal data set)				
2.24	Learning process for automated vehicles (including necessary online SW update-infrastructure)				
	Developement tools				
2.25	Tools to develop components and systems using Automative EtherNet based on OABR (open alliance broad reach communication): e.g. ADAS sensors, sensors and actuators for automated driving; multimedia components				

Figure 3 - ECS for partial, conditional, highly and fully automated transportation

6.1.5.3 Roadmap: ECS for integrated and multimodal mobility networks

The development path of **integrated and multimodal mobility networks** will build on achievements in the domains of vehicle technologies and travel information systems. Infrastructure development that is necessary for navigation, communication, information awareness systems and traffic management systems and interfaces between multiple modes of transport, intelligent booking, ticketing, tolling, and billing is important. This necessitates the development of both big data applications using high performance computing systems and deeply embedded systems using versatile hardware/software/communication to optimize these integrated and multimodal mobility networks (also open data or crowd sourcing concepts can be considered as well).

This requires on the one hand significant research to establish affordable intermodal ECS-based infrastructures, and on the other hand research within the different modes to interact in an efficient and secure way (see also [22]). Specialized user interfaces and ways of communications for people with special requirements (as elderly or disabled persons or disabled citizens) need to be created.

Major milestones include the creation of an open common secure and trustworthy architecture for the interplay of all actors in all modes of transportation - whether public or private - in a comprehensive and intelligent system, the development and deployment of applicable vehicle technologies and services, and the standardization and harmonization of interfaces regarding **interoperability, efficiency, safety and security.**

These goals require intense work on highly dependable **multi-communication platform(s)** combining car to car or infrastructure (C2X) communication with e.g., 5G, Radar, DAB, eLicense Plates, NFC, Bluetooth, 802.11p or even novel protocols that are better prepared for immense network dynamics and traffic density. Considering personal mobility, vehicle routing, road-infrastructure and traffic management in combination with the deployment in different environments (e.g. cities or countries) or the establishment of a European Corridor and the alignment with other continents is crucial for a seamless integration and cooperation of multiple communication platforms. Special focus is also required to provide built-in security and privacy from component level to the overall system.

Vehicles and infrastructures will both benefit from advances in technologies (sensors, actuators, computing), positioning/navigation, timing, control and communication enabled by ECS. **Seamless integration and interaction** in a broad co-modal sense from road and energy infrastructure, traffic management to the individual types of transport from ships, trains, airplanes to cars, busses, trucks and off-road machines will be facilitated by significantly advanced connectivity in various forms and by the intelligent use of consumer electronics devices along with vehicle built-in technology.

[22] Embedded CyberPhysical Systems ARTEMIS Major Challenges; 2014-2020, 2013 Addendum to the ARTEMIS SRA 2011

#	Topic \ Time (year of program call)	2016	2017 - 2018	2019 - 2020	2021 - 2030
3. ECS enabled functions for integrated and multimodal mobility networks					
	Communication				
3.1	Cloudbased beackbone services for multimodal mobility coordination				
3.2	Intelligent infrastructure and information systems for integrated and multimodal mobility (multiple environments as for example multiple countries, cities, ...)				
3.3	Standardization of intermodal communication				
	Traffic management				
3.4	Traffic density control and (re)routing and cooperative decision making				
3.5	Multi modal, multi country traffic tolling and payment				
3.6	Trajectory generation and validation using HPC				
3.7	User interface to multi modal and integrated transport systems (including gamification algorithms)				
3.8	Online status/location monitoring and trajectory re-routing				
3.9	Intermodal cross country travel information				
3.10	Access and parking management				
3.11	Fleet management				
3.12	Rail energy use and storage management				
3.13	Aerospace SW platform for 100% operational availability and reliability, full situational awareness, human centered operation, seamless connectivity with the in-flight and ground environment				
3.14	Cost efficient, flexible reconfigurable, dependable and safely operating satellite systems for Smart Environment developments				
	Guidance systems				
3.15	Predictive online traffic information (using social media and historic information from big data)				
3.16	Assistive transport networks systems (e.g. for the elderly living)				
3.17	Intermodal traffic guidance with personalized user interfaces and personalized way of interaction for people with special interestes (e.g. elderly people, handicapped people)				

Figure 4 - ECS for integrated and multimodal mobility networks

6.2 Smart Society

6.2.1 Objectives

Europe is in a changing world: More and more people living in urban environments pose major challenges like individual mobility, efficient energy consumption and distribution, security, safety, smart administration, food and water supply, logistics, entertainment etc. Intelligent, secure and easy-to-use solutions are needed to satisfy those demands in a sustainable way, guaranteeing citizen privacy and reaching broad acceptance in the public.

In this area, business opportunities for Europe will be supported by a holistic integration of new technology trends such as big data analysis, machine to machine interactions, multi-functional mobile devices, and autonomous systems. The vision of a dramatic increase in use of connected sensors (illustrated below) is a key element in these trends.

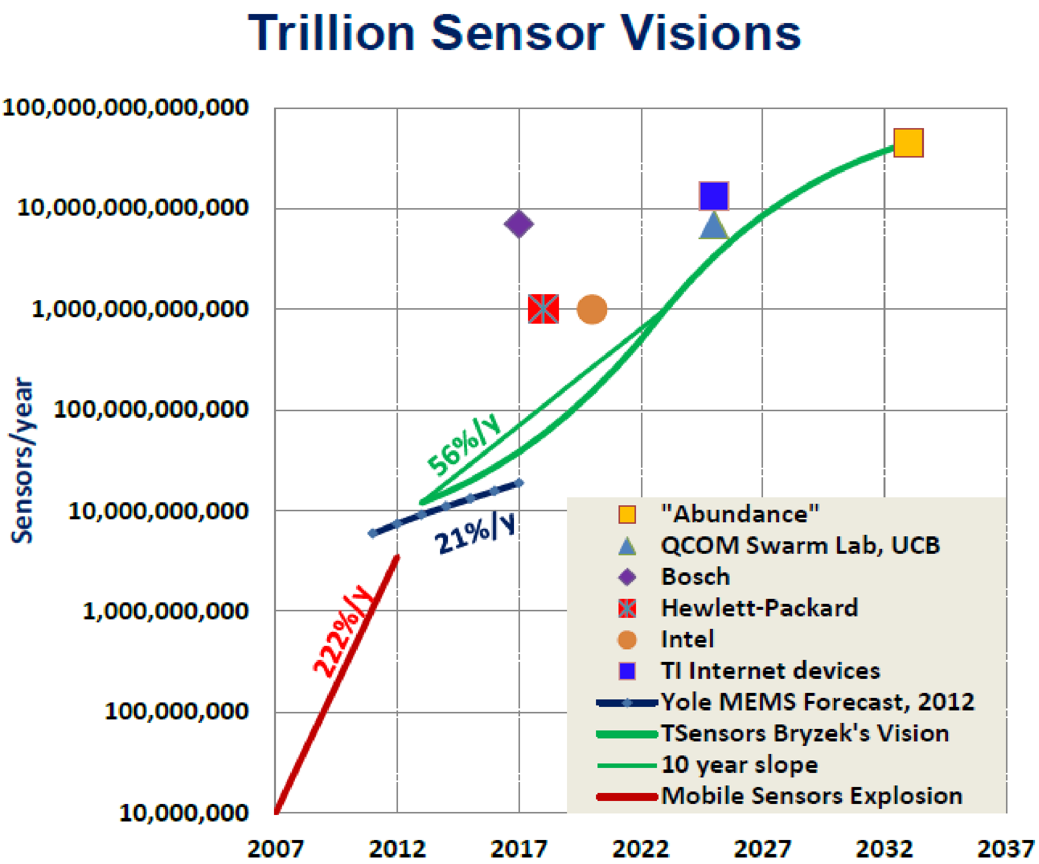


Figure 1 - After J.Bryzek, Semicon 2013, San Francisco. Dramatic increase of use of sensors connected within IoT networks expected within next years will dramatically change life of societies, creating opportunities and threats.

Fast information exchanges between people, objects and machines in real-time, as well as efficient processing of this information will be the backbone of the smart digital society (illustrated below), hence a necessary, but not a sufficient contribution to such solutions. The “Smart society” chapter of ECSEL addresses this gap, while ensuring to keep in pace with global technology trends and aiming to offer reliable and valuable services for users.

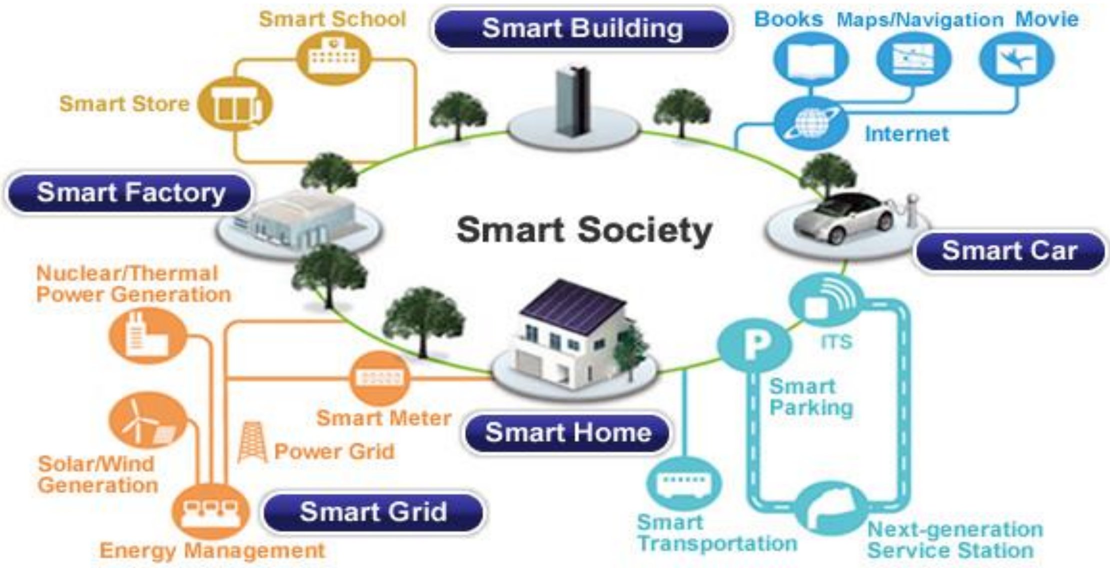


Figure 2 - After http://kr.renesas.com/edge_ol/technology/01/index.jsp

The application scope in this context includes the security of critical infrastructures, information exchange, access rights and authorizations, secure mobile computing, ticketing and payment as well as the security and privacy of personal data, and smart home/building related applications. The technical focus is the integration and development of electronic components and systems, delivering always-connected end-to-end information security and providing trust anchors on which security management can be based. This finally will provide growth areas for new digital services without threatening the individual rights to secure information, secure data handling, and privacy. Knowledge of expectations, doubts and valuations of potential users will guide the technology development, to ensure that new digital services will be perceived as secure/reliable, acceptable and manageable by users.

6.2.2 Strategy

The overall strategy is to leverage European industry strengths, in the first phase of ECSEL. Focus should be made on components for security and safety connected (over the Internet or other networks), but also on trustable components and associated software.

The goal is to select the most promising market opportunities (in Europe and outside Europe, such as the equipment of new cities, by the deployment of Internet of Things, big data exploitation, etc.) to improve/integrate the technical building blocks most appropriate to address these markets.

Understanding of what creates trust, what is experienced as challenges and what kinds of smart society needs exist among users and what kinds of implications to security these include, need to be explored from initial steps of the development and continuously in parallel with it.

On selected application areas, Living labs experimentations shall be based on multidisciplinary approaches, and involve service providers, end users and operators. The Public Authorities will generally play significant roles in these experiments, both through Public Procurement and as evaluator / regulator. The experiments shall provide actual feedback, provide ideas for new solutions and services, demonstrate how technology innovations can be adopted, and how “smart” usages can be supported. In addition, these experiments shall contribute to increase end-users trust, which is mandatory for a sustainable growth of the corresponding market. On another end the lack of public implication and slowness in decision process favours the emergence of solutions driven by the market and/or usage brought by end-users (e.g.: social networks, services for Taxi and co transportation, etc.) in this perspective, Public/Private partnership has to be considered also as a strong vector of development.

In both cases development and implementation of the Smart Society solutions will need from one side public acceptance and from the other side deep understanding of the societal needs and consequences of the Smart Society. All these aspects are strongly connected with culture of the European societies, being different in different regions. Thus, the Smart Society addressed solutions and innovations will much better harmonize the European way of life, values and societal preferences when developed in Europe.

The priority is to support projects aiming at higher TRL solutions. This will include the definition and development of application specific security architectures, higher level building blocks and subsystems based on adopted or modified existing components and recognized opportunities for new services.

Low TRL topics include investigations on new algorithms and protocols, data sharing schemes, secure architectures' (embedding cryptography and Secure Information Sharing solutions) protection against new attacks on data safety and security (e.g. tapping, manipulating, spying or copying), authentication and adaptability of security mechanisms. New concepts and solutions should aim at user acceptance by ease of use and protection of personal data privacy. From the end-user viewpoint one of the key elements concerning interaction with the Smart Society is the secure and seamless authentication to services of the Smart Society. A specific goal is to investigate and evaluate different authentication techniques and their combinations from various aspects (e.g. usability, non-intrusiveness, privacy) in collaboration with users in order to identify requirements for the usable and secure authentication and seamless user experiences in the Smart Society.

Transverse to low and high TRLs, in the context of Smart Society, massive introduction of IoT will, for sure, pose a lot of questions around privacy, data security and policy making. So in order to set up a legal framework to protect citizens, standardization is a key element that is also necessary to boost European competitiveness and will ease IoT deployment and its interoperability in a secured environment.

6.2.3 Impact

Smart society is a worldwide topic.

The impact pursued by ECSEL include European independence on critical assets, European leadership for the Internet of Things, European assets protection, and competitiveness of European industry.

6.2.3.1 Europe independence for security enabling components and systems

The aim is to ensure availability of trusted components and subsystems as building blocks for smart applications. In particular, all critical hardware and software components with respect to security shall be available from European sources (including sensors, actuators, sensor networks, gateways, servers, middleware, etc. for IoT/M2M support), and be independant as much as possible from US and Asia solution.

6.2.3.2 European leadership for Smart and Connected Things (including Internet of Things)

Low-cost components and reference architectures, exploiting short range wireless connectivity with demonstrated benefits in applications such as (but not limited to) home/building automation, home entertainment, payment and ticketing, indoor localization, security and safety and more generally leveraging the "internet of things" in European and ECSEL leading applications.

6.2.3.3 European assets protection

Focused demonstrations of critical functions, such as end-to-end security, to protect the integrity of the data and guarantee the authenticity of the transmitters. These functions could be deployed in different application areas of ECSEL, and could benefit from space and terrestrial navigation, communication, positioning and observation. The impact includes reduction of attacks on critical infrastructures, avoiding theft of digital identity (e.g., in payment transactions), and opening the way to new European interconnected applications – in addition to increased emergency management capabilities, increased safety and security of road, air, rail and marine transports infrastructures.

Public awareness of Europe's efforts on Safety and Security

Field demonstrations of selected applications, involving such components and subsystems in urban spaces or areas (such as cities, airports, buildings), in ECSEL and European leading applications with digitalization and more connectivity and with impact on safety, security, and privacy.

Reducing time to market of European innovations

Innovative architectures combining smart devices with broadband connectivity, enabling new digital life and new digitalization (including interactive e-shopping, video surveillance and conferencing, online gaming, etc.) with guaranteed and adequate privacy.

Open up new market opportunities for European industry

Development of today's leading European companies with secure and safe products (components manufacturers, equipment or systems integrators) as well as new actors, in the very fast growing markets of secure and safe solutions for the smart digital society.

6.2.4 Cross references

Some of the core technologies needed for the smart society building blocks (in terms of devices, associated integration technologies, embedded software and reference architectures) are expected to be developed in the context of the "Cyber-Physical Systems" and of the "Smart System Integration" technology domains of ECSEL.

The system design tools addressing safety and security developed in the context of the "Design Technologies" domain of ECSEL will be needed for the specification and design of system architectures. Of particular importance is vulnerability analysis and investigation of attack scenarios.

The technical building blocks and reference designs developed in the context of this "Smart Society" domain of ECSEL should feed other domains (mobility, health, and manufacturing) for applications where security is a transverse concern.

Applications can be found e.g. in:

Health care
1) Fall detection, medical devices
2) Sport and fitness sensors
3) Distance health monitoring and health care
4) Monitoring of daily patterns of elderly, and changes in them

Home entertainment and home automation
1) Barometer /weather station, remote controls, game controllers, robots, smart TV controls, light dimmer, light on/off, fire detection, smart energy, context aware media services, time management & mobility services, etc.

Internet based services
1) Secure authentication for mobile payment / secure implementation of mobile apps /secure connection to cloud services / BYOD scenarios in the context of a customized wallet that will include also corporate functions such as physical and logical access, authentication, and signature.
2) Technologies to ensure user acceptance by ease of use and comfort and fast processing.

3) Secure and anonymous identification within the web (e.g. derived identity).
4) Secure communication and authentication of electronic identities.

Smart mobility
1) Convergence of mobility as consequence of the urbanization: Using different transportation systems with one media for access and fare collection (public transport, car sharing, bikes, rental cars, etc.).
2) Secure connectivity for the car to ensure safety, convenience and to manage the urban mobility; secure car2car, car2x and other communication into and out of the car.
3) Secured in vehicle networking especially for safety relevant systems.
4) Efficient services for easy navigation and transportation such as multimodal and geolocalization (e-beacon, Find me) information.

Smart Manufacturing and logistics
1) Security in intelligent networks (e.g. machine to machine communication) and industrial automated control systems
2) Communication and access in open systems; protection by end2end security
3) Trusted electronic IDs for man and machines
4) Protection of the critical infrastructure by de-centralized security architectures

Further applications are foreseen in all kind of autonomous devices using new energy harvesting approaches as well as for versatile devices for multiple applications (supporting cognitive radio).

6.2.5 Schedules/Roadmaps

Visible results are expected as follows:

Short term: availability of core technology building blocks and reference designs, preliminary demonstrations of pilot systems, and initial technology road mapping for next steps based on market priorities including identification of needs and critical aspects based on user understanding and co-innovation through collaborative projects.

Midterm: demonstration of innovative system architectures based on these building blocks and reference designs. Consolidation of technology road mapping.

Long term: co-developed concepts for trusted smart society services, strategies for creating trusted solutions, demonstration of user trust and acceptance. Evidence of the actual support to implementation of innovative digital services for a smart society.

A limited number of living labs experimentations, spanning the whole duration of the program, fed by technology innovations, contribute to their integration, and support the demonstrations.

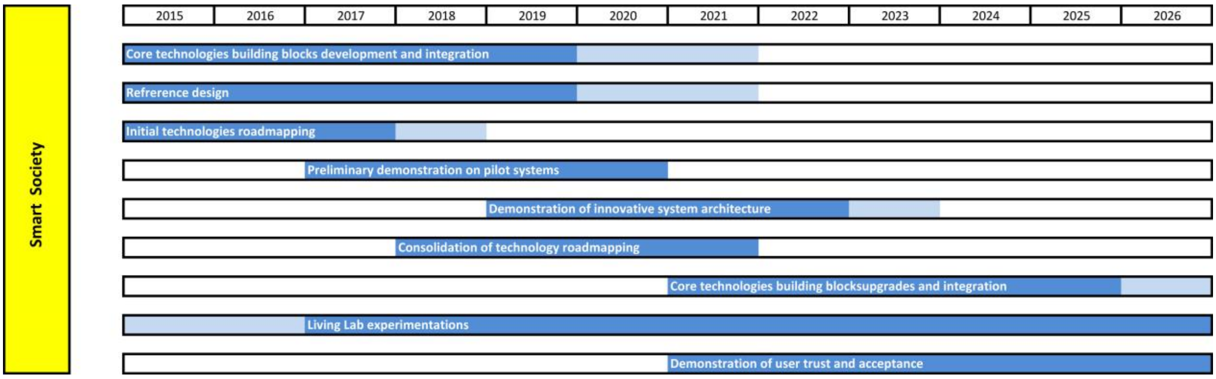


Figure 3 - Expected visible results

6.3 Smart Energy

6.3.1 Objectives

Significant reduction of primary energy consumption along with the reduced carbon dioxide emissions [3) 4) 5)] is the key objective of the Smart Energy chapter. Electronic components and systems (ECS) are key enablers for higher efficiencies and intelligent use of energy along the whole energy value chain, from generation to distribution and consumption. Enhancing efficiency in the generation, reducing energy consumption and carbon footprint are the driving forces for the research in nano/micro-electronics, embedded and integrated systems in order to secure in all energy applications the balance between sustainability, cost efficiency and security of supply.

