2015 Multi Annual Strategic Research and Innovation Agenda for the ECSEL Joint Undertaking

MASRIA 2015
as prepared by the ECSEL PMB representing AENEAS, ARTEMIS-IA and EPoSS

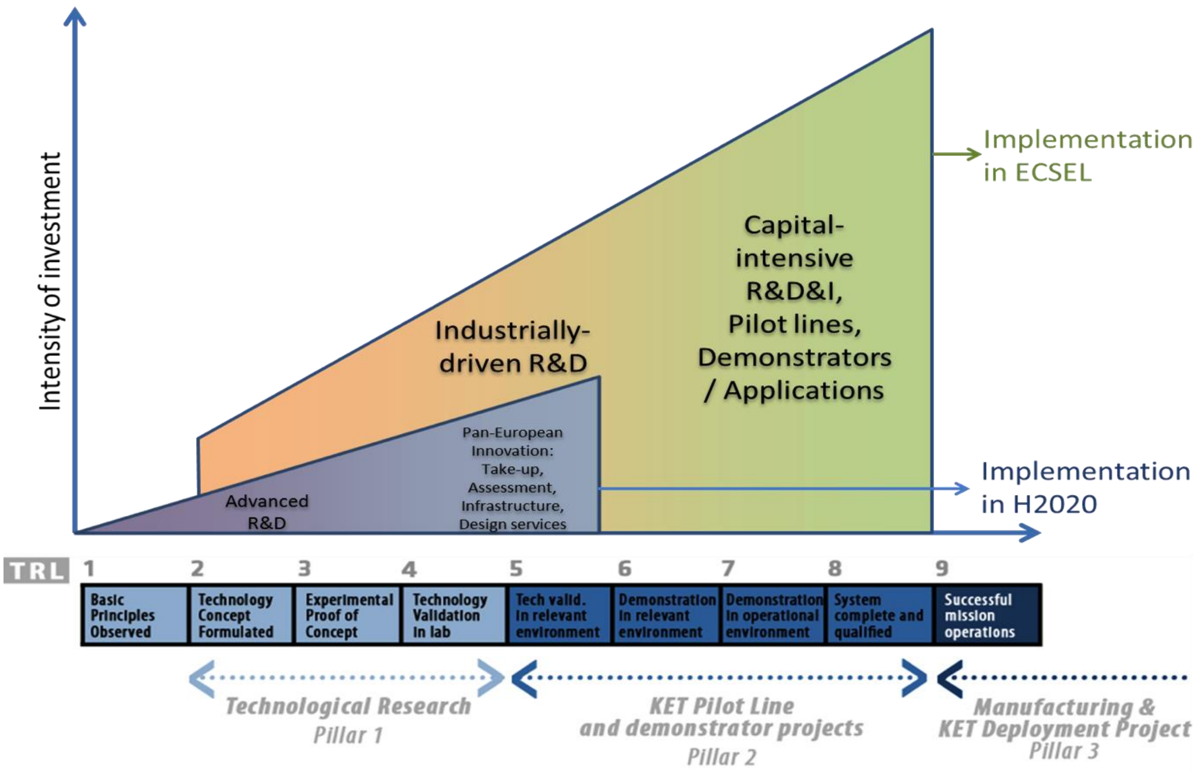
REVISION STATUS		
1.0	First Draft V1, written as updated MASP 2014	2014-09-22
1.1	V1.1 now written as MASRIA and including comments of the PMB from its meeting of Sept. 30 and from chapter-leaders in e-mails sent before Sept. 30. Still to be done: 1) Improve lay-out (homogeneous fonts, readable pictures and tables) 2) Linear Chapter numbering 3) Captions under all tables and pictures	2014-10-02
V1.2	Layout consistency, chapter numbering, captions and minor editorial corrections - AF	2014-10-03
V1.3	Final comments from chapter-leaders and support/steering/boards of the three associations included. Still to be done 1) Linear chapter numbering and update Table of Contents 2) Improve lay-out after final comments included 3) Improve homogeneity of captions style and numbering	2014-10-12
V1.4	Inclusion of late inputs Insertion of requested corrections. Layout adjustments to some figures (readability) Editorial checks to assure compatibility with MASP derivation	2014-10-13
V1.4a	Chapter numbering aligned to MASP	2014-10-20

Table of Contents

1 Introduction

This 2015 ECSEL Multi Annual Strategic Research and Innovation Agenda (MASRIA), on behalf of the ECSEL Private Members Board (PMB), serves as input/recommendation for the 2015 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 as recommended by the PMB. In its structure this MASRIA 2015 follows the structure of the MASP 2014.

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), as well as lower TRLs when this is relevant for industry. However, this does not preclude smaller projects focusing on topics with strong industrial support. In this way, the ECSEL JU agenda complements the other cPPPs as well as the 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 [HLSRIA 2012]. Based on a very wide set of technologies they will together enable the provision of breakthrough products and services.

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, have a presence in cyber space, exploit the 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 new products, systems and services and their applications essential for 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.

The ECS domain is enabled by the partially overlapping 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 [IA2030], of which over 1 million direct and induced jobs in the semiconductor industry [ELGRM]. Together, they allow Europe to address a global market of more than 2,600 billion $ [IA2030], enabling the generation of at least 10% of GDP in the world [ELGRM].

Europe needs unrestricted access to solutions for its societal challenges; it also needs industrial drive for wealth creation and global competitiveness. The ECS industries and institutes are engaged in solving these societal challenges by providing key enabling technologies, components, and competencies. Its innovations are essential in all market segments where Europe is a recognized global leader. 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.

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 one of the implementation instruments of the European Horizon 2020 programme, an innovation-driven programme, with a clear intent to bring innovations to the market by contributing towards building the bridge across the valley of death separating scientific discovery from its economic success.
2) The ECSEL actions will apply the ECS technology capabilities to address industry-defined key applications to enable solutions for the societal needs defined in Horizon 2020. Furthermore the ECSEL actions will drive the technological progress required to provide solutions capable of meeting the challenges of the future. In this role, the ECSEL programme is ideally positioned as the instrument of choice for developing the Nano- and Micro semiconductor Key Enabling Technologies [HLGKETS] alongside the essential complementary technologies that allow such KETs to deliver, to their full potential, real solutions to today's industrial and societal challenges.
3) ECSEL will address TRL 2-8 by engaging the whole ecosystem, including large companies, medium size and small enterprises, and grass root innovation brought by academic and institutional research from across Europe, 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 to future societal evolutions and to prepare the responses of this fast moving industry. It will combine the dynamism and agility to respond to unexpected market development of an open, "bottom-up" approach to participating R&D 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 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[1] 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[2]

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 awards, 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 Information and Communication Technology at large, The ECSEL JU shall use the Horizon 2020 instruments both R&D&I, to leverage the required investments to secure the sustainable controlled access to the technology for the European industry.

---

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

[2] 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.

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.

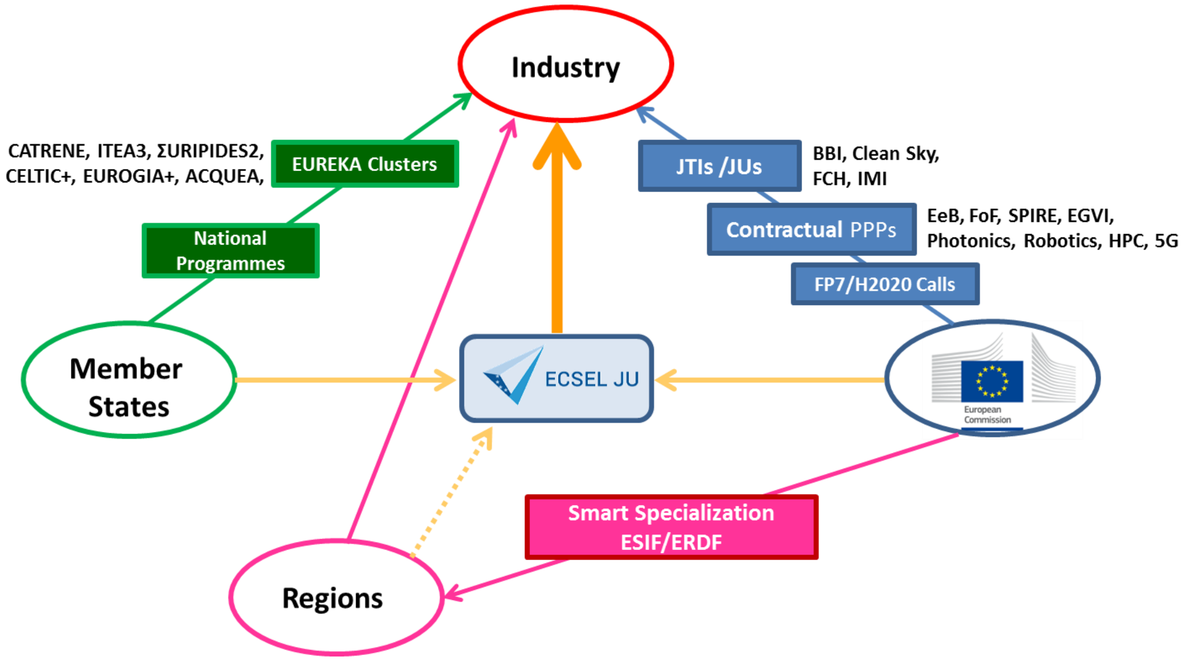
Microchips and embedded software can provide effective solutions to the societal challenges only if integrated in smart systems. Smart systems are here understood in the wider sense, extending the scope of ECS to include complex and large platforms. The ECSEL JU actions shall include projects that integrate 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 allowing the community of RD&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, the constructive relationship built up between respectively ARTEMIS/ITEA and ENIAC/CATRENE during the execution of the ARTEMIS and ENIAC programmes is expected to continue - a 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 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.

Reference: 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 "

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, 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 [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.*"

This MASRIA document synthesises a set of key application and technology capabilities that is (by definition) of strategic importance to European industry, provides a structure around which work can be organised and indicates the expected outcomes of the RD&I work. The definition of detailed work at the execution level that best fits the needs perceived by industry at the relevant time is then driven by the participants via the RIAP, which is consolidated into the ECSEL Work Plan. This model, as was the case in the ARTEMIS and ENIAC JU programmes, provides for clear strategic direction for the community of RD&I actors to follow, and yet is flexible and agile in responding to the rapidly changing industrial and business environment that is typical of the industries involved.

1.4 References

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

[NE2020] Nano-Electronics beyond 2020: Innovation for the Future of Europe (Nov 2012)

[IA2030] ITEA ARTEMIS-IA High-Level Vision 2030: Opportunities for Europe (Dec 2013)

[AEN2013] AENEAS SRA/VMS 2007

[ART2013] ARTEMIS SRA 2011 plus addendum 2013, on Embedded/CyberPhysical Systems

[EP2013] Strategic Research Agenda of the European Technology Platform on Smart Systems Integration (2013)

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

[H2020WP] HORIZON 2020 WORK PROGRAMME 2014 – 2015: 5. Leadership in enabling and industrial technologies: Information and Communication Technologies"

[HLGKETS] High-Level Group on Key Enabling Technologies Final Report, June 2011

Relevant EU documents:

H2020 R1290	Rules of Participation and Dissemination
H2020 R1291	Establishing H2020
H2020 D743	Council decision implementing the H2020 programme

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 [NE2012].

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, software and integration. 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 [NE2012, IA2030]. Objective of this holistic approach is to reinforce the ecosystem and have Europe regain its leading position for products and services in this highly competitive domain. By 2020, this will increase Europe's world-wide revenues by over 200 billion € per year [NE2020], and create up to 800,000 jobs in Europe's ECS enabled ecosystem [IA2030]. Within this overall ambition, the semiconductor industry has accepted the challenging goal to double their economic value in Europe by 2020-2025 [HLGRM].

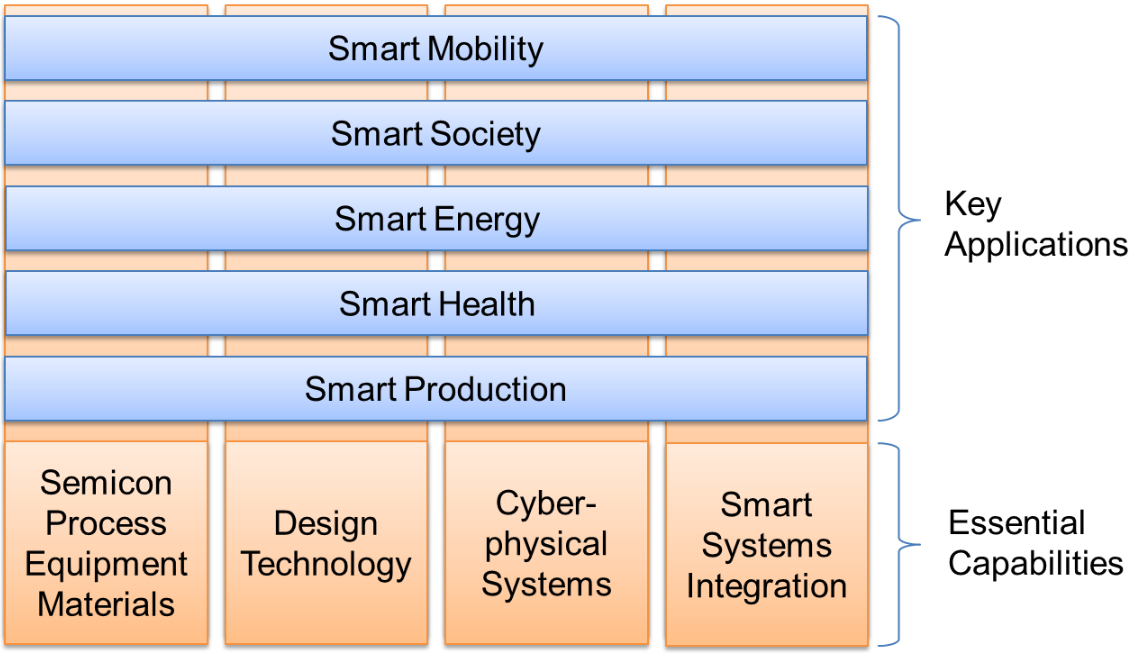
Realisation of the above goals and objectives requires extensive collaboration across the innovation and value chain for ECS, with research institutes and academia, SME and large companies, and R&D&I actors from materials, equipment and microchips, together with design tools and architectures, to embedded 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.

2.2 Strategic thrusts

The ECSEL JU MASRIA takes inspiration from the report of the Electronic Leaders Group [HLGRM] that proposes "… *A combined market-pull-supply-drive strategy to optimise impact*." (Chapter VII). 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, which embodies this principle.

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. For each Thrust an 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 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 ECSEL Strategic Thrusts are outlined in Part A: Key Applications and Part B: Essential Capabilities of this MASRIA. 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 a priori technological 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 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, focussing on 'Smart Everything Everywhere' solutions for the European Societal Challenges. Addressing the challenges highlighted in each of these areas has the potential to strengthen Europe in terms of global market success and sustainable impact. Being rooted in core technology capabilities of the Union, the selected topics 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. 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. A strategy for standardisation is foreseen, particularly in the context of the Innovation Pilots Projects and Inter-Operability Specifications related to Reference Tool-Platforms. This will include a rationale taking into account strategic standardization activities undertaken by the Private Members.[3]

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 Nation 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

[3] As in the ARTEMIS-IA Standardisation SRA

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 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. In practice, the funding types of H2020 will be used to finance these projects, for the most part Research and Innovation Actions or Innovation Actions. The reader is referred to the relevant H2020 documentation [H2020WP] for further explanation.

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 prototype in a laboratory or simulated environment.

R&D projects (referred to as RIA projects in the ECSEL-JU) are characterised as follows:

1) Executed by an industrial consortium including universities, institutes, SMEs and large companies, with at least three non-affiliated partners from three different Participating States;
2) Addressing lower TRL’s (TRL 2 to 5);
3) Developing innovative technologies and/or using them in innovative ways;
4) Targeting demonstration of the innovative approach in a relevant product, service or capability, clearly addressing the applications relevant for societal challenges in relation with the ECSEL Strategic Thrusts;
5) Demonstrating value and potential in a realistic environment representative of the targeted application;
6) Having a deployment plan showing the valorisation for the ECS ecosystem and the contribution to ECSEL goals and objectives.

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.[4]

A Pilot Line project (referred to as IA project in the ECSEL-JU) is identified by:

1) Executed by an industrial consortium including universities, institutes, SMEs and large companies, with at least three non-affiliated partners from three different Participating States;
2) Addressing higher TRL's (TRL 4 to 8);
3) Using innovative technology;
4) Developing innovative solutions in relation with the ECSEL Strategic Thrusts;
5) Establishment of a new and realistic R&D&I environment connected with an industrial environment, such as a pilot line facility capable of manufacture;
6) Product demonstrators in sufficient volume to establish their value and potential;
7) Having a deployment plan leading to production in Europe.

Where the infrastructures required by Pilot Line 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 legality 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 project;
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.