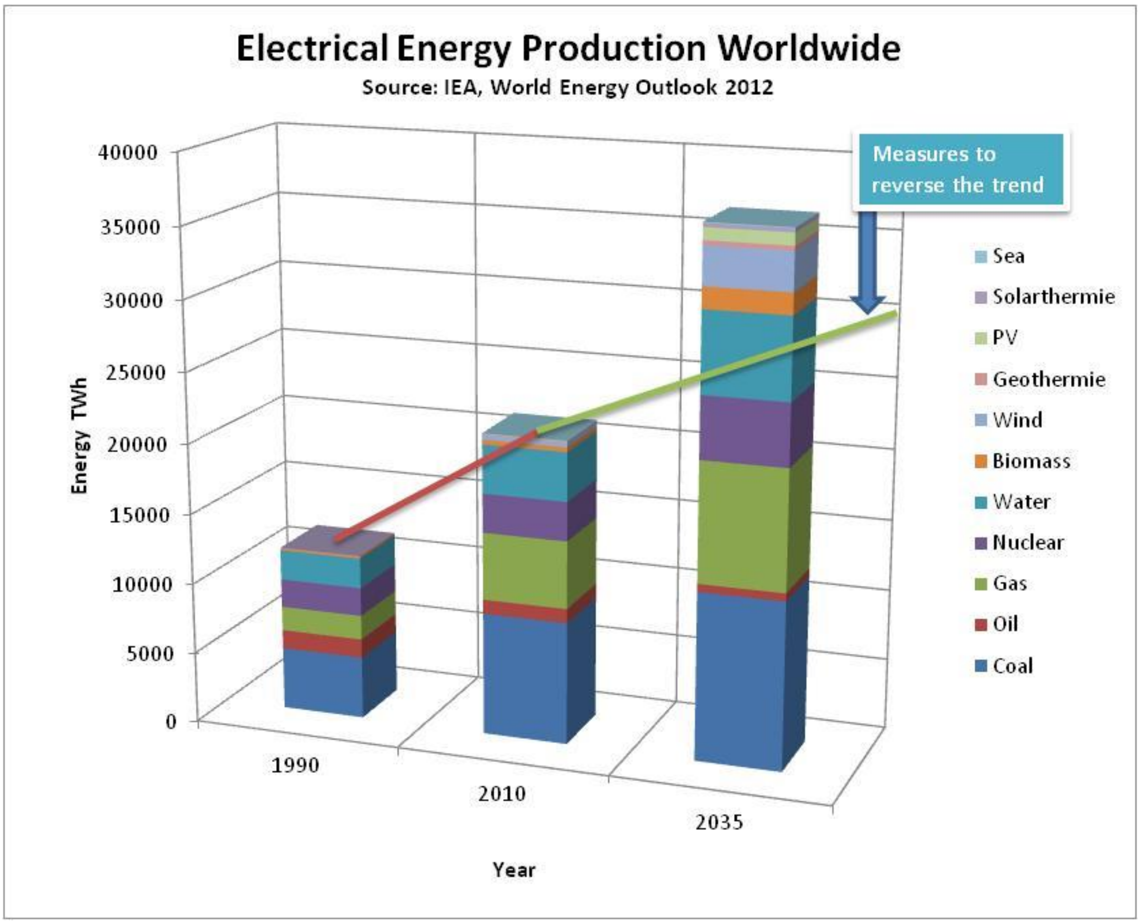


Figure 1 - Electrical Energy Production – Efficiency measures, electrification in particular in transport and installation of renewable as the only way to limit greenhouse gas emissions by coal, oil and gas.

6.3.2 Strategy

Three main domains will be in the focus of upcoming research for ECS:

1) Sustainable **power generation and energy conversion**
2) Reduction of **energy consumption**
3) Efficient community **energy management**

Research targets have to cover innovations in further enhancement of efficiency, reduction of consumption and by miniaturization of the system sizes. Almost equally important becomes research and innovation on opportunities to reduce green house gas emission by the so called electrification of primary energy intensive processes in industry, infrastructure, buildings, transport and logistics. Along with new applications the demand for highly reliable and robust devices has to be supported. In addition the capability of self-organization of devices in a smart grid as a system of systems to enable highly efficient use of energy becomes a priority research issue. The potential of digitalization and new topologies has to be leveraged to achieve significant energy savings keeping costs down and comfort high on the user side.
The necessary innovations in smart energy require applied research including validation and prototyping. Both development and pilot projects can address these areas. Furthermore research activities, developments and demonstration scenarios should be open to different application scales (like home, building, district, city and region but also industry and transport). As an application oriented area the majority of projects and in terms of spent funding should be on research projects with capability to be quickly transferred into market relevant solutions.

SMART ENERGY	**NEED** *Energy Innovation*	**ACTION** *Technical innovation*	**RESULTS** *Economic impact*	*Societal Impact*
sustainable **Power Generation** and **Energy Conversion**	Growing energy demand remains, increased share of renewables supported by ECS	Efficiency improvements; lifetime, robustness and reduced life cycle cost including smart maintenance	Competitive position of European industry to create an increase in the EU value chain	Reduced GHG emissions, more efficient renewable energies, creation of local employment
	Efficient distribution	Intelligent and highly efficient converter		
reduction of **Energy Consumption**	New solutions for energy efficiency on system level	Efficient energy usage; scavenging, intelligent drive controls; smart controls for demand site integration, monitoring on system level by sensor networks	New markets for system solution and services; sensors, control systems, efficient equipment and appliances	Less dependency on energy supply, less costs for energy, new employment opportunities
efficient community **Energy Management**	Efficient management of demand, distribution and supply including storage	Self-organizing grids and multi-modal energy systems incl. energy storage, resilient and self healing infrastructure, energy scavenging and IoT services	New businesses for management of energy supply and storage, competitive position of European industry	Enhanced involvement and acceptance of citizens for reduced energy consumption Decentralized services with local employment

Figure 2 - Strategic areas for Smart Energy components and systems

6.3.3 Impact

Smart Energy related research has to support the EU target for 2020 of saving 20% of its primary energy consumption compared to projections (source Energy Efficiency Plan 2011 (Com 2011-

109)). European companies are amongst the leaders in smart energy related markets. With innovative research on European level this position will be strengthened and further employment secured. The research therefore has to address: [3] [5]

1) **reduction and recovery of losses** by significant values (application and SoA related),
2) **decreased size of the systems** by miniaturization and integration,
3) **increased functionality, reliability** and lifetime (incl. sensors & actuators, ECS HW/SW, ...),
4) **increased market share** by introducing (or adopting) disruptive technologies
5) **the game change to renewable energy** sources and decentralized networks involving energy storage to stabilize the power grid preferably on medium and low voltage levels as well as to manage the intermittence of renewable power generation, offering new opportunities to consumers.
6) "plug and play integration" of ECS into **self-organized grids** and multi-modal systems
7) **safety and security** issues in self-organized grids and multi-modal systems

The ECS for smart energy (incl. components, modules, CPS, service solutions) which support the EU and national energy targets[1] [2] [3] will have huge impact on the job generation and education if based on the complete supply chain and fully developed in Europe. [5] The key will be the capability to have the complete systems understanding and competence for small scale solutions up to balanced energy supply for regions. [6] Mandatory are the capability for plug and play of the components enabled by a broad research contribution from SMEs, service providers including EU champions in the ECS and energy domain.

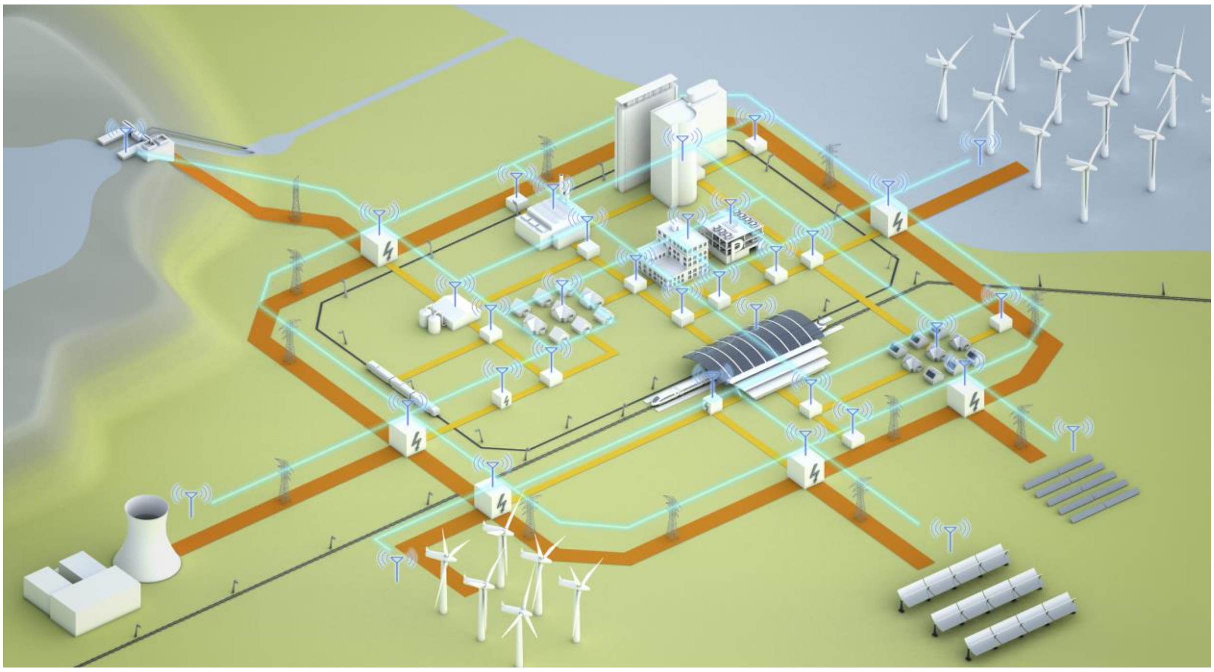


Figure 3 - Smart Energy landscape – from centralized to distributed (PV, wind, biogas, ...) generation and conversion, consisting of High/Medium Voltage grid (orange), Low Voltage grid (yellow) including Communication Network (aquamarine) linking producers and consumers down to regional and community level.

6.3.4 Cross references

The ambition of ever and ever higher efficiency and reduced losses in the use of energy requires continuous innovation from semiconductor process to integration technologies (see Part "Essential Capabilities", e.g. semiconductors for power and control, assembly and package technologies). Since safe and stable energy supply is a dominant factor in all application areas, innovation in different kind of domains from **mobility** (e.g. eMobility, Car2X), **production** (e.g. efficient control of sensor networks and actuators for collaborative robots), networked **society** (e.g. safe & wireless communication among networked sensor systems, self controlled HVAC and lighting) and robust **healthcare** (e.g. high performance storage or converter controls for un-interruptible power supply) can benefit from synergetic solutions (see also Fig. 4).

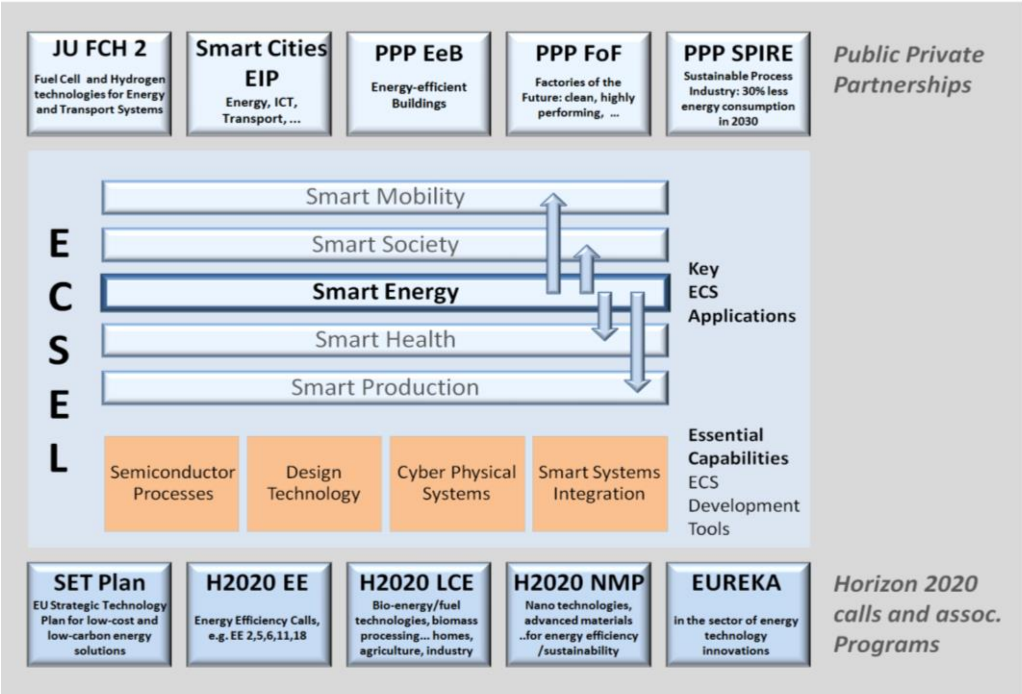


Figure 4 - Major cooperation lines for synergy of ECSEL Smart Energy with other chapters and the relations to energy related programs within H2020 and the PPP initiatives

The ECS value chain needs to take advantage of synergies based on generic R&D from basic functionalities in ICT, NMP, Low Carbon and Energy Efficiency technologies up to system relevant design and systems integration including CPS based modelling and real time control, big data and cloud infrastructures with demonstration on use cases in homes, large office buildings, production facilities, agriculture, and infrastructure.

ECSEL will deliver innovative ECS functionality to application-oriented energy research programs as the Joint Undertaking for Fuel Cells and Hydrogen, European Innovation partnership on Smart Cities and Communities, to PPPs for Energy efficient Buildings, Factories of the Future and Sustainable Process Industry to generate competitive answers for Europe's challenges described in the SET plan (Fig. 3.3 and Ref. [5) 6)]).

References:

1) *COM (2014) 15 final – A policy framework for climate and energy in the period from 2020 to 2030, Brussels January 2014 – The so called 20-20-20 targets*
details see in : http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52014DC0015&from=EN
2) *Climate and energy priorities for Europe: the way forward; Presentation of J.M. Barroso President of the European Commission, to the European Council of 20-21 March 2014 –*
https://ec.europa.eu/energy/sites/ener/files/20140522_3nd_meeting_dgenergy.pdf
3) *"Leaders´ declaration G7 summit, 7-8 June 2015, p15 and following:*
"... commitment to the elimination of inefficient fossil fuel subsidies ....": "...common global goal of GhG emissions reduction ...of 40 to 70% by 2050 compared to 2010..." ;
" We will strengthen cooperation in the field of energy efficiency and launch a new cooperative effort on enhancing cyber security of the energy sector. And we will work together and with other interested countries to raise the overall coordination and transparency of clean energy research, development and demonstration, highlighting the importance of renewable energy and other low-carbon technologies. We ask our Energy Ministers to take forward these initiatives and report back to us in 2016."
https://www.g7germany.de/Content/DE/_Anlagen/G8_G20/2015-06-08-g7-abschluss-eng.pdf
4) *Reacting to the summit's final declaration, the European Climate Foundation described the G7 leaders' announcement as historic, saying it signalled "the end of the fossil fuel age" and was an "important milestone on the road to a new climate deal in Paris".*
5) *The new Integrated SET Plan, fit for new challenges, Sep 15 2015, adopted by the EC as the new* ***Strategic Energy Technology (SET) Plan****. The upgraded SET Plan is the first research and innovation deliverable on which the fifth dimension of the Energy Union will be built. Building on an integrated approach going beyond technology silos,* ***the upgraded SET Plan proposes ten focused research and innovation actions to accelerate the energy system's transformation*** *and create jobs and growth, ensuring the European Union's leadership in the development and deployment of low-carbon energy technologies.*
for more information see: https://ec.europa.eu/energy/en/news/integrated-set-plan-fit-new-challenges
6) *EU project EXPRESS - Mobilising Expert Resources in the European Smart Systems Integration Ecosystem deliverable D3.2, chapter on Energy and lists of Drivers, Barriers and Application Opportunities for SSI in the Energy sector based on analysis of the 15 international and national roadmaps and strategy documents. These opportunities respond to needs identified by actors outside of the ECSEL community to create business with the sectors who published these strategy documents. Examples include the integration of tracking control electronics and the inverter into one device as highlighted by the EUPV Technology Platform, and monitoring devices for analysing the aging of the equipment for Smart Grids etc.*
for more details see: http://www.express-ca.eu/public

6.3.5 Schedules/Roadmaps

ECSEL MASRIA 2016	SMART ENERGY Road Map				
1	**ECS for Sustainable Power Generation and Energy Conversion**	**2016**	**2017 - 2018**	**2019 - 2020**	**2021 - 2030**
1.1	**Highly efficient and reliable ECS** for all kind of electrical energy generation – de-centralized to large power plants, cross link to processes and materials				
1.2	Smart and micro **converter reference architecture** with integrated control				
1.3	**Highly integrated power electronics**, actuators for safe and reliable DC and AC grids				
1.4	**Converter on a chip** or integrated modules				
2	**ECS for Reduction of Energy Consumption**	**2016**	**2017 - 2018**	**2019 - 2020**	**2021 - 2030**
2.1	**Implementation** of smart electronics **in smart grid nodes** including system integration with communication interfaces				
2.2	ECS for controlled power/drive trains and illumination				
2.3	**Smart electronic components** for (MV/LV)DC power supply implemented in e.g. buildings, factories, infrastructure and vehicles/planes)				
2.4	**Distributed DC network**				
2.5	Smart electronic components for MV/DC grid integration of **storage** and renewable				
2.6	**Fully connected ECS** for e.g. illumination and city energy use				
3	**ECS for Efficient Community Energy Management**	**2016**	**2017 - 2018**	**2019 - 2020**	**2021 - 2030**
3.1	**monitoring** of energy infrastructure and cross domain services (e.g. maintenance, planning and IoT services)				
3.2	Decreased integration costs in **self-organizing grids**				
3.3	Smart systems enabling optimized heat / cold and el. power supply				
3.4	ECS support for standalone grids and self-organization incl. Scavenging				
3.5	Smart systems enabling optimized **power to fuel** and **coupling of transport and el. Power sector**				

Figure 5 - Smart: Energy Road Map – short to long term application driven R&D&I targets

Smart Energy	**Short term**	**Medium term**	**Long term**
overall targets embedded in EU strategy	EU targets for 2020 supported (20/20/20) **greenhouse gas** levels reduced by 20% Increase share of **renewable** to 20%. Reduce energy **consumption** by 20% Projection regarding the targets in 2020: 24/21/17	ECS for recovery of the not matched targets in 2020 and preparation for 2030 targets Supply by European manufacturing of ECS secured	EU targets for 2030 supported by ECS from European suppliers: share of renewable energy in the electricity sector would increase from 21% today to at least 45% in 2030
targets for energy supply from communities to regions	**1st order decentralized** simple connected local systems – higher efficiency and first integration approaches including power system services (last mile – around 100 users)	**2nd order decentralized** regional area balanced energy supply (villages and cities up to 100.000 users) ECS capable for efficient fast reaction oversupply and peak load management	**3rd order decentralized** on country level balanced energy supply

6.4 Smart Health

6.4.1 Objectives

World global healthcare expenditure is currently estimated to 6000 billion of euros and its growth will continue greater than the GDP in virtually all countries magnifying budget deficits. By 2030, world population will increase by 1.3 billion, the middle class by 3 billion, due to ageing, the world's **population** ages **65+** is projected to increase by 436 million people and urban population by 1.5 billion requiring increased access to healthcare facilities and service.

A January 2013 survey in USA by The Pew Research Center's Internet & American Life Project reported that 33% of US adults keep track of indicators like blood pressure while 40% with one chronic disease condition are tracker and 62 % with 2 conditions are tracker. But most people do not share the information with anyone, including their physician.

Consumers are ready for more innovative high tech health care solutions (reference Deloitte's 2012 Survey of US Care Customers). 62% are interested in using self-monitoring devices to track their health and report information to their doctors electronically.

It is estimated that 40% of healthcare expenditures result from inefficiencies or inappropriate care.

In order to cope with these issues, healthcare will evolve versus **Smart Health**, which will cover affordable care and well being at home, abroad and in hospitals; heuristic care; food processing; and food safety. **Smart Health** will be people- and patient-centric, with a key role for medical technology supporting patients throughout the phases of the care cycle (prevention, diagnosis, treatment/therapy, and after-care).

Objective 1: Transform from now to 2025 healthcare from state of the art to standardized care in order that existing medical devices and medical supplies become more and more applicable outside the hospitals. The transformation should result in gradual migration to a more controlled uniform and efficient delivery of care for the population, the decrease of cost and quality differential between care providers, patient management not only local at the medical doctors and in hospital but largely spread.

Objective 2: Creation of an open Digital Health Platform ecosystem, enabling cost effective development and validation of healthcare appliances and applications. The platform will provide an open environment, enabling a wide range of collaboration opportunities and easy market access for new applications. The platform is open for new appliances and applications by providing API's (Application Programming Interfaces), while taking safety, security and privacy into account.

Objective 3: Mobile healthcare systems based on micro-/nano-electronics, to increase sustainability and efficiency of health systems and support the improvement of quality of life for patients, in particular of elderly people with chronic disease. In the end, dedicated sensor systems have the potential to significantly reduce number of casualty and unscheduled hospitalizations. Patients should be more self-empowered to manage their disease by their own.

Technology can enable a new form of patient care that effectively moves away from a hospital setting for patients that require routine monitoring with their well-being and comfort is enhanced when in a home environment. This also frees up hospital beds and has the potential to reduce the pressure on hospitals.

Objective 4: Medical equipment and devices are evolving fast, especially in the changeover from open surgery to closed (minimal invasive) surgery.

Innovation in imaging (e.g: functional imaging, higher resolutions), multi-model imaging (e.g. HIFU) and image guided intervention will open up complete new treatments, workflows and markets.

Objective 5. Contribution to creation of healthy living conditions through broad deployment of ICT based monitoring systems, including healthy food chain from farm to the table as well as healthy environment.

6.4.2 Strategy

Health continuum

Development and innovation in "Smart Health" should focus on Platforms to enhance the health continuum and standardized care complementing medical equipment with wearable / implanted, multi parameter sensor systems, and related algorithms covering the whole health spectrum between healthy living and home care. See the figure below.

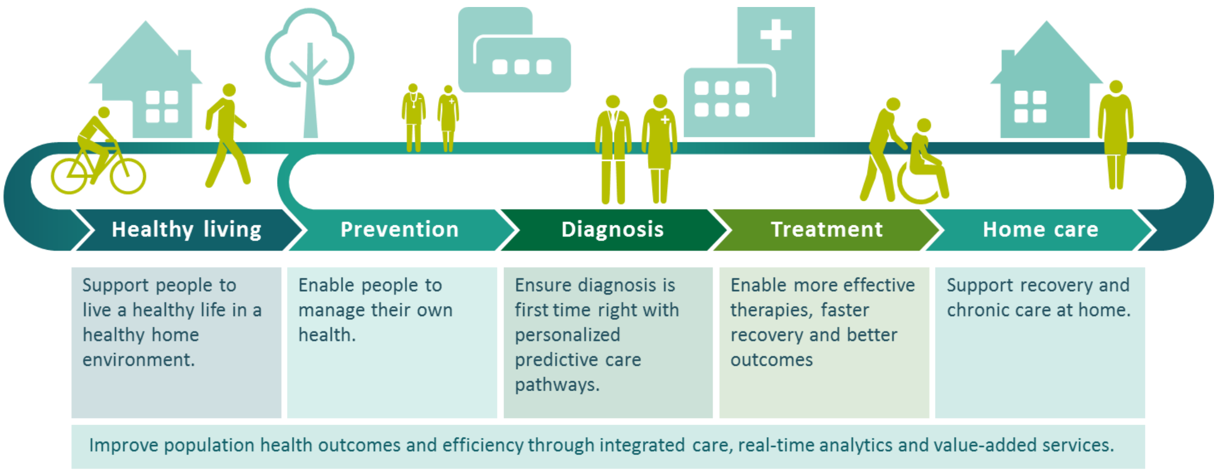


Figure 1 - Health Continuum

The challenges of the Digital Health Platform ecosystem are twofold: organizational and technical. The organizational challenges should deal with the definition of the ecosystem and partner contributions and around platform validation as well as quality assurance of the building blocks. The technical challenges deal with the API's and the technical building blocks in the collaboration cloud, connected device cloud and secure data cloud.

IoT devices for healthcare body worn or implanted should become commodities to feed data into analytics applications and predictive algorithms. Smartphones and tablets allow ubiquitous connectivity. Cloud computing can facilitate physician support and disease management. Interoperable electronic health records and information exchange could allow care quality metrics monitoring and technology assessment, reducing duplicative tests and procedure, reducing errors and readmissions.

Artificial Intelligence, natural language processing, machine learning, cognitive computing should be able to provide more reliable, real time data to the physician that impact faster on accurate clinical decisions. This is essential when it is expected by 2020 that new medical knowledge is going to double every 73 days (ref: 2020 Vision, Curriculum Renewal Project a message from Dean Rothman, Univ. of Iowa Carver College of Medicine 2012).

As quality of food and environment have a considerable impact on health status of citizens, monitoring of food quality and environment pollution is of paramount importance for healthy society. It is especially worth to note, that observed climate changes result in unstable farming conditions, therefore, the precise monitoring of plant or livestock farming using advanced ICT IoT solution should be used to prevent necessity of excessive usage of chemistry *fertilizers, and pesticides) in farming, fishery and forestry. Furthermore, environment quality monitoring

Research is still needed in setting the right diagnoses, requiring new multi model imaging equipment, new minimal invasive devices for diagnostics and treatments, enhanced clinical decision support, validation and certification methods and improving speed of bringing these innovations to the market. The emerging permanent monitoring capability creates the need for new health care approaches based on multiple sensor data sources running permanently.

Improvements needed for home care and well-being in:

1. Disease prevention, promotion of healthier life-style, and remote coaching
    a. Life-style profiling and activity recognition
    b. Personal lifestyle monitoring and guidance (diet, activity)
    c. Smart assistive services to support daily life activities
    d. Oral health measurement for regular assessment of home oral hygiene efforts
    e. Smart textiles with connected sensors and energy autonomous systems
    f. Improvement of wellbeing through environmental influences e.g. lighting
    g. Wellness environments for enhanced mental health and wellbeing
2. Remote health monitoring and support (e.g. for the elderly)
    a. Personal health management
    b. Autonomy monitoring and pre-dependency assessment
    c. Flexible textile-based systems for on-body diagnostic and therapeutic functions
    d. Domestic accident detection, monitoring, warning and emergency alert
    e. Advanced tele-health, including personalised facilities to engage patients in the self-care process, and early identification of potential personal risk factors
    f. Home monitoring systems for health related parameters by non or minimally invasive molecular diagnostics
3. Remote disease management
    a. Prevention of hospitalization for chronic diseases for a large elderly population
    b. Tele-medicine, home diagnostics monitoring, point-of-care screening devices, ultra-small smart implanted and on-body diagnostic and therapeutic devices, broadening diagnostic scope
    c. Non-invasive measurement eg. of blood parameters, bio markers and (de)hydration
    d. Smart devices, e.g. e-inhalers, bandages, in vivo treatments and new responsive biomaterials
4. Advanced tele-rehabilitation services (e.g. with portable robotics)
    a. Adherence to long-term therapies
    b. Personalized therapy through smart implantable devices
    c. Peripheral medical devices to power and control ultra-small diagnostic or therapeutic implanted devices

5. Technological cross-application advances
    a. Secure/private tele-monitoring networks
    b. Wearable and in vivo electronics and smart integration to measure biometric parameters and related treatments
    c. Personalization and consumerisation
    d. Localization techniques (indoor and outdoor)

Improvements for hospital and heuristic care in:

1. Advanced imaging based diagnosis and treatment
    a. Robotic image-guided surgery
    b. Improved image detectors that capture greater detail
    c. Advanced imaging for several modalities
    d. Smart micro-tools for advanced medical treatment (surgery, biopsy, …)
    e. Image-guided biopsy and treatment procedures
    f. Multi-modal heterogeneous data processing for advanced decision support
2. Screening for diseases
    a. Non-invasive screening for disease
    b. Early screening for diseases and improved screening imaging systems
    c. Efficient screening of drug potential with bio-electronic devices
    d. Decision support systems based on heterogeneous multi-parametric data
    e. Point of care monitoring of health related parameters by non- or minimally invasive molecular diagnostics
3. Intelligent data management
    a. Personalized health data ensuring data security
    b. Heuristic algorithms for personalized treatment
    c. Risk profiling based on biomarkers or genetic profiles
    d. Big data analysis
        i. on image sets for treatment preparation and screening
        ii. of medical imaging and signal processing systems
        iii. of unstructured medical information
4. Personalized medicine
    a. Real-time response to drugs
    b. High performance computing systems for drug design
    c. Human organ and disease model technologies (organ-on-a-chip)
5. Intervention / therapy
    a. Digital patient for planning surgical procedures
    b. Image-guided biopsy, treatment and therapy procedures
    c. Robotic image-guided surgery and therapy for many diseases
    d. Multi-modal, low X-ray dose, accurate visualization and guidance
    e. Smart intervention devices with e.g. image guidance, pressure sensing
    f. Operating room of the future: swallowed or implantable miniaturized capsules with imaging or sensors for diagnosis / surgery / therapy
    g. Patient safety, pharma compatibility and treatment consistency verification
6. Smart environments, devices and materials
    a. Healing environments for improved patient wellbeing
    b. Energy autonomous smart systems with multi-parameter sensors
    c. Smart automated drug delivery with or without smart implants
    d. Adaptive prosthetics, artificial organs
    e. Improved smart systems-based biosensors

    f. Microsystem technology based implants and implant support, e.g. deep brain stimulation, neuromodulation, multifunctional components, (nano)coatings for harsh environments and long term use
7. Remote diagnosis and monitoring / support
    a. Remote medical intervention and virtual team support

Food impact on health, needs for food processing and safety

The impact of food on health is demonstrated. Still there is a need of devices helping the people to prepare a healthier food, to help them to eat the proper quantities and select the proper ingredients. Also there is a need to monitor the food intake with trackers in order to stay healthy or get healthier. There is a need to provide assisted automatic coaching based on these devices.

The food supply chain needs also improvements in environmentally friendly sustainable food processes and combine efficiency and responsiveness to changing consumer demand for quality and diversity. For food production there are still unmet needs like wireless sensor nodes on cattle, positional tracking of animals, health and physiological state monitoring, improved growth yield, energy efficiency smart tools for scalable and flexible food manufacturing, intelligent in-line control. production line, on-site monitoring for contamination of food.

For food distribution there are still unmet needs like active and intelligent packaging solutions and tracking, disposable biosensors for quality control of food products.

For food retail there are still unmet needs like cold chain management of food, dynamic shelf life prediction and improved shelf life of food products.

For food processing there are still unmet needs like optimization of food process for waste reduction, cost-efficient, precise and miniaturized sensor systems for quality and performance control in food processing, smart labelling for simplifying life of people having for health reasons nutrition constraints.

For food preparation there are still unmet needs like smart delivery of functional ingredients, novel ways of cooking and food preparation, innovative packaging for diet monitoring

6.4.3 Impact

The ambition is to influence all stakeholders in the entire health continuum. The stakeholders are individual patients, healthcare professionals, industry and economy as a whole. Targeted disease areas to be addressed will be cardiology and cancer. For each category of stakeholders the main ambitions and impact are stated below:

Impact for Patients:

- Shorter hospital stay
- Safer and more secure access to healthcare information
- Better personalized prevention, diagnoses and treatment
- Improved quality of life
- Reduced risk to further complications that could result from hospital treatment
- …

Impact for Healthcare professionals:

- Improving decision support
- Providing safer and more secure access to healthcare information
- Unlocking totally new clinical applications
- Enabling better training programs leading to more well trained professionals
- …

Impact on European industry

- Maintaining and extending leadership positions of European Industry
- Creating new market opportunities in the Digital world for European large industry and SME's
- Opening up a new world of cloud based collaborative care
- Increasing efficiency of health prevention, diagnoses and treatment
- …

Impact on European society:

- Creating of a European ecosystem around digital healthcare
- Contributing to the reduction of growth of healthcare cost
- Improving quality of life and productivity of labor force
- Decreasing or considerably slow down increase of number of morbidity among society.

Impact on Health Care Payers (insurance companies, national authorities)

- Reducing cost
- Introducing a more lean approach to health care provision
- Appropriate budget is not wasted and value for money is prioritized

6.4.4 Technical challenges

<u>Technical challenges are on the whole health care system foreseen:</u>

- A reference architecture and platform combining the enormous amount of connected equipment types and versions is needed to assure interoperability on technical level and information level. This architecture and platform should ensure dependable interoperability in the cloud and over the internet taking into account the large amount of dependability variation in the devices themselves.
- New sensors and systems are needed to measure and monitor specific health parameters to improve the diagnostic quality and specificity. Beside miniaturization biocompatibility, lifetime and robustness are key challenges for new technological advances.
- An infrastructure is needed to manage all the data both in hospital and outside the hospital ensuring data capture, information presentation, security (prevent unwanted access to data), privacy (keep personal information personal and use data for personal needs) and ethics (prevent misuse of data).
- New decision support techniques using many data sources, including data mining, taking differences in data source dependability into account have to be developed.
- New applications will be developed, analyzing available data taking security, privacy and ethics into account

6.4.5 Cross references

Synergies between ‘Smart Health’ and the other chapters:

Application chapters:

1) Smart Mobility: e.g. mobile health status monitoring (for example, monitoring a car driver’s vital signs)
2) Smart Society: the next-generation digital lifestyle should guarantee prevention and privacy of medical data, requiring trusted components. Smart healthcare needs to become part of the smart environment, only this allows ubiquitous support for patients, and providing prevention
3) Smart Production: certification of medical equipment implies careful manufacturing using affordable and flexible production tools such as 3D printing and tools capable that the used parts are traceable and documented.

Technology chapters:

1) Process technologies: microfluidics and heterogeneously integrated smart systems, including advanced sensors, advanced materials and novel process technologies (e.g. for MEMS); 3D printing and packaging for low to medium volume medical device production.
2) Design technologies: Because healthcare systems are complex and demanding, designing such systems requires an integrated tool chain that supports all stages of system design. Access to design tools that are adapted to low to medium volume industrial needs should also be made available to SMEs and larger companies.
3) Cyber-Physical Systems: As most medical equipment will be wirelessly ‘connected’ and will measure multiple physical parameters, secure, adaptive CPS platform architectures are required.
   Standardization and semantic interoperability issues will also be addressed, as well as health-care data mining expert systems.
4) Smart Systems Integration: For multidisciplinary system integration - e.g. for devices ranging from lab-on-chip and point-of-care diagnostics to complex diagnostic, interventional/therapeutic systems. Unobtrusive, mobile health-status monitoring and smart-treatment systems also require multidisciplinary integration and packaging.
4) With the four technological domain contributions low power devices have to be enabled: autonomous, low-power techniques for both wearable and implantable smart devices, including energy harvesting and wireless power transfer for autonomous implants or wearables

6.4.6 Schedules/Roadmaps

ROADMAP for SMART HEALTH

#	Topic \ Time	2016	2017-2018	2019-2020	2021-2030
1. HEALTHY LIVING					
1.1	Life style, diet support and physical exercice promotion based on artificial Intelligence AI, natural language processing				
1.2	Connected trackers powered by energy scavengers or having more than one year autonomy				
1.3	Inexpensive sensor systems that can detect changes in health status without bothering the user				
1.4	Aggregating sensor systems or trackers data from different vendors to the cloud or to a secured hub				
1.5	Interoperable secured electronic records from sensor systems				
1.6	Artificial Intelligence AI, natural language processing, machine learning, cognitive computing for communicating with a person				
2. Prevention					
2.1	Autonomous sensor system that could detect diseases 10 -14 days before the usual assessment by a health care provider or the adult self-reported illness. Devices powered by energy scavengers or having more than one year autonomy without the need to actively use or wear a device				
2.2	Linking sensor system to cloud a patient hub				
2.3	Inexpensive autonomous sensor system for genomic and biomarkers of vital signs				
2.4	Artificial Intelligence AI, natural language processing for prevention capable of communicating with a patient or a healthcare provider for prevention				
3. DIAGNOSIS					
3.1	Inexpensive autonomous sensor systems for referenced biomarkers vital signs used in emergency situations				
3.2	Artificial Intelligence AI, natural language processing for emergency situations capable of communicating with a patient or a physician				
3.3	Aggregating sensor systems data from different vendors to the cloud or to a secured hub				
3.4	New multi model imaging equipment , new minimal invasive devices for improving diagnostis				
4. TREATMENT					
4.1	Quality metrics monitoring and technology assessment, reducing duplicative tests and procedure, reducing errors and readmissions				
4.2	Atomatic delivery of the therapy with minimal or no patient involvment				
4.3	Aggregating data from therapy delivery systems from different vendors to the cloud or to a secured hub				
4.4	Artificial Intelligence AI, natural language processing for prevention capable of communicating with a patient for providing a therapy				
4.5	New multi model imaging equipment , new minimal invasive devices for improving treatments				
5. HOME CARE					
5.1	Systems having artificial Intelligence, natural language processing capable of communicating and interacting with patient for providing a therapy at home				
5.2	Atomatic delivery of the therapy at hone with minimal or no patient involvment				
5.3	Aggregating data from therapy delivery systems from different vendors to the cloud or to a secured hub				

Figure 2 - Roadmaps for Smart Health

6.5 Smart Production

6.5.1 Objectives

The key objective of 'Smart Production' is the automation and digitalization of the European industrial production by means of advanced electronic components and systems (ECS) covering the entire product lifecycle from product design, manufacturing, product in-use till recycling. This would even apply to production sectors in which automation is yet hardly present.

The European industrial production faces strong global competition. The further development of the European leadership in automation and process control is key to increase European competitiveness in production. Thus, world leading automation and disruptive production technologies enabled by innovative ECS form a cornerstone for the re-industrialisation of Europe. Examples of innovative ECS are: cyber-physical production systems, human-machine interaction, autonomous manufacturing equipment, advanced sensor systems, high-integration manufacturing technologies, integrated additive and subtractive manufacturing processes, high-speed closed-loop control and traceability technologies and embedded smart software.

Leading European producers are demanding improvements regarding availability, flexibility and controllability in integrated, secure and functional safe production systems, for supporting their ambitions on overall equipment efficiency (OEE), energy efficiency, raw material yield, flexible and sustainable manufacturing. They are facing lot-size one production (personalization) and thus, need to ensure availability, flexibility and controllability in integrated, security and safe production systems. Further there is a trend of increasing hybrid cross-over products/embedded IT and integrated services. Transformation opportunities are numerous when companies cross traditional boundaries. Hybrid solutions that help such crossovers are mandatory, and this calls for next generation solutions.

In the ECSEL-focus of "Smart Production" are both the European manufacturer improving their production efficiency along the entire value chain as well as the industrial equipment supplier and tool vendors providing innovative automation solutions, process control and logistic management systems.

Therefore ECSEL will complement the efforts by H2020, EFFRA and Spire PPPs in the field of manufacturing and process automation by addressing new and demanding capabilities to be provided by next generation of leading-edge electronics systems and their embedded software.

6.5.2 Strategy

"Smart Sustainable and Integrated Production" R&I will focus on enhancing the capabilities for automation and smart production through novel technologies, tools and methodologies in the domains of:

- Procedures, methods and tools for planning and operating collaborative automation environments, as well as support for the transformation from legacy to future system
- System integration of smart device capabilities such as sensing, communication, knowledge management, decision-making, control, actuation, resulting in smart maintenance and smart production execution

- Improved production system integration along the three production axes, life cycle, value chain and enterprise, enabling and improving consistent quality and delivery reliability, availability, flexibility, improved controllability, improved interoperability, and production planning, security and increased utilisation of production capacities along the value chain

- Autonomous optimization of life cycles, value chain integration and enterprise efficiency and flexibility

- Enabling of collaborative automation environments comprising both human and technology while maintaining security and functional safety under real-time conditions

- Enabling of large systems featuring distributed big data to useful information transformation in collaborative environments.

- Tools, methodologies and technologies enabling:

  1) the engineering of collaborative automation environments,
  2) the migration from current legacy systems and
  3) the future systems evolvability
- New digital manufacturing methods, equipment and tools powered by sensing, tracing, data acquisition, data processing and analytics and cloud

- Large flagship program with integrated R&D&I projects supporting product life cycle optimisation, value chain integration and manufacturing efficiency and flexibility – application independent and across domains

The TRL level for the electronics systems and their embedded software to be addressed is TRL2-4 for research projects and TRL4-7 for innovation projects.

The top level needs for smarter production are:

- Competence management

- Digital production

- Sustainable production

- Improved OEE

- Overcoming stakeholders hesitations

Combined with an understanding that smart production will have many stakeholders, within the production system and external to the production system, and that these stakeholders have to interact “smartly” to meet the top level needs of production. In extended enterprises and globalized markets, applications (e.g. Life Cycle Management, Supply Chain Management, Monitoring & Control, and Customer Relationship Management) will no longer operate in closed monolithic structures. Stakeholders and customers collaborating on a common application platform implemented with the cloud approach will bank on new software development and testing environments more oriented towards nontechnical users and support development of business processes. These software platforms will also enable new production methods, such as highly-customized or even personalized, rapid manufacturing. Distributed applications with low footprints targeting large user base would be supported by enhanced Business Process

Reengineering tools for rapid development and deployment. This leads to the long term direction of collaborative automation where stakeholders provide necessary services timely and cost effective enabling meeting the market needs.

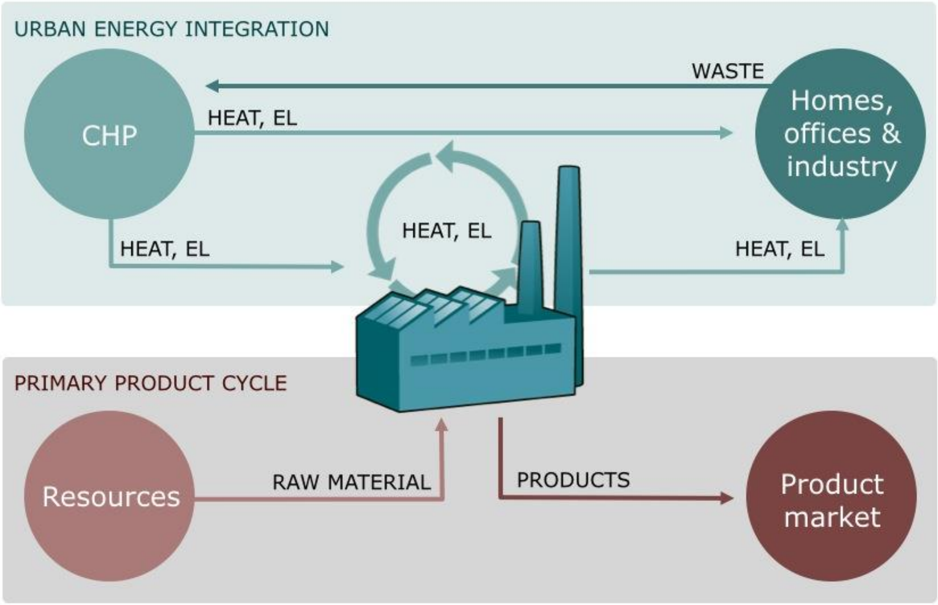


Figure: Collaborative Automation is key strategy and enabler for reaching top level need like sustainable production, improved OEE and competence management.

Technologies to realise such collaborative automation are e.g. IoT, cloud service, virtual world, big data, system of systems, autonomous, adaptive and predictive control, computing (multicore), mobility, connectivity, complex event processing, real-time data analysis, and forecasting of complex scenarios.

Collaborative automation, integrating automation needs and technologies, can be visualised as Ideal Concepts [2]. Nine ideal concepts have been defined:

- Instant access to a (Digital and) Virtual dynamic factory.
- Increased Information transparency between field devices and ERP.
- Real-time sensing & networking in challenging environments.
- Process Industry as an agile part of the energy system.
- Management of critical Knowledge to support maintenance decision-making.
- Automation service and function development process.
- Open simulator platform.
- Automation system for distributed manufacturing.

• Balancing of system security and production flexibility.

The dependencies of the realisations these scenarios on technologies is indicated in figure below.