3.3 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

[4] As in the ENIAC Pilot Lines

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.[5] [6]

An Innovation Pilot Project (also referred to as IA project in the ECSEL-JU) is identified by:

1) Executed by an industrial consortium including universities, institutes, SMEs and large companies, with at least three non-affiliated partners from three different Participating States;
2) Addressing higher TRL's (TRL 4 to 8);
3) Using innovative technology;
4) Developing and demonstrating innovative solutions in relation with the ECSEL Strategic Thrusts;
5) Establishment of a new and realistic R&D&I environment connected with an industrial environment, such as a zone of full-scale testing;
6) Product demonstrators in a relevant environment to prove their value and potential;
7) Having a deployment plan leading to production/commercialisation in Europe.

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'.

---

[5] As in the ARTEMIS Innovation Pilot Projects

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

3.4 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[7].

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.

3.5 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.

3.6 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) Standardisation;
4) Education / training actions;
5) Coordination of actions across European R&D&I programmes;
6) Planning and organisation of important dissemination events.

---

[7] 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'

In part, such activities are on an in-kind basis by the Private Members. Funding through Horizon 2020 actions will be pursued.[8]

[8] 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 b€, 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 2.34b€, is expected to leverage a total investment approaching 5b€ 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 while advancing towards an accident-free mobility scenario, which also addresses the needs of an ageing population. In this context, Europe must 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) is key to achieving this: ECS aims to provide vehicles (e.g. cars, airplanes, vessels, trains, off-road vehicles, satellites, etc.) and transportation systems with the required intelligence by extending and reinforcing the well-established strengths of the European industry.

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, decision-making, control and actuation based on ECS and the necessary development and validation tools and methods.

These functions will lead to **resource-efficient transport** 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 enable different levels of **highly automated and autonomous transport** leading to more safety. Additionally it shall ensure mobility for the elderly, reduce congestion in cities 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, in airspace and on waterways, stations, airports, hubs, …) and increased level of information awareness (vehicle, route, weather conditions, …). Thus, it also contributes to less congestion, more safety, more resource efficiency, smooth intermodal shifts, and less pollution by the transport 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) and “soft” transportation (pedelec, bicycle, pedestrians...).

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. 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. Hence, it will help to strengthen those industrial sectors that are most important for employment and economic growth in Europe.

ECSEL is supporting 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 component and systems for smart mobility. In doing so, ECSEL is helping to achieve the long-term objectives of the EC's Transportation White Paper[9].

6.1.4 Cross References

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

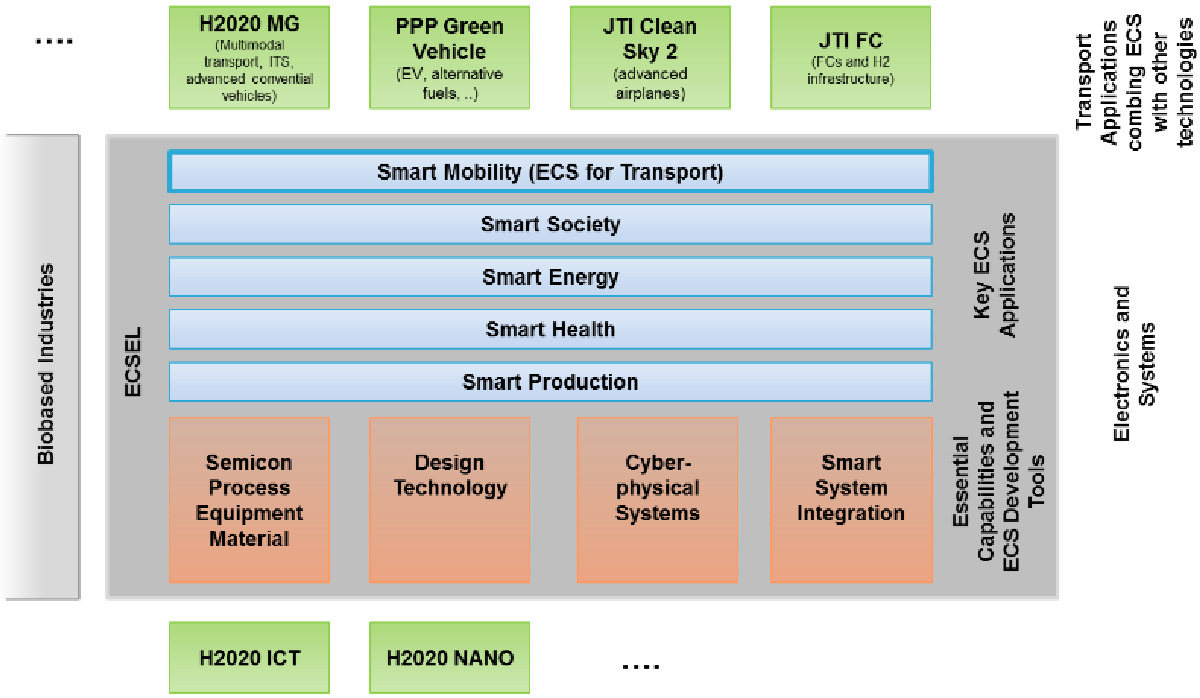


Figure 6-1: Relation of ECSEL Smart Mobility with other EU Research Programs

ECSEL delivers new revolutionary ECS functionality to application-oriented transport research program as H2020-"Mobility for Growth", H2020-"Green Vehicle", JTI Fuel Cells and Hydrogen 2 and Clean Sky 2, where ECS results are combined with mechanical, chemical and application research to solve European transport problems.

As ECSEL application domains takes advantage of cross domain ECS technologies, the smart mobility research program expects research results from horizontal ECSEL capabilities as

---

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

semiconductor processes, equipment and material, design technologies, CPS technologies (as 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 [10]):

1) By 2016 the 2nd generation of electrical vehicles (EV) with updated powertrains including plugin capabilities and the first small scale deployment and demonstration of fuel cell based electrical vehicles (FCEV) will be launched to the market.
2) By 2020 mass production of EV as well as medium scale production of FCEV shall be established in Europe. In addition, conventional ICE (internal combustion engine based) vehicles will be largely transformed to hybrid concepts to achieve the European CO_2 reduction goals.
3) By 2025 mass production of a 3rd generation commodity priced EVs as well as 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.

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, grid integration, safety, integration into infrastructure (e.g. parking, charging …) and transport system integration. **All of these features are critically enabled by ECS** as such vehicles will be based on novel and increasingly powerful but more complex hardware, mixed-criticality embedded software, electrical and thermal architectures and on interfaces supporting intelligent charging and refuelling technologies, where safety and security are a prerequisite for successful market penetration.

In parallel to the advancement of electric and plug-in hybrid passenger as well as light duty vehicle technologies, electrified trucks and buses as well as fuel cell vehicles will be developed. However, the ramp-up 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 [11]

Additionally, the usage of wireless sensors, actuators and interconnections for non-safety critical functions will help to save precious raw materials in the production of vehicles.

---

[10] European Roadmap for Electrification of Road Transport, EGVIA, 2012

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

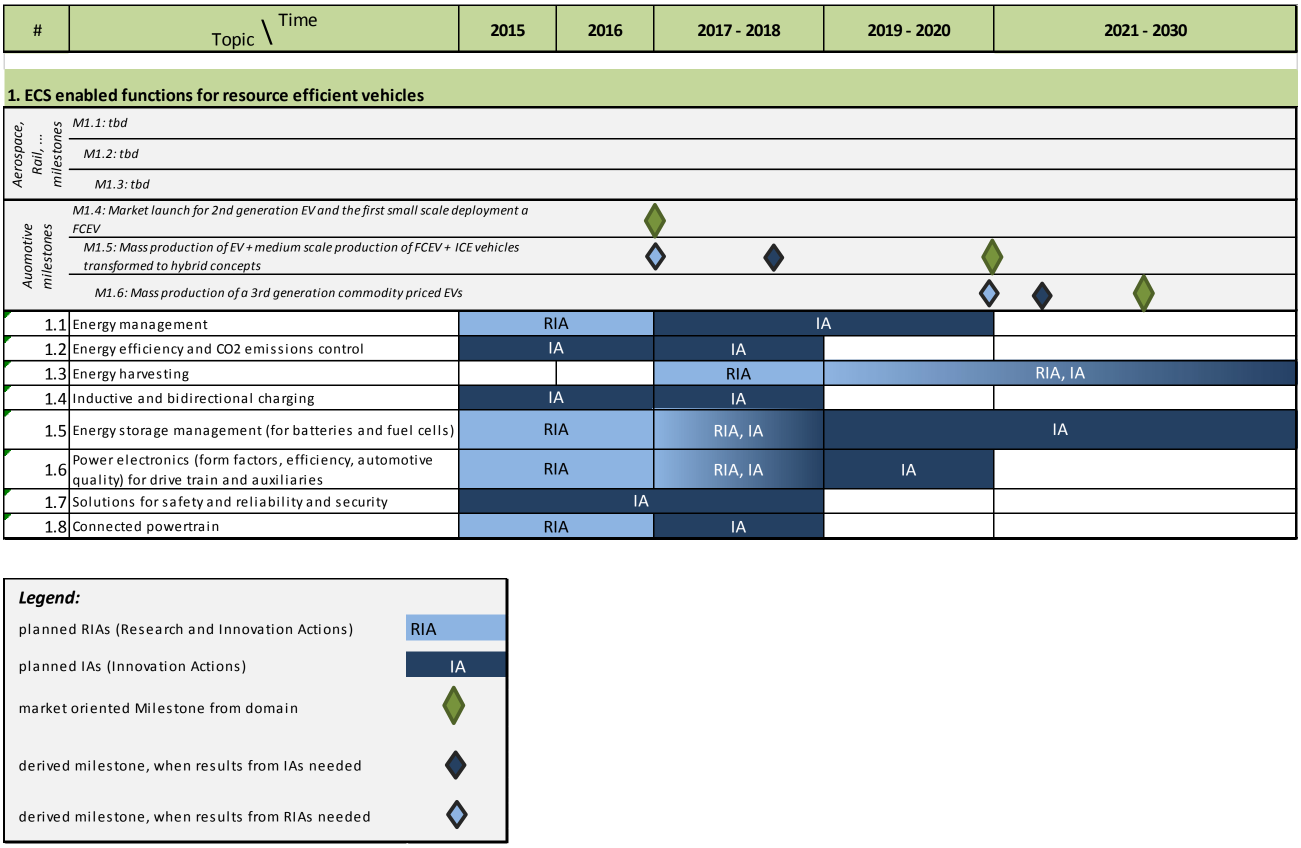


Figure 6-2: Roadmap: ECS for resource efficient vehicles

6.1.5.2 Roadmap: ECS for highly automated and autonomous transport

Significant breakthroughs have been made in advanced driver assistance systems by European vehicle manufactures and vehicle suppliers recently. 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 [12], similar steps exists for the other domains in the mobility sector):

1) By 2020, conditional automated driving (SAE Level 3, see [13]) 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 automated driving is expected to be available at higher speeds in environments with limited complexity, e.g. on highways.
3) By 2030, (conditional) automated driving is expected to be available in most complex traffic situations, i.e. in cities.

[12] European Roadmap for Automated Driving, EPoSS, 2014

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

In closed and secured environments (e.g. factory floor, new city areas with dedicated infrastructure, precision farming, etc.), a revolutionary scenario to introduce automated vehicles without intermediate steps is likely to be proposed.

Such vehicles with different levels of automation will be built on advanced systems for driver assistance, cooperative systems, and driver status monitoring as well as environment perception. Systems will be validated under virtual, semi-virtual and real world conditions. This requires dependable solutions for advanced sensors and actuators, data fusion, efficient use of connectivity, human interaction technologies, CPS, and (real-time) simulation concepts.

Secure and reliable communication networks, data links among vehicles as well as between humans, vehicles and 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 is an essential part of the development process, and the creation of regulatory frameworks as well as in-vehicle standardization has to go hand in hand with technology development.

#	Topic \ Time	2015	2016	2017 - 2018	2019 - 2020	2021 - 2030
2	**ECS enabled functions for highly automated and autonomous traffic**					
M2.1	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.					
M2.2	Conditional automated driving at higher speeds in environments with limited complexity, e.g. highways.					
M2.3	Highly automated driving in most complex traffic situations					
2.1	Sensing, actuation and data fusion – in- vehicle and with sensors and actuators in the environment	RIA, IA				
2.2	Environment recognition	RIA, IA			IA	
2.3	Traffic scene interpretation	RIA		RIA, IA	IA	
2.4	Mapping and routing	RIA		RIA, IA		
2.5	Control strategies & real time data processing	RIA		RIA, IA	IA	
2.6	Verification, validation & simulation for automation	RIA		IA		
2.7	Fail safe and secure operation	RIA		RIA, IA		
2.8	Cooperative systems	RIA		IA		
2.9	Human-vehicle interaction	RIA		RIA, IA	IA	
2.10	Infrastructure supporting autonomous transport	IA				
2.11	Positioning and navigation	RIA		RIA, IA	IA	
2.12	Cognitive modelling			RIA	RIA, IA	IA
2.13	Interacting safety	RIA		IA		
2.14	Lifetime, reliability, robustness and functional safety	RIA, IA			IA	
2.15	Certification and testing	RIA		RIA, IA	IA	
2.16	Intelligent in-vehicle networking and CAR2X communication	RIA		RIA, IA	IA	
2.17	Quality of services in extreme situations			RIA	RIA, IA	
2.18	ECS for precision farming	IA				

Figure 6-3: ECS for highly automated and autonomous transport

6.1.5.3 Roadmap: ECS for integrated and multimodal mobility networks

The development path of **integrated and multimodal mobility networks** will build on recent achievements in the domains of vehicle technologies, travel information systems. Infrastructure development as well as navigation, communication, information awareness systems and traffic management systems and interfaces between multiple modes of transport, booking, ticketing, tolling, billing and intelligent. This will mean developing big data applications using high performance computing systems to optimize these integrated and multimodal mobility networks.

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 [14]).

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.**

Vehicles and infrastructures will both benefit from advances in technologies (sensors, actuators), control and communication enabled by ECS. **Seamless integration and interaction** in a broad multimodal 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.

#	Topic \ Time	2015	2016	2017 - 2018	2019 - 2020	2021 - 2030
3	**ECS enabled functions for integrated and multimodal mobility networks**					
3.1	Safe and secure communication	RIA		IA		
3.2	Intelligent infrastructure and information systems for integrated and multimodal mobility	IA				
3.3	Traffic density control and (re)routing and cooperative decision making			RIA, IA	IA	
3.4	Multi modal, multi country traffic tolling and payment				IA	
3.5	Trajectory generation and validation using HPC	RIA		RIA, IA	IA	
3.6	User interface to multi modal and integrated transport systems (including gamification algorithms)			RIA	IA	
3.7	Online status/location monitoring and trajectory re-routing			RIA	IA	
3.8	Intermodal cross country travel information	RIA		IA		
3.9	Access and parking management			IA		
3.10	Fleet management			IA		
3.11	Predictive online traffic information (using social media and historic information from big data)	RIA		IA		
3.12	Standardization of intermodal communication			IA	IA	
3.13	Rail energy use and storage management	IA				
3.14	Aerospace SW platform for 100% operational availability and reliability, full situational awareness, human centered operation, seamless connectivity with the in-flight and ground environment	RIA		IA	IA	
3.15	Cost efficient, flexible reconfigurable, dependable and safely operating satellite systems for Smart Environment developments	RIA		RIA, IA	IA	
3.16	Assistive transport networks systems (e.g. for the elderly living)			IA	IA	

Figure 6-4: ECS for integrated and multimodal mobility networks

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

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, 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 technologies trends such as big data analysis, machine to machine interactions, multi-functional mobile devices, and autonomous systems. The vision of a dramatic increase of use of connected sensors (illustrated below) is a key element in these trends.

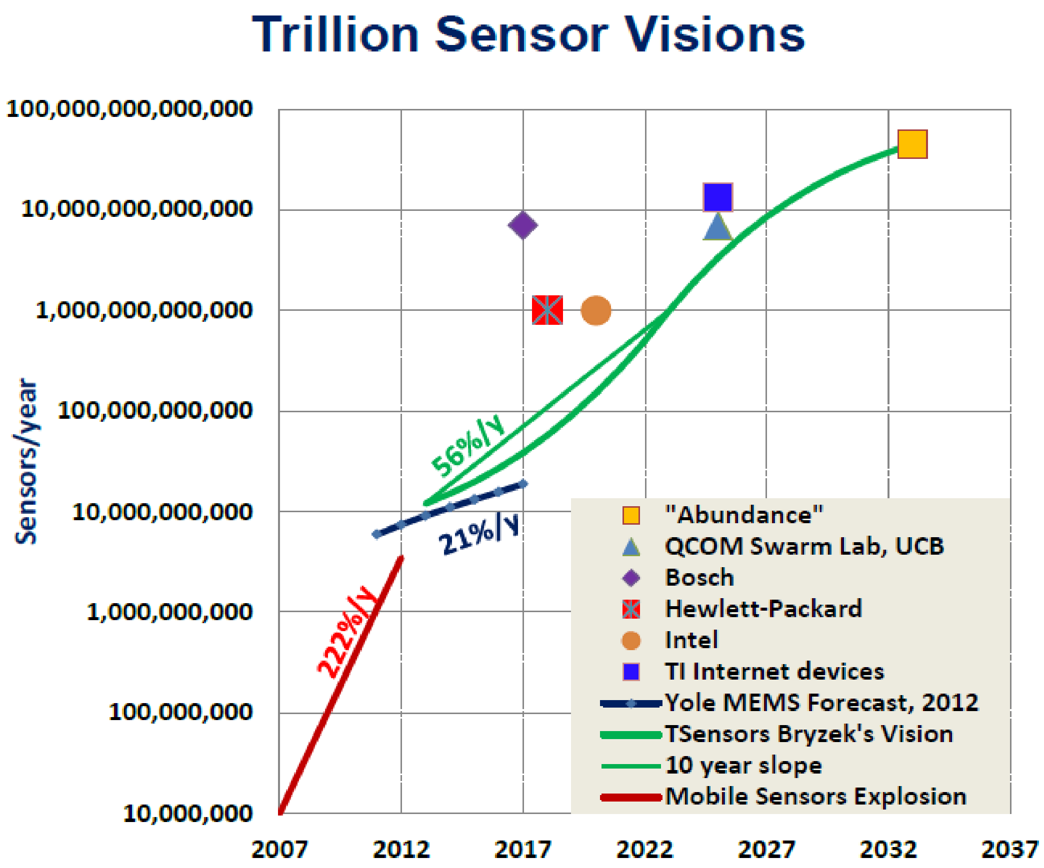


Figure 1 - After J.Bryzek, Semicon 2013, San Francisco. Dramatic increase of use of sensors connected within IoT networks expected within next years will dramatically change life of societies, creating opportunities and threats.