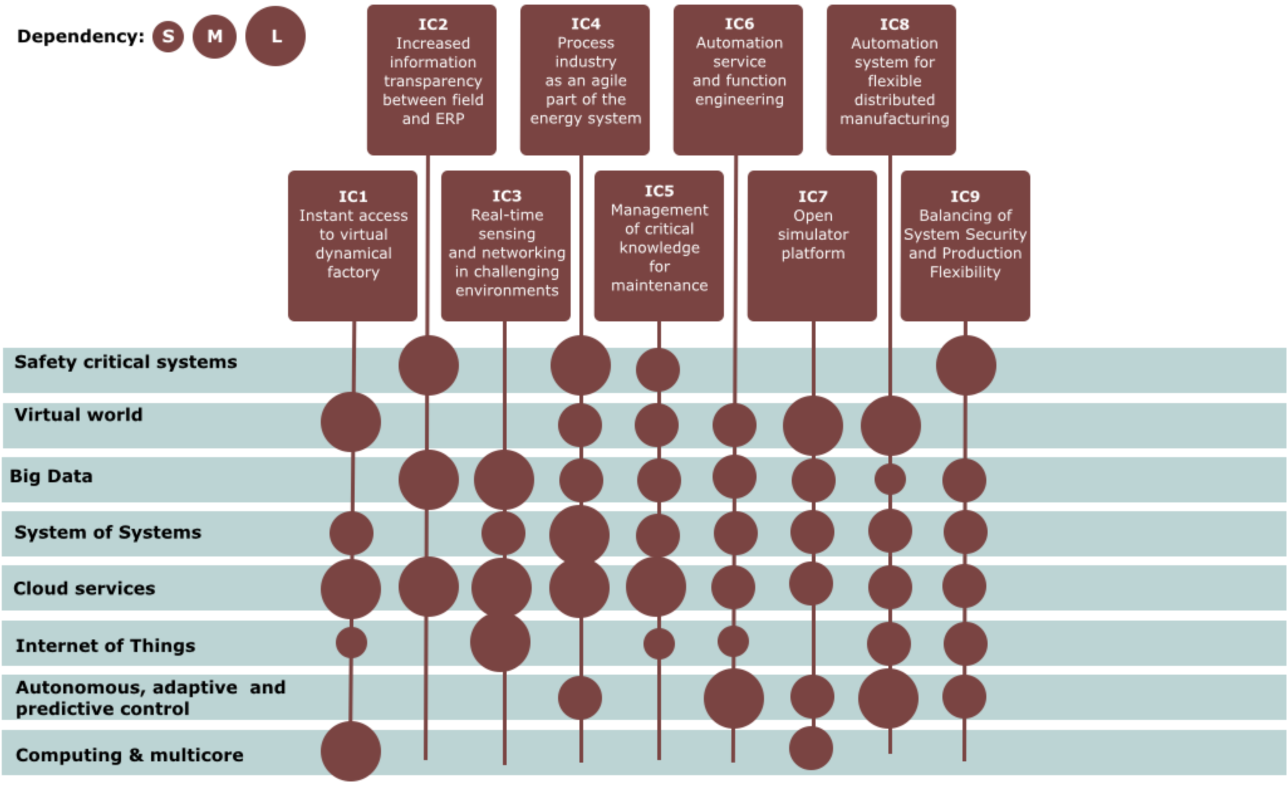


Figure: Nine ideal Concepts ("ICn") for smart production and their respective technology dependencies

Additional to these nine ideal concepts could be mentioned:

1) Additive and subtractive manufacturing technologies integrated in real production chains
2) Design tools and closed digital chain for additive manufacturing technologies
3) Autonomous systems in manufacturing
4) Sensor systems easily plugged in
5) Plug & Produce agent based equipment for production

Distributed and collaborative applications will be implemented through mash-ups of services implemented by different small and large ICT and manufacturing vendors. The cloud will be the "agora" for provisioning customised functionalities through services that are reliable, secure, and guarantee performance. Open standards will ensure the full inter-operability in terms of data and applications.

6.5.3 Impact and expected major achievements

Comprehensive ECS-and ICT-based solutions for Smart Production will maintain the European industry on the way towards a complete digitalization of production and therefore fit for the global market.
Large integrated R&D&I projects will enable strong standardisation and early adoption of new and efficient automation and production technologies in Europe. The cooperation along value and life cycle chains in large R&D&I efforts will support collaborative automation technology supporting strong integration within the complex network of stakeholders necessary for efficient and sustainable production. New disruptive production methods, technologies and services are enabled by novel electronics systems and their embedded software; these are exemplarily additive and subtractive manufacturing technologies for metal and plastics that are seamless integrated in the production chain and that are empowered by new design tools and the digital world.

Production line availability, flexibility and controllability/traceability will be improved through increased automation and disruptive production technologies. Thus supporting European production to increase well above average and become globally more competitive.
Large R&D&I activities like flagship programs could foster the building of new cross domain ecosystems especially with high SME-involvement.
This will enable the production in Europe of next generation of consumer and professional products.

6.5.4 Cross references

The strategy relies on incorporation of new technology. Particularly important will be advancement in system design technologies, architectures and tools (design, engineering, test verification, deployment and operation), integrating new CPS and smart system technologies like easy integratable sensor systems, wireless high-speed communication ability, labeling technologies like RFID, standardized interface technologies and production data analytics. Critical success factors will be robustness to industrial production environments, interoperability, validation and standardisation, and last but not least security. Also, strategies, technology and methods used and under development for highly automated semiconductor manufacturing addressed in Essential Technologies Chapter 7.1: Semiconductor Manufacturing, Technology, Equipment and Materials, are directly connected with the challenges and opportunities addressed in this chapter.

6.5.5 Schedules/Roadmaps

Short-term innovations expected relate to design technologies enabling the introduction and migration of smart CPS into production automation and new production technologies.

Mid-term innovations are industrially proven production automation systems with integrated smart CPS. This includes maintenance thanks to real time large data collection.

Long-term innovations are collaborative automation systems enabling radically increased OEE, production being an agile part of society regarding energy efficiency, sustainability and flexible production.

Two major roadmaps related to smart production have recently been developed by EFFRA and ProcessIT.EU [1,2]; the later focusing only on production automation for continuous production processes. In addition national visionary scenarios are provided like in Germany for *Industrie 4.0* from the perspective of year 2025 [3]. And whilst the German “Platform Industrie 4.0” continues to drive forward its activities - especially by increasing and broadening its communication efforts - a few future-orientated results are already available. First of all, the Reference Architecture Model for Industrie 4.0 should be taken into account [4,5]. All these documents give important direction on the development of smart production based on increased connectivity, real-time capabilities, seamless process simulation, distributed big data collection and distributed advanced analytics.

ROADMAP for SMART PRODUCTION	2015		2016		2017		2018		2019		2020	
Instant access to virtual dynamical factory												
HW component models as a service.	■	■	■	■	■	■						
Robust parameter and state update mechanisms for complex dynamic models.	■	■	■	■	■	■	■	■				
Platforms supporting multi functional views, e.g., dynamic, topological, steady-state.			■	■	■	■	■	■				
All purposes and multi-technology simulators with integration of computations, simulations and engineering data.			■	■	■	■	■	■	■	■		
Data management enable backtracking.					■	■	■	■	■	■		
Virtualisation of legacy systems.					■	■	■	■	■	■		
Computing architecture for large number of simultaneous instances of a virtual factory.							■	■	■	■	■	■
Fast and robust virtualisation of the control system and its pairing with the virtual factory with seamless transition between the virtual and physical representations.							■	■	■	■	■	■
Strategies for exchanging virtual representations as a natural part of achieving collaborative automation.							■	■	■	■	■	■
Increased information transparency between field and ERP												
Integration of field devices with high-level systems addressing transparency including data compression, distributing computation and decision support, service descriptions and semantics.	■	■	■	■	■	■						
Services-Oriented Architecture at the field level enabling advanced properties and functions to ERP/MES.			■	■	■	■	■	■	■	■		
Systems engineering approach to architectures and applications					■	■	■	■	■	■	■	■
Automation in the cloud through loosely coupled sensors and systems.					■	■	■	■	■	■	■	■
Real time sensing and networking in challenging environmets												
Interoperable IoT solutions using cloud-computing approaches	■	■	■	■	■	■						
Open yet secure systems mechanisms for IoT devices	■	■	■	■	■	■	■	■	■	■		
Industrial-purpose sensor and tracking equipment with the adoption of low-cost technologies					■	■	■	■	■	■	■	■
Energy management of sensor and actuator systems					■	■	■	■	■	■	■	■
Production industry as an agile part of the Energy system												
Production flexibility through integration of control, business, ERP, cap and trade and maintenance systems.	■	■	■	■	■	■	■	■				
Automation and support systems to maximise overall plant efficiency while integrating into the larger context of societal functions.					■	■	■	■	■	■	■	■

Production industry as an agile part of the Energy system												
Production flexibility through integration of control, business, ERP, cap and trade and maintenance systems.												
Automation and support systems to maximise overall plant efficiency while integrating into the larger context of societal functions.												
Management of critical Knowledge for maintenance decision support												
Methods and technologies for the combination of data and information from various levels of the ISA-95 structure (e.g., ERP, CMMS, sensors, automation).												
Data and information validation.												
Maintenance service business models												
Tools for estimating the remaining useful lifetime (RUL), e.g. simulations and analyses.												
Transformation personnel knowledge to system knowledge												
Technologies to support specialised remote maintenance services.												
Technology for context awareness – only the information needed for the tasks and user.												
Ubiquitous self-diagnostic methods and techno- logies												
Automation service and function engineering												
Model based development of functionality for systems- of-systems including automatic code generation												
Verification tests for complete systems												
Engineering tools supporting: open simulator platforms, plant wide optimisation, control optimisation												
Interoperability of the virtual plant and component models at all development stages:												
Open simulator platform												
Dynamic component- based simulations												
Support for multi-domain and multi-physics simulations.												
Model configuration must be neutral, i.e., it should not be simulation tool-specific.												
Need for distributed simulation model configuration and usage, including version and access control.												
Simulation data visualisation												
Links from simulators to engineering tools.												
Support for validation and verification of simulation models												
Seamless simulation of production system at different levels within a product life-cycle												
Automation system for flexible distributed Production												
Principles and methods to automatically generate the requirement specifications for distribute automation systems.												
Methods for automatically generating cost-effective temporal solutions for the rapid replacement of production units and their respective roles												
Balancing of system security and Production flexibility												
Tools and methods for emerging technical approaches within production automation assuring system reliability, security and safety.												
Online hazard analysis tools.												
Detection of tampered automation devices and services.												

References:

[1] Factories of the Future 2020: Roadmap 2014-2020,
http://www.effra.eu/attachments/article/129/Factories%20of%20the%20Future%202020%20Roadmap.pdf
[2] A European Roadmap for Industrial Process Automation,
http://processit.eu/Content/Files/Roadmap%20for%20IPA_130613.pdf
[3] Zukunftsbild Industrie 4.0, http://www.bmbf.de/pubRD/Zukunftsbild_Industrie_40.pdf
[4] Status Report: Reference Architecture Model Industrie 4.0 (RAMI 4.0),
http://www.zvei.org/Downloads/Automation/5305%20Publikation%20GMA%20Status%20Report%20ZVEI%20Reference%20Architecture%20Model.pdf
[5] The Reference Architectural Model Industrie 4.0 (RAMI 4.0),
http://www.zvei.org/Downloads/Automation/ZVEI-Industrie-40-RAMI-40-English.pdf

7 Strategic thrusts Part B: Essential technologies

7.1 Semiconductor Manufacturing, Technology, Equipment and Materials

7.1.1 Objectives: Semiconductor Manufacturing, Technology, Equipment and Materials

Semiconductor technology is indispensable for meeting the challenges of the European society. The availability of in-Europe manufacturing is essential to supply Europe's electronic systems manufacturers with critical components. The European manufacturing position must be reinforced through leadership in processing know-how for all advanced technologies: advanced and beyond CMOS (More Moore, MM), heterogeneous integration (More than Moore, MtM) and System in Package (SiP). The complete European value chain in process technology, materials, equipment and manufacturing capability must be supported to realize next generations of devices meeting the needs expressed by the application roadmaps of Part A. Pilot lines in MM, MtM and SiP and supporting test beds are needed to accelerate the uptake of KETs and enable manufacturing. These Pilots should cover all essential aspects for short time-to-market (cost-efficiency, standards, test, etc.), including equipment development and manufacturing science. Competitiveness of European semiconductor manufacturing must be increased through manufacturing science. The well-concerted combination of activities will increase the attractiveness for private investment and talent with the goal to keep skilled jobs in Europe and meeting the specific needs of European industry.

7.1.2 Strategy: Semiconductor Manufacturing, Technology, Equipment and Materials

Promote the involvement of all actors in the value chain of process technology, materials and equipment, with application specific partners or cross-links to application specific projects. Complement Pilot Line projects (higher TRL) for the validation of new technologies and equipment with manufacturing science (typically lower TRL), mastering cost competitive semiconductor manufacturing in Europe including packaging and assembly. Goal is to develop new solutions, cost competency and business models that enable a high degree of manufacturing flexibility required by diversified products, while achieving sustainability targets (resource-efficiency and "green" manufacturing) without loss of productivity, cycle time, quality or yield performance at reduced production costs.

More Moore manufacturing will especially require innovative solutions to control the variability and reproducibility of leading-edge processes. A Productivity Aware Design (PAD) approach will focus on predictive maintenance, virtual metrology, factory simulation and scheduling, wafer handling automation and automated decision management. In addition attention should be given to Control System Architecture: predictive yield modelling, holistic risk and decision mastering (integrate control methods and tools and knowledge systems).

While some of these elements are essential for MtM also, specific focus areas here are: (i) cope with high volumes and high quality (for e.g. power semiconductors, sensors and MEMS devices) and (ii) enable flexible line management for high mix, and distributed manufacturing lines. It will also require adapting factory integration and control systems to adopt industrial internet principles to manufacturing environment in Europe.

Well-focused projects in the TRL 2 to 4 are needed as technology push enabling new applications. Extended projects will aim at Pilot lines with emphasis on TRL 4 to 8 delivering industry-compatible flexible and differentiating platforms for strategic demonstrations and for pushing manufacturing uptake. Technologies will drive the realization of industry roadmaps in MM, extending it to extreme and beyond CMOS nodes - and in MtM and SiP - including amongst others power electronics, III-V and 2D materials, RF technologies, integrated logic, photonics, 3D integration technologies, MEMS and sensor systems, interlinked with key application challenges. Special attention will be given to emerging technologies as they come along as well as to new developments in the equipment and materials industry, in which Europe has a leading position.

In addition, attention should also be given to university education in close collaboration with the industry in the above fields, for example by means of joined (Academia and Industry) courses.

7.1.3 Impact: Semiconductor Manufacturing, Technology, Equipment and Materials

The European semiconductor ecosystem employs approximately 250,000 people directly and is at the core of innovation and competitiveness in all major sectors of the economy. ECSEL will help doubling the economic value of the semiconductor production in Europe by 2020-2025 [23]. The overall value chain of equipment, materials, system integration, applications and services employs over 2,500,000 people in Europe. By launching new process and equipment technologies based on innovative materials, designs and concepts into pilot-lines, ECSEL projects will facilitate a strongly growing market share, increase employment and investments for innovative equipment, materials and for manufacturing of semiconductor devices and systems through European leadership positions in MM, MtM and SiP. Ensuring the continuation of competitive manufacturing in Europe supported by a high level of excellence in manufacturing science and efficiency will enforce strong global industrial positions (security, automotive, aircraft manufacturing, power generation and medical/healthcare) and significantly contribute to safeguard our strategic independence in critical domains and secure tens of thousands of jobs directly or indirectly linked to the semiconductor manufacturing.

7.1.4 Cross-references

Europe needs leadership throughout the value chain from process, materials and equipment to production of devices, systems and solutions and deployment of services to leverage Europe's strong differentiation potential and to drive its competitiveness. Semiconductor manufacturing and technology is strongly linked with the other Essential Technologies. Furthermore it is key to Europe's strong global positions in all application domains (e.g. security, automotive, aircraft manufacturing, power generation and medical/healthcare industries). Therefore the key milestones and deliverables of projects on semiconductor manufacturing and technology will take into account the progress in the other key enabling technologies (B). The timely set-up of the pilot lines and platforms will enable the downstream projects in Key Applications for 'Smart everything', and should deliver timely and competitive solutions for the manufacturing of the chips and components

[23] Challenging goal launched in May 2013 by Neelie Kroes, Vice President of the European Commission (EC)

required for these applications. This will allow the European industry to take the lead in various challenging multidisciplinary application domains.

7.1.5 Roadmaps: Semiconductor Manufacturing, Technology, Equipment and Materials

All leading European industry and research actors align their activities with international roadmaps and timelines like the ITRS, ENI2, CATRENE, etc. [24]. The 'Action Tracks' recently proposed by the Electronic Leaders Group[25] have goals in the timeframe 2014-2020 of which Demand Accelerators (Track1) relates to the highly relevant application needs and test beds and Track 2 calls for preparing the supply, raising production capacity and capability across the value chain.

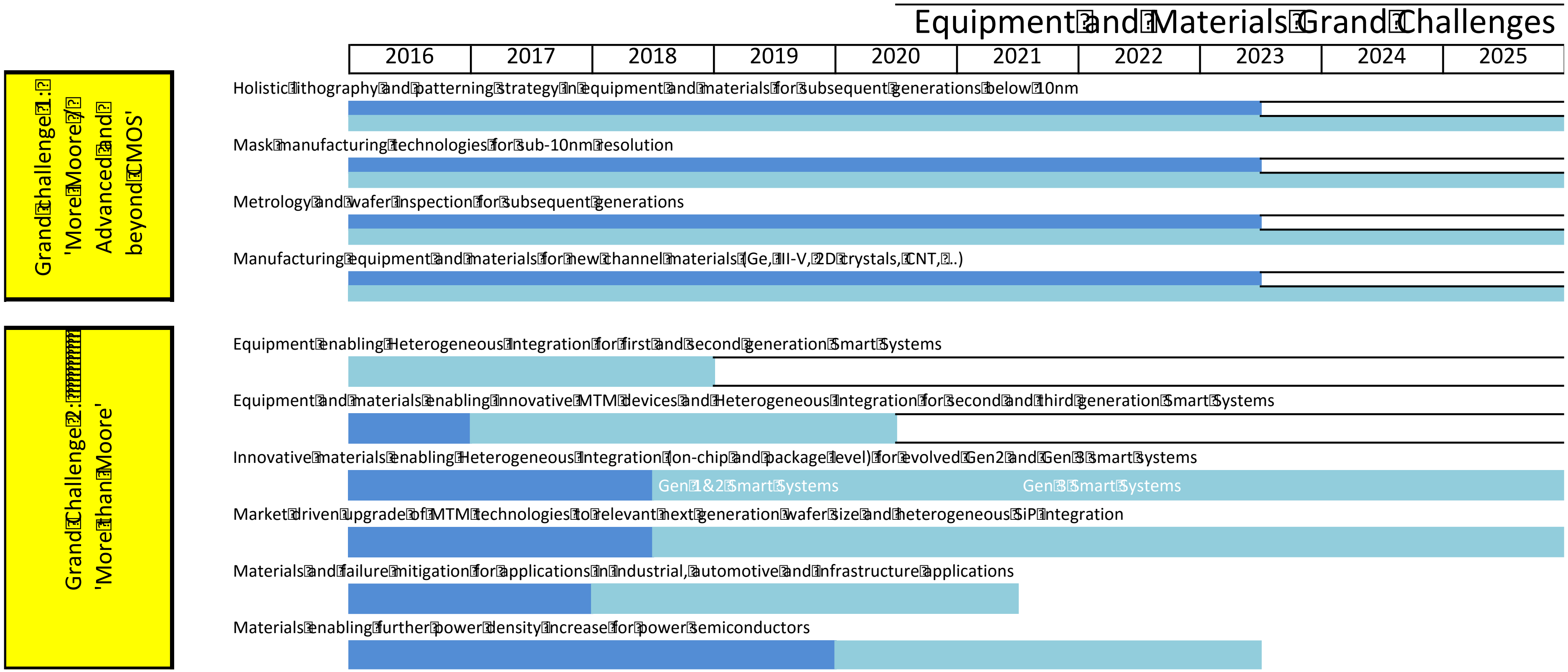
Fundamentals of 'manufacturing science' will concern projects at rather low TRL levels (typically 3 to 5). In addition, implementation in Pilot Lines and full scale manufacturing lines will contemplate higher TRL level projects (typically 7 to 8). For most of the Manufacturing Science projects, the execution will be spread along medium to long term time span, though shorter term impact, such as improving uptime of equipment thanks to productivity aware design or the improvement of robustness of the manufacturing processes), will get due attention to enhance competitiveness.

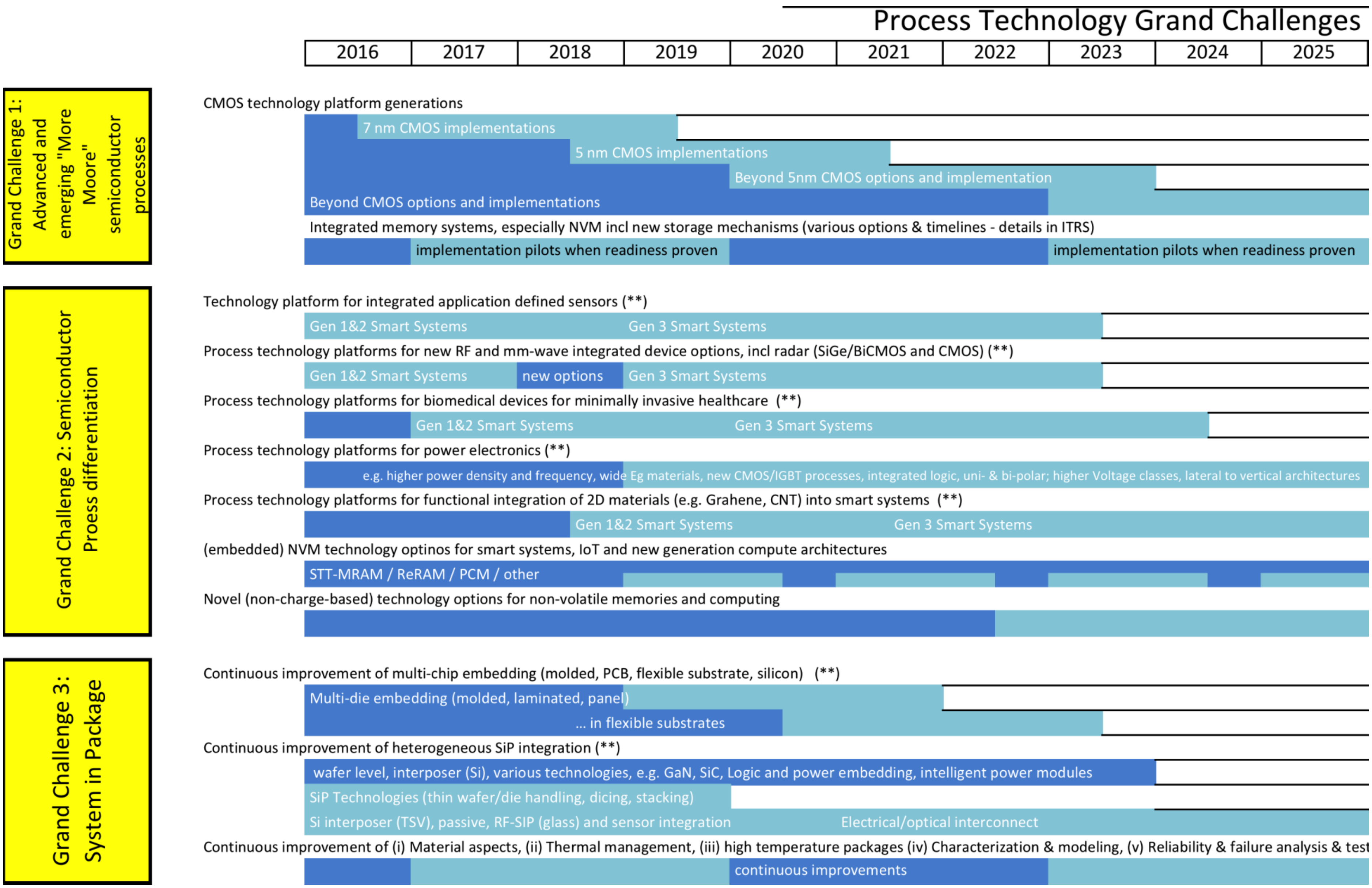
Results on the short term can be in supporting immediate application needs through test beds and pilots for leading edge processing. Results on the medium term are generated on pilots with next generation processes and equipment. On the longer term the implementation of disruptive technologies will be enabled. All schedules support a sustainable European leadership position and keeping high quality jobs in Europe.