Fast information exchanges between people, objects and machines at 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 sufficient contribution to such solutions. The “Smart society” chapter of ECSEL addresses this gap, while ensuring to keep in pace with global technology trends.

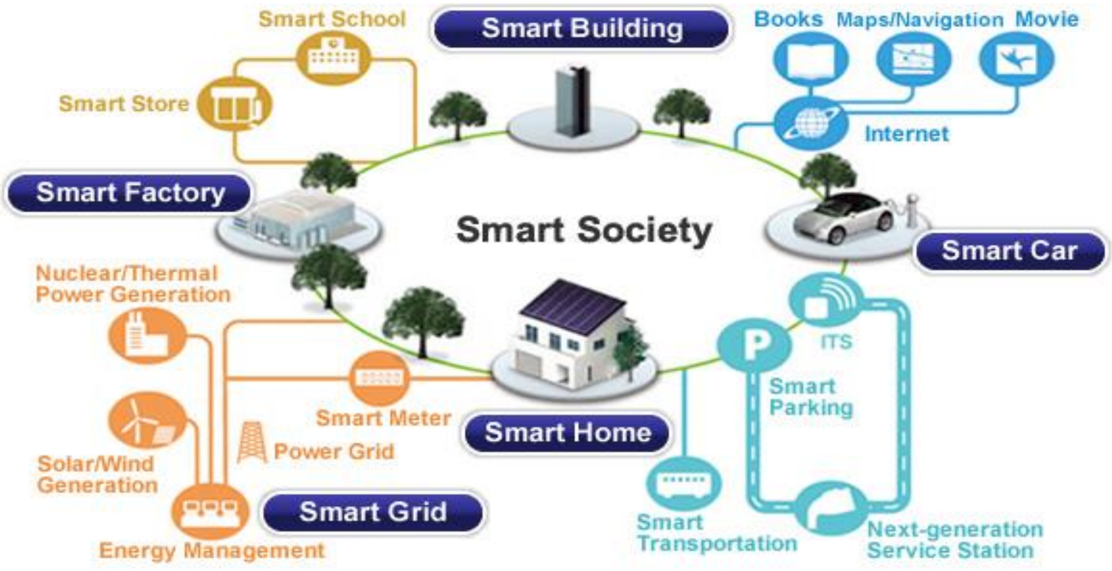


Figure 2 - After http://kr.renesas.com/edge_ol/technology/01/index.jsp

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 personnel data, 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.

6.2.2 Strategy

The overall strategy is to leverage European industry strengths, in the first period of ECSEL in particular in the critical areas of components for security and safety as well as connected (over the Internet or other networks) and trustable components and software, to select the most promising market opportunities (in Europe and outside Europe, such the equipment of new cities and rapidly growing cities, the deployment of Internet of Things, big data exploitation, …), and to improve/integrate the technical building blocks most appropriate to address these markets.

On selected application areas, Living labs experimentations shall – besides technology providers and integrators – involve multidisciplinary approaches, as well as 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, 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 markets. Development and implementation of the Smart Society solutions will need from one side - public acceptance and from the other - a deep understanding of societal needs as well as societal consequences of the Smart Society. All this aspects are strongly connected with culture of the European societies, different in different regions. Thus, Smart Society addressed solutions and innovations will much better harmonize with 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.

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 against data safety and security (e.g. tapping, manipulating, spying or copying), authentication and adaptability of security mechanisms in the field. New concepts and solutions should target user acceptance by ease of use and protection of personal data privacy.

Transverse to low and high TRLs, in the context of smart Society, IoT massive introduction will for sure poses 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 Europe competitiveness and will ease IoT deployment and its interoperability in a secured environment.

6.2.3 Impact

Smart society is a worldwide topic.

The impacts targeted by ECSEL in this area 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 or 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), with impact in terms of independence 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 to 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. 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 on 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 Europe's industry

Development of today 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.

6.2.5 Schedule/Roadmap

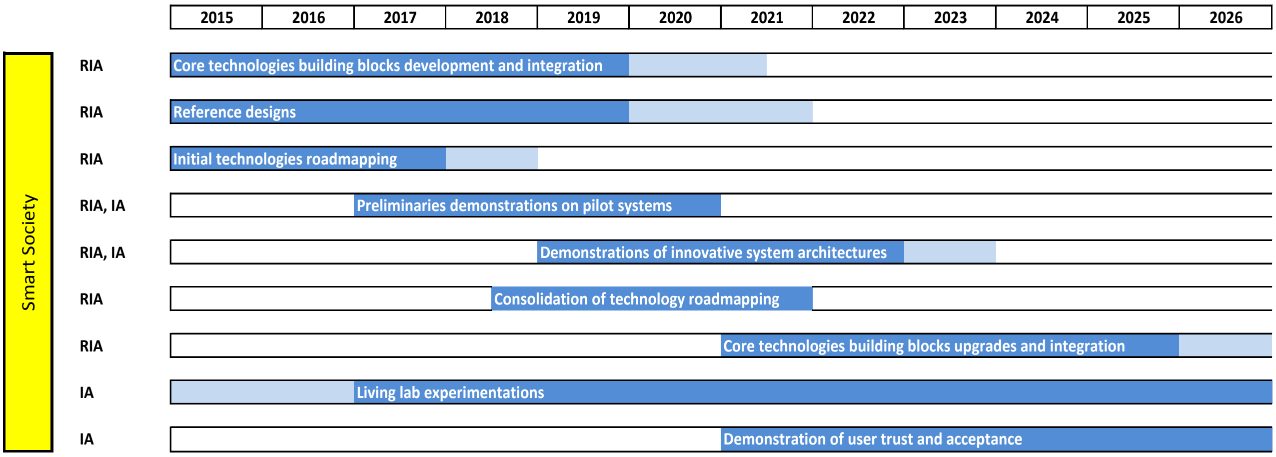
Visible results are expected as follows:

Short term: availability of core technology building blocks and reference designs, preliminary demonstrations on pilot systems, and initial technology road mapping for next steps.

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

Long term: 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.



6.3 Smart energy

6.3.1 Objectives

Significant reduction of primary energy consumption along with the reduced carbon dioxide emissions 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 nanoelectronics, embedded and integrated systems in order to secure in all energy applications the balance between sustainability, cost efficiency and security of supply.

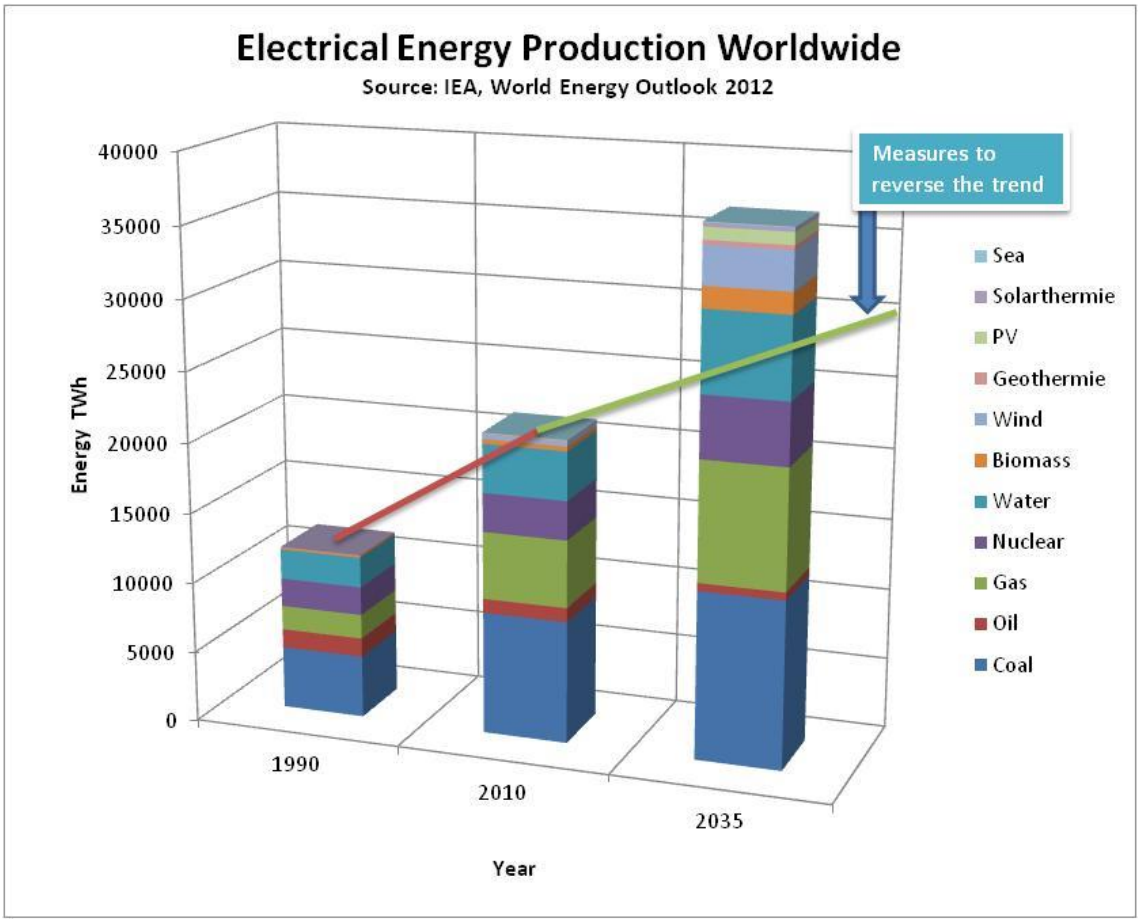


Fig. 3.1: Electrical Energy Production – Efficiency measures and installation of renewables as only way to limit greenhouse gas emissions by coal, oil, gas.

6.3.2 Strategy

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

1) Sustainable energy generation and conversion
2) Reducing energy consumption
3) Efficient community energy management

Research targets have to cover innovations in further enhancement of efficiency, reductions of consumption and in the miniaturization of the system sizes. 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 is a high level research issue. The potential of digitalization and new topologies has to be leveraged to achieve significant energy savings keeping costs and comfort. The necessary innovations in smart energy require applied research including validation (TRL 2-6) and prototyping (TRL 6-8). Both development and pilot projects can address these areas. Furthermore research activities, developments and demonstration scenarios should be open to different application scales (home, building, district, city). As an application oriented area the majority of projects and in terms of spent funding should be on RIA projects.

	NEED	ACTION	RESULTS	
Smart Energy	Energy Innovation	Technical innovation	Economic impact	Societal Impact
Generation	Growing energy demand – renewables supported by ECS	Efficiency improvements; lifetime and robustness	Competitive position of European industry	More efficient, with renewable energies local employment
Conversion	Efficient distribution	Intelligent inverter		
Reduction in consumption	Sustainability	Reduced dissipation; intelligent drive controls; smart controls for selective usage	New market for control systems and efficient appliances	Less dependence on energy sources, less costs for energy
Energy management in communities	Efficient management of demand, distribution and supply	Self-organizing grids and multi-modal energy systems	New markets for energy control infrastructure Competitive position of European industry	Elimination of energy waste More efficient with less costs Decentralized services with local employment

Table 3.1 Smart Energy – Need, action and expected results

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 has to address:

1) reduction/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 (by including sensors, SW, and others),
4) increasing market share by introducing (or adopting) disruptive technologies
5) the change to renewable energy sources and decentralized networks
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 (components, modules, CPS for smart energy, service solutions) supporting the EU and national energy targets will have huge impact on the job generation and education if fully further developed in Europe. 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. Mandatory are the capability for plug and play of the components enabling a broad research contribution from SMEs, service providers up to top leaders in the energy domain.

6.3.4 Cross references

The ambition of ever and ever higher efficiency and reduced losses in the use of energy demands new innovations from the integration and process technologies (Part B, e.g. power semiconductors, assembly and package technologies). Since energy use is a dominant factor in all the application areas, innovations in different kind of applications from mobility (e.g. e-mobility) towards manufacturing (e.g. drive controls and introduction of electronic actuators) are cross linked.

References:

1) *COM(2014) 15 final – A policy framework for climate and energy in the period from 2020 to 2030, Brussels January 2014 – 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 – http://ec.europa.eu/clima/policies/2030/docs/climate_energy_priorities_en.pdf*

6.3.5 Schedules/Roadmaps

Smart Energy	**Short term**	**Medium term**	**Long term**
Overall – Embedded in EU strategy	EU targets for 2020 supported (20/20/20) greenhouse gas levels reduced by 20% Increase share of renewables 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 (1)
Energy supply landscape	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

Generation & Conversion	Highest efficient and reliable ECS for all kind of electrical energy generation – de-centralized to large power plants, cross link to processes and materials		
	smart and micro inverter reference architecture with integrated control	new power electronic actuators for DC and AC grids	inverter on a chip or integrated modules
Reduction in consumption	Implementation of smart electronics including system integration with communication interfaces ECS for controlled power/drive trains and illumination	smart electronic components for (MV/LV)DC power supply for buildings and vehicles (e.g. data centres, planes) Distributed DC network	smart electronic components for MVDC grid integration of storage and renewable fully connected ECS for illumination and city energy use
Energy management in communities	monitoring of energy infrastructure and cross domain services (e.g. maintenance, planning) Decreased integration costs in self-organizing grids.	Smart systems enabling optimized heat / cold and el. Power supply ECS support for standalone grids and therefore decreasing demand for “big” power plants.	Smart systems enabling optimized power to fuel and coupling of transport and el. Power sector New energy market design. E.g. self-coordinated energy supply in local grids

Table 3.2 Smart Energy – short to long term application driven targets

6.4 Smart health

6.4.1 Objectives

In order to cope with increasing healthcare costs, mainly related to the aging society, healthcare will evolve towards **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).

6.4.2 Strategy

The necessary innovation in healthcare for each stage of the care cycle will be achieved through corresponding technological improvements, with economic and social impact:

Smart Health	GOAL	ACTION	RESULT	
	Healthcare Innovation	Technical Innovation	Economic Impact	Societal Impact
1 Prevention	Enhanced healthy lifestyle support: food & nutrition, activity levels, mental health	Unobtrusive monitoring; coaching with new interaction mechanisms	New markets for preventative products (> 1 B€)	Longer,healthy lifespan. Reduced healthcare cost
2 Diagnosis	Simple, fast, low-cost, routine early diagnosis	Cheaper, faster, safer and easier-to-use diagnostic equipment; data mining based decision support systems	Minimum interruption of working life; access to emerging markets	Cheap screening of large populations, covering a broader scope of threats; better treatment due to early diagnosis
3 Treatment / Therapy	Fast enabling of minimally-invasive, image-guided intervention; personalized medicine	More advanced imaging and treatment workflows; advanced, smart implants and prosthesis	Strengthened position of EU in therapeutic equipment	Reduced treatment and hospitalization; increased patient independence
4 Aftercare	Assisted rehabilitation support; prompt detection of complications or relapse	Integrated monitoring and support environments though dedicated smart devices	New markets for aftercare products (>> 1 B€)	Increased recovery rates, reduced periods of hospitalization
5 Food Quality Control	Improved monitoring and control of quality in the food chain	Disposable biosensors, sensor nodes, quality algorithms	New markets for food quality products (>> 1 B€)	Improved food quality and reduced food waste

Table 4.1: Goals, actions and targeted results for the stages of the Smart Health care cycle

The necessary innovations in healthcare require applied research (TRL 2-4), validation (TRL 4-6) and prototyping (TRL 6-8). Both development and pilot projects can address these areas.

6.4.3 Impact

As shown in the table above, achieving the set targets will result in increased employment, increased availability of labour, reduced cost of healthcare and its supporting equipment (per treatment and per patient), increased market share in existing markets and access to new markets, enabling a growth rate above a CAGR level of 7%. In addition, the societal impact includes longer healthy living, reduced hospitalization, and personalized on-demand support.

6.4.4 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
3) Smart Energy: autonomous, low-power techniques for both wearable and implantable smart devices, including energy harvesting for autonomous implantables or wearables
4) Smart Manufacturing: certification of medical equipment implies careful manufacturing using affordable and flexible production tools such as 3D printing

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 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 ‘connected’ and will measure multiple physical parameters, secure 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.

6.4.5 Schedules/Roadmaps

The following schedule is envisioned in general:

1) Short term: evolutionary developments according to technology roadmaps
2) Mid-term: innovation in new applications in adjacent markets
3) Long term: technology breakthroughs creating new markets

Smart Health	Short term	Medium term	Long term
1 **Prevention**	Diet support; activity promotion	Unobtrusive monitoring	Interactive applications for more active user involvement
2 **Diagnosis**	Improved components, sensors, imaging solutions and diagnostic algorithms Improved aggregation of data sources	Human friendly modalities, covering a broader scope of threats	Inexpensive modalities
3 **Treatment / Therapy**	Workflow improvement	Advanced imaging and treatment technologies Customized treatment through large data computing	Smart implants and prosthesis
4 **Aftercare**	Improved monitoring devices	Unobtrusive monitoring devices	Virtual doctor
5 **Improved Food Quality**	Innovative packaging and origin tracking	Shelf-life prediction; sensor nodes for cattle	Disposable biosensors

Table 4.2: Roadmaps for the different stages of the Smart Health care cycle

<table>
<tr><th>1</th><th>Home care and well-being</th><th>2015</th><th>2016</th><th>2017</th><th>2018</th><th>2019</th><th>2020</th></tr>
<tr><td>1.1</td><td>Disease prevention, promotion of healthier life-style and remote coaching</td><td colspan="2">RIA</td><td colspan="3">RIA,IA</td><td>IA</td></tr>
<tr><td>1.2</td><td>Remote health monitoring and support (e.g. for the elderly)</td><td colspan="3">RIA</td><td>RIA,IA</td><td colspan="2">IA</td></tr>
<tr><td>1.3</td><td>Remote disease management</td><td colspan="2">RIA</td><td colspan="3">RIA,IA</td><td>IA</td></tr>
<tr><td>1.4</td><td>Advanced tele-rehabilitation services (e.g. with portable robotics)</td><td colspan="2">RIA</td><td colspan="2">RIA,IA</td><td colspan="2">IA</td></tr>
<tr><td>1.5</td><td>Technological cross-application advances</td><td colspan="2">RIA</td><td colspan="2">RIA,IA</td><td colspan="2">IA</td></tr>
<tr><th>2</th><th>Hospital and heuristic care</th><th>2015</th><th>2016</th><th>2017</th><th>2018</th><th>2019</th><th>2020</th></tr>
<tr><td>2.1</td><td>Advanced imaging based diagnosis and treatment</td><td colspan="4">RIA,IA</td><td colspan="2">IA</td></tr>
<tr><td>2.2</td><td>Screening for diseases</td><td colspan="2">RIA</td><td colspan="2">RIA,IA</td><td colspan="2">IA</td></tr>
<tr><td>2.3</td><td>Intelligent data management</td><td colspan="3">RIA</td><td colspan="2">RIA,IA</td><td>IA</td></tr>
<tr><td>2.4</td><td>Personalised medicine</td><td colspan="4">RIA</td><td>RIA,IA</td><td>IA</td></tr>
<tr><td>2.5</td><td>Intervention / therapy</td><td colspan="4">RIA,IA</td><td colspan="2">IA</td></tr>
<tr><td>2.6</td><td>Smart environments, devices and materials</td><td colspan="2">RIA</td><td colspan="2">RIA,IA</td><td colspan="2">IA</td></tr>
<tr><td>2.7</td><td>Remote diagnosis and monitoring / support</td><td colspan="3">RIA</td><td colspan="2">RIA,IA</td><td>IA</td></tr>
<tr><th>3</th><th>Food processing and safety</th><th>2015</th><th>2016</th><th>2017</th><th>2018</th><th>2019</th><th>2020</th></tr>
<tr><td>3.1</td><td>General food processing</td><td colspan="4">RIA,IA</td><td colspan="2">IA</td></tr>
<tr><td>3.2</td><td>Food production</td><td colspan="2">RIA</td><td colspan="3">RIA,IA</td><td>IA</td></tr>
<tr><td>3.3</td><td>Food distribution</td><td colspan="3">RIA</td><td colspan="2">RIA,IA</td><td>IA</td></tr>
<tr><td>3.4</td><td>Food retail</td><td colspan="2">RIA</td><td colspan="3">RIA,IA</td><td>IA</td></tr>
<tr><td>3.5</td><td>Food processing</td><td colspan="3">RIA</td><td>RIA,IA</td><td colspan="2">IA</td></tr>
<tr><td>3.6</td><td>Food preparation</td><td colspan="2">RIA</td><td colspan="3">RIA,IA</td><td>IA</td></tr>
</table>

Table 4.3: Detailed roadmap of key Smart Health innovations (ref. Annex A.4)
Transitions in TRL may shift due to market dynamics

6.5 Smart Production

The Application Area is industrial production in general, for which the ECSEL community offers electronic components and systems to realise smart production; this would even apply to production sectors in which automation is yet hardly present.

Smart production relates to manufacturing and process automation and new manufacturing and process technologies enabled by advanced electronics systems. Industrial production in general is addressed in section 5.1. As part of the ECSEL community is active in manufacturing themselves, the manufacturing of semiconductors is singled out and addressed separately in section 5.2.

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

6.5.1 Smart, sustainable and integrated production

6.5.1.1 Objectives

Industrial production faces strong competition from the rest of the world. The further development of the European leadership in automation is key to increase European competitiveness in production. Thus, world leading automation and disruptive production technologies enabled by innovative electronics systems and their embedded software form a cornerstone for the re-industrialisation of Europe. Leading European producers are requesting improvements regarding availability, flexibility and controllability in integrated, security and safe production systems, for supporting their ambitions on overall equipment efficiency (OEE), energy efficiency, raw material yield, flexible and sustainable production.

6.5.1.2 Strategy

“Smart Sustainable and Integrated Production” will focus on capabilities for automation and smart production system integration in the domains of technologies, tools and methodologies for system integration of smart device capabilities such as sensing, communication, knowledge management, decision-making, control, actuation, resulting in smart maintenance and smart production execution.

The strategic approach is:

- Improved production system integration along the three production axes, life cycle, value chain, and enterprise. Thus enabling and improving availability, flexibility and controllability.
- Large integrated R&D&I projects supporting life cycle optimisation, value chain integration and enterprise efficiency and flexibility.
- Enabling of collaborative automation environments comprising both man and technology while maintaining security and safety
- Enabling of large systems featuring distributed 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

The TRL level for the electronics systems and their embedded software to be addressed is low to mid-range.

6.5.1.3 Impact and expected major achievements

The large integrated R&D&I project 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.

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. This will enable the production in Europe of next generation of consumer and professional products.

6.5.1.4 Cross references

The strategy relies on incorporation of new technology within the domain of electronic components and systems. 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. Critical success factors will be robustness to industrial production environments, interoperability, validation and standardisation.

6.5.1.5 Schedules/Roadmaps

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

Mid-term innovations are industrially proven production automation systems with integrated smart cyber physical system. This included 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 the Germany initiative *Industrie 4.0* [3] gives important direction on the development of smart manufacturing based on simulation, visualisation, big-data and analytics.

The top level needs for smarter production are:

- Competence management
- 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.

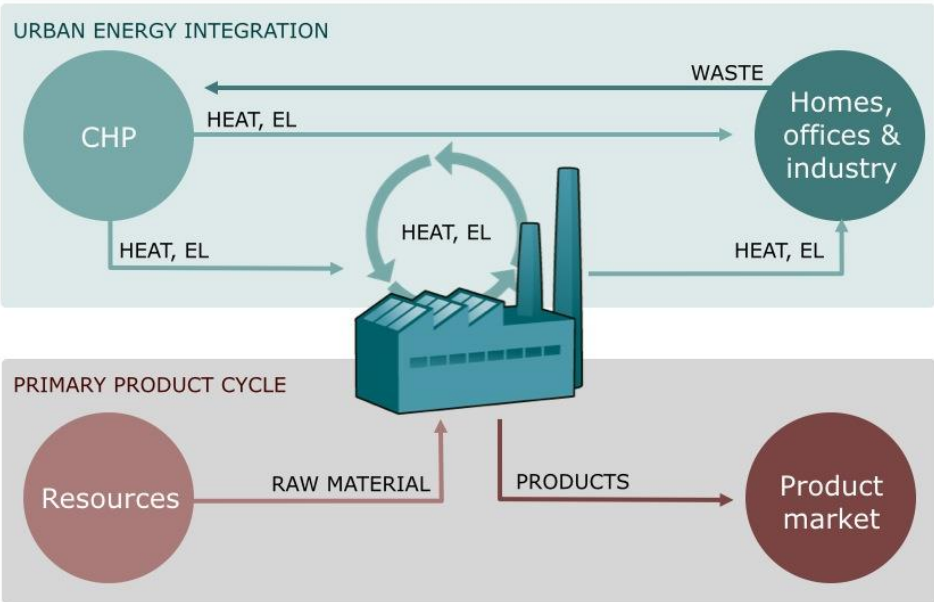


Figure: Collaborative Automation is key strategy and enabler for reaching top level need like sustainable production, improved OEE and competence management.

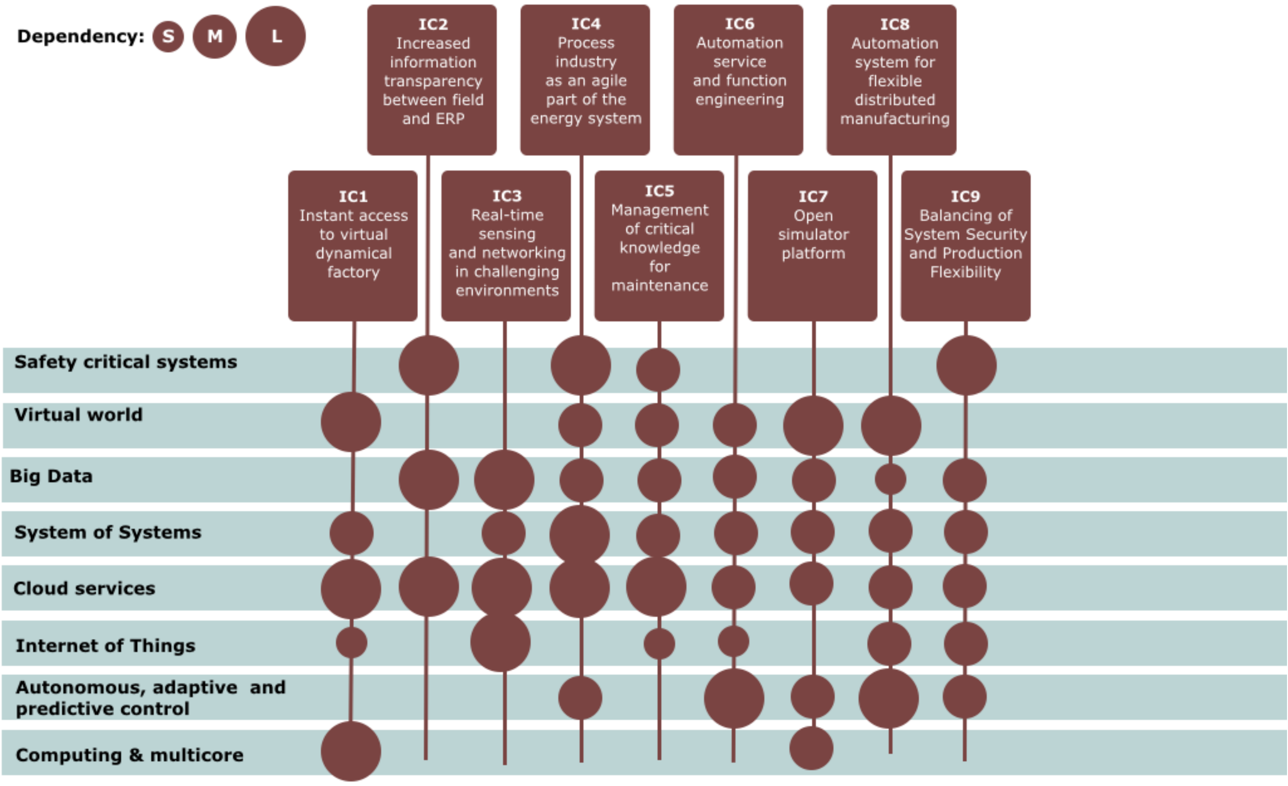
Technologies to realise such collaborative automation are e.g. IoT, cloud service, virtual world, big data, system of systems, autonomous, adaptive and predictive control, computing (multicore), mobility, connectivity, complex event processing, real-time data analysis, and forecasting of complex scenarios.

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

1) Instant access to a Virtual dynamic factory.
2) Increased Information transparency between field devices and ERP.
3) Real-time sensing & networking in challenging Environments.

4) Process Industry as an agile part of the Energy system.
5) Management of critical Knowledge to support maintenance decision making.
6) Automation service and function development process.
7) Open simulator platform.
8) Automation system for distributed manufacturing.
9) Balancing of system security and production flexibility.

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



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

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.

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.												

6.5.2 Semiconductor Manufacturing

6.5.2.1 Objectives

Semiconductor manufacturing in Europe is indispensable for meeting the societal challenges described above. In the future, even more focus is required for supplying Europe's electronic systems manufacturers with electronic devices "Made in Europe". Not only is a significant quantitative increase of device manufacturing and respective market share needed. Future activities will specifically have to evolve into new business opportunities resulting from the multidisciplinary domains. Important will be to meet the specific needs of the European industry.

6.5.2.2 Strategy

A key demand for reaching these objectives is mastering cost competitive semiconductor manufacturing in Europe including packaging and assembly. Goal is to develop new wafer fab management solutions and business models that enable a high degree of manufacturing flexibility and cost competency, support resource saving, energy-efficiency improvement and sustainability, and "green" manufacturing without loss of productivity, cycle time, quality or yield performance at reduced production costs. Investing in personnel skills and competencies will also be of key importance.

New manufacturing approaches will have to address More Moore and More-than-Moore related challenges. More Moore manufacturing will especially require innovative solutions to control the variability and reproducibility of leading-edge processes. This will require in particular: Predictive Maintenance, Virtual Metrology, Factory simulation and scheduling. In addition attention should be given to Control System Architecture: predictive yield modelling, holistic risk mastering (integrate control methods and tools).

The focus of More-than-Moore manufacturing will be on flexible line management for high mix, and distributed manufacturing lines. It will also require adapting factory integration and control systems to move from the current monolithic approach to the "Apps" world.

6.5.2.3 Impact

The expected impact of future ECSEL projects belonging to this category of actions is to ensure that we'll continue serving at best electronics markets in which Europe already holds strong global industrial positions - for example, security, automotive, aircraft manufacturing, power generation and medical/healthcare industries. Maintaining a high level of excellence in manufacturing science and efficiency of our fabs is therefore of paramount importance in keeping competitive semiconductor manufacturing in Europe, despite the strong pressure this industry suffers from external competitors from Asia and the USA. In addition, ensuring the continuation of competitive More Moore and More than Moore manufacturing in Europe will significantly contribute to safeguard our strategic independence in domains where it is highly detrimental to rely on external sources (such as security), and will also secure tens of thousands of jobs directly or indirectly (process equipment, clean room design and maintenance, materials,…) linked to the semiconductor manufacturing.

6.5.2.4 Cross-references

The successful execution of projects in the domain of semiconductor manufacturing is obviously strongly related to the delivery of other ECSEL projects in the Essential capabilities category, the first being Process technology, Equipment and Materials.

Semiconductor manufacturing science projects will especially have to prepare the needed evolution of the European manufacturing lines to process in time and in a competitive way, the future More Moore technology nodes and More than Moore new process differentiations (according to 1.5 roadmaps).

A strong link will also be required with Design Technologies to master the increasing process-design interdependency and with Smart Systems Integration that will require new developments to efficiently support the virtual fab concepts.

On the other hand, process and characterization equipment will have to be ready for seamless introduction in upgraded production lines with state of the art communication and control features.

The projects will also have strong influences on downstream projects in Key Applications for 'Smart everything', if they are able to deliver timely and competitive solutions for the manufacturing of the chips necessitated by these applications.

In addition, attention should also be given to avoid a potential "lack of talents" or rather a lack (in general) of university education in close collaboration with the industry universe. ECSEL offers a very suitable opportunity to increase our European potential in this field, for example by means of joined (Academia and Industry) courses.

6.5.2.5 Schedules/Roadmaps

Fundamentals of 'manufacturing science' to address in particular: fab data analysis, yield management, advanced and quality process control, software solutions for virtual metrology, predictive maintenance and flexible manufacturing strategies, 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) such as: new factory information and control systems, faster diagnostics and decision making processes, variable lot size manufacturing, manufacturing robustness and fab automation robotics. Due to the present state-of-the-art, a balance in work on low and high TRL categories should be sought, though an emphasis on the higher TRLs (e.g. with a roughly 40-60 ratio) is considered strategically important in order to reinforce/increase the release of mature products/solutions (with new/integrated features) in Europe.