[24] www.itrs.net/, www.aeneas-office.eu/web/nanoelectronics/Eni2.php, www.catrene.org/.

[25] A European Industrial Strategic Roadmap for Micro- and Nano-Electronic Components and Systems, Electronic Leaders Group 2013 (Chapter IX, P19)

Roadmap tables. *The dark blue regions are up to TRL 4. After that the technology options are deemed to move in development phase. This transition may shift due to market dynamics. Also, continued innovation will be challenging the maturing technologies constantly and the above roadmaps are not rigid in that respect. These timelines are to be synchronised with the timelines for TRL4-5 transition of major application drivers enabled by Semiconductor Process, Equipment and Materials.*





Process Technology Grand Challenges
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
Grand Challenge 1: Advanced and emerging "More Moore" semiconductor processes
CMOS technology platform generations
7 nm CMOS implementations
5 nm CMOS implementations
Beyond 5nm CMOS options and implementation
Beyond CMOS options and implementations
Integrated memory systems, especially NVM incl new storage mechanisms (various options & timelines - details in ITRS)
implementation pilots when readiness proven
implementation pilots when readiness proven
Grand Challenge 2: Semiconductor Process differentiation
Technology platform for integrated application defined sensors (**)
Gen 1&2 Smart Systems
Gen 3 Smart Systems
Process technology platforms for new RF and mm-wave integrated device options, incl radar (SiGe/BiCMOS and CMOS) (**)
Gen 1&2 Smart Systems
new options
Gen 3 Smart Systems
Process technology platforms for biomedical devices for minimally invasive healthcare (**)
Gen 1&2 Smart Systems
Gen 3 Smart Systems
Process technology platforms for power electronics (**)
e.g. higher power density and frequency, wide Eg materials, new CMOS/IGBT processes, integrated logic, uni- & bi-polar; higher Voltage classes, lateral to vertical architectures
Process technology platforms for functional integration of 2D materials (e.g. Grahene, CNT) into smart systems (**)
Gen 1&2 Smart Systems
Gen 3 Smart Systems
(embedded) NVM technology optinos for smart systems, IoT and new generation compute architectures
STT-MRAM / ReRAM / PCM / other
Novel (non-charge-based) technology options for non-volatile memories and computing
Grand Challenge 3: System in Package
Continuous improvement of multi-chip embedding (molded, PCB, flexible substrate, silicon) (**)
Multi-die embedding (molded, laminated, panel)
... in flexible substrates
Continuous improvement of heterogeneous SiP integration (**)
wafer level, interposer (Si), various technologies, e.g. GaN, SiC, Logic and power embedding, intelligent power modules
SiP Technologies (thin wafer/die handling, dicing, stacking)
Si interposer (TSV), passive, RF-SIP (glass) and sensor integration
Electrical/optical interconnect
Continuous improvement of (i) Material aspects, (ii) Thermal management, (iii) high temperature packages (iv) Characterization & modeling, (v) Reliability & failure analysis & test
continuous improvements

7.2 Design technology

7.2.1 Objectives

Effective design methods, tools and technologies are the way in which ideas and requirements are transformed into innovative, producible, and testable products, at whatever level in the value chain. They aim at increasing productivity, reducing development costs and time-to-market, in order to reach the level of targeted requirements such as quality, performance, cost and energy efficiency, safety, security, and reliability.

Design methods, tools and technologies must ensure the link between the ever-increasing technology push and the demand for new innovative products and services of ever-increasing complexity that are needed to fulfil societal needs. Design methods, tools and technologies cover the design flows required to enable the specification, concept engineering, architectural exploration, implementation, and verification of Electronic Components and Systems[26] (ECS). The design process embraces in addition to design flows and tools, libraries, IPs, process characteristics and methodologies including such to describe the system environment and uses cases. It involves both hardware and software components, including their interaction and the interaction with the system environment, covering also integration into (cloud-based) services and ecosystems.

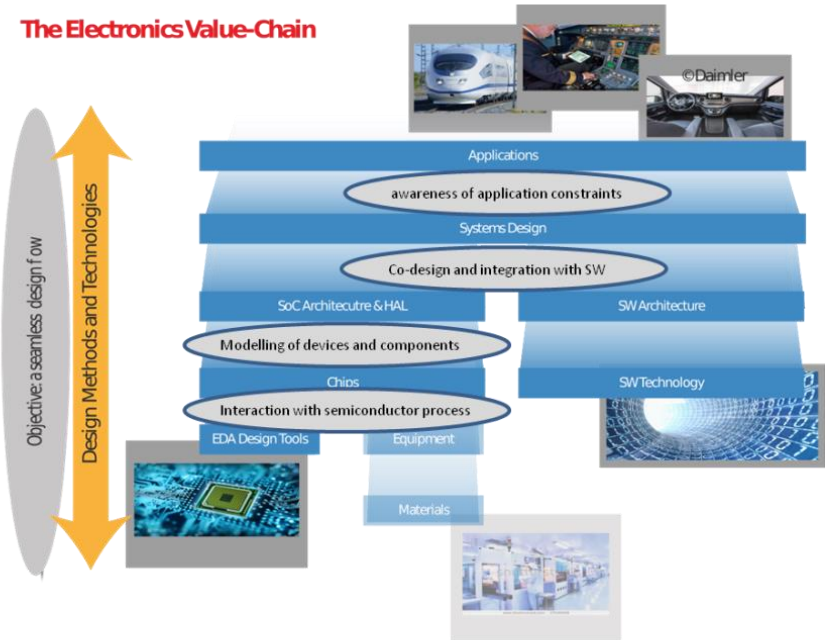


Figure 7.2.1: Design methods and technologies cover the entire value chain, from semiconductor materials and processes to chip level and systems including the development of applications / platforms.

---

[26] The word "systems" is used in this context for the respective highest level of development which is targeted within the given part of the value chain. It may range from semiconductor device characteristics along chip or block level up to the level of complex products – such as aircrafts, cars, or complex lithography systems. While ECSEL has to take into account product level requirements for such complex products, it focuses on innovations in ECS for these, and design methods and technologies enabling their integration into the complete product.

7.2.2 Strategy

In the frame of ECSEL program, design technologies will focus to meet the following four challenges:

1) **Technologies for Model-Based and Virtual Engineering**: aim at enabling the design of complex smart systems at high abstraction level, providing tools, models and environments for verification and validation for the HW and SW architectures. We start from the modelling of devices and components, based on use of existing TCAD tools (as far as possible), and extend up to Systems of Systems.
2) **Managing complexity, safety and security**: aims at developing solutions for managing the design of complex smart systems, starting from specifications and insuring consistency along all the design chain, including HW and SW, functional and non-functional property verification, validation and test.
3) **Managing diversity**: aims at the development of design technologies to enable the design of complex smart systems and services incorporating heterogeneous devices and functions, including verification and validation coping with functional and non-functional properties.
4) **Increasing yield, robustness, reliability and speed of development**: aims at enabling the design of large, potentially extendable systems that communicate with each other and involve multiple owners, optimizing the characteristics of yield, reliability and robustness of the final products.

These challenges are considered as high priority for the presently required increase of design efficiency, design ability and the respective competitiveness improvement. It is therefore recommended that a balance in the activities on low and high TRL activities should be sought.

7.2.3 Impact and main expected achievements

A success in overcoming these challenges will lead to the development of systems and products (incl. services) which are several times more powerful – and, from a design perspective, thus several times more complex – than the current ones and needed to solve existing societal problems without increasing development costs.

On system level, increase of complexity handling by 100%, design effort reduction by 20%, reduced cost and cycle time of product/system design of up to 50%, while improving design and development efficiency as well as validation speed will lead to improved product and service quality.

On a larger scale, systems are evolving from single-owner designs to larger systems or even systems-of-systems, which communicate with each other, using internet or similar media, produced by multiple companies. Effective design methods and technologies will cope with this paradigm shift and will allow for larger market share, higher competitiveness of European industry in all application sectors addressed by the MASRIA and contributing to increase employment in Europe.

7.2.4 Cross references to other chapters

The design technologies provide the tools and methods enabling the design of the products (incl. services) required for all applications addressed in this MASRIA, described under “Smart everywhere”. They are also essential in the design of Cyber Physical Systems and Smart Systems Integration; hence, a strong interaction with these two technology areas is expected. Finally, a particular interaction will be required with the Semiconductor Manufacturing, Technology, Equipment and Materials considering that the design performance, yield and robustness will be based on their inputs. After intense discussions we also indicate the relevance of "Modelling of Devices and Components" to all application chapters, even if in most cases models for them will be required on higher levels.

Challenges	Technologies	Smart Mobility	Smart Societies	Smart Energy	Smart Health	Smart Production	Semiconductor Process, Equipment & Materials	Cyber Physical Systems	Systems Integration
Technologies for Model-Based and Virtual Engineering	Modelling of devices and components	X	X	X	X	X	X	X	X
	Virtual Platforms and Simulation of ECS	X	X	X	X	X		X	X
	Model based design of ECS and system environment	X	X	X	X	X		X	X
	Extendable and evolvable Systems	X	X	X	X	X		X	X
	Human Aspects and interactions	X	X	(X)	X	X		(X)	X
Managing complexity, safety and security	Verification and validation methodology and tools for complex, safe and secure ECS. (V&V of ECS)	X	X	X	X	X		X	X
	(Incremental) Certification	X	X	X	(X)	(X)		X	X
	Monitoring and Diagnosis	X	X	X	X	X	(X)	X	X
	Runtime Support	X	X	X	X	X	X	X	X
Managing diversity	Multi-objective Optimization	X	X	X	X	X	X	X	X
	Multi-dimensional specification and modelling	X	X	X	X	X	X	X	X
	Eco-System for PMT for the cost efficient design, analysis and test of safe and secure ECS	X	(X)	X	X	X	(X)	X	X
	Connection of Digital and Physical World	X	X	X	X	X	X	X	X
Increasing yield, robustness and reliability	Integrating Analog and Digital Designs and Design Methods	X	X	X	X	X	X	X	X
	ultra-low power design		X	X	X	X	X	X	X
	Efficient methodologies for reliability and robustness in highly complex systems including modelling, test and analysis, considering variability and degradation effects	X	X	X	X	X	X	X	X

Fig. 7.2.4: Cross reference between challenges of Design chapter to the other chapters

7.2.5 Schedules and Roadmaps

7.2.5.1 Technologies for Model-Based and Virtual Engineering

Based on existing EDA design tools and tools developed in former research projects, this challenge should provide the basic models, the methods and development tools to allow model centric design and simulation, starting from devices and components, up to systems of systems. As the systems are increasingly embedded into their environment with which they have to interact, this challenge includes a dedicated activity on modeling of the environment.

In this challenge, TCAD will be also addressed considering that it is tightly linked to technology development and new materials (strained-Si, SiGe, highK/MG). Alternative architectures and new devices (FDSOI, FinFET) require excellent description of the device physics including ab initio calculations for material properties, quantum transport, etc. Yet, the software providers need to further develop their physical modelling, in particular to implement multi-scale approaches.

For efficient use of TCAD in circuit optimization, TCAD should further progress on advanced computing technologies (parallel computing including GPU, MPI or cloud computing). TCAD must be better integrated into design tools to enable TCAD to be used as a super circuit simulator with very limited user interactions

#	Topic \ Time (year of prog. call)	2016	2017 - 2018	2019 - 2020	2021 - 2030
1. Technologies for Model-Based and Virtual Engineering					
1.1	**Modelling of devices and components**	Appropriate models of devices, components, modules and subsystems, covering several operational conditions operational conditions: focus on system simulation with integrated special devices and on simulation performance.		Appropriate models of devices, components, modules and subsystems, covering several operational conditions operational conditions: Focus on improved simulation to include aspects like variation and aging of devices.	
1.2	**Modelling of environment**	Apropriate models of environment (of system), capturing environmental application context (use cases, scenarios), and able to drive system simulation, validation and test	Apropriate models of environment (of system), capturing environmental application context (use cases, scenarios); focus on (rapidly) changing, evolvable, 'unknown' environments (changing over time even after system deployment)		
1.3	**Virtual Platforms and Simulation of ECS**	Feature and model based system simulation for easier integration.	Virtual engineering of ECS and its subsystems and components on HW and SW level.		Model-based engineering test methodologies for complex systems in rapidly changing environments.
		Virtual platform in the loop: Enabling the efficient combination of model-based design and virtual platform based verification.		Virtual prototyping of complex systems involving the interconnection of up to thousands of components.	Virtual prototyping of complex systems involving the interconnection of up to thousands of components , with debug capabilities.
		Efficient virtual platforms (simulation of the embedded target platform on a simulation host faster than the target platform) for early software integration and testing. (simulation speed in virtual prototyping)		Reuse: Component based design for components and subsystems	Reuse: Component based design for complete products, product line designs, SW blocks, digital, analog IP, subsystem, and standards for the efficient integration in order to improve productivity of platform integrator.
		Virtual prototype providing view of SMP and cache-coherent architectures HW & SW jointly	Virtual prototype support for debug of SW/HW co-design for SMP and cache-coherent archtiectures		Virtual prototype support for automation of SW/HW codesign for SMP and cache-coherent architectures
1.4	**Model based design of ECS**	Interoperability standards (development Tools, Reference Technology Platform); re-use of legacy knowledge	Tools and methods for assuring back-traceability.		Seamless model based design and development processes, including for safety critical systems with constraint-driven design methodology
		Efficient Methods and Tools for modelling and simulation based on interoperability standards (including Reference Technology Platform and knowledge re-use)	Seamless modelling of functional blocks / units		Provide complete interoperable tool-chains for Model-Based Design.
1.5	**Extendable and evolvable Systems**	Basic structures and elements for extendable systems	Monitoring of open systems	Design methods and tools to meet requirements to real-time, high availability and safety of open systems including monitoring techniques	
		Update and evolution strategies, including self learning and adaptation.	Update and evolution strategies for open systems, including self learning and adaptation		Life cycle management for innovative (esp. ECS based) products.

Fig. 7.2.5.1: Roadmap for Model-Based and Virtual Engineering
Color code: Dark blue = short term actions, based on higher TRL

7.2.5.2 Managing Complexity, Safety, and Security

With increasing role of electronics systems and especially under the influence of connected systems the need for better methods and tools for verification and validation is emerging. Even for multiple connected systems the simulation of emergent behaviour cases should be possible and allow full functional safety analysis and prediction / avoidance of failure modes. For safety critical and security demanding applications these developments should lead to immediate support of certification actions, with incremental certification leading to significant savings in overall development process.

<table>
<tr><th>#</th><th>Topic \ Time (year of prog. call)</th><th>2016</th><th>2017 - 2018</th><th>2019 - 2020</th><th>2021 - 2030</th></tr>
<tr><td colspan="6">2. Managing complexity, safety and security</td></tr>
<tr><td rowspan="3">2.1</td><td rowspan="3">Verification and validation methodology and tools for complex, safe and secure ECS (V&V of ECS)</td><td>Modelling enabling extended verification and validation (including coverage, including failure mode analysis) of heterogeneous systems, starting from specification and higher abstraction levels</td><td colspan="2">Extended verification coverage: functional (esp. safety), non-functional; use cases, virtual prototyping, links between HW and SW design, automatic test design and reduction, ECS supported system integration and validation.</td><td>V&V methods and tools for Life-Cycle and in-service phase: Adaptation/Upgrades/ Evolvability/Maintainability</td></tr>
<tr><td colspan="2">SW development tools and debug environment for verification and validation of the HW and SW ECS architectures and their applications</td><td>Extended verification methods: (functional, non-functional, …) supporting quality metrics</td><td>Specific compliance standards; considering non-functional requirements with respect to their impact on functionality</td></tr>
<tr><td colspan="2">Extended verification and validation, including coverage for heterogeneous systems towards functional and non-functional properties, including failure mode analyisis; use cases - virtual prototyping and its link to simulation and test.</td><td>Faster simulators to handle complex circuits and large number of influencing parameters (especially non-functional properties like power, temperature, and degradation) as well as methods to handle non-uniform distributions.</td><td>Handling mixed criticality as it shows up in automotive where safety critical and entertainment components interact (e.g. display);</td></tr>
<tr><td rowspan="3">2.2</td><td rowspan="3">(Incremental) Certification</td><td colspan="2">Enable modeling of safety and security requirements in early design steps to get certification approval and enable incremental certification.</td><td>Design methods and tools for safety and security</td><td>Design for compliance for safety and/or security critical applications (e.g. ISO 26262, EAL6+);</td></tr>
<tr><td>Safety and Security Co-Engineering (Modelling, Dependencies, Analysis)</td><td colspan="2">Consistent design and tool chain for automated transfer of system level design into functional blocks and given HW/SW blocks with inclusion of design checking.</td><td>Certified models transformation engines and rules</td></tr>
<tr><td>Concept of certified design flows</td><td colspan="2">Complete design tool-chains and methods supporting long term archiving needs and standards</td><td>Support for long term archiving needs, standards, and back traceability management</td></tr>
<tr><td>2.3</td><td>Monitoring and Diagnosis</td><td>Monitoring, prediction and diagnosis methods and tools</td><td colspan="2">Normalization for testability and diagnosis efficiency metrics.</td><td>Monitoring, prediction and diagnosis in real-time</td></tr>
<tr><td>2.4</td><td>Runtime System Support</td><td>Support for OS virtualization methods and tools</td><td colspan="2">BIST and reconfiguration linked to and supported by OS</td><td>Complete integrated health check of systems via BIST and monitoring.</td></tr>
</table>

Figure 7.2.5.2: Roadmap Design for Managing Complexity, Safety, and Security
Color code: Dark blue = short term actions, based on higher TRL

7.2.5.3 Managing Diversity

In the ECSEL context a wide range of applications have to be supported. With growing complexity of the mode of use and the application context an optimisation shall be possible under multi objective constraints. This requires the respective requirements to be correctly set and models to support these dimensions. It also requires a good link between the physical world and its digital counterparts. As this calls for significant efforts, a dedicated ecosystem will emerge.

<table>
<tr><th colspan="6">3. Managing diversity</th></tr>
<tr><td rowspan="3">3.1</td><td rowspan="3">Multi-objective Optimization</td><td colspan="2">Constraint-driven, easy integration of SW, analog/RF, power devices, sensors, actuators and MEMS at system and component levels multi-dimensional optimisations</td><td>Cross-Domain Analysis, V&V, Simulation, Testing Methods (incl. Standards for…)</td><td>Manage various constraints (electrical, thermal, mechanical, etc.) over the whole design flow</td></tr>
<tr><td colspan="2">Full integration of SW-development process, analog/RF, power devices and sensors/ MEMS in system design flows.</td><td>Consistent and complete co-design of IC, SiP, PCB, subsystems, incl. mechatronics and their interfaces.</td><td>Cross domains optimization, cross engineering domains across supply chain</td></tr>
<tr><td>New design technologies to reflect multidimensional optimisation and coupled performances.</td><td>3D-Design: improvements to manage systems implemented along the supply chain</td><td colspan="2">Methods and tools to exploit the benefits provided by emerging HW technologies and devices, as well as new SW design tools and methods, including e.g. those incorporating the notion of time in the code.</td></tr>
<tr><td>3.2</td><td>Multi-dimensional specification and modelling</td><td colspan="2">Enable specifications for the affected class of systems including the handling of engineering requirements, mission profiles, use cases, architectural design, executable specifications to be consistent with all design domains, including HW and SW design, applications, functional property verification on HW and SW, validation and test.</td><td>Capture of specifications and use cases covering not only the functionality of the system, but also its performance, timing, and non-functional properties such as power, temperature, robustness, environmental conditions</td><td>Seamless design flow defining standards and models for multi technologies and reuse.</td></tr>
<tr><td>3.3</td><td>Eco-System for processes, methods and tools for the cost efficient design, analysis and test of safe and secure ECS based on Standards, including the whole value chain</td><td>Create Eco-Systems for the design of safety critical complex and/or distributed systems (ECS)</td><td colspan="2">Design Eco-System based on standards: common methodology for functional and non-functional properties for system integration and validation; open for all partners</td><td>Design Eco-Systems based on standards extended to heterogeneous components and reliability, yield and robustness.</td></tr>
<tr><td>3.4</td><td>Connection of Digital and Physical World</td><td>Integration of environment modelling and simulation into the HW and SW design flow.</td><td colspan="2">Integrated multi-physical - logical simulation: Simulation of (digital) functional and physical effects, extending classical simulations to multi-physics simulations</td><td>Connection of virtual prototyping and physical world (including complex environment models) in complex validation environments</td></tr>
</table>

Figure 7.2.5.3: Roadmap Design for Diversity
Color code: Dark blue is for short term actions, based on higher TRL of at least 4

7.2.5.4 Managing Reliability, Yield, and Robustness

Merging the world of analog design and digital technologies on one chip requires specific harmonisation efforts, which in some basics is already available, but needs significant improvements. Only this will lead to acceptable reliability and robustness of the design with competitive yields.