Finally, in terms of timing execution, one can consider that for most of the Manufacturing Science projects, the execution will be spread along medium to long term time span, while short term issues have to be covered e.g. for the uptime of equipment in the European clean rooms (thanks to predictive maintenance improvement) or the robustness of the manufacturing processes (to maximise yields) as means to react to the lower prices offered by Asian silicon foundries.

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

7 Strategic thrusts - Part B: Essential technologies

7.1 Semiconductor Process, Equipment, and Materials

7.1.1 Objectives

Reinforce European manufacturing position by gaining leadership in processing know-how for advanced and beyond CMOS (More Moore, MM), heterogeneous (More than Moore, MtM) and System in Package (SiP) technology. Support the complete European value chain in process technology, materials and manufacturing equipment to realize advanced next generation devices as innovative products aligned with the application roadmaps of Part A. Establish pilot lines in MM and MtM and supporting test beds to accelerate the uptake of KETs covering all essential aspects for short time-to-market (cost-efficiency, standards, test, etc.) in front and back-end wafer processing, device packaging and assembly. Boost competitiveness of long-term manufacturing industry and the whole supply chain and increase attractiveness for private investment and talent with the goal to keep skilled jobs in Europe.

7.1.2 Strategy

ECSEL projects promote the involvement of all actors in the value chain of process technology, materials and manufacturing equipment industry, with application specific partners or cross links to application specific projects. Two main types of projects are envisaged. To sustain a leading edge in view of future long-term competitiveness well focused RIA in the TRL 2 to 4 are needed as technology push enabling new applications. A second type are extended projects that 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. ECSEL projects will present leading edge activities on highly advanced materials and process modules, manufacturing equipment and processing capabilities at the industry-relevant wafer sizes for MM, MtM and SiP domains. They will drive the realization of industry roadmaps in MM – extending to nodes N1x and Nx and beyond CMOS - and MtM and SiP - including amongst others power electronics, III-V, photonics and sensor systems, interlinked with key application challenges. The relevant approximate timelines are in Table B1.1, where the Grand Challenges for Equipment and Materials and for Process Technology are listed.

7.1.3 Impact: What will be the impact, if the targets are achieved?

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. The impact of ECSEL is to help double the economic value of the semiconductor production in Europe by 2020-2025[15]. The overall value chain of equipment, materials, system integration, applications and services employs over 2,500,000 people in Europe. By launching new process technologies based on innovative materials, designs and concepts into pilot-lines, ECSEL projects will facilitate a strongly growing market share, increased employment and investments for innovative

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

equipment, materials and for manufacturing of semiconductor devices and systems through European leadership positions in MM, MtM and SiP.

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. ECSEL projects on semiconductor process, equipment and materials will be in synergy and coordination with other key enabling technologies (B) and the schedules of application roadmaps (A).

Table B1.1 links the application roadmap needs to the timeline for semiconductor process, Equipment and Materials. The TRL4 milestone target for application drivers indicated in the table will be synchronized with the set-up of the pilot lines in their key enabling technology platforms throughout the ECSEL projects to enable the European industry to take the lead in various challenging multidisciplinary application domains.

7.1.5 Schedules/Roadmaps

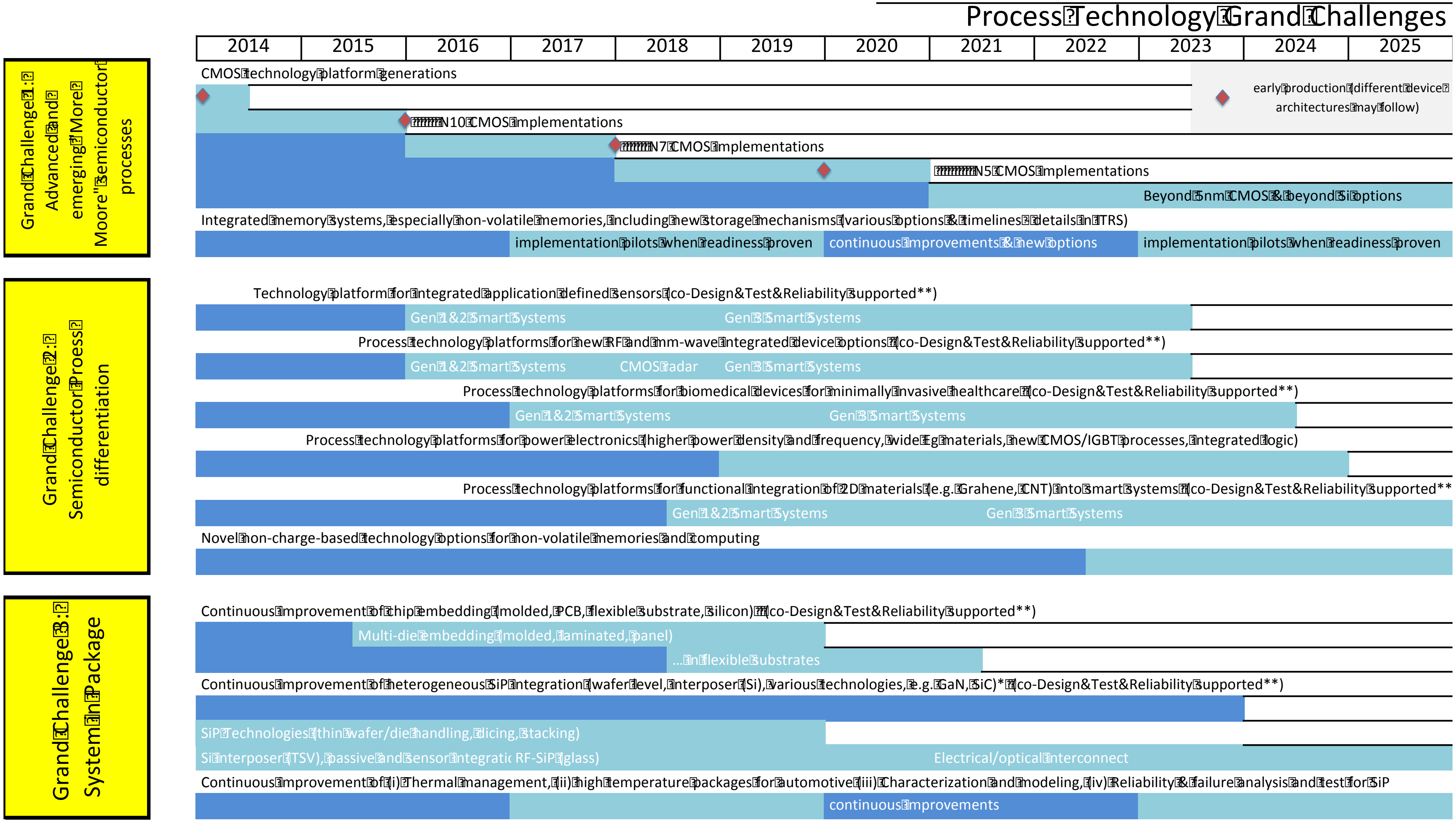
All leading European industry and research actors align their activities with international roadmaps and timelines like the ITRS, ENI2, Catrene, etc.[16]. The 'Action Tracks' recently proposed by the Electronic Leaders Group[17] have goals in the timeframe 2014-2020 of which *Demand Accelerators* (track1) 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*. 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.

---

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

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

Equipment and Materials Grand Challenges



Process Technology Grand Challenges
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
Grand Challenge 1: Advanced and emerging "More Moore" semiconductor processes
CMOS technology platform generations
early production (different device architectures may follow)
N10 CMOS implementations
N7 CMOS implementations
N5 CMOS implementations
Beyond 5nm CMOS & beyond Si options
Integrated memory systems, especially non-volatile memories, including new storage mechanisms (various options & timelines details in TRS)
implementation pilots when readiness proven
continuous improvements & new options
implementation pilots when readiness proven
Grand Challenge 2: Semiconductor Process differentiation
Technology platform for integrated application defined sensors (co-Design&Test&Reliability supported**)
Gen 1&2 Smart Systems
Gen 3 Smart Systems
Process technology platforms for new RF and mm-wave integrated device options (co-Design&Test&Reliability supported**)
Gen 1&2 Smart Systems
CMOS radar
Gen 3 Smart Systems
Process technology platforms for biomedical devices for minimally invasive healthcare (co-Design&Test&Reliability supported**)
Gen 1&2 Smart Systems
Gen 3 Smart Systems
Process technology platforms for power electronics (higher power density and frequency, wide Eg materials, new CMOS/IGBT processes, integrated logic)
Process technology platforms for functional integration of 2D materials (e.g. Grahene, CNT) into smart systems (co-Design&Test&Reliability supported**
Gen 1&2 Smart Systems
Gen 3 Smart Systems
Novel non-charge-based technology options for non-volatile memories and computing
Grand Challenge 3: System in Package
Continuous improvement of chip embedding (molded, PCB, flexible substrate, silicon) (co-Design&Test&Reliability supported**)
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)* (co-Design&Test&Reliability supported**)
SiP Technologies (thin wafer/die handling, dicing, stacking)
Si interposer (TSV), passive and sensor integratic RF-SiP (glass)
Electrical/optical interconnect
Continuous improvement of (i) Thermal management, (ii) high temperature packages for automotive (iii) Characterization and modeling, (iv) Reliability & failure analysis and test for SiP
continuous improvements

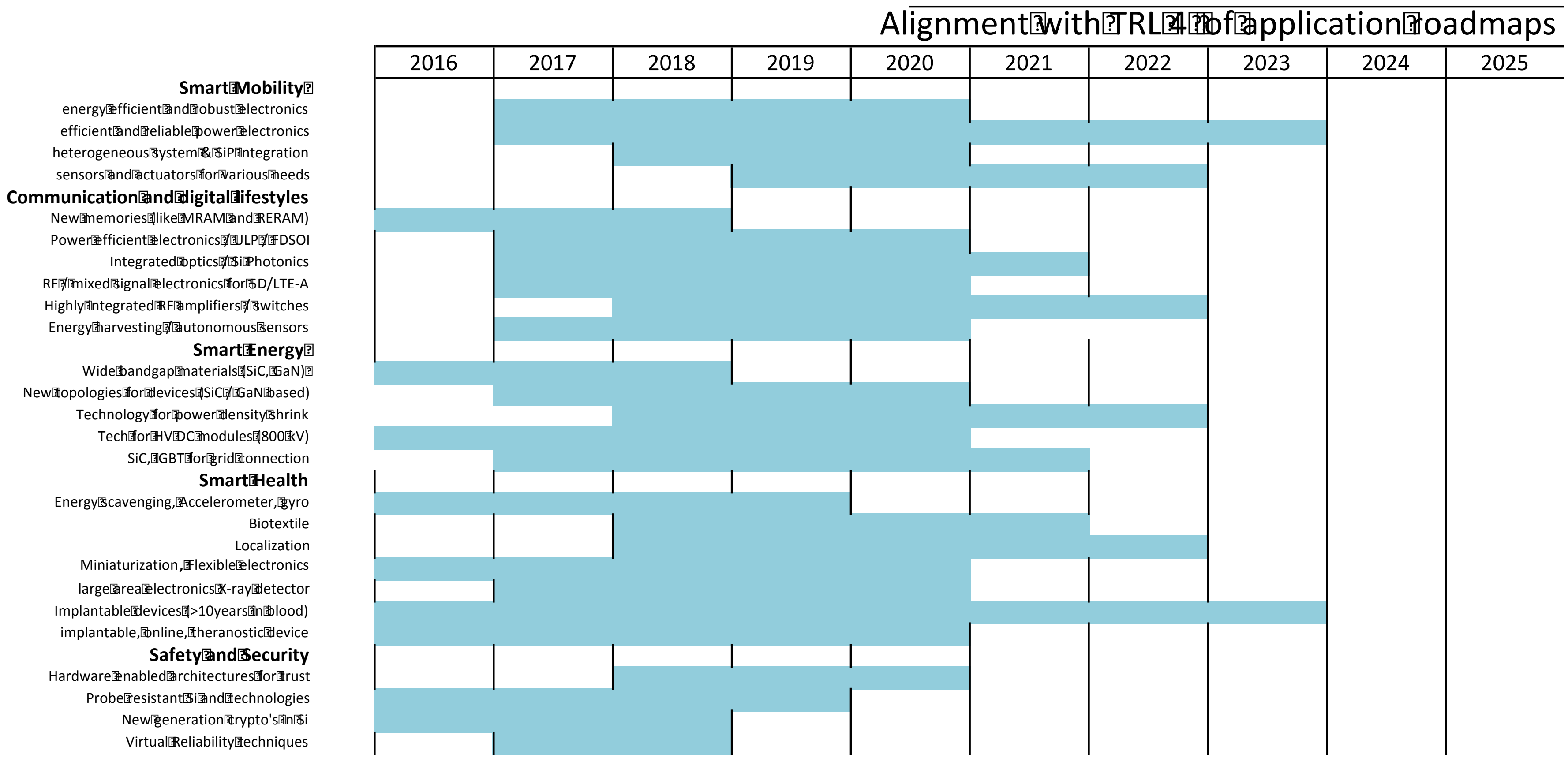


Table B1.1 Top: Grand Challenges and their activity roadmaps.

The transitions to TRL 4 and above may shift due to market dynamics and for most of the listed items continued innovation will be sought even for maturing technologies. Below selected major application drivers enabled by Semiconductor Process, Equipment and Materials. Colour indicates the TRL 4 - 6 stage of the development. (*) depending on industry decision on when to move to 450mm; (**) aligned with Design technologies roadmaps

7.2 Design technology

7.2.1 Objectives

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

Design methods and technologies must ensure the link between the ever-increasing technology push and the demand for innovative new products and services of ever-increasing complexity that are needed to fulfil societal needs. Design methods and technologies enable the specification, concept engineering, architectural exploration, implementation, and verification of Electronic Components and Systems[18] (ECS). The design process embraces use cases, design flows, tools, libraries, IPs, process characteristics and methodologies. It involves hardware and software components, including their interaction and the interaction with the environment.

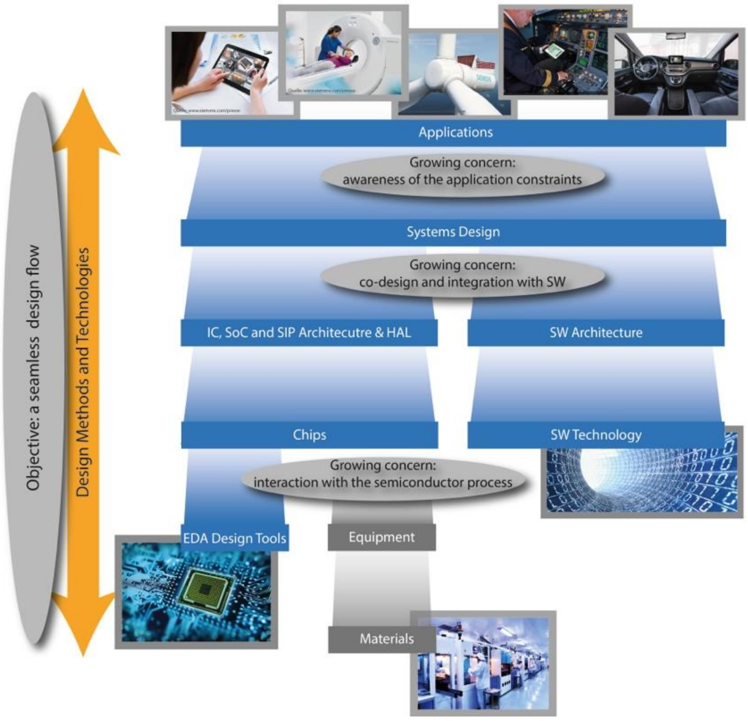


Figure 2.1: Design methods and technologies cover the entire value chain, from semiconductor materials and processes to chip level and systems including the development of applications / platforms.

---

[18] 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, ECSEL itself 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
2) Managing complexity, safety and security
3) Managing diversity
4) Increasing yield, robustness and reliability, and generate system openness

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 taking these challenges will lead to:

1) On system level, increase of complexity handling by 100% with 20% design effort reduction while improving product and service quality.
2) Reduced cost and cycle time of product/system design of up to 50%.
3) Significant improvement of design and development efficiency as well as validation speed
4) Re-use of existing results (being already qualified before) and certification evidence, leading to significant reduction of iterations and reduced cost for product and service configuration.
5) Improved reliability and robustness especially for long-term deployed safety critical systems.
6) Ability to manage openness of Cyber-Physical Systems, i.e. provide design methods and tools to cope with the switch from single design process owner systems to larger open systems which communicate with each other, employ the internet, and are produced by multiple companies; Extend design methods and tools to meet requirements to real-time, high availability and safety even in such open systems.
7) Highly efficient ECS platforms offering advanced safety and security mechanisms.
8) Share of knowledge and push for standards to ensure efficient interoperability in the full supply chain.
9) Ability to cover new devices and their behaviour, from physical effects and behaviour via intermediate levels (such as e.g.," AUTOSAR Block level descriptions") to system level behaviour.
10) Seamless Design and Development Process with interoperable tools and processes throughout the entire product development and life cycle; full traceability, improved logistic support leading to extended product life cycle
11) Raised development quality especially for complex heterogeneous systems
    i) Reduced development risk and automated documentation.
12) Improve exchange between multidisciplinary teams, access to common documents, reuse of results, continuous functional safety check
13) Larger market share, higher competitiveness and increase of employment in Europe.

In the end, it will enable the development of systems and products which are several times more complex than the current ones and that are needed to solve societal problems without increasing development cost.

7.2.4 Cross references to other chapters

The design technologies provide the tools and methods allowing the design of the products 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 Processes, Equipment and Materials considering that the design yield and robustness will be based on their inputs.

7.2.5 Schedules and Roadmaps

Seamless and efficient model-based development processes (Design Eco System) addressing:

Short Term: virtual prototyping, simulation speed; SW development tools and debug environments for verification and validation for the HW and SW architectures and the applications developed in ECSEL; constraint-driven, easy integration of SW, analog/RF, power devices, sensors, actuators and MEMS at system and component levels; specification models at different abstraction and feature levels supporting functional and non-functional parameters (time, power, temperature,…); safety and security, supporting incremental certification; modelling of heterogeneous systems, starting from higher abstraction levels, extended verification and validation (including coverage); multi-dimensional optimisations; interoperability standards; HW/SW sign-off for reliability and robustness; ultra-low power design, efficient software for low-power-systems; monitoring, prediction and diagnosis methods; yield loss and test escape measure methods; design methods and tools to meet requirements to real-time, high availability and safety of open systems

Mid Term: integrated physical-logical simulation; integration of non-digital domain; connection between virtual and physical world; seamless interoperable modelling of functional units; design Eco-System based on standards; common methodology for functional and non-functional properties (time, power, temperature,…) for system integration, validation, and virtual prototyping; consistent links between HW and SW design; 3D-Design; consistent and complete co-design incl. mechatronics; efficient methodologies for reliability and test in highly complex systems including modelling and analysis, considering variability and degradation effects; ultra-low power design with energy scavenging capabilities; normalization for testability and diagnosis efficiency metrics; design methods and tools to meet requirements to real-time, high availability and safety of open systems; monitoring of open systems; update and evolution strategies for open systems, including self-learning and adaptation

Long Term: human aspects; life-cycle management; verification and validation for complex CPS; model-based engineering test methodologies for complex systems in rapidly changing environments; integration of environment modelling; complete tool-chains; support for long term archiving needs, standards, and back traceability management; automated transfer of system level design into functional blocks; reuse by component-based and product line designs; improve productivity of platform integrator; Eco-System extended to heterogeneous components and reliability, yield and robustness; manage various constraints (electrical, thermal, mechanical, etc.) over the whole design flow;; incorporating the notion of time in the code; ultra-low power design considering low power autarkic systems, extremely long battery power lifetime, and the process covering power supply; design for safety; handling mixed criticality; design of error robust circuits and systems; automated tools for testability metrics in particular for measuring yield loss and test escape; monitoring techniques for open systems; update and evolution strategies, including self-learning and adaptation.

More details are given in the appendix.

Aggregated Roadmap:

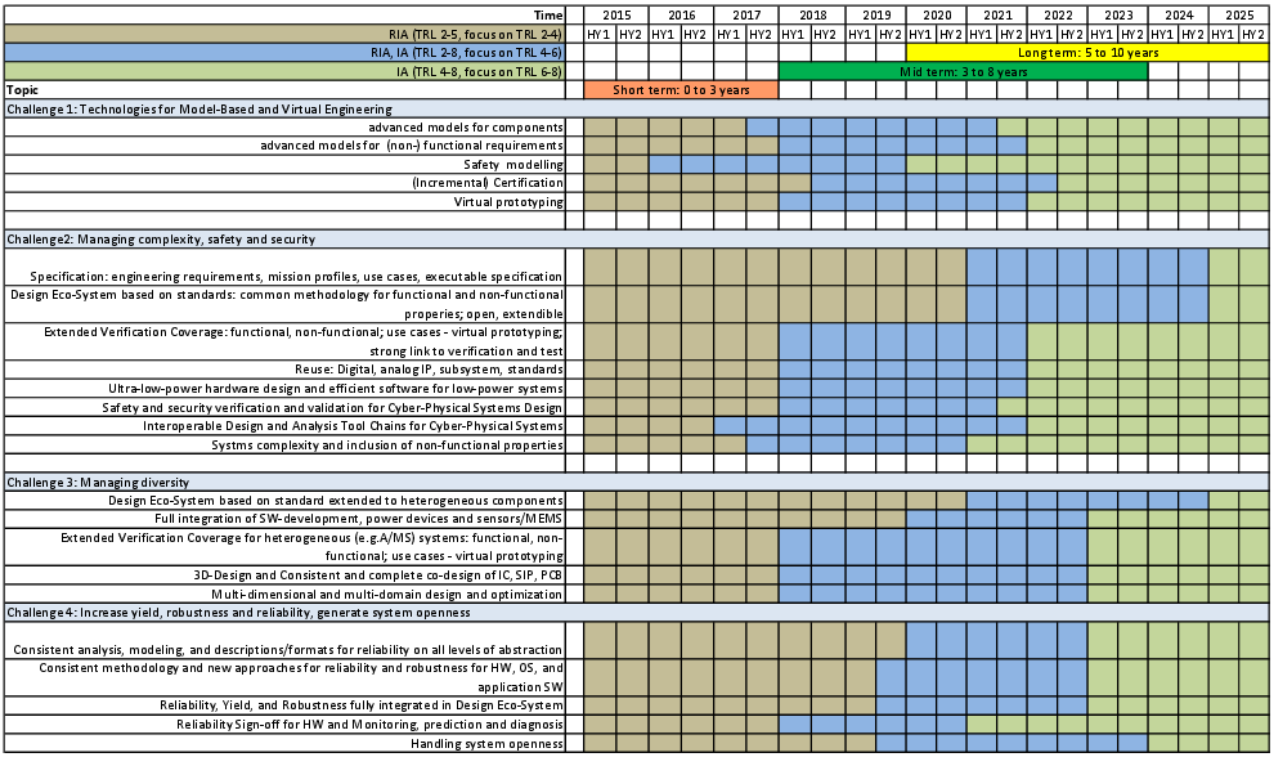


Figure 2.2: Roadmap for Design Methods and Technology topics.

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.

7.3.1 The Objectives

Cyber-Physical Systems (CPS) are embedded intelligent ICT systems that are interconnected, interdependent, collaborative, and autonomous. They provide computing and communication, monitoring/control of physical components/processes in various applications. Future CPS need to be scalable, distributed, decentralized allowing interaction with humans, environment and machines while being connected to Internet or to other networks. Adaptability, reactivity, optimality and security are features to be embedded in such systems, as the CPS are now forming an invisible 'neural network' of the society. It leverages the exploitation of cloud computing and Internet of Things (IoT) capabilities in embedded system's context. CPS focus additionally on the various system functions including smart systems integration and system of systems convergence.

The main R&D&I objective is to strengthen European stakeholders leadership by securing complementarity, computation, connectivity, interoperability, and standardization of hardware/software, by stimulating innovation, maintaining and expanding a strong research, design, technology development and manufacturing base while:

1) Increasing the competitiveness in the field of CPS technology through R&D investments in Europe in order to overcome its fragmentation and take advantage of the new CPS paradigm to gain a worldwide leadership.
2) Capitalizing on the impact of the ever growing 'Internet Economy', and the rise of the 'Embedded Industrial Internet', where human and machines increasingly interact to provide new services and solutions
3) Taking advantage of the strong demand of the 'Always Connected Society' to utilize new powerful software and communication intensive systems by the integration of information systems infrastructures, services, big data analytics and possibilities for global optimisations
4) Providing safe and secured solutions ensuring to the user a high level of trust, confidence and privacy.
5) Supporting the integration of cyber-physical and other applications on common HW/SW and communication platforms, as needed in complex systems in key application areas.

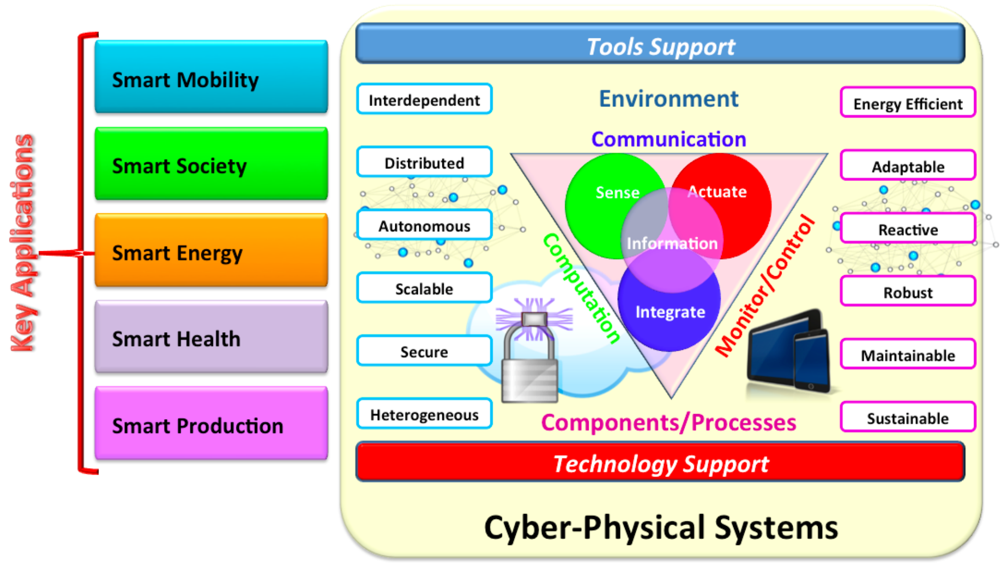


Figure 1: Key elements of Cyber-Physical Systems (CPS).

7.3.2 The Strategic approach for CPS is:

The strategic approach to reach the above mentioned goals is to:

1) Develop CPS global reference architectures that include interoperability, composability, scalability, **safety**, **security**, robustness, (self-) diagnosis integration and maintenance. Standardization will play an important role in interoperability and practical acceptance.

2) Provide computing platforms and develop reliable, secure and trustable HW/SW, able to cope with user needs and real world requirements such as hard real time constraints, energy awareness, dynamic reconfiguration, reliability, safety and security.
3) Create Knowledge through development of new designs, Verification & Validation & Testing (V&V&T), methods and tools for CPS design integration and deployment, based on technology market roadmaps in multiple time-scales and for various application domains, particularly for the safety-critical high reliability and real-time secure applications.
4) Expand the technology developments to address societal challenges through applications platforms and innovation ecosystems in smart cities, grids, buildings/homes, mobility and transport, healthcare and ambient assisted living, agriculture, and water treatment by addressing technological needs across these sectors and favouring the cross-fertilization and consolidation of R&I&D investments from mass market to safety critical systems.
5) Address and solve the ethical issues, the trust of the user on confidential handling as well as respect for property and financial value of the data, in order to accelerate the deployment and the social acceptance of CPS.

The proposed development of Cyber-Physical systems is structured along three strategic axes:

1) **Architectures** principles and models for safe and secure CPS: to define and develop global interoperable, distributed and certifiable CPS architectures,
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,
3) **Computing Platforms including hardware, software and communication** to address the challenges **energy efficiency**, security, complexity, reliability, and safety of the multiple and various computing systems (from deeply embedded sensor/actuator to mobile, industrial, embedded control, server, data centre, and HPC systems).

7.3.2.1 Architectures principles and models for safe and secure 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, cross-domain generic platforms for embedded systems is a technological and economic necessity. These frameworks need to be supported by a pool of **industry standards and best practice documents** to further stimulate the ubiquitous mass adaption in various markets. Key challenges are:

1) **“Virtual verticality”:** Interoperability, scalability, variability management, each system being a brick for a larger system (and this possibly recursively).
2) **Systems of systems methodology**. Due to the complexity of CPS, and of all the inter-relations between sub-systems, new engineering methods are required to master increasing complexity including monitoring and diagnostics in CPS. 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.
3) **Reference Architectures** for safe and secure CPSs: multi-domain reference architectures will provide the technical ground to ensure coherence between CPS systems and their components. It is therefore necessary to develop architecture principles, programming paradigms and tools, reference architectures including hardware, software and communication, integration platforms, design patterns, component-based architectures and

code generation, HW/SW co-design, to target a variety of application domains. This should cover computing together with communication and security in local and in open systems.

4) **Providing safety and security and enabling certification** (e.g., ISO26262 in automotive) in highly complex and non-deterministic environments, to enable the validation and certification of mixed critical systems at an affordable cost, through specification, design, programming,, tests and deployment. Exploring the usage of formal methods throughout the lifecycle. Ensuring a complete secure end-to-end protection of the data and programs, during computation and communication for enforcing more security and privacy even in open systems.
5) Development and implementation of ethical principles for CPS systems, to ensure societal acceptance of CPS.

7.3.2.2 CPS for autonomy and cooperation

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 competitive approaches (Bayesian, Neural Networks …) with traditional ones for natural data analysis. Assessing application-specific robustness using appropriate V&V&T methods.
2) **Evolving, continuously adapting systems through learning and adaptive behaviour** possibly inspired from biological systems (e.g. morphogenetic behaviour, digital tectonics, etc.). Designing systems able to adapt to changing environments and learn to understand and cope with complex situations in a safe and secure way. This includes both the application and the underlying hardware, software, and communication platforms.
3) **Optimal control using autonomous CPS:** Efficient use of resources (power, computing, communication, development efforts and resources), optimization of global application 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.
4) **Reliable and trustable decision making and planning** for safety-related autonomous CPS/SoS that provide stability, safety, security in dynamically evolving system-of-systems, enable V&V&T in reasonable time and cost. Supporting the interconnection of deterministic systems to highly non-deterministic and dynamically changing environments. Detecting and tolerating unreliable constituent subsystems in an 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 interact and cooperate with humans as well as other CPS.

7.3.2.3 Computing platforms

Cyber-Physical systems encompass a large range of computing devices and must integrate innovations in order to manage energy, data access and storage, application deployment, reliability and security of the data and processes. These developments will allow the seamless integration of the Internet of Things (IoT) concept with applications to Internet of Energy (IoE), Internet of Buildings (IoB) and Internet of Vehicles (IoV). The key challenges are:

1) **Energy efficiency, by all possible means:** avoiding unnecessary data communications, pushing for new innovative architectures, holistic optimization. New silicon technologies, photonics, adaptive voltage and frequency control, 3D interconnect, energy aware operating systems and middleware, data placement, application development and so on will required to harmoniously cooperate in order to further increase energy efficiency.
2) **Ensuring Quality of the Service (QoS)** including real-time is a major challenge that worsens with the emergence of multi-core systems. Solution covers real heterogeneous parallel processor, new (memory) architectures, the development of parallel programming languages and design methods, as well as software architectures and setting up respective education. Techniques continuously monitoring the performance of the CPS systems should be designed in order to assess the reliability of the system. 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 such as the use of silicon or organic interposers to integrate heterogeneous devices (various dies of various functions made of possibly different technologies) on the same substrate.

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 competeviness. 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, grid, manufacturing) through development and deployment of 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 technology.
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 market share.

7.3.4 Cross references

Societal Challenges are the key drivers for innovation for CPS, being products or services. CPS technology has an impact on all application contexts of ECSEL: autonomous and safe mobility, wellbeing and health, sustainable production[19] and smart manufacturing, smart communities and

[19] 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)

society, smart energy management, smart homes/buildings. It also leverages the 3 other essential capabilities: Process Technology to deliver the most efficient compute and communication elements, Design Technologies and Smart System Integration.

7.3.5 Schedules/Roadmaps

1	Architectures Principles and Models for Safe and Secure CPS	**Short term**	**Mid term**	**Long term**
1.1	"Virtual verticality"	RIA	RIA	IA
1.2	Systems of systems methodology	RIA	IA	IA
1.3	Reference Architectures (HW, SW, communication)	RIA	RIA, IA	IA
1.4	Providing safety and security and enabling certification	RIA	RIA	IA
1.5	Developing ethical principles for CPS systems	RIA	RIA	IA
2	Autonomous, adaptive and cooperative CPS	**Short term**	**Mid term**	**Long term**
2.1	Safe and robust environmental perception of environment	RIA	RIA	RIA, IA
2.2	Evolving, continuously adapting systems through learning and adaptive behaviour of application and platform	RIA	RIA, IA	IA
2.3	Optimal control using autonomous CPS	RIA	RIA	RIA, IA
2.4	Reliable and trustable decision making and planning	RIA	RIA, IA	IA
2.5	Cooperation	RIA	RIA, IA	RIA, IA
3	Computing Platforms	**Short term**	**Mid term**	**Long term**
3.1	Energy efficiency	RIA	RIA, IA	RIA, IA
3.2	Ensuring Quality of the Service (QoS)	RIA	RIA, IA	IA
3.3	Decreasing global cost	RIA	IA	IA

7.4 Smart systems integration

Although Smart Systems Integration, as contributing to complete systems, is always performed towards specific applications, many technological topics and issues in these systems are generic (application independent) and as such, Smart Systems Integration can be regarded as an enabling technology.