A further challenge is the design for ultra low power, especially for mobile and remote units.

Bringing together all the different requirements and technologies in one system – whether on one chip or in several - calls for significant efforts in development of new methods and tools.

Marketplaces are very dynamic and rapidly changing. The ECS need to be designed and developed with very short cycle times and in most cases need to be integrated into connected services, calling for first pass success to meet the cycle time constraints.

4. Increasing yield, robustness and reliability					
4.1	**Integrating analog and digital designs and design methods**	Metric method for testability and diagnosis efficiency in particular for AMS verification, validation and test		Harmonsation of analog and digital design and verification tools and methods to come to a common design and verification environment.	Easy re-use of analog IP in system context; efficient machine to integrate analog and digital design flows
4.2	**Ultra-low power design**	Ultra-low-power: novel design flows for hardware design and efficient software for low-power autarkic systems.	Ultra-low-power: novel design flows for hardware design and efficient software for low-power autarkic systems with energy scavenging	Ultra-low-power: novel design flows for hardware design and efficient software for low-power autarkic systems with energy scavenging capabilities or extremely long battery power lifetime (including the design process covering power supply)	
4.3	**Efficient methodologies for reliability and robustness in highly complex systems including modelling, test and analysis, considering variability and degradation effects**	Improved handling of special critical aspects like ESD, EOS, latch-up, EMC, electro-migration, thermal and mechanical stress at SoC and system levels;	Improved handling of special critical aspects like ESD, EOS, latch-up, EMC, electro-migration, thermal and mechanical stress at SoC and system levels along the value chain		Automated tools for testability metrics in particular for measuring yield loss and test escape
		Efficient management of the design for test (DFT), design for yield (DFY), design for reliability (DfR), and design for variability (DFV), from IP/subsystems up to full SoC.		Consistent analysis, modelling, and descriptions/formats for reliability at all levels of abstraction.	Design and development of error robust circuits and systems;
		Appropriate models of subsystems, covering several operational conditions.	Consistent methodologies and new approaches for reliability and robustness for each component: hardware (HW), OS, and application software (SW), but also in conjunction to each other.		Avoidance, recognition and handling of errors at physical, logical, block, SW, and application levels
		HW/SW sign-off for reliability and robustness at block and system levels. Target is to achieve this for HW/SW at the same time.		Models with variability, reliability and robustness information including degradation effects.	Automated tools for testability and diagnosis efficiency metrics in particular for measuring yield loss and test escape.
		Design for yield (DFY) and litho friendly design (LfD);	Real time monitoring of lifetime behaviour and implementation of control mechanisms	Reliability, yield, and robustness fully integrated in Design Eco-Systems including appropriate interoperable design tool chains in order to enable reduced design cycles even with increasing complexity.	

Figure 7.2.5.4: Roadmap for Managing Complexity, Safety, and Security
Color code: Dark blue is for short term actions, based on higher TRL of at least 4

7.3 Cyber-Physical Systems

Although Cyber-physical systems, as complete systems, are built to fulfil certain applications, many technological topics and issues in these systems are generic (application independent) and as such, cyber-physical systems can be regarded as enabling technologies.

Cyber-Physical Systems (CPS) are Electronic Systems, Components and Software that are tightly interacting with Physical Systems: their embedded intelligence provides capabilities to monitor, analyse and control physical components and processes in various applications. Their ability to connect and interoperate, through all kinds of networks and protocols (including the Internet, wired, wireless communications), allows them to collaborate, to coordinate and optimize high-level functionalities. They offer exponentially growing opportunities for many application sectors and businesses.

Eengineering approaches have to be radically rethought under the requirements and constraints of the CPS-based Industrial Systems Especially when key issues on cross-layer collaboration, (near) real-time interaction, complexity and emergency behaviour management, support of system of systems evolvability, heterogeneity, interoperability, scalability etc. are coming into play.

7.3.1 The Objectives

For the coming period (2016-2020), the following priority targets are selected to guide the ES/CPS R&D&I programmes/projects with the purpose of having greater impact and deliver quick to market results to strengthen European stakeholder's leadership positions in the new 'digital transformation age' and gain in competitiveness:

1. Expand strong research and innovation potential while **overcoming fragmentation** in the European supply base, optimising investments and use of resources to yield multi-domain and reusable smart products and related services.
2. Exploit the growing **'Internet Economy'** opportunities**,** where human and machines[27] interact & collaborate to provide a myriad of new services and businesses responding to the strong demand of the **'Always Connected Society'**. CPS are becoming the 'Things of the Internet'.
3. **Master the complexity** while reducing the cost of utilizing powerful software intensive products/systems, integrating new distributed and fail-safe computing capabilities, encompassing System of Systems engineering and multi-disciplinary approaches, leveraging on the potentials of new information and communication networking techniques, big data analytics, cloud, and enabling the development of cognitive and collaborative autonomous systems.
4. Provide **dependable[28] solutions** ensuring for users a high level of trust, confidence and privacy.
5. Provide support for related **Certification, Standardization Activities and Education & Training.**

[27] Including M2M
[28] Dependability includes: reliability, maintainability, resilience, safety and security requirements.

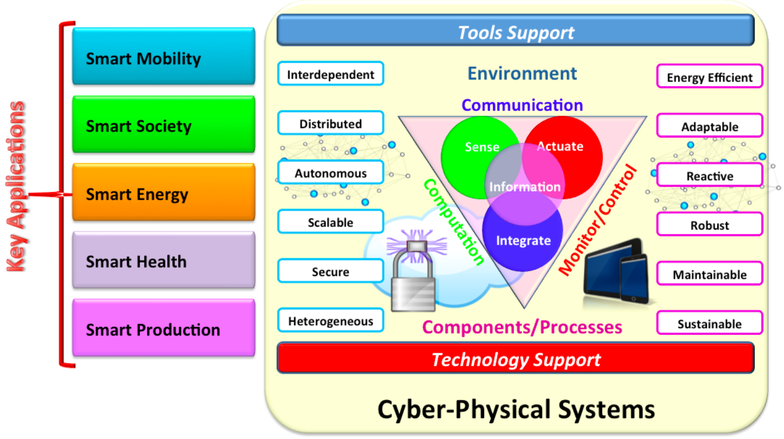


Fig1 CPS platforms accomplishing ultimate functionalities and serving key application areas

7.3.2 Strategy and Strategy implementation

To reach the above-mentioned objectives, the strategy and its implementation are built on:

- **A cross-domain sharing of technologies and research**: Expand the technology developments to address societal challenges through applications platforms and innovation ecosystems in smart cities, grids, buildings/homes, mobility and transportation, security of citizens, farming, production, healthcare and ambient assisted living, water and waste treatment, by addressing technological needs across these sectors and favouring the cross-fertilization and consolidation of R&D&I investments from mass market to safety critical systems.
- The vision of **'virtual vertical integration'**[29] that encourages market leaders to define the conditions for successful business innovation building on emerging technological developments, and vice versa, to coordinate technological **platform developments** (hardware and manufacturing to system design and software engineering). On an organizational level, the horizontally specialized European industry faces a critical situation in this competition, unless vertical ecosystems emerge. Based on this assumption, the ECSEL CPS thrust pushes for contributing to and embracing standards, complementarity of the actors and solutions, scalability and interoperability.
- **A programme approach, with particular emphasis on developing interoperable platforms, using complementary instruments:** The emergence of hyper connected CPS faces long term challenges on both scientific and technical levels. There is an urge for disruptive technologies, design processes, programming environments and methodologies, and to let these emerge through a phased research and development programme that includes:
  a) **Focused projects**: a suite of projects to embrace both technological and application oriented development. They should typically span along TRL 3 to 5 and TRL 4 to 6 or higher
  b) Larger 'Think Big' projects that act as umbrella for suite of projects aiming in the same direction and building upon each other (not necessarily all of them being funded in ECSEL. In addition to research and development, they encompass the user's concerns in particular those related to social acceptance of CPS applications, privacy and trust, ethical and legal issues. Such flagship projects should:
     i) Have a European dimension by combining R&D efforts across Europe,

[29] such as GAFA: Google, Apple, Facebook, Amazon. More could be found at : http://www.supplymanagement.com/news/2013/virtual-vertical-integration-is-the-future-of-supply-chain

ii) Build on existing assets, to bring concrete results to the market through ‘infrastructures’/platforms for deployment testing.
iii) Address topics relevant to the competitiveness and future positioning of Europe.

The proposed **Programmes** for the strategy implementation for Cyber-Physical systems are structured along three strategic axes:

1) **Architectures, principles and models for dependable[30] CPS**: to define and develop global interoperable, distributed and certifiable CPS architectures, for the development of complex monitoring and control strategies for smart key applications including the realisation of dependable systems also from un-trustable, unreliable or partially unknown (grey box) sub-systems.
2) **Autonomous, adaptive and cooperative CPS** to develop core enabling functionalities for the efficient use of resources, for the seamless integration of computational and physical components for the resilience of systems, and for the global optimization of applications, all in a dynamic, evolving and complex environment, including the necessary overarching infrastructure (HW, particular SW providing the required intelligence, data bases) enabling smart cooperation in an optimized manner.
3) **Distributed Computing Platforms including hardware, software and communication** to address the challenges of resource and energy efficiency, security, complexity, reliability, and safety of the multiple and various computing systems (from deeply embedded sensor/actuator to mobile, industrial, embedded controls, edge-computing, servers, data centres, and HPC systems, up to building of system of systems), their computing heterogeneous (hardware), distributed (firmware) and operating systems, and the software stack. They should facilitate validation, verification and certification during the application life time.

7.3.2.1 Architectures principles and models for dependable CPS

In order to reduce the effort for establishing the desired interoperability of diverse products and be able to take full advantage of the economies of scale, developing cross-domain generic platforms for embedded systems is a technological and economic necessity. Developing CPS global reference architectures will provide for: connectivity, interoperability, composability, scalability, safety, security, robustness, (self-) diagnosis integration and maintenance. These framework architectures need to be supported by a pool of **industry standards, policies and best practice documents** to further stimulate the ubiquitous mass adoption in various markets as standards play an important role in interoperability and practical acceptance. Moreover, reference architectures should definitely aim at having more effective validation, verification and, most of all, certification processes. The key challenges are:

1) **“Virtual verticality”:** Connectivity , interoperability, scalability, variability management, secure and trustful transparency between tiers, definition and adoption of standards, each system being a brick for a larger system (and this possibly recursively).
2) **Systems of systems (SoS) development**. Due to the complexity of CPS, and of all the inter-relations between sub-systems, new engineering methods and tools are required to master increasing complexity including monitoring, diagnostics and prognostics in CPS and for managing requirements. Global simulation environments, “design space” exploration tools and verification methods need to be further developed for CPS applicability. Comprehensive process and tool integration frameworks are also needed to support efficient inter-discipline collaboration for global optimisation of CPS solutions.

[30] Dependability includes: reliability, maintainability, resilience, safety and security requirements.

3) **Reference Architectures** for safe and secure CPSs: multi-domain reference architectures will provide the technical ground to ensure coherence between CPS and their components. It is therefore necessary to develop architecture principles, programming paradigms and tools, reference architectures including hardware, software and communication, integration platforms (as for plug and play backbones), design patterns, component-based architectures and code generation, HW/SW co-design, to target a variety of application domains. This should cover computing, communication and security in local and in open systems. They should also provide for robust scalable interoperability solutions integrated with the environment.
4) **Dependability [31]'by design', and enabling certification** (against e.g. ISO26262 in automotive, DO-178/C in aeronautics and Common Criteria, ..) of mixed critical systems in highly complex and non-deterministic environments at affordable costs. This must be extended from the design phase to operation (particularly in case of adaptive and dynamically configurable systems). Exploring the usage of formal methods throughout the lifecycle. Ensuring a complete secure end-to-end protection of the hardware components, data and programs, during computation and communication for enforcing more security and privacy even in open systems and developing resistance/resilience to **cyber-attacks** and mitigation and continuity /recovery strategies (self-healing) and building dependable systems from un-trustable, unreliable or partially unknown (grey box) sub-systems.
5) Answering to the **fundamental challenges in CPS design** that arise from their dual cyber/physical nature, their multi-scale spatial-temporal nature, and the inherent uncertainty in the actions of the environment. Harmonizing the discrete mathematics of the cyber, with the continuous mathematics of the physical, the time-driven mathematics of the physical with the event-driven mathematics of the cyber, with the stochastic mathematics of the sensors, actuators and the environment.
6) Addressing the development and implementation of societal acceptance of CPS, to support the integration into and the interaction of human with the digitalizated CPS-baed world.

7.3.2.2 CPS for autonomy and cooperation (or autonomous, adaptive and cooperative Cyber-Physical Systems)

Structural Integration and Behavioural Collaboration are major goals especially for a domain relative new to IT technologies and their rapid evolution pace. A digitalization of the industrial environment based on CPS-technologies has been proven to be a real and feasible innovation backbone at Internet scale, and are finding their way in the future Industrial Systems, allowing the realization of the Internet-of-Automation-Things. Cyber-Physical systems need to tackle the following common issues and challenges:

1) **Safe and robust perception of environment**. Dealing with the complexity of the real world, arbitrary complex situations and scenarios in real-time. Sensor data fusion and the combination of several sensor modalities in order to deal with increasing complexity and robustness of HW/SW systems. Integrating new approaches (Soft computing, Bayesian, deep learning, …) with traditional ones for data analysis. Assessing application-specific robustness using appropriate V&V&T methods.
2) **Continuously evolving, systems**, **learning and adaptive behaviour** possibly inspired from biological systems (e.g. morphogenetic behaviour, digital tectonics, multimodal interaction, graceful degradation, etc.). Designing systems that are able to adapt themselves to changing environments and learn to understand and cope with complex situations in a safe and secure way. This includes the application and the underlying hardware, software, and communication platforms reconfiguration.
3) **Optimal control using autonomous CPS:** Efficient use of resources (power, computing, communication, development efforts and resources), optimization of global application

[31] Dependability includes: reliability, maintainability, resilience, safety and security requirements

performance and life-cycle costs enabling the development of intelligent, autonomous agents, despite limited accuracy/reliability in sensing and actuation, limited computational resources, and limited reaction time. As a consequence of this intelligence, such agents should be able to self-diagnose, self-reconfigure, self-repair and self-maintain in order to insure the needed failure tolerance and a proper performance level according to their global status.

4) **Reliable and trustable decision making, mission and action planning** for safety-related autonomous CPS/SoS that provide stability, safety, security in dynamically evolving system-of-systems, enable V&V&T and certification in reasonable time and cost. Supporting the interconnection of deterministic systems to highly non-deterministic and dynamically changing environments. Detecting and tolerating unreliable constituting subsystems in open SoS.
5) **Cooperation**. In particular cooperation with humans requires solution of several issues, such as understanding and informing them about the system intents. Development of new approaches, solutions, technologies using networked environment to enhance the 'human-in-the-loop' approach. Standardization activities for safe and modular service, autonomous vehicles, service robots and other complex CPS that interacts and cooperates with humans as well as other CPS. **Data Analytics** to realize further system optimization, including data analytics in the loop (streaming analytics, HPC in the loop) and high-level decision making. Machine learning capabilities are specially challenging in critical heterogeneous co-operative systems.
6) Appropriate advanced methods and techniques for validation & verification, qualification and certification of autonomous, adaptive, cooperative systems, including e.g. scenario based techniques to assess coverage of sensing, perception, decision making and action planning, and algorithms for optimal control.

7.3.2.3 Computing platforms

Cyber-Physical systems encompass a large range of computing devices and must integrate innovations in order to cope with the user's needs and real world requirements, such as hard real-time constraints, energy management, data access and storage, dynamic reconfiguration, fault tolerance, application deployment, safety, reliability and security of the data and processes. Their connectivity will enable functions and functionalities to be performed at all level of the CPS, such as distributed computing, edge-computing or fog computing. These developments will allow the seamless integration of the Internet of Things (IoT) concept with applications e.g. smart Energy smart Buildings or smart Vehicles … .The key challenges are:

1) **Energy efficiency, by all possible means:** avoiding unnecessary data communications (e.g. by processing data to extract the useful information where it is captured), pushing for new innovative architectures and protocols, holistic optimization. New silicon technologies, new energy harvesting abilities, new non-volatile storage technologies (which can change the existing storage paradigm), photonics, adaptive voltage and frequency control, 3D interconnect energy aware operating systems and middleware, data placement and retrieving. Application development and so on will require to harmoniously cooperate in order to further increase energy efficiency.
2) **Ensuring Quality of the Service (QoS),** in a real-time context, is a major challenge that worsens with the emergence of many/multi-core systems. Solutions cover real heterogeneous parallel processor, new memory architectures and chains, the development of parallel oriented programming languages and novel design methods, as well as new software architectures and setting up respective education. Techniques continuously monitoring the performance of the CPS should be designed in order to assess the dependability of the whole system through V&V&C. The security of data and the global integrity of a CPS are also of paramount importance. Other important platform requirements derived from CPS applications are reliability, safety, and resilience.
3) **Decreasing global cost (and development costs in new technology nodes)** is key to the commercial success of solutions. Development of solutions to keep diversity of designs.

4) **Edge Computing:** due to connectivity functions, computing capabilities may be shared/exist outside the physical device and in the 'Cloud'. Deploying Cloud dependent services (software running on the device or outside as well as software applications not embedded in the product) to provide adequate guarantees, handling issues such as latency, QoS, increasing the security at SOS level and providing methods and tools to improve quality offered by cloud-based heterogeneous service infrastructures.

7.3.3 Impact

The CPS results will deliver cross-domain solutions with reduced time-to-market, yielding significant economic results and growth in sectors critical to Europe's economy and competiveness **and drive innovation to cope with the 'new digital transformation' of Europe**. This should lead to a "virtual verticalisation" of the European industry to make it competitive to the big vertical non-European companies. The expected impacts of CPS projects are:

1) **Increased and efficient connectivity and ubiquity of CPS** as the neural system of society to address societal challenges, "Always Connected" and enabling Smart-X applications (cities, mobility, spaces, health, grid, farming, manufacturing, security) through development and deployment of scalable, trusted, reliable, secure and safe technological solutions.
2) **Increased efficiency of use of resources** (energy, materials, manufacturing time) through integration, analysis, collaboration, optimization, communication, and control by the deployment of CPS capabilities.
3) **Mastering complexity** while reducing the cost, the global power consumption of the systems and increasing the performance, reliability and security to create greater market opportunities and access greater market share.
4) **Create Knowledge** through development of new designs, Verification & Validation & Testing (V&V&T) as well as certification, methods and tools for CPS integration and deployment, for various application domains based on technology market roadmaps in multiple time-scales, particularly for the safety-critical high reliability and real-time secure applications, while valorising the already available know-how.
5) **Enable continuous evolution and innovation** of pre-existing large scale CPS and facilitate smooth transition and integration with legacy systems**.**

7.3.4 Cross references

Societal Challenges are the key drivers for innovation in CPS. CPS technology has an impact on all application contexts of ECSEL as developed above: Smart Mobility, Smart Societies (particularly for the security and cyber-security aspects), Smart Energy, Smart Health, and Smart Production[32]. It also leverages the 3 other essential capabilities: Semiconductor Process, Equipment and Materials, System Integration, and especially Design Technologies, with which it has a number of topics in common.

[32] CPS technology is expected to be integrated solution for industrial automation in the future; a market that is estimated at $ 155 billion in 2011, 35% in Europe, and is forecasted to reach $ 190 by 2015. 'Advancing Manufacturing – Advancing Europe' report of the Task Force on Advanced Manufacturing (Mars 2014)

7.3.5 Schedules / Roadmaps

All topics may be started in the call 2016; results are expected to be provided for:

(a) Short term 3 to 5 year, (b) Medium (5 to 7) or (c) Longer term (beyond 7).
The colours are related to the TRLs: Low TRL: 3 to 5 High TRL: 4 to 7

1	Architectures principles and Models for safe and Secure CPS	Short Term	Medium Term	Longer Term
1.1	Virtual Verticality Standardization activities: Interoperability, scalability, variability management, each system being a brick for a larger system			
1.2	System of Systems Methodology Global simulation environment, design space exploration, verification methods			
1.3	Reference Architectures (HW, SW, Communication) Multi domain reference architecture			
1.4	Dependability by design and enabling certification Mixed criticality- dependability of open systems Dependable systems built from un-trustable or trustable systems			
1.5	Answering to the fundamental challenges in CPS design			
1.6	Social acceptability of CPS			
2	Autonomous, adaptive and cooperative CPS	Short Term	Medium Term	Longer Term
2.1	Safe and Robust environmental perception of environment Dealing with complexity – integrating new approaches			
2.2	Evolving, continuously adapting systems through learning and adaptive behaviour of application platform			
2.3	Optimal control using autonomous CPS Efficient use of resources for Self-x capabilities			
2.4	Reliable and trustable decision making and planning Dynamically evolving SoS			
2.5	Cooperation With humans, enhancing Human-in-the loop - Data analytics			
2.6	Advanced methods for V&V&Q&C Of autonomous, adaptive and cooperative systems			
3	Computing Platforms	Short Term	Medium Term	Longer Term
3.1	Energy efficiency By all possible means			
3.2	Ensuring Quality of the Service (QoS) In real time context			
3.3	Decreasing global cost			
3.4	Edge Computing Computing capabilities shared/existing outside the physical device and in the 'Cloud'.			

7.4 Smart Systems Integration

Smart Systems Integration (SSI) is one of the essential capabilities that are required to maintain and to improve the competitiveness of European industry in the application domains of ECSEL. Although, in practice, SSI is often geared towards specific applications, the materials, technologies and manufacturing processes that form part of this domain are generic. SSI is hence an enabling technology in the area of ECS that needs to be developed further through research, development and innovation (R&D&I).

7.4.1 Objectives

The objective of the proposed R&D&I activities is to consolidate and to extend the present world leadership of European Smart Systems companies and to leverage progress in SSI for innovations on the application level.