7.4.1 Objectives

The objective of the proposed R&D&I activities is to consolidate and extend the world leadership of European Smart Systems companies and to provide, by Smart Systems, the necessary functionalities in order to maintain and to improve competitiveness of European industry in the application domains of ECSEL.

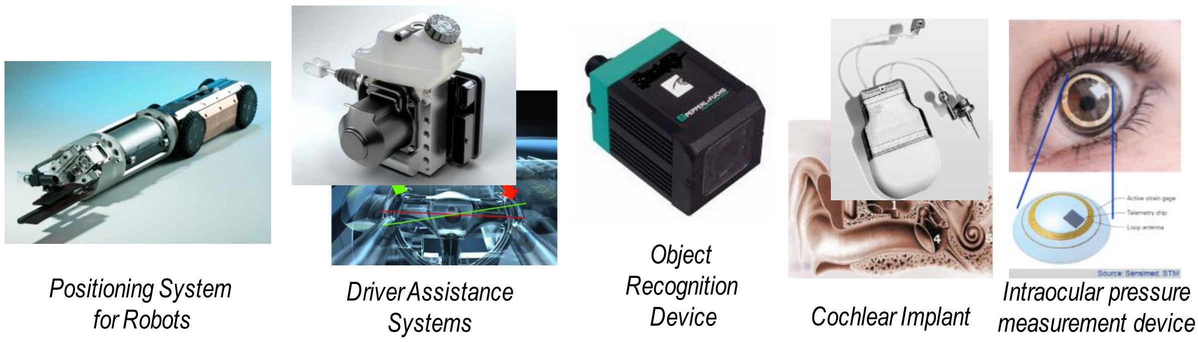


Figure 1 Examples of existing Smart Systems

Smart Systems are defined as (multi-)sensor and actuator based devices that are capable of describing, diagnosing and qualifying a given complex situation, to make predictions, to come to decisions and to take actions. They are networked, autonomous and as small as required by the application. *Smart Systems Integration* (SSI) addresses the system itself, enabled by heterogeneous (3D) integration of new building blocks for sensing, data processing, actuating, networking, and smart powering from battery or external supply or energy scavenging and managing. The building blocks combine nano-, micro-, and power-electronics with 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 assure the highest performance, reliability, functional safety and security as required for operations under complex and harsh conditions, with multiple loads of critical magnitude acting simultaneously. Consequently SSI also addresses the integration of the systems into their target environment.

7.4.2 Strategy

ECSEL projects shall focus on the Smart System itself, including the necessary key components and their development, if not yet available and on the integration of the Smart Systems in their environment, taking into account the requirements of a particular application or application domain. The following types of projects are envisaged:

1) R&D projects of TRL between 2 and 5
2) Large scale innovation projects of TRL between 4 and 8
3) Furthermore pilot lines and projects shall be established, which are able to provide the performance of the SSI solutions and support high TRLs for industrial usage.

It is recommended that a balance in the activities on low- and high TRL activities should be sought.

7.4.3 Impact

Today the Smart Systems sector in Europe represents nearly all necessary technologies and disciplines. With more than 6,000 innovative companies in the EU it employs approx. 827,600 people (2012) of which 8% or 66,200 are doing R&D with a budget of 9.6 B€ per year[20]. New R&D&I actions are expected to further strengthen this European leadership in Smart Systems technologies and to increase their global market share. New Smart System solutions shall feature higher levels of integration, decreased size (x5) and decreased costs (x5). Time to market for subsequent products shall be reduced by new design, building blocks, test 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

Smart Systems Integration is bridging the gap between components and products by using key enabling technologies (KET) and by integrating the knowledge from a variety of disciplines. Therefore cross-links to all other key applications and technologies within ECSEL are an intrinsic characteristic of Smart Systems. Development of Smart Systems will benefit from progress in nanoelectronics and in design methods and tool development. They also can be part of a CPS. 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:

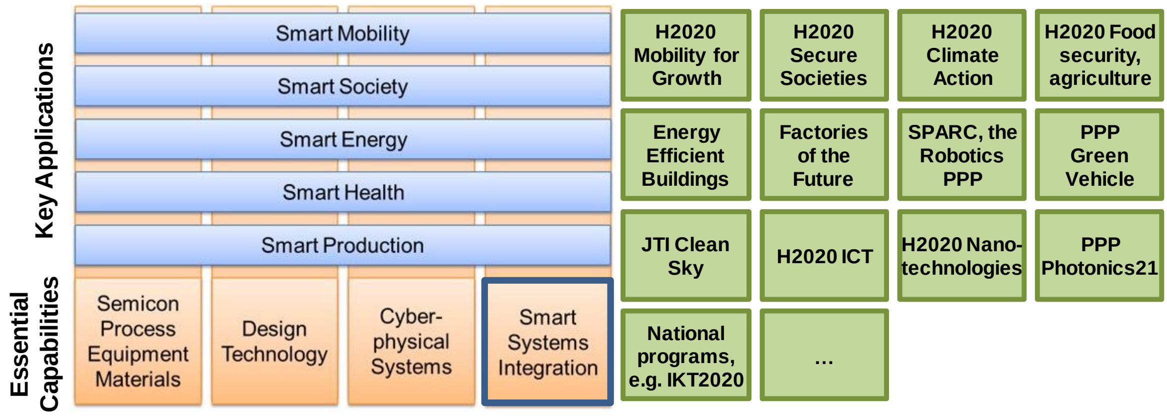


Table 1 Smart Systems Integration cross links.

7.4.5 Schedules/Roadmaps

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.

---

[20] 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.

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 (towards end of the ECSEL period): 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.

Table 2 Roadmap of Implementation of Priority Topics in ECSEL RIAPs 2015-20

(for definition of the generation 1, 2 and 3 of Smart Systems refer to the annex):

Year	Technologies	Functionalities	Applications
2015	Building blocks, components, integration concepts and HW/SW platforms for the integration of smart systems in their environment: sensors and systems, (power) electronics, actuators, wireless communication systems, smart energy, their packaging and thermal management: control, storage, transfer, generation, harvesting of energy and supporting safe and secure communication solutions as well as materials and methods for physical integration ensuring reliability and robustness	Gen 1/2 sensing and actuation, energy management and scavenging, communication and networking	power train control and battery management for EVs, smart grids, renewable energy sources, secure module for mobility, environment recognition for robots, body area networks for health monitoring
2016	Solutions and methods for automation and operation of smart systems in complex environments: sensor fusion, cognitive cooperation, robust and reliable materials and components, physics of failure, dynamic adaptation, maintenance and life cycle management	Gen 2 smart systems and partly 3 signal and cognitive processing, Gen 1/2 interfaces	automated vehicles and manufacturing processes, environment recognition
2017	Integration methods and interfaces for smart systems operating under harsh and complex conditions: compatibility with organic, chemical, biological, neural systems	Gen 2/3 interfaces	neuro plug, micro needles, artificial organs, smart fluids, environmental monitoring
2018	Advanced smart systems for autonomous operation based on building blocks linked to knowledge base, system evolution under safety and security constraints	Gen 3 sensing and actuation, communication and networking, Gen 2 signal and cognitive processing, knowledge base	Autonomous transportation systems, artificial organs, robots
2019	Smart systems for complete user interaction matching requirements of augmented reality, data fusion	all of the above as well as Gen 3 interfaces	prosthetics, implants, artificial eyes, human machine interfaces
2020	Breakthroughs in the impact of smart systems on reduction in materials use, waste production, energy consumption, and cost; self-healing capabilities	Gen 3 of all functionalities	visionary products in transportation, health etc.

Part C: Relevant Annexes

8 ANNEXES

8.1 Annex to A1: Smart Mobility

A Resource-efficient transport

Expected research on new innovative functionality

1) ECS for smarter vehicles (traditional or electrified) to reduce energy consumption, CO_2 and emissions,
2) ECS mounted on vehicles to harvest energy and/or connected to a smart grid
3) Electronics to control and connect advanced storage technologies (applied to innovative battery cells, hybrid batteries and fuel cells)
4) Energy efficient power electronics - e.g. for inductive or bilateral charging technologies
5) ECS for the management of heterogeneous system integration reducing energy consumption and/or emissions in vehicles, trains, ships, airplanes (as for example integration of thermal and high-voltage architectures)
6) Advanced safety and reliability research to ensure full operation under required security functionality (e.g. EMC, safety monitoring, thermal mechanical reliability)

Interfaces to other research topics in ECSEL

1) New vehicle concepts from the European Green Vehicles Initiative PPP, Clean Sky JTI, H2020, ERTRAC aim to deliver the needed mechanical concepts and components, which may be combined with the new innovative ECSs, making use of integration methods created by the research projects envisioned in this subchapter Smart System Integration
2) Reliable and secure communication technology and components needed from the design technologies and CPS subchapter
3) Model based decision making and control, real-time simulation from the design technologies and the CPS subchapter
4) CPS based verification and validation technology from CPS subchapter
5) Interfaces for efficient transfer of energy from the Smart Systems Integration Chapter
6) Building blocks, controls and interfaces of the Smart Systems Integration Chapter
7) Functional safety design methods from ECSEL technologies subchapter Design

B Less congestion, more safety

Required research on new innovative functionality

1) Seamless bi-directional communication networking (on-board, and car to X) featuring enhanced security concepts, including secured transfer of data inside and outside of the vehicle to ensure safe operation (security of control, access and communication)
2) Smarter, reliable and robust communication and interaction between vehicles, and between vehicles and other traffic participants, including pedestrians.
3) Interacting information systems for secure connection of electrified vehicles to grids for remote identification, diagnostics, charging and metering
4) Intelligent and interactive on-board traffic management and navigation systems to achieve maximum efficiency and driving range

5) Innovative advanced driver assistance systems
6) Interaction between individual vehicles as well as between vehicles and infrastructures, to enable intelligent urban and metro area traffic management systems
7) Advances in sensor technology, signal processing and fusion enabling vehicle-based
8) traffic scenario analysis and drive trajectory control
9) Innovative interacting safety systems
10) Lifetime, reliability, robustness and safety at all levels - component (e.g. sensor), module and application level in vehicles right through to complex vehicle and traffic safety management systems
11) Functional safety in operation, control and communication, including Human-Machine Interfaces, initiation of European standardization for deployed technologies, safe communication protocols, certification and testing
12) Systems that enable interaction between pedestrians, vehicles and traffic infrastructures

Multimodal transport information management and payment system interfaces to other research topics in ECSEL

1) Reliable and secure communication technology and components needed from the design technologies and the CPS subchapter
2) CPS based verification and validation technology from CPS subchapter
3) Functional safety design methods from ECSEL technologies subchapter Design

Building blocks, methods and components for sensors/actuators and integration of electronics, communication devices, interfaces for safe transfer of data, mechanics and embedded SW from ECSEL subchapters Design Technologies and Smart System Integration

C Next generation vehicles

Required research on new innovative functionality

1) Context assisting, semi-autonomous and up to autonomous driving based on reliable, cost and time efficient feature specification and testing of distributed vehicle-on- and -off-board hardware and software systems
2) intelligent in-vehicle networks, CAR2X communication as stepping stone towards an Internet-of-Car, UWB for vicinity applications, quality of services in extreme situations
3) Car as a collection of intelligent sensors, including environment awareness, secure big data handling and broadband communication in a self-sufficient and fault-tolerant way.
4) Real-world modelling and testing environments for advanced driver assistant systems and autonomous vehicles
5) Rail energy networks managed as smart grid, smart on-board distribution, use and storage, increased efficiency rolling stock
6) Aerospace platform-based systems with 100% operational availability and reliability, providing full situational awareness, human centred operation, seamless connectivity with the in-flight and ground environment, enabling advanced diagnostic and preventive maintenance, ensuring total safety over 20-30 years life-cycle of the products
7) Application of multi-core processor technology for real-time control in mixed- criticality systems
8) Cost efficient, dependable and safely operating satellite systems, with reconfigurable, flexible architectures, integrating seamlessly services like sabotage-free satellite communication or geolocation with global coverage in the future Smart Environment developments.

Interfaces to other research topics in ECSEL

1) Model based decision from ECSEL subchapter CPS
2) Real-time (co-)simulation from ECSEL subchapter CPS
3) Building blocks, methods and components for Sensors/actuators, sensor fusion and reliable and safe integration of electronics, mechanics and embedded SW from Smart System ECSEL subchapters design technologies and Smart Systems Integration
4) Sensors and actuators or stimuli to connect virtual world (using real-time simulation) with real world from ECSEL subchapters design technologies and CPS
5) Reliable and secure communication technology needed from CPS subchapter
6) CPS based verification and validation technology from CPS subchapter
7) Functional safety design methods from Design ECSEL technologies subchapter
8) Integration methods enabling smart functionality, automation and reliable operation in harsh and complex environments from the design technologies and Smart Systems Integration chapter
9) Mechanical and electrical components for next generation vehicles from Green Vehicle and H2020-MG research programs

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 wireless connections. If no provisions are taken the applications are vulnerable for 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 authenticity 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 a so called end-to-end security of a communication line can be established. The degree of security will depend on the sensitivity of the data. To that end, we propose the following topics to be addressed:

1) Security based on design time and tested cryptography
2) Secure M2M communication technology as the foundation for the internet of things that can be trusted and is self-organizing.
3) Next-generation hardware building blocks with improved security and safety (e.g. by larger embedded non-volatile memories for embedded software stacks)
4) Technologies for decentralized security, where security breaches can be detected early and breaches never compromise all the components.
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) Fast communication protocols for the next generation of IT architecture (smart manufacturing) that enable a self-adopting and self-controlling.
7) Protection and unique generation of secret keys by physical unclonable functions (PUF) against tampering and fraud.
8) Improved trusted virtualization and compartmentalized operating systems; multi- level security according to targeted protection profile(s).
9) New form factors integrating secure and safe elements; related trust and security hardware and firmware features for embedded computing platforms.
10) 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 how businesses scale (= positive marginal return with respect to resources). New hyperscalable 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 realm of traditional businesses and 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 providing ubiquitous connectivity that in general can manage the volume of data required by the current broadband services; the next generations of internet will evolve beyond this and provide more services and functionality enabled by the always-on paradigm and layered on social networks and alike.

The consumer will have access to multiple multimedia services through a variety of receiving 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. The increasing amount of date will lead to a data centric approach in data management. Future networks will provide high-capacity at low cost and low energy consumption. The reduction of latencies as well the increase of bandwidth will enable more 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 mobile devices ubiquity and the wireless networks deployment 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 aim is to develop for future sensor nodes single-chip systems at reasonable cost 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.

Applications can be found e.g. in:

Health care

1) Fall detection, medical devices
2) Sport and fitness sensors

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, 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).

8.3 Annex to A3: Smart Energy

Sustainable energy generation and conversion

Objectives are electronic systems and components to support highly efficient energy generation and conversion with innovative new approaches, higher efficient elements or miniaturized system solutions.

1) Affordable energy conversion efficiencies of 93% to 99% or more allowing better use of renewable energy resources, exploiting new materials, new devices architectures, innovative new circuit topologies, architectures and algorithms lowering the system cost.
2) Enhanced device and system lifetime and reliability with effective thermal management ensuring life expectancy for renewable energy systems of 20 to 30 years.
3) Developing semiconductors-based solar energy technologies including photovoltaic technologies and integrating them with solid state lighting applications.
4) Reduced physical size and weight of individual transformer stations with equivalent power ratings by the development of solid state transformers. These actuators will provide new functions for the operation of power systems and avoid infrastructure extensions caused by increasing share of distributed generation.
5) Innovative devices exploiting new materials to dramatically increased their power density capabilities to be used in efficient converters, supported by passive elements, new interconnect technologies and packaging techniques to achieve further miniaturization and further reduce losses.
    i) System reliability enhancement with focus on thermo-mechanical and thermo-electro-mechanical reliability

Synergies are essential with More than Moore technologies, covered in the MASRIA in the chapter on process technologies. Research areas for power semiconductors, assembly and packaging technologies for high temperatures and frequencies including the integration of passive elements have to be considered. In addition design technologies have to support new systems architectures and the integration of new materials.

An example for targets is the introduction of a smart inverter – as short term achievement the “smart inverter reference architecture” by 2017, “power electronic actuators (e.g. solid state transformers) by 2018” and “power inverter on a chip” by 2022

Reducing energy consumption

Reaching higher efficiencies in the applications and enablers to manage energy use in an intelligent way by switching off or down whenever possible are the ambition of the research for reducing the consumption of energy.

1) Intelligent drive control: technology, components and miniaturized (sub) systems, new system architectures and circuit designs, innovative module, interconnect and assembly techniques addressing the challenges at system and device level for efficiently controlled engines and electrical actuation in industrial applications
2) Technologies and control systems to improve lighting system energy performance
3) Efficient (in-situ) power supplies and power management solutions supported by efficient voltage conversion and ultra-low power standby, based on new system architectures, innovative circuit and packaging concepts, specific power components for lighting and industrial equipment serving portable computers and mobile phones, and standby switches

for TVs, recorders and computers. Power management solutions in industrial, municipal and private facilities

4) Low weight power electronics, with advanced thermal management solutions, based on novel materials and innovative devices particularly benefiting, among other areas, medical applications, where improved energy management is one of the keys to cost-effective solutions (for example, medical imaging equipment)
5) Efficient high-performance computing data centres and sever infrastructures, including computing architectures.