Smart systems for robots in collaborative Environments (Bosch) | *Intraocular pressure measurement device (Sensimed, STM)* | *Advanced driver assistance systems (Bosch)* | *Minimal invasive cardiac surgery device (Sorin)* | *Recognition system for dangerous substances (FhG IPM)*

Figure 7.4.1 Examples of Smart Systems

Smart Systems are defined as (multi-)sensor and actuator-based devices that are capable of describing, diagnosing and qualifying their environment in a given complex situation, to make predictions, to come to decisions and to take actions. They are networked, autonomous and as small as required to enable the respective application. R&D&I in Smart Systems Integration (SSI) targets future improvements in the design, the functionality and the manufacturing of smart systems, enabled by heterogeneous (3D) integration of new building blocks for sensing, data processing, actuating, networking, energy management and smart powering with batteries, external supplies or by energy harvesting and storage. The building blocks combine nano-, micro-, and power-electronics with functions based on micro-electro-mechanical and other physical (e.g. electromagnetic, chemical and optical) as well as biological principles. They can be built out of a diversity of materials to ensure highest performance, reliability, functional safety and security as required for operation under complex and harsh conditions. They must be able to deal with multiple loads of critical magnitude and act simultaneously. SSI also addresses the integration of the systems into their target environment. This includes also materials and technologies for the formation of surfaces and interfaces between the individual ECS in order to guarantee the required interconnect functionality in multiple ways, e.g. from rigid to flexible, from electrical or thermal connect to insulation, bio/chemically inert to activation layers and more of that to achieve the desired form factors as well performance and robustness. SSI enables individual manufacturing as a key element in the factory of the future as well as predictive quality management by online monitoring of manufacturing processes. Smart systems will therefore be key elements of modern production lines. This includes also the manufacturing processes of smart systems themselves.

7.4.2 Strategy

Funding instruments shall focus on the Smart System itself. Possible R&D&I activities cover necessary key components, their development and manufacturing, and the integration of Smart Systems into their environment, taking into account the requirements of a particular application or application domain. The following types of projects are envisaged:

1) Projects at lower TRL level
2) Large scale projects at higher TRL level
3) Pilot lines and projects which are able to provide the performance of the SSI solutions and support high TRLs for industrial usage.

It is recommended that a balance between low- and high TRL activities is sought.

7.4.3 Impact

Today the Smart Systems sector in Europe covers nearly all required technologies and competencies. With more than 6,000 innovative companies in the EU, the sector employs approx. 827,600 people (2012), of which 8% or 66,200 are involved in R&D with a budget of 9.6 B€ per year[33]. New R&D&I actions are expected to further strengthen the European leadership in Smart Systems technologies and to increase the global market share of European companies in the sector. New Smart System solutions will feature higher levels of integration, decreased size (x5) and decreased cost (x5). Time to market for subsequent products will be reduced by new designs, building blocks, testing and self-diagnosis strategies, methods and tools capable of meeting the prospect use-case requirements on reliability, robustness, functional safety and security in harsh and/or not trusted environments.

7.4.4 Cross references

The field of SSI draws upon key enabling technologies (KET) and integrates knowledge from a variety of disciplines. Furthermore, it bridges the gap between components and functional, complex systems. Within the framework of the ECSEL MASRIA, Smart Systems benefit from cross-links to all other essential capabilities. They are the key to novel functionality in all application areas. The development of Smart Systems will benefit from progress in nanoelectronics, design methods and tool development. Smart Systems are key elements in a wide variety of activities, among others also in the Internet of Things and Services as well as for sensor-based electronic systems for Industry 4.0, Environment and Climate Action, Security, and Food and Water Supply:

[33] Sources: Prognos AG: Analyse zur ökonomischen Bedeutung der Mikrosystemtechnik, Studies about the Smart Systems economy in Baden-Württemberg and Germany; European Competitiveness Report; EU Industrial Structure 2011; Figures provided by major industry associations.

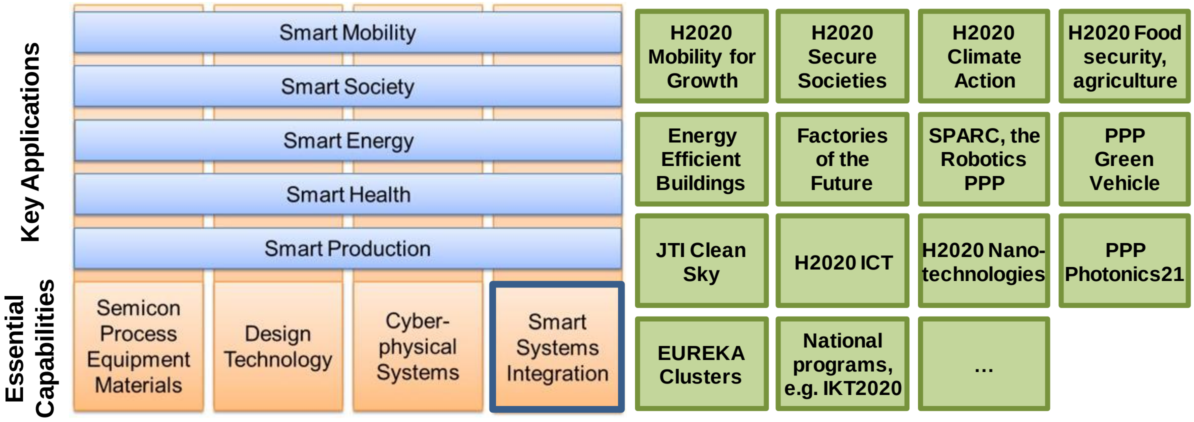


Table 7.4.1 Smart Systems Integration cross links

7.4.5 Schedules/Roadmaps

The achievements defined in the roadmaps shall support the short to long-term evolution of Smart Systems:

Short-term: Advanced 1st and 2nd generation Smart Systems, focussing on functional integration of sensing and actuation combined with control, monitoring, communication and networking capabilities. In many cases these systems need to be self-sustaining and operate stand alone.

Mid-term: Strongly increased integration of sensors and actuators, management, energy-harvesting, transfer of energy supporting multifunctional perception, predictive, adaptive and advanced capabilities and self-test, network facilities, and suited for critical environments.

Long-term: Strongly improved technology and integration supporting 3rd generation Smart Systems with human-like perception, autonomy and decision processes, energy management, self-organizing networks, self-calibration and self-healing.

The evolution of Smart Systems can also be described in the three-generation concept:

1st Generation Smart Systems integrate sensing and/or actuation as well as signal processing to enable actions. Such Smart Systems are already routinely and successfully deployed in many sectors. Examples include: Systems that are able to monitor the health status of persons and to initiate necessary actions e.g. pacemakers or safety systems in automotive applications such as airbag systems or electronic stability control systems for vehicles.

2nd Generation Smart Systems are predictive and adaptive systems with self-testing capabilities, built on multifunctional perception and able to match critical environments. Moreover, they are equipped with network facilities and advanced energy harvesting and management capabilities. Systems of this generation are able to assess and address variability and uncertainty by generating an informed suggestion in the decision preparation process, which takes into account the original sample and the multitude of answers required by the detection objective. They will have the ability to learn and adapt, to change environmental conditions, and to respond accordingly. A striking example of a 2nd generation Smart System is a continuous glucose monitoring system for patients with diabetes, which is measuring subcutaneous fluid parameters, predicting blood sugar trends and warning the user to take action if needed. Cross-disciplinary development of 2nd generation

Smart Systems may also enable simple artificial organs and in-body implants that work with the body chemistry rather than guarding themselves against it, as is the case with conventional heart pacemakers. Other examples of such systems that have already been introduced into the market include smart RFID labels with measurements of multiple parameters such as temperature, inclination and shock for transport monitoring.

3rd Generation Smart Systems exhibit human-like perception and autonomy and generate energy. The Smart Systems of this generation act independently and do not require any human control or decision. They may also be able to establish self-organizing communication networks and they develop from self-test to self-calibration, self-learning and self-healing. A prominent example of a 3rd generation Smart System is a highly or fully automated vehicle, which is executing steering, acceleration and deceleration autonomously. It does so by monitoring the driving environment by itself, and it either does not need the driver at all, or just as a backup. Other free-ranging systems, e.g. autonomous bio-robots and swarming agents interacting between the physical and virtual world, are at the far end of this vision. In order to become a commodity, the cost of third generation Smart Systems should be affordable for a large population all over the world.

The following tables cover the roadmaps for the technology areas that are identified as essential for the further development of Smart Systems Integration. They detail the technical topics that should be a priority within the R&D&I actions.

#	Topic \ Time (year of program call)	2016	2017 - 2018	2019 - 2020	2021 - 2030
1. Building blocks of Smart Systems (sensors, actuators, controls and interfaces)					
SSI generation milestones	*M1.1: Short-term activities on smart systems*				
	M1.2: Mid-term activities on smart systems				
	M1.3: Long-term activities on smart systems				
1.1	MEMS and other physical, chemical and biological sensors and systems				
1.2	Effective and efficient mechanical, piezoelectric, electrostatic, electromagnetic, inductive, pneumatic, thermal, optical, chemical, biological and other actuators				
1.3	Modular and highly integrated schemes of power control and actuation				
1.4	Electrical, thermal, mechanical and biological energy management				
1.5	Energy generation and scavenging				
1.6	Digital light, photonics and micro-optics				
1.7	Power electronic inverters/converters and components for high-density energy storage				
1.8	Suitable and tailored structural, electronic, magnetic, piezoelectric, active, fluidic, biocompatible and other materials (for harsh environments)				
1.9	Wide band gap materials for power conversion as well as electro-active polymers and metal organic				
1.10	Building blocks for advanced security functions, e.g. physical unclonable functions				
1.11	Technologies for mechanical, electrical, optical, chemical, and biological interfacing and transmitters and receivers for the transfer of energy and data				

#	Topic \ Time (year of program call)	2016	2017 - 2018	2019 - 2020	2021 - 2030
2. Safe, secure and efficient transfer of information and power					
2.1	Technologies for intelligent wired and wireless interconnection				
2.2	Body area networks				
2.3	Fast, compact, energy efficient, fail-safe and secure wireless communication systems for energy and data and technologies therefor				
2.4	Standardisation of machine to machine interfaces – both data and physical				
2.5	Strategies and technologies for the smart management of electric energy				
2.6	Technologies for energy generation, harvesting and storage				
2.7	Technologies for energy transfer such as wireless charging and seamless power supply				
2.8	Advanced solutions for thermal management				
2.9	Powerful computational and mathematical methods for signal processing, data analysis, data fusion, data storage and data communication				
2.10	Hardware based data fusion methods				
2.11	Dynamic, adaptive and cognitive data processing and methods for cognitive cooperation				
2.12	Dynamic integration of systems or nomadic devices in swarms				
2.13	Research on interfacing, networking and cooperation to enable distributed applications				
2.14	Technologies for mechanical, electrical, optical, chemical, and biological interfacing				
2.15	Advanced intuitive man-machine interfaces and technologies therefor				
2.16	Secure data interfaces for the integration into the Internet of Things				
2.17	Safe and secure HW/SW platforms including privacy and security management				

#	Topic \ Time (year of program call)	2016	2017 - 2018	2019 - 2020	2021 - 2030
3. Integration methods enabling smart functionality, automation and reliable operation in harsh and complex environments					
3.1	Multi-physics and multi-scale modelling and simulation methods for components, systems, data and communication channels				
3.2	Certification standards as well as design rules and testing and inspection methods				
3.3	Innovative manufacturing processes for top-down as well as bottom-up fabrication				
3.4	Methods and materials (metals, ceramics, polymers etc.) for system-level interconnection				
3.5	Methods for the physical system integration in-package, on-chip, on-surface, inside printed-circuits, on-tag, in-fabric, or on-PCB for systems				
3.6	Advanced (additive) manufacturing equipment and new integration methods on unusual substrates such as, for example, garments, construction materials or building structures				
3.7	Technologies for smart adaptation, self-testing, self-learning and self-healing at system level				

Legend:

planned in WP of ECSEL

market oriented Milestone from domain

derived milestone, when results from IAs needed

derived milestone, when results from RIAs needed

Table 7.4.2 Roadmap of Implementation of Priority Topics in ECSEL RIAPs 2016-20

Part C: Relevant Annexes

8 ANNEXES

8.1 Annex to A1: Smart Mobility

No annex text for Smart Mobility.

8.2 Annex to A2: Smart Society

Securing critical community assets

Secure and safe management and trusted processing of the entire system for European-wide applications, both at the infrastructure and at the devices level, is one of the major challenges in a smart society. Privacy must be protected at all times. First set of mandatory items to be addressed are:

1) Trusted execution, computing and connectivity for embedded systems and complex information networks and computing systems.
2) Validation, verification and proof of safe and secure infrastructure and services (trust provided to end users and customers - for example, OEMs, cities, etc.).

Trusted components and systems

Many applications in the scope of smart societies are characterized by data transfer over wired / wireless network connections. If no provisions are taken the applications are vulnerable to intruders who could try to steal or modify data. Attacks on payment transactions, attacks on critical infrastructures and theft of digital identity are very well known examples. To protect the integrity of the data and to guarantee the identity through strong authentication plus privacy protection of the transmitters, security is required on all levels of the implementation. However, to establish “security by design” the protection has to be an intrinsic part of the overall product architecture of the application itself. Beside that a secured and managed deployment has to be considered. Only then the so-called end-to-end security of a connection can be established. The level of security will depend on the sensitivity of the data. To that end, we propose the following topics to be addressed:

1) Next-generation hardware building blocks with improved security and safety (e.g. by larger embedded non-volatile memories for embedded software stacks)
2) New form factors integrating secure and safe elements; related trust and security hardware and firmware features for embedded computing platforms.
3) Security based on design time and tested cryptography
4) Protection and unique generation of secret keys by physical unclonable functions (PUF) against tampering and fraud.
5) Technologies that enable isolation of attacked parts of systems in order to keep the minimum functionality available even in case of attack (e.g. protect against shut down of systems, DDoS, blackouts, etc.).
6) Technologies for decentralized security, where security breaches can be detected early and breaches never compromise all the components.

7) Secure M2M communication technology as the foundation for the internet of things that can be trusted and is self-organizing.
8) Fast and low energy communication protocols for the next generation of IT architecture (smart manufacturing) that enable self-adopting and self-controlling functionality.
9) Improved trusted virtualization and compartmentalized operating systems; multi- level security according to targeted protection profile(s).
10) Platforms to ensure a Safe and secure deployment including the remote monitoring and management within new applications related to the Internet of Things such as smart grids, smart cities and building, smart mobility, manufacturing, e-health etc. (with heterogeneous systems for smart mobility, smart objects for e-Transaction and embedded machine-to-machine communication), integration with enterprise IT security.

Next generation digital lifestyle

Impact: Breeding global champions and strong local clusters

Digitalization changes the industry dynamics, especially in terms of scalability of businesses (= positive marginal return with respect to resources). New hyper-scalable businesses, based on digital services and digital products, have emerged, where the marginal return increases according to the Metcalfe's law. Initial examples are from gaming and entertainment, but with Internet of Things making the real world susceptible to digital tools and ways, the new industry dynamics will eventually find its way to the realm of traditional businesses and the whole society. The winner is the one who gets most users and takes it all in terms of profit. Therefore it is necessary to have a fair share of European winners and strong local clusters to help them initially succeed and monetize the success in local jobs and economic growth.

The Internet has evolved over the last decades into a mature network technology providing ubiquitous connectivity that in general can manage the volume of data required by the current broadband services; the next generations of the Internet will evolve beyond this and provide more services and functionality enabled by the always connected necessity brought by the social network users.

The consumer will have access to multiple multimedia services through a variety of devices connected to ubiquitous networks with improved intuitiveness in interaction in order to enhance user experiences; and to enable broadcasters and content providers to produce multi-platform content and seamlessly delivery it in a plurality of new formats at reduced cost. User authentication to services is non-intrusive, seamless and secure through different authentication techniques. The increasing amount of different sorts of data will lead to an increasing role of data management. Future networks will provide high-capacity at low cost and low energy consumption. The reduction of latencies as well as the increase of bandwidth will enable enhanced real-time interaction and more cloud based applications such as:

1) Tactile internet (e.g. remote surgery, interactive e-shopping).
2) Video on demand (e.g. TV over internet (IPTV), Over The Top content (OTT)).
3) Improved video surveillance and conferencing (everywhere for everybody), for private and security applications.
4) Secure and convenient Contactless payment and ticketing.
5) Traceability (food processing, forest products, logistics, etc.).
6) Convergence of app services with physical world: e.g. direct download of access right to one media (smartphone or tablet): e.g. hotel room key, visitor’s badge, visa, legitimations, etc.

7) Secure Home automation (smart lighting, heating and ventilation, automatic tariff selection, smart energy, etc.).
8) Online Gaming with very low latency.
9) More energy efficient networks both in computing, e.g. by using photonics at the heart of the high-speed broadband services as well as in network operation.
10) Voice over LTE improving audio user experience

The ubiquity of mobile devices and the wireless networks deployments offer extensive need for energy efficient, robust and secure wireless interfaces at device level. Short-range connectivity seems to be an interesting development path. The In the long term perspective the goal is to develop low cost single-chip sensor node systems to sense, communicate, reason and actuate. Such a sensor node will:

1) Enable the Internet of Things (IoT)
2) Provide capabilities for machine-to-machine (M2M) communication
3) Make smart devices ubiquitous and
4) Pervade people's environment (for example in smart cities, smart buildings, …) with computing power with functionality boosted by technologies such as Near Field Communication (NFC), Radio Frequency Identification (RFID), Bluetooth Low Energy, etc.

8.3 Annex to A3: Smart Energy

No annex text for Smart Energy.

8.4 Annex to A4: Smart Health

Home care and well-being

1) Disease prevention, promotion of healthier life-style, and remote coaching
   a) Life-style profiling and activity recognition
   b) Food intake monitoring / diet adherence control
   c) Personal lifestyle monitoring and guidance (diet, activity)
   d) Smart assistive services to support daily life activities
   e) Oral health measurement for regular assessment of home oral hygiene efforts
   f) Smart textiles with connected sensors and energy autonomous systems
   g) Improvement of wellbeing through environmental influences e.g. lighting
   h) Wellness environments for enhanced mental health and wellbeing
2) Remote health monitoring and support (e.g. for the elderly)
   a) Personal health management
   b) Autonomy monitoring and pre-dependency assessment
   c) Flexible textile-based systems for on-body diagnostic and therapeutic functions
   d) Domestic accident detection, monitoring, warning and emergency alert
   e) Advanced tele-health, including personalised facilities to engage patients in the self-care process, and early identification of potential personal risk factors
   f) Home monitoring systems for health related parameters by non or minimally invasive molecular diagnostics
3) Remote disease management
   a) Prevention of hospitalization for chronic diseases for a large elderly population
   b) Tele-medicine, home diagnostics monitoring, point-of-care screening devices, ultra-small smart implanted and on-body diagnostic and therapeutic devices, broadening diagnostic scope
   c) Non-invasive measurement eg. of blood parameters, bio markers and (de)hydration
   d) Smart devices, e.g. e-inhalers, bandages, in vivo treatments and new responsive biomaterials
4) Advanced tele-rehabilitation services (e.g. with portable robotics)
   a) Adherence to long-term therapies
   b) Personalized therapy through smart implantable devices
   c) Peripheral medical devices to power and control ultra-small diagnostic or therapeutic implanted devices
5) Technological cross-application advances
   a) Secure/private tele-monitoring networks
   b) Wearable and in vivo electronics and smart integration to measure biometric parameters and related treatments
   c) Personalisation and consumerisation
   d) Localisation techniques (indoor and outdoor)

Hospital and heuristic care

1) Advanced imaging based diagnosis and treatment
   a) Robotic image-guided surgery
   b) Improved image detectors that capture greater detail
   c) Advanced imaging for several modalities
   d) Smart micro-tools for advanced medical treatment (surgery, biopsy, …)
   e) Image-guided biopsy and treatment procedures
   f) Multi-modal heterogeneous data processing for advanced decision support

2) Screening for diseases
   a) Non-invasive screening for disease
   b) Early screening for diseases and improved screening imaging systems
   c) Efficient screening of drug potential with bio-electronic devices
   d) Decision support systems based on heterogeneous multi-parametric data
   e) Point of care monitoring of health related parameters by non- or minimally invasive molecular diagnostics
3) Intelligent data management
   a) Personalized health data ensuring data security
   b) Heuristic algorithms for personalised treatment
   c) Risk profiling based on biomarkers or genetic profiles
   d) Big data analysis
      i) on image sets for treatment preparation and screening
      ii) of medical imaging and signal processing systems
      iii) of unstructured medical information
4) Personalised medicine
   a) Real-time response to drugs
   b) High performance computing systems for drug design
   c) Human organ and disease model technologies (organ-on-a-chip)
5) Intervention / therapy
   a) Digital patient for planning surgical procedures
   b) Image-guided biopsy, treatment and therapy procedures
   c) Robotic image-guided surgery and therapy for many diseases
   d) Multi-modal, low X-ray dose, accurate visualization and guidance
   e) Smart intervention devices with e.g. image guidance, pressure sensing
   f) Operating room of the future: swallowed or implantable miniaturized capsules with imaging or sensors for diagnosis / surgery / therapy
   g) Patient safety, pharma compatibility and treatment consistency verification
6) Smart environments, devices and materials
   a) Healing environments for improved patient wellbeing
   b) Energy autonomous smart systems with multi-parameter sensors
   c) Smart automated drug delivery with or without smart implants
   d) Adaptive prosthetics, artificial organs
   e) Improved smart systems-based biosensors
   f) Microsystem technology based implants and implant support, e.g. deep brain stimulation, neuromodulation, multifunctional components, (nano)coatings for harsh environments and long term use
7) Remote diagnosis and monitoring / support
   a) Remote medical intervention and virtual team support

Food processing and safety

1) General
   a) Development of environmentally friendly sustainable food processes (better utilization of side streams, innovations to avoid excessive packaging)
   b) Determination of opportunities for innovation and improvement in the organization of food processing (combining efficiency and responsiveness to changing consumer demand for quality and diversity)
2) Food production

   a) Wireless sensor nodes on cattle, positional tracking of animals, health and physiological state monitoring
   b) Improved growth yield (food development) and energy efficiency
   c) Smart tools for food production: Introduction of scalable and flexible food manufacturing techniques and their intelligent in-line control
   d) Production line on-site monitoring for contamination of food products
3) Food distribution
   a) Active and intelligent packaging solutions and origin tracking
   b) Disposable biosensors for quality control of food products
4) Food retail
   a) Cold chain management of food, towards a dynamic shelf life prediction
   b) Improved shelf life of food products
5) Food processing
   a) Optimize food processing for waste reduction
   b) Cost-efficient, precise and miniaturized sensor systems for quality and performance control in food processing
   c) Smart labelling for better nutrition: labelling for personal nutrition (e.g. salt)
6) Food preparation
   a) Smart delivery of functional ingredients
   b) Novel ways of cooking and food preparation
   c) Innovative packaging for diet monitoring

8.5 Annex to A5: Smart Production

Smart, sustainable and integrated production

For 2016, key electronic systems topics supporting Smart production to be addressed by ECSEL are the following:

1) Virtual dynamic factory and its control systems with embedded, automated process controls, operator tools, and service information systems for optimizing plant operations and safety.