High reliability and functional safety enabled by embedded on-chip diagnostics

1) Highly efficient high-performance routing and switching engines incorporating 3D nanoelectronics-based integrated devices and photonics.
2) Energy efficient sensor networks, including hardware and software application layers.

Synergies for the reduction of energy consumption are seen in all applications areas (smart mobility, health, society and manufacturing) and in the “essential capabilities”. Especially for integrated intelligence like on chip diagnostics and efficient wireless access technologies with self-organizing and frequency agile capabilities More than Moore related research, new design and smart system integration technologies are required.

Research targets have to fulfil innovations in further reductions of consumption and in the miniaturization of the system sizes.

Efficient community energy management

With connected environments and users a coordinated approach regarding the supply and use of energy is mandatory. Following fields can be addressed by research:

1) Smart living supported by increasingly autonomous systems in the private space
2) Technological solutions for efficient and smart buildings (indoor) and outdoor subsystems including heating, ventilation, air conditioning and lighting, as well as traffic access, to achieve optimal energy-efficient performance, connectivity and adaptive intelligent management while ensuring scalability and security, also including smart agriculture (e.g., greenhouse energy efficiency).
3) Smart cities, providing smart spaces in an urban environments involving many concurrent users (both humans and devices) accessing services like energy distribution, transportation, education, entertainment, health care, security etc.
4) Self-organising grids and multi-modal energy systems
a) Improved grid visibility through advanced grid monitoring, including medium and low voltage levels
b) Highly resilient grid through the introduction of proactive control algorithms, significantly improving the grid self-healing and self-protection capabilities
5) Full implementation of Smart Grid technologies, resulting in the massive deployment of the necessary control options for the complete realization of the Agile Fractal Grid

Synergies are seen in the applications area for smart mobility and smart society, and for research regarding CPS and design and smart system integration technologies. In addition new miniaturization technologies in the area of More than Moore have to be developed to enable distributed elements.

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 (and wellness) 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
3) Remote disease management
   a) Prevention of hospitalization for chronic diseases for a large elderly population
   b) Tele-medicine, home diagnostic monitoring, point-of-care screening devices, ultra-small smart implanted and on-body diagnostic and therapeutic devices, broadening diagnostic scope
   c) Non-invasive measurement e.g. blood parameters 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

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

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 2014, 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 cyber physical systems.
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 Cyber physical System and Smart system

Semiconductor Manufacturing

For 2014 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) Advanced fab automation, related decision systems, and automation robotics

8.6 Annex to B1: 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, 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 maskless lithography), DSA (Direct Self Assembly) and Nano-Imprint.
7) Mask manufacturing equipment for 1Xnm / Xnm 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.)
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 inspection, thin film metrology, 3D critical dimension, overlay accuracy, defect repair and verification and physical failure and defect analysis for nano-scale devices.

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, 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).
3) Engineered substrates, low-resistivity substrates for power applications, high-resistivity substrates for RF applications, and SOI. Advanced substrates - e.g. for 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) Printing technology on wafer scale for functional material deposition and hybrid integration of printed electronics with silicon. 3D printing manufacturing for SiP.
9) 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.
10) 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.

8.7 Annex to B2: Design Technology

Priorities and Schedules in some more detail

Challenge	Short-term priority
Technologies for Model-Based and Virtual Engineering	Seamless model based design and development processes, including for safety critical systems with constraint-driven design methodology Modelling and simulation techniques for efficient methods (including Reference Technology Platform) and tools. SW development tools and debug environments for verification and validation for the HW and SW architectures and the applications developed in ECSEL. Feature and model based system simulation for easier integration. Efficient virtual platforms (simulation of the embedded target platform on a simulation host faster than the target platform) for early software integration and testing. Virtual platform in the loop: Enabling the efficient combination of model-based design and virtual platform based testing. Connection of virtual and physical world in complex validation environments including complex environment models Virtual prototype providing view of SMP and cache-coherent architectures HW & SW jointly
Managing complexity, safety and security	Specifications, essentially based on state of the art systems engineering for the affected class of systems (from “aircraft/car/..” type of system down to “system on a chip” level): engineering requirements, mission profiles, use cases, architectural design, executable specifications to be consistent with all design domains, including HW and SW design, applications, functional and non-functional property verification on HW and SW, validation and test. 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, etc. are also needed. Enable safety and security requirements in early design steps to get certification approval and enable incremental certification. Ultra-low-power: novel design flows for hardware design and efficient software for low-power autarkic systems. Support for OS virtualization
Managing diversity	Full integration of SW-development process, analog/RF, power devices and sensors/ MEMS in system design flows. Create Eco-Systems for the design of safety critical complex and/or distributed systems Extended verification and validation, including coverage for heterogeneous systems towards functional and non-functional properties; use cases - virtual prototyping and its link to test.

Increasing yield, robustness and reliability, and generate system openness	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. Monitoring, prediction and diagnosis methods and tools design methods and tools to meet requirements to real-time, high availability and safety of open systems Appropriate models of devices, components, modules and subsystems, covering several operational conditions. New design technologies to reflect multidimensional optimisation and coupled performances. Specific compliance standards; considering non-functional requirements with respect to their impact on functionality Metric method for testability and diagnosis efficiency in particular for AMS test 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.

Challenge	**Mid-term priority**
Technologies for Model-Based and Virtual Engineering	1) Integrated physical-logical simulation: Simulation of functional and physical effects,, extending classical simulations to multi-physics simulations 2) Efficient transfer of the non-digital domain to those of IC design and verification tools, which are more consolidated and fully automated. 3) Seamless modelling of functional blocks / units a) Virtual engineering of CPS and its subsystems and components on HW and SW level. b) Virtual prototype support for debug of SW/HW co-design for SMP and cache-coherent architectures 4) Integration of environment modelling and simulation into the HW and SW design flow. 5) Provide complete interoperable tool-chains for Model-Based Design. 6) Design tool-chains and methods supporting long term archiving needs and standards
Managing complexity, safety and security	1) Design Eco-System based on standards: common methodology for functional and non-functional properties for system integration and validation; open for all partners 2) Extended verification coverage: functional, non-functional; use cases, formal verification, virtual prototyping, links between HW and SW design, automatic test design and reduction, CPS supported system integration and validation. 3) Ultra-low-power: novel design flows for hardware design and efficient software for low-power autarkic systems with energy scavenging capabilities.
Managing diversity	1) 3D-Design: improvements to manage systems implemented along the supply chain 2) Consistent and complete co-design of IC, SiP, PCB, subsystems, incl. mechatronics and their interfaces.

Increasing yield, robustness and reliability, and generate system openness	1) Consistent methodologies and new approaches for reliability and robustness for each: hardware (HW), OS, and application software (SW), but also in conjunction to each other. 2) Consistent analysis, modelling, and descriptions/formats for reliability at all levels of abstraction. 3) design methods and tools to meet requirements to real-time, high availability and safety of open systems 4) monitoring of open systems 5) update and evolution strategies for open systems, including self-learning and adaptation 6) Models with variability, reliability and robustness information including degradation effects. 7) 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. 8) Normalization for testability and diagnosis efficiency metrics.

Challenge	**Long-term priority**
Technologies for Model-Based and Virtual Engineering	Accurate and parametric modelling including advanced modelling and simulation of human aspects Life cycle management for innovative (esp. CPS based) products. Verification and validation methodology and tools for complex, safe and secure CPS. Model-based engineering test methodologies for complex systems in rapidly changing environments. Certified models transformation engines and rules Tools and methods for assuring back-traceability. Virtual prototype support for automation of SW/HW co-design for SMP and cache-coherent architectures
Managing complexity, safety and security	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. 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. 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)

Managing diversity	Design Eco-Systems based on standards extended to heterogeneous components. Seamless design flow defining standards and models for multi technologies and reuse. Manage various constraints (electrical, thermal, mechanical, etc.) over the whole design flow 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.
Increasing yield, robustness and reliability, and generate system openness	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. This includes Design for compliance for safety and/or security critical applications (e.g. ISO 26262, EAL6+); Handling mixed criticality as it shows up in automotive where safety critical and entertainment components interact (e.g. display); Design for yield (DFY) and litho friendly design (LfD); Improved handling of special critical aspects like ESD, EOS, latch-up, EMC, electro-migration, thermal and mechanical stress at SoC and system levels; Development error robust circuits and systems; Avoidance, recognition and handling of errors at physical, logical, block, SW, and application levels Automated tools for testability and diagnosis efficiency metrics in particular for measuring yield loss and test escape. monitoring techniques for open systems Update and evolution strategies, including self-learning and adaptation.

8.8 Annex to B3: Cyber Physical Systems

Cyber-Physical Systems are an enabling technology for a wide variety of domains, for instance in:

1) Automotive: autonomous vehicles to increase road safety and optimize traffic density in conventional traffic, but also in sectors like farming, building and mining.
2) Rail: equipping low traffic lines with low-cost small autonomous trains to support quality of life.
3) Aerospace: enhance autonomous functionalities in particular for UAVs (unmanned aerial vehicles) for innovative civil applications, emergency cases or in scarcely populated or hardly accessible regions.
4) Healthcare: to enhance functionalities of robotic systems helping in aging society demands for increased home care capabilities, in rehabilitation, and for hospital and medical processes to increase safety and efficiency.
5) Food chain and manufacturing processes: industrial automation is actually the leading application domain of robotic systems, needing high flexibility while preserving safety by increasing sensory and intelligence capabilities.
6) Domestic applications, smart buildings/homes and cities: In the "private spaces" domain as well as in the co-operative application of home appliances in communities, autonomous systems can serve a huge set of autonomous tasks.

More details for the three strategic axes (Architectures, Autonomous adaptive and cooperative CPS and Computing Platforms) are given below.

Architectures principles and models for safe and secure CPS:

1) **Short term:** Define and develop global interoperable and certifiable CPS architectures principles for efficient operation within the future Internet, the 5G networks, the IoT, and in safety critical networked applications while the programming paradigms, run-time environments, software architectures and frameworks for CPS will take into account safe and secure operation in non-deterministic environments, and sound application of design principles for dynamically reconfigurable CPS. Software architectures for networked CPS shall be developed integrating many applications. Develop first solutions for open systems to interface CPS with IoT. Develop methodologies, from design to validation, covering all aspects of CPS systems and allowing to efficient develop, assess and validate complex CPS.
2) **Medium term:** Translate these principles into modular and composable reference architectures and protocols accommodating variability in environment, functions and performance, including monitoring and diagnosis as well as application independent software and communication. Propose certification guidelines and work towards standards. Develop interoperability of tools for the design, verification, validation and test of complex and distributed CPS. Development of approaches ensuring that CPS will cope with ethical principles. Develop advanced solutions to use the IoT for networked CPS communication including related software functions and architectures.
3) **Longer term**: Add cognitive users' models to the global CPS architectural models- extension for building novel application contexts. Propose certification approach and evolution of standards. Dissemination of environments and tools for design, validation, verification and test of CPS systems composed of elements from various providers. Implementation of mechanisms safeguarding the application of ethical systems.

The implementation of ethical rules will be a major advantage for Europe as industrial site.

Autonomous adaptive and cooperative CPS:

1) **Short term:** Develop core enabling functionalities for efficient use of resources (e.g., computing, communication, power, secure connectivity) and for optimizing global application performance (e.g., by auto-reconfiguration, planning and decision making capabilities) and aware of the life-cycle costs for CPS (e.g., autonomous vehicle and Internet of Vehicles). Develop interoperability of multiple different approaches for robust perception of the environment, including approaches like Bayesian, Neural Networks.
2) **Medium term**: Adding adaptation and run-time optimization capabilities (HW and SW), as well as reliable and trustable decision making and planning for safety-related autonomous CPS. Increase understanding of the environment by cooperation between sensors and knowledge (cognitive computing). Developing new approaches for self-reconfiguration of systems (self-diagnose, self-reconfigure, self-repair and self-maintain) to cope with the required Quality of Service.
3) **Longer term**: Adding learning capabilities and distributed decision making, introducing attractive, intuitive and enhanced accessibility for users for autonomous CPS including Human Machine Interface/World Machine Interface (HMI/WMI) and augmented reality (AR) for providing a view of a physical, real-world environment whose elements are augmented (or supplemented) by computer-generated sensory (sound, video, graphics, location data). Accurate perception and understanding of the environment by the system. Realization of self-reconfiguring systems, optimizing their resources for achieving their tasks.

Computing platforms:

1) **Short term:** Address low power computing systems (from sensor/actuator to cloud servers and across application sectors) for global system view for energy management, while managing complexity, integration, maintainability, reliability and security for mixed critical systems. Define “de-facto” standard in order to realize a European computing platform for Cyber-Physical systems including software and related communication architectures and protocols. Develop scalable and low power solutions based new technology (new software technologies, new nodes, interposers, non-volatile memories, photonics, and so on) as building blocks for the platform. Support End-to-end protection of data (cryptography) or execution in an untrusted environment.
2) **Medium term**: Realize and implement the European computing platform both at software, tooling and hardware levels. Extending to dynamic adaptation/selection of heterogeneous multi/many core computing resources to application needs (Quality of Service adaptation). Focusing on “System level programming” with emphasis on integration, portability, virtualization. Supporting global cooperative and distributed system debugging and validation. Development of reactive systems (hardware, software and methodology) dynamically coping with the available resources or requirements. Development of computation and communication systems ensuring data and program protection. Dissemination of the European computing platform for Cyber-Physical systems, and of the modular approach. Interoperability of the building blocks from various European manufacturers.
3) **Longer term:** Adding environment modelling in the loop (for predictive and adaptive computations). Adopting rule-based system behaviour construction and “programming”. Proposing scalable and modular approaches for affordable qualification and certification.

8.9 Annex to B4: Smart Systems Integration

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

Building blocks of Smart Systems (sensors, actuators, controls and interfaces):

1) MEMS and other physical, chemical and biological sensors and systems
2) Effective and efficient mechanical, piezoelectric, electrostatic, electromagnetic, inductive, pneumatic, thermal, optical, chemical, biological and other actuators
3) Modular and highly integrated schemes of power control and actuation
4) Electrical, thermal, mechanical and biological energy management
5) Energy generation and scavenging
6) Digital light, photonics and micro-optics
7) Power electronic inverters/converters and components for high-density energy storage
8) Suitable and tailored structural, electronic, magnetic, piezoelectric, active, fluidic, biocompatible and other materials (for harsh environments)
9) Wide band gap materials for power conversion as well as electro-active polymers and metal organic compounds for flexible substrates
10) Building blocks for advanced security functions, e.g. physical unclonable functions

Safe, secure and efficient transfer of information and power:

1) Technologies for mechanical, electrical, optical, chemical, and biological interfacing and transmitters and receivers for the transfer of energy and data
2) Energy efficient and fail-safe communication systems
3) Research on interfacing, networking and cooperation to enable distributed applications
4) Better intuitive man-machine interfaces
5) Powerful computational and mathematical methods for signal processing, data analysis, data fusion, data storage and data communication
6) Body area networks
7) Research on the dynamic integration of systems or nomadic devices in existing swarms
8) Strategies and technologies for the smart management of electric energy
9) Hardware based data fusion methods
10) Technologies for energy generation and scavenging
11) Technologies for energy transfer such as wireless charging and seamless power supply
12) Advanced solutions for thermal management
13) Technologies for fast, compact, energy efficient, fail-safe and secure wireless communication systems for energy and data
14) Secure data interfaces shall be defined for the integration into the Internet of Things
15) Technologies for intelligent wired and wireless interconnection
16) Technologies for mechanical, electrical, optical, chemical, and biological interfacing
17) Advanced intuitive man-machine interface technologies
18) Dynamic, adaptive and cognitive data processing as well as methods for cognitive cooperation
19) Safe and secure HW/SW platforms including privacy and security management
20) Standardisation of machine to machine interfaces – both data and physical

Integration methods enabling smart functionality, automation and reliable operation in harsh and complex environments:

1) Multi-physics and multi-scale modelling and simulation methods for components, systems, data and communication channels
2) Certification standards as well as design rules and testing and inspection methods
3) Innovative manufacturing processes for top-down as well as bottom-up fabrication
4) Methods and materials (metals, ceramics, polymers etc.) for system-level interconnection
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
6) Smart Systems shall be embedded in, for example, garments or robots through advanced manufacturing equipment and new integration methods
7) Technologies for smart adaptation, self-testing, self-learning and self-healing at system level

The achievements in the above subchapters shall support the short to long-term evolution of Smart Systems 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 would be: 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 techniques for vehicles.

2nd Generation Smart Systems are built on multifunctional perception and are predictive and adaptive systems with self-test capabilities that are able to match critical environments. Moreover they are equipped with network facilities and advanced energy scavenging and management capabilities. Systems of this generation are able to measure and deal with variability and uncertainty, yet generate an informed suggestion in the decision-preparing process regarding the original sample and the multitude of answers required by the detection objective. They will be more and more featured with 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 the blood sugar trends and warning the user to take action. Cross disciplinary development of 2nd generation Smart Systems will furthermore bring about 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 perform 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, monitoring the driving environment by itself and either needs the driver not 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.