2) Asset management systems with predictive maintenance tools, based on real time measurements and information evaluation and decision support, supporting overall equipment efficiency.

3) Smart systems integrated within the industrial energy management system and externally with the smart grid to enable real-time energy optimization.

4) Production flexibility in global production processes supported by integrated legacy and smart CPS.

5) Robust and smart sensors and actuators that cost effective can be integrated to governing systems.

6) New production technologies e.g. digital manufacturing enabled and optimised by the application of Design technologies capable of integrating CPS and Smart system

8.6 Annex to B1: Semiconductor Manufacturing and Technology

8.6.1 Semiconductor Manufacturing

Key topics to be addressed are the following:

1) Next Generation Work-in-Progress and resources management, process control planning and corresponding simulators
2) Advanced Predictive Maintenance, Equipment Health Factor, Virtual Metrology techniques, Time Constraint Tunnels management methods and necessary tools for real time maintaining
3) Integration of decision and analysis systems in consistent and flexible frameworks providing adaptation of control plans with respect to real time equipment status and product critical layers
4) Flexible fab solutions, such as for load analysis and optimization, and lot logistics optimization for MtM fabs
5) Advanced data handling and yield analysis systems, defect analysis and test methods for yield improvement
6) Solutions to detect and control very subtle contamination sources in vacuum/airborne for MM and MtM manufacturing for yield improvement
7) Holistic approaches for optimum pattern transfer considering image transfer, Critical Dimension metrology, overlay metrology, defect metrology, and defect repair and verification
8) For MtM technologies following the increasing demand technologies for the transfer to larger wafer diameters wherever required
9) Enhanced data processing methodologies for advanced fab automation solutions in M2M manufacturing and chip/module assembly (incl. 3D-packaging)
10) Intelligent robotic and transport solutions for advanced fab automation solutions in M2M manufacturing and chip/module assembly (incl. 3D packaging) Yield, quality and reliability enhancements adopting e.g. big data analysis methods in electronics manufacturing

8.6.2 Semiconductor Processes, Equipment, and Materials

More Moore Process Technology, Equipment and Materials

New advanced CMOS architectures and beyond CMOS concepts to extend logic circuit performances and reduce power dissipation, enabling flexible adaptation to system needs; new memory concepts for stand-alone and embedded applications. Activities on Process modules, equipment (including sub-systems) and materials concurrent with the European leadership and in line with the ITRS roadmap and on the industry-driven relevant wafer sizes. (This list is a non-exhaustive list and other topics that contribute to general objectives of the theme "Semiconductor Processes, Equipment and Materials" are eligible.)

1) Node 1X CMOS process integration including various enhancements to known embodiments (e.g., FD-SOI, SiGeOI, III-V substrates, high Ge content channel and contacts, highly strained materials)
2) Node 7 and below and beyond CMOS - link with disruptive approaches currently in TRL 1-4 (e.g., nanowires FET, TFET, multichannel vertical integration e.g. by 3D sequential integration)

3) Integrated memory systems, especially non-volatile memories, including new storage mechanisms (e.g., STT-RAM, ReRAM)
4) Si-substrates, Silicon on Insulator substrates, SiC, III-V materials, advanced substrates with multifunctional layer stacking, including insulators, high resistivity bulk substrates, mobility boosters such as strained Silicon, SiGe and strained SOI, corresponding materials and related technologies, and corresponding manufacturing equipment and facilities.
5) Advance lithography equipment for 1Xnm / Xnm wafer processing using EUV and VUV, and corresponding sub-systems.
6) Advance holistic lithography and pattern transfer using EUV and NGL (next generation lithography such as e-beam and mask-less lithography), DSA (Direct Self Assembly) and Nano-Imprint.
7) Mask manufacturing equipment for 1Xnm / X nm mask patterning, defect inspection and repair, metrology and cleaning.
8) Thin film processes including thin film deposition, such as (PE)ALD (Plasma Enhanced Atomic Layer Deposition) and PIII (Plasma Immersion Ion Implantation) for doping and material modification, including cold and low-thermal budget processing. Including the processing and manufacturing and standardization of novel materials, precursors and chemicals (e.g. magnetic multilayers, nanowires and nanotubes, 2D materials deposition processes, photonic materials.) Including emerging field of selective deposition and material modification combined with the required surface modification techniques such as use of SAM's (self assembled monolayers)
9) Wet processing, wet and dry etching, thermal treatment, and wafer preparation (polishing, cleaning, thinning, bonding and laser marking).
10) Interconnect technology including metallization (extend the scalability of Cu interconnects), low-k dielectrics, contact filling, optical interconnects...), 3D technology options and monolithic 3D integration.
11) Pre-assembly equipment and technologies, such as thinning and dicing, and for preparing semiconductor devices for assembly and packaging
12) Inspection, test and metrology equipment with a holistic approach: including amongst others Optical, X-Ray and Mass techniques, TEM, fast AFM, E-Beam and Scatterometry techniques for e.g. in-/off-line wafer and mask defect inspection and review, nuisance defects filtration, materials analysis, thin film metrology, roughness metrology, 3D critical dimension, electrical characterization, overlay accuracy, defect repair and verification and physical failure and defect analysis for nano-scale devices.
13) Holistic metrology: combined inspection and metrology technologies as data hybrid (e.g. OCD/CDSEM), and complementary approaches (e.g. mask and wafer inspections).
14) Equipment's productivity aware design (PAD): support semiconductor manufacturing key topics in the area of Advanced Predictive Maintenance, Equipment Health Factor, Virtual Metrology techniques, improve performance efficiencies for smaller node and cost of ownership reduction. The scope includes specific hardware and algorithms developments in the areas of:
    a) Molecular contamination reduction
    b) Motion control jitter free air bearing
    c) Acoustic vibration suppression
    d) Light ultra-stiff and clean modules
    e) New algorithm and advance heterogeneous computing platform for:
        i) Real time big data processing
        ii) Smart sampling
        iii) fingerprint detection virtual intelligence (VI)

MtM and SiP Process Technology, Equipment and Materials

MtM and SiP focuses on generic process technologies, equipment and materials for novel device concepts that are highly diverse and differentiating, with multi-fold and strongly application-driven performance metrics where European leadership potential is strong or proven. A holistic approach is requested focusing on the - application dependent - optimum mix of monolithic, heterogeneous or SiP integration in (sub-)systems that significantly advance functionalities such as multi-parameter sensor systems, energy harvesting, RF and wireless communication, power systems biomedical devices etc.

Activities on Process modules, equipment (including sub-systems) and materials concurrent with the European leadership and in line with application roadmaps on the industry-driven relevant wafer sizes (supporting the transition to the next generation wafer diameters) or flexible substrates and carriers. This list is a non-exhaustive list and other topics that contribute to general objectives of the theme “Semiconductor Processes, Equipment and Materials” are eligible.

1) advanced process technology, (disruptive) materials and equipment for manufacturing of devices and systems based on amongst others nano-structures and thin films and multilayers, III-V, silicon photonics, integrated technologies for photonic sensors, including CMOS imaging sensors, technologies for embedded non volatile memories targeting eg low power, high security or high safety applications, photonic materials, advanced dielectrics, organic and oxide semiconductors, combination of active devices with passives, biochemical coatings and (packaging) materials, thermal interface materials, etc. . All modules are considered including lithography, deposition, etch, etc.
2) Generic technologies for sensors and actuators, Analog/mixed signal technologies, RF and power devices (including GaN-on-Si and SiC), as well as integrated technologies for energy management and harvesting.
3) Engineered substrates for specific electronics: Power application low-resistivity substrates, RF application high-resistivity and engineered substrates (RF-SOI, new material stack, piezo material...), photonics applications Si / SiN combination using SOI and Layer transfer, 3D stacking with industrial circuit transfer, Si interposer, glass interposer, ceramics.
4) Alternative patterning approaches such as imprint, maskless litho and inkjet printing. Reel-to-reel, sheet-to-sheet and or roll-to-roll processes and integration approaches.
5) Back-end-of-line/back-end processes and FE/BE compatibility (sintering, die-attach bonding, copper bonding, lead-free soldering and cost-efficient TSV’s (Through Silicon Vias), chip embedding (based on moulded wafer, PCB, flexible & silicon/glass substrates, advanced substrates), 3D stacking at wafer and chip-level. 3D (electrical, RF and/or optical) and interposers - high density and fine pitch, accurate placement of components on wafer scale (e.g. ICs, filters, windows) E&M
6) Wafer thinning, dicing and device singulation including defect and crack detection, handling and processing of ultra-thin and MEMS wafers (including test equipment)
7) Assembly and packaging
8) Chip embedding and fan-out technologies
9) Printing technology on wafer scale for functional material deposition and hybrid integration of printed electronics with silicon. 3D printing manufacturing for SiP.
10) Process characterization tools, in-line and in-situ metrology and defect/contamination control equipment and corresponding sensors. Specific methodologies and tools for Advanced Process Control (APC), optimized for high-mix environments. Industry viable continuous-

process manufacturing lines to allow rapid commercial implementation and lead to standardization including measures for process and quality control.

11) Scalable and modular testing and reliability approaches for e.g. extreme conditions (e.g. power devices) and non-electrical parameters (e.g. MEMS), high-voltage testing, highly-parallel testing, and contact-less testing; reliability-limiting degradation and failure mechanisms in complex systems, 3D and SiP specific test equipment for high aspect ratio metrology, failure localization including TSV and interposer based devices

For both 1.1 and 1.2:

1) Multi-physics and multi-scale expertise in the TCAD, thermo-mechanical properties and stress engineering, multi-scale materials, characterization, modelling and simulation covering also non-electrical parameters for sensors and actuators (e.g. mechanical, fluidics, optical), model validation and improvement using physical nano-analysis techniques, in order to release more predictive tools for the production lines.
2) All these need to be supported by the relevant ‘Design Technologies’ on chip/package/board as well as technology aware system partitioning and cost models for trade-off between SiP and SoC - i.e. optimum (sub)system design capabilities.
3)

8.7 Annex to B2: Design Technology

No annex text for Design Technology.

8.8 Annex to B3: Cyber-Physical Systems

No annex text for Cyber-Physical Systems.

8.9 Annex to B4: Smart Systems Integration

No annex text for Smart Systems Integration.

9 Contributors

First Name	Name	Affiliation
Victor	Acinas Garzon	CCAN - Collaborative Centre for Applied
Josef	Affenzeller	AVL List GmbH
Gerold	Alberga	ASML
Sanna	Alberto	HSR
Luisa	Andreone	CRF, Centro Ricerche Fiat S.C.p.A.
Marcel	Annegarn	AENEAS
Aitor	Arnaiz	IK4-TEKNIKER
Paolo	Azzoni	Eurotech
Stefan	Baelen, van	iMinds vzw
Keith	Baker	Philips Applied Technologies Business Group
Livio	Baldi	Micron Semiconductor
Kathy	Barla	IMEC
Anton	Bauer	Fraunhofer
Ronald	Begeer	Philips Business Group Research
Ad	Berg, ten	ARTEMIS-IA Office
John	Blankendaal	BRAINPORT INDUSTRIES
Jo	Boeck, de	IMEC
Wolfgang	Bosch	Technische Universität Graz
Anne	Bosch,van den	IMEC
R.	Brederlow	TI
Francois	Brunier	Soitec
Germán	Cabañero	IK4-CIDETEC
Claudia	Caligiore	STMicroelectronics s.r.l
	Ceiemta	UDG
Patrick	Cogez	STMicroelectronics Grenoble 2 SAS
Albert	Cohen	INRIA
Armando Walter	Colombo	Schneider Electric Automation GmbH
Jose luis	Conesa	AlphaSIP
Gérard	Cristau	Thales
Gérard	Cristau	Thales
Heinrich	Daembkes	Airbus Defence and Space GmbH
Renzo	Dal Molin	Sorin CRM SAS
Renzo	DalMolin	Sorin
Werner	Damm	OFFIS
Jo	deBoeck	IMEC
Simon	Deleonibus	CEA
Jerker	Delsing	Lulea University of Technology
Jerker	Delsing	Lulea University of Technology
Wolfgang	Dettmann	Infineon Technologies AG
Mario	Diaz Nava	STMicroelectronics s.r.l
Thomas R.	Dietrich	IVAM e.V. Fachverband für Mikrotechnik
Manfred Werner	Dietrich	Fraunhofer EAS
Marc	Duranton	CEA
Shankar	Ekkanath Madathil	University of Sheffield

Christian	El Salloum	AVL List GmbH
Wolf	Engelbach	Fraunhofer IAO
Sebastian	Engell	Technische Universität Dortmund
Ilan	Englard	AMAT
Amedeo	Enrico Zuccaro	STMicroelectronics S.A.
Rolf	Ernst	Technische Universität Braunschweig
Leire	Etxeberria	Mondragon Goi Eskola Politeknikoa
Miguel Pascual	Ferreruela	TomTom International BV
Richard	Foggie	Knowledge Transfer Network
Luis	Fonseca	Consejo Superior de Investigaciones
Jesus Angel	Garcia Sanchez	Indra Sistemas S.A.
Casper	Garos	Philips Medical Systems NL B.V. Healthcare
Wolfgang	Gessner	VDI/VDE Innovation + Technik GmbH
Wolfgang	Gessner	VDI/VDE Innovation + Technik GmbH
Laila	Gide	Thales
Luigi	Glielmo	Universitá degli Studi del Sannio
Piotr	Grabiec	ITE Warsaw
Mart	Graef	University of Technology Delft
Dieter	Graef	Siltronic
Hans	Grönqvist	Swerea IVF AB
Radu	Grosu	Vienna University of Technology
*	Grund	IMEC
Rainer	Guentzler	HSG-IMIT
Jan	Haagh	Technical University Eindhoven
Marko	Häckel	Robert Bosch GmbH
Paul	Haren, van	Technolution B.V.
Rob	Hartman	ASML
Eliav	Haskal	Philips Business Group Research
Maurits	Heiden, van der	TNO
Stefan	Heinen	Rheinisch Westfälische Technische
Mark	Helvoort, van	Philips
Jens	Herrmann	Daimler A.G.
Wolfgang	Herzner	AIT - Austrian Institute of Technology GmbH
Michael	Heuken	AIXTRON AG
Marc	Heyns	IMEC
Christina	Hirschl	CTR Carinthian Tech Research AG
Leonard	Hobbs	Intel Deutschland GmbH
Karsten	Hofmann	Continental Automotive GmbH
Hans	Hofstraat	Philips research
David	Holden	CEA
Romano	Hoofman	NXP Semiconductors
I.	Hotska	FEL
Knut	Hufeld	Infineon Technologies AG
Knut	Hufeld	Infineon Technologies AG
Matthias	Illing	Robert Bosch GmbH
*	Jama	DTU
Ahmed	Jerraya	CEA

Sylvian	Kaiser	Doceapower
Sytze	Kalisvaart	TNO
Nelly	Kernevez	Soitec
Olaf	Kievit	TNO
Jyrki	Kiihamäki	VTT Technical Research Centre of Finland
Anton	Koeck	Materials Center Leoben Forschung GmbH
Tatu	Koljonen	VTT Technical Research Centre of Finland
Sabine	Kolodinski	GlobalFoundries
Matti Heikki Juhani	Kutila	VTT Technical Research Centre of Finland
Christoph	Kutter	Fraunhofer EMFT
Agnès	Lancelot	NXP Semiconductors France SAS
Jochen	Langheim	STMicroelectronics s.r.l
Cees	Lanting	CSEM - Centre Suisse d'electronique et de
Roland	Lartigue	Photomask
Matthijs,Willem	Leeuw	TNO
Matthijs Willem	Leeuw	TNO
Norbert	Lehner	Infineon Technologies AG
Frank	Linden, van der	Philips Medical Systems NL B.V.
Frank	Linden,van der	Philips Medical Systems NL B.V.
Jan	Lohstroh	ARTEMIS-IA
Jan	Lohstroh	ARTEMIS-IA
Jean-Christophe	Loume	Valotec
Günter	Lugert	Siemens AG
Johan	Lukkien	Technical University Eindhoven
Jon	Mabe	IK4-TEKNIKER
Jan	Madsen	Technical University of Denmark
Laurent	Maillet-Contoz	STMicroelectronics s.r.l
Marco	Manso	Rinicom Ltd.
Horn	Martin	TU Graz
M T	Martinez	ICB CSIC
Pär-Erik	Martinsson	Lulea University of Technology
John	Massoner	Infineon
Johann	Massoner	Infineon Technologies Austria AG
Gérard	Matheron	STMicroelectronics s.r.l
Kutila	Matti	VTT Technical Research Centre of Finland
Jürgen	Meister	OFFIS
Gaudenzio	Meneghesso	University of Padua
Georg	Menges	NXP Semiconductors Germany GmbH
Paul	Merkus	Philips Business Group Research
Chris	Merveille	IK4-IKERLAN
Michael	Metzger	Siemens AG
Gereon	Meyer	VDI/VDE Innovation + Technik GmbH
Jean-Paul	Morin	STMicroelectronics
Reinhard	Neul	Robert Bosch GmbH
An	Nguyen-Dinh	VERMON S.A.
Jürgen	Niehaus	SafeTRANS e.V.
Ronald	Nucua	Valotec

Cian	O'mathuna	Tyndall National Institute - University College
Frank	Oppenheimer	OFFIS
Mikael	Östling	KTH
Peter	Otterloo, van	Technical University Eindhoven
Herbert	Pairitsch	Infineon Technologies Austria AG
Carmelo	Papa	EPoSS
Stefano	Pasquariello	Selex Sistemi Integrati
Steffen	Paul	University Bremen
Michael	Paulweber	AVL List GmbH
Francois	Pecheux	UPM/Lip6
Mr	Peter	Microbiocomms
Ralf	Pferdmengers	Infineon Technologies AG
Lothar	Pfitzner	Fraunhofer IISB
Rainer	Pforr	Carl Zeiss SMT GmbH
Kim	Pham	Thales Electron Devices SAS
Ralf	Popp	Edacentrum
Harald	Pötter	Fraunhofer IZM
Klaus	Pressel	Infineon Technologies AG
Patrick	Pype	NXP Semiconductors
Pertti	Raatikainen	VTT Technical Research Centre of Finland
Popp	Ralf	EDA Centrum DE
Stephan	Rebbelmund	Bosch
Jochen	Reisinger	Infineon Technologies Austria AG
Carlo	Reita	CEA
Jochen	Rissinger	Infinion
Nigel	Rix	KTN UK
John	Rodrigues	INOV INESC INOVACÃO
Francesco	Rogo	Finmeccanica S.p.A
Dominik	Rohrmus	Siemens
Miguel	Roncalés Poza	AlphaSIP
Juha	Röning	University of Oulu
Kurt	Ronse	IMEC
Laurent	Roux	Ion Beam Services
Ben	Rutten	Technical University Eindhoven
Sven	Rzepka	Fraunhofer ENAS
Daniel	Sáez Domingo	ITI, Instituto Tecnológico de Informática
Jürgen	Salecker	Siemens AG
Tullio	Salmon Cinotti	Università di Bologna - Alma Mater Studiorum
Enrico	Sangiorgi	Università di Bologna - Alma Mater Studiorum
Andreas	Schaller	Robert Bosch GmbH
Erwin	Schoitsch	AIT - Austrian Institute of Technology GmbH
Michael	Scholles	Fraunhofer IPMS
Ina	Sebastian	Infineon Technologies AG
Tanja	Seiderer	Infinion
Shaun	Sequeira	KONE Corporation
Alberto	Sillitti	Cons. Interunivers. Nazionale per
Karsten	Smeulders	Bosch

Juha-Pekka	Soininen	VTT Technical Research Centre of Finland
Hessel	Sprey	ASM International N.V.
Medur	Sridharan	Bull SAS
David	Storer	CRF, Centro Ricerche Fiat S.C.p.A.
Wolfgang	Templ	Alcatel-Lucent Bell Labs France
Dominique	Thomas	STMicroelectronics S.A.
Michel	Tissier	Photomask
Erlbacher	Tobias	Fraunhofer
Bruno	Tranchero	Finmeccanica - Alenia Aermacchi S.p.A
Elena	Tsiporkova	Sirris
Francois	Tuot	Gemalto S.A.
Roberto	Uribeetxeberria	Mondragon Goi Eskola Politeknikoa
Fred	van Roosmalen	NXP
Christos	Verikoukis	CTTC: Centre Technòlogic de
Ovidiu	Vermesan	SINTEF
Eugenio	Villar	University of Cantabria
Daniel	Watzenig	Kompetenzzentr. Das virtuelle Fahrzeug
Michael Bernd	Weber	Daimler A.G.
Werner	Weber	Infineon Technologies AG
Pieter	Wolf, van der	Synopsys
Roberto	Zafalon	STMicroelectronics s.r.l
Anastasiya	Zagorni	Fraunhofer
Peter	Zegers	NXP Semiconductors
Ehrenfried	Zschech	Fraunhofer
Maurizio	Zuffada	STMicroelectronics s.r.